Status, Ecology & Behaviour

Antilope cervicapra (Linnaeus, 1758) in Proposed Community Reserve for Blackbuck, Ganjam District, Orissa, India

ARUN KUMAR ROY MAHATO
RAMAKRISHNA
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ZOOLOGICAL SURVEY OF INDIA

Status Survey of Endangered Species

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INTRODUCTION

Demographic pressure together with activities such as deforestation, agriculture, urbanisation lead to an ever increasing encroachment of the area on wildlife population. Thus the fragmentation and shrinkage of wildlife habitat has threatened the existence of many species and forces to adopt to altered habitats in small patches. Herbivores like blackbuck with large home range and equality large food requirements due to its herd size have been among the most affected species. Fortunately enough, India have many areas that ensures and maintains viable population, as wildlife is an integral part of the indigenous culture of rural community and are closely linked together to their traditional beliefs. While keeping the landscapes without further disintegration on several occasions, clashes do occur during the conservation and restoration of healthy wildlife population in their natural state to meet the needs of the people. Therefore, it is utmost important to understand the ecological and behavioural features of the wildlife to protect them from the present challenges for their survival.

Antilope cervicapra (Linnaeus, 1758 commonly known as blackbuck is a gregarious, terrestrial antelope belonging to the family Bovidae of the order Artiodactyla and a threatened, free ranging species endemic to Indian sub-continent being distributed widely in the different pockets of the plains and semi-natural habitats where struggling for existence due to the destruction of natural habitat and anthropogenic activity. In the past, the blackbuck was one of the most numerous wild ungulates living in close proximity to human settlements as mentioned in many legends. A truly indigenous animal, associated with classical Indian Ragas like the Bhimpalasi and Todi. It is protected in some areas due to sacred associations and religious taboos of the local community.

Indian antelope or blackbuck although known to science for more than 250 years, the available studies pertaining to the herd structure, distribution pattern, territoriality, general habits, status and behaviour are centered only on the different wild and captive population. Still certain lacunae exist on different aspect of their ecology and behaviour, especially on the native population of blackbuck surviving in the vicinity of the human settlement. Antelopes, with their strongly developed social organization, are interesting subject of ethological studies. This is especially true for blackbuck, in which the significance of the various behaviour patterns is not well understood.

Hence, the study is aimed to understand the ecology, behaviour and sociobiology of blackbuck and how their activities fluctuate in relation to age, sex, habitat, over time and with the ecological parameters. The outcome of the study is very important for a plethora of disciplines ranging from conservation to evolutionary biology. When we get a clear understanding of a species behaviour and ecology then only we could be able to understand why and how the populations fluctuate, how to successfully manage a species. Further the need of the present intensive study is essential for the better management of this important characteristic of this threatened animal in the wilderness and in Community Reserves.

The study was conducted at Community Game Reserve, Ganjam district, Orissa, India, now known as Proposed Community Reserve for Blackbuck (PCRB) situated in the Eastern Ghats of Peninsular India. Topographically the area is undulating with scattered hills ranging at an elevation from 200-350 m. Proposed Community Reserve for blackbuck (PCRB) is unique among protected areas in India because of the conservation of blackbuck socio-religiously by the resident human population. The belief that the presence of blackbuck in the human habitations and agricultural fields brings prosperity to the local villager has contributed greatly to the conservation of this species.

DESCRIPTION OF THE SPECIES

Term 'Antilope' derived from Greek word 'anthalops' meaning horned animal; and the term *'cervicapra'* from two Latin words as *'cervus'* means deer and *'capra'* means a sheep-goat. In India it is called by various local names viz., Kala hiran, Krishna mriga, Sasin, Iralai Maan, Krushna Sara, Kala baoutia and Krishna jinka.

Taxonomic Position

Kingdom	:	Animalia
Phylum	:	Chordata
Subphylum	:	Vertebrata
Class	:	Mammalia, Linnaeus, 1758
Subclass	:	Theria, Parker and Haswell, 1897
Infraclass	:	Eutheria, Gill, 1872
Order	:	Artiodactyla, Owen, 1841
Family	:	Bovidae, Gray, 1821

Subfamily : Antilopinae, Gray, 1821

Genus : *Antilope*, Pallas, 1766

Species : *Antilope cervicapra* (Linnaeus, 1758)

Sub species or geographic races (Grove, 1980)

1. *Antilope cervicapra cervicapra,* linnaeus, 1758
2. *Antilope cervicapra rajputanae,* Zukovsky, 1927
3. *Antilope cervicapra centralis,* Zukovsky, 1928
4. *Antilope cervicapra rupicapra,* Mueller, 1776

The subspecies found in the present study area is *Antilope cervicapra cervicapra* according to Grove (1980). This subspecies is distributed in Orissa and various pockets of Andhra Pradesh.

Physical Description

Antilope cervicapra, a medium-sized antelope, found in semi-desert plains and open forest throughout India. Blackbucks have a graceful and slender built. They stand about 32-35 inch. (81 cm) at the shoulder and weigh about 40-45 kg. Adult bucks stand approximately 73-83 cm at the shoulder and on an average have a head and body length of 120cm with a 10-17 cm tail. One of the few antelopes which exhibit pronounced sexual dimorphism; the genders in the blackbuck are readily distinguishable by their color differences between sexes. In mature males the colouration in upper part of the body is black with the belly and the eye rings in white colour, while subadults are dark brown above and white below, and a prominent white circular patch around the eye. In the non-breeding season, after the spring molt, adult males may lighten considerably and retain their darkest colouration only on the face and legs. The horns are borne only by males and range from 50-61 cm; they are corkscrew-shaped heavily ringed at the base and twisted spirally up to approxiamtely 4 turns. Measured from base to tip, horns reach up to 79 cm in length, in a V-shaped pattern. The females are fawn-colored above and white below which is usually hornless.

General Behaviour

Blackbucks are active in the very early morning and late afternoon, resting in the shade at other times. They are very fast runners, and leap to demonstrate their stamina to predators, as do other gazelles.

A. Adult female.

B. Adult male.

C. Fawn.

Figure 1 : Age-sex group of individuals of blackbuck, *Antilope cervicapra* (Linnaeus, 1758)

A. 1-year old male.

B. 2-year old male.

C. 3-year old male.

Figure 2 : Individuals of age group of male blackbuck, *Antilope cervicapra* (Linnaeus, 1758)

Because of past persecutions, blackbucks are very shy and wary. Their sense of smell and hearing are not highly developed so they rely on eyesight in detecting danger. When in danger, a single animal bounds in the air and is soon followed by the rest of the herd. These animals have great speed and endurance when in danger. They are usually silent, but sometimes females give a hissing noise that warns the herd of danger. They are vocal animals that use several kinds of sounds to communicate with each other.

Adult males are highly territorial and defend areas ranging from 1.2 to 12 ha in size against trespass by other males. Female groups may graze through male territories, and breeding activity may take place at such times, but other males are excluded. Young males, and bucks without territories, form their own all male groups. At physical maturity (2-2½ years of age) young bucks may split from the all-male group to establish or win their own territory.

Outside the breeding season, blackbucks are found in mixed groups comprising an old male and several females and fawns, but as the breeding season approaches, the younger males stay away avoiding competition with the old ones and form bachelor groups or manage to defend a territory individually. Males mark their territories with scent glands in front of the eye as well as dung and urine, and posture to each other and to females. During other times of the year, they all gather together to form mixed herds.

Blackbuck-Ecology

Ecologically, *Antilope cervicapra*, a grazer, prefers open area and shows remarkable kind of social organization and behaviour. Blackbuck lives on open woodlands to semi-desert areas, but also enjoy areas with subtropical to thorn or tropical dry deciduous forest. Its original habitat is open plain and not dense jungles but only lightly-wooded country. They like to stay near areas where grassland is available. On the open plain the blackbuck is one of the fastest animals and can outrun most predators over long distances. On hot days blackbucks rest in the shade. Blackbucks can quite easily get habituated to human presence, arable land and pasture land.

Due to shrinkage and fragmentation of habitat, the pressure on existing habitats is quite high. This also tells us that it is inappropriate to think of shifting and relocating them elsewhere.

Blackbuck requires open grass lands with intermittent tall grass or bushes (for delivery, fawn nursing and to seek protection against predators as well as the rain and wind). Blackbucks usually roam in the plains, graze in herds of 10 to 100

individuals and, unlike most antelopes, graze mostly by day, even in intense heat with one dominant male. They are extremely swift animals; a cheetah can run down a blackbuck, but only if it overtakes it in the first few hundred yards.

Blackbucks are also very territorial and sensitive to environmental pressures. An adult male blackbuck tries to maintain his territory by marking it and defending it in the rutting season. When the population increases they require adequate space for healthy survival. Similarly, the female blackbuck requires tall grass or small bushes to delivers fawns (mostly one per year). The fawn will "lie down" during the first one week hidden in the grass/bush and the mother will nurse at few hours of interval. The blackbuck fawns are quite weak during the first few weeks and can be easily predated by dogs. Therefore it is very essential to have undisturbed open areas with small bush/tall grass cover for the healthy survival of young blackbuck. The fawn will join the mother and other group members when it is about two weeks old.

Blackbucks are grazers, prefers to graze on short to mid-length grasses, browse on common bush species and various cultivated cereals. The diet of the blackbuck consists mostly of grasses, although it does eat pods, flowers and fruits to supplement its diet.

REVIEW OF LITERATURE

Earlier studies by different workers were on the general habits, distribution, status and behaviour of blackbuck; Lydekker (1907), Spillett (1966), Prater (1973), Schaller (1967), Cary (1976), Mungall (1978), Prasad (1983-86), Ranjitsinghji (1982 & 1989), Chattopadhyay & Bhattacharya (1985 & 1986), Isvaran (2000, 2003 & 2005) etc.

Blackbuck is one of the fastest long distance runners in the world (Gee, 1969; Krishnan, 1964). A full-grown adult blackbuck stands at about 80-81 cm at shoulder height and its average weight is about 37-40 kg (Prater, 1973; Walker, 1964; Schaller, 1967). One of the most conspicuous characters of blackbuck is the striking colour change of its male during the period of development from fawn to adult stage (Schaller, 1967; Mungall, 1978). The dark colour of the males is secondary sexual character and the age, sex, season and social status would interact with genetic constituent of the individual to determine coat colour (Mungall, 1976). The horns are borne only by males and the length ranges between 50-61 cm. They are heavily ringed at the base and twisted spirally in a V-shaped pattern (Hall, 1936).

The blackbuck, *Antilope cervicapra* (Linnaeus, 1758) is a medium sized antelope, only representative of the sub-family Antilopinae (Linnaeus, 1758) and a single

species of the genus *Antilope* (Prater, 1971), endemic to Indian sub-continent being distributed widely in the plains and semi-natural habitats of India, Pakistan, Nepal etc. (Prater, 1973; Roberts, 1992). This species has been introduced in Kyle Ranch, Taxas, USA (Mungall, 1978). Blackbuck is distributed in scattered pockets and open areas of Indian sub-continent (Rahmani, 1991). Blackbuck is also an ecological indicator species (Padhy *et al.*, 1997) indicating the environment where blackbuck naturally abode and move freely in the sacred and suitable place for performance of sacrifice and human habitation. They are struggling for existence due to poaching and destruction of habitat (Oza, 1973).

Blackbuck is associated with classical Indian Ragas like the Bhimpalasi and Todi (Dharmakumarsinghji & Gaikwad, 1958). Because of sacred associations and religious taboos the local sentiment has protected blackbuck in some area (Krishnan, 1964). Bishnois, a community in Rajasthan protects blackbuck and violently resists them from killing (Prakash, 1988). Due to the community conservation efforts, the blackbuck (*Antilope cervicapra*) and the Indian gazelle (*Gazella gazella*) are seen along with human habitations near the agricultural fields (Oza, 1988). The belief that the presence of blackbuck in the paddy fields brings prosperity to the local villager has contributed greatly to the conservation of this species (Kar, 2001). However blackbuck, also supposed to be a vertebrate pest like some ungulates nibbling young shoots of various cereal and pulse causing crop damages in some areas (Chauhan & Singh, 1990; Chandra, 1997).

Schaller (1967) made studies on general behaviour on a population of blackbuck in Kanha National Park. Krishnan (1964) surveyed and conducted preliminary observations on the ecology of blackbuck. A population survey and observation on the behaviour of the blackbuck in the Point Calimere Sanctuary, Tamilnadu, have also been carried out by Nair (1976). Habitat preference, feeding and survival of blackbuck have been examined by Sharma (1980). Lehmkuhl (1980) investigated some aspects of the life history of blackbuck in Nepal. Behaviour of male *Antilope cervicapra* and its development according to age and social rank was studied by Dubost & Feer (1981). Prasad (1982) reported about the home range, dispersal and movement of blackbuck population in relation to seasonal change in Madumal, Andhra Pradesh and also studied its daily activity time budget. Ranjitsinghji (1982) focused on ecology and behaviour in Velevedara National Park, Gujarat. Natarajan (1991) worked on the ecology of blackbuck in Point Calimere Wildlife Sanctuary. Population dynamics of blackbuck in Ballavpur Wildlife Sanctuary, West Bengal was analyzed by Chattopadhayay & Bhattacharya (1985). Information on food habits and basic diurnal activity patterns of blackbuck in Ballavpur Wildlife Sanctuary, West Bengal is also available (Chattopadhayay and Bhattacharya, 1986a & b). Srivastava

& Srivastava (1991) observed on some aspects of ecology and social behaviour of blackbuck around Luni Basin.

Territorial and reproductive behaviour of blackbuck was reported by Schaller (1967), Cary (1976), Mungall (1978), Ranjitsinghji (1986) and Prasad (1987). Interspecific interaction like dietary overlap between blackbuck and cattle at the Point Calimere Sanctuary has also received attention (Nedumaran, 1987). Mungall (1991) recorded and analysed the establishing of lying-out by blackbuck for new born. Barucha and Asher (1993) have worked out on ecological behaviour, herd structure and herd dynamics of blackbuck in a sub-optimal habitat of Rehekuri Blackbuck Sanctuary, Maharastra. Variation in the lekking costs in an Indian Antelope, in relation to female mating pattern has also been reported (Isvaran, 2000). Evolution of lekking in blackbuck has been analyzed by Isvaran (2003) and lekking in blackbuck best predicted by female grouping was investigated by Isvaran (2005a). Blackbucks have resource based territories for the attraction of female, a male mating tactic described by Isvaran (2005b).

Habitat structure of blackbuck in Andhra Pradesh was evaluated by Ramna Rao & Prasad (1982). Seasonal changes in the herd structure and movement of blackbuck in Madumal, Andhra Pradesh was described by Prasad (1986) and seasonal change in the herd structure and composition of Indian blackbuck (*Antilope cervicapra*) at Pipli Deer Park in Kurukshetra District of Haryana State was recorded and analysed by Gupta & Bhardwaj (1990). Shankar Raman *et al.,* (1996) worked on the density, demography and the habitat utilization of blackbuck in Guindy National Park, Madras, while Srinivasulu (1999) looked at herd structure and habitat preference of the blackbuck in Mahavir Harina Vanasthali, Andhra Pradesh. Chhangani (2006) investigated the group organization, reproduction and feeding habits of blackbuck in Thar Desert. Jhala (1998) investigated the seasonal effects on the nutritional ecology of blackbuck. In addition, food availability of blackbuck at Lal Sunahara Sanctuary, Pakistan was described by Mirza & Waiz (1973).

The state wise distribution of lesser known populations of blackbuck in India was reviewed by Rahmani (1991). Chandra (1997) also investigated the distribution of blackbuck in India. Ranjitsingh (1982) estimated that the total blackbuck population in India to be ranging from 22,000 to 24,000. Kar (2001) described the distribution and population of blackbuck in Orissa. Distribution pattern, home range, territoriality and foraging behaviour of blackbuck in Balipadar-Vetnoi areas of Ganjam district, Orissa was investigated by Kar (2001).

Topics of conservation and management problems of blackbuck have also received attention by various researchers (Ramana Rao and Prasad, 1982). Oza & Gaikwad (1973) mentioned that blackbuck faces extinction in India, again Oza

(1988) mentioned that the habitat of blackbuck come under severe pressure from agriculture. Barucha and Asher (1993) gave some recommendations for the management of blackbuck populations in Rehukari Blackbuck Sanctuary, a sub-tropical habitat, in Maharashtra. Prasad & Ramana Rao (1984) investigated the blackbuck conservation in cultivated areas of Andhra Pradesh and proposed some measures for the conservation of blackbuck. Ullas Karanth & Mewa Singh (1985) received attention on the dry-zone afforestation and its impact on blackbuck population in the Ranibennur Sanctuary, Karnataka. Shankar Raman *et al.* (1995) suggested some consideration for the management of cheetal and blackbuck in Guindy National Park, Madras. Crop damage by blackbuck is a problem for sanctuary management in bustard sanctuary, Karera (Chandra, 1997) and in Rallapadu Wildlife Sanctuary, Andhra Pradesh (Manakadam *et al.*, 1998). Chandra (1995) gave some measures to manage the blackbuck population to prevent crop damage. Sinha (1977) investigated some threats which pose adverse effects on the blackbuck population of Velavadar National Park and others sanctuaries in Gujarat State.

Apart from these works on blackbuck populations, several studies have been carried out on other antelope and related ungulate species by a number of workers. Schaller (1964) recorded herd dynamics and social behaviour of blue sheep (*Pseudosis nayaur*) in Nepal. Social organization of antilope in relation to their habitat was described by Jarman (1974). Martin (1977) studied the status and ecology of barasingha (*Cervus davauceli branderi*) in Kanha National Park. The quantitative and functional variations of certain behaviour patterns in male Thomson's gazelle (*Gazella thomsoni*) of different social status in Serengeti National Park, East Africa were investigated by Walther (1978). Miura (1979) have worked on social behaviour of the spotted deer during the dry season in Guindy sanctuary, Madras. Sharatchandra *et al.* (1980) investigated the time budget of different life history stages of cheetal. The ecology and ethology of spotted deer (*Axis axis*, Eryxleben) was studied by Tak & Lamba (1984). Schaller *et al.* (1991) have observed the different aspects of behaviour of Tibetan antelope (*Panthelope hodgsoni*). Hart *et al.* (1992) analyzed the biological basis of grooming behaviour in antelope in relation to body size, vigilance and habitat principles. Sukla & Khare (1998) have investigated food habit of wild ungulates and their competition with livestock in Pench Tiger Reserve, Central India. Kankane (2000) worked on status survey of Chinkara (*Gazella gazella bennetti*) in Rajasthan. Goyal *et al.* (2000) have considered Nilgai (*Boselephes tragocamelius*) as a mammalian crop pest around Jodhpur. Infield *et al.* (2001) have studied on community attitude towards the conservation of wild animal. Variation in male mating behaviour within ungulate populations was discussed by Ishvaran (2005b).

STUDY AREA

The study was conducted at Bhetnoi, Balipadar, Buguda, Kodala areas of Ganjam district, Orissa, India now known as Proposed Community Reserve for Blackbuck (PCRB) situated at the Eastern Ghats of Peninsular India (Figure 3) and cover an area of approximately 64 sq. km. Topographically the area is undulating with scattered hills ranging at an elevation from 200 to 350 m. The population of blackbuck is scattered and distributed in various pockets along the northern side of Rushikulya River from Buguda to Purusottampur.

Vegetation and Climate

The natural vegetation of the area is Tropical dry deciduous forest (Champion and Seth, 1968) and three broad habitats occur in the park : (i) Cultivated land (occupying about 60% of total study area)—characterized by the cultivation of paddy and other crops, vegetables and pulses (ii) Scrubland (occupying about 10% of area)—with semi-open habitat (iii) Grassland (occupying 15% of the study area) where at least 7 major species of grasses, sedges and herbs are known to occur (Figure 4 & 5).

The mean annual rainfall is 1100 mm based on climatological table of the Meteorological Department, Gopalpur. Most of the precipitation occurs during the southwest (June-September) and northeast (October-December) monsoons (Figure 6). Further details about GNP are available elsewhere (Kar, 2001). Four seasons were identified using a climatological table and data on rainfall collected on a daily basis for Gopalpur (Orissa) during 2005-2007: dry season (Jan-Mar), summer (March-June), southwest monsoon (June-Sep.), and northeast monsoon (Oct-Dec.).

Floral composition of the study area

Kar (2001) described the tree species of this area characterized by Babul (*Acacia nilotica*), Sishum (*Dulbergia sissoo*), Mahua (*Madhuca latifolia*), Siris (*Albizzia lebbek*), Tamarind (*Tamarindus indica*), Jamun (*Syzygium cumini*), Ziziphus (*Ziziphus jujuba*), Neem (*Azardicta indica*), Teak (*Tactona grandis*), Date Plam (*Phoenix dactylifera*), Palmyra palm (*Borassus flabellifer*), Mango (*Mangifera indica*), Custard apple (*Anona squamosa*), Pipal (*Ficus relgiosa*), Banyan (*Ficus bengalensis*), Sal (*Shorea robusta*), Arjuna (*Terminalia arjuna*), Saij (*Terminalia alata*), Amla (*Emblica officinalis*), Jack fruit (*Artocarpus heterophyllus*), Cashew (*Anacrdium occidentale*), Coconut (*Cocos nucifera*), Bel (*Aegle marmelos*), Bomboo (*Bambosa arundinacia*) etc.

Figure 3 : Location of Ganjam district (black color) of Orissa. (Yellow spot represents the distribution of blackbuck).

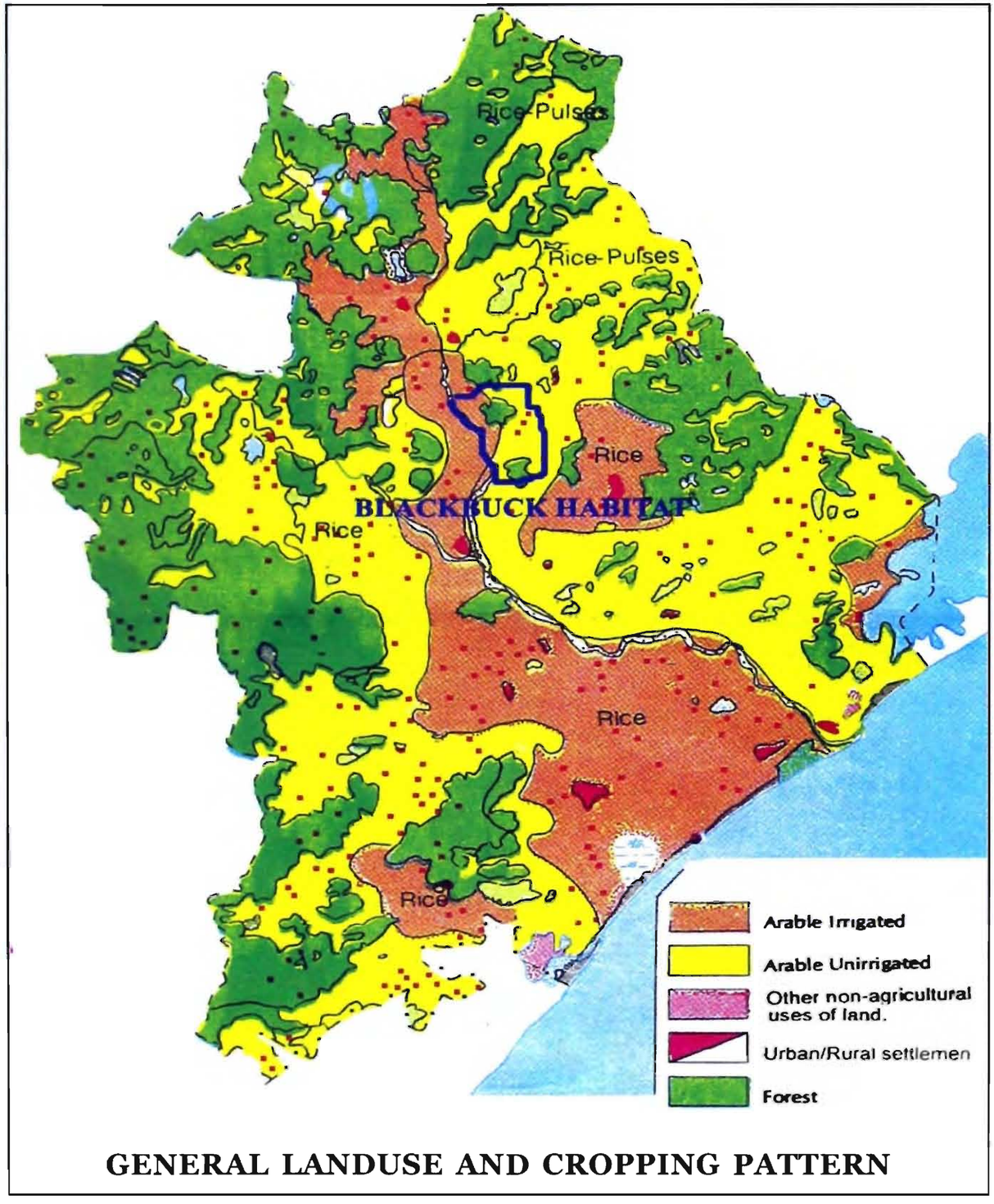


Figure 4 : General landuse and cropping pattern (redrawn from NATMO, Govt. of India).

A overview of the grassland habitat in PCRB.

Aerial view of the habitat at Vetnoi.

Overview of the bush habitat in PCRB.

Figure 5 : Vegetation of the study area at PCRB.

The grass layer is moderately developed in agricultural land and water resource areas includes three species of Duba (*Cynodon dactylon, Cynodon plectostachys, Cynodon barberi*), *Cyperus rotendus, Celosia argentea, penicum sps., Borreria hispida, Vernonia cinerea, Paspalum scrobiculatum, Fimbristylis miliacea, Kylinga triceps, Commelina benghalensis* etc. Shrub species characterized by *Mimosa pudica, Cerissa spinarum, Bryophyllum calycinum, Tridex procumbens, Ageratum conigoides, Eupatorium odoratum* etc.

As most of the blackbuck area is predominantly cultivated land and the common cultivated crop species are *Oryza sativa, Zea mays, Peninsetum americanum, Eleusine coracana.* Legumes includes Green gram (*Phaseolus aureus*), Black gram (*Phaseolus radiatus*), Pegion pea (*Cajanus cajan*), Bengal gram (*Cecir arientinum*), Ground nut (*Arachis hypogea*), Garden pea (*Pisum sativum*) and Sweet pea (*Lathyrus odoratus*) etc. Oil seeds includes Til (*Sesamum indicum*), Castor (*Ricinus communis*), Sunflower (*Helianthus anus*), Hemp (*Cannabis sativa*), economic crop includes Sugarcane (*Saccharum officinarum*), Cotton (*Gossypium herbaceum*) and vegetables characterized by Potato (*Solanum tuberosum*), Tomato (*Lycopersicon esculentum*), Brinjal (*Solanum melongena*), Lady's finger (*Abelmoschus esculentus*), Cabbage (*Brassica oleracea Var. capitata*), Carrot (*Daucus carota*), Cucumber (*Cucumis sativus*), Gourd (*Trichosanthes cucumerina*), Onion (*Allium cepa*), Radish (*Raphanus sativus*), Sweet potato (*Ipomoea batatus*), Watermelon (*Citrulus vulgeri*), Elephant foot yam (*Discorea sps.*) and Spinach (*Spinacia oleracea*) etc.

Faunal composition of the study area

The faunal composition and population is very scanty. Apart from the blackbuck few mammalian species are found on the PCRB including langur (*Semenopethicus entellus*), Rhesus monkey (*Macaca mullata*), Wild boar (*Sus scrofa*), Bengal fox (*Vulpes bengalensis*), wolf (*Canis lupus*), Jackal (*Canis aurius*) and small Indian civet (*Vivericula indica*). Apart from blackbuck no other species of wild ungulate found in the PCRB. Some other species of mammal present are namely Hare (*Lepus nigricolis*), Palm squirrel (*Funambulus palmarum*) and species of rodents. Some reports from villagers that leopard is also present on the dense forest areas on scattered hills surrounding the habitat of blackbuck. Reptilian fauna includes Indian chameleon (*Chameleon zeylanicus*), Cobra (*Cobra cobra*), Krait (*Bungarus caeruleus*) and Rat snake (*Ptyas molurus*) are commonly found in PCRB. The common bird species of the PCRB are House crow (*Corvus splendens*), Parakeet, Indian myna, king fisher, peocock, owl and a few other species.

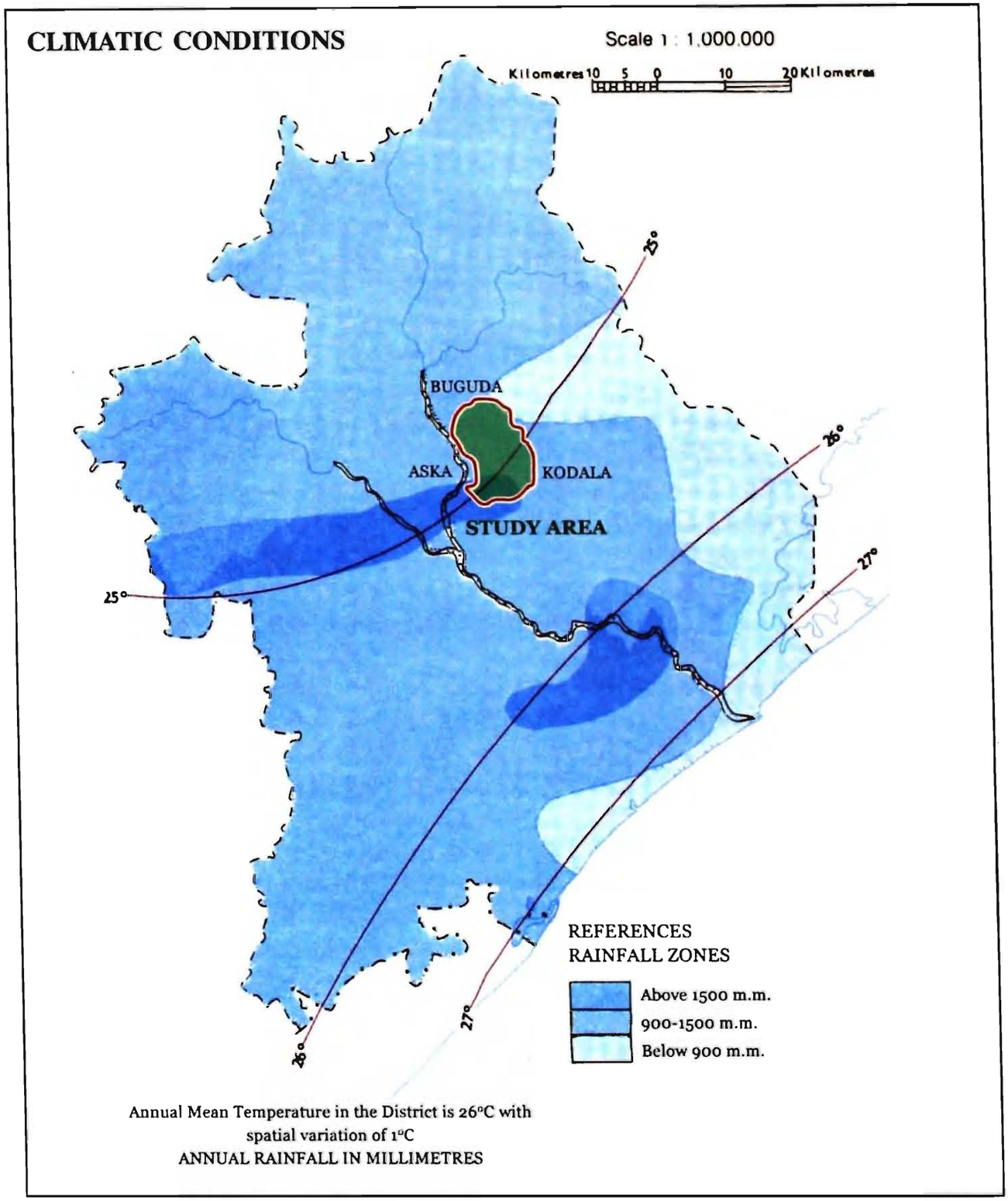


Figure 6 : Map showing climatic conditions of Ganjam district (redrawn from NATMO, Govt. of India). Red circles representing the Proposed Community Reserve for Blackbuck (PCRB).

DISTRIBUTION

A detailed review about the distribution of blackbuck was made by Schaller (1967). Prasad (1981) gathered information on the distribution of blackbuck in India around seventies. Ranjitsinghji (1982) estimated the total blackbuck population in India to be range between 22,000-24,000. Rahamani (1991) gave a rough estimate of the blackbuck population ranging between 29,000-38,000. The present distribution of blackbuck in India reveals that once enormous, is now restricted to a few pockets where they struggling for existence (Figure 7).

Blackbuck is native to Indian subcontinent mainly found in India (except North-east India) but also in parts of Pakistan and Nepal where they were widespread in plains and open woodlands; wet coastal areas, western deserts, and northern mountains limited in their distribution. Today the blackbuck population of India is confined to areas in Punjab, Rajasthan, Haryana, Gujarat, Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka and Orissa with a few small pockets in Central India. There are also introduced populations in various parts of the world including numerous ranches in Texas in the United States of America.

Antilope cervicapra formerly distributed across almost the whole of the Indian subcontinent. Range decreased sharply during the 20th century and the taxon is now extinct in Bangladesh, and few population found in Nepal and Pakistan. Attempted reintroductions have taken place in Pakistan and Nepal. Today, extensive hunting and habitat destruction have restricted blackbuck to only small, isolated populations in their former native habitat.

Blackbuck Distribution in Protected Areas

I. In India

1. Velavadar National Park, Gujarat
2. Bandhavgarh National Park, Gujarat
3. Savainagar Sanctuary, Gujarat
4. Gir National Park, Gujarat
5. Ranthambhore National Park, Rajasthan
6. Bharatpur Bird Sanctuary, Rajasthan
7. Tal Chhapar Blackbuck Sanctuary, Rajasthan
8. Corbett National Park, Uttranchal

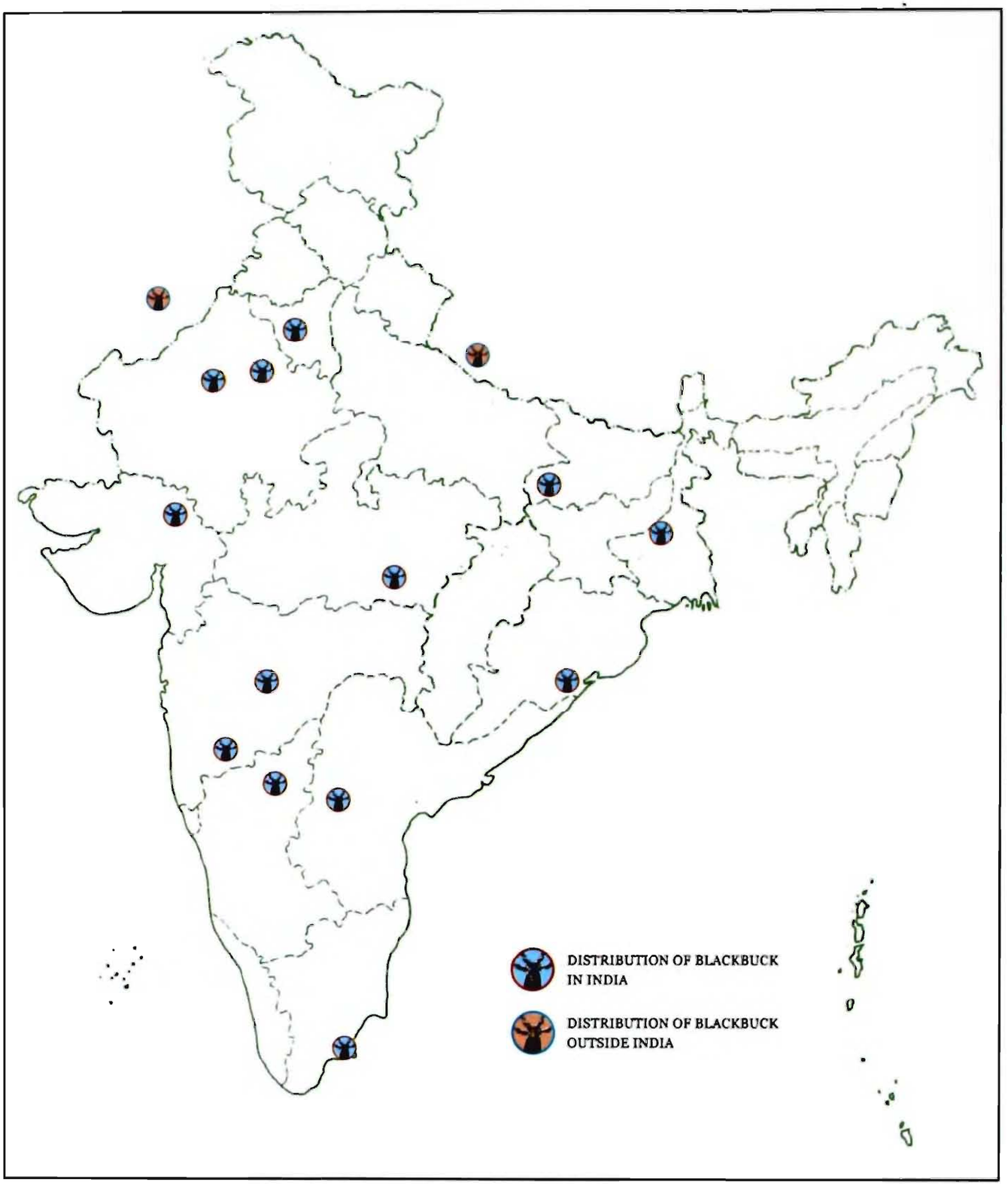


Figure 7 : Showing the distribution of blackbuck, *Antilope cervicapra* (Linnaeus, 1758) in India and adjoining countries of Indian sub-continent.

9. Kanha National Park, Madhya Pradesh
10. Rehukuri Blackbuck Sanctuary, Maharastra
11. Nanaj Sanctuary, Maharastra
12. Guda-Bishnoi, Rajasthan
13. Rollapadu, Andhra Pradesh
14. Madumal Sanctury, Andhra Pradesh
15. Point Calimere Sanctuary, Tamilnadu
16. Guidy National Park, Tamilnadu
17. Kaimur Sanctury, Rohtash District, Bihar
18. Ballavpur Wildlife Sanctuary, Bolpur District, West Bengal
19. Konark-Balukhand Sanctuary, Puri, Orissa
20. Balipadar-Vetnoi Community Reserve, Ganjam, Orissa
21. Ranibennur Wildlife Sanctuary, Karnataka

II. Elsewhere

1. Royal Bardia National Park, Terai Arc (Nepal)
2. Kirthar National Park (Pakistan)
3. Lal Sohanra National Park (Pakistan)
4. Kyle Ranch, Taxas

BACKGROUND OF BLACKBUCK IN ORISSA

The Balipadar-Bhetnoi area now described as a Proposed Community Reserve for Blackbuck (PCRB) comprising of about 70 villages of Buguda, Aska, Kodala Forest Ranges in Ghumasar south division and Purusottampur of Ganjam District hold most of the population of blackbuck except few population reported in Konark-Balukhand Sanctuary, Puri in the state of Orissa. Once the blackbuck population found near by Chilika Lake (Schellar, 1967) but could not found any population

during the present survey on this area. The Blackbucks of Balipadar-Bhetnoi area is protected religiously by the local community.

More than a century ago, there had a long spell of drought in the locality. During this period, a small group of blackbuck appeared in the area and then there was rain and the drought spell was broken. Since then people had started rigidly protecting these animals as they feel that their fate is linked with these blackbuck. During 1918, a Britisher known as "Green saheb" and the 'Sardar' of the locality Sri Madeshi Chandramani Dora took initiative for protection of this species and published a notification in the Oriya news paper "Prajamitra" prohibiting killing of the blackbuck. The Forest Department conducted a census of blackbucks on 14.5.1973 in the Balipadar-Bhetnoi area. The last census conducted in year 2004 in the same area indicate that, there is 42% increase in the blackbuck population over the last count in 1998, and out of three Forest ranges, namely Buguda, Aska and Kodala, range alone holds 56% of the blackbuck population at present.

Schaller (1967) reported a population of 55 blackbuck near Chilika lake area. Behura (1981 pers. comm.) reported 140 blackbuck in Ganjam district. Rangitsinghji (1982) reported 700 blackbuck and Prasad (1982) reported 140 individuals. Kar (1998) reported that in Balipadar-Vetnoi area, Ganjam district the population of blackbuck is 551.

In year, 2005 the Forest department of Orissa set up Blackbuck Management Committee jointly with the local people of the PCRB under the presidentship of Amulya Upadhayay, Honarary Wildlife Warden for conservation and management of the population of blackbuck in the three forest ranges namely Aska, Buguda and Kodala.

Regularly, the Blackbuck Management Committee conducting awareness campaign involving local people, school and college student with popular slogan for the protection of blackbuck. The slogan for the continued existence of his nature beckon is –

"Krishnasara Mriga, Ganjamera Garba"

MATERIALS AND METHODS

A. Ecological Study

Data collected includes territory, location, group composition, habitat type, time of day and behavioral status. For each blackbuck observed, species, age, sex, date, group size and composition, habitat and location were recorded with the help of binocular (10 × 25), camera (300 mm, 800 zoom) and GPS. The number of individuals and age-sex composition of groups of blackbuck were recorded during regular block sampling as well as during walks along paths and animal trails in the habitat.

Most of the counts were sampled more or less uniformly across habitat in the morning (0600-0900 h) and evening (1600-1800 h), when an average of 90% of the animals are actively foraging or moving. About 5 field visits were made in a month, enabling observation of groups and tallying of group size on a monthly basis in the three major habitats considered here. Age-sex classification of blackbuck observed (described in Mungall, 1978) was used to estimate the monthly percentage of adult males in herd and the monthly proportion of fawns to females. Animal density was estimated using total count of the blocks of cultivated land, scrubland and grassland.

Habitat study

Abundance and phenology of the trees between October 2004 and April 2007 were recorded. Eight quadrates measuring 50 × 50–m plots were laid randomly in the study site. The fruiting and flowering phenology of grasses, tree, shrub, vegetables and crops belonging to 30 species, were monitored once a month. Presence and absence of young leaves, mature leaves, and inflorescence were recorded. At the end of the study, vegetation sampling was carried out to estimate the density of important grasses. This sampling was carried out in 100 random circular plots of 40 × 40 cm radius each. Leaf/fruit samples were collected and preserved for verification or identification by plant taxonomists. Additional data were recorded during early morning and evening periods. Location of blackbuck were plotted on map (1 : 50,000).

Population, Abundance and Distribution Pattern

Direct observations were made to collect data on population status and distribution of the blackbuck. In order to collect data on the current status and distribution of blackbuck, field surveys were carried out in PCRB to locate blackbuck populations. In each area, blackbuck was counted by vehicles and random searches were also attempted in different grassland patches, agricultural landscape and shrub land.

All data pertaining to herd size composition were collected mainly in selected 12 villages. Other areas occupied by blackbuck were also visited frequently to assess the population. The grassland, cultivated land and major habitat of blackbuck in PCRB were surveyed regularly through fixed routes between dawn and dusk. The areas not accessible by road network were visited on foot. All encountered blackbuck, were aged and sexed whenever possible and location and activity of each group was also recorded during the time of observation.

Five sex and age classes were distinguished. These are a) adult males, b) adult females c) sub-adult males d) sub-adult females and e) fawn according to Mungall (1978). Sub-adult male also categorized as less than 1-year, between 1-year and 2-year, more than 2-year up to adult (Figure 1 & 2) in the present study.

Home Range and Territory

The individuals of blackbuck were identified at the beginning of the study by natural physical differences: size, facial differences, and differences in horn morphology of the bucks. Home ranges were determined by establishing a grid of 50 × 50 m over the map of the scale 1 : 50,000 (Topo Sheet, Survey of India). The number of occurrences of each blackbuck in each square of the grid was tabulated and minimum convex polygons were drawn to include all squares where the blackbuck had been found more than once.

Blackbuck with more than 50 observations was only used for home range calculations. Grid squares containing at least 5% of the total number of observations represented the core area. Minimum convex polygons of core areas were determined in the same way as the home ranges.

All cases of urination and defecation were considered to be territorial marking, since the blackbucks were never seen to urinate or defecate at random while walking. Other territorial marking like thrashing and marking on bushes were also included in this activity.

Herd Size or Group Size

All units of animals seen in one sighting was recorded as a group. A group was defined after Mungall, 1978 as the number of individuals interacting with each other, behaving in a coordinated fashion during foraging or moving, or present in close proximity to each other (< 10 m apart) when first observed was followed in the present study. In cases where one or more individuals occurred near the periphery of another group, the peripheral individuals were included in the group if their distance from the outer animals of the group was less than the group's approximate radius. Groups where all the individuals could be clearly seen were only tallied for group size. If movement of animals or vegetation indicated that some individuals

were hidden or only partly visible in dense vegetation, or if the animals were far away (> 50 m) from the observer when detected in the semi-open vegetation, then the group was not included in the data. Although such doubtful cases occurred occasionally, the majority of detections recorded in the field were unambiguous.

Herd Composition

Data were collected from June 2004 to May 2007 by using binoculars (8 × 30) to observe blackbuck, their sex and age-classes from a far distance. All blackbuck sightings in the study area occurred from 0600 h to 1800 h. The size, composition and number of groups were recorded whenever the group or individuals encountered. Number of blackbuck, time, location, habitat type, elevation and activity (viz., feeding, resting, walking etc.) were recorded and efforts were made to identify sex and age-classes for each member in a group. Individuals were considered as members of the same group if the distance between an individual and at least one other member of the group was less than 100 m.

Forage Preference

Forage preference was determined by a careful examination of feeding sites. After a blackbuck or group of blackbucks left the feeding site and moved out, feeding site was inspected and grasses consumed by group were recorded. Identification of grazed plants were made on the spot, immediately after the grazing animal had been watched through binoculars. To estimate grass frequency, density, richness and diversity, quadrilateral plots were selected and record of grass species, number of grass, grass height etc. was maintained. Grass cover was estimated visually and ranked them in an ascending order.

Habitat Utilization

Data on habitat utilization by blackbuck was based on direct sighting and the habitat use was only at the time of observation. Whenever an individual of blackbuck was encountered, a record of date, time, habitat characteristics, age/sex etc was noted. If a group was sighted then a record of type of social group, age/sex composition of the group for quantification of habitat utilization was maintained. The sightings of blackbuck were recorded in different major habitats.

The habitat utilization by the blackbuck was calculated by technique described by Prasad (1984) which is as follows:

$$\text{Habitat use} = \frac{\text{Incidence of total number of sightings of individuals in one habitat in a season}}{\text{Total number of sightings of individuals in all habitats in a season}} \times 100$$

Habitat use by different categories of blackbuck like territorial male, female, mixed herd and bachelor herd was calculated separately. All sex and social categories of blackbuck were treated separately in the analysis to determine the habitat use.

Habitat overlap and Preference

The study on habitat selection and habitat overlap of blackbuck with livestock in PCRB was carried by direct methods. Number of individuals and groups of livestock on the major 8 selected habitat were observed and compared with the blackbuck. A comparison of the proportion of occurrence in each habitat with its corresponding availability determined habitat preference. The data recorded was used to calculate habitat overlap between blackbuck and livestock's.

The habitat overlap or Niche overlap was calculated as the technique described by Pianka (1973) which is as follows:

$$C_{ik} = 1 - \frac{1}{2}\left[\frac{Nij}{Ni} - \frac{Nhj}{Nh}\right]$$

Where,

C_{ik} = Value of Niche overlap

E = Sigma

Nij = value of species i (blackbuck) in niche category j

Ni = total of values for species i in all niche categories

Nhj = value for species h (livestock) in niche category j

Nh = total of values for species h in all niche categories

B. Behavioural Study

Individual Behaviour

Blackbucks are habituated to human being, which made easy for observing natural behaviors at close range was possible. After searching herd and territorial male in the study site they were followed for minimum 2 hours to maximum 4 hours in the morning, noon and after noon hours or whenever going to the field. Each observation site was chosen to minimize the risk of disturbance to the blackbuck while maximizing the chances of observations. So, most observations were made within 50-200 m of the focal animal or individual. Behaviour of the individual male and female were recorded by using focal animal sampling method (Altman, 1974). Starting with an initial observation (time 0), the behaviour of the individual male and female recorded continuously for 5 minute with an interval of 10 minutes

(Prasad, 1985), thus making 4 observations in 1 hour. On any particular day the male was observed for 4 hours in a day and time varied in case of female due to invisibility in the herd and selection of another female for next observation. Observation was made from sunrise to sunset between 06.00 hours to 18.00 hours.

The behaviour recorded, which was short in nature are liable to be missed using scan sampling. Hence this method was used to put a frequency of incidences of these short behaviours. Those behaviours which last in a certain length of time, such as feeding, scanning, walking, lying and chasing are recorded as time to the nearest 30 sec, from when the behaviour starts to when it stops as mentioned in Prasad (1985). Behaviors were divided into following major activity categories: resting (all inactive periods not associated with a second behavior except ruminating), social, foraging (feeding bouts), vigilance (scanning of surroundings or staring at other animals/objects in the area), aggression (all aggressive behavior towards other blackbuck), moving (walking or running), and others (all other observed activities). Resting could be distinguished from alert in that focal animals were not actively scanning or searching but were instead almost randomly, in intensity and direction, viewing their environment. Multiple behaviors were recorded if observed at the same time, but the dominant behavior was used for timing. During aggression periods, the sex of other blackbuck involved was recorded. Moving did not include any walking or running that was associated with a second behavior (e.g., if a male was walking towards another blackbuck aggressively, then the behavior was categorized as aggression). The category "others" included such behaviors as scratching, non-aggressive defecation, and alertness to the observer (that primarily occurred at the start of observation). The activity recorded in blackbuck in the study area was defined and classified under the following categories –

Feeding (Grazing): Head down, eating grass and other vegetation.

Browsing: Eating bush, plant and tree material without grass.

Resting: Relaxed either lying down on the ground or standing without body movement and not involves in any other activities.

Walking: All movement, not standing still or chasing by other individual.

Scanning: Standing still in alert position with head upright.

Grooming: Scratching the body by mouth or by horn.

Allogrooming: Grooming to the other conspecific individual.

Auto grooming: Self grooming.

Dominance Display: Parallel walking or standing near another individual.

Walk towards (WT): Approach movement served as a threat.

Flehmen: Act in which the upper lip is drawn up and nasal passages modified, to assess the state of the female urine.

Mount: Adult male attempt to climb on the back of adult female in order to mate. The male fail to mate due to the female walking off.

Object aggression: Rubbing or threshing horn against the objects like bushes, plant, tree or ground.

Body push (BP): The signaler approached the recipient from behind and pushed its body.

Forcing to stand up (FS): Refers to animal forces another to stand up by simply approaching in a certain posture like threatening with ears, presenting horns from the front or rear, or giving the light taps with the horns on the head, horns or rump.

Supplanting (S): An animal attaches itself to another of inferior rank and follow it relentlessly at a normal walk or dominance display, thereby forcing it to continually yield in front of him. The animal followed is unable to stop and walk or circle among the herd, with tail down and head and ears raised.

Dominance display (DD): The animal displaying dominance in the herd, drops his ears vertically as in threat, and hold his tail curled over his back. His body is straight, head raised; chin horizontal and pre-orbital gland open.

Ear threat (ET): Refers to letting the ears hang down on the side of the neck. This display an individual forces another to move aside, or to stand up. By this display mother defending their young, are especially common, as in other ruminants.

Horn or frontal threat (HT): The animal presents its horns towards the recipient as a ritualized intension movement for fighting.

Charge (Cg): It is a violent and rapid threat designed to drive a conspecific away, consist of rushing at an opponent with horn ready to hit. It was found frequently in mixed herd and mostly in territorial males towards the same or opposite sex of any age classes.

Butting (B): An individual drive off a rival or make her stand up with lowered ear butt another on her side or shoulder. It was very common in females of all ages and younger bachelor males.

Sparring (Sp): Clashing of head or horn between two individual with head to head pushing, without any mutual harm. It was very common among the

individuals of bachelor males. Sparring between adult male was much longer and more violent.

Fight (F): Intensive clashing between two males and refers to any kind of horn contact between the opponents. This is quite frequent between territorial and bachelor male, while less frequent in between females. It was observed that the reciprocal threat leads to fight.

Chasing (Ch): When one individual run towards another individual and the challenged animal flees drawing pursuit from the aggressor. Also occurs at the end of fight when one of the two opponents is defeated and has turned for flight. It is very mostly initiated by territorial male chasing the other adult male, younger bachelor male and sometime sub-adult female of the mixed herd.

Individual activities of all age-sex categories of blackbuck were analyzed in hourly, monthly and seasonal basis and calculated as:

$$\% \text{ Activity} = \frac{\text{Total time spent / Number of time in particular activity in that hour / month / season}}{\text{Total time spent / Total number of records in all activities in that hour / month / season}} \times 100$$

Group Behaviour

Instantaneous sampling or scan sampling (Altmann, 1974) was used to gather information about group/individual activity. Group scans were taken on all visible members of the group for a period of 5 min at every 10-min interval. Each herd was followed for about 6 days every month, and data were collected from dawn to dusk. Information recorded during scan sampling included date, time, individual (age-sex class), activity (resting, ranging, feeding, social and self-directed activities) and the place at which the herd was seen. Different activities recorded were as follows:-

Resting: When an individual showed passivity either standing or lying. During feeding bouts, if the individual was inactive, it was recorded resting only if it lasted for more than 30 s (Prasad, 1985).

Walking: Any movement of the herd results changes in the activity place. Movement in between feeding bouts was not recorded as walking.

Feeding: When an individual ingested either plant food (fruits, leaves, flowers, etc.).

Social and self-directed behavior: Social behaviors such as grooming, play, agonistic interaction within the members of the group, and inter-group aggression were recorded under this category. Self-directed behavior included auto-grooming, self-play as in the case of infants, or exploring objects by infants.

Data recorded on the group activities of blackbuck in the field were analyzed in hourly, monthly and seasonal basis calculated as:

$$\% \text{ Activity of group} = \frac{\text{Number of animal engaged in particular activity in a sample}}{\text{Total number of animal engaged in all activities in a sample}} \times 100$$

Activity Budget, Schedule and Activity Pattern

Data were recorded on basic activities including feeding, standing/scanning, walking, running, lying and others activities. Other activities include all social activities (includes grooming, play, sparring, aggression, chase etc.) and maintenance activities (urination-defecation, rubbing, marking etc). Observations were conducted on 8 identified territorial males and selected females. All age-sex categories individuals were observed from June 2004 to May 2007 and their activities were recorded from sunrise to sunset with the aid of binoculars and stopwatch. Males were identified by their natural markings. Individuals were sampled repeatedly during all hours of the day, months and seasons by using focal animal sampling method (Altman, 1974).

Activity budget data were converted into percentage by (e.g. [total time in particular activity during sample/total sample time] × 100) and the difference in activity patterns of the individuals in different hours, month and seasons were calculated by the method of Prasad (1985). The mean time spent by territorial males in each hours of daylight was calculated separately for pre-monsoon, monsoon and post-monsoon.

Change in behaviour patterns between different hours of the day, months of year and seasons were tested for significance by use of Chi-square test and ANOVA. $P < 0.05$ was accepted for significance for all tests.

Social Behaviour

Field observations were conducted from November 2004 to December 2006, 6-8 days per month with 200 h of observations. Binocular were used for identification of the individual and for observation of behaviour patterns. More than 10 groups and 12 territorial males as individuals were identified through natural marking such as broken horn, numbers of spiral in horn and face coloration when present. Observation for a single group of blackbuck was carried out continuously from 1 h to 6 h. Most data were collected all hours between 6.00 to 18.00 h.

Activities were categorized social and non-social behaviour. Social activities included all behaviour directly involving at least two individuals where as non-social activities involved only the animal being observed.

Agonistic behaviour was sampled by scan sampling method (Altman, 1974). When interactions were recorded the time of occurrence, sex, relative size and identity of both the individual that initiated the interaction and the recipient were also noted. Three sex classes of participants in agonistic encounter are considered 1) encounter between males (male-male) 2) encounter between females (female-female) 3) encounter between male and female (male-female) as described by Koutnik (1981).

Social Interaction

Behavioural act and social interaction were recorded on a minute-by-minute basis noting sex, age, and when possible known individuals. These data were analyzed in terms of the number of behavioural act per active hours. Time spent for bedded activity was not included in the frequency calculation, as little behaviour occurred when blackbucks were bedded. During 36 week study (June, 2004 to May, 2007) a total of 540 sightings of blackbuck (14 individuals) was made and 720 active blackbuck hours were recorded.

Data recorded were movements, activities, the frequency and location of scent marks and interactions with other blackbuck. All interactions between the individuals of all age and sex categories were recorded. These include events such as fight, chasing, mount, flehmen etc. They were recorded in detail as to which individual was involved, how long the event continued for, and also which males, females and young ones were present.

Intra-group interactions among the study group were noted whenever two or more interacting individuals were present in the vicinity of each other within a radius of about 30 m. Data were collected on date, time, study herd followed during the day, age and sex of interacting individual, activity of the individuals before the encounter, activity of the individuals during the encounter, distance between the interacting individuals (visually estimated), type of interaction (aggressive or affiliative), aggressor and the recipient, displacement (if any), individual displaced, and duration of the interaction (time spent in proximity).

Social interactions of all categories were also analyzed by sex and size class matrices (Kuchera, 1978).

C. Community Conservation

A semi-structured questionnaire survey (Jackson, 2003) was conducted in the study area from April 2005 to March 2007 of 108 randomly interacted local people and landowners. Generally local people had a detailed knowledge of the fauna in their region, and their answers are considered very reliable. Local people were interviewed singly or in groups. Most interviews were conducted in late morning,

around mid-day or in the evening, after people had returned from their work in the fields. Sample questions are divided into 4 categories to collect information and baseline data about the PCRB, which are (1) Factor for conservation of blackbuck by local community (2) knowledge about PCRB (3) Crop damage by blackbuck (4) Attitudes towards blackbuck. Data on the above was analyzed by calculating the mean, frequency and percentage of total response in each category. For multiple response questions, relative frequency based upon the total number of responses rather then upon the total number of people surveyed in order relative frequency sum to 100 was reported (Newmark *et al.*, 1993).

Data Analysis:

The data processing was carried out using SPSS Statistical software (SPSS Inc.). The behaviour scan and focal data were analyzed by T-test, Chi-square test, ANOVA, Correlation and Regression of all variables and interactions. The statistical procedure tests whether each of the predictors were significant predictors for each of the depending variables (means). Due to relatively small number of males that fitted the condition necessary in the analysis, the significance of the predictors should be interpreted with care. As a result some P values that are slightly greater than the standard P = 0.05 are reported as significant. It is noted that this increases the probability of getting false significance, but also decrease the probability of declaring a predictor non-significant when it is actually significant.

RESULTS AND DISCUSSIONS

A. Ecology of Blackbuck

I. Habitat types and characteristics

Present area of the intensive study on PCRB (Figure 8) can be divided into five ecologically diverse habitat subtypes:–

1. Grassland land with few tree and bushes.
2. The bushes with plantation and seasonal cropland.
3. Grassland with seasonal cropland.
4. The agricultural area which has seasonal crops or fallow land.
5. Intensive agricultural area.

These five habitat subtypes were again divided into 8 plots for the sake of the present study shown in figure 9 as:–

Watch tower left (WTL): dense bushes with plantation and seasonal cropland.

Watch tower right or Banabali (WTR): Grassland with few tree and bushes. Area used as a grazing land for livestock's.

Sidhanai (SDN): Grassland with seasonal cropland. This area is also used as a intensive grazing land for livestock's.

Vetnoi back (VTB): The area is primarily intensive agricultural land with scattered tree and a nala remarketed with bushes.

Vetnoi right (VTR): Seasonal cropland and some parts fallow land with scattered trees.

Vetnoi left (VTL): Intensive agricultural area with bushes on the edges of the agricultural plots. Area used as intensive grazing land for livestock's.

Vhejiputu right (VJR): Agricultural land with scattered tree.

Vhejiputu left (VJR): Seasonal cropland with bushes of grass on the edges of crop field. Area used as intensive grazing land for livestock's.

Vetnoi left B (VTLB): Seasonal cropland with grassland and scattered bushes (This habitat was observed only for home range overlap of 9th territorial male).

II. Home Range and Territory

Adult bucks (four years and older) appeared to occupy large, non-overlapping home ranges marked by urination-defecation spot or rubbing the ground, bushes and trees. The range covered by the mixed herds in daytime was recorded 4 time shown in figure 10. The size of home range and territory of nine selected territorial male was calculated and the result is shown collectively as territorial clusters in figure 11. The range and territory of each individual territorial male is shown in figure 12 to 16. Bucks younger than three years ranged widely through these home ranges. The entire PCRB was dominated by the adult buck and there was only 1-2% overlap between the home ranges of the two bucks. Moreover, the bucks were never actually observed in the area of overlap. Females appeared to have overlapping home ranges with largely distinct and were more or less stable home range.

Home ranges and territory for the eight adult bucks were calculated. The largest size of home range recorded was 5.4 sq. km of the male named as WTR while the small size of the home range recorded was 3.15 sq. km of the male named as VJR. Similarly the size of territory differs between the eight selected males. The largest size of territory observed of the VTL was 1.72 sq. km and smallest herd observed was 0.98 sq. km of VTB. In general, home ranges were larger for adult males found in the open areas of grassland. The differences between the range and territory of buck were not significant.

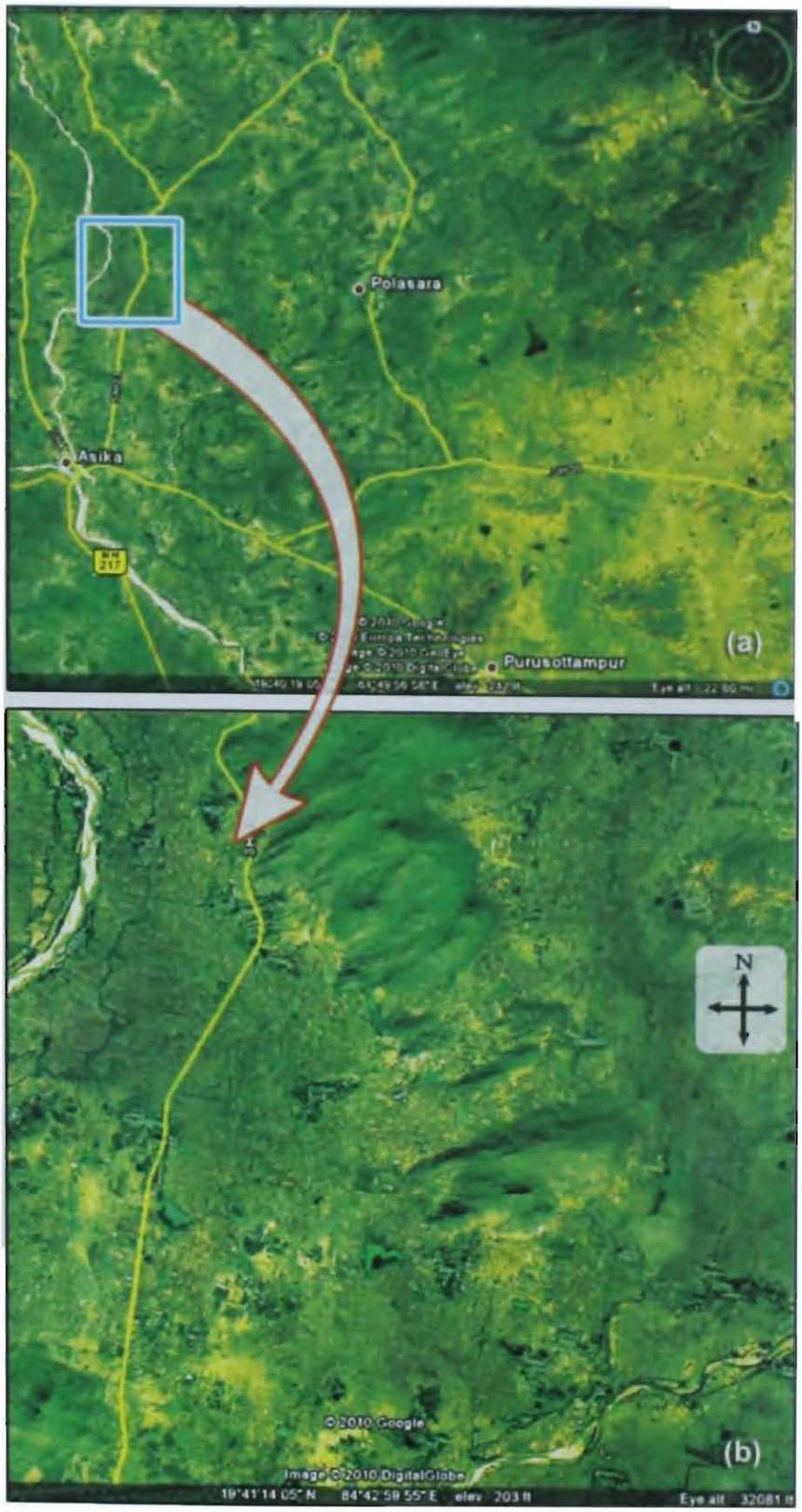


Figure 8 : Satellite image of the PCRB (a) and the intensive study area (b). *(redrawn from google@earth image)*

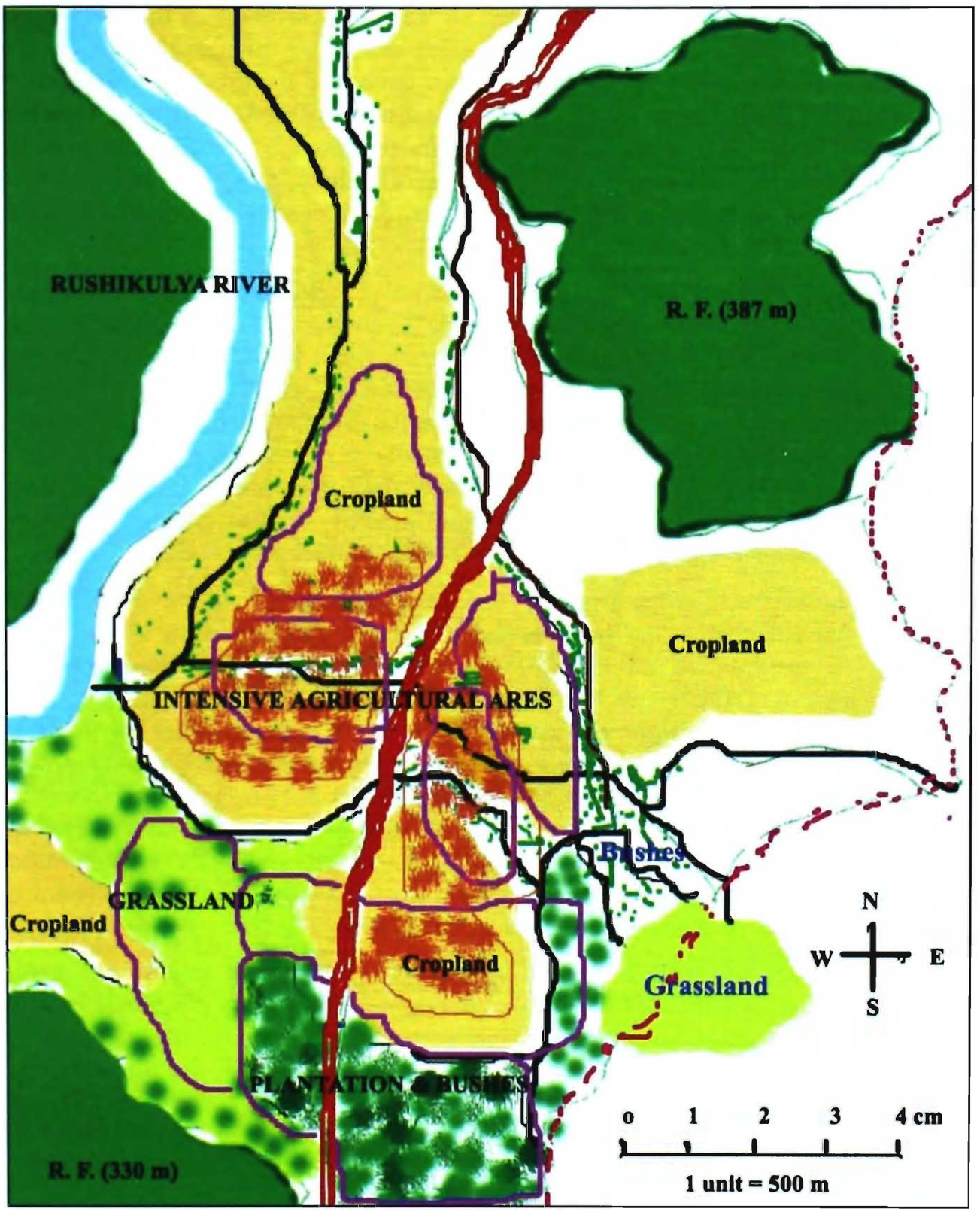


Figure 9 : Habitat subtype of the intensive study area in PCRB, Ganjam district, Orissa, India.

Home range has been popularly defined as "that area traversed by the individuals in its normal activities of food gathering, mating and caring for young" (Burt, 1943). In defining the areas only the presence of an animal is required; no reference is necessarily made to particular behaviour (defense or advertisement), or together individuals (Orians, 1961). But home range characteristics are strongly influenced by the manner in which individuals of a species react to their habitat and to each other and are thought to reflect population features such as density and social structure (Orian, 1961; Schoener, 1981).

Data reflects that adult blackbuck has stable home ranges and are living in group, occasionally seen solitary, while adult males are most of the time solitary in1 territory except when herd visiting their territory. Adult male, three years old and more, maintained exclusive home ranges and territory. Females maintained more or less exclusive home range but showed substantial overlap in their home ranges. Some seasonal shifts in home range undoubtedly exist; for example, blackbucks were observed to range more widely in monsoon and before winter, the period when habitat is more disturbed due to agricultural activity of local people. The home range of female increased in summer when food resources were scarce.

The extensive use of urine, droppings and dropping piles in markings is unusual in ungulate, but common in territorial species (Walther, 1984). Marking of borders is common in male territorial ungulates such as pronghorn (Gilbert, 1973) and Thomson's gazelle (Walther, 1978). It would be interesting that the use of dropping in blackbuck with other antelope species that there was a slight tendency for males to mark the borders of their territory, and the tendency of marking outside their territory significantly more than neighbored adult male (Dubost & Feer, 1982; Ranjitsinghji, 1982; Prasad, 1984). An active defense of the territory by adult male was observed on number of times during the present study. This may be the result of the semi-natural situation, in which immigration and emigration exist as much of their lives is spent in heavy disturbed territorial location surrounding human presence.

In conclusion, the male blackbuck was usually solitary and maintained stable home ranges which were exclusive. Males marked relatively more frequently outside their core areas, while females and juveniles marked less frequently within their core areas. Since the blackbucks were in a semi-natural area, the size of their home ranges was certainly constrained seasonally depending upon the human disturbances. These areas probably thus represent minimum home ranges or minimum areas.

III. Distribution Pattern

A total of 165 groups of blackbucks were encountered during the study period across different sites. The maximum numbers of groups were observed in the

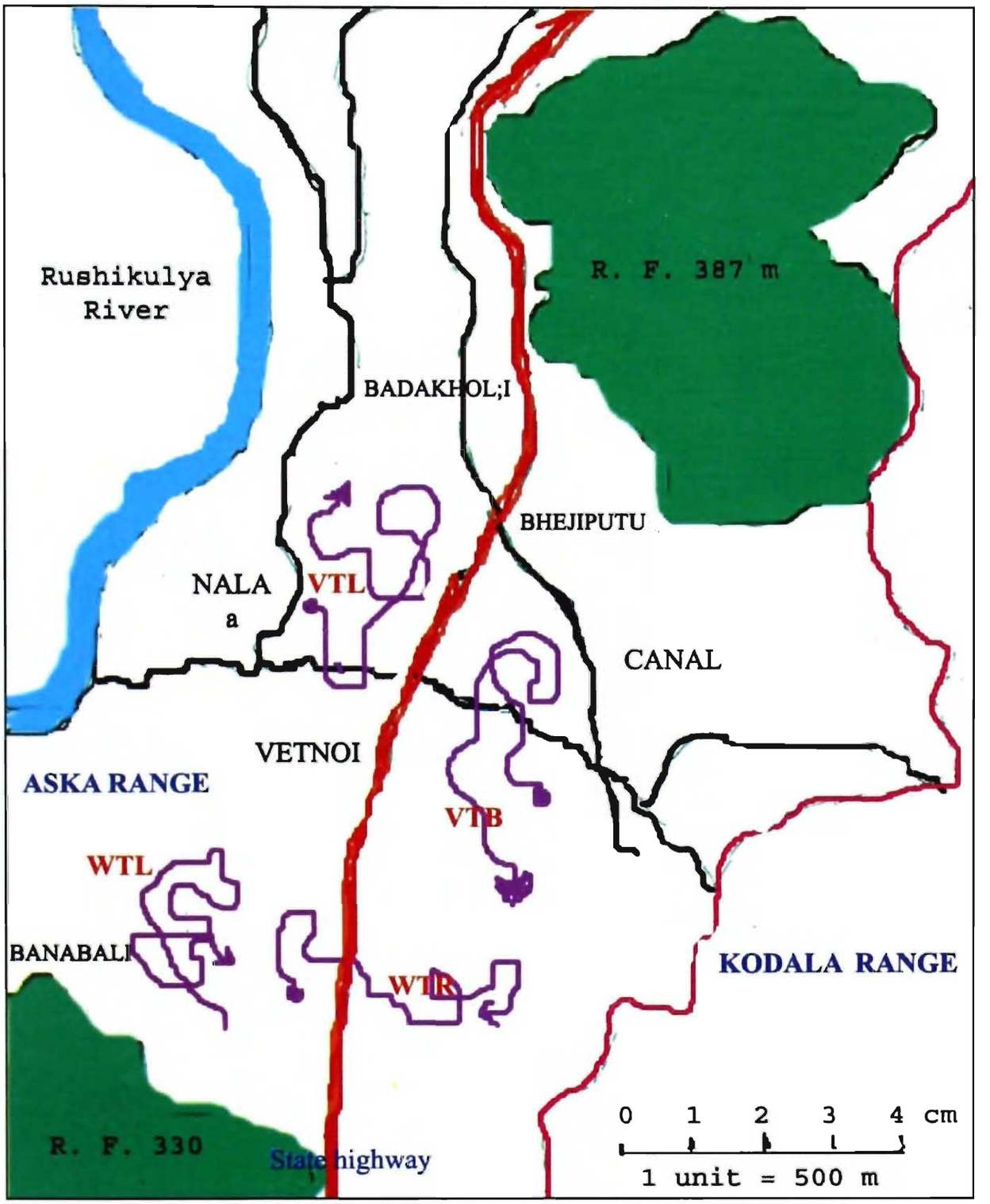


Figure 10 : Schematic diagram of intensive study area showing range of 4 selected herd trekking in one day.

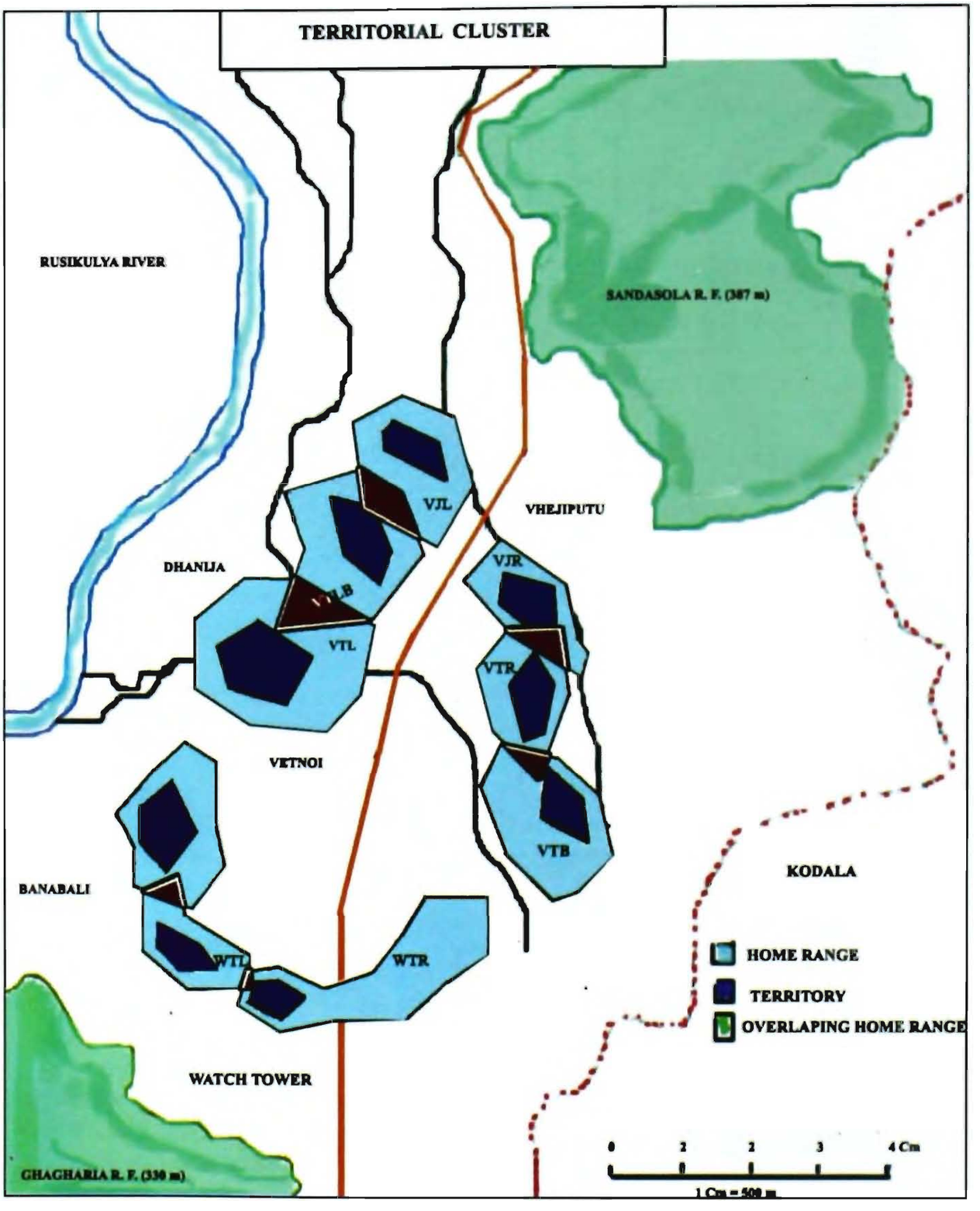
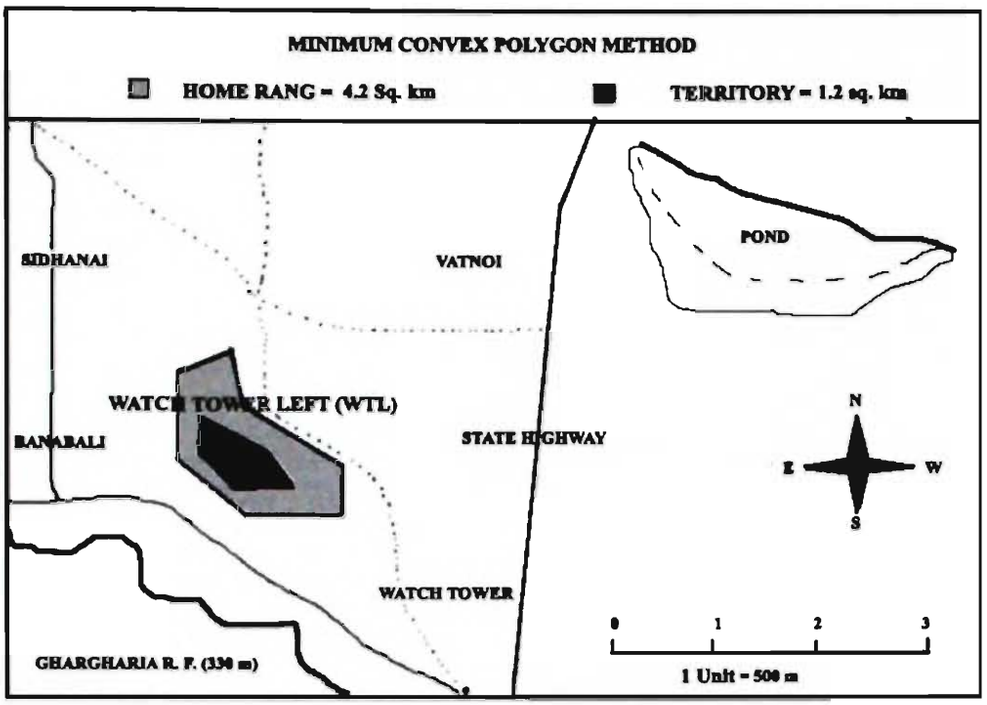


Figure 11 : Sketch diagram of territorial clusters of the adult male of blackbuck in PCRB with range and range overlap.



(a)

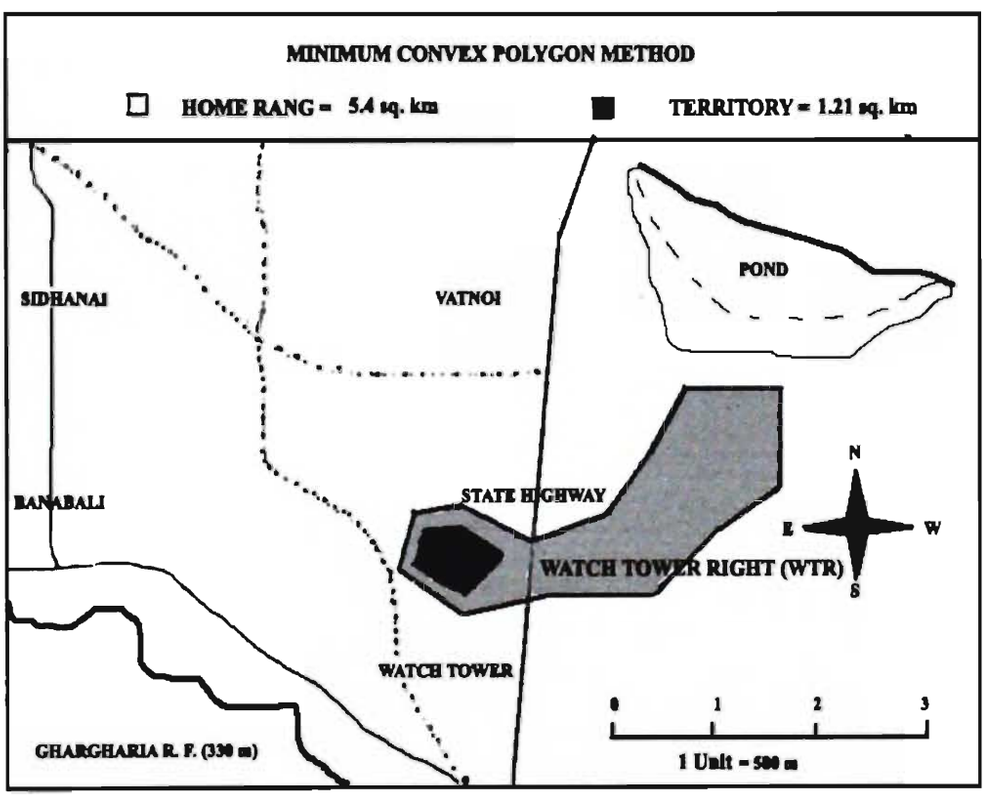


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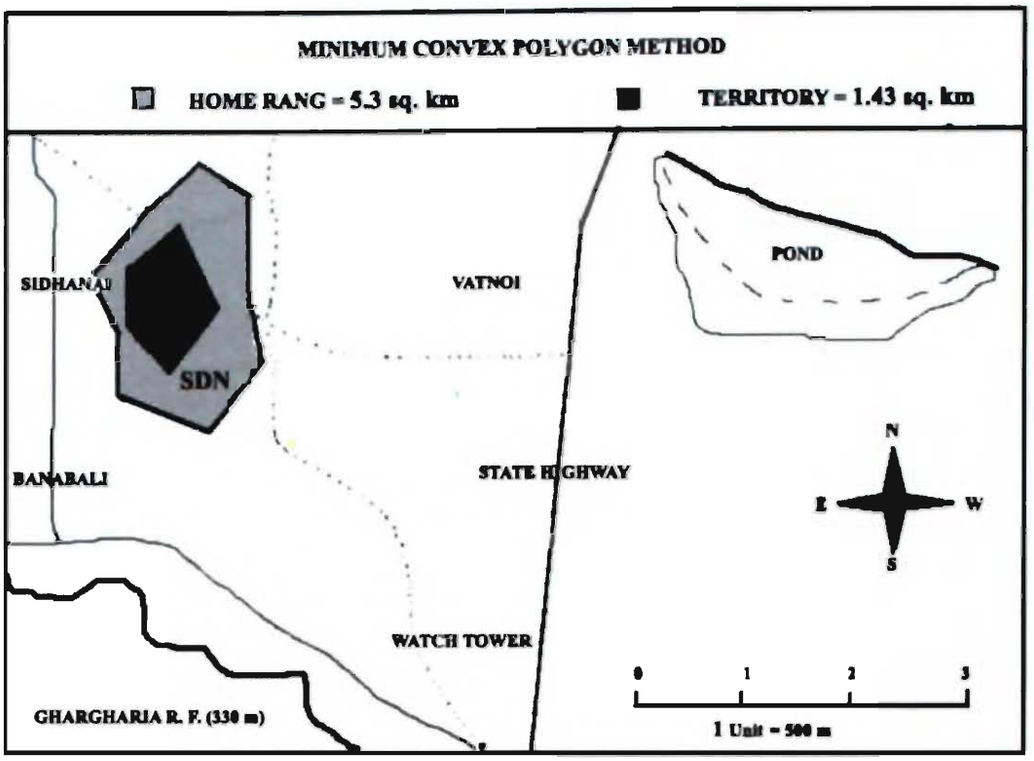
Figure 12 (a & b) : Home range and territories of selected territorial males of blackbuck in intensive study areas of PCRB.



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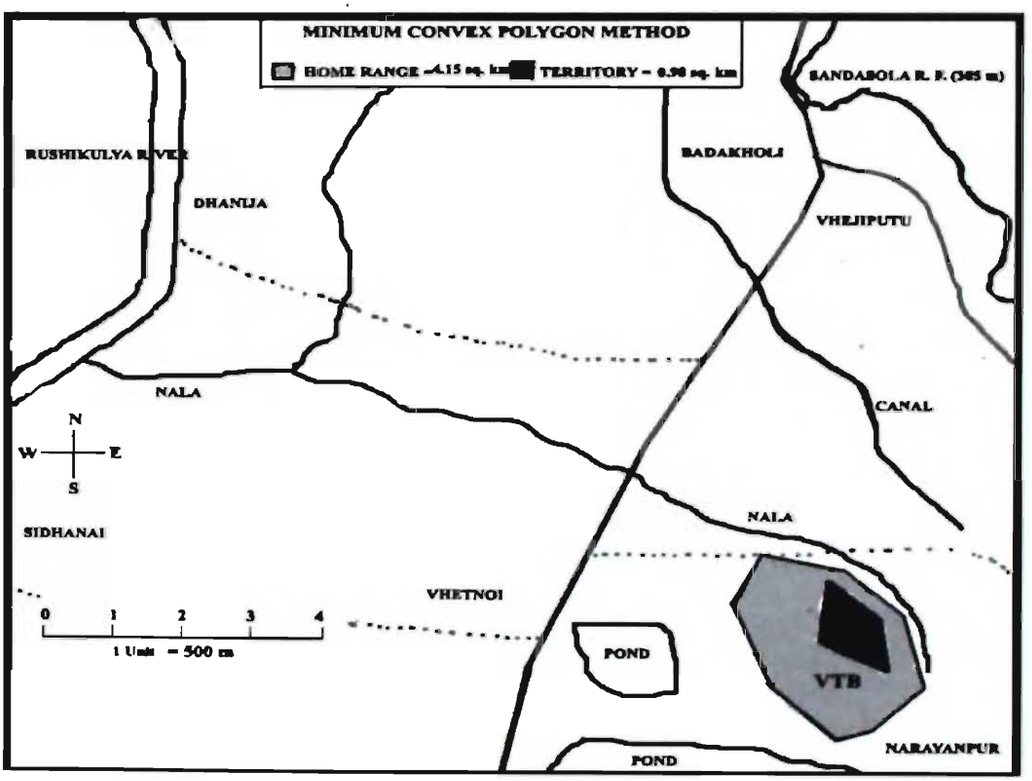

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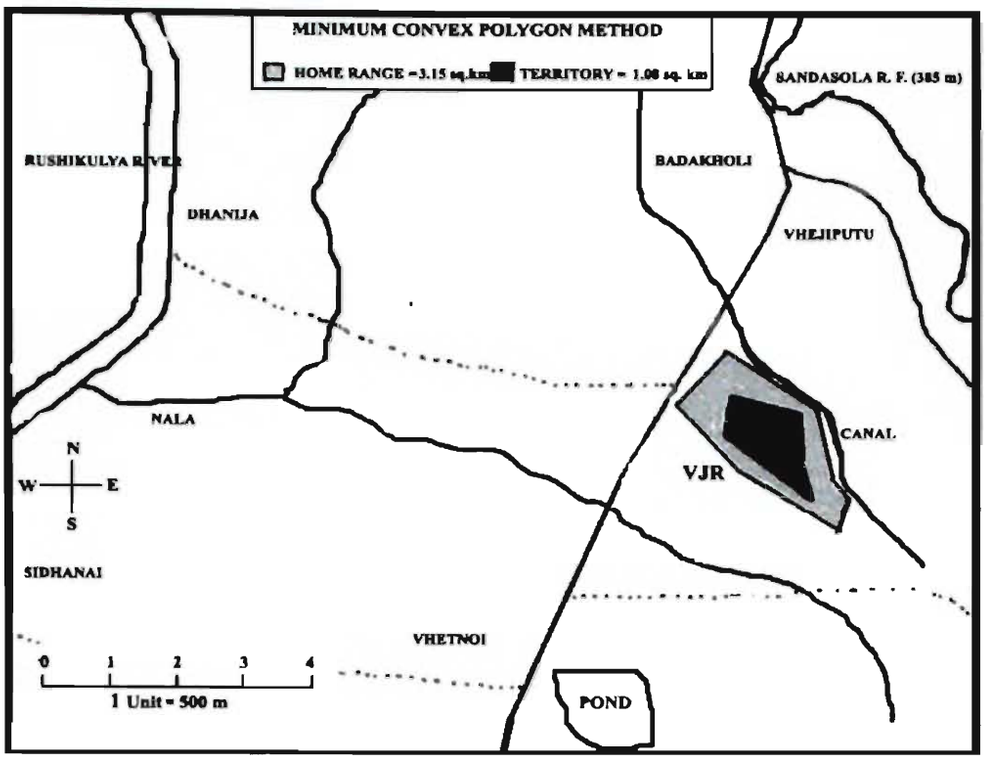
Figure 13 (a & b) : Home range and territories of selected territorial males of blackbuck in intensive study areas of PCRB.



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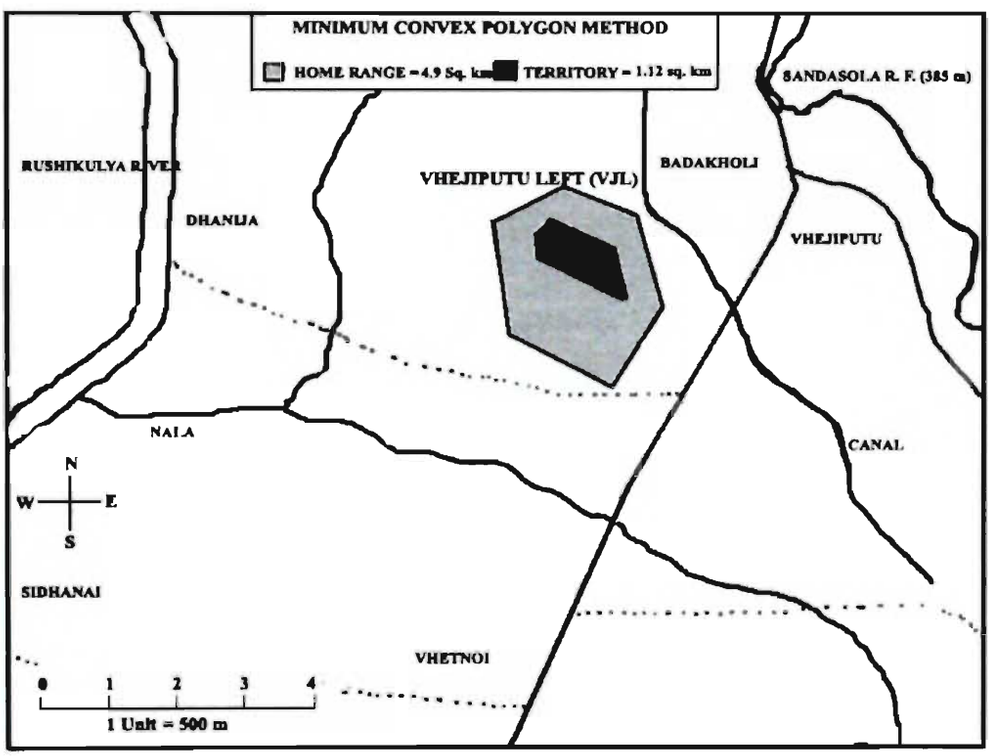

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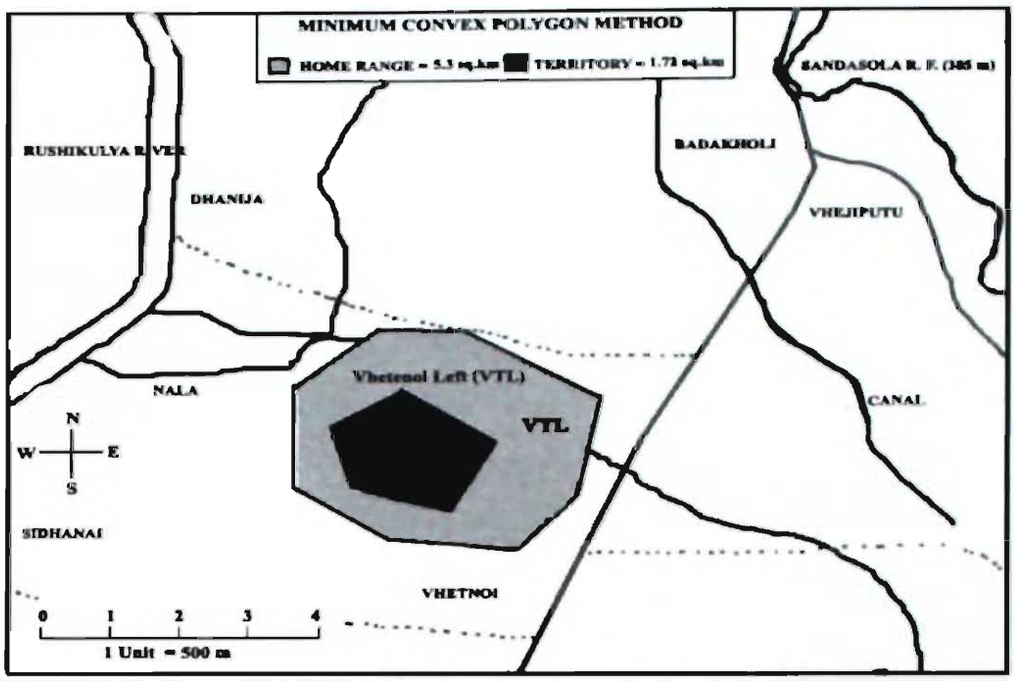
Figure 14 (a & b) : Home range and territories of selected territorial males of blackbuck in intensive study areas of PCRB.



(a)

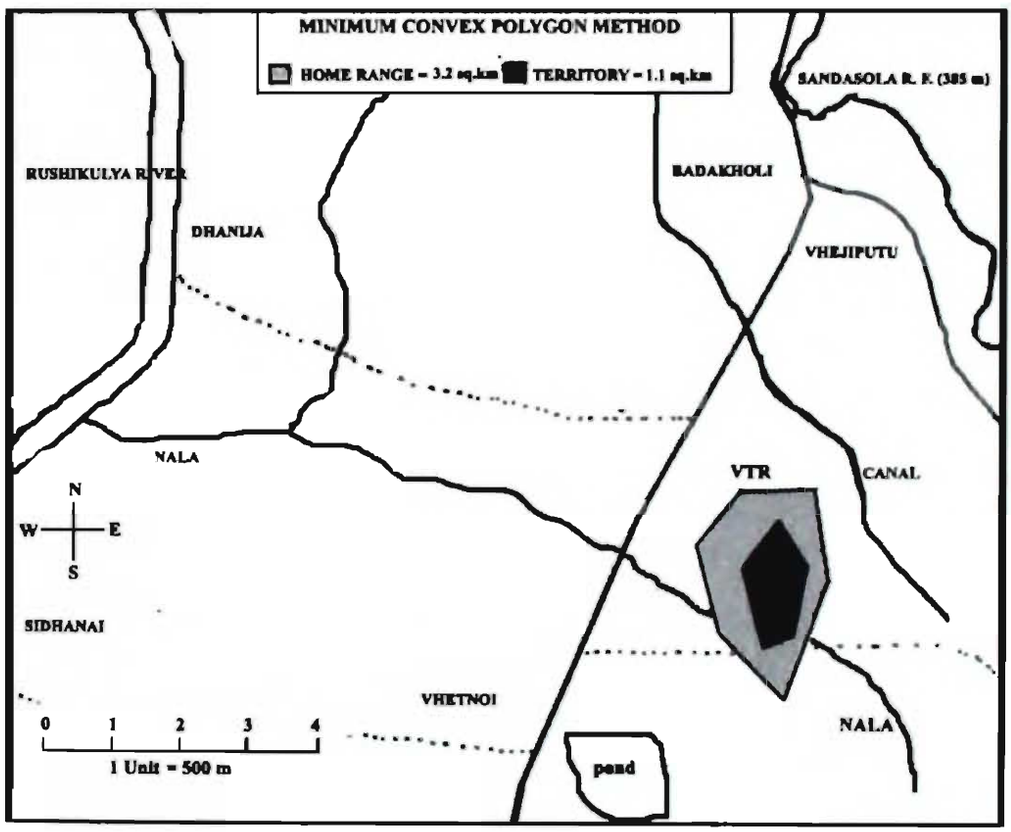


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Figure 15 (a & b) : Home range and territories of selected territorial males of blackbuck in intensive study areas of PCRB.

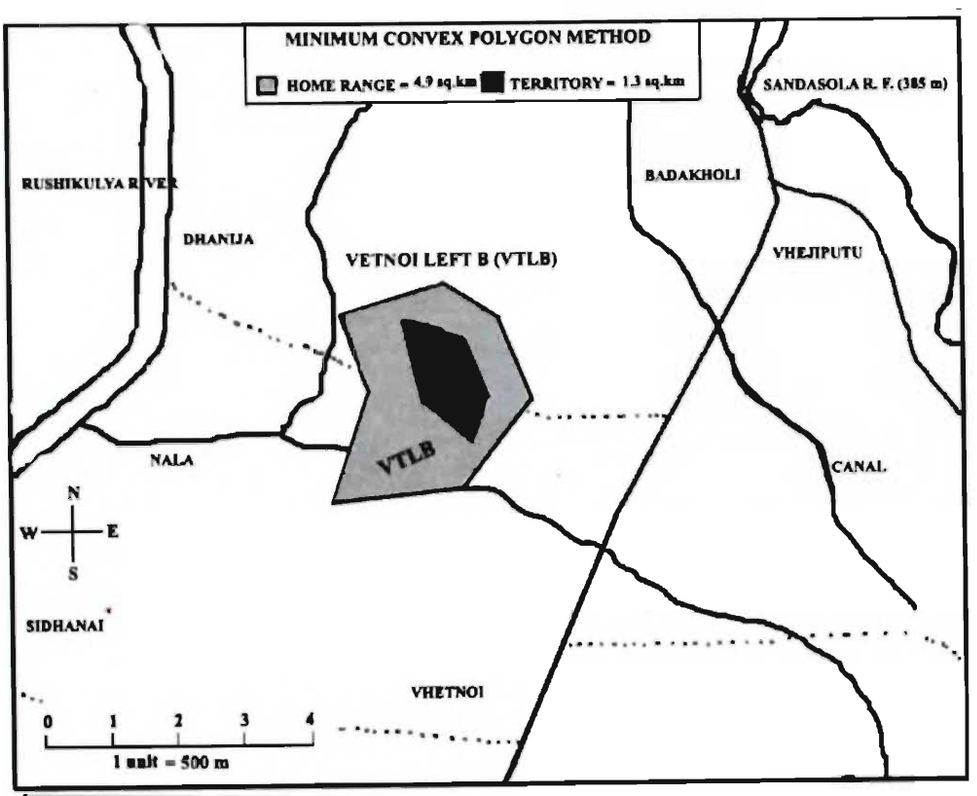
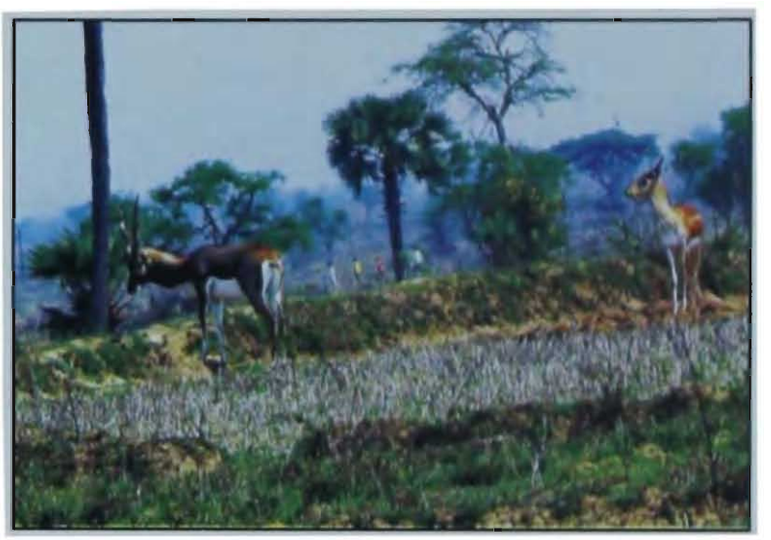


Figure 16 : Home range and territories of selected territorial males of blackbuck in intensive study areas of PCRB.

agricultural areas (58%), while the minimum number of groups in bushes and shrubs (7%). Across different sites in PCRB, the largest herd of 36 blackbucks observed in a day, during the period of study, was in Gahangu village, while the smallest herd was observed in Banabali, comprising 3 individuals. It was observed that Vetnoi village harbour the highest population of blackbucks. The population, its composition, mean population, SD and distribution of herd of blackbuck in 8 selected habitat sub-type of PCRB is given in Table 1 and the average number of each age-sex of individuals in each habitat sub-type shown in figure 17 & figure 18.

Block sampling method was used to estimate population distribution pattern of blackbuck in PCRB, because the habitat was not continuous. In all areas of PCRB, the highest population of blackbuck was found in and around Vetnoi. There has been undoubtedly been an increase in the blackbuck population in this area, probably as a result of the large open areas in this locality. Blackbucks are known to be traditional and have a strong tendency to return to their seasonal ranges over the year (Mungall, 1978; Prasad, 1982). The PCRB described as covered with grassland, cropland and scrub forest which are the seasonal choice of the blackbuck. The distribution pattern of blackbuck in these mosaic habitats differs seasonally according to the availability of food and agricultural activities.

A defecation spot of blackbuck used as a territorial boundary.



A male engaged in territorial marking.

A slender built territorial male in Vetnoi.

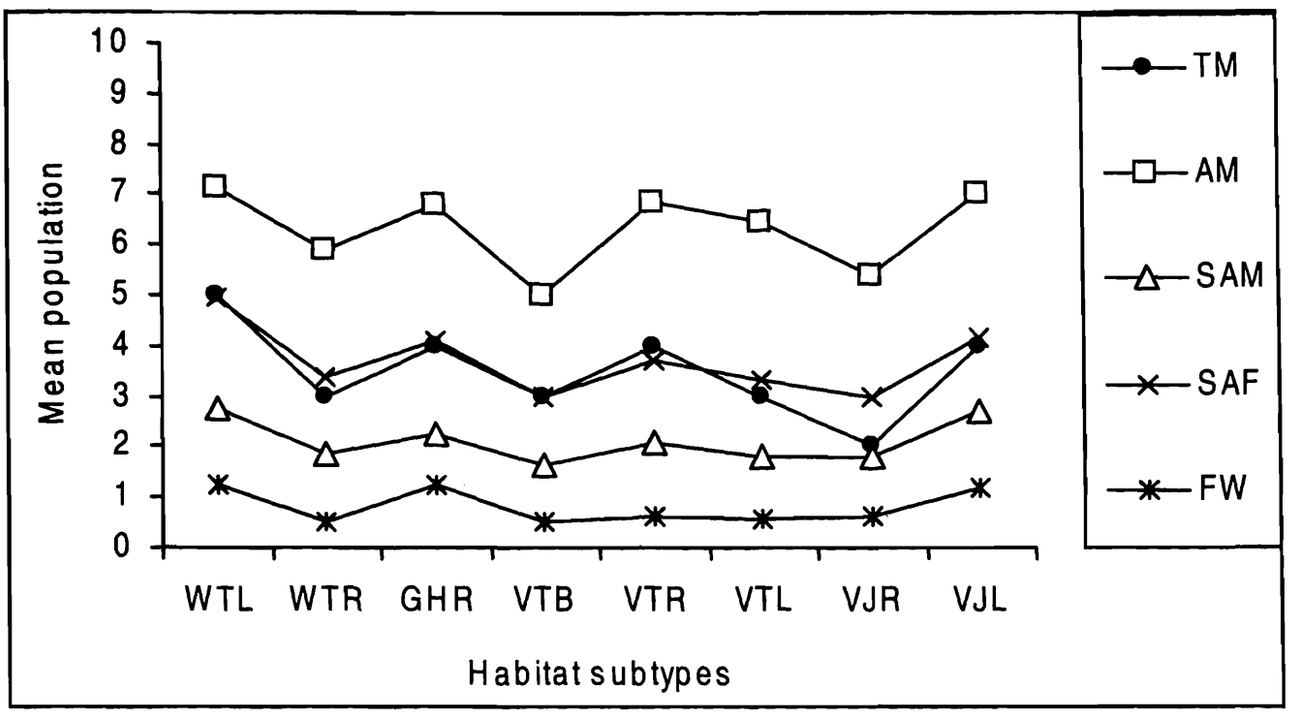


Figure 17 : Mean population of all age-sex category of blackbuck in eight habitat subtypes at PCRB.

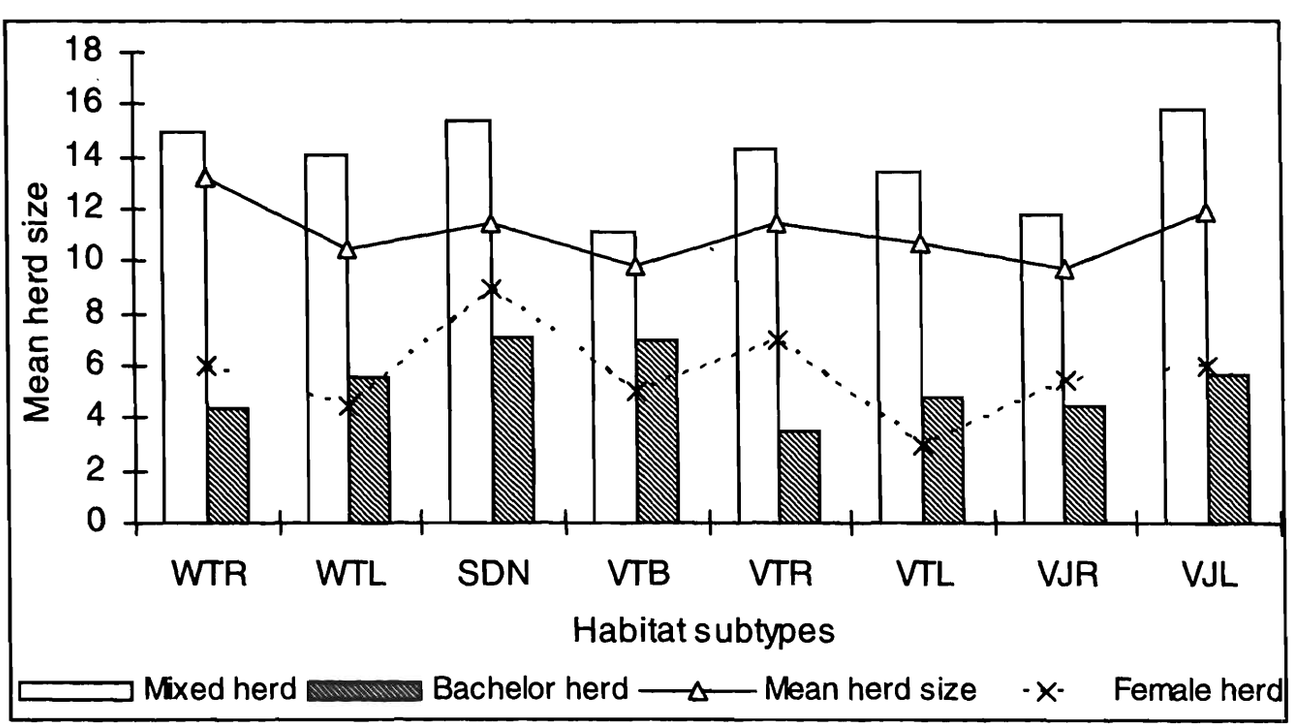


Figure 18 : Mean herd size of all types of herds of blackbuck (mixed herd, bachelor herd & female herd) in comparison to average herd size of all eight habitat subtypes at PCRB.

Table 1 : Mean population ± SD of various age-sex categories of blackbuck in eight selected habitat at PCRB.

	Territorial male	3 year adult male	2 year bachelor male	1 year bachelor male	Adult female	Sub-adult male	Sub-adult female	Fawn	Observed population	Mean population	SD
WTL	5	1	2	2	7	3	5	2	27	17.13	4.3
WTR	2	1	3	2	6	2	3	0	19	12.61	4.33
SDN	4	2	2	2	7	2	4	1	24	15.33	5.29
VTB	3	2	3	1	5	2	4	1	21	11.12	3.56
VTR	4	1	2	1	7	2	3	1	21	14.23	4.39
VTL	3	1	2	1	6	1	3	0	17	13.44	7.43
VJR	2	0	2	1	5	2	3	1	16	11.8	6.9
VJL	4	1	2	1	6	3	4	1	22	15.83	6.76
Total	27	9	18	11	49	17	29	7	167	111	

Table 2 : Population composition of the blackbuck in the intensive study area at PCRB.

Month	TM	3YRAM	2YRM	1YM	AF	SAM	SAF	FWAN	Total
Feb-05	21	3	6	3	38	11	21	5	108
May-05	15	1	3	2	37	16	22	7	104
Aug-05	23	7	8	8	53	11	21	5	137
Sep-05	13	2	3	2	56	18	32	6	132
Nov-05	27	3	7	5	46	14	24	6	131
Mar-06	24	2	7	5	31	12	18	4	103
Jan-06	21	5	5	4	35	10	21	5	106
Jun-06	23	4	3	2	38	12	21	5	117
Jul-06	15	2	6	5	67	16	36	6	153
Oct-06	37	11	20	17	81	28	47	8	249
Dec-06	21	4	9	4	45	6	13	2	104
Apr-07	18	2	6	5	41	14	25	5	116
Grand Total	**258**	**46**	**83**	**62**	**568**	**168**	**301**	**64**	**1560**
Mean	**21.5**	**3.83**	**6.91**	**5.16**	**47.33**	**14**	**25.08**	**5.33**	**130**

IV. Herd Size

Blackbucks were encountered 165 times in the whole observation period and a total of 1550 individuals were sighted in the study area. Solitary animals were observed 178 times during the total observation period. However, solitary animals composed only a small percentage (8.7%) of the total observed individuals. The rest of the animals were observed in groups ranging from 2 to 32 with 50 percent of the animals observed in groups larger than 15 individuals. Mean group size recorded was 13.86 (n = 165) individuals if solitary animals were excluded.

The overall mean group size of blackbuck was found to be 9.93 ± 1.02 S.E. across the eight selected habitat of PCRB. Largest group size was reported from Gahangu village 36 and lowest in Banabali was 3 (2 adult female + 1 sub-adult female). The group size of blackbuck varied significantly across different sites ($f = 5$, $P < 0.05$). One group with 3 individuals occurred in May, but the largest group, with 36 members, was seen in October, 2006.

Population mean and standard deviation of the eight selected herds in PCRB is shown in table 3. After categorization the mixed herd into 4 categories (less then 10, 11 to 15, 16-20 and more then 20) the size varied and the mean herd size of mixed herd was 13.86 ± 1.66, size of the bachelor herd 5.31 ± 1.28 and size of female herd 5.66 ± 1.68 (Figure 19). The overall size of the herd of blackbuck in the selected eight habitats was 11.08 ± 1.16 SE (Figure 20 & Table 3). Out of 8 selected habitats mean size of larger in Watch tower area i.e grassland (13.18) and smallest size observed in VJR i.e. Crop land, canal and road (9.71).

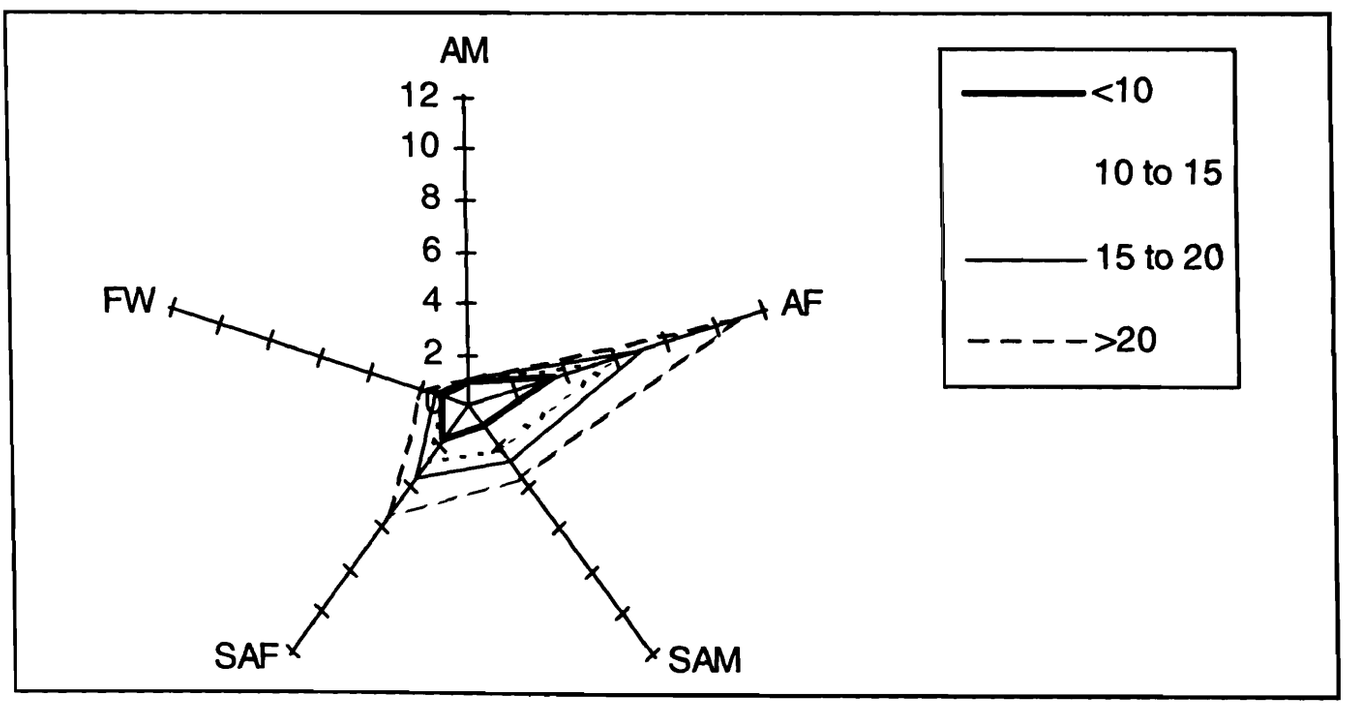
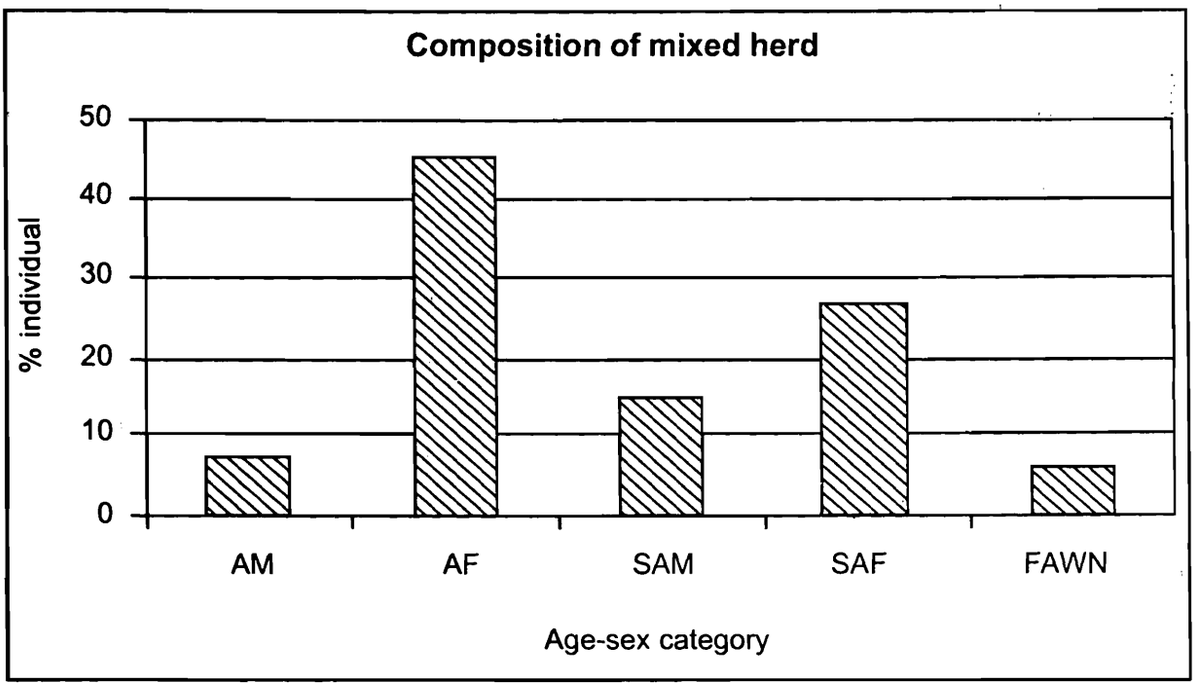


Figure 19 : Herd size of different age-sex category of blackbuck.



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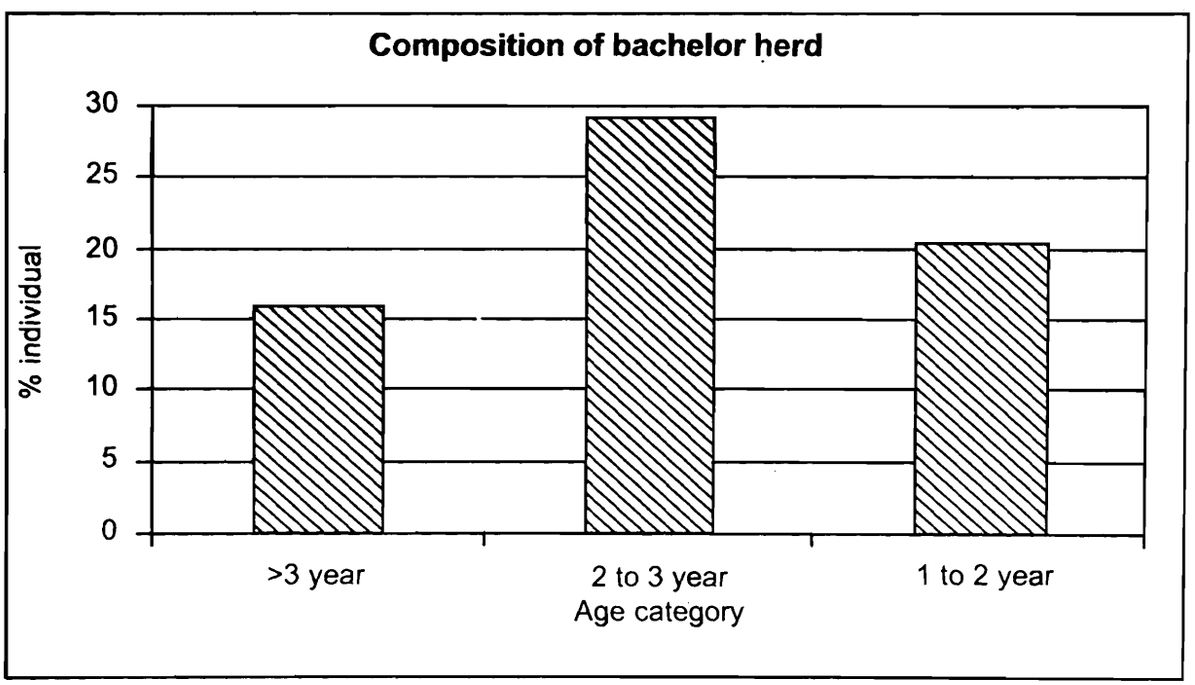


(b)

Figure 20 : Herd composition of blackbuck mixed herd (a) and (b) bachelor herd at PCRB.

Table 3 : Mean herd size of blackbuck in different habitat sub-type of PCRB.

		Mixed herd				Bachelor herd		Female herd	Lone territorial male	Total herd observed	Total individual ovserved	Herd Size
		<10	10 to 15	15 to 20	>20	<5	>5					
WTR	No. of herd	4	4	6	4	2	1	1	23	**22**		
	No. of individual	29	51	97	93	6	7	7	23		**313**	13.18
WTL	No. of herd	0	5	5	0	3	2	2	52	**17**		
	No. of individual	0	67	74	0	11	17	9	52		**230**	10.47
SDN	No. of herd	1	4	2	2	2	5	1	43	**17**		
	No. of individual	8	49	35	46	9	41	7	43		**238**	11.47
VTB	No. of herd	4	3	1	0	1	1	1	6	**11**		
	No. of individual	34	37	18	0	5	9	5	6		**114**	9.81
VTR	No. of herd	2	4	6	1	4	0	1	31	**18**		
	No. of individual	13	49	103	21	14	0	7	31		**238**	11.5
VTL	No. of herd	3	3	1	2	2	2	1	19	**14**		
	No. of individual	18	37	17	49	7	12	9	19		**168**	10.64
VJR	No. of herd	3	1	0	1	2	0	0	13	7		
	No. of individual	22	14	0	23	9	0	0	13		**81**	9.71
VJL	No. of herd	1	2	1	2	1	2	1	13	**10**		
	No. of individual	8	22	19	46	2	15	7	13		**132**	11.9
Mean herd size± SD					13.86±1.66		5.31±1.28	5.66±1.08				11.08±1.16
Grand total										**116**	**1514**	

V. Age-Sex Ratio

A total of 1550 individual observed in PCRB and their sex was identified. Among the identified individuals of blackbuck in PCRB, the population of male was 617 (39.80%) and the population of female was 933 (60.19%). So, the male : female ratio based on the observed and identified population of blackbuck at PCRB is 1 : 1.51. Among the observed population of blackbucks, the number of adult individuals was 816 (53.29%), the sub-adult population was 660 (42.58%) and remaining 4.12% (64) individuals was fawns. Out of the adult population the 258 were (16.64%) adult males and 568 (36.64%) were adult females. So, the adult sex ratio of blackbuck at PCRB was 1 adult male : 2.2 adult female. The population composition of the blackbuck in the intensive study area is provided in table 4 and figure 20 (a & b) respectively.

Overall the age-sex ratio of blackbuck at PCRB was 9.64 male : 14.57 female : 1 fawn. The sex ratio recorded in the mixed herd was 1 male : 3.58 female, while the adult sex ratio was 1 adult male : 6.28 adult female. The age-sex ratio of mixed herd was 1 fawn : 2.62 sub-adult male : 4.7 sub-adult female : 1.25 adult-male : 7.85 adult female. The herd of bachelor male composed of mainly different age groups of males so, the age ratio observed was 1 1-year male : 1.8 2-year male : 1.34 3-year male respectively. The proportion of various age-sex categories in different sites of PCRB is given in Table 5 and Figure 21 and 22. In all the eight sites blackbuck population showed biased sex ratio in favor of females while male to female and fawn to female ratios were relatively the same in all habitats.

VI. Herd composition

112 groups with 1550 blackbucks were analysed accordingly their age and sex out of the 165 groups. Among those animals there were 258 adult males, 568 adult females, 660 sub-adults and 64 fawns (Table 6). The ratio of adults to sub-adults to calves was 1.0 : 0.79 : 0.07. Adult individuals in the recorded groups were obviously favored to females; the ratio of adult males (1) to adult females (2.20) was 1.0 : 2.20. The average participation of adult females varied from 1 to 12 individuals in groups (n = 112). Only three groups (3.36%) observed did not include at least one adult female, and 68.75% of all groups included more than one adult female. Only one adult male was encountered in 89% groups. There was no adult male in 12.7% groups, no fawn in 48.6% groups. More than half of all groups (74.3%) included more than one sub-adult.

Relationships between group members loosened as the group size increased. Smaller groups were often split off from a large group as animals were feeding and

Table 4 : Population structure of blackbuck in PCRB.

Category	No. / Percentage
Total blackbuck observed	1550
Total no of adult individual observed	826
% of adult individual in observed population	53.29
Total no of sub-adult individual in observed population	660
% of sub-adult individual in observed population	42.58
Total no. of male individual observed	617
% of male in observed population	39.80
Total no. of female individual observed	933
% of female in observed population	60.19
Total no of fawn observed	64
% of fawn in observed population	4.12
Total no. of adult male observed	258
% of adult male observed	16.64
Total no. of adult female observed	568
% of adult male observed	36.64

Table 5 : Different age-sex ratio of the herd of blackbuck at PCRB.

Category	Ratio
Ratio of mixed, bachelor, female herd & solitary individual	8 : 3.2 : 1 : 17.8
Ratio between male, female & fawn	9.64 : 14.57 : 1
Adult, sub-adult & fawn ratio in observed population	12.9 : 10.31 : 1
Sex ratio of blackbuck in PCRB	1 : 1.40
Adult sex ratio of blackbuck	1 : 1.86
Age ratio in bachelor herd	1 : 1.8 : 1.34
Sex ratio in mixed herd	1 : 3.58
Age-sex ratio in mixed herd	1.25 : 7.85 : 2.62 : 4.7 : 1
Ratio between adult, sub-adult and fawn in mixed herd	9.10 : 7.32 : 1
Ratio between adult & sub-adult in mixed herd	1.24 : 1
Adult sex ratio in mixed herd	1 : 6.28

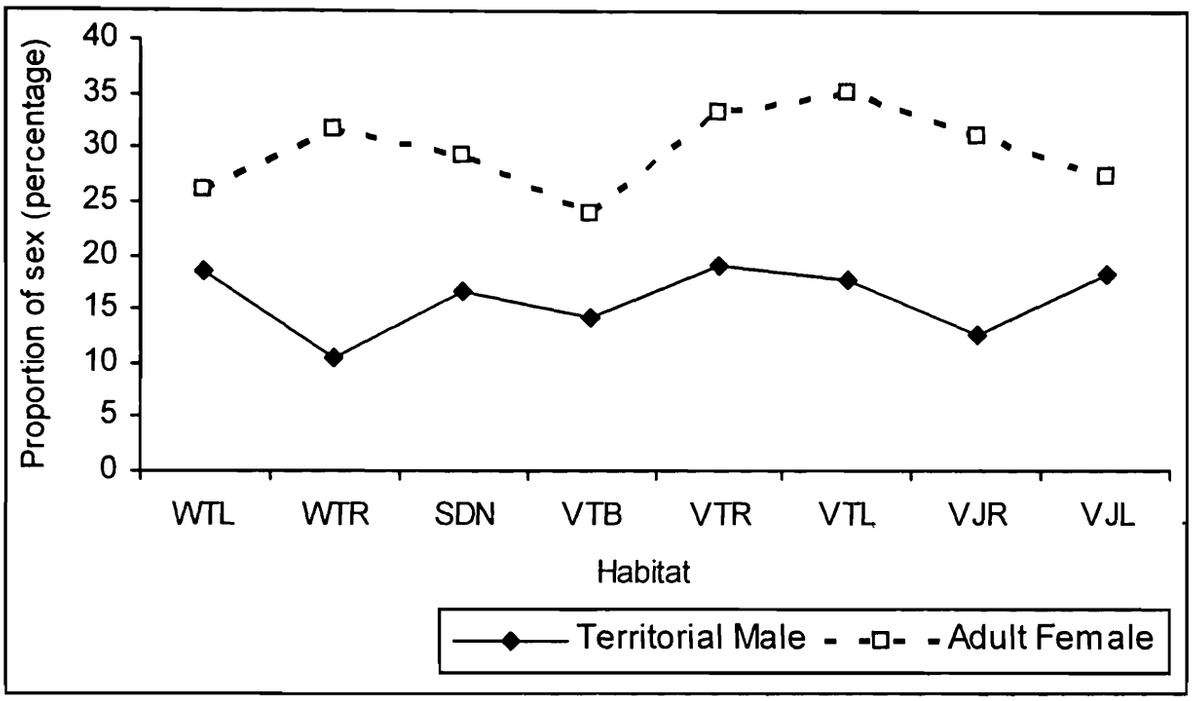


Figure 21 : Relative frequency of territorial male and adult female in all eight blackbuck populations at PCRB.

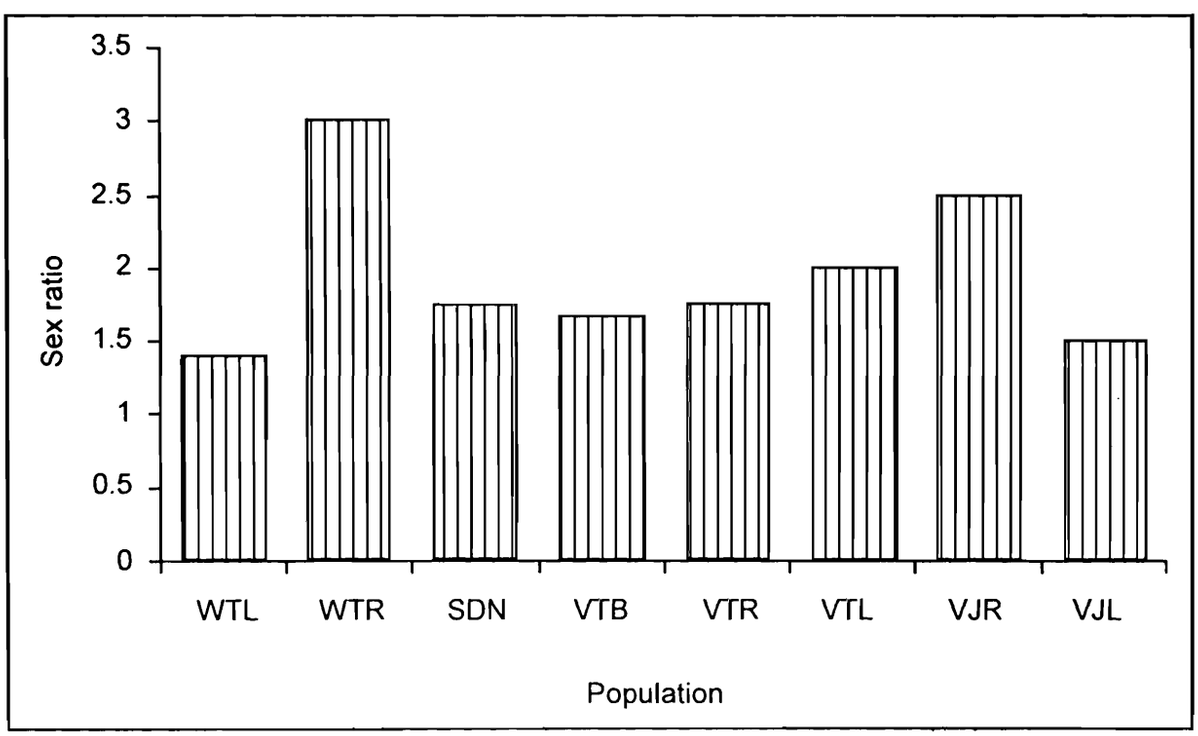


Figure 22 : Sex ratio of Blackbuck, *Antilope cervicapra* in eight different populations at PCRB.

moving. Out of 1550 observed blackbucks, 178 number of individual observed as solitary animal mostly the territorial male and few adult or sub-adult female and fawn.

Out of the total observed population of blackbucks in PCRB, 76.19% populations were recorded in mixed herd and 12.88% in bachelor herd, while rest of the populations were in female and territorial male herds. 68.16% of the population of the mixed herd was female, 20.9% male and rest were unidentified sex including fawns.

Table 6 : Herd Composition of blackbuck at PCRB.

Category	**No/Mean/Percentage**
Total no of herd observed	165
Mean size of herd	9.93
Lone individual observed	178
% of lone individual observed	8.70
Total no. of mixed herd observed	80
% of mixed herd observed	48.48
Total no. of female herd observed	10
% of female herd	6.06
Total no. of female observed in female herd	65
Mean size of female herd	6.5
Total no. of bachelor herd observed	32
Mean size of bachelor herd	5.96
% of bachelor herd	19.39
Total no. of territorial male observed	178
Total no. of territorial cluster observed	40
Mean size of territorial Cluster	4.45

Table 7 : Age-sex composition of mixed herd of blackbuck in PCRB.

Category	No/Mean/Percentage
Total no of individual observed in mixed herd	1181
% population in mixed herd in observed population	76.19
Total no of adult female observed in mixed herd	503
% of adult female in mixed herd	42.59
Total no of female in mixed herd	869
% of female in mixed herd	73.58
Total no of male in mixed herd	248
% of male in mixed herd	20.99
Total no. of adult male observed in mixed herd	80
% of adult male in mixed herd	6.77
Total no of sub-adult male observed in mixed herd	168
% of sub-adult male in mixed herd	14.22
Total no of sub-adult female observed in mixed herd	301
% of sub-adult female in mixed herd	25.48
Total no of sub-adult individual in mixed herd	469
% of sub-adult individual in mixed herd	39.71

Table 8 : Composition of bachelor herd of blackbuck at PCRB.

Category	No/Mean/Percentage
Total no individual of bachelor male observed	191
No. of 3 year bachelor male observed	46
Mean size of 3 year bachelor male in herd	1.43
% 3 year male observed in bachelor herd	24.08
No. of 2 year bachelor male observed	83
Mean size of 2 year bachelor male in herd	2.59
% 2 year male observed in bachelor herd	43.45
No. of 1 year bachelor male observed	62
Mean size of 1 year bachelor male in herd	1.93
% 1 year male observed in bachelor herd	32.46

The recorded population of mixed herd of blackbuck at PCRB composed of 6.77% adult male, 42.59% adult female, 14.22% sub-adult male, 25.48% sub-adult female and 5.41% fawn (Table 7).

Bachelor herd of blackbuck composed of the male individuals of all age categories. Total individuals observed in bachelor herd of blackbuck were 191 in 32 herds encountered in PCRB. The bachelor herd of PCRB composed of 24.08% 3-year or more than 3-years old male, 43.45% 2-years old male and rest 38.46% of population were 1-year old male (Table 8).

Disscussions

Large mammalian herbivores, such as ruminants, make up groups that are easily recognizable in the field. They consist of individuals located at short distance from one another and most often engaged in a common activity, for example, feeding, traveling, or resting (East, 1991). There are two main hypotheses regarding the herd behaviour of the ungulates. The first suggests that when in herds the animals can prevent or avoid the predation better than when alone (Hamilton, 1971). This could be done by a variety of methods including improved predator detection, active group defense and predator confusion (Wirtz & Lörscher, 1983). The other hypothesis links the animal social organization with the distribution and availability of its food supply (Jarman, 1974).

The size of groups is often considered a fundamental attribute of the social organization of such species (Jarman, 1974; Wilson, 1975). The variation of group size with habitat openness was assumed to be a biological adaptation, encoded in the individual (Caughley, 1964). As a consequence, natural selection retained individuals preferring to be within small groups when in closed habitat, and within large groups when in open landscape (Jarman, 1974). Herd size of group living species increases with habitat openness: whereas groups are small in forested habitats, they are much larger in grassland and other open landscapes (Leuthold, 1970; LaGory, 1986). This was supported by the observations of Ranjitsinghji (1982), who recorded larger groups of blackbuck composed of 430 individuals in Velavedar National Park, characterized by large open habitat. Similarly, Bharucha & Asher (1993) recorded herd size of 200 in an open habitat of Rehukari Wildlife Sanctuary. The present study, largest herd recorded was composed of only 35 individuals hypothetically due to the scattered open space in between the crop field and very less predation pressure. As Jarman (1974) advocates that in closed habitat, a herbivore can easily reduce the probability of being detected by predators while living in small groups.

In species, which exhibit flexible social system, it is suggested that they will form large groups when there is abundance of high quality forage but will be

forced into smaller groups when food supply is less abundant and dispersed in distribution. This was supported by the result of the present study that the group size of blackbuck varied in relation to abundance of palatable food availability according to the season. Group size showed decline with advancement of summer season. It was highest in the month of July when there were enough palatable grasses due to start of rain results grass growth and lowest in the April and May, when the grass became dry. Similarly, Bharuch & Asher (1993) recorded herd of blackbuck size varies from 2-200 in Rehekuri Blackbuck Sanctuary and found that changes in group size and composition coincides with change in vegetation type. Thus, from the present study it is hypothesized that the group size of blackbuck in PCRB was found to be influenced by seasons indicating the direct relation with food availability.

The sex ratio of blackbuck recorded by various authors on different study sites were 1 : 2 in Point Calimere by Danial (1967), 1 : 3 at Velavadar by Rashid (1977), 1 : 6 (non-mating season) and 1 : 11 (rutting season) by Sharma (1982) and 1 : 1.37 in Rehekuri by Bharucha & Asher (1993). Kar (2000) recorded sex ratio in the present study area was 1 : 4 very close to the sex ratio observed by Bharucha & Asher (1993) in Rehekuri Blackbuck Sanctuary. The above results on the sex ratio of blackbuck are biased towards the female dominancy in all observed population.

The data recorded in the present study indicate that blackbuck is gregarious. Although blackbuck mainly lived in groups, a few solitary individuals were also observed. Study indicates that strong males of solitary blackbuck occurred throughout the study period, frequency of finding them was higher in the rutting season than other seasons. Then, sub-adult leavings from their mother's group also appear to be a factor responsible for group size variation. It appears that sub-adults gradually break off contacts with her mother in the course of maturation. Furthermore, human disturbance may be a factor for the group variation.

VII. Social structure

Identifying the occurrence, number and composition of social groupings reveal individual association preferences, and is an important prerequisite for characterizing the social structure of a population (Whitehead, 1997). Measuring how much time animals spend together is a behaviourally meaningful way of quantifying their social association (Hinde, 1976).

The calculated values of harem size, adult sex ratio, age structure and AM-Sam ratio of blackbuck in all seasons i.e., winter, rut period, summer and monsoon of eight selected habitat has been given in table 9. Value of harem size reflects that the mean size of harem was 6.28 ± 0.26 and large size of harem recorded during winter and rut period (the period of sexual intercourse) in all habitats except VJL.

A bachelor herd comprising individuals of all age group.

A bachelor herd consisting of different age category.

A female herd in the agricultural habitat at Bhejiputu.

The significant differences found in the size of harem between season ($P < 0.01$) and no significant differences found between the habitats. After analysis, it was found that as harem size increased the adult sex ratio decreased i.e., both were negatively correlated (Figure 23). The overall mean adult sex ratio observed was 0.19 ± 0.08, which was equal to 1 : 5.6 (adult male: adult female). The highest sex ratio recorded in 0.12 equal to 1 : 8.4 and the lowest recorded was 0.66 equals to 1 : 0.8 in the monsoon season. It has been observed that the relative frequency of harem size 5 was maximum (n = 508) and as the herd size increased the harem size decreased.

The mean age structure of the blackbuck recorded in PCRB was 0.5 ± 0.03 means in an average 2 sub-adult males in a herd. The maximum number of sub-adult male recorded was 6 in a herd while lowest recorded in an average of 1.2. No significant difference found in the age structure between seasons and habitats. Again the mean Am-Sam ratio of blackbuck in the study area was 2.08 ± 0.12 and similarly no significant difference found in Am-Sam ratios between seasons and habitat. Analysis of the data on social structure reveals that the proportion of sub-adult male holding in a harem was negatively correlated with the age structure. In other word as the proportion of adult male increased in herd the proportion of sub-adult male decreased.

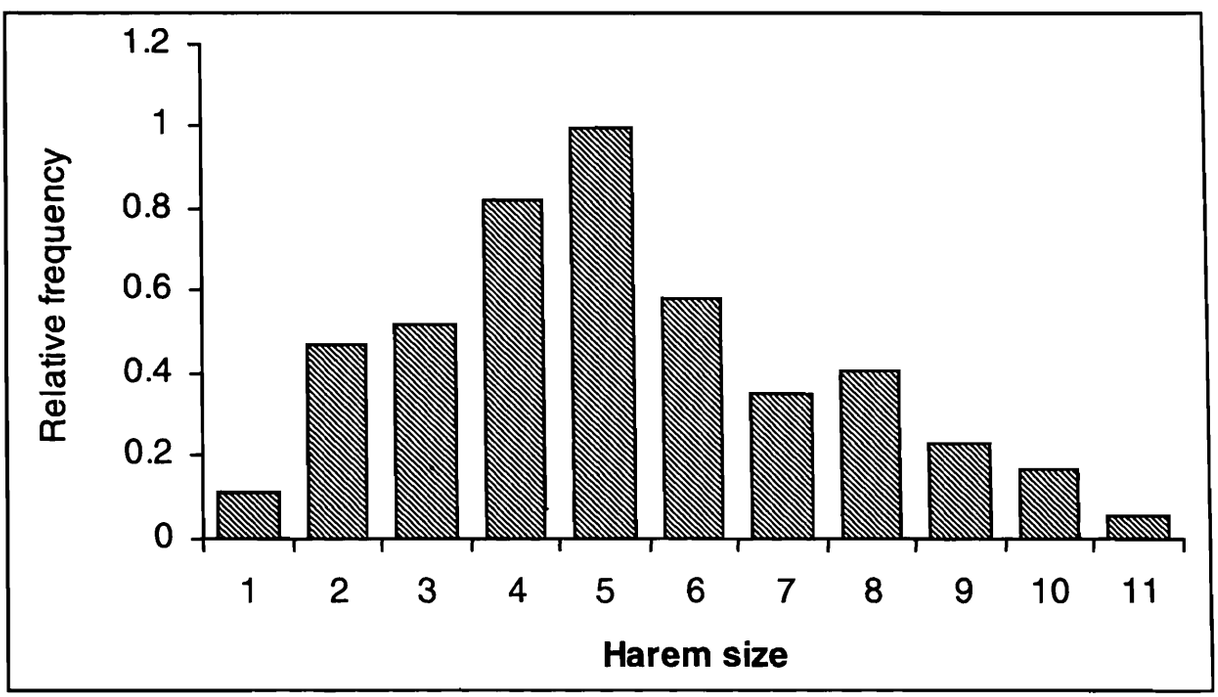


Figure 23 : Distribution of blackbuck *Antilope cervicapra* harem sizes (no. of adult females) defended by adult male in PCRB (n = 508).

Table 9 : Social structure of blackbuck in eight selected habitat of PCRB.

Habitat	Season	Harem Size	Sex Ratio	Age Structure	Am-Sam Ratio
WTR	Winter	7	0.14	0.66	1.66
	Rut period	6	0.16	0.44	2.66
	Summer	4.66	0.22	0.5	0.33
	Monsoon	7.33	0.15	0.38	2.66
WTL	Winter	6.5	0.15	0.66	2
	Rut period	7.66	0.14	0.41	2.66
	Summer	5.33	0.21	0.52	2.66
	Monsoon	7.5	0.14	0.39	2.75
SDN	Winter	7.66	0.15	0.52	2.33
	Rut period	6.58	0.16	0.55	2.16
	Summer	5	0.2	0.75	1.5
	Monsoon	7	0.15	0.38	2.66
VTB	Winter	6	0.17	0.75	1.5
	Rut period	5.33	0.19	0.61	2
	Summer	4.66	0.21	0.83	1.33
	Monsoon	4.5	0.24	0.66	2
VTR	Winter	7.33	0.14	0.38	2.66
	Rut period	6	0.19	0.61	2
	Summer	6.66	0.15	0.27	1.66
	Monsoon	6.75	0.17	0.37	1.5
VTL	Winter	3.5	0.35	0.25	1
	Rut period	6	0.17	0.37	3
	Summer	6.33	0.2	0.56	2.33
	Monsoon	8	0.12	0.33	1.75
VJL	Winter	6	0.22	0.62	2.5
	Rut period	4.33	0.24	0.66	1.66
	Summer	9.5	0.1	0.16	3.5
	Monsoon	7	0.66	0.61	2
Study area	Mean	6.28	0.19	0.5	2.08
	SD	1.31	0.1	0.16	0.66

Blackbuck are gregarious and social animals with herds generally ranging from 5 to 50 animals. The herds are harems with a single adult male and a number of adult females and their young. Groups of blackbuck was spatially organized consisting of a central core of leading male plus all females and their young, with the other males, specially the bachelor male on the periphery. The density or size of a population is associated with variation in age- and sex-specific vital rates and population dynamics (e.g. Nicholson, 1933; Saether, 1997; Gaillard, *et al.* 1998). Density-dependence is an important biological process both in demographic and population dynamic studies. The total number of individuals within a population is the measure most commonly chosen, but many studies concentrate on the total number of males or females and the number of adult males or females.

Female ungulates usually produce and raise offspring alone, and they are therefore obviously the most important component with regard to population dynamics. Most large herbivores have a polygynous mating system, and males typically do not help females raise young (Davies, 1991). Only a few males are required to ensure fertilization in production systems. A single male is capable of inseminating a large number of females within a short period of time and were successfully served in one rut. The female distribution patterns during the rut may also vary with sex ratio and male age structure and hence affect the likelihood of a synchronous calving season. Mating strategies in mammalian herbivores are mainly thought to be determined by female and not male distribution (Ims, 1990; Davies, 1991).

VIII. Habitat utilization

Blackbuck utilizes different major habitats of PCRB mainly for basic activities and social interaction. Observations were also made on the habitat uses of livestock on seasonal basis to find out any competition with blackbuck. Seasonal habitat use and selection by different sex and social groups of blackbuck are shown in figure 24. It was found differences in seasonal habitat use by both sex and social groups of blackbuck.

In summer, territorial males used grassland 43.67% and prefer bushes only 24.63% and crop field with 31.88%. So, result showed in that particular season males prefers grassland in comparison to crop field and bushes (Table 10). Similarly, in monsoon season grassland was preferred in highest degree (55.26%) in comparison to crop field (28.94%) and bushes (15.78%). While in the winter season territorial male gave preference on crop field (38.7%) in relation to bushes (32.25%) and grassland (29%). In above all these data found a significant differences ($P > 0.001$).

Females in summer season prefers crop field 44.76%, grassland 42.85% and 12.38% in bushes which was different from that of the territorial male. While female preferred grasslands in monsoon (47.5%) and winter (44.4%) seasons in comparison to crop field (monsoon: 36.25%; winter: 38.88%) and bushes (monsoon: 16.25%; winter: 16.66%). Data represent significant difference between seasons (ANOVA, df = 2, $P < 0.010$).

The two different major social categories also prefers habitat in different degrees in seasonal basis. In summer season mixed herd prefers or select crop field (46.66%), grassland (40%) and bushes (13.33%), while bachelor herd prefers grassland (50%), crop field (33.33%) and bushes (16.66%).

The most preferred habitat of mixed herd in monsoon season was grassland (62.5%), than crop field (33.3%) and least preferred habitat was bushes (4.16%). The habitat use by mixed herd in that season differed significantly ($P < 0.001$). Similarly most preferred habitat of bachelor herd was grassland (54.54%) and least preferred

Table 10 : Seasonal habitat utilization by the different age-sex and social categories of blackbuck based on frequency of sighting in major habitat of PCRB.

Sex/herd	Habitat	Summer	Monsoon	Winter
Territorial male	Crop field	31.88	28.94	38.7
	Grassland	43.67	55.26	29.03
	Bushes	24.63	15.78	32.25
	n =	**138**	**152**	**124**
Female	Crop field	44.76	36.25	38.88
	Grassland	42.85	47.5	44.44
	Bushes	12.38	16.25	16.66
	n =	**420**	**640**	**432**
Mixed herd	Crop field	46.66	33.33	38.09
	Grassland	40	62.5	47.63
	Bushes	13.33	4.16	14.38
	n =	**30**	**48**	**42**
Bachelor herd	Crop field	33.33	27.27	42.5
	Grassland	50	54.54	45
	Bushes	16.66	18.18	12.5
	n =	**12**	**22**	**16**

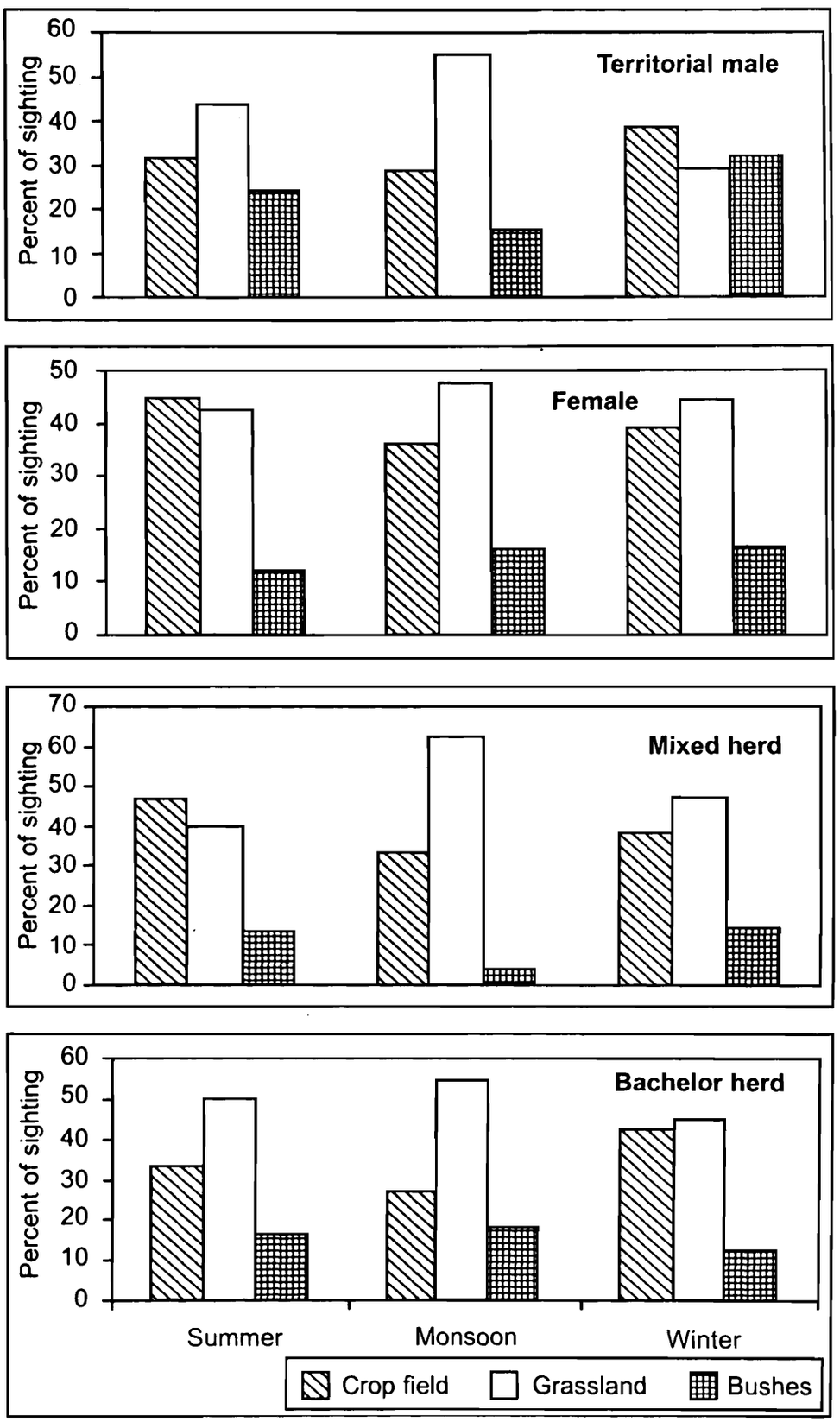


Figure 24 : Seasonal habitat use by sex categories and social group of blackbuck at PCRB.

habitat was bushes (18.18%) and significantly varied ($P < 0.05$). In the winter season, most preferred habitat of mixed herd was grassland (47.63%) in comparison to crop field (38%) and bushes (14.38%). Similarly the most preferred habitat of bachelor herd also in that season was grassland (45%), crop field (42.5%) and bushes (12.5%). Results of habitat utilization by various age-sex categories and social categories in PCRB in different season were also shown in figure 24.

Discussions

In a geographical area many types of habitats are found and an animal species utilize different habitats in different degrees. In the case of blackbuck, they are highly influenced by the forage availability (Prasad, 1981). Natural environment consist of mosaic of habitat and resource patches and are distinguished in term of environmental resources which have biological significance to the organism (Weins, 1976). The greater suitability of some patches draws increasing number, until increased density causes a drop in suitability from intra-specific effects. The next most suitable patches are then colonized (Fretwell, 1972).

The studies were carried out to provide substantial evidence useful in exploring blackbuck-habitat relationship. The presence or absence of other animal that may act as competitor or predator may also influence the habitat use. Animals may use such features as cues that they may not be the same as the factors that have resulted in evolutionary association between animal and habitat. Ultimate factors are those parameters that determine how successful, an animal is within a particular habitat. An individual's ability to reproduce, obtain food and avoid predators is example of ultimate factors.

The results of this study showed that both food availability and vegetation cover were very important for blackbuck habitat selection. The results are similar to those of Jhala (1998) from his study of blackbuck at Belvedere. Utilization of habitat is often determined by the availability of cover and food. In general, the feeding habits of blackbuck concentrated on herbage. These kinds of food items are more abundant in grass and shrub habitats of the study area. Therefore, it was not surprising that the blackbuck preferred grass to shrub habitat.

The data collected on various habitat parameters showed that blackbuck in PCRB prefer open land like grassland and cropland in different degree according to seasons, grass condition, presence of minimum predator and less disturbances by anthropogenic activities.

In conclusion, the habitat use by blackbuck varied accordingly in different seasons due to forage availability, predator pressure, competition with livestock and interaction to human being.

IX. Habitat preference and overlap

Livestock's are important competitor in the study areas in relation to food resources. The calculated values of the data recorded on the habitat overlap between blackbuck and livestock is given in table 11 and the mean population recorded in various seasons in eight different habitats shown in figure 25 and figure 26.

About 60% of study area was cropland, 20% grassland, 5% bushes and rest are villages and settlements. It was observed that in summer season Gahir (GHR) was the most preferred habitat (0.806) of both blackbuck and livestock, while Watch tower right (i.e. bushes dominated area) was the least preferred habitat and minimum habitat overlap value (0.664).

In monsoon, maximum overlap (0.901) was recorded in Vhejiputu left (VJL) i.e. least disturbed habitat preferred by both blackbuck and livestock and least overlap was recorded again in WTR (0.710). Similarly maximum habitat overlap found in Vhejiputu left in winter season (0.932) and least overlap in the Vhetnoi back (VTB) habitat (0.580).

Overall, maximum overlapping in habitat between blackbuck and livestock observed in large open areas and rich forage availability like the areas between Vhetnoi village and Vhejiputu village lying on both side 100 m far from the road and in the large grassland adjoining with crop land. While the least preferred habitat was scattered forest and bushes in the study area.

Animal species prefers certain habitat due to food, covers, others factors of that habitat (Martin, 1972). Preference for a given habitat type is largely determined by the available vegetation within the area, providing food, water, minerals, shelter from climatic extremes and cover from predators (Jarman and Sinclair, 1979). Food resources however not only vary between different habitat types, but also show marked seasonal variation within a given habitat, in response to change in rainfall patterns (Sinclair, 1975).

The maximum fluctuation of the population of blackbuck and livestock was recorded in crop land areas due to agricultural activities, while least disturbed habitat was bushes. Bushes are the least preferred habitat of blackbuck in PCRB due to less availability of food and more risk of predation by the presence of small and medium size predators. The value of overlap and habitat preference on the grassland was mainly dependant upon the grass condition in different seasons.

In summer season, the maximum sighting of both blackbuck and livestock population was recorded in cropland habitat while least in bushes except some territorial males of blackbuck. It was observed that in pre-monsoon season

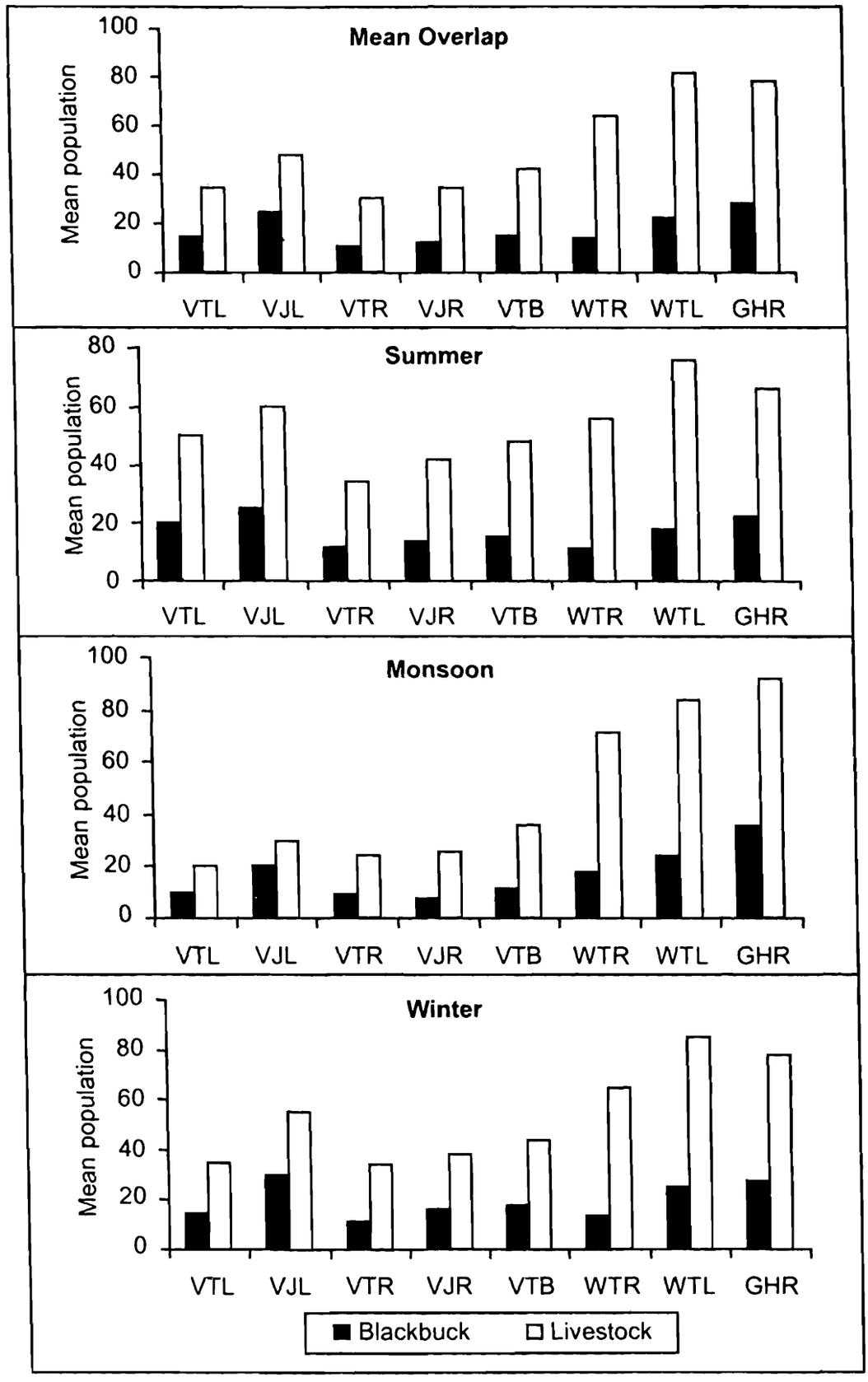


Figure 26 : Mean seasonal population of blackbuck and livestock in 8 selected habitats of PCRB.

blackbuck prefers crop land due to availability of young shoots and leaves of paddy but as the season proceeds and crop land were full of water blackbuck migrated towards the grassland. In the same season livestock's were prevented by the owner to graze in cropland, so the maximum populations of them were observed in grassland. In the winter, the grass condition in both grassland and crop land similar so, overlapping was more or less similar in that season.

Table 11 : Habitat overlap between blackbuck and livestock in 8 selected habitat at PCRB.

Habitat	Summer	Monsoon	Winter	Mean
VTL	0.785	0.833	0.800	0.800
VJL	0.794	0.901	0.852	0.932
VTR	0.760	0.772	0.744	0.757
VJR	0.751	0.735	0.796	0.678
VTB	0.738	0.752	0.580	0.760
WTR	0.664	0.710	0.677	0.681
WTL	0.691	0.722	0.727	0.714
GHR	0.806	0.789	0.764	0.766

X. Forage preference

Many types of habitat may occur within a home range of an animal but it may utilize only a few of these available patches. Preference for certain habitat types can be due to food preference, cover or other factor. However the dominance of a species and its distribution pattern has a great deal to do with its preference rating. Figure number 27 and 28 shows the important food items of blackbuck in different months and also showed the percentage of total month diet accounted for by particular food type in PCRB, Ganjam district, Orissa, India. It was found that among the grasses 3 species of *Cynodon* was a important food items of blackbuck out of 11 recorded grass species. Most of the grasses were consumed in monsoon than in winter and in summer very few species of grasses were foraged.

It was observed that many types of shrubs and bushes species were also foraged in the summer season while few types of them were foraged in other seasons. *Prosopis julifera* was an important food item in the diet of blackbuck in PCRB. Other recorded shrub used as food items in the diet includes *Acacia nilotica*, *Phoneix sylvestris*, *Terminalia belericea*, *Zizyphus jujuba* etc.

The entire plant of most of the grass species are consumed by the blackbuck but in case of shrubs and bushes only leaves and fruits were consumed as a diet. As most of the habitat of blackbuck was crop field dominated by paddy and other cultivated species in the monsoon season they were also very important food items of blackbuck in monsoon season. In winter pulses were found an important food items in the diet of blackbuck. Oil seed and vegetables were also observed in the diet.

Discussions

The herbivore diet is influenced by several factors including anatomical and physiological characteristic of animals, community structure of plants, and its structure and chemical constituents (Ranjitsingh, 1982). How foraging patterns of large herbivores vary depending on their population density. It is important for two main reasons. First, large herbivores may have huge impacts on ecosystem processes. Secondly, density-dependent responses in life-history traits are the keys to understanding population regulation in wild mammals (Sæther, 1997; Gaillard *et al.*, 2000).

The dominance of species and its distribution pattern in a certain locality has a great deal to do its preference rating (Martin, 1977). The most dominant species in PCRB was *Cynodon dactylon*. So, the most conspicuous forage during the month of summer was *Cynodon dactylon*, a dense stand along water courses were regularly and extensively grazed upon throughout this season.

The blackbuck were primarily 'nibblers' (Jarmon, 1974), feeding on tender leaves, twigs, seed pods and shrub fruits. These food items have higher protein and accessible plant cell content and tend to be small, distinct, and spatially scattered foliage (Jarmon, 1974). At our study area, blackbucks were recorded feeding on more than 50 species of plants. The positive relations of the habitat use to the habitat variables indicative of food abundance explained the importance of food abundance when animals selected their habitat. Additionally, higher availability of new-grown shoots at forage sites than at bed sites indicated that ungulate species select those areas that allow them to acquire food resource most efficiently (MacArthur & Pinaka, 1966).

Bed sites are located on the back side of large bushes and large size grasses in the study area. The selection of this type of ground cover for bed site by ungulate calves is a strategy for defending against predators (Bowyer *et al.*, 1999). In the present study area, no predation on blackbuck was detected. However, jackal, stray dog and some small carnivores can be considered as main predation pressure against blackbuck young ones. Blackbuck selected dense vegetation sites for resting and for their concealment value and those sites offer less forage because they are more closed than forage sites.

Food	Part eaten	Months												Times eaten
Grasses		M	A	M	J	J	A	S	O	N	D	J	F	
Cynodon dactylon	EP													62
Cynodon barberi	EP													28
Cyperus rotundus	EP													31
Celosia argentea	EP													16
Commelina benghalensis	EP													28
Borreria hispida	EP													15
Vernonia cinerea	EP													18
Kyllinga triceps	L,S													16
Paspelum sps.	EP													14
Fimbristylis sps.	EP													17
Panicum sps.	L,S													15
Shrubs & Bushes														
Acacia nilotica	L													22
Prosopis julifera	L,F													30
Phoneix sylvestris	L,F													4
Tridex procumbens	L													10
Terminalia belericea	F,L													5
Abutilon indicum	F,L													11
Zizyphus jujuba	L,F													14

Abbreviations: EP – entire plant, L – leaves, S – stem, F – fruit, P – pod, B – bud etc.

Figure 27 : Food preference (grasses & bushes) of blackbuck in different months, PCRB. Histogram height indicates the percentage of total monthly diet accounted for by particular food type.

Food	Part eaten	Months												Times eaten
Crop		M	A	M	J	J	A	S	O	N	D	J	F	
Oryza sativas	L,F													55
Eleusine corocana	L,F,P													8
Zea mays	L,B													5
Pulses														
Cajanus indicus	L													13
Lathyrus sativas	L													6
Pisum sativum	L													12
Cicer arietinaum	L													5
Phaseolus rasiatus	L,F,P													16
Oil seed														
Arachis hypogea	L													8
Vegetables														
Lycopersicum esculantum	L													6
Brassica oleracea	L													5
Cucumis sativas	L,B													4
Trichosanthes cucumerina	L													4
Ipomea batata	L													3

Abbreviations: EP – entire plant, L – leaves, S – stem, F – fruit, P – pod, B – bud etc.

Figure 28 : Food preference (crops, pulses, oil seed & vegetables) of blackbuck in different months, PCRB. Histogram height indicates the percentage of total monthly diet accounted for by particular food type.

A cattle herd as a competitor of blackbuck in the grassland habitat.

Blackbuck with cattle egret in the habitat.

Cattle in the habitat of blackbuck.

B. Behaviour of blackbuck

I. Activity Budget

The total database included 8640 scan sample of the activity of blackbuck. Analysis of this data reveals that feeding is a dominating activity in all age-sex category individuals except fawns in which lying (38.75 ± 6.99) was a dominating basic activity. Among the age-sex category female (40.76%) engaged maximum times in feeding and only 14.75% of times by fawn (14.75). The percentage frequencies of basic activities of blackbuck is given in table 12 and shown in figure 29 and 30. The percentage frequency of other activity in adult male was 21.86% while in other age-sex categories it was less then adult male. The frequency of resting not significantly varies in between age-sex category except fawn. Frequencies of walking, scanning did not vary between the age-sex categories of blackbuck in PCRB.

Territorial male blackbuck spent most of their time foraging (34%), followed by alert (15%) and resting (13%). Prasad (1985) also found that territorial male spent a large amount of time in foraging (34%) and Chattopadhyay & Bhattacharya (1986a) recorded about 38% of time spent in foraging. In fact, time budgets of territorial males did not vary significantly within similar condition but very in different social group type, the number of females present, or the total number of animal present in the herd.

Table 12 : Mean percentage frequencies of the basic activities of blackbuck at PCRB.

	% Feeding Mean ± SD	% Walking Mean ± SD	% Scanning Mean ± SD	% Resting Mean ± SD	% Others Mean ± SD	*F*
Adult male	24.4 ± 6.6	16.8 ± 7.8	15.7 ± 3.6	21 ± 4.7	21.8 ± 4.8	4.7*
Adult female	40.7 ± 3.4	12.5 ± 2.6	12.8 ± 2.7	24.3 ± 3.4	9.3 ± 2	36.1**
Sub-adult male	32.6 ± 6.7	14.6 ± 2.3	14.4 ± 3.3	26.1 ± 4.7	12.5 ± 2.7	51.2*
Sub-adult female	38.1 ± 3.8	14.2 ± 3.7	13.3 ± 1.9	24.4 ± 3.7	9.8 ± 2	15*
Fawn	14.4 ± 3.8	16.9 ± 3.7	19.3 ± 5.2	38.7 ± 6.9	11.8 ± 3.5	58.3**

Discussion

Activity profiles indicate the time budgeting of animals and suggest species utilize resources in relation to its environment, their fitness on the habitat (Jarmon, 1974). How and while an organism spends its time and energy represent important aspects of that organism survival strategy (Gettinger, 1984). Evidences from field studies suggests that the amount of time allocated among mutually exclusive

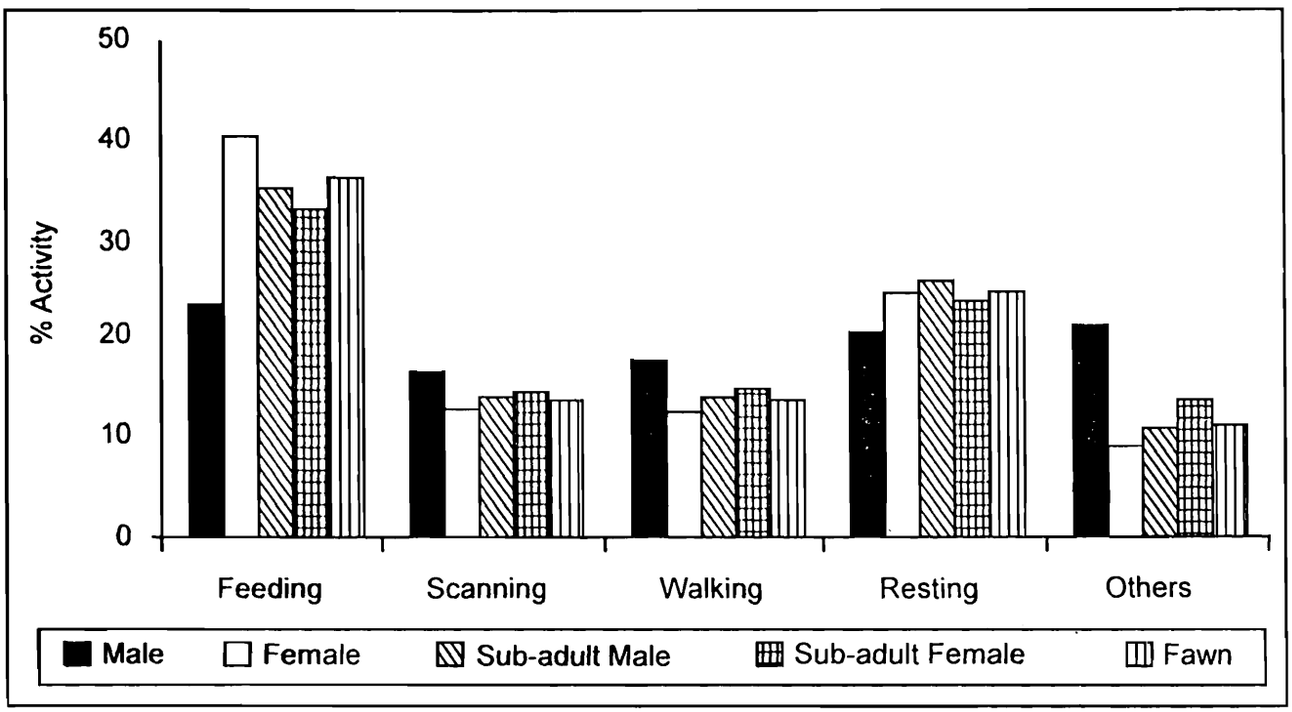


Figure 29 : Activity (%) of the individuals of different age-sex categories of blackbuck (*Antilope cervicapra*) at PCRB.

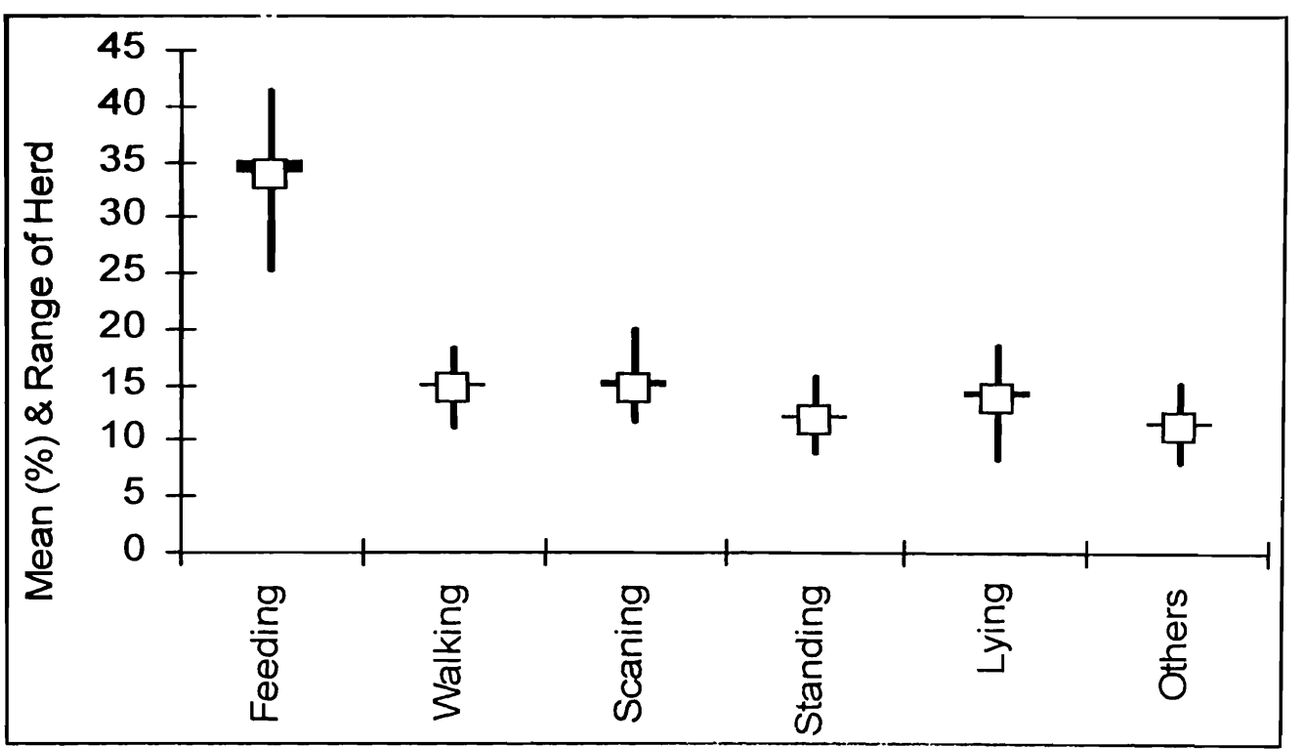


Figure 30 : Means, standard error and range of the activities the herd of blackbuck (*Antilope cervicapra*) at PCRB.

activities (including foraging, avoiding predators, social interaction and caring for dependent offspring) can affect survival (Bertram, 1978). By inference, individual should optimize daily time budgets to enhance their relative fitness (Orians, 1961). Many changes in its environmental conditions are reflected in adaptive changes in animal time budget (the allocation of time to different activities). Activity budgets should reflect a balance between the cost and benefits of expending energy (Orians, 1961). Blackbuck is a polygamous animal and its male hypothetically must compete for access of females; this activity requires expending energy on aggressive as well as sexual activity.

Blackbuck, like most ungulates, spend most of their active time in foraging (Bhattacharya *et. al.,* 1984; Prasad, 1985). Doe spent more time in foraging per observation period, and had longer foraging bouts, than adult blackbuck. Females accordingly spent more time lying than adult male and had significantly longer lying bouts. Previous studies on a wide range of ungulates also found that females spent more time in foraging than males (Bunnell & Gillingham, 1985). For yearling male and female that stay in female or mixed groups, there might be a tradeoff between predator protection in the group and adjustments/synchronization of their foraging behaviour, which could have a negative effect on their foraging time budgets and energy assimilation. The animal spent most of its time for resting as evident from the activity time budget and grazing and walking was other major components.

Analysis reveals that significant difference in activity time budgets based on the diurnal hours and animal more active in dawn and dusk. Results supported the observations of Prasad (1985); Chattopadhayay & Bhattacharaya (1986a). Results also showed differences in between the individuals of age-sex categories hypothetically due to their different social status. Again analysis focused mixed herd spent more mobile in relation to bachelor herd as because of the possession of large size of mixed herd.

II. Active behaviour Vs Inactive behaviour

Chi-square tests for contingency were conducted on the number of times animals were seen in inactive and active states in each of the 3 phases, between the following age-sex classes; adult males vs adult females, sub-adult males vs sub-adult females, adult males vs sub-adult males and adult females vs sub-adult females. Count data on inactive states and level of significance are presented in Table 13 and active states are presented in Table 14.

Adult females were significantly more often seen lying (relative to standing) than adult male in the summer season in the level of significance 0.08. Similarly, sub-adult males were significantly more often seen lying than adult males in the level of

significance 0.08. In addition sub-adult females were also observed significantly more in resting state than sub-adult males in the level of significance 0.05. The results reflect that adult females were more in lying or standing states than adult males, do not necessarily mean that adult females actually rest more often than adult males. The possibility exists that a particular age-sex class moves differentially into protective cover in different type of habitat to rest.

Four behavioural elements included in active state-feeding, walking, scanning and others including socializing were between age-sex category and seasons. From the data of table 14 no significant difference found in the number of time seen active in between age-sex and seasons. Only differences were found in between adult males and other age-sex categories because, the data which were analysed are gathered from the mixed herds. So, most of the time one finds only one adult male in comparison to more number of other age-sex category individuals.

III. Activity probability

Figure 31 and 32 plotted indicate the probability (as a proportion of all observed activity per hour of the day) for the activities of blackbuck including feeding, walking, scanning, resting and other under different conditions of locality, sex, season and heat period.

There was considerable overall similarity in diurnal activity for different localities of PCRB. In case of male the time spent in feeding was not varied in seasons, but considerable difference in diurnal pattern between different seasons. The feeding was maximum at early morning and evening and minimum at noon hours probability due to the effect of temperature on the feeding activity. The probability of walking of male was highest in winter (2.48 hr) in relation to other season. From the above results no considerable differences recorded in the ratio between feeding and walking in seasons. No significant difference found in the activity probability in rest of the basic activities between seasons. Resting dominated all activities in summer and winter with single peak hour between 12.00 to 14.00 while no single peak hours in monsoon season due to habitat disturbance maximum in that particular season.

In the case of female, it was observed that the probability of time spent in feeding varied only from 5.39 hr to 5.31 hr in between season with significant differences in diurnal hours. It was noted that the probability of resting dominated all the activities including feeding between 10.00 to 15.00 hr in the summer season. The ratio between the times spent in feeding and walking maximum in the monsoon (4.42), it means less amount of time spent in walking probably due to the more availability of food in that season in the food patches.

Table 13 : Chi-square test results on the number of times animals were seen lying and standing by season and animal age-sex class.

Season/ Class	n Lying	n Standing		Class	n Lying	n Standing	X2	Significance
Winter								
Ad. Male	22	21		Ad. Female	179	143	0.301	0.584
Sub-Ad. Males	67	34		Sub-Ad. Female	95	81	4.037	0.045
			vs.					
Sub-Ad. Males	67	34		Ad. Male	22	21	2.942	0.086
Sub-Ad. Female	95	81		Ad. Female	179	143	0.120	0.729
Summer								
Ad. Male	16	19		Ad. Female	184	119	2.927	0.087
Sub-Ad. Males	67	34		Sub-Ad. Female	128	87	0.130	0.719
			vs.					
Sub-Ad. Males	67	34		Ad. Male	16	19	1.573	0.210
Sub-Ad. Female	128	87		Ad. Female	184	119	0.074	0.785
Monsoon								
Ad. Male	19	22		Ad. Female	192	172	0.606	0.435
Sub-Ad. Males	56	52		Sub-Ad. Female	101	90	0.029	0.854
			vs.					
Sub-Ad. Males	56	52		Ad. Male	19	22	0.361	0.548
Sub-Ad. Female	101	90		Ad. Female	192	172	0.001	0.975

Table 14 : Chi-square test results on the number of times animals were seen feeding, walking, scanning and others activity by season and animal age-sex class.

Season/ Class	n Feeding	n Walking	n Scanning	n Others	Season/ Class	n Feeding	n Walking	n Scanning	n Others	f value	Signi-ficance
Winter											
Adult Male	42	29	36	42	Adult Female	505	182	171	121	40.22	0.0001
Sub-Adult Males	139	57	65	44	Sub-Adult Female	269	124	98	80	2.84	0.416
					vs						
Sub-Adult Males	139	57	65	44	Adult Male	42	29	36	42	17.99	0.0001
Sub-Adult Female	269	124	98	80	Adult Female	505	182	171	121	4.00	0.261
Summer											
Adult Male	51	31	29	46	Adult Female	524	162	160	113	42.79	0.0001
Sub-Adult Males	164	76	65	49	Sub-Adult Female	294	109	98	76	1.99	0.573
					vs						
Sub-Adult Males	164	76	65	49	Adult Male	51	31	29	46	19.08	0.0001
Sub-Adult Female	294	109	98	76	Adult Female	524	162	160	113	2.31	0.509
Monsoon											
Adult Male	43	42	31	35	Adult Female	593	158	186	139	42.74	0.0001
Sub-Adult Males	159	55	57	49	Sub-Adult Female	304	90	98	65	3.13	0.372
					vs						
Sub-Adult Males	159	55	57	49	Adult Male	43	42	31	35	20.35	0.001
Sub-Adult Female	304	90	98	65	Adult Female	593	158	186	139	1.02	0.796

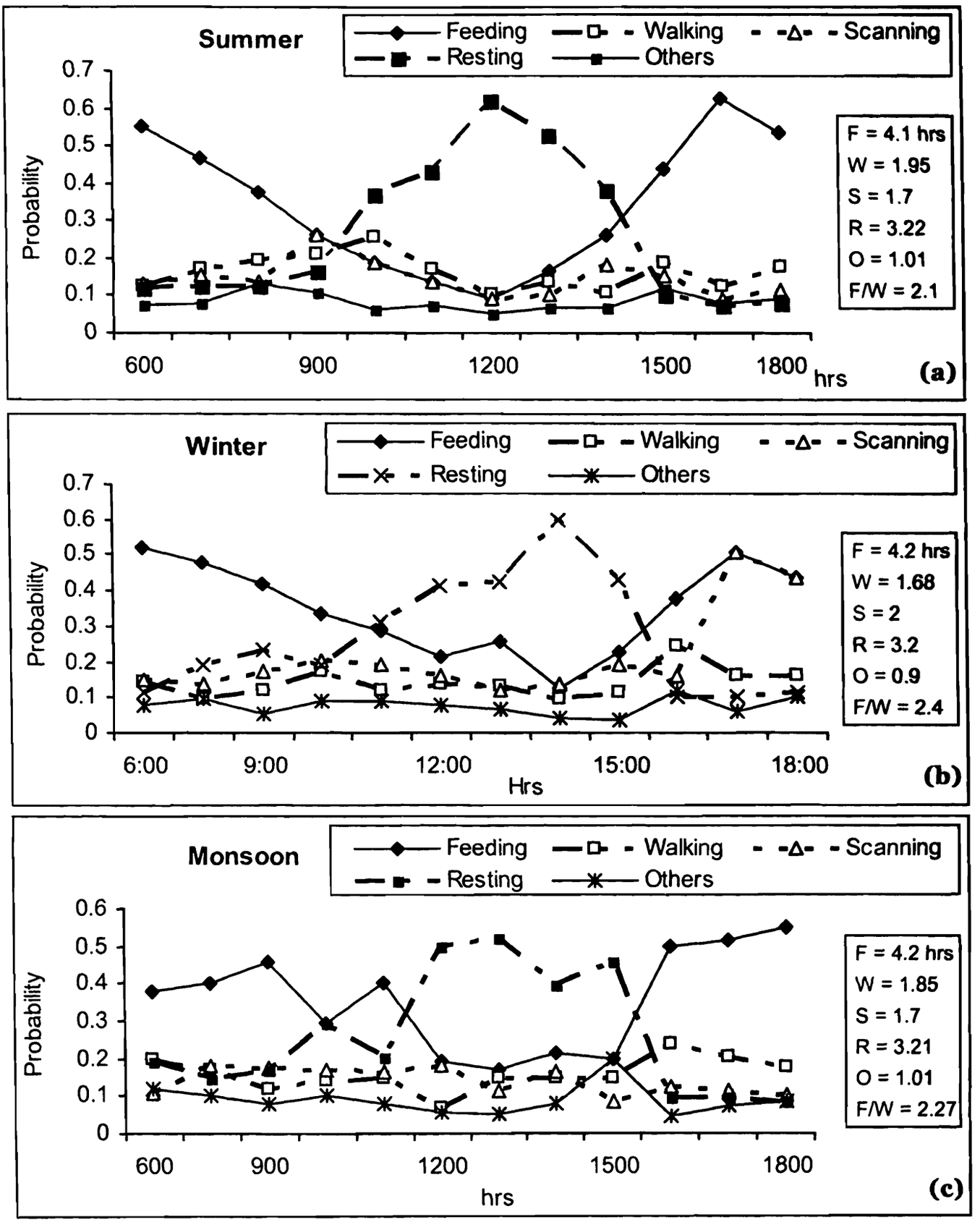


Figure 31 : Activity probabilities throughout the day for male blackbuck at PCRB on (a) summer (b) winter and (c) monsoon.

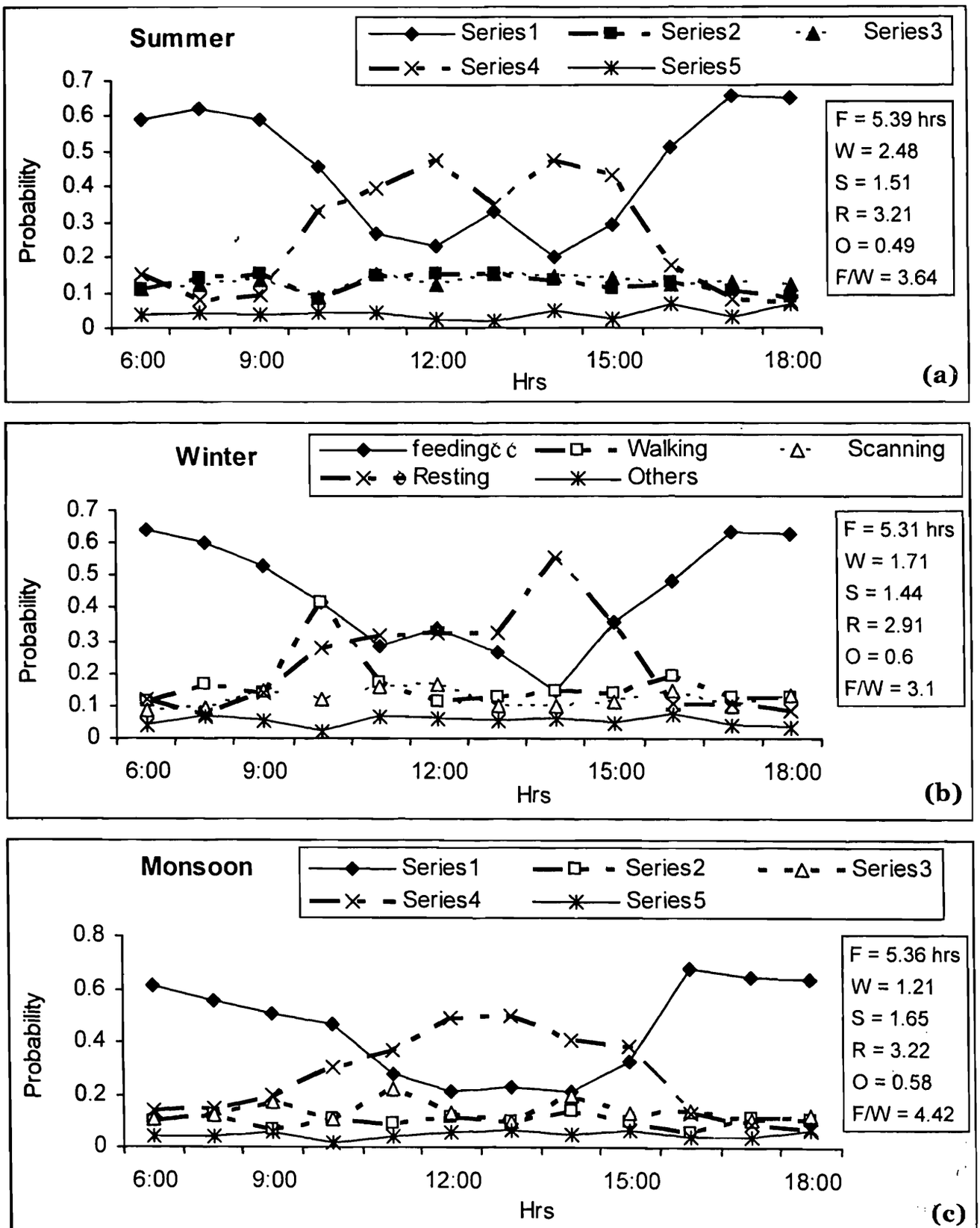


Figure 32 : Activity probability throughout the day for female blackbuck at PCRB on (a) summer (b) winter and (c) monsoon.

IV. Activity pattern and activity schedule

This study presents data gathered during systematic focal animal sampling of different age-sex categories of individuals of blackbuck in the Community Reserve, Ganjam district, Orissa during the period June, 2004 to May, 2007. These data were examined for intersexual, inter-seasonal, inter-individual and diurnal variability in amount of time spent in each of the inactivity state or resting behaviour (standing and lying) and activity state (feeding, moving, scanning and others).

a. Sexual variation in activities

Males and females showed similar activity pattern though female showed significantly more feeding than males. Adult males were less active in morning apart from walking more than females overall.

Variation in basic activities in different sexes was observed in terms of monthly mean and the same is depicted in Table 15A and shown in figure 33. The monthly mean of feeding (34.72 ± 0.87) observed in male was less in comparison to female (44.59 ± 0.87). A significant difference has been noticed in monthly feeding between sexes ($p < 0.001$). Monthly mean of walking and scanning varied between sexes ($p < 0.05$), but the monthly mean of these activities were slightly more in male in relation to female. The monthly mean of other activities were recorded higher in male (8.15 ± 0.72) than in female (4.65 ± 0.54) and significant variation was found in between sexes ($p < 0.001$). No significant variation was observed in monthly mean of lying and standing in between sexes.

Similarly hourly variation was also observed in the feeding, walking, standing and other activities between sexes. No significant differences were observed in hourly mean of lying and scanning (Table 15B and figure 34). The hourly mean of feeding (male = 34.88 ± 4.04; female = 44.62 ± 4.93) and others (male = 8.04 ± 0.39; female = 4.64 ± 0.25) was higher in male in compare with female.

The monthly and hourly variation of basic activities in male was tested by two-way analysis of ANOVA. The results are given in Table 16A, similar test was applied in females also and the results are given in Table 16B. The percentage of time male and female spent grazing or lying is a better measurement of behavioural differences between the sexes. Indeed, differences in percentage of time spent lying or grazing were in the expected direction. Adult male and female differed greatly in the percentage of time spent foraging and lying. Blackbuck, like most ungulates, spent most of their active time in foraging. They are mainly active during the day and seldom, if ever, feed at night.

Table 15 : Comparative values of percentage mean, SE, f-values (Two-way ANOVA) of the basic activities of blackbuck.

A. Month

	Male	Female	Month		Sex	
Activities	Mean ± SE	Mean ± SE	F value	p value	F value	p value
Feeding	34.72 ± 0.87	44.59 ± 0.87	1.17	0.39	59**	0.001
Walking	15.27± 0.68	12.28 ± 0.90	0.76	0.66	6.1*	0.03
Scanning	15.03 ± 0.55	12.81 ± 0.56	0.63	0.76	6.49*	0.02
Standing	12.85 ± 0.60	11.83 ± 0.5	3.61*	0.04	2.55	0.13
Lying	13.92 ± 0.46	13.74 ± 0.90	0.83	0.61	0.02	0.87
Others	8.15 ± 0.72	4.65 ± 0.54	6.22**	0.002	53.5**	0.001

B. Hour

	Male	Female	Hours		Sex	
Activities	Mean ± SE	Mean ± SE	F value	p value	F value	p value
Feeding	34.88 ± 4.04	44.62 ± 4.93	37.98**	3.88	45.43**	0.0001
Walking	15.41 ± 0.83	12.28 ± 0.68	0.84	0.6	11.21**	0.006
Scanning	12.47 ± 0.68	11.85 ± 1.11	4.93*	0.006	0.66	0.43
Standing	14.98 ± 0.61	12.8 ± 0.62	1.56	0.23	8.04*	0.01
Lying	14.28 ± 4.15	13.68 ± 3.60	25.64**	0.0001	0.16	0.69
Others	8.04 ± 0.39	4.64 ± 0.25	0.93	0.54	50.73**	0.0001

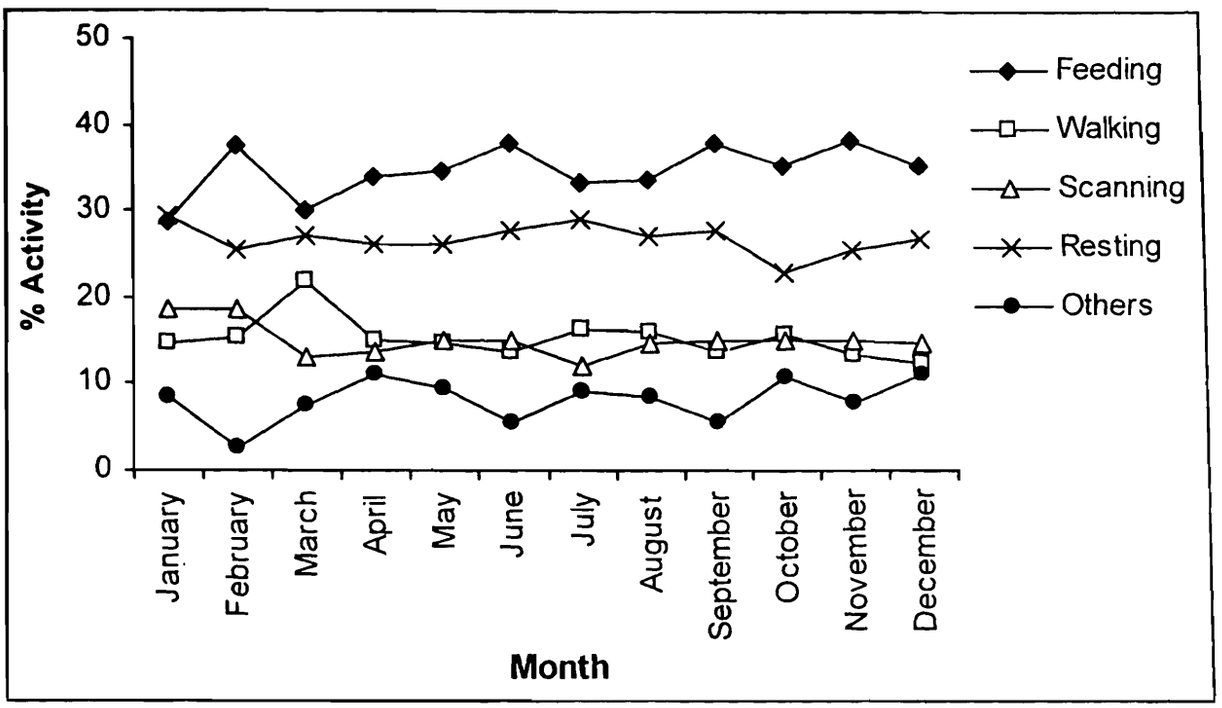
Table 16 : Two-way ANOVA of the basic activities of blackbuck at PCRB.

A. Male

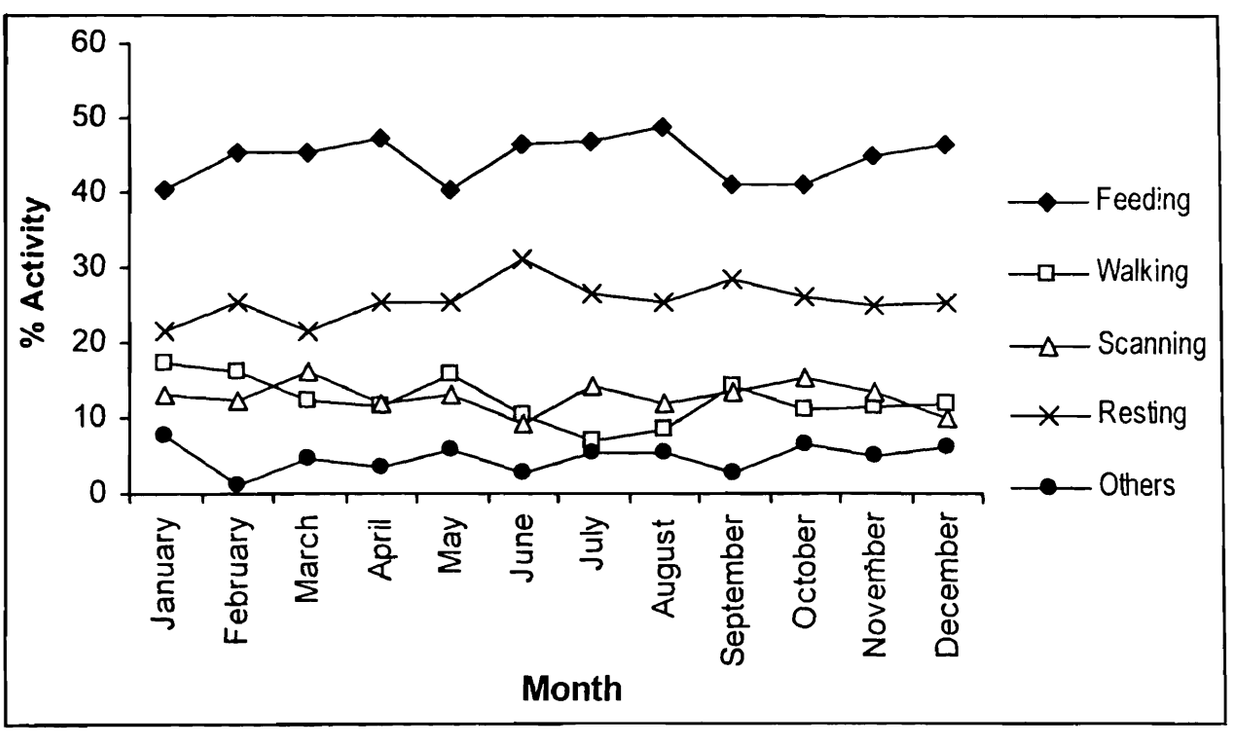
	Source of Variation	SS	df	MS	F	P-value	F crit
Feeding	Hour	4145.8	11	376.88	14.7	0.0001***	1.87
	Month	223.25	11	20.29	0.79	0.64	1.87
Walking	Hour	178.66	11	16.24	1.96	0.03*	1.87
	Month	113.33	11	10.3	1.24	0.26	1.87
Scanning	Hour	94.5	11	8.59	1.49	0.14	1.87
	Month	78.16	11	7.1	1.23	0.27	1.87
Standing	Hour	122.97	11	11.17	1.63	0.09	1.87
	Month	113.8	11	10.34	1.51	0.13	1.87
Lying	Hour	4511.1	11	410.09	12.4	0.0001***	1.87
	Month	65.38	11	5.94	0.18	0.99	1.87
Others	Hour	40.05	11	3.64	1.24	0.26	1.87
	Month	149.38	11	13.58	4.64	0.001**	1.87

B. Female

	Source of Variation	SS	df	MS	F	P-value	F crit
Feeding	Hour	6172.52	11	561.13	22.16	0.00001***	1.87
	Month	188.02	11	17.09	0.67	0.75	1.87
Walking	Hour	27.33	11	2.48	0.48	0.90	1.87
	Month	208.66	11	18.96	3.72	0.0001**	1.87
Scanning	Hour	97.41	11	8.85	1.70	0.07	1.87
	Month	80.41	11	7.31	1.40	0.17	1.87
Standing	Hour	315.40	11	28.67	4.57	0.00008***	1.87
	Month	93.57	11	8.50	1.35	0.20	1.87
Lying	Hour	3350.66	11	304.60	8.56	0.00004***	1.87
	Month	207.83	11	18.89	0.53	0.87	1.87
Others	Hour	16.22	11	1.47	0.75	0.68	1.87
	Month	75.55	11	6.86	3.50	0.0002**	1.87

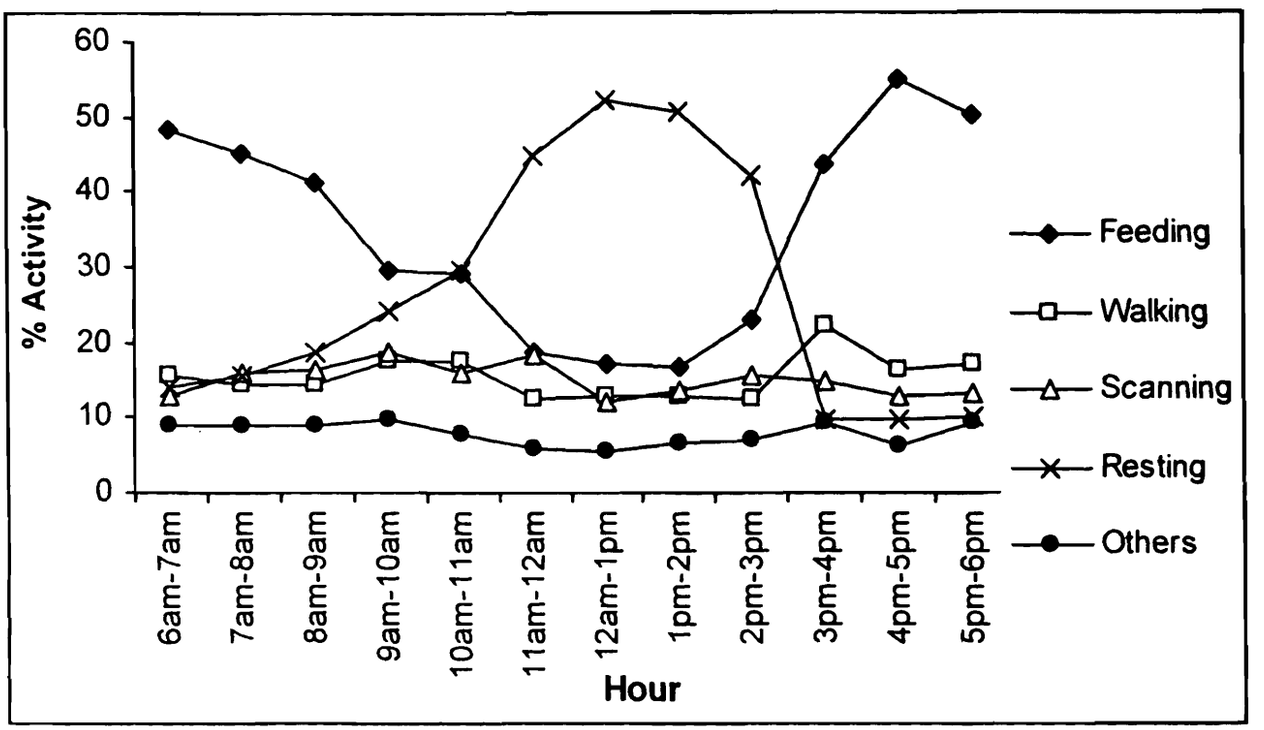


a. Male

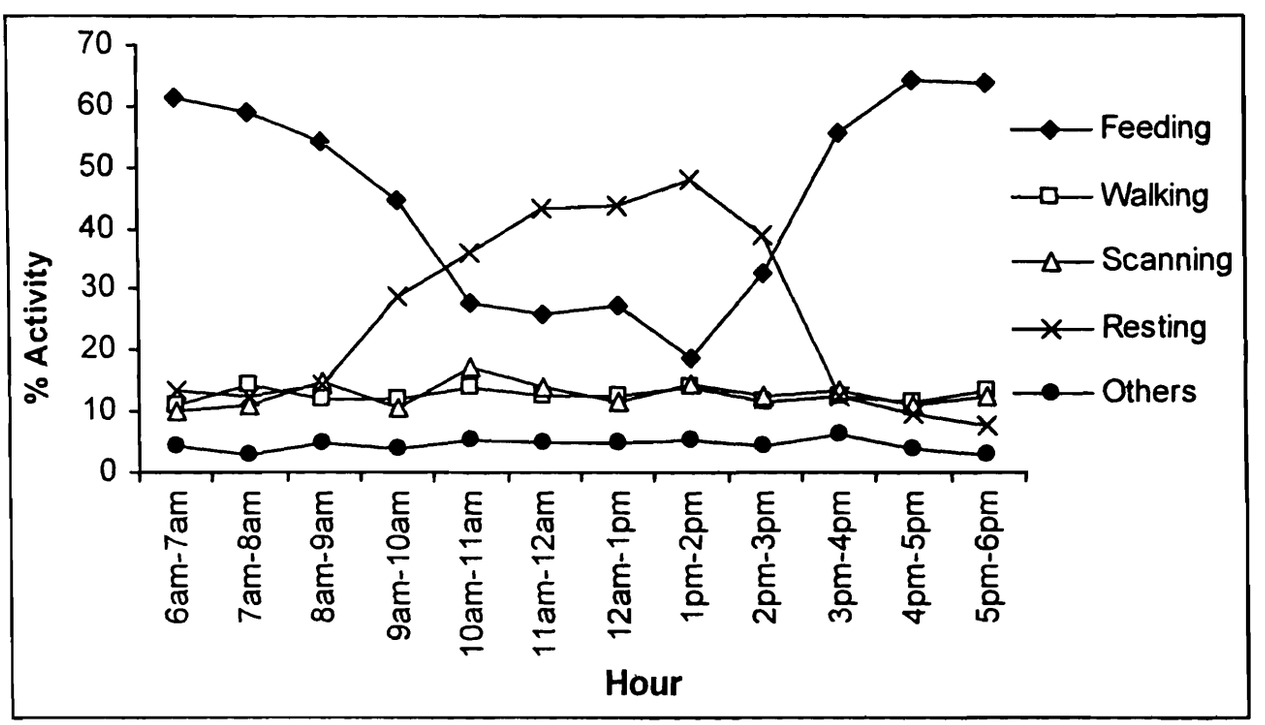


b. Female

Figure 33 : Monthly activity pattern of male (a) and female (b) of blackbuck at PCRB.



a. Male



b. Female

Figure 34 : Diurnal activity pattern of blackbuck (a. male; b. female) at PCRB.

b. Diurnal activity pattern

Hourly basis

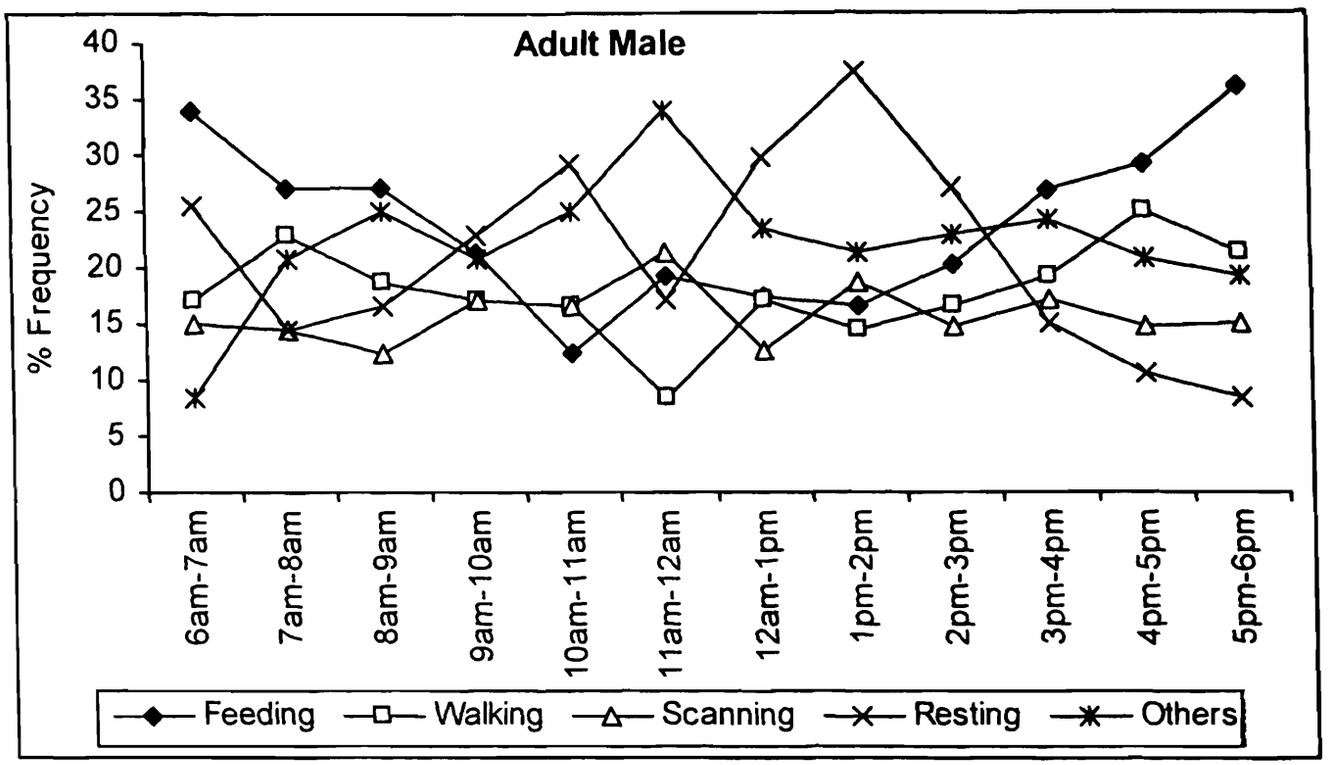
This study presents data gathered during systematic focal animal sampling of different age-sex categories of individuals of blackbuck in the PCRB, Ganjam district, Orissa during the period June, 2004 to May, 2007.

Diurnal variation of all the basic activities of all age-sex category shown in figure 35 and 36, and the variation between hours and age-sex category was tested by two-way analysis of variance (ANOVA) and the values are given in Table 17. The hourly pattern of feeding, resting and others activities varied significantly ($p < 0.001$) in adult male showing two peak (early morning and late afternoon), two peak of resting (standing at 10-11 am and lying 12-2 pm) and one peak of others (11-12 am). No significant difference found in the diurnal pattern of walking and scanning, except on some occasions due to external disturbances, presence of predator etc.

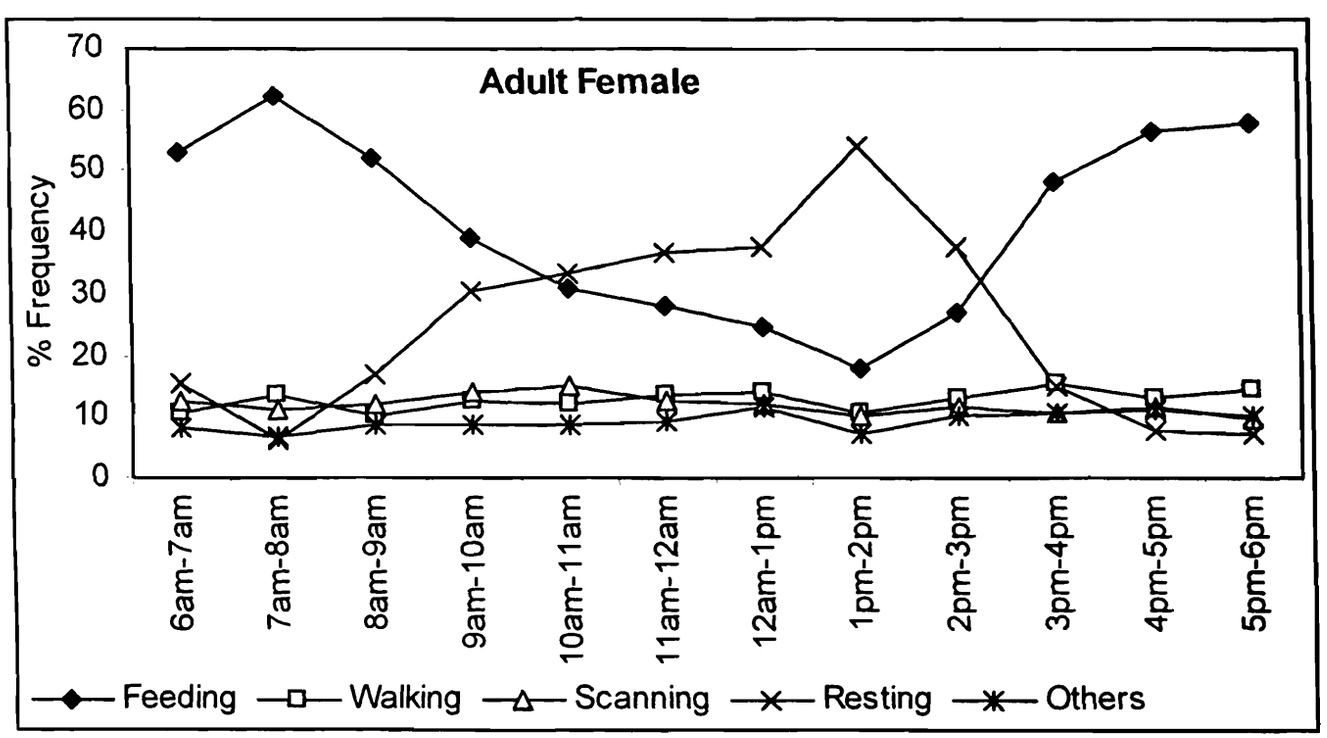
The pattern of feeding and resting varies significantly in diurnal hours with one peak hour of resting (1-2 pm) and two peak hours of feeding (7-8 am and 5-6 pm). But no significant difference was observed in the activities like walking, scanning and others showing uniform pattern in day light hours.

Table 17 : Values of ANOVA (Two-way analysis) of basic activities tested between different hours and individuals of various age-sex categories of blackbuck.

	Source of Variation	SS	df	MS	F	P-value	F crit
Feeding	Hours	5991.50	11	544.68	21.68	2.93E-14	2.01
	Age-sex	6342.81	4	1585.70	63.13	1.16E-17	2.58
Walking	Hours	365.98	11	33.27	5.01	5.17E-05	2.01
	Age-sex	260.65	4	65.16	9.81	9.17E-06	2.58
Scanning	Hours	82.59	11	7.50	1.34	0.234334	2.01
	Age-sex	302.01	4	75.50	13.51	2.93E-07	2.58
Resting	Hours	8952.75	11	813.88	42.38	9.28E-20	2.01
	Age-sex	2116.70	4	529.17	27.55	1.74E-11	2.58
Others	Hours	236.74	11	21.52	1.86	0.070728	2.01
	Age-sex	1406.23	4	351.55	30.52	3.49E-12	2.58

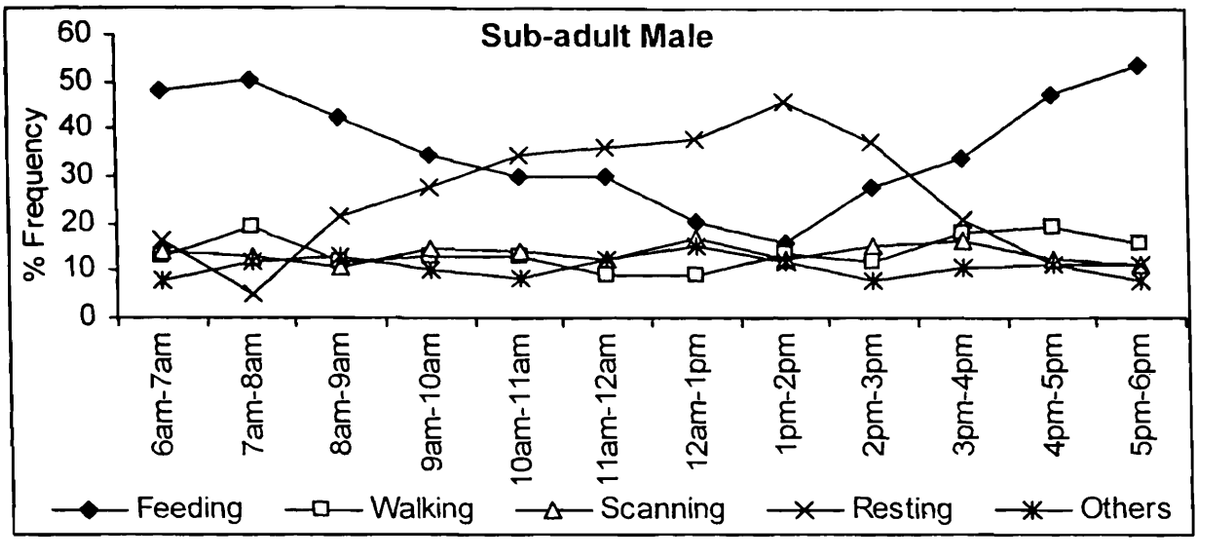


a. Male

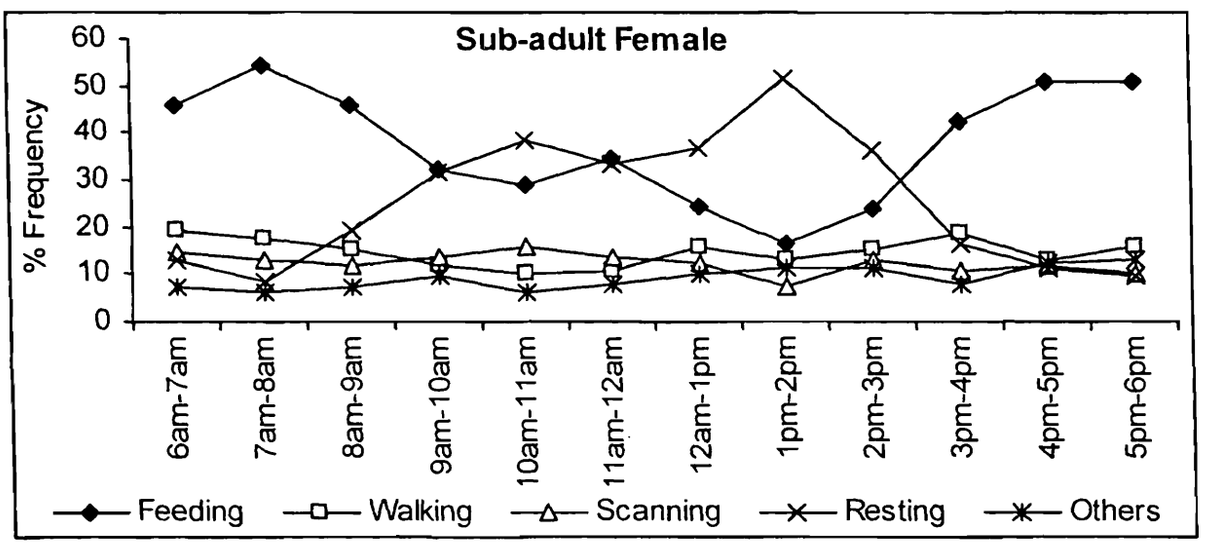


b. Female

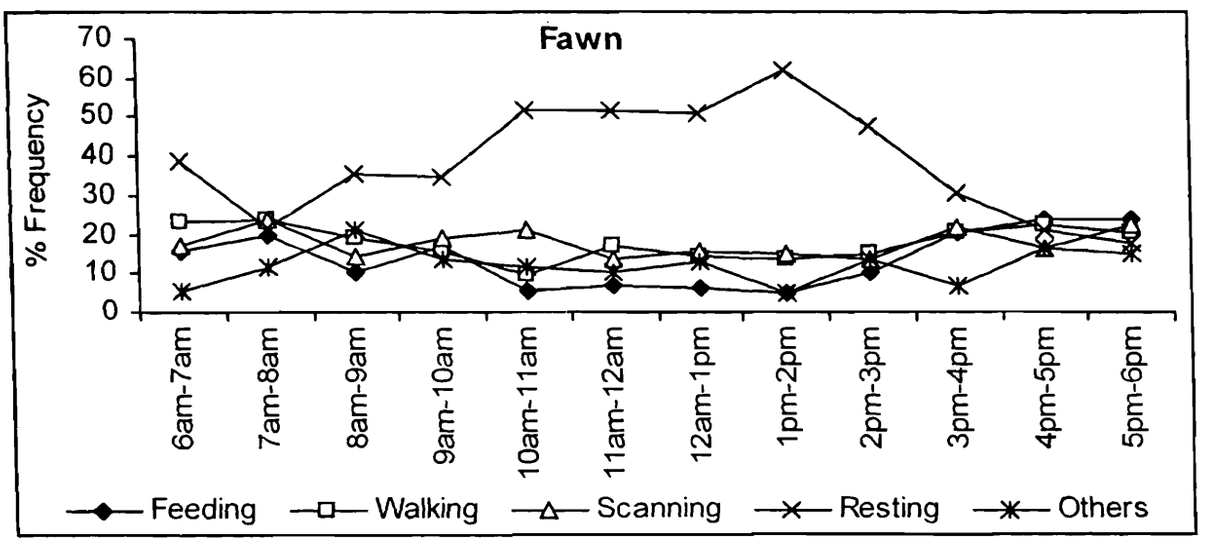
Figure 35 : Percentage frequencies of basic activities of adult male (a) and adult female (b) of blackbuck in different hours of the day at PCRB.



(a)



(b)



(c)

Figure 36 : Percentage frequencies of basic activities of sub-adult male (a) and sub-adult female (b) and fawn (c) of blackbuck in different hours of the day at PCRB.

Interestingly, it was observed that resting in fawn dominated all the basic activities in all hours of day except 7-8 am and late afternoon. No continuous pattern was observed in activities like feeding, scanning, walking and others in case of fawn.

The diurnal distribution of the basic activities of sub-adult male and sub-adult female showed similar kind of pattern and no significant variation was found in hourly distribution of the activities in both the sub-adults of blackbuck.

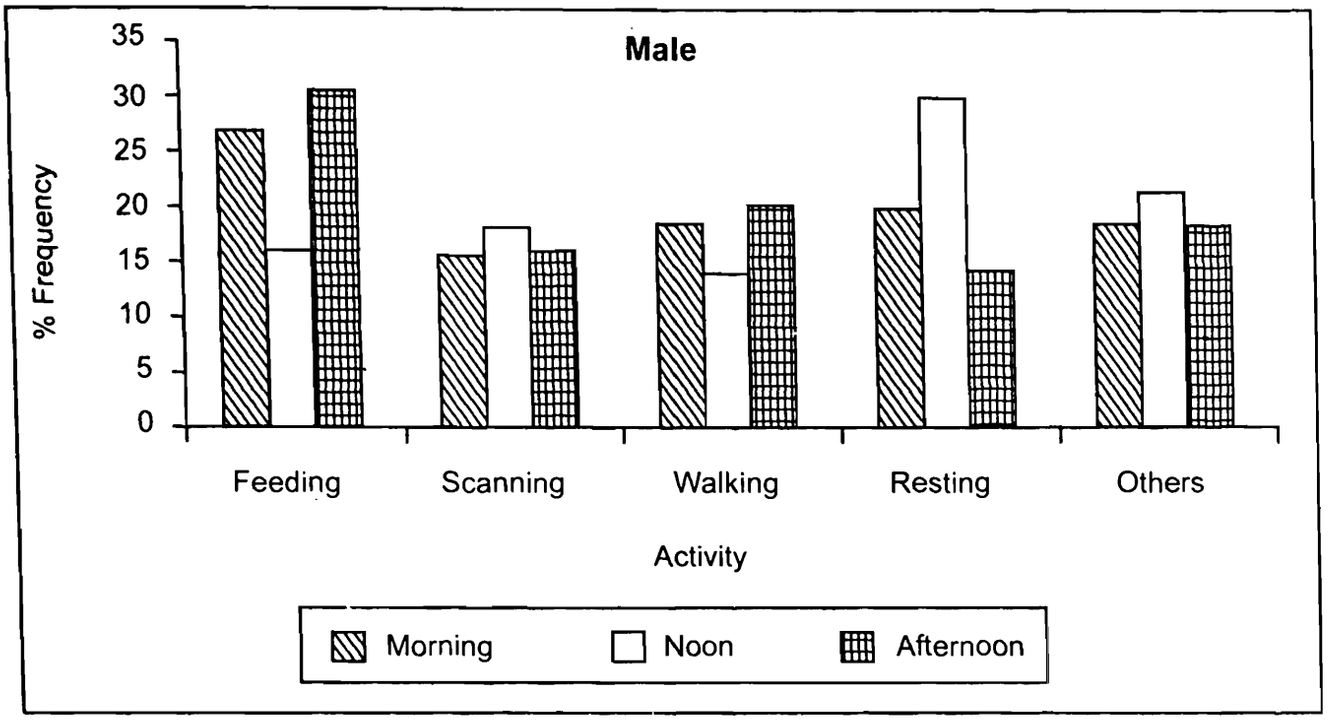
Table 17 represents the tested values (Two-way analysis ANOVA) of the data gathered on the basic activities in different day light hours on different age-sex categories of blackbuck. From the above analysis, it was found that the diurnal distribution of feeding, walking and resting varied significantly ($p < 0.001$). Similarly, the diurnal distribution of all activities varies between age-sex category of blackbuck.

Periodic Basis

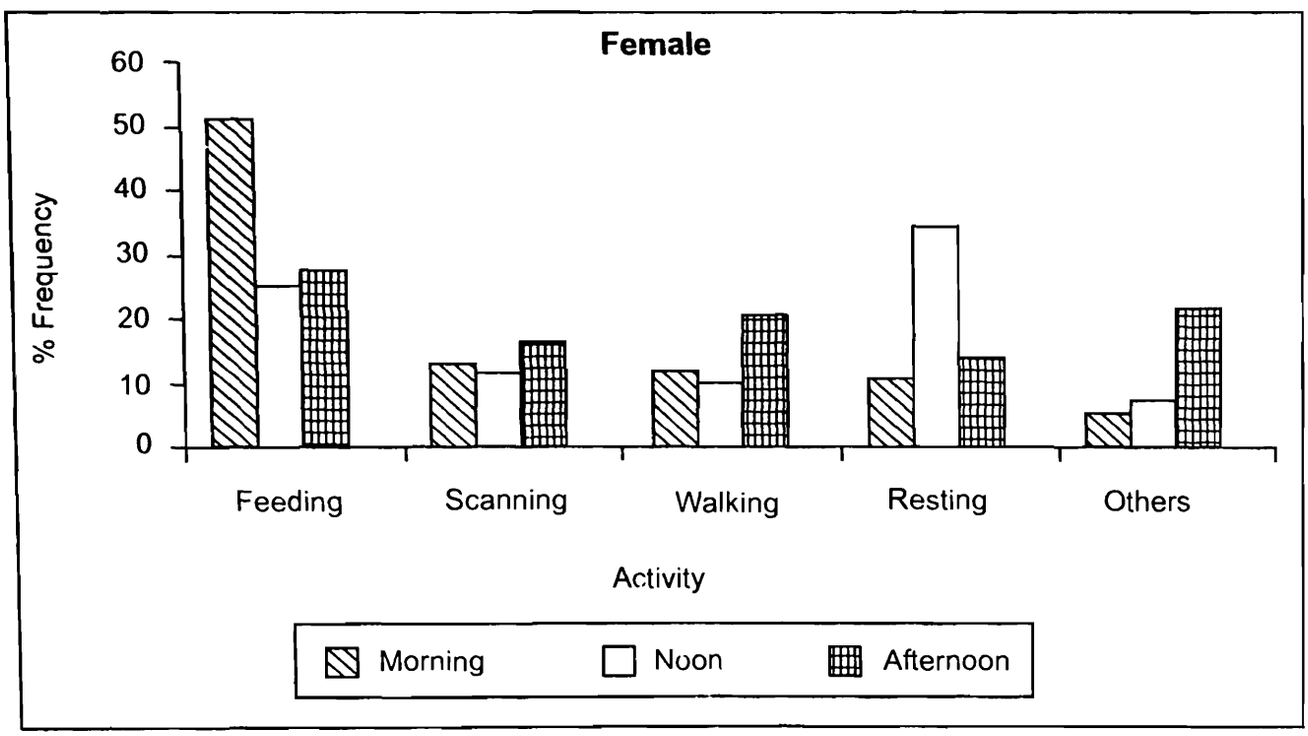
To show more clearly the effect of season, age, sex and diurnal temperature on animals activities, the day was divided into three periods viz., morning 06.00 hours to 10.00 hours, noon 10.00 hours to 14.00 hours, and afternoon 14.00 hours to 18.00 hours. In Tables 18, 19 and 20 gives the figures of all the basic activities of age-sex category consists of feeding, walking, scanning, resting and others activities for these three periods of the day of all seasons.

Figure 37 and 38 represents the day time activity patterns of age-sex categories on three different major periods of the day. A feature of this data is their great heterogeneity. The proportion of time spent in feeding by adult male 34.37% in afternoon session of summer to 12.5% in the noon of winter, walking varies from 25% in the after noon of monsoon to 9.37% in the noon of winter, scanning varies from 25% to 12.5% with an average of 19% maximum in the noon. The average maximum lying recorded in the noon was 34.5%. Other activity varies from 28% to 5% in an average 18% in the noon.

The average maximum feeding (51.3%) of male was observed in morning session, maximum lying was observed in noon and the average maximum walking, scanning and other activities were recorded in the afternoon session. Most of the individual sub-adults of both sexes engaged in feeding and walking activities during the morning and afternoon sessions, similarly most of the individuals engaged in resting during noon hours. It was found that, resting varies in fawn between sessions with maximum recorded in the noon, scanning uniform in all hours, while feeding, walking and others activities were recorded more in morning and afternoon hours.

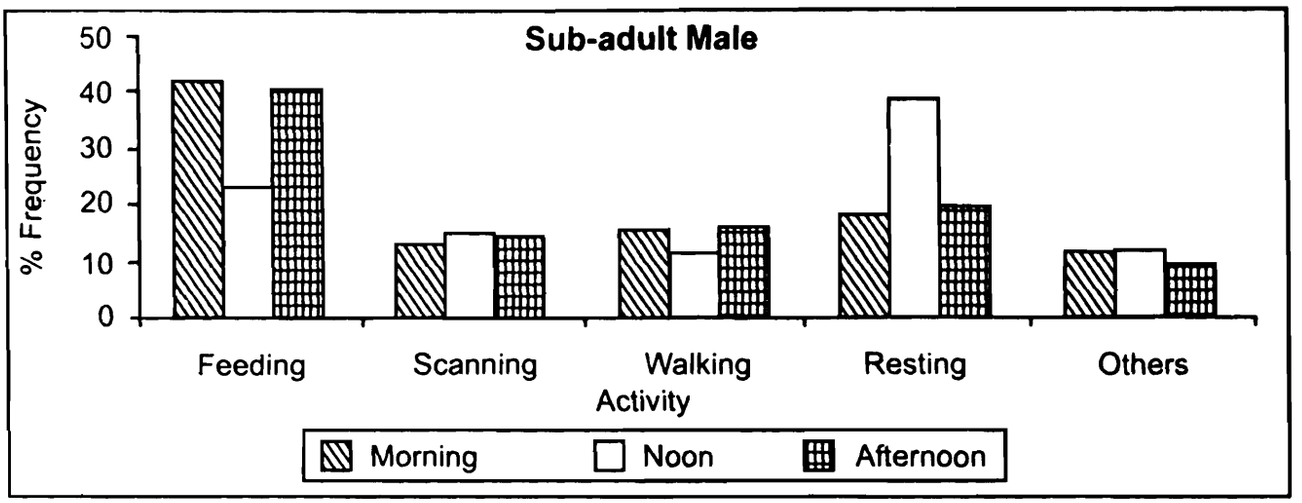


(a)

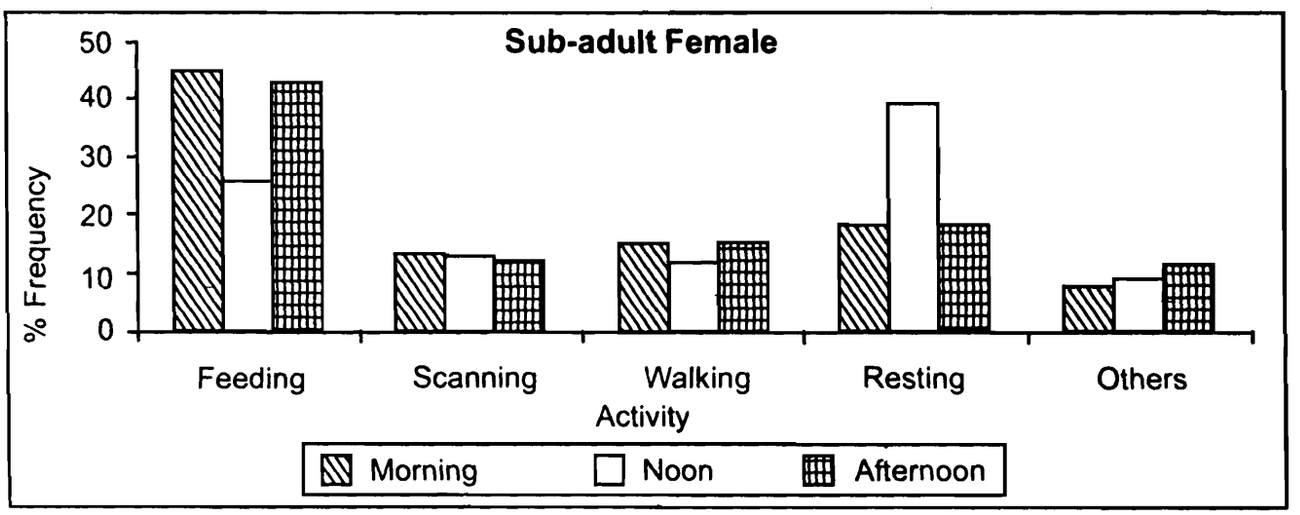


(b)

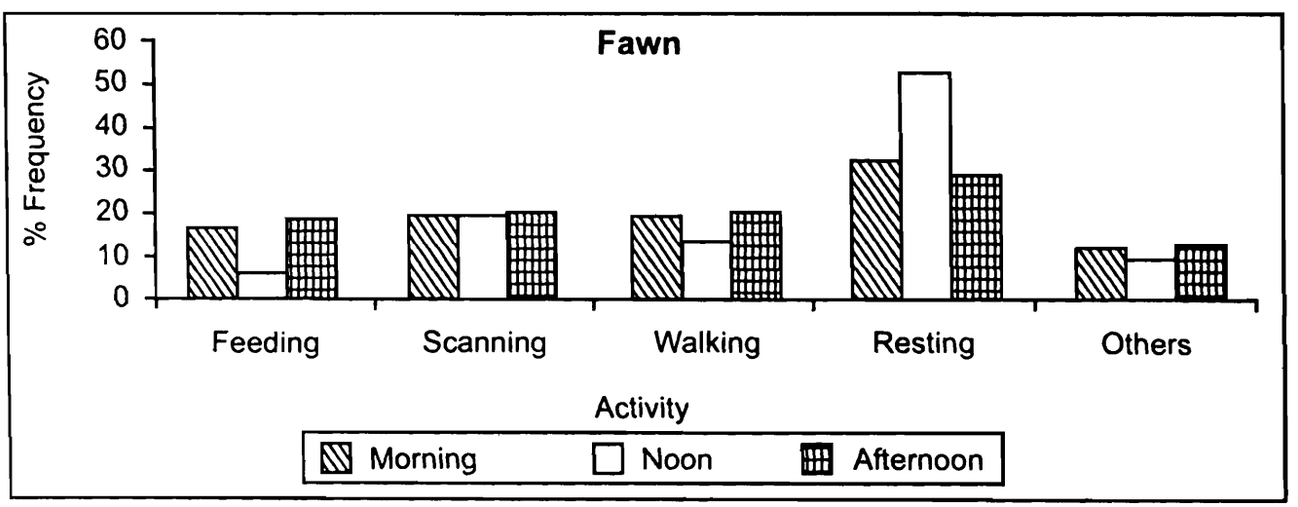
Figure 37 : Diurnal distribution of basic activities of all age-sex categories of blackbuck in PCRB. (a. adult male, b. adult female).



(a)



(b)



(c)

Figure 38 : Diurnal distribution of basic activities of all age-sex categories of blackbuck in PCRB. (a. sub-adult male, b. sub-adult female and c. fawn).

Table 18 : Activity bout and percentage frequencies of diurnal activities of adult male and adult female of blackbuck in different seasons at PCRB. (M = Morning, N = Noon and A = Afternoon).

	Winter			**Summer**			**Monsoon**		
Activity	M	N	A	M	N	A	M	N	A
Feeding	18	8	16	16	13	22	18	10	15
	28.12%	12.50%	25%	25%	20.31%	34.37%	28.12%	15.62%	23.43%
Walking	11	6	12	11	9	11	14	12	16
	17.18%	9.37%	18.75%	17.18%	14.06%	17.18%	21.87%	18.70%	25%
Scanning	11	16	9	8	11	10	11	8	12
	17.18%	25%	14.06%	12.50%	17.18%	15.62%	17.18%	12.50%	18.75%
Resting	14	19	10	14	13	8	10	22	9
	21.87%	29.68%	15.62%	21.87%	20.31%	12.50%	15.62%	34.37%	14.06%
Others	10	15	17	15	18	13	11	12	12
	15.62%	23.43%	26.56%	23.43%	28.12%	20.31%	17.18%	18.75%	18.75%

Adult Male

	Winter			**Summer**			**Monsoon**		
Activity	M	N	A	M	N	A	M	N	A
Feeding	179	118	208	140	120	264	216	102	275
	48.50%	25%	45.21%	46.05%	25.97%	53.22%	58.69%	24.05%	42.43%
Walking	40	65	77	40	62	60	39	37	82
	10.84%	13.77%	16.73%	13.15%	13.41%	12.09%	10.59%	8.72%	12.65%
Scanning	54	62	55	41	59	60	42	63	81
	14.63%	13.13%	11.95%	13.48%	12.77%	12.09%	11.41%	14.85%	12.50%
Resting	67	187	68	54	179	70	49	184	131
	18.15%	39.61%	14.78%	17.75%	38.74%	14.11%	13.31%	43.39%	20.21%
Others	29	40	52	29	42	42	22	38	79
	7.85%	8.47%	11.30%	9.53%	9.09%	8.46%	5.97%	8.96%	12.19%

Adult Female

Table 19 : Activity bout and percentage frequencies of diurnal activities of sub-adult male and sub-adult female of blackbuck in different seasons at PCRB. (M = Morning, N = Noon and A = Afternoon).

	Winter			**Summer**			**Monsoon**		
Activity	M	N	A	M	N	A	M	N	A
Feeding	55	31	53	45	46	73	62	30	67
	32.60%	20.94%	41.40%	36.88%	24.46%	41.47%	46.96%	23.43%	39.88%
Walking	17	17	22	22	25	29	20	11	24
	23.91%	13.28%	17.18%	18.03%	13.29%	16.47%	15.15%	8.59%	14.28%
Scanning	21	23	20	14	25	26	15	21	21
	13.04%	15.54%	15.62%	11.47%	13.29%	14.77%	11.36%	16.40%	12.50%
Resting	22	58	21	28	70	34	18	52	38
	17.39%	39.18%	16.40%	22.95%	37.23%	19.31%	13.63%	40.62%	22.61%
Others	13	19	12	13	22	14	17	14	18
	13.04%	12.83%	9.37%	10.65%	11.70%	7.95%	12.87%	10.93%	10.71%

Sub-adult Male

	Winter			**Summer**			**Monsoon**		
Activity	M	N	A	M	N	A	M	N	A
Feeding	103	55	111	85	86	123	119	59	126
	41.70%	21.82%	44.75%	39.35%	29.45%	43.30%	55.09%	26.33%	40.90%
Walking	37	42	45	37	35	37	27	16	47
	14.97%	16.66%	18.14%	17.12%	11.98%	13.02%	12.50%	7.14%	15.25%
Scanning	37	36	25	31	31	36	25	33	40
	14.97%	14.28%	10.08%	14.35%	10.61%	12.67%	11.57%	14.73%	12.98%
Resting	48	92	36	46	112	57	31	99	61
	19.43%	36.50%	14.51%	21.29%	38.35%	20.07%	14.35%	44.19%	19.80%
Others	22	27	31	17	28	31	14	17	34
	8.90%	10.71%	12.50%	7.87%	9.58%	10.91%	6.48%	7.58%	11.03%

Sub-adult Female

Table 20 : Activity bout and percentage frequencies of diurnal activities of sub-adult male and sub-adult female of blackbuck in different seasons at PCRB. (M = Morning, N = Noon and A = Afternoon).

	Winter			**Summer**			**Monsoon**		
Activity	M	N	A	M	N	A	M	N	A
Feeding	13	5	17	12	6	14	12	4	20
	17.10%	5.68%	19.31%	15.78%	6.52%	16.66%	17.64%	5.55%	20%
Walking	15	12	22	17	14	16	11	7	17
	19.73%	13.63%	25%	22.36%	15.21%	19.04%	16.17%	9.72%	17
Scanning	17	15	19	10	14	16	16	19	19
	22.36%	17.04%	21.59%	13.15%	15.21%	19.04%	23.52%	26.38%	19
Resting	23	42	21	28	51	27	19	39	30
	30.26%	47.72%	23.86%	36.84%	55.43%	32.14%	27.94%	54.16%	30%
Others	8	14	9	9	7	11	10	3	14
	10.52%	15.90%	10.22%	11.84%	7.60%	13.09%	14.70%	4.16%	14

Fawn

M = Morning, N = Noon, A = Afternoon. The figures represent corrected total time spent in the activities referred expressed in 30 sec. units.

c. Monthly Activity Pattern

Herd: The mean percentage of animals engaged in various activities in the different months has been shown in figure 39. Figure shows that feeding varies between months with two peaks; one in March and another in September. Similarly, scanning varies between month activity budget with two peaks; one in February and another in August. Distribution of monthly budget of standing, lying and other activities were varied between months. No significant differences observed in the walking activity of herd in between months.

Age-sex category: Monthly variation in the percentage of animal of each age-sex category of blackbuck (*Antilope cervicapra*) involved in various basic activities is shown in figures 40 and 41. Significance of inter-month and inter-individual variability in activity proportions tested with a two-way analysis of variance without replication is also shown in Table 21.

The monthly proportion of feeding in female was comparatively higher in relation to others categories. Monthly budget of feeding in adult and sub-adult males varies

between months. A significant variation is found in the monthly budget of feeding between age-sex categories (ANOVA, df = 4, f = 71.4, p < 0.001).

Analysis of the data on the walking activity, represents monthly distribution on adult male varies between months with'peak walking in the month of July and least in March. No significant variation is found for the monthly activity pattern of walking, with no specific pattern observed in rest of the age-sex categories.

Scanning was an important activity in term of the signaling processes for observation of external disturbances and predator avoidance. The monthly budget of scanning varies in all age-sex category with significant difference observed in between months (ANOVA, df = 11, f = 2.17, p < 0.05) and age-sex category (ANOVA, df = 4, f = 8.44, p < 0.01).

Table 21 : Values of variance test (Two-way analysis of ANOVA) calculated on the basic activities of blackbuck in between the months and on the age-sex categories.

Activity	Source of Variation	SS	df	MS	F	P-value	F crit
Feeding	Month	404.44	11	36.76	1.88	0.06*	2.01
	Age-sex	5577.27	4	1394.31	71.41	1.15E-18***	2.58
Walking	Month	198.08	11	18.00	0.84	0.59	2.014
	Age-sex	172.06	4	43.01	2.02	0.10	2.58
Scanning	Month	234.08	11	21.28	2.17	0.03*	2.01
	Age-sex	330.63	4	82.65	8.44	3.8E-05***	2.58
Standing	Month	277.45	11	25.22	4.16	0.0003**	2.01
	Age-sex	209.96	4	52.49	8.65	3.03E-05***	2.58
Lying	Month	384.03	11	34.91	2.00	0.05*	2.01
	Age-sex	914.10	4	228.52	13.13	4.02E-07***	2.58
Others	Month	106.25	11	9.65	0.87	0.57	2.01
	Age-sex	1235.02	4	308.75	27.88	1.44E-11***	2.58

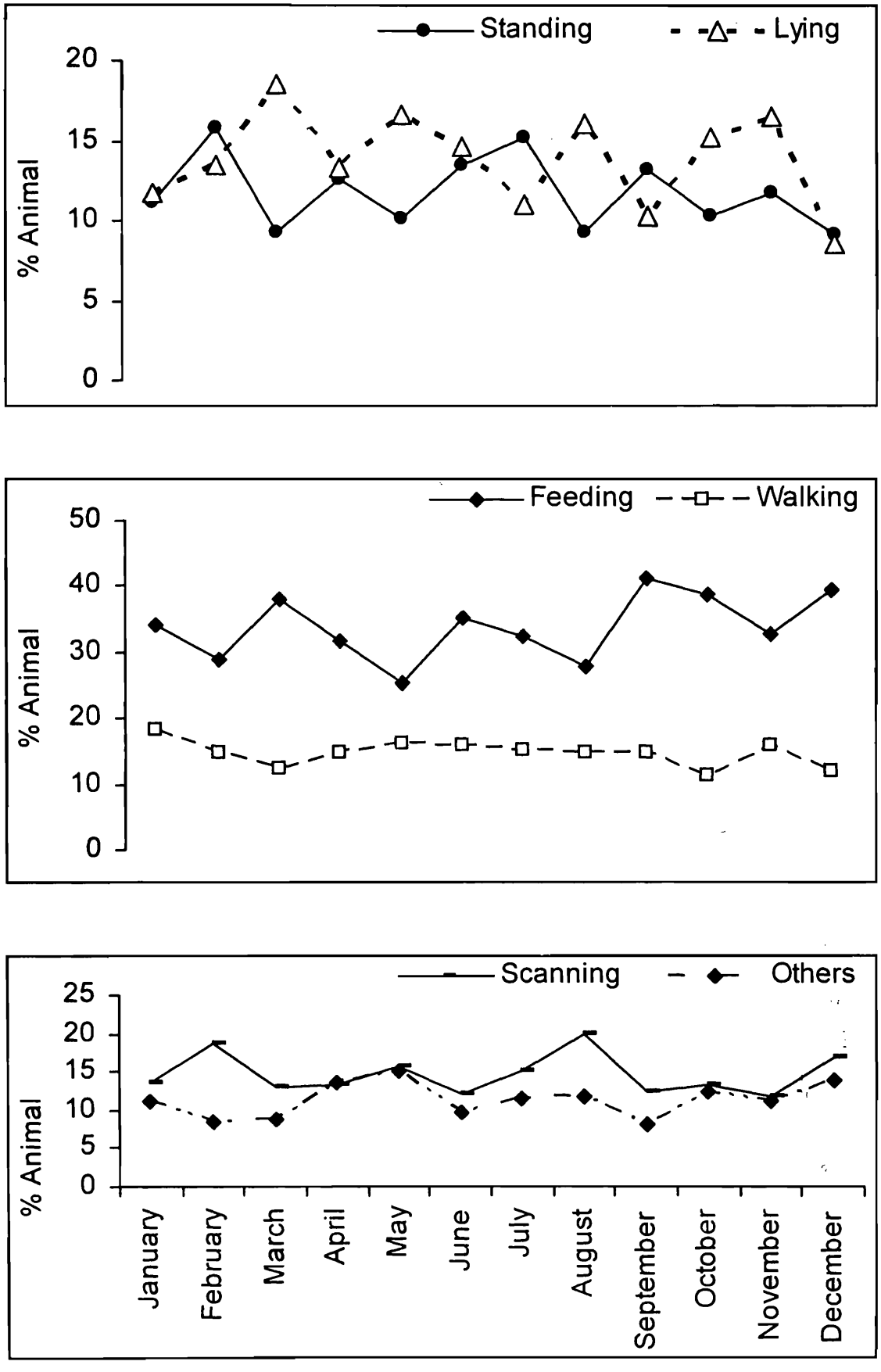


Figure 39 : Monthly activity pattern of herd of blackbuck at PCRB.

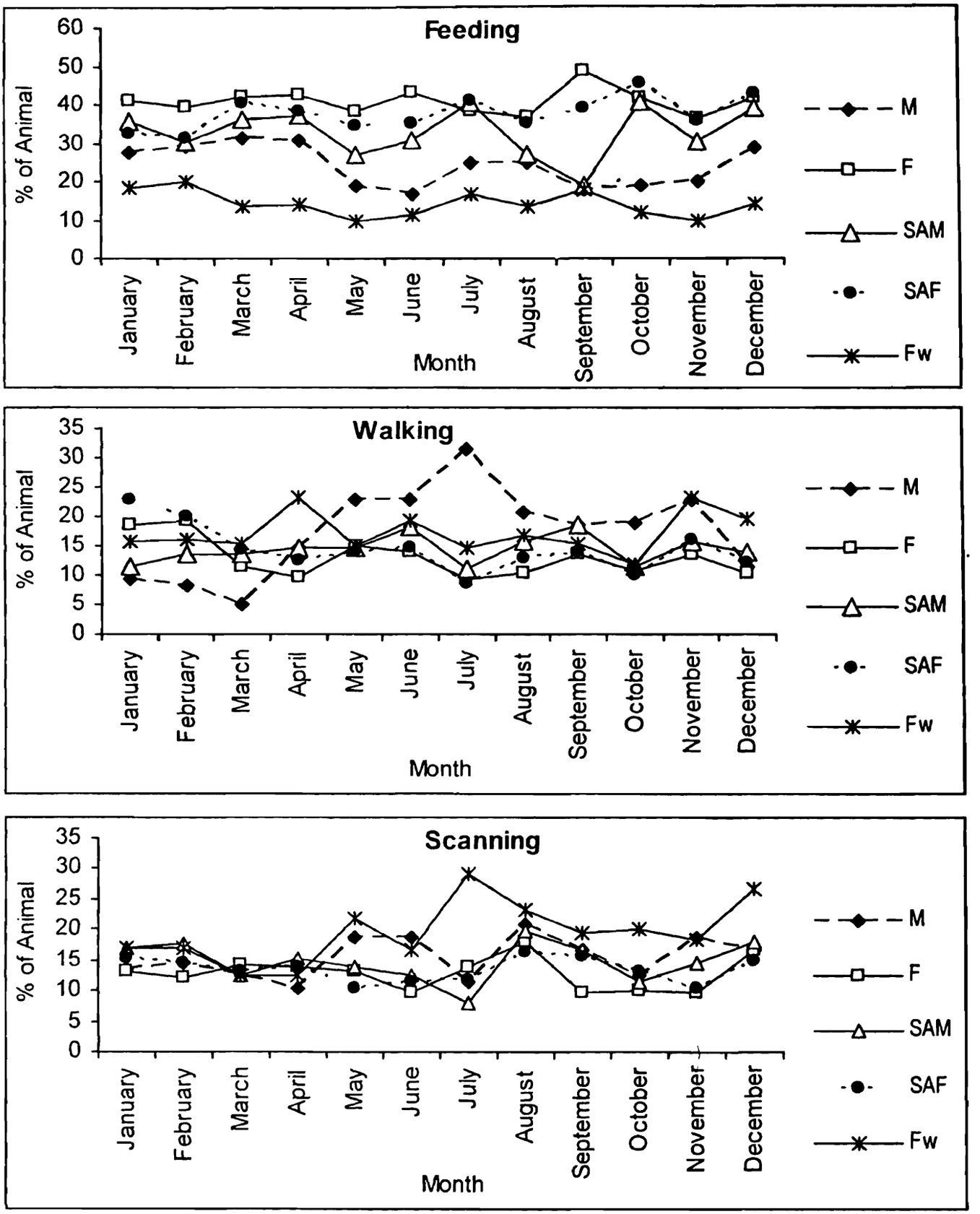


Figure 40 : Monthly variation in the percentage of animal of each age-sex category of blackbuck (*Antilope cervicapra*) involved in various basic activities at PCRB.

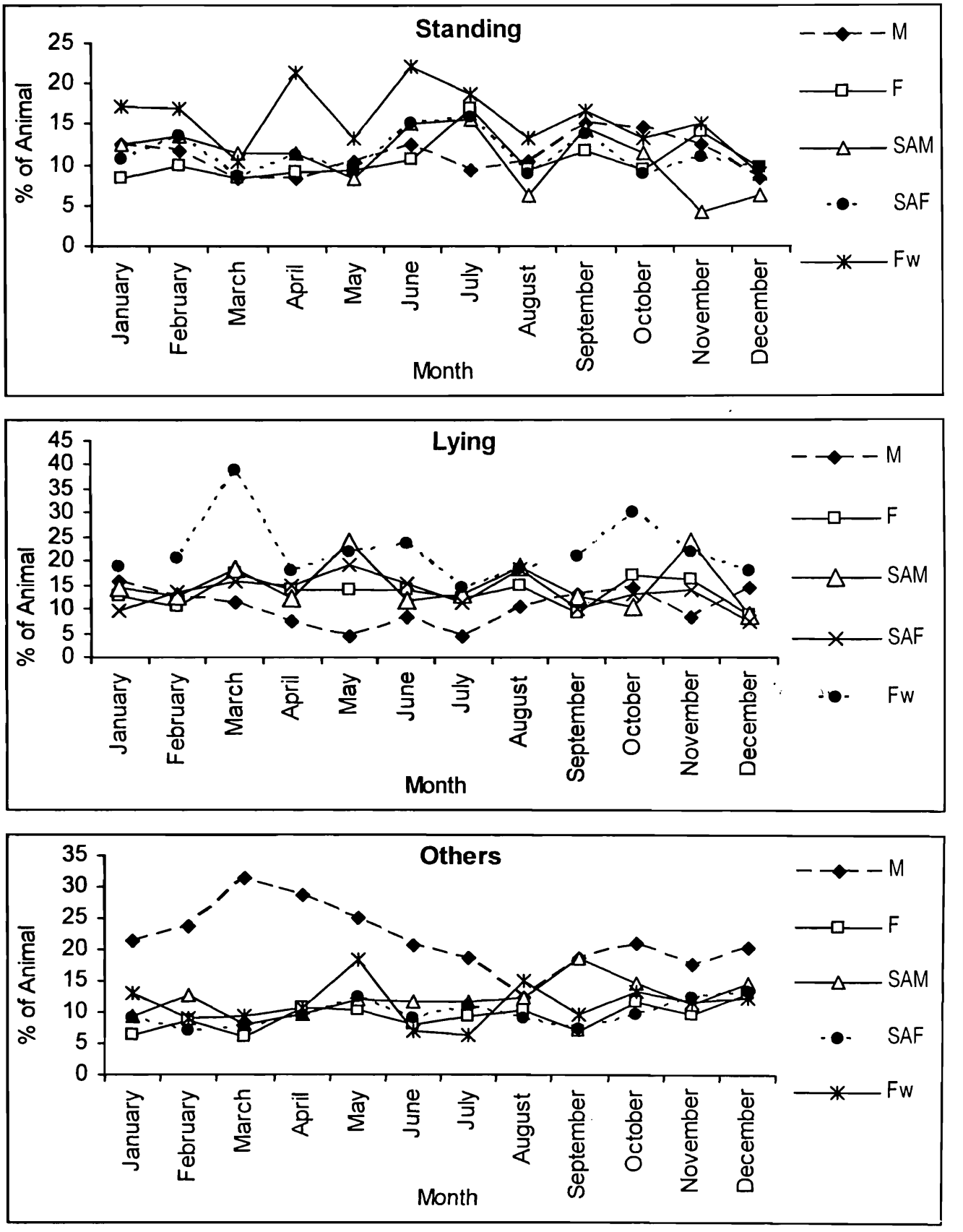


Figure 41 : Monthly variation in the percentage of animal of each age-sex category of blackbuck (*Antilope cervicapra*) involved in various basic activities at PCRB.

Similarly monthly variation was found on standing in age-sex category (ANOVA, df = 4, f = 25.22, $p < 0.001$) and in between months (ANOVA, df = 11, f = 52.4, $p < 0.001$) with peak standing in summer months.

The proportion of monthly lying was maximum recorded in fawn and minimum lying observed in adult male. Monthly lying varies between month (ANOVA, df = 12, f = 2.22, $p < 0.05$) and also in between age-sex category (ANOVA, df = 4, f = 13.13, $p < 0.001$).

Adult male dominated in all age-sex categories in term of the monthly proportion in others activities, with peak others activities in the month of March i.e., a peak month of rutting seasons of blackbuck. A significant variation is found in the monthly budget between age-sex category (ANOVA, df = 4, f = 27.88, $p < 0.001$), while significant variation has not been found in between the monthly budget of all age-sex categories individuals.

Discussions

An analysis of how different species distribute their time among various activities is essential to any characterization of their life cycle, and lays a foundation for interrelating their ecology and behaviour (Struhsaker & Leland, 1979). Intraspecific variability in activity budget has been documented in many species and may reflect fluctuation in resource availability or other environmental variables (Clutton-Brock, 1977). The flexibility of behavioural responses of an animal with the fluctuations in resource availability has frequently been cited as an essential component of the adaptive strategy that has resulted in the successful colonization in particular habitat.

A common pattern for many diurnal animals is one of early morning and late afternoon peaks of feeding separated by mid day period (Harcourt, 1956). The mean number of individual blackbuck observed during each hour of observation at the study area was determined; the trend was a bimodal distribution in activity to occur, with a morning peak from 07.30-09.30 hr and an afternoon peak at 14.30-16.30 hr.

Present study showed a clear difference in foraging behaviour between males and females. Synchronization of foraging behaviour by an individual greatly different in size from the rest of the group would probably result in a cost for that individual. Sub-adult males changed their behaviour according to the type of group they were in. Two-year-bachelor males changed their activity bout duration when they changed groups.

The behaviour of young males provides strong support for the hypothesis that adult males and females segregate because of differences in foraging behaviour. For

young males that stay in female or bachelor male groups, there might be a tradeoff between predator protection in the group and adjustments/synchronization of their behaviour.

Sub-adult males could therefore show very different behaviour and still keep up with bachelor groups. Three-year-old males, in contrast, did not synchronize their behaviour with those of adult males or females and showed foraging/lying bout durations that were somewhat independent of the group.

The activity patterns are determined by numbers of biotic and abiotic factors (Prasad, 1985). As the study area was agricultural pasture so, it was essential to understand that how the activity pattern of blackbuck changes and maintains in presence of human activities basically in monsoon season when the agricultural work increases.

Feeding constitutes the major component of all activities and has described by physiological control of daily and seasonal feeding (Jarman, 1974). The activity patterns of ungulates may also be influenced by sex and age of the animals (Jarman, 1974). Majority of wild ungulates are with many phases of daily activity rhythm in which feeding bouts are interspersed with other activities.

The present study in PCRB indicates that the daily activity pattern of blackbuck is of polyphasic nature where feeding is interspersed with resting and walking. Resting and walking occurred almost throughout in between the feeding bouts. During the dawn and dusk grazing was in peak, when about 90% of the animals were active. Prasad (1985) and Bhattacharya & Chattopadhyay (1986) found similar phenomenon in blackbuck during hot season. Bhattacharya & Chhatopadhyay (1986a) reported many phases of daily activity of rhythm in which feeding was interspersed with resting phase. Thus, it assumes that there is a definite pattern of major activities in the fixed hours of the day which varies with the season.

Blackbuck found in close proximity to human habitation, faces certain amount of stress throughout the season by the activities of cultivator in the monsoon season, engaged basically on paddy cultivation. The pasture and environmental factors are major determinant of activity pattern of blackbuck. In addition human interference by the pattern of cultivation has also guided them to change the pattern of basic activities in monsoon. Present study shows that feeding and walking affect vise-versa throughout the season, it hypotheses that before the onset of monsoon, availability of large pasture, fresh grass and palatable plants are easily available so minimum amount of time is spent in feeding and consume more food as a result of very less walking. At the peak of monsoon the frequency of feeding, walking and scanning increases due to less availability of grasses because

the pasture land are covered by water and soil. Also, the activities of cultivator increases in that season which results in increase in walking and scanning activities. At the onset of monsoon, time spent in feeding and walking was less due to easy availability of food by the growth of crop, while the time spent in resting and social activities increases due to less human interference and concealing by growth of crop.

Family-group and solitary territorial male blackbuck did differ in the amount of time budgeted for others behaviours. In many territorial mammals, there are differences in male behavioral patterns that influence an individual's mating success. In this study, variation in reproductive success rates of territorial male blackbuck could not be explained by individual behavioral time budgets.

d. Seasonal activity pattern

The results of the analysis, using data of various seasons pooled together and the significance level of inter-seasonal variability in activity proportions tested with a one-way analysis of variance without replication as shown in Table 22.

The proportion and variation in activities of the individuals of the all age-sex categories of blackbuck are represented in figure 42 and 43. The proportion of time spent in feeding by adult male is highest in summer and lowest in winter, scanning and resting highest in winter, walking in monsoon and others activities in summer. A significant differences found in basic activity of adult male in between the seasons ($p < 0.05$).

Proportion of time spent in feeding by adult female more or less equal in summer and monsoon with lowest in winter. The proportion of walking was highest in winter and lowest in monsoon, while no significant variation found in the proportion of activities like scanning, resting and others in between seasons. Overall significant variation is found on the proportion of activities of females in between seasons ($p < 0.001$).

The proportion of feeding and others activity was highest in monsoon, scanning highest in winter, walking and resting in monsoon in sub-adult male. In the same age group of sub-adult female feeding was highest in monsoon, walking and others in winter, resting in summer and no variation in the proportion of scanning between seasons. In both these category of sub-adults a significant variation is found between the seasons ($p < 0.001$).

Although a small sample-size was studied for the activities of fawn, the observed data reveal that, proportion of feeding and scanning was highest in monsoon, walking and others in winter and resting in summer. Significantly overall seasonal variation in activity proportion was found ($p < 0.001$).

Table 22 : Seasonal mean of basic activities of all age-sex category of blackbuck (tested by one-way ANOVA) at PCRB.

Age-Sex	Season	Feeding	Scanning	Walking	Resting	Others	F-value
Male	W	21.87	18.75	15.1	22.39	21.87	3.25*
	S	26.56	15.1	16.14	18.22	23.95	
	M	22.39	16.14	21.87	21.35	18.22	
Adult female	W	38.81	13.14	13.98	24.75	9.3	35.38**
	S	41.52	12.67	12.83	24	8.95	
	M	41.18	12.91	10.97	25.27	9.65	
Sub-adult male	W	34.4	15.84	13.86	25	10.89	168.92**
	S	33.74	13.37	15.63	27.16	10.08	
	M	37.14	13.31	12.85	25.23	11.44	
Sub-adult female	W	36.01	13.11	16.59	23.56	10.7	130.53**
	S	37.12	12.37	13.76	27.14	9.59	
	M	40.64	13.1	12.03	25.53	8.68	
Fawn	W	13.88	20.23	19.44	34.12	12.3	43.89**
	S	12.69	15.87	18.65	42.06	10.71	
	M	15	22.5	14.58	36.66	11.25	

(* = Significant, ** = highly significant, W = winter, S = summer and M = Monsoon)

Discussion

After comparing blackbuck activity in these seasons it was found that animals spent more time in walking and less time in feeding in the season when less availability of food patches *i.e.*, appeared to be working harder for food. This gives a decrease in the feeding-walking ratio which can be used as a crude measure for foraging success. Reverse was seen in the season when there were more availability of food resources. There is a very marked difference between the pattern for dry and wet days. In the dry days there was a considerable increase in the time spent resting in the mid day period with a corresponding decrease in both feeding and walking. Thus, the availability of pasture and environment seem to be the strongest ecological determinants in the seasonal variation of the basic type.

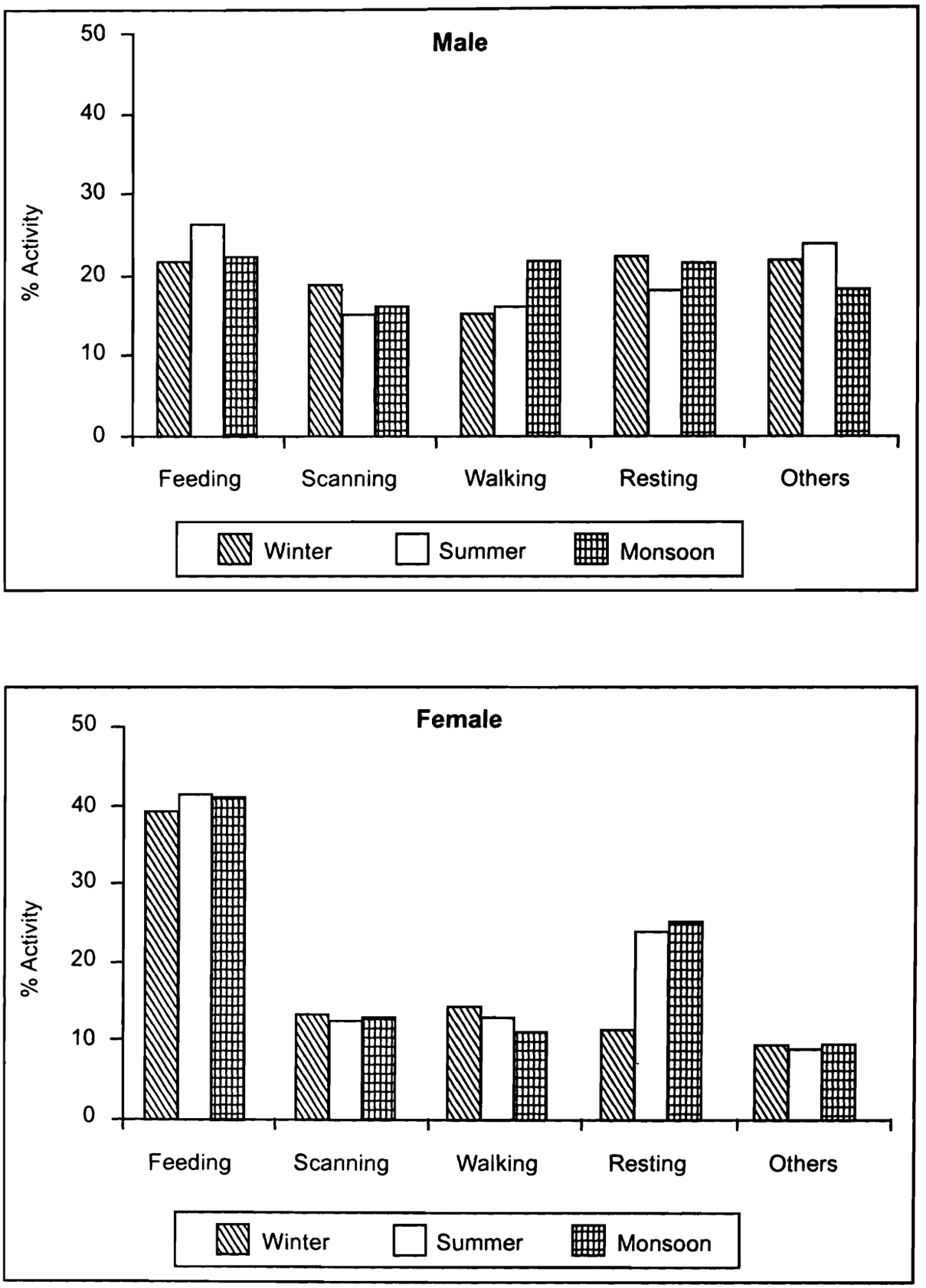


Figure 42 : Seasonal percentage frequencies of basic activities of blackbuck at PCRB. (a. Male, b. Female).

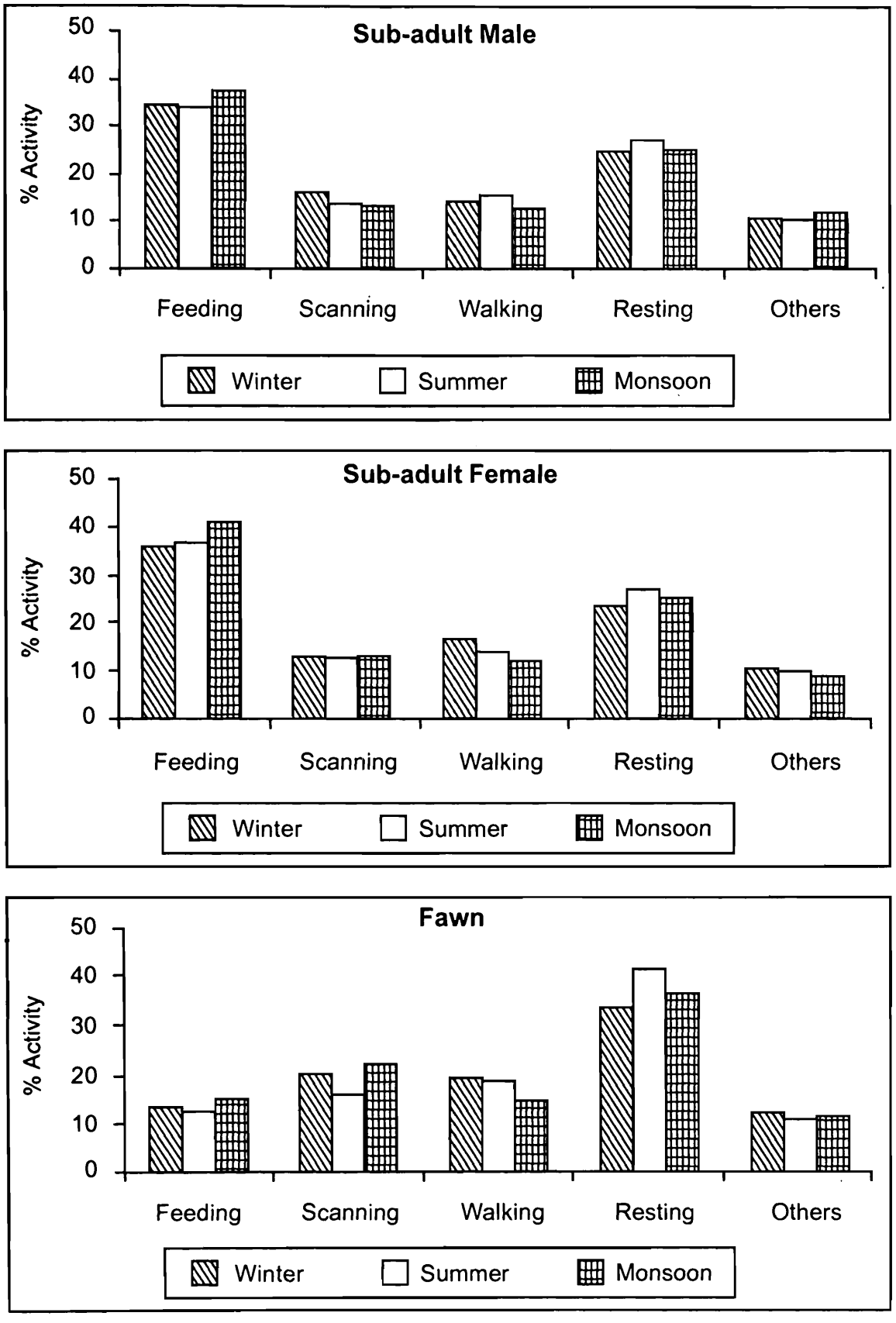


Figure 43 : Seasonal percentage frequencies of basic activities of blackbuck at PCRB.

e. Activity pattern in relation to habitat

A habitat characteristic of a locality is an important factor for the variation and adaptation of the activity features or pattern of the animal surviving in that local environment. There were differences in blackbuck behaviours based on habitat type. Male spent more time in aggression and miscellaneous activities in Watch tower area. Use of these open Watch tower areas for aggressive behaviours could be advantageous to the males. The upland grasslands have an extensive view and are relatively safe from predators as well as human presence. Also this area does not provide high quality food resource for the females. Although Watch tower areas and Vetnoi back areas may not be on direct routes used by female blackbuck, aggressive behaviour between two males on Watch tower could provide female blackbuck with knowledge of the male territories. From a grassland area, territorial males can still see the rest of their territory while engaged in aggressive behaviors.

Territorial behavior of other male ungulates is frequently used to attract and secure mates (Owen-Smith, 1977), but in the population of blackbuck, males attract mates solely through resource defense (Isvaran, 2006) rather than through differences in behavior. The habitats in which male blackbuck establish territories act as the main resource to attract females (Isvaran, 2003). Although some still doubt on whether female choice is based solely on a male's defended resources, the lack of behavioral differences between mating and non-mating males.

V. Activity bout Duration

Duration of a bout of particular activities is an important indicator for the habitat condition, forage availability, adaptability of the animal to the habitat and suitability of the habitat for the animal. Mean bout duration of all the basic activities are presented in Table 23. Among the basic activities, the bout duration of

Table 23 : Mean bout duration & Standard error of the basic activities of blackbuck at PCRB. (tested by ANOVA 1-way analysis).

Activity	Male (Mean ± SE)	Female (Mean ± SE)	F	P-value
Feeding	144.03 ± 6.91	191.41 ± 10.41	14.36	0.001**
Walking	69.98 ± 3.10	70.2 ± 2.97	0.02	0.95
Scanning	76.42 ± 2.54	73.57 ± 2.65	0.59	0.44
Standing	74.84 ± 2.48	73.26 ± 3.05	0.16	0.69
Lying	187.01 ± 12.46	227.87 ± 16.23	3.98	0.05*
Others	41.86 ± 1.06	36.51 ± 0.95	14.07	0.001**

(* Significant, ** Highly significant)

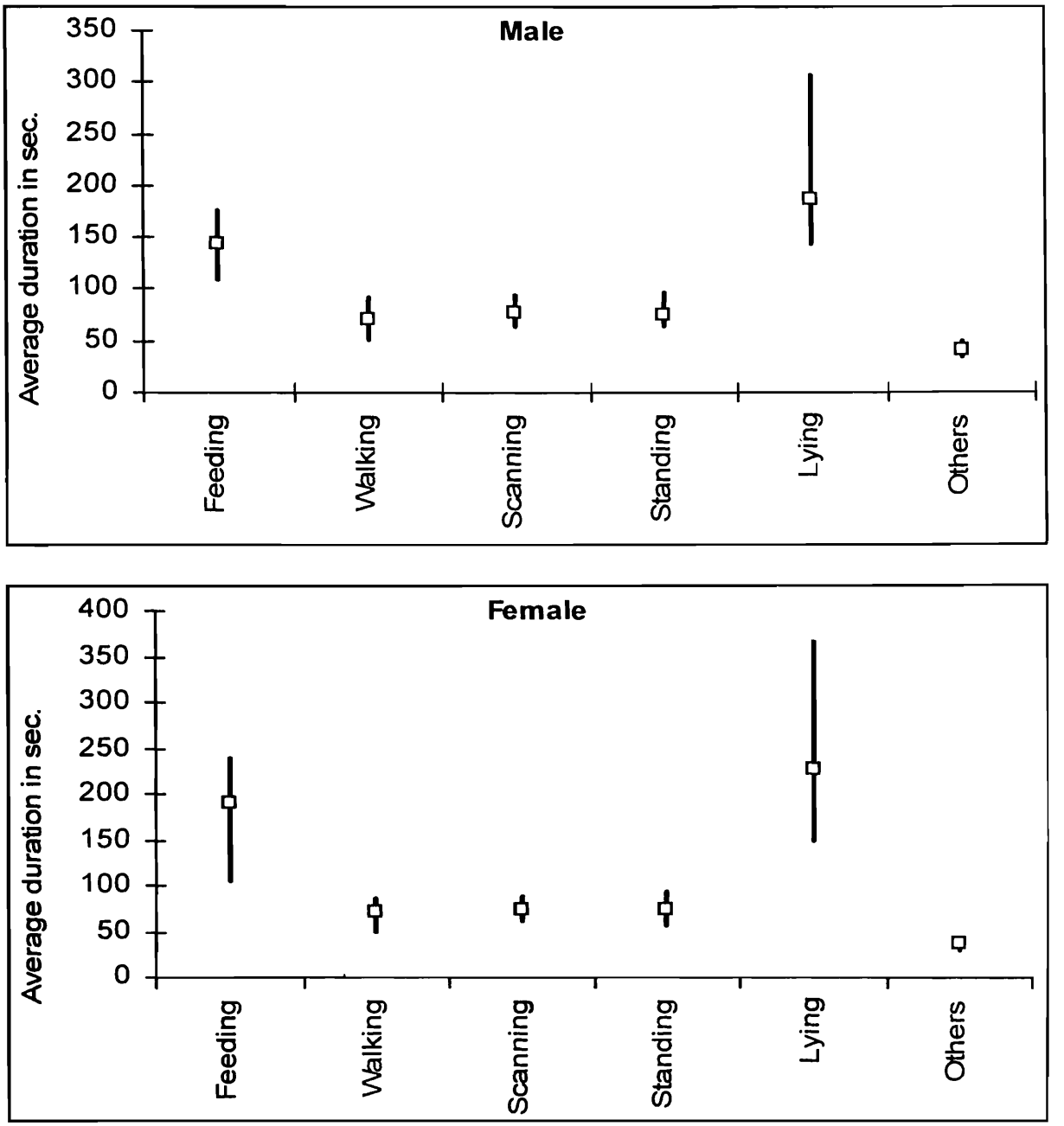


Figure 44 : Mean, Range and Standard error of average duration (in sec.) of the basic activities of both the sexes of blackbuck at PCRB.

feeding and lying was recorded longer and other activities (social, urination-defecation, running etc.) were shorter in duration.

Duration of feeding and lying was longer in female in comparison to male. A significant difference in the duration of feeding ($p < 0.001$), others activities ($p < 0.001$) and lying ($p < 0.05$) was found in between the sexes of blackbuck. No significant difference found in rest of the basic activities between male and female. The mean, their range and standard error of the activity duration of basic activities in male and female of blackbuck is given in Table 23 and shown in figure 44.

VI. Activity Rate

Activity per hour represents the animal suitability to the habitat, density of the group, group movement. Observation on the activity was calculated as number of activity per hour by individuals of both sexes in each hour of the day and summarising the same for morning, noon and afternoon hours of all seasons (Table 24A & Figure 45).

It was found that, the activity rate of male was highest in morning hours in all seasons except in winter when the rate was more or less equal in morning, noon and afternoon. It was also observed that, the rate of activity was slow in the noon hours in comparison to morning and afternoon hours. The average activity per hour observed in PCRB was 39.85 ± 3.2 in case of male with minor variation (morning, 42.7; noon, 37.6; afternoon, 39.3) and 34.12 ± 1.6 in female but no significant variation in diurnal hours. It was also observed that the activity rate of female did not vary in between seasons. It was interestingly noted that activity rate of female in winter season was highest in noon hours as compared to morning and afternoon hours.

The rate of feeding (8.89 ± 0.8) per hour was highest and lying (2.80 ± 0.67) lowest in relation to other activities in male. Similarly rate of feeding per hour (8.83 ± 0.70) was the highest and lying (2.20 ± 0.49) lowest in term of activity rate. The activity rate of other activities was recorded maximum in male as compared to that of female. On the observation of activity rate of each individual basic activities, feeding ($p < 0.001$) and lying ($p < 0.01$) varied significantly between hours, while the rate of walking ($p < 0.001$) and scanning ($p < 0.05$) varied between sexes. The mean and standard error of the activity rate of each individual activity is given in Table 24B and shown in Figure 46.

Discussions

Females spent more time in foraging per observation period, and had longer foraging bouts, than adult bucks. Fawn accordingly spent more time lying than females and had significantly longer lying bouts. Previous studies on a wide range of ungulates also found that females spent more time foraging than males.

Synchronization of foraging behaviour by an individual greatly differs as the group size and composition of the group. The activity pattern of herd results on the activities of individuals would probably result in a cost for that individual. Sub adult males changed their behaviour & activity bout duration according to the type of group they were in. The duration of an activity bout may therefore be dependant on which particular group the individuals select and stay. If the duration of lying bouts were very different, some animals would move away while grazing, while others stayed bedded. When adult males were with adult females, their activity bout durations were similar to those of adult females, but when they were with adult males, their activity bouts were shorter. The same was true for the male in bachelor

group should have longer foraging bouts than adult males, and 3-year-olds bachelor male should have longer lying bouts than females. There are two possible explanations, one is that young males may interact much more with each other in male groups and would therefore interrupt their activity bouts more often, leading to shorter grazing and lying bouts. The other explanation is that young male in adult bachelor groups may not have to synchronize their behaviour with those of adult males as much as they would with females, because male groups do not move far while foraging.

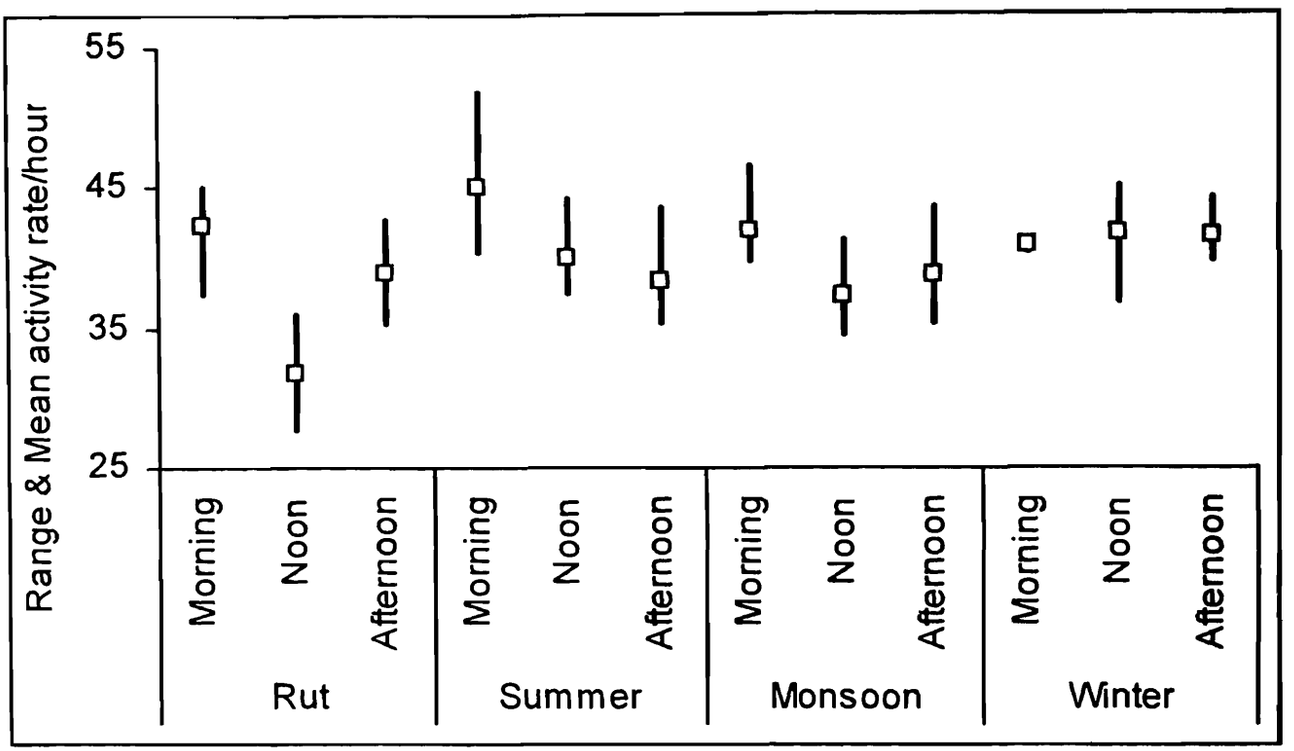
Table 24 : Mean activity/hours showed by blackbuck in different sessions of the day of all seasons at PCRB. (A. total frequencies of activity/hour, B. frequencies of each activity/hour).

Season	Hours (Mean ± SE)	Male (Mean ± SE)	Female
Rut (February to April)	Morning	42.33 ± 1.86	31.75 ± 2.16
	Noon	31.75 ± 1.71	31 ± 2.03
	After noon	39 ± 1.52	32.75 ± 1.19
Summer	Morning	45 ± 2.27	35.5 ± 2.44
	Noon	40 ± 1.96	34.25 ± 2.94
	After noon	38.25 ± 1.65	35.25 ± 3.24
Monsoon	Morning	42.75 ± 1.66	33.5 ± 1.32
	Noon	37.25 ± 1.86	33.75 ± 1.48
	After noon	38.75 ± 1.58	31.75 ± 2.46
Winter	Morning	40.75 ± 1.62	34.75 ± 1.62
	Noon	41.75 ± 2.64	38.75 ± 2.31
	After noon	41.5 ± 1.46	36.5 ± 2.68

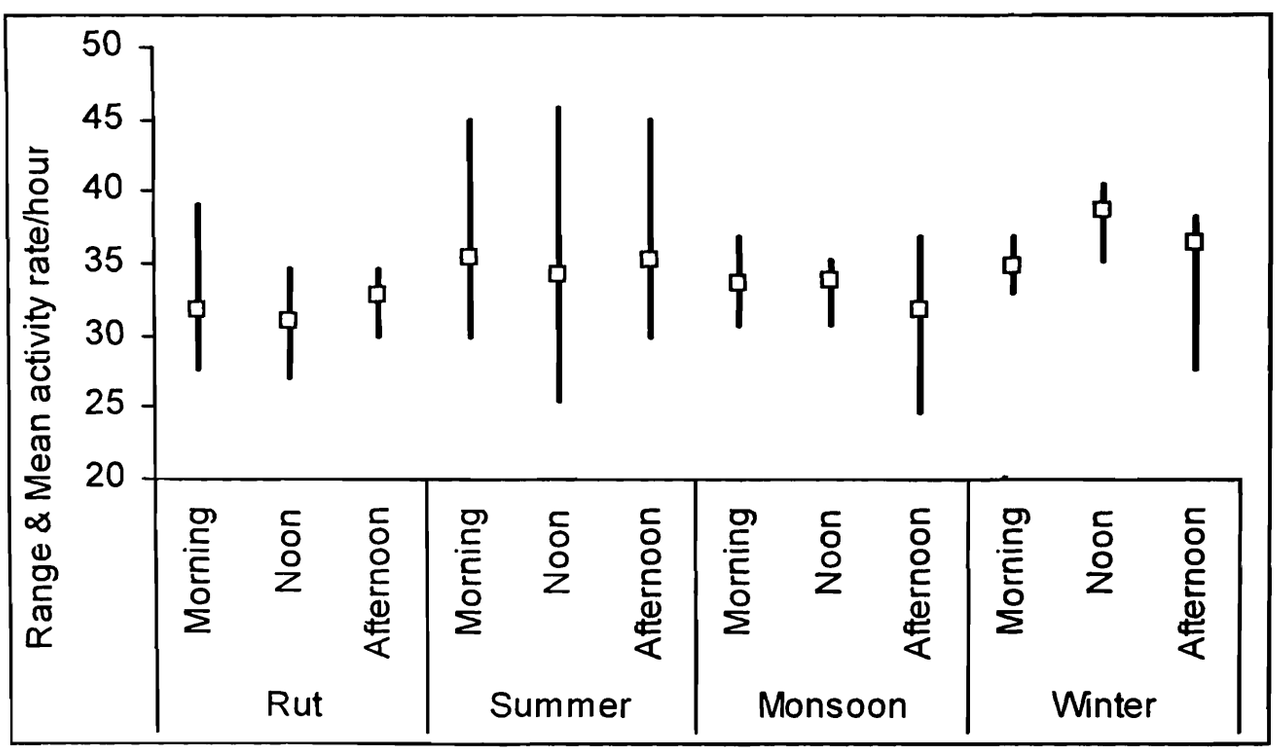
(A)

	Mean ± SE		F-value	
Activity	Male	Female	Between hours	Between sexes
Feeding	8.89 ± 0.89	8.83 ± 0.70	22.2**	0.03
Walking	7.89 ± 0.42	6.25 ± 0.20	1.05	12.63*
Scanning	7.16 ± 0.26	6.29 ± 0.24	0.28	3.73*
Standing	6.25 ± 0.29	5.97 ± 0.44	1.87	0.37
Lying	2.80 ± 0.67	2.20 ± 0.49	10.66*	2.97
Others	6.95 ± 0.30	4.56 ± 0.28	1.33	1.09

(B)

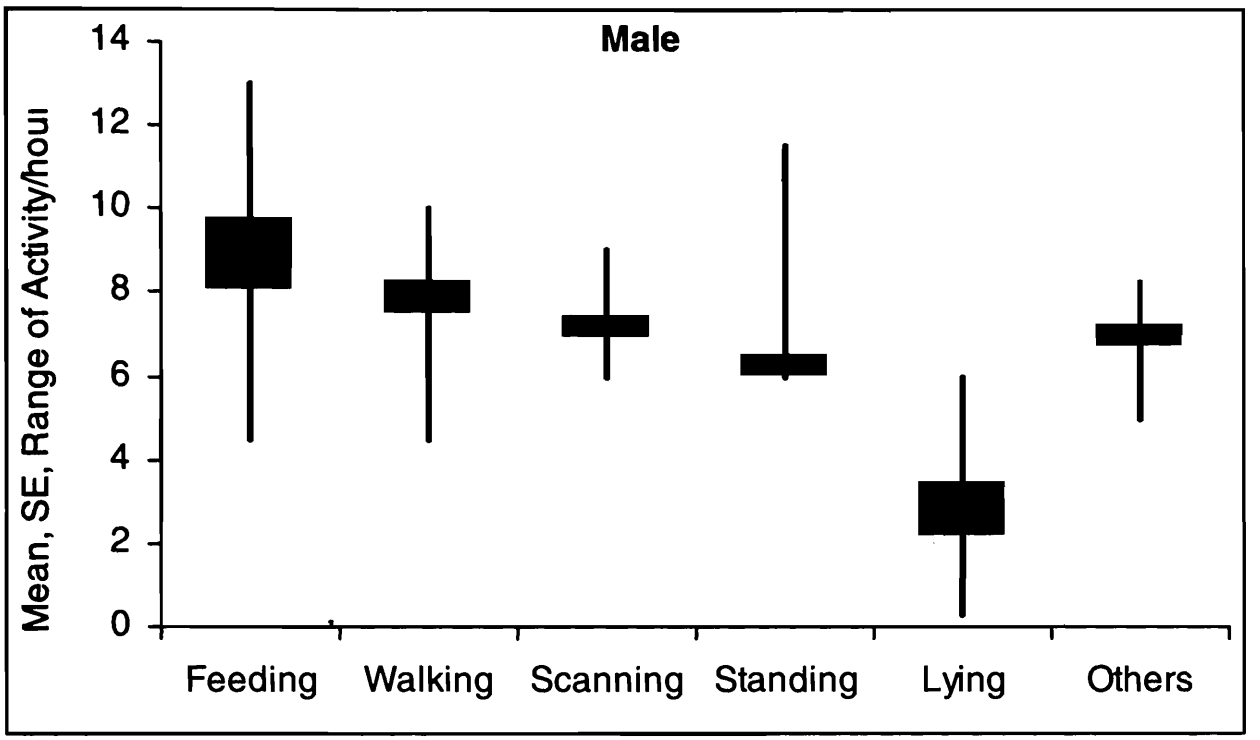


(A) Male

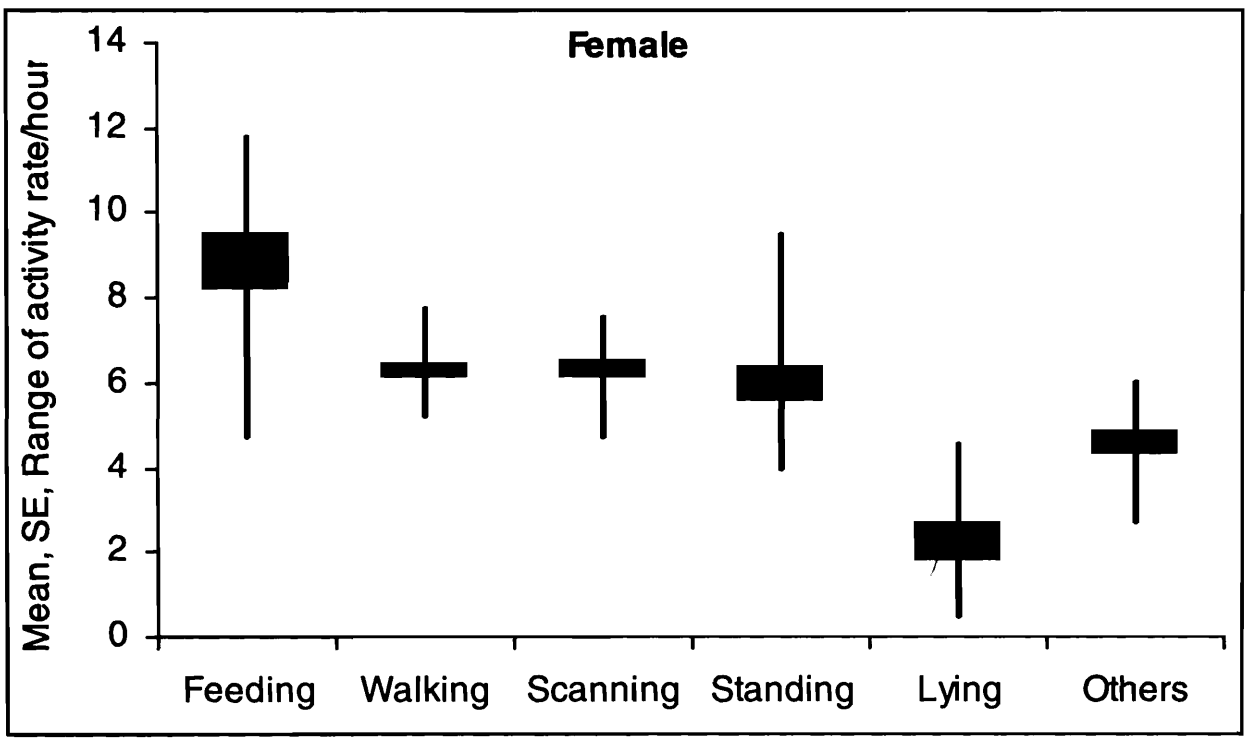


(B) Female

Figure 45 : Mean and range of activity per hour in three sessions (Morning, noon & afternoon) of day showed by blackbuck in different season at PCRB.



(a)



(b)

Figure 46 : Means, SE and range of the activity/hours of the basic activities of blackbuck at PCRB.

A 3-year old male (left) in defecation mode.

A bachelor herd engaged in different activities.

A blackbuck in running mode in the cultivated field.

A female (right) in urination mode.

A mixed herd in resting mode.

A territorial male in scanning mode.

Defecation mode of a territorial male.

Three bachelor males feeding and at the same time one male scanning.

Two males in scanning mode (one male with broken horn).

A territorial male in standing mode at PCRB.

Aggregation of bachelor males during disturbances in habitat.

Bachelor males in scanning and grooming mode.

VII. Vigilance behaviour

It has been observed that fawn and yearling spent more time in comparison to other age-sex categories of individual in vigilance, while next to them was adult male. The monthly and hourly mean of time spent was maximum in male probably due to solitary living for maximum time. So, there is more predatory pressure on them. Sub-adult female spent less time in comparison to other age-sex category individuals as because they were always living in a herd. Monthly and hourly mean ± standard error of time spent in vigilance by herd and various age-sex categories of blackbuck is given in Table 25 and Figure 47 and 48.

Table 25 : Monthly and hourly mean ± standard error of vigilance activity of herd and various age-sex categories of blackbuck.

Herd & age-sex	Monthly Mean ± SE	Hourly Mean ± SE
Herd	13.63 ± 0.58	13.69 ± 0.32
Adult Male	16.66 ± 1.28	16.66 ± 0.81
Adult Female	14.44 ± 1.40	13.45 ± 0.40
Sub-adult Male	14.18 ± 0.97	14.08 ± 0.60
Sub-adult Female	12.84 ± 0.56	12.95 ± 0.50
Fawn	19.78 ± 1.45	15.85 ± 2.04

Significant difference was found in vigilance activities between month ($df = 11$, $f = 2.70$, $p < 0.01$), between age-sex ($df = 4$, $f = 6.95$, $p < 0.01$) and also between herd size ($df = 3$, $f = 2.96$, $p < 0.05$). But there is no difference in vigilance activity in between diurnal hours.

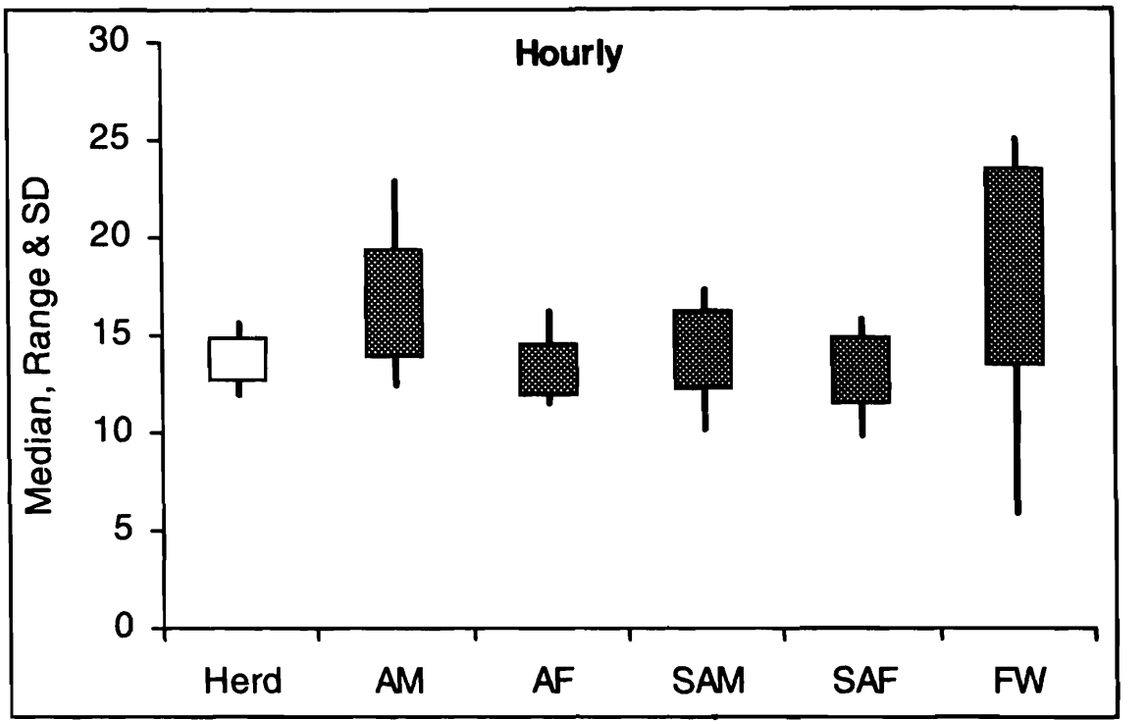
It was recorded that the vigilance activity of all categories of individuals varied monthly ($p < 0.05$) and hourly ($p < 0.001$). The monthly pattern of the vigilance of adult male and fawn was fluctuating more in comparison to others categories of the individuals (Figure 47A). Similarly, hourly mean of the time spent in scanning varied significantly in these categories individuals (Figure 47B). It was also observed there was no difference in alert behavior of blackbuck between the habitat types.

From the analysis of the data on the frequency of vigilance by categorization of the herd in 4 groups size (less than 10, 10-15, 15-20, more than 20), it was found that as herd size increased the frequency of vigilance also increased (see Table 48). The frequency of vigilance of adult male increased as the herd size increased, while the frequency of vigilance decreased as the herd size increased. So, the vigilance frequency in the opposite sex differs and female fill more defense from the predators as the herd size increased but in case of adult female the increase of frequency is

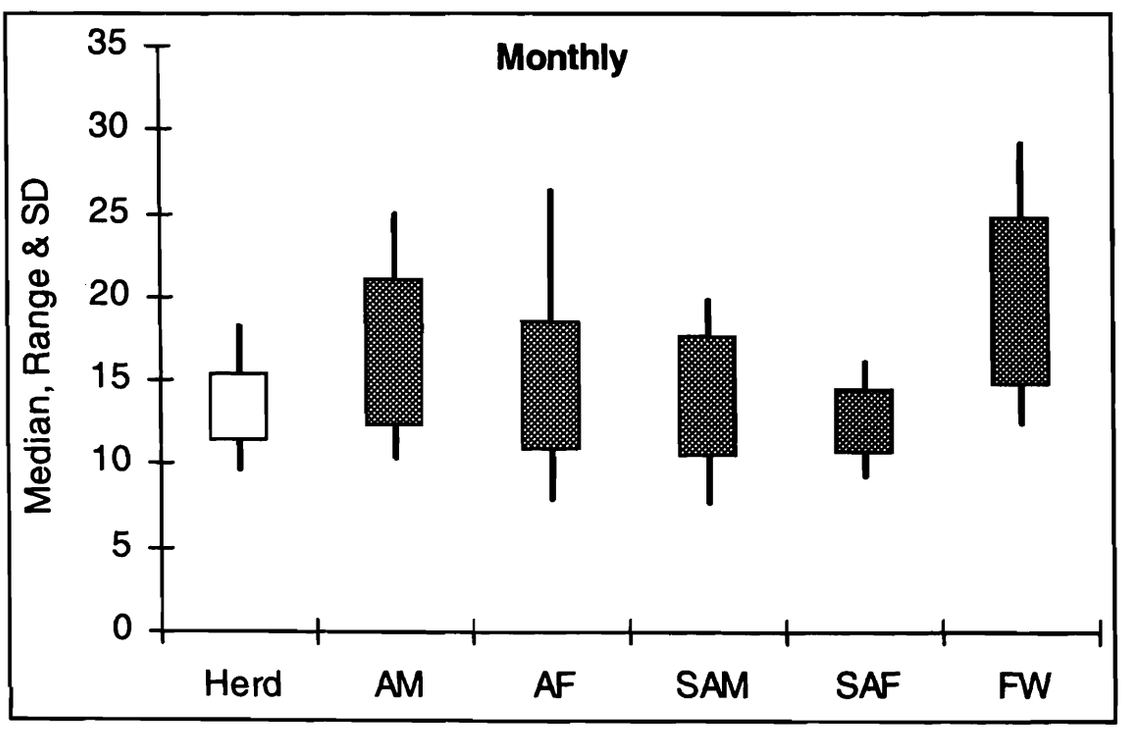
the strategies to keep the herd in their own territory. The frequency of vigilance of sub-adult individuals of the herd decreased as the herd size increased similar to the adult female. It was noticed that the frequency of vigilance of fawn was not varied according the herd size but the percentage frequency was always greater than the other age-sex category individuals (Table 26 and Figure 49).

Table 26 : Frequencies of vigilance in all age-sex categories individuals in different herd size of blackbuck in PCRB.

Category	Herd Class	Vigilance Frequency	No. of observation of all activities	% frequency	Herd size Mean ± SD
Herd	<10	131	804	16.29	7.33±0.67
	10 to 15	375	2712	13.82	13.29±1.22
	15 to 20	397	2860	13.88	17.43±0.83
	>20	293	2388	12.26	23.88±1.01
	Total	**1196**	**8764**	**13.64**	**15.19±5.34**
Adult male	<10	19	100	19	0.94
	10 to 15	32	200	16	0.98
	15 to 20	24	168	14.28	1.02
	>20	19	104	18.26	1.06
	Total	**94**	**572**	**16.43**	**1**
Adult female	<10	63	384	16.4	3.55
	10 to 15	157	1156	13.58	5.67
	15 to 20	170	1148	14.8	7
	>20	121	1096	11.04	10.96
	Total	**511**	**3784**	**13.5**	**6.79**
Sub-adult male	<10	22	108	20.37	1
	10 to 15	53	416	12.74	2.03
	15 to 20	65	438	14.84	2.67
	>20	46	356	12.92	3.56
	Total	**186**	**1318**	**14.11**	**2.31**
Sub-adult female	<10	25	180	13.88	1.66
	10 to 15	78	563	13.85	2.75
	15 to 20	78	580	13.44	3.53
	>20	62	532	11.65	5.32
	Total	**243**	**1855**	**13.2**	**3.31**
Fawn	<10	22	108	20.37	1
	10 to 15	45	216	20.83	1.05
	15 to 20	39	228	17.1	1.39
	>20	39	192	20.31	1.92
	Total	**145**	**744**	**19.48**	**1.34**

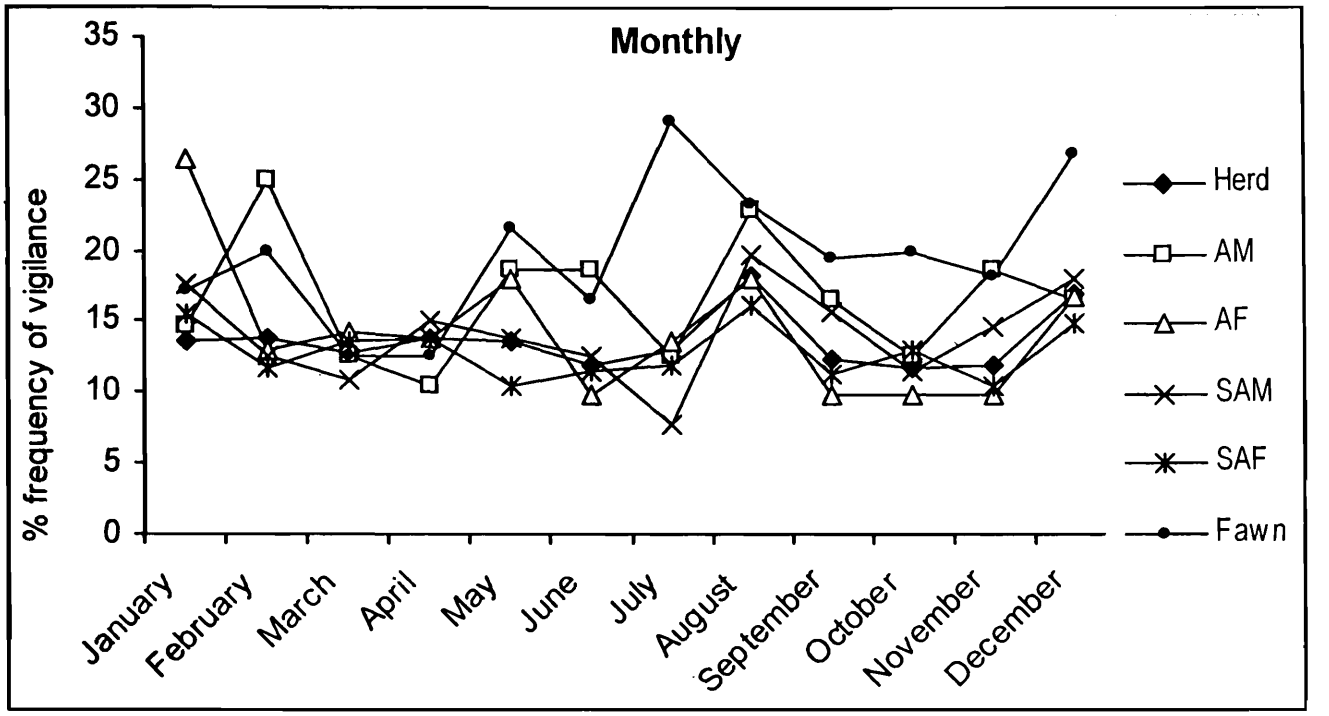


A. Monthly

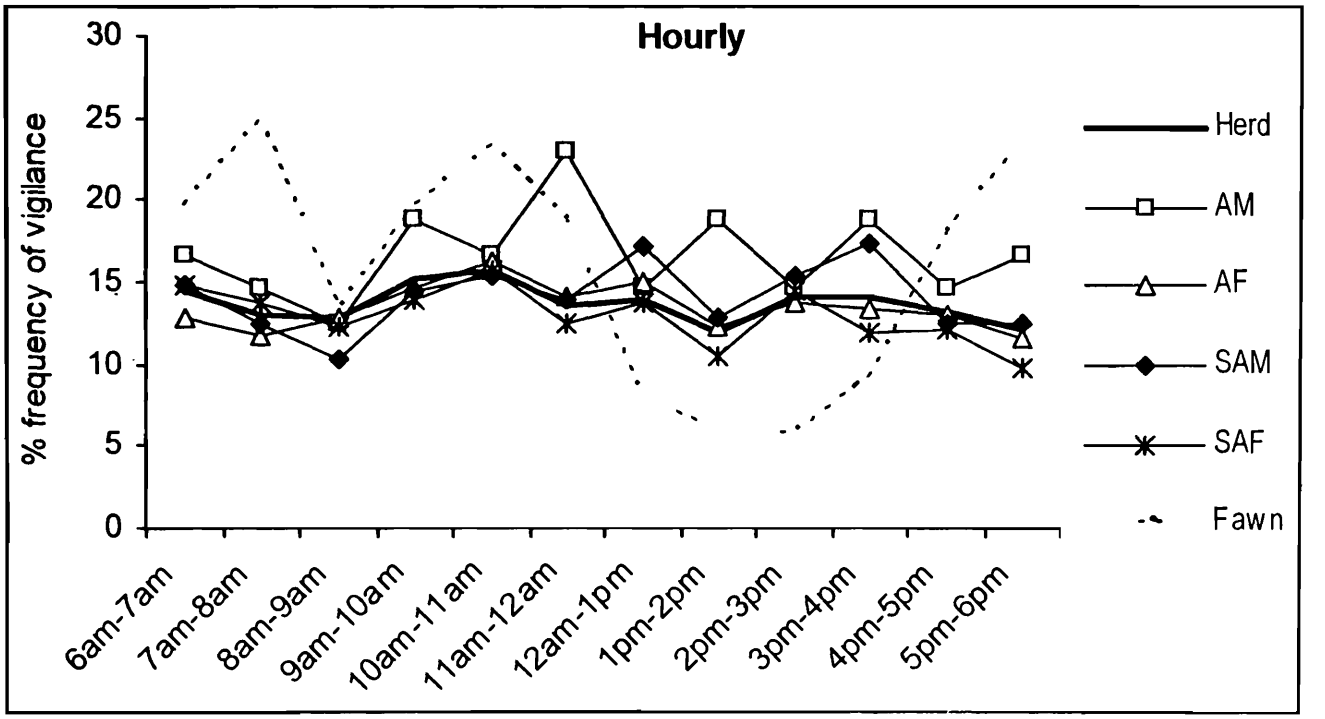


B. Hourly

Figure 47 : Represents the median, range and SE of the vigilance frequencies of herd and age-sex categories of blackbuck at PCRB.



A. Monthly



B. Hourly

Figure 48 : Represents the percentage frequencies of vigilance of the herd and age-sex categories of blackbuck at PCRB (A. Monthly, B. Hourly).

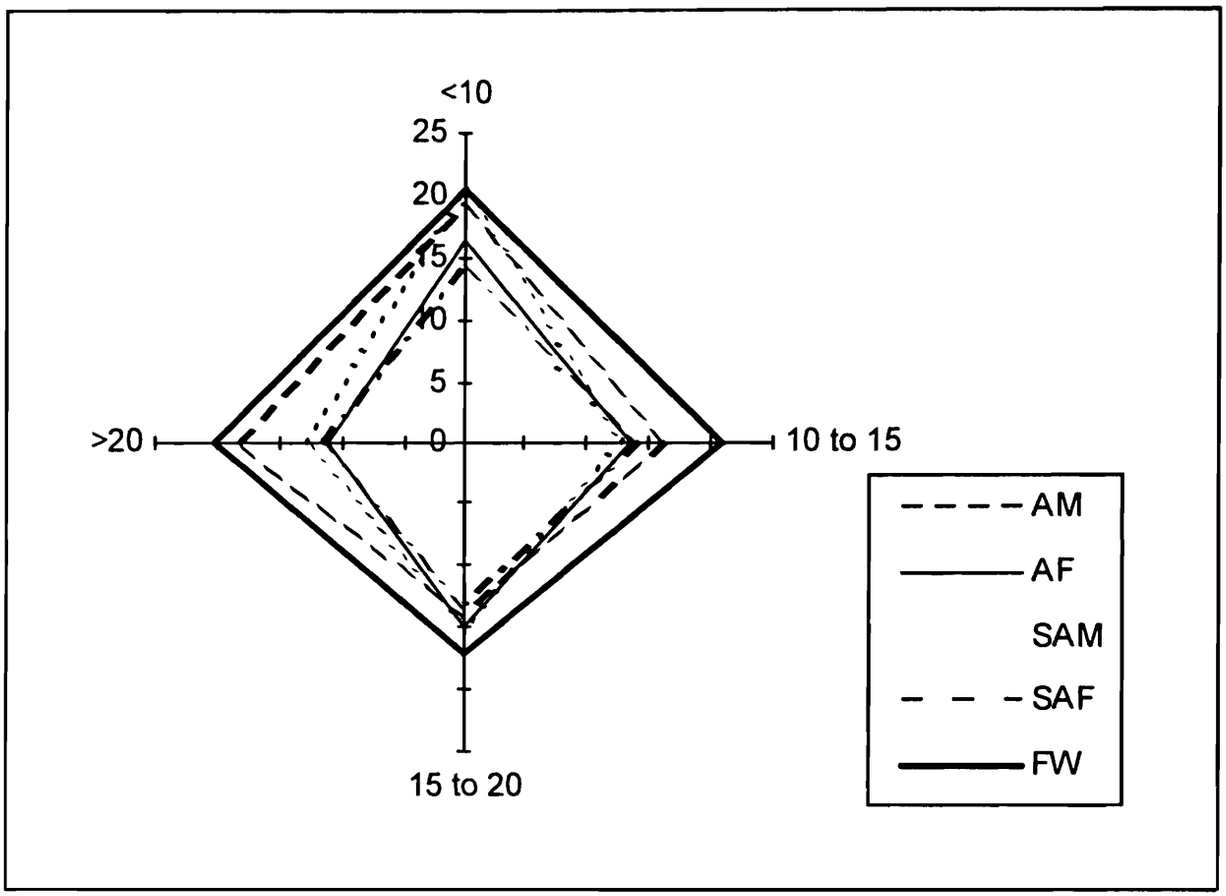


Figure 49 : % frequency of vigilance of age-sex categories in difference herd size of blackbuck in PCRB. (ANOVA between herd size df = 3, f = 2.96, p-value = 0.076; age-sex df = 4, f = 6.95, p-value = 0.003).

VIII. Social Behaviour

Social behaviour includes comfortable behaviour, marking, grooming, aggression, defensive, care and sexual which socially interlink the individuals of the group for maintenance and reproduction.

A total of 2035 sample of social behaviour recorded during the observation period (see plates). After analysis of these data, the proportion of comfortable behaviour was 31.84%, grooming 26.63%, aggression 19.86% of the total observed social activities (Figure 50). Sexual behaviuor contribute 10.31%, marking 6.83% and very small proportion in care & maintenance (0.58%). The number of bout on social activities in various season shown in figure 51. The seasonal frequency, range and deviation of the social activities recorded in blackbuck at PCRB is shown in figures 52. Maximum proportion of social behaviour recorded in the rut period (February to April), than in monsoon. Among the social behaviuor, the frequency of comfortable behaviour was highest and maximum variability between hours, next to that grooming and aggression. Very few records of care and maintenance (parental care) activities were found during the observation periods. The seasonal frequencies of various social activities of male and female are shown in figure 53.

The diurnal frequencies of social behaviour observed in blackbuck in the different sessions (I = 6 am to 9 am, II = 9 am to 12 am, III = 12 pm to 3 pm and IV = 3 pm to 6 pm) of daylight hours are shown in figure 57 and 58. The maximum frequency of social behaviour was recorded in late afternoon hours of the day and minimum recorded in the morning hours. A significant diurnal variation ($P < 0.001$) was found in the frequencies of social behaviour recorded in PCRB. In the noon hour's maximum fluctuation were recorded on the frequencies of social behaviour.

Data related to social behaviour calculated in both sexes to assess the distribution of social activity in the diurnal hours, which are shown in figures 54 and 56. Grooming did not vary significantly in both sexes, but the maximum proportion of grooming was recorded in the morning hours in males and late afternoon hours in case of females.

Urination-defecation is not a social behaviour but is associated with territorial marking in male. In female, it interacted with the adult male for flehmen. So, in analysis it was included under social behaviour. The maximum proportion of urination-defecation exhibited by males recorded in afternoon hours and in females it was highest in 9-12 hr.

Out of the total observed aggressive behaviour, most of them were initiated by adult males and very few of them were initiated by females. The proportion of

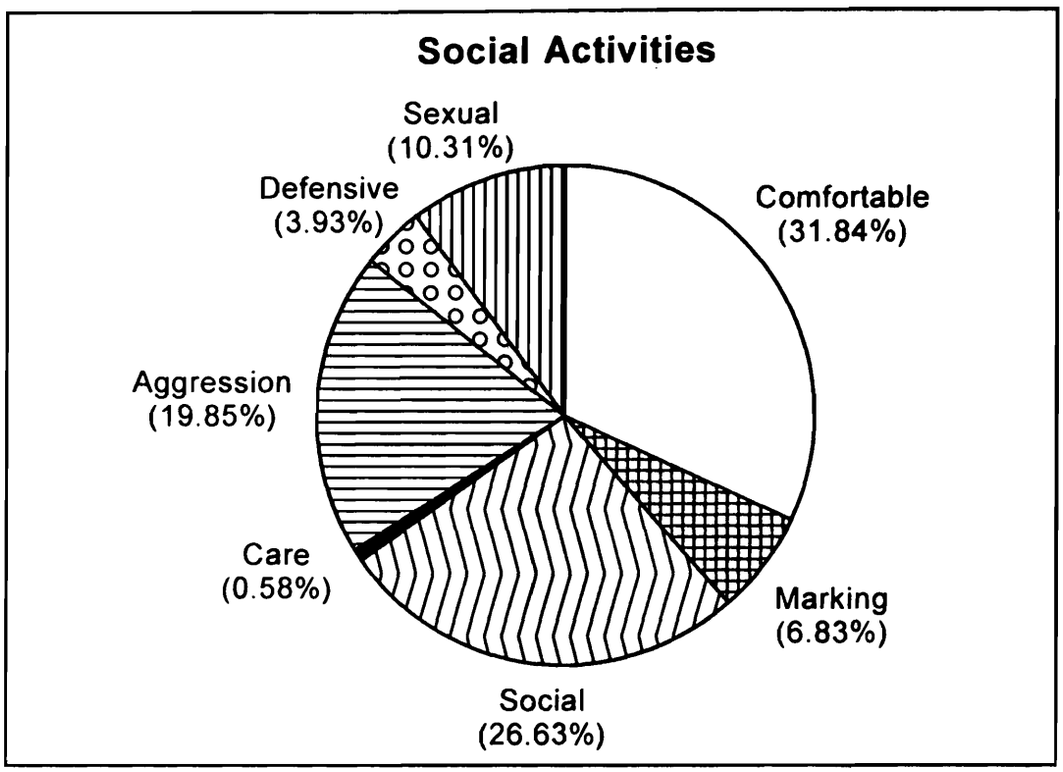


Figure 50 : Percentage of each social activities of blackbuck at PCRB.

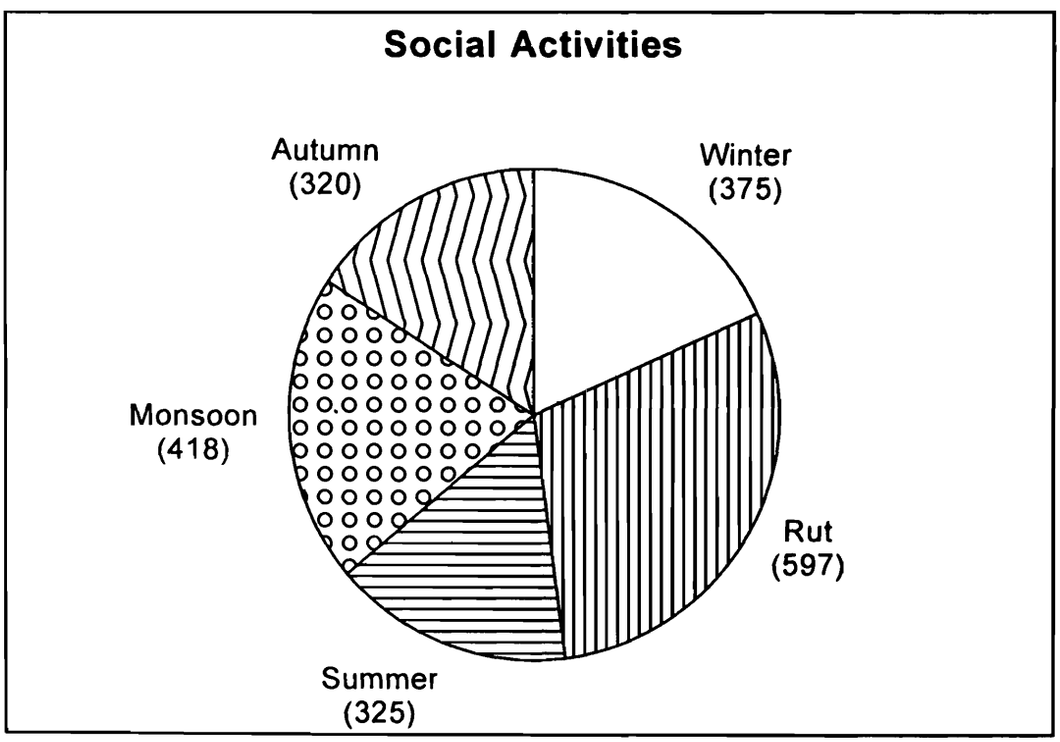


Figure 51 : Seasonal frequencies of social activities of blackbuck at PCRB. Paranthesis represent the total number of social activity sample.

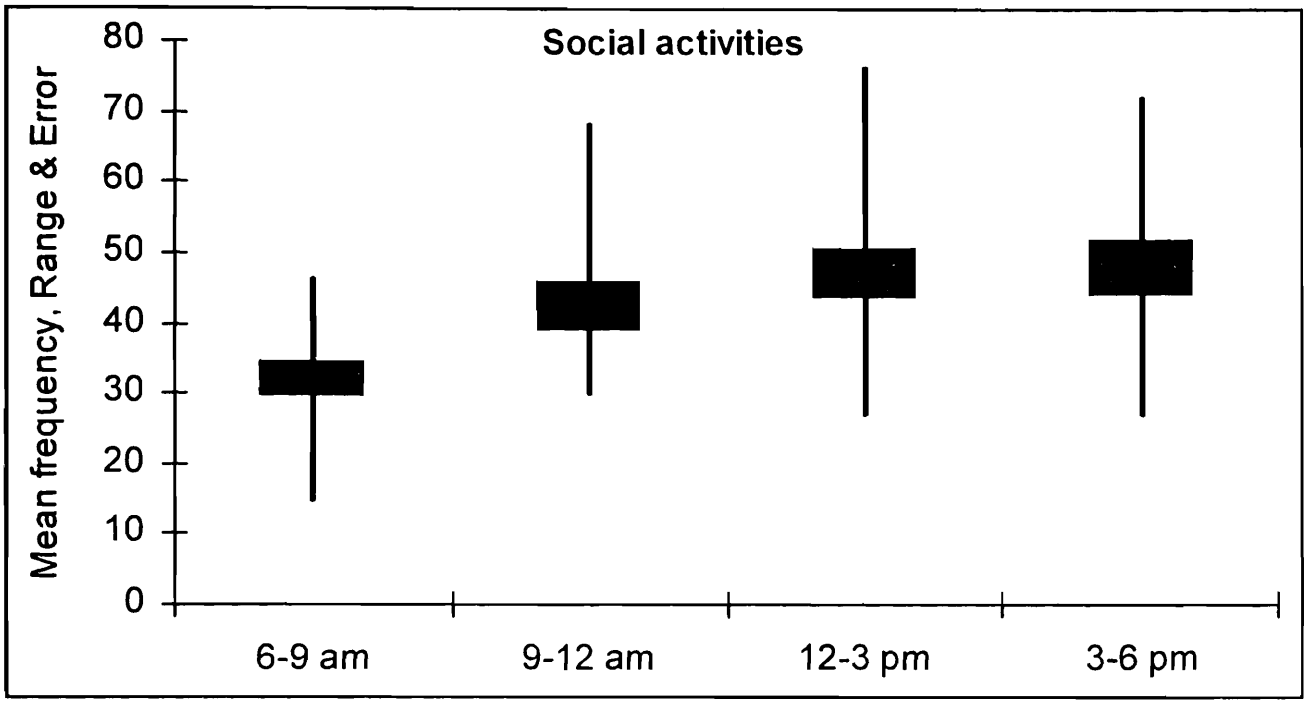


Figure 52 : Diurnal mean frequency, range and standard error of social activities of herd of blackbuck at PCRB (n = 2035). (ANOVA between hours; df = 11, f = 12.34, p-value < 0.001).

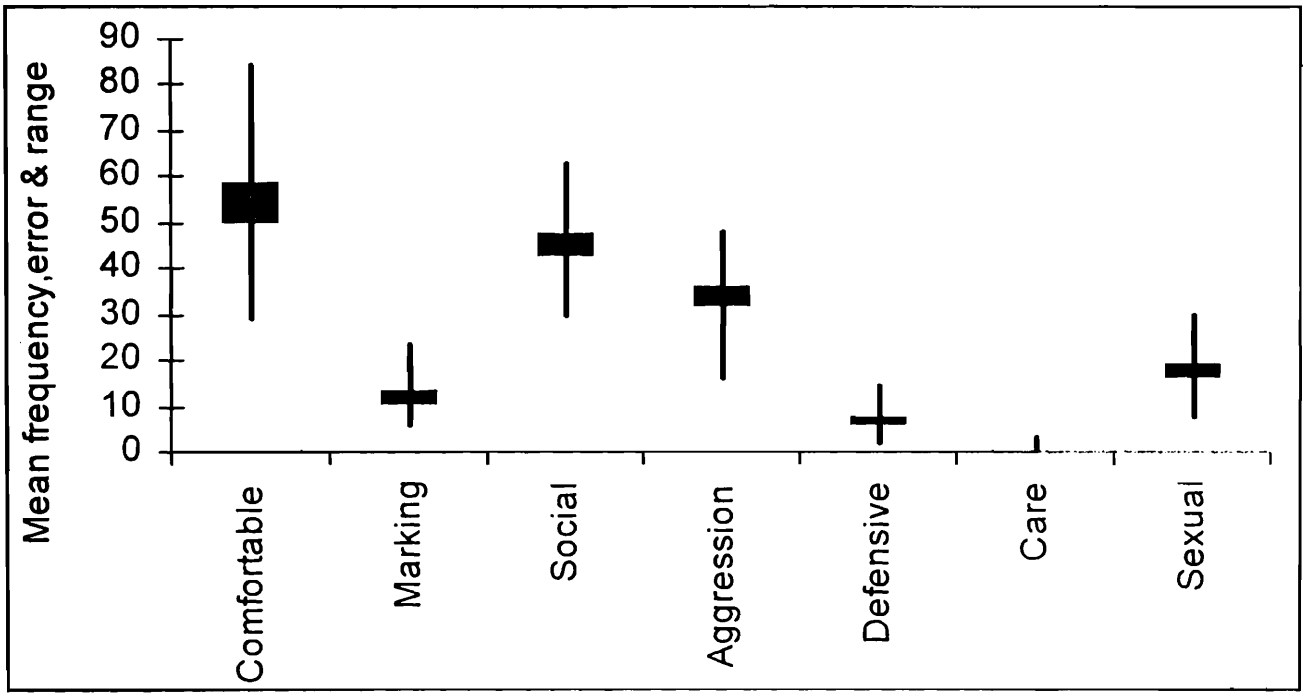
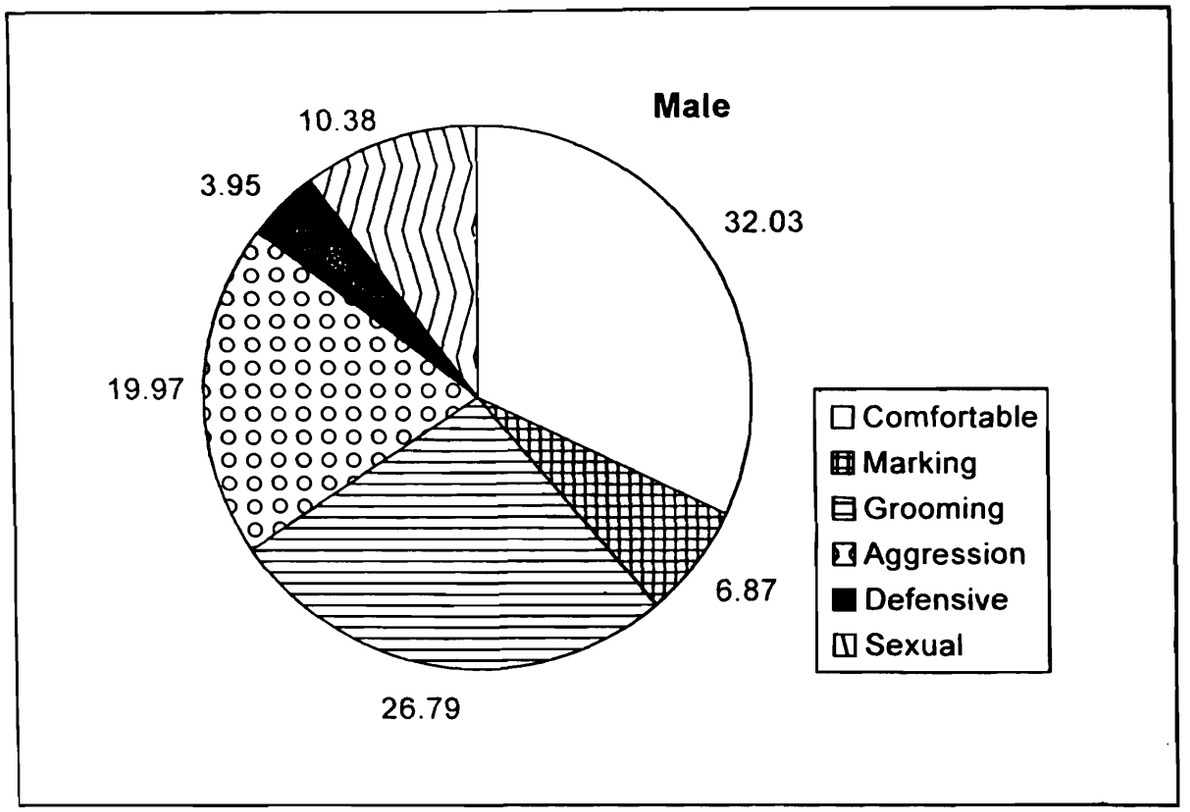


Figure 53 : Seasonal mean frequency, standard error and range of social activities of blackbuck in PCRB (n = 2035). (ANOVA; df = 4, f = 6.05, p-value = 0.001).



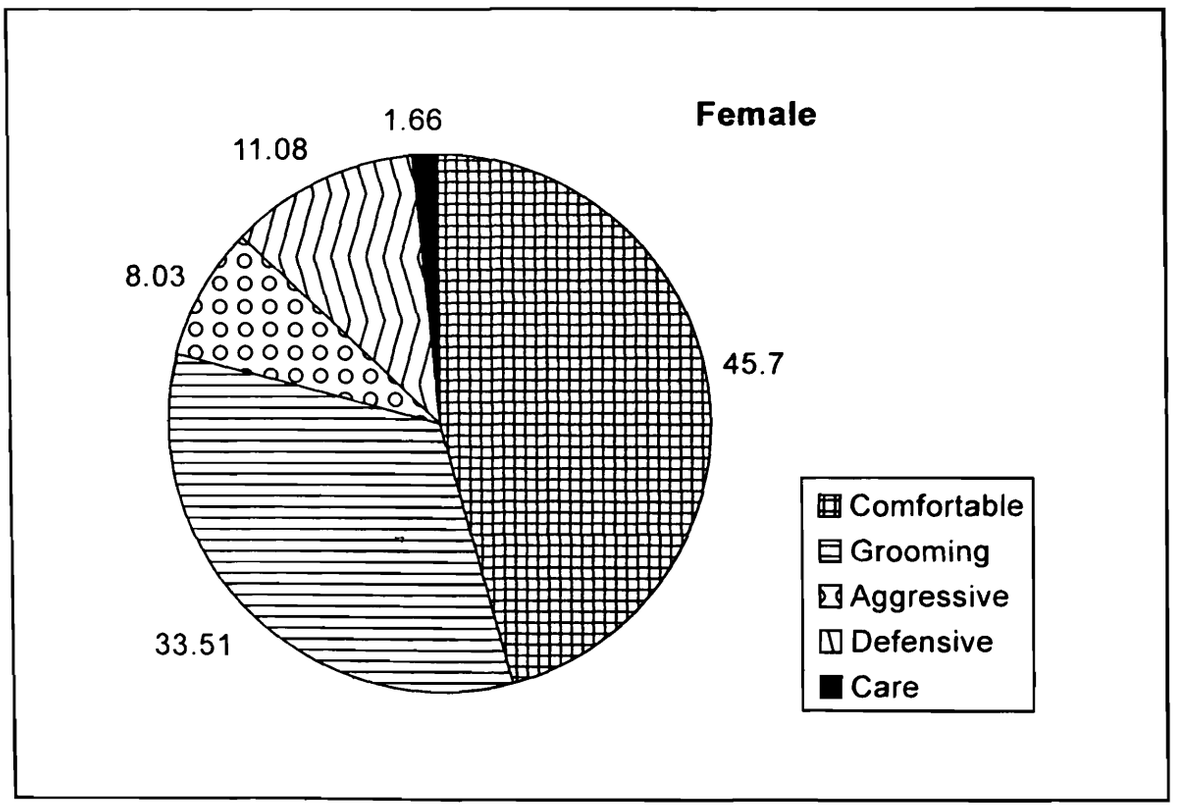


Figure 54 : Frequencies of various social activities of blackbuck at PCRB.

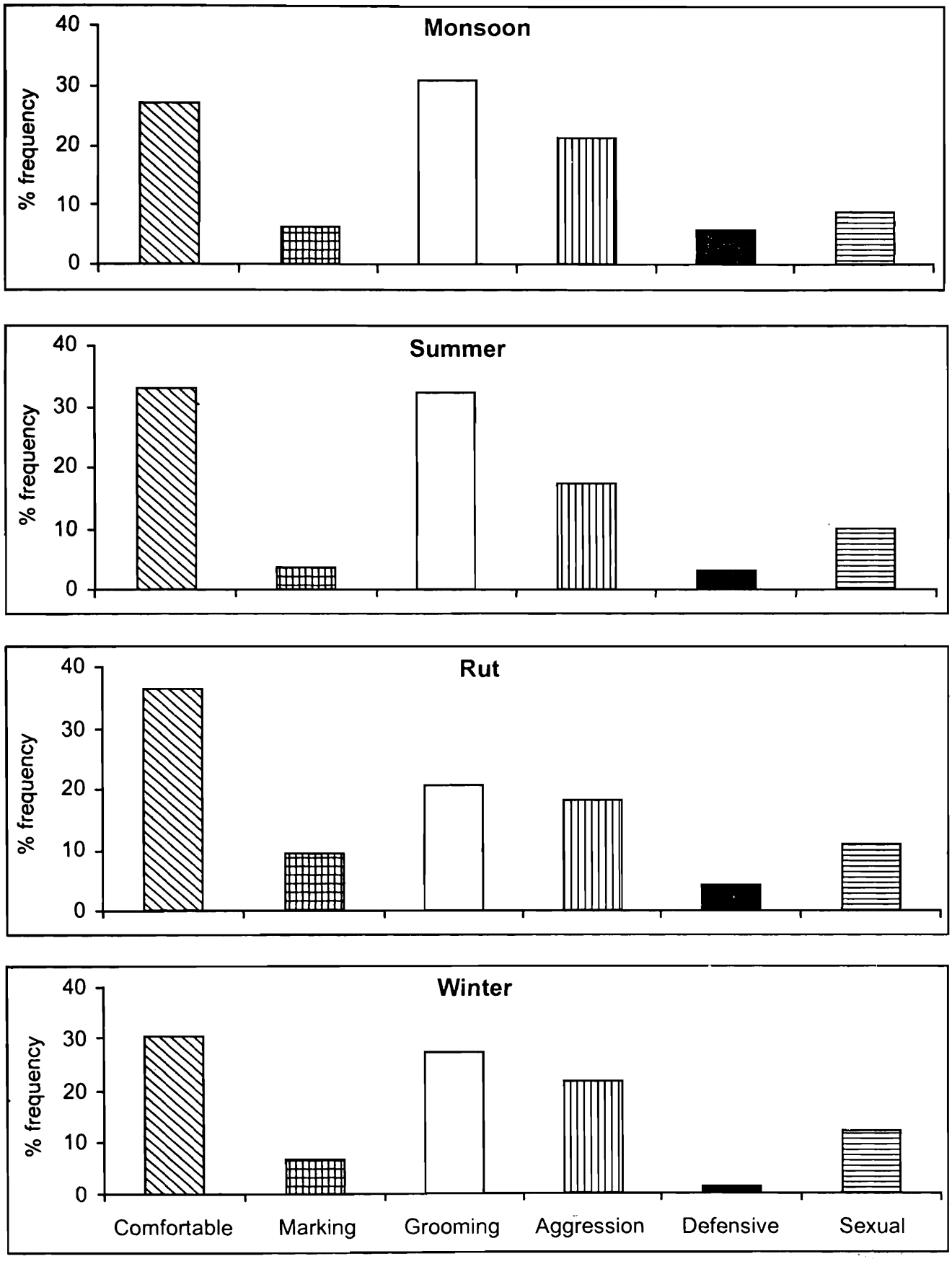


Figure 55 : Seasonal frequencies (%) of various social activities of blackbuck (male) at PCRB.

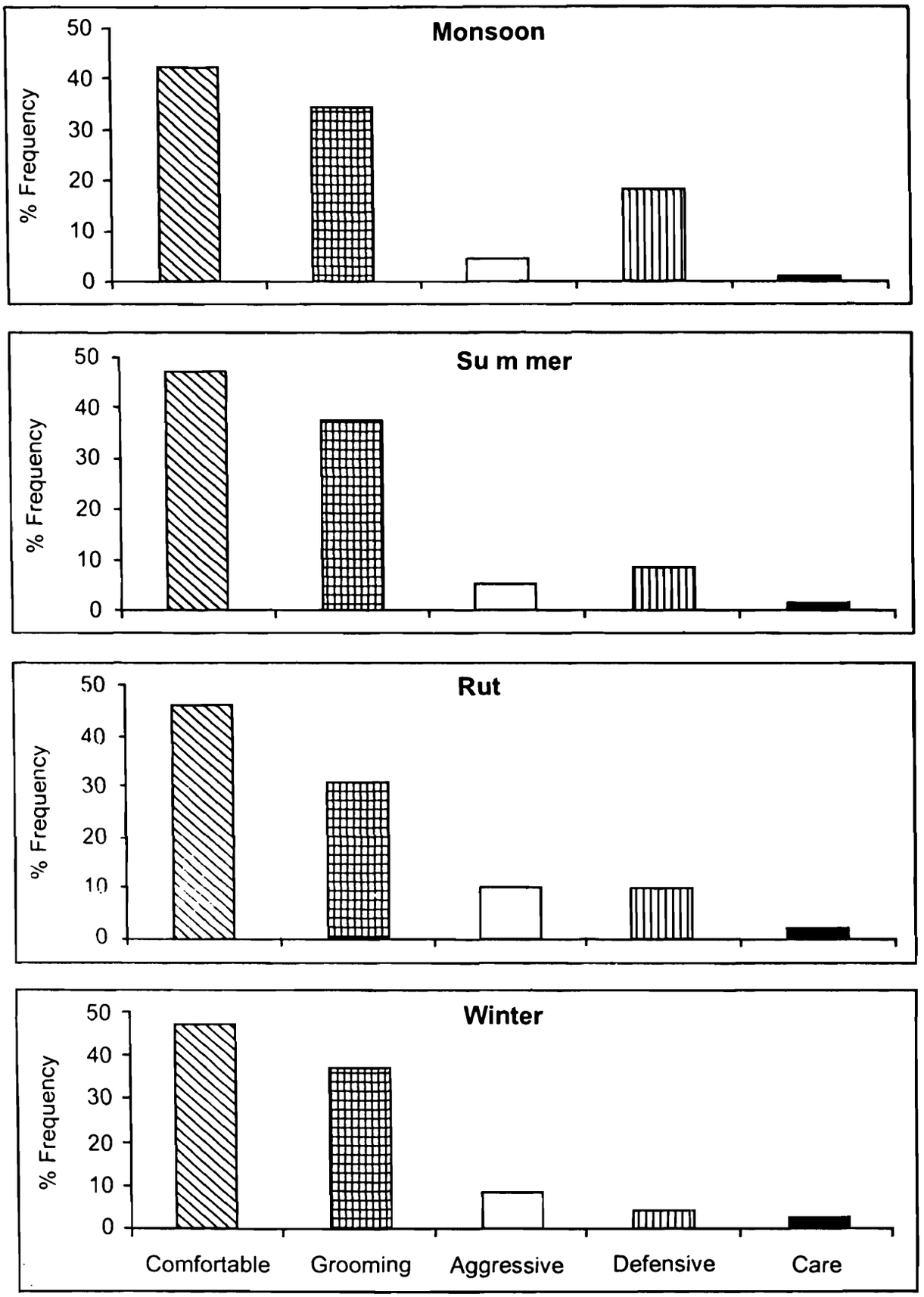


Figure 56 : Seasonal frequencies (%) of various social activities of blackbuck (female) at PCRB.

aggression was not varying significantly in males, but varied in females in between hours ($p < 0.05$). Similarly about 95% of observations on the marking behaviour was exhibited by male, while there were very few observations on the marking by female and the proportion of marking varied significantly between hours. The observations on the sexual behaviour showed that their recorded proportions, out of total behaviour were mostly in the afternoon hours. However the reported variations were not significant statistically.

Defensive behaviour possesses by females or lower rank individuals in a herd expressed by feeling away or head down. The observed samples on defensive behaviour were recorded maximum after the peak hours of feeding and showed significant variations. Parental care was exhibited by female and expressed as licking the fawn. It was recorded mostly in afternoon hours.

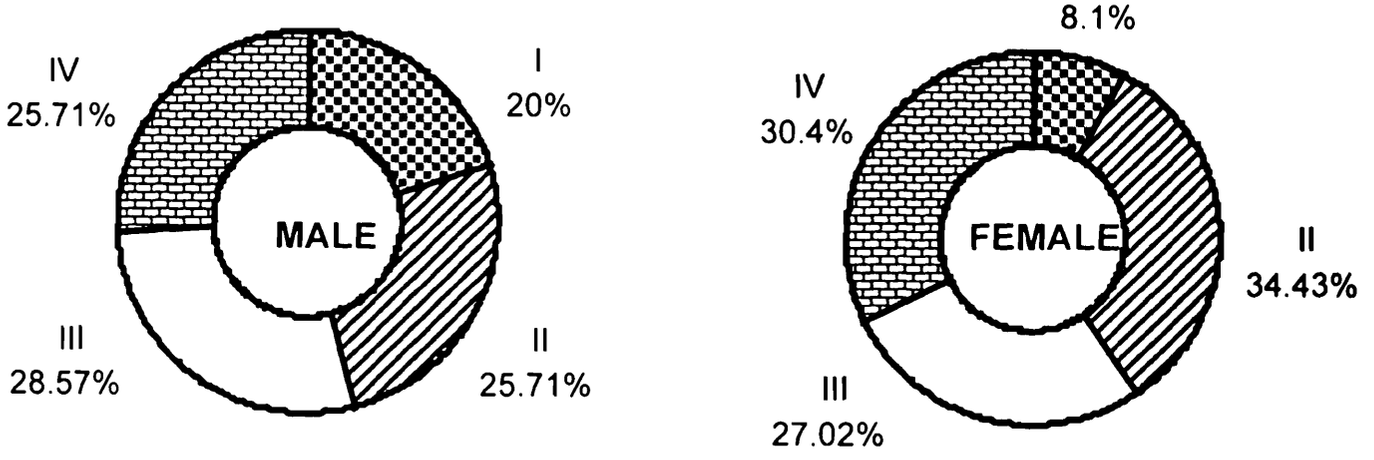
Discussion

Antilope cervicapra is a social species (Schaller, 1967). Its whole life is spent among as conspecific with which it share its space and time (Mungall, 1978). The activities of the members of a herd are highly synchronized, a characteristic of many other gregarious species (Dubost *et al.*, 1981). The social behaviour enforces the maintenance of individual distance, especially among females, function in the establishment and maintenance of territories in case of male and co-ordination of group activities (Walther, 1974).

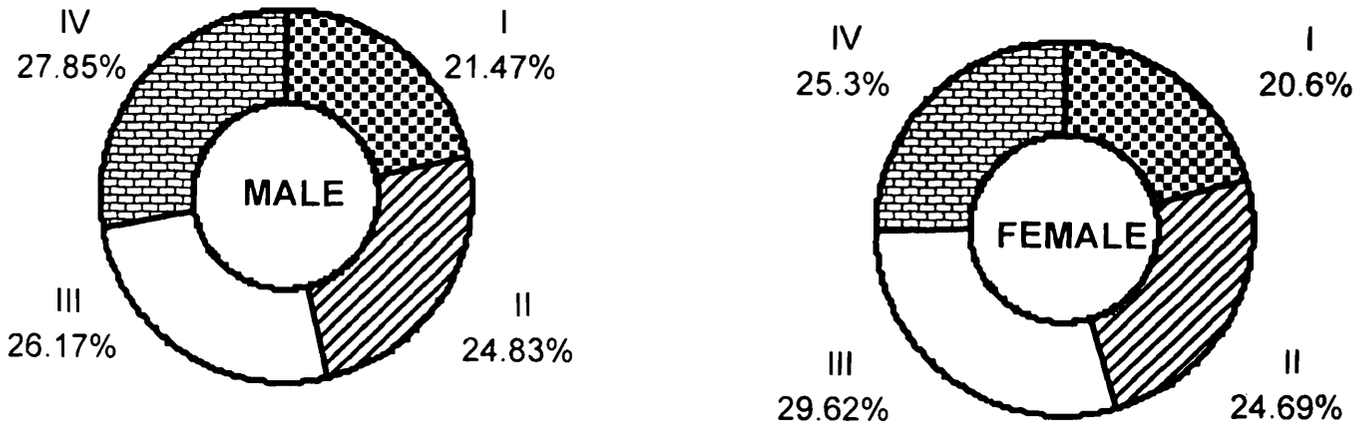
Activities of the group members change in the predominant group activity can be associated with change in the form and frequency of social behaviour. During the winter and rut season most of the ungulates are socially active in all daylight hours (Wilson, 1975). Similar observation was recorded in blackbuck as active intermittently throughout the daylight hours in rutting season and monsoon season. Hypothetically rutting season is important for maintenance of social life and monsoon is most disturbing seasons at PCRB due to more anthropogenic activities.

Analysis showed that aggressive and submissive behaviour contributed the most predominant social activities in mixed herd of blackbuck and play behaviour recorded maximum in bachelor herd with some variation in between group structure possibly due to living in different type of social group.

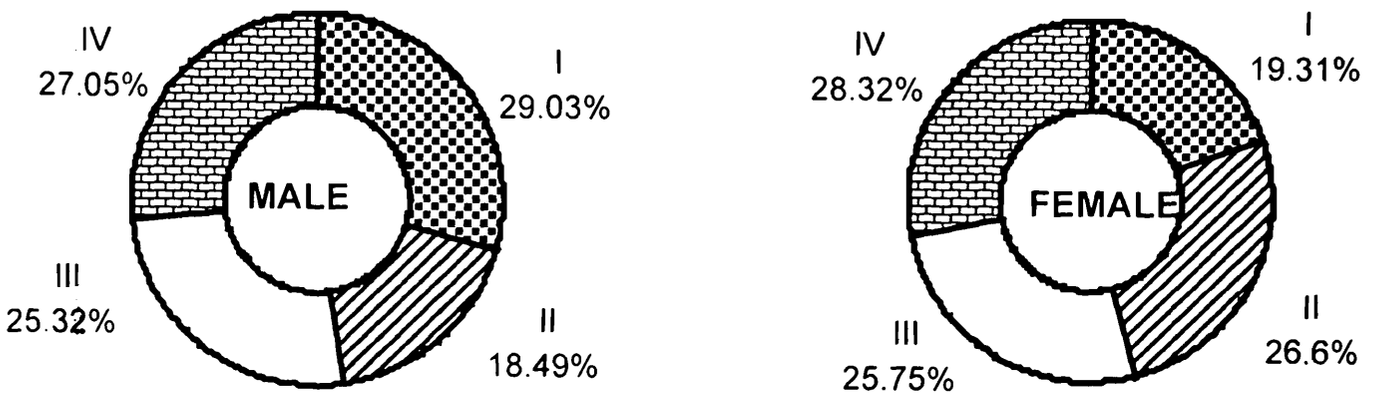
Results of the observations on the variation in social behaviour in between the different social status viz., alpha male (male dominated in the mixed herd), territorial male and bachelor male showed that alpha males were socially more active in comparison to others males although some variations were found in between the frequencies of social behaviour. Analysis also reveals that sexual



Urination and defecation



Auto-grooming



Allo-grooming

Figure 57 : Diurnal distribution of urination-defecation & grooming (Auto and Allo) frequency of blackbuck at PCRB. (Clockwise from the top; I = 6 am-9 am; II = 9 am-12 pm; III = 12 am-3 pm; IV = 3 pm-6 pm).

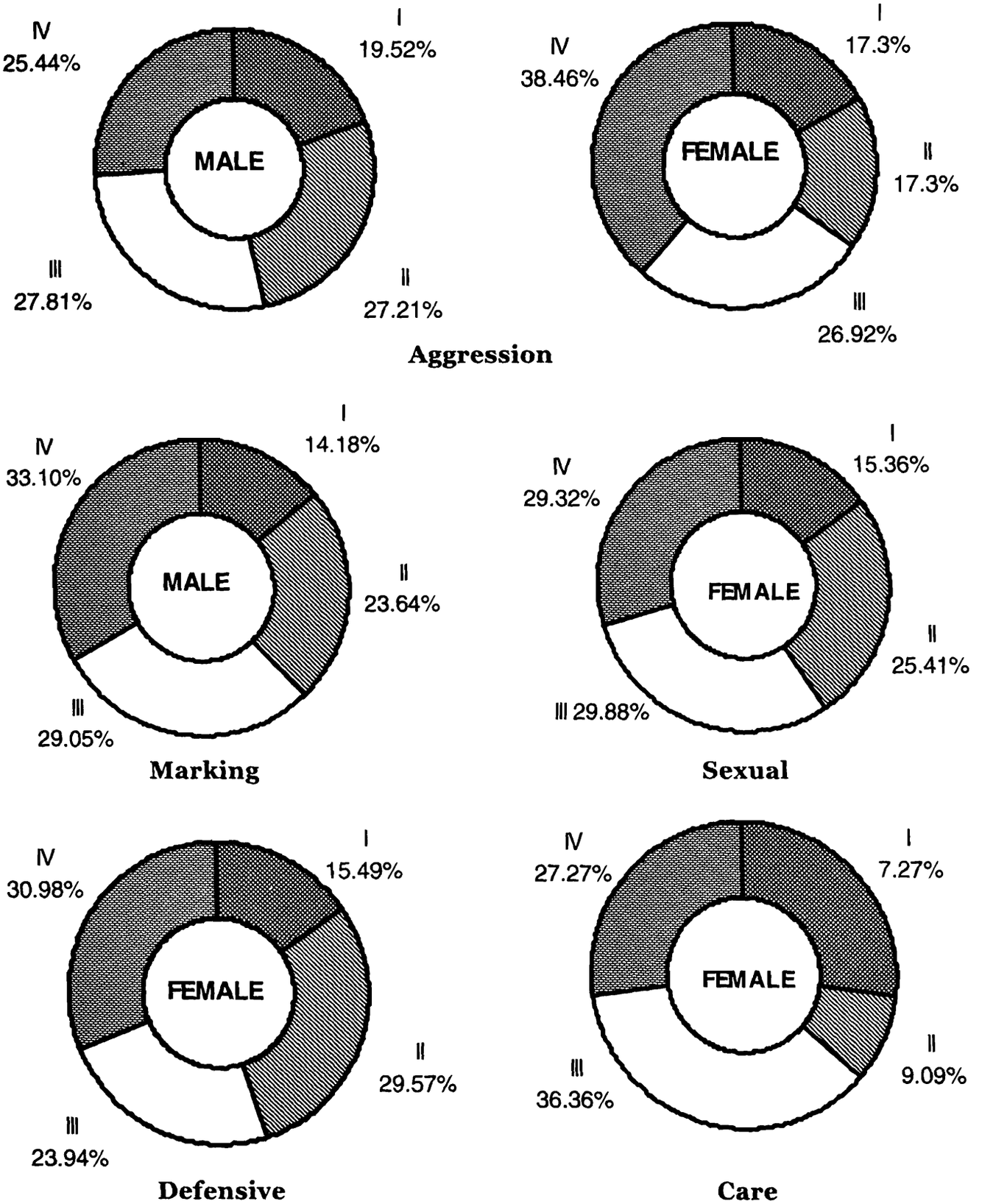


Figure 58 : Represents the diurnal distribution of social and sexual activity frequency of blackbuck at PCRB. (Clockwise from the top; I = 6 am-9 am; II = 9 am-12 pm; III = 12 am- 3 pm; IV = 3 pm-6 pm).

A bachelor male engaged in rubbing mode.

A bachelor male in tail flaging mode.

A fawn following her mother during herd movement.

A pair of blackbuck in the habitat at Badakholi village.

Butting in between the females.

Chasing of male by a rival male in bachelor herd.

Dominance display shown by a female to her lower rank female.

Dominance display shown by a territorial **male.**

Fighting between a territorial male and bachelor male of 2-year old.

Head up display shown by a female in the herd.

Head up display shown by a territorial male.

Horn threat given by a male to another male.

Intimation display between two males.

Milking by a mother to her fawn.

Submissive behaviour.

variation exist in diurnal hours on the frequencies of social behaviour. Males are more active in auto-grooming, marking, aggression and sexual behaviour while females are more active in allo-grooming, submissive, care and maintenance. It is hypothized that males of blackbuck are aggressive and females are submissive in nature with some degree of variation in herd type and herd size.

IX. Social interaction

Usually there was no observable encounter between sub-groups but very few interactions were observed between different groups of blackbuck during joining and breaking of herd. Each group maintained a distinct and recognizable unit of their social systems. Immature interacted with their mothers during rest period but with sub-adult and others group members during feeding and walking periods.

A total of 1475 encounters or interactions were observed throughout the study period, basically between the individuals of a group of bachelor males, mixed herd, female herd and territory holders (Table 27). Out of total interactions observed, 50.13% interactions were in mixed herd, 39.18% in bachelor herd, while 10.79% of interactions were between territorial holders which were mostly under aggressive category. Among the total recorded interactions, 62.3% of interactions were between males, 13.35% between females and rest 24.75% were inter-sexual interactions. These observations clearly indicates that male-male competitiveness exist among the blackbuck.

The total recorded interactions summed up in interaction types (Table 27 and figure 59) showed 44.16% aggressive interactions, 15.79% interactions due to play, 36.61% submissive interactions and very few sexual interactions (3.25%). In mixed herd 44.18% aggressive, 41% submissive and 5.08% sexual interaction observed (Figure 60), while in bachelor herd 45.16% aggressive, 30.35% submissive, 23.11% play and very few in sexual (0.92%), all pseudo-sexual interactions (Figure 61). After categorization of these interactions in both type of social groups it was found that variations were significant in all categories except aggressive. Result indicates aggression exists in both type of herds but playing is an important activity in maintaining the bachelor herd and submissive activity help in maintaining the mixed herd.

Observations on the frequencies of each interaction indicates that aggressive charge, threat (horn and ear), following, grooming and sexual encounter were maximum in mixed herd while sparring (play and aggressive) and butting were mostly recorded in bachelor herd. No significant difference observed in the frequency of chasing, muzzling and parallel walk between mixed and bachelor herd.

The comparative account of all basic types of interaction includes aggressive, play, submissive and sexual in between the mixed herd and bachelor herd are shown in figure 62. The comparative account of frequencies of all interaction categories are also shown in figure 63 indicating that except the interaction by means of play all interaction categories were more in mixed herd.

The mean and SE of the percentage frequency of various interaction categories are given in Table 28 and mean, standard error and range are shown in Figure 64 (mixed herd) and Figure 65 (bachelor herd). The mean of the percentage frequencies of interaction type like chasing (9.56 ± 2.48), horn threat (7.5 ± 0.66), charge (12.34 ± 1), following (16.34 ± 1.83), butting (7.26 ± 1.48), grooming (17.07 ± 1.07 and flehmen (2.9 ± 0.57). In case of bachelor herd sparring aggressively (10.93 ± 1.44), sparring play (12.78 ± 1.62), chasing (9.39 ± 1.7), butting (10.32 ± 2.5) and grooming (13.09 ± 1.37) was observed.

Also found significant differences in the frequencies of various social interaction in between the sexes ($p < 0.01$), age categories ($p < 0.001$) and in seasons ($p < 0.05$). The frequencies social categories in a particular herd varied seasonally.

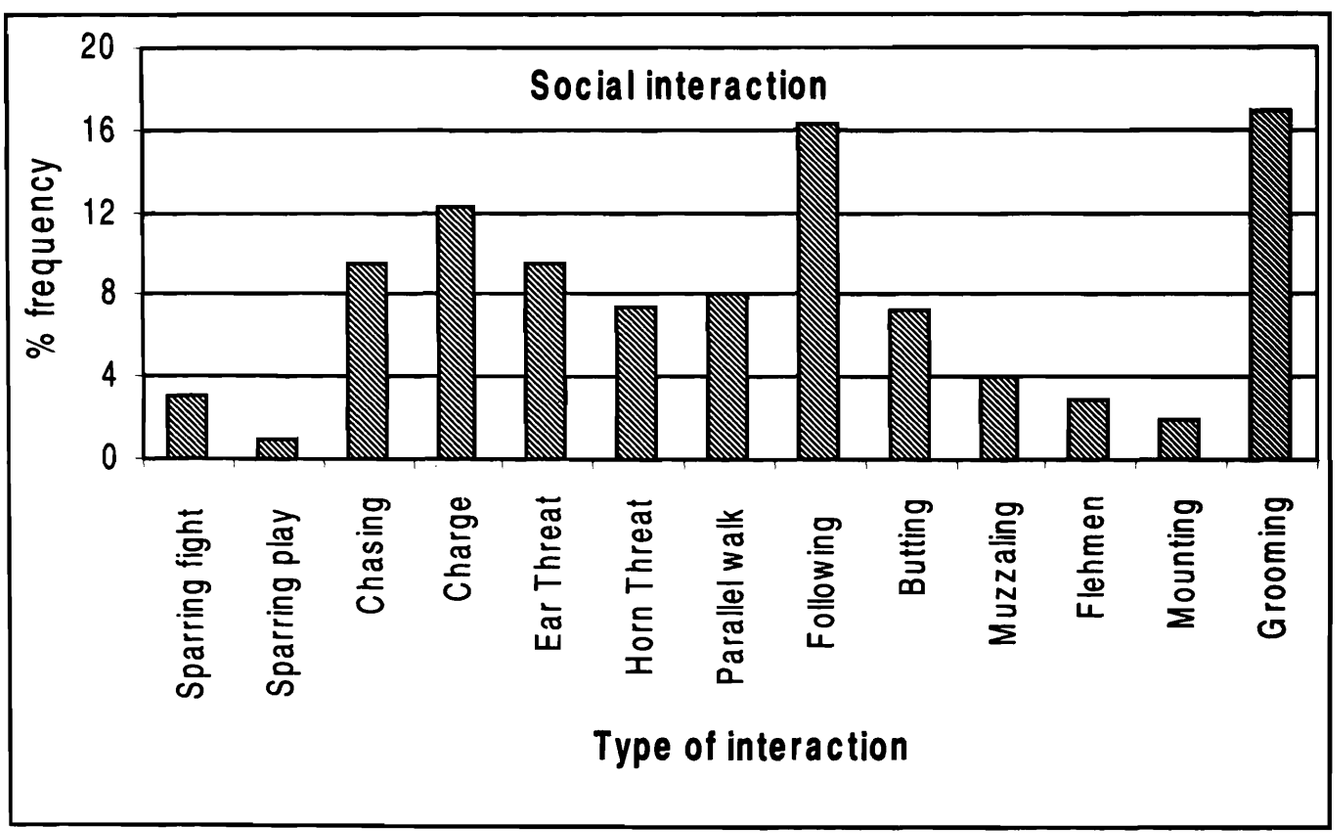


Figure 59 : Percentage frequencies of all categories of social interactions recorded in blackbuck at PCRB.

Table 27 : Frequencies of interaction of blackbuck at PCRB.

	Bachelor	Mixed	Blackbuck	% Total	% Aggressive
Aggressive					
Sparring	71	25	96	4.75	11.33
Chasing	61	79	140	8.74	20.84
Charge	64	102	166	11.73	27.97
Ear Threat	24	79	103	7.28	17.36
Horn Threat	43	62	105	6.21	14.8
Butting	30	18	48	3.22	7.67
Total	**293**	**365**	**658**		
% Total	**45.14**	**44.18**	**44.61**		
Play					% Play
Sparring play	83	8	91	5.52	35.64
Butting	37	42	79	5.52	35.64
Muzzaling	30	33	63	4.44	28.71
Total	**150**	**83**	**233**		
% Total	**23.11**	**10.04**	**15.79**		
Submissive					% Submissive
Parallel walk	50	67	111	8.51	22.02
Following	62	135	185	14.18	36.7
Grooming	85	141	226	15.95	41.26
Total	**197**	**343**	**540**		
% Total	**30.35**	**41.52**	**36.61**		
Sexual					% Sexual
Flehmen (F)	2	0	2	0.15	4.16
Mounting (F)	4	0	4	0.3	8.33
Flehmen	0	24	24	1.84	50
Mounting	0	16	16	1.22	33.32
Copulation	0	2	2	0.15	4.16
Total	**6**	**42**	**48**		
% Total	**0.92**	**5.08**	**3.25**		
Grand Total	**649**	**826**	**1475**		

(F) = False

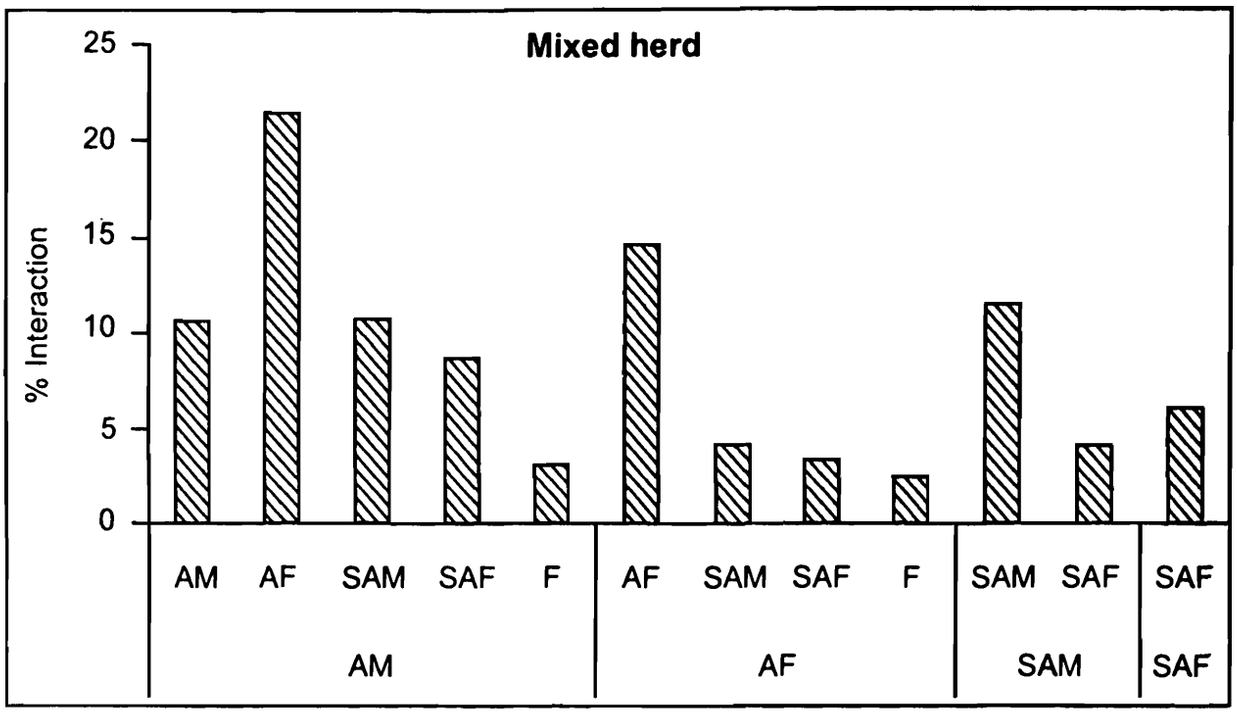


Figure 60 : Percentage social interaction observed between the different age sex categories of individuals of mixed herd of blackbuck.

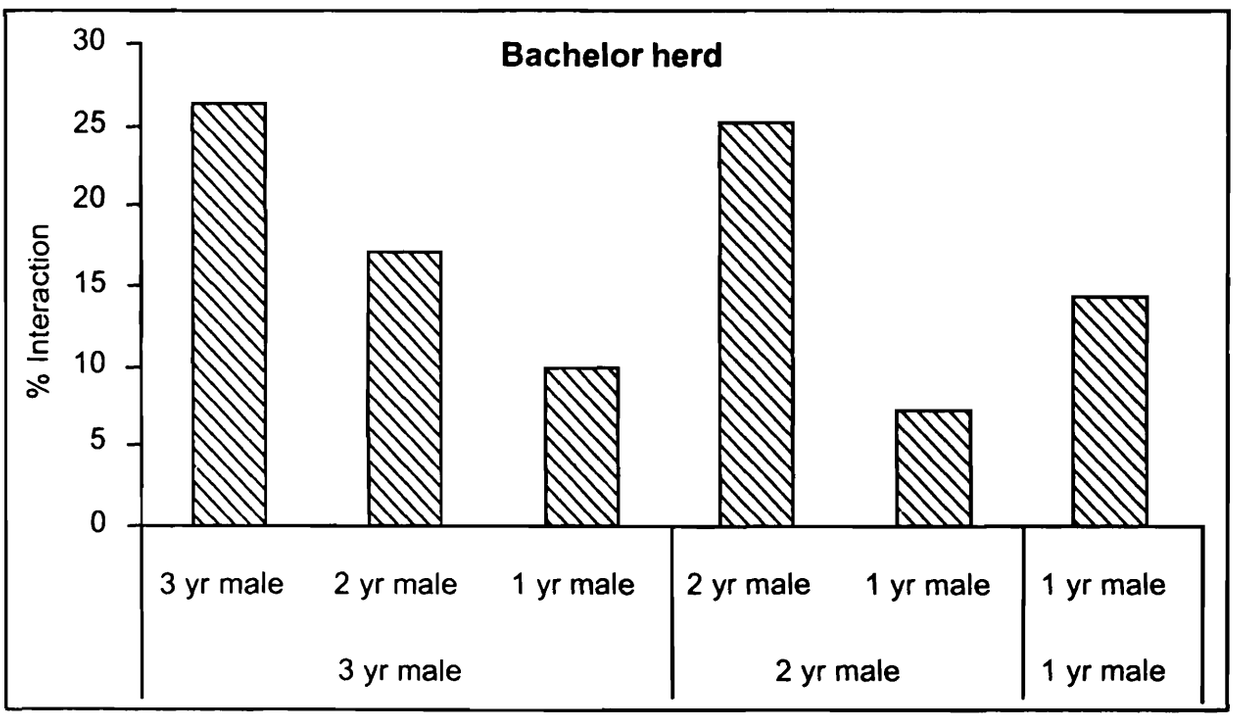


Figure 61 : Percentage social interaction observed between the different age sex categories of individuals of mixed herd of blackbuck.

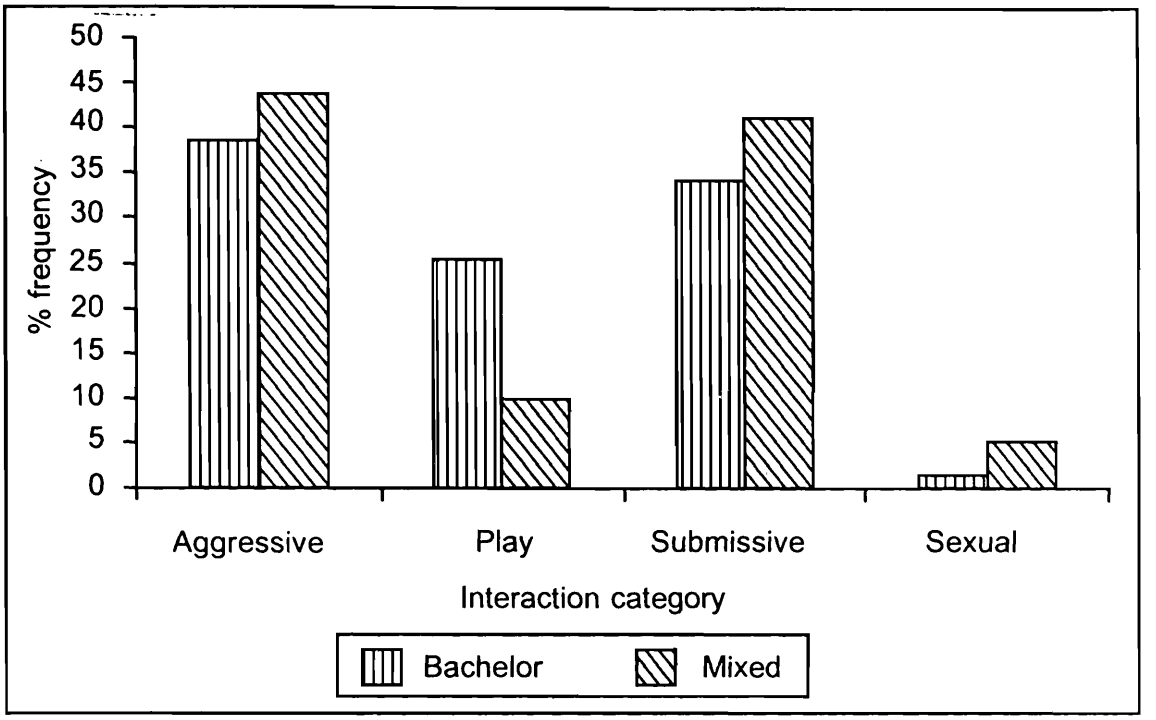


Figure 62 : Percentage frequency of different categories of social interaction in mixed herd & bachelor herd of blackbuck.

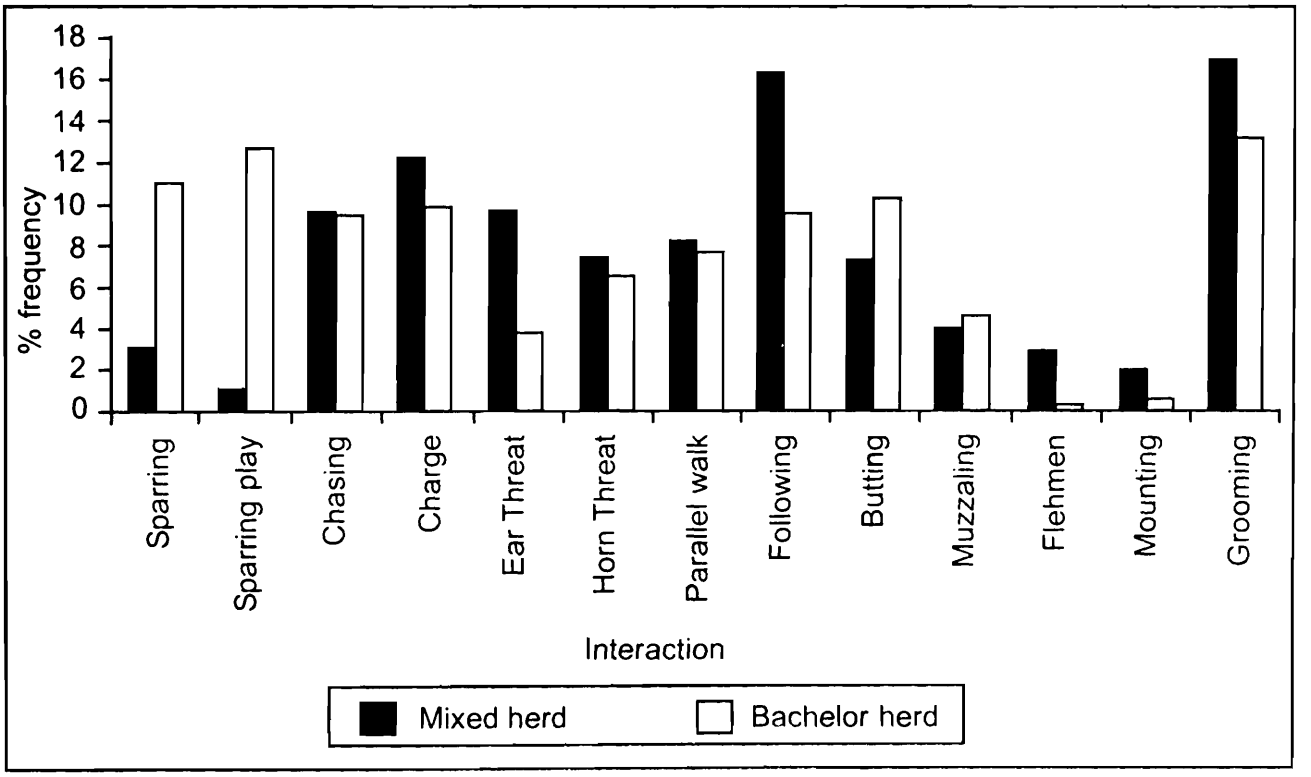


Figure 63 : Percentage frequency of social activities in mixed herd & bachelor herd of blackbuck.

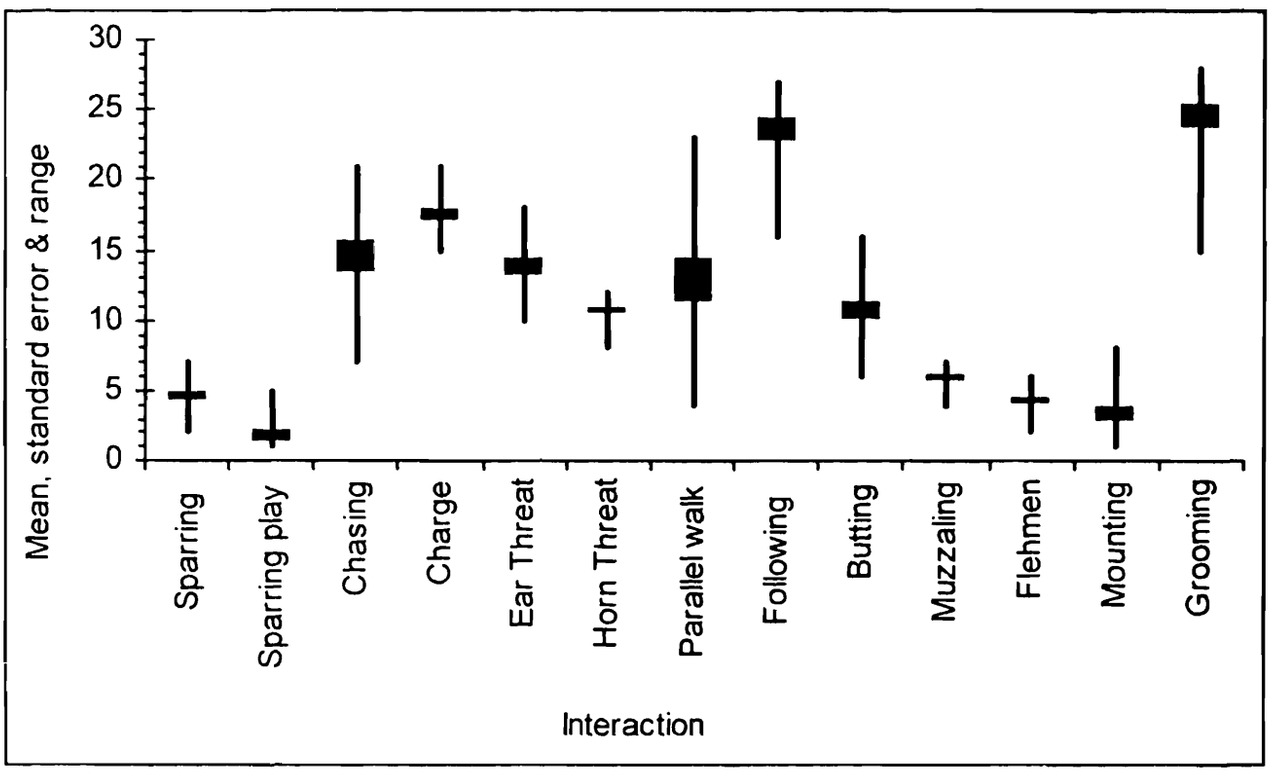


Figure 64 : Mean, standard error and range of social interaction observed in mixed herd of blackbuck.

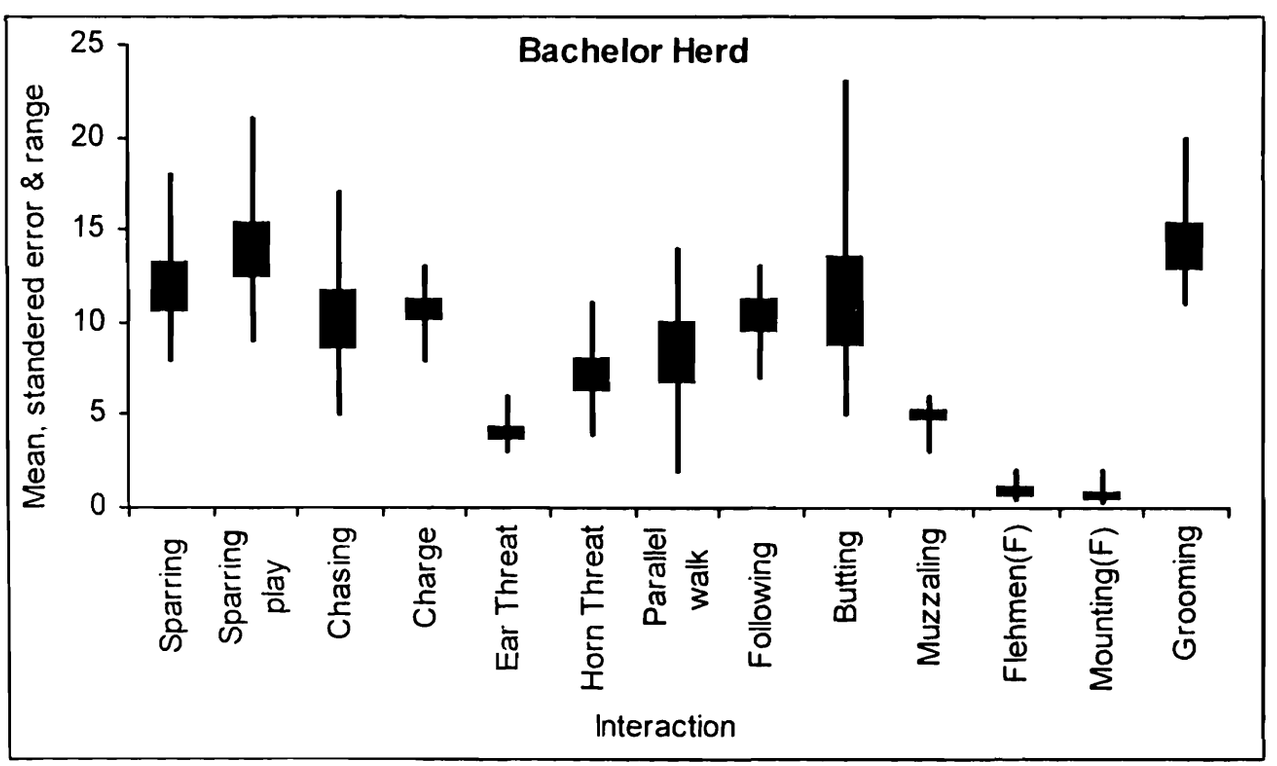


Figure 65 : Mean, standard error and range of social interaction observed in bachelor herd of blackbuck.

Table 28 : Mean and SE of percentage frequencies of various interaction categories of 2 types of herd of blackbuck at PCRB.

Interaction Category	Mixed herd (Mean ± SE)	Bachelor herd (Mean ± SE)
Sparring	3.02 ± 0.79	10.93 ± 1.44
Sparring play	0.96 ± 0.88	12.78 ± 1.62
Chasing	9.56 ± 2.48	9.39 ± 1.72
Charge	12.34 ± 1	9.86 ± 0.71
Ear threat	9.56 ± 1.53	3.69 ± 0.51
Horn threat	7.5 ± 0.66	6.62 ± 1.01
Parallel walk	8.11 ± 3.26	7.7 ± 1.72
Following	16.34 ± 1.83	9.55 ± 0.98
Butting	7.26 ± 1.48	10.32 ± 2.5
Muzzaling	3.99 ± 0.67	4.62 ± 0.44
Flehmen	2.9 ± 0.57	0.3 ± 0.4
Mounting	1.93 ± 1.2	0.61 ± 0.33
Grooming	17.07 ± 1.89	13.09 ± 1.37

Discussions

Social animals express various types of interactions with the conspecific groups for purposes like competing for limited resource, such as mates or food, maintenance of herd and signal transmission for predator avoidance and external disturbances (Wilson, 1975). Among ungulate species interaction confers advantages such as priority of access to food, water, mates and territories (Leuthold, 1970). The benefits of the social interaction are the coordination among the group member and the frequencies of social interaction can change with change in the predominant maintenance activity of a group.

Usually there was no observable encounter between sub-groups but very few interactions were observed between different groups of blackbucks during joining and breaking of herd. Each group maintained a distinct and recognizable unit of their social systems. In the present study, the frequencies of various kinds of social interaction varied among the sexes and herd type. These observations clearly indicates that male-male competitiveness exist among the blackbuck. Results from the above observations also indicate that aggression exists in both type of herds but playing is an important activity in maintaining the bachelor herd. Submissive activity helps in maintaining the mixed herd.

The findings in PCRB on social interaction shows that the lower rank blackbuck is able to acquire better quality diets because they spend less time in contesting with dominance and more time in foraging than their higher rank conspecifics. Thus subordinate individuals tend to avoid interactions with high rank individuals, while dominant individuals show elevated rate of interactions with conspecifics. Alternatively, low rank individuals may be those who spend less time being vigilant, thus able to acquire grater resources than their more vigilant conspecifics.

The differences in frequency of social interactions in different seasons were dependant on food availability, food quality, rut period and establishment of territories by males. The present study area is a semi-natural habitat and most of the parts are cultivated land. So factors like public interference by involvement in agricultural activities influence up on the social behaviours and on the seasonal variation in social interaction. As a result in the monsoon season most of the blackbuck population drives away towards the small pockets of grassland and due to this the frequency of social interaction increases because of food competition by population pressure. However, when the agricultural activities are over in the month of December i.e., pre-rut season, the frequency and degree of interaction increases significantly among males.

X. Aggressive Behaviour

The frequency of above mentioned all observed aggressive interactions varied with the sex of the participants (Figure 66). The overall frequency of agonistic interactions challenged by male was more then five times greater than that of the interactions challenged by female, a significantly higher frequency. The frequencies of male-male agonistic interaction were 52% of total interaction observed in the study period, and were frequent with some of them were most dangerous. Among the agonistic behaviour dominance display (16%), threats (18.31%) and chasing (20%) are very common in between males, while walk towards (18%) and body push (42%) are very common among females. Agonistic behaviour like walk towards

(15%), supplanting (12%), threats (20%) and chasing (13%) were common in between male and female. The frequency of agonistic interaction changed markedly throughout the year basically in between seasons (Figure 67) and also varied between the sexes. The monthly mean of agonistic interaction of male-male was 25.9% (S.D. = 15.08), male-female 15.83% (S.D = 7.58) and female-female was 8.08% (S.D. = 2.63). The frequency of aggressive encounters initiated by males and directed towards females was low throughout the year. The average agonistic behaviour initiated by male were varied (Figure 68) and were maximum in winter (40.3%) i.e., pre-rut period and progressed towards rut period and were least in the summer (24.6%).

Discussions

Most of the agonistic behaviour patterns under discussion considerably differed in frequencies and degree of aggressiveness between social classes, age classes and in season.

Agonistic behaviour is associated with conflict and fighting between two conspecifics, and includes patterns of threat, fighting and submission (Scott and Fredericson, 1951). Agonistic behaviour in the strict sense is referred to fight, threat and chase according to different social status of the individual of the species. These behaviour patterns are obviously important for social life of the

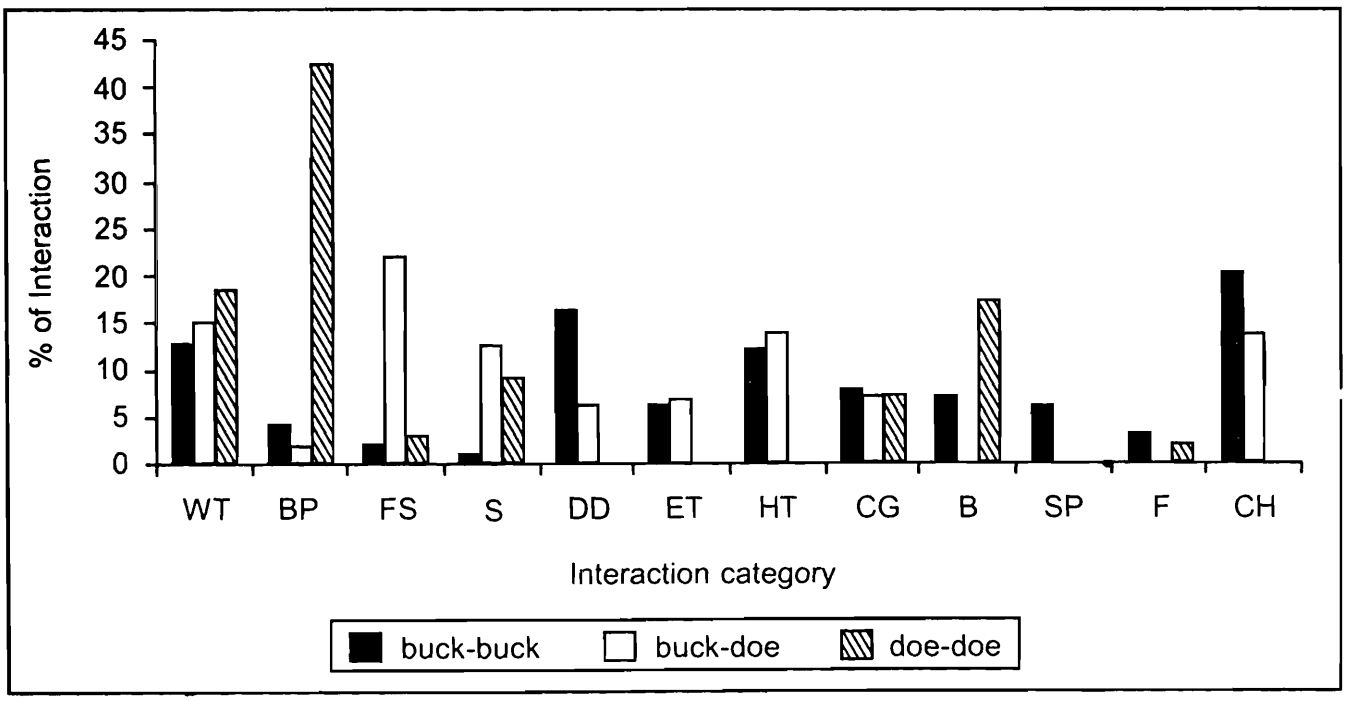


Figure 66 : Frequencies of agonistic interaction between individual of both sexes of blackbuck at PCRB, Ganjam district, Orissa, India.

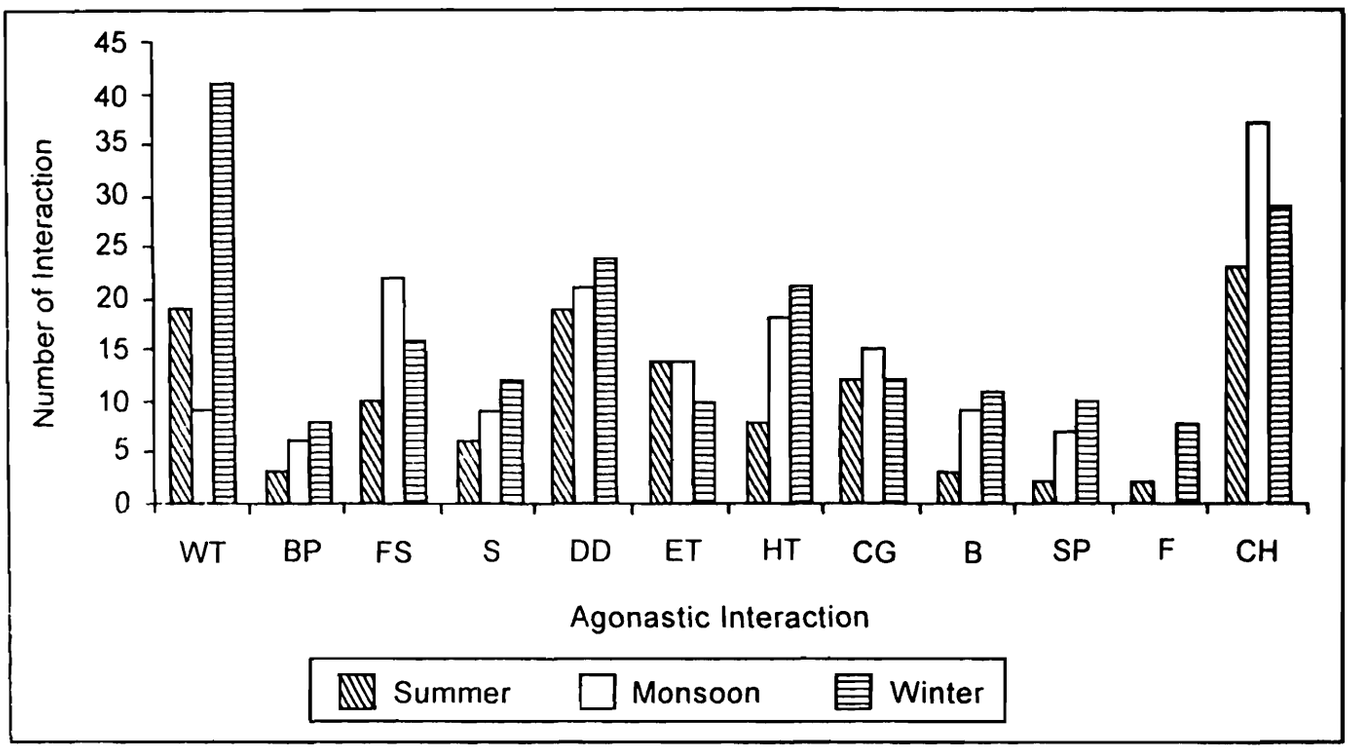


Figure 67 : Seasonal variation in agonistic interactions challenged by buck in PCRB, Ganjam District, Orissa, India.

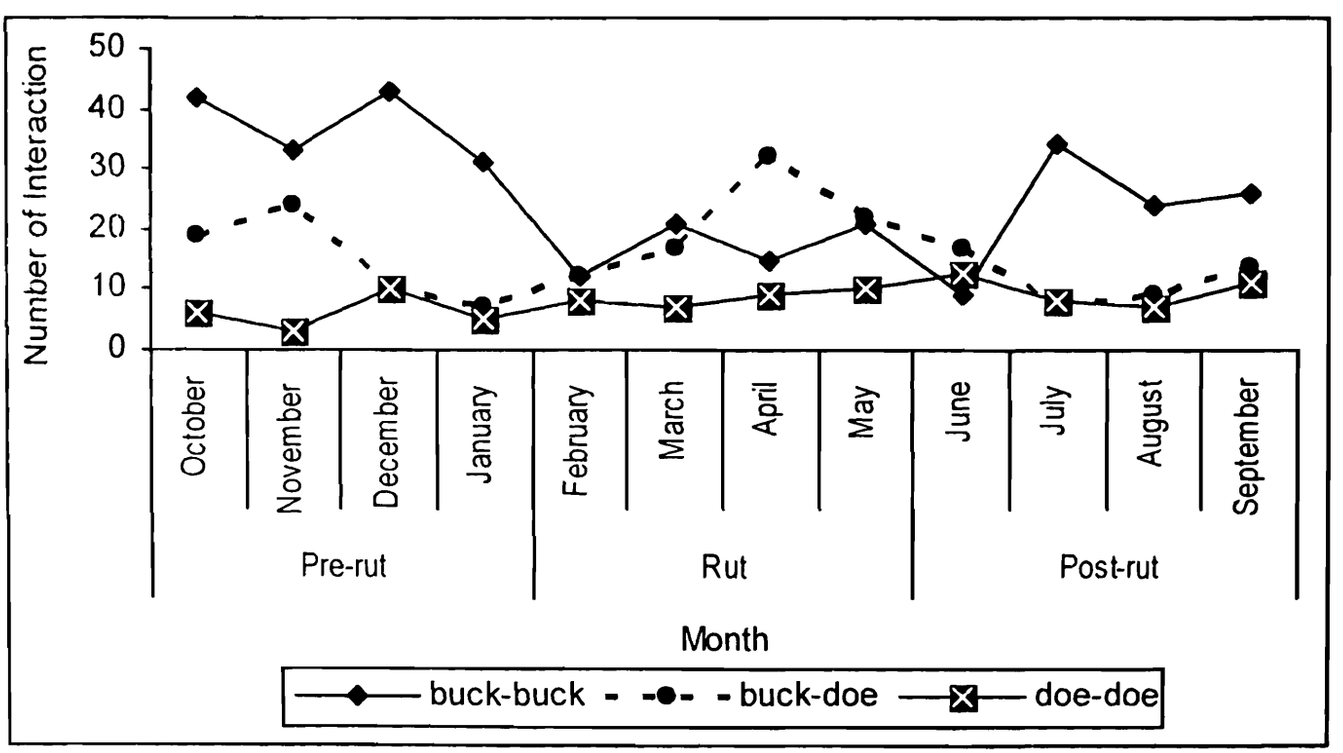


Figure 68 : Seasonal variations in agonistic interactions between individual of different social status of blackbuck in PCRB, Ganjam District, Orissa, India.

species (Walther, 1978). The agonistic behaviour enforces the maintenance of individual distance, especially among females, function in the establishment and maintenance of territories in case of male and co-ordination of group activities (Walther, 1974).

Blackbuck agonistic behaviour is closely associated with social organization. Most of the encounter between individual are on same age, sex or social class. As blackbuck found to live in different type of herd so unequal intensity and frequency of encounters between the members of the herd. In cases where the herd is composed of one age class, there is minimum chance of encounter with individuals of other classes like in female herd. However in bachelor herds containing males of several ages there is a maximum chance for the encounter between individuals of equal ages. This type of encounters is found in other ungulates like *Axis axis* (Schaller, 1967). Certain agonistic displays like fight, chase, charge and butting found among the same age classes are less frequent but more aggressive while others agonistic displays found among different age classes are more frequent but less aggressive.

Blackbucks live in herds comprising an old male and several females and fawns, while younger males stay away avoiding competition with the old ones, but as the breeding season approaches the males form bachelor groups which interacted aggressively to defend the territory individually (Mungall, 1978 & Nocon, 1999). Adult males are highly territorial in nature and their territories are adjacent so the male-male interactions are very frequent possibly due to holding the ownership of the areas, which are rich in term of food resources, and female groups graze through these territories.

The more frequent and high degree of agonistic interaction by intra sexual competition in males is possibly due to high reproductive success which monopolies all the females of the herd (Srivastava, 1991) which is supported by the present result that the agonistic interaction challenged by males increase in pre-rut season. But the male-male interaction decreases in rutting season possibly due to development of tolerance during the breeding season. It was observed that well-established males tended to fight less with males on adjacent territories than with new comers trying to find a territory. The other bucks without territories, and young males, form their own all male groups and are less interacted except the fight. Youngster is placed at the bottom of the social hierarchy, which gives him a particular social role typified by few agonistic interactions (Dubost *et al.*, 1981).

C. Community Conservation

I. Factor for conservation by local community

After analyzing the data it was found that 42.8% of people conserve blackbuck due to religious sentiments as they belief that blackbuck is a symbol of Lord Vishnu, 31.35% of them conserve by the belief that grazing of crop by blackbuck increase the yield of crop, 14.4% due to enjoyment and only 11.4% of people conserve due to laws and protective measures adopted by the forest department. 65.7% of respondents enjoyed with the presence of blackbuck (Table 29).

Table 29 : Frequency of responses and percentage frequency of the factors for conservation of blackbuck by local community in PCRB (n = 100).

Question	Frequency	% frequency of response
1. Why do you conserve blackbuck in your surroundings?		
a. Religious sentiment (symbol of lord Vishnu)	101	42.8
b. Belief (crop raiding will increase the yield)	74	31.35
c. Laws and protection by forest department	27	11.44
d. Enjoyment	34	14.4
2. Do you enjoy seeing blackbuck?		
a. Yes	88	88
b. No	3	3
c. No response	9	9

II. Knowledge about PCRB

An analysis of the data on the knowledge of respondent towards the PCRB (Table 30) found that 67% of people surveyed had seen predator like jackal, domestic dog and wolf in the habitat of blackbuck. 54.6% of people agreed that the number of blackbuck increased in comparison of past 10 year, while 25% of people responded that the population of blackbuck remained same in past 10 years. At the same time 58% of people agreed that the population of livestock increased, 22% agreed that population of livestock decreased and rest people did not offer any opinion. Domestic livestock was main competitor for food resources of blackbuck in that particular study area, which posed a threat to each others. But people had sympathy towards the livestock because livestock farming is an economic activity of local community.

Table 30 : Frequency of responses and percentage frequency of the responses of local community to analyze their knowledge about PCRB (n = 100).

Question	Frequency of response	% frequency
1. Have you ever seen any wildlife apart from blackbuck?		
a. Yes	78	78
b. No	22	22
3. Have you seen any predator in the habitat of blackbuck like?		
a. Wolf	10	5.26
b. Jackal	58	30.52
c. Stray dog	108	56.84
d. Others	14	7.36
4. In your view has the number of blackbuck in comparison to past 10 year?		
a. Increased	53	53
b. Decreased	6	6
c. Not changed	28	28
d. I don't know	13	13
5. In your view has the number of livestock farming in comparison to past 10 year?		
a. Increased	16	16
b. Decreased	13	13
c. Not changed	57	57
d. I don't know	14	14

Table 31 : Frequency of responses and percentage frequency of the responses of local community to assess the crop damage by blackbuck in PCRB (n = 100).

Question	Frequency of response	% frequency
1. Blackbuck damages your food crops?		
a. Yes	87	87
b. No	13	13
2. If Yes, which crops mostly damaged?		
a. Cereals	136	48.92
b. Pulses	105	37.76
c. Vegetables	37	13.3
3. What amount of financial damage due to crop raiding by blackbuck?		
a. High	56	56
b. Low	22	22
c. Too low	4	4
d. I don't know	16	16
4. What actions do you take to protect your crops from wildlife damage?		
a. Simply drive them	219	62.92
b. Chasing	68	19.82
c. Use of noise	35	10.5
d. Use of coloured cloth	14	4.02
e. Use of duplicate structure like a man placed on the field	12	3.44

Table 32 : Frequency of responses and percentage frequency of the responses of local community to assess their attitude in protecting blackbuck in PCRB (n = 100).

Question	Frequency of response	% frequency
1. Do you like blackbuck even after they damage your crop?		
a. Strongly like	44	44
b. Slightly like	29	29
c. Slightly dislike	8	8
d. Strongly dislike	2	2
e. No opinion	17	17
2 Do you think that it is necessary to take control measure for the loss of crop by blackbuck?		
a. Yes	57	57
b. No	43	43
3. Do you want financial compensation from government for the loss?		
a. Yes	28	28
b. No	72	72
4. "The presence of blackbuck is a sign of a healthy environment." Do you –		
a. Agree strongly	7	7
b. Agree	64	64
c. Disagree	3	3
d. I don't know	26	26
5. "Blackbuck should be protected." Do you –		
a. Agree strongly	18	18
b. Agree	66	66
c. Disagree	6	6
d. No opinion	10	10

III. Crop damage by blackbuck

Data related to crop damage by blackbuck was assessed (Table 31) and it was found that 87% of landowner and cultivator agreed that blackbuck damaged their crop. Observations were found that 53% of instances raided on cereals and 38% on pulses. The analysis showed that 78% of respondents agreed that the financial damage due to crop raids by blackbuck was low and only 4% of them agreed high damage. Under the column action taken by local community to prevent the crop damage, data reflected that the relative frequency of simply driven them was 63.2, chasing (20.2), use of noise (10.4), use of coloured cloth (4.3) and use of duplicate man type of structure on the crop field (2.7) were also reported by the community.

IV. Attitudes towards blackbuck

Analysis of the data on the attitudes of local community (Table 32) reflected that 44.4% of respondents strongly liked blackbucks and they neglected the damage caused due to blackbuck raids, 28% liked slightly, 10.2% disliked blackbucks and 17.3% of respondents gave no opinion. 57% of local community suggested taking control measure on the crop damage by blackbuck. Only 30.2% of local people responded that the presence of blackbuck is a sign of healthy environment and rest of them gave no opinion on that question. Analysis of the last question that 'Blackbuck should be protected' 74.7% of local people agreed to be protected the blackbuck.

Various combinations of factors finally contributed to different attitudes and behaviour of the local people. For example, if we look at landowners, they suffered serious crop damage from blackbuck raids. So, their attitudes were relatively more negative than those people from other categories. Newmark (1993) found a bimodal relationship between wildlife population and human density. On the contrary, some studies suggest that cost always restrict people's support for protected areas, especially from those people who suffer direct agricultural losses (De Boer and Baquete, 1998; Infield, 1988).

THREATS OF BLACKBUCK IN PCRB

The blackbuck was once the most abundant hoofed mammal in Indian sub-continnent, but their populations have been greatly reduced through excessive hunting and loss of habitat due to conversion of their natural habitat to agricultural use and economic development. Today, extensive hunting and habitat destruction have restricted blackbuck to only small, isolated populations in their former native habitat, range and numbers have declined sharply during the last 100 years. More recently, numbers increased from 24,000 in the late 1970s to an estimated 50,000 in India, and the population was described as reasonably secure and increasing in

A domesticated female of blackbuck at Vetnoi.

A domesticated female of blackbuck with a farmer.

Chasing of blackbuck by feral dog in Vetnoi.

many protected areas and a crop pest in some places (Rahmani, 2001). However, blackbuck habitat is subject to heavy pressure from human population growth, increasing numbers of domestic livestock, and economic development. The habitat available in the present study area is declining as the other areas of blackbuck population found in India. So, the current population and habitat declination the species is estimated to be close to Near Threatened Category of IUCN. Current status of this animal is Lower Risk Least Concern in the IUCN list of threatened animal.

In recent decades, the habitat of the blackbuck has come under severe pressure from agriculture, making the species vulnerable throughout the plains of the Indian subcontinent to which it is naturally restricted (Oza, 1988). At present the main threats to the remaining populations are from agriculture, poaching, predation, habitat destruction, overgrazing, diseases, unbreeding, human-animal conflict, and visitors. The natural habitat of the blackbuck is being encroached upon by man's need for arable land and grazing ground for domesticated cattle. Exposure to domesticated cattle also renders the blackbuck exposed to bovine diseases.

Major threats for the survival of blackbuck particularly in PCRB is that Local community of PCRB are struggling with severe social and economic problems such as poverty, rapid population growth, and environmental deterioration, resulting in indirect impact on blackbuck population. In present time conversion of natural habitat of blackbuck into cropland, commercial plantation, livestock grazing area and expansion of human settlement which reduce the food resources and interfere with their territory, home range and the route of seasonal migration like other ungulates in their wild land. The PCRB is a Proposed Community Reserve and the local communities conserve it from time immemorial due to belief and religious sentiments but loss of these values and increasing agricultural activities possess threat on the survival of blackbuck in PCRB. Destruction of natural vegetation by the use of different kinds of pesticide, weedicide, fungicides and herbicide for higher yield of crops, invasion of grazing lands due to increase in livestock populations resulting in the desertification of the habitat, spread of roads and highway leading to increase in the frequency of vehicular traffic causing the chance of accident of blackbuck, and with or without indiscriminate burning of vegetation, shrubs, grasses, and leaves of tree results in reduction of food availability leading to starvation. According to Simonetti (1995), the lands surrounding parks are vital for conservation of wide-ranging mammals, the risk of disease transmission and other costs such as crop damage may discourage landowners from permitting wildlife to use of their lands.

Most of the open areas have been used for construction without realizing that blackbuck require open areas and private space for rearing the young ones.

Destruction of native wild plants, grass and herbs without realizing their role in sustaining a species like blackbuck and introduction of non-edible, exotic grass species, spraying with pesticides are shrinking vital space of the blackbuck habitat further. Number of blackbuck killed by vehicles almost matches the numbers killed by stray dogs in the recent years. During the present study it was observed that 9-10 times stray dog of villages chases the blackbuck but killing of blackbuck not recorded. This type of threat may harmful to the fawn or yearling. Also observed that blackbuck regularly crosses the state highway which will be harmful to the blackbuck as the frequency of vehicular traffic increased day by day. Though there is only limited area in the Community Reserve, by judicious planning with willing heart, it is not difficult to protect this natural heritage forever.

The blackbuck population has increased in the recent years due to implementation of provisions in Indian Wildlife (Protection) Act, 1972 and also due to people's religious belief in blackbuck conservation. A major challenge for the conservation of blackbuck in present and in future is how one can come out of a limited vision of considering blackbuck as being responsible for crop damage and a competitor for food resources for the livestock. There has to be a broader perspective in right directions in the vision from conservation point of view. Are there other beliefs and cultural mechanisms that could be used to increase local people's tolerance against the crop damage, and if so, how can these belief systems be encouraged to spread from one community to another? (Jafri, 2007)

CONSERVATION MEASURES

In this current scenario, it is outmost important to establish a long term management plan to fulfill the need of both human and for the threatening blackbuck in natural areas for their continued existence, especially in the PCRB, a partially protected area that has high population density of human, livestock and blackbuck. Therefore, more micro-level or site-specific management plans are recommended. Secondly, only when local communities' positive attitudes are put into practice will conservation policies succeed. But the local communities are partners too, to work together with government to help to meet these goals and to share in the benefits, which may arise from conservation, hence the term Co-management (Sidhartha *et al.,* 2006; Robert & Martin, 2003). Present study suggests following recommendations for continued existence and survival of Blackbuck harmoniously in PCRB with local community–

- Education on local culture, belief, ethics and values of wildlife should be given to the new generation in school level for improving the relationship between blackbuck and people. Sustenance of beliefs and cultural mechanisms that could be used to increase local people's tolerance of crop damage by blackbuck.

- Making scientific policies and programmes that how one can be encouraged with the belief, ethics and cultural systems to be spread from one community to another?
- Farming methods should be improved so as to prevent wild animal's invasion and enhance crop harvest.
- To improve awareness among local communities on National policies and laws regarding community development and sustainable utilization of natural resources.
- Exchange of ideas between communities from different locations should be enhanced so as to build trust and joint ventures for more efficient implementation of activities.
- Co-management of blackbuck conservation involving all landowners, forest department personnel and NGOs.
- Essential pre-requisite to conserve the blackbuck in PCRB, that how the other beliefs and cultural mechanisms applied elsewhere that could be used to increase local people's tolerance of crop damage by blackbuck and how can these belief systems be encouraged to spread from one community to another?
- Maintain their habitat area as open grasslands and plantation for food and shelter. Details of the blackbuck habitat area are shown on the study area map.
- Avoid the use of pesticides and herbicides which are harmful to the health of blackbuck.
- Avoid construction and concreting, especially in the blackbuck habitat area. This reduces the food availability of these animals.
- Protect local bio-diversity by protecting the native wild fauna and flora.
- Driving should be careful and slow in the PCRB area. There have been some cases where blackbucks were killed by vehicles. Sign boards with pictures regarding speed limits should be displayed at key points, such as turnings, crossings etc.

In conclusion, with all of these steps, local community of PCRB will be leading the way in maintaining the intricate links between blackbuck and local cultures, for the long-term benefit of both.

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