HABITAT USE BY RADIO INSTRUMENTED CHITAL, SAMBAR AND NILGAI IN SARISKA TIGER RESERVE

DISSERTATION SUBMITTED TO THE SAURASHTRA UNIVERSITY, RAJKOT IN PARTIAL FULFILLMENT OF MASTER'S DEGREE IN WILDLIFE SCIENCE (1991)

BY

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CERTIFICATE

This is to certify that Shri Bipul Chakrabarty has carried out an original piece of reasearch in partial fulfilment of his M.Sc (Wildlife Science) degree of Saurashtra University, Rajkot. The topic of dissertation is " Habitat use by radio-instrumented chital sambar and nilgai" in Sariska Tiger Reserve. The investigations were carried out at Wildlife Institute of India, Dehra Dun under my supervision from November. 1990 to June 1991. I hereby certify that this work has not been submitted for any degree of any University.

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SUMMARY

A study on the habitat use by radio instrumented sambar, chital and nilgai hinds was conducted in Sariska Tiger Reserve from November 1990 to April 1991. The climate of the study area is semi-arid with a mean rainfall of 650 mm largely during south-west monsoon (June-September).

Radio locations were obtained by triangulation. The maximum area of polygon was < 150 ha. for all the three species and this did not differ statistically between the two seasons. Nilgai didn't show any significant difference in distance moved at different times of day, whereas chital and sambar showed significant differences ($P<0.001$) in distance moved at different times of the day in both the seasons.

Chital, sambar and nilgai were more active during day than at night in winter whereas sambar was more active at night during summer.

The average distance moved in a particular time interval period by all three species was strongly correlated ($r=0.85-0.95$) with mean percentage activity of that period.

Home range calculated on using one day and one night independent location revealed that summer home ranges of nilgai and sambar are smaller than winter home ranges. Winter home range of Chital was 18% larger than in summer range. Home range size and

extent of overlap among three species were in the following order sambar < nilgai <chital and sambar > nilgai > chital respectively. The home range size was inversely related to the amount of browse where as the range overlap is directly related to the extent of browse eaten.

Nilgai showed a proportional use of flat terrain in both winter and summer to its availability. _Acacia_ scrub was more preferred during winter, whereas _Zizyphus numularia_ scrub was preferred during summer. _Z.numularia_ is a good fodder species. Nilgai preferred the grids having 0-50 trees/ha during winter while in summer preferred grids having 50-100 trees/ha. Shrub density preferred were in classes of (400-600 /ha) and (600-800 /ha) during both the seasons.In winter grass cover preferred was in the class of (25-50%), and herb cover utilized was in the class of (0-25%). In summer no such preference was shown.

Chital too showed a preference for flat terrain in both winter and summer. _Zizyphus_ mixed vegetation and _Acacia_ mixed scrub were preferred during winter and summer respectively. Chital showed a preference for the tree density of (50-100 tree/ha) class in winter but in summer the preference varied between 50-150 /ha class. There was no particular selection of shrub density class, both in winter and summer. Grass cover of class (50-75%) and (25-50%) were preferred in winter and summer respectively. Herb cover of class (25-50%) and (50-75%) were preferred during winter and summer. This suggests high dependency on herbs and grasses to meet food requirements.

Sambar showed a clear preference for the steep slopes both during winter and summer. Sambar had distinct preference for Anogeissus mixed vegetation during winter, no such preference was seen in summer. This may be because sambar feed on fallen Anogeissus leaves during winter. Shrub density of class 200-400 ha was selected during winter. In summer, sambar showed a preference for higher tree and shrub density zones. In summer grass cover of 50-75% was preferred. No such preference for herb cover was shown.

In the present study it was found that the three ungulate species in Sariska have the ability to use the terrain and vegetation types spatially and temporally. Such an adaptation would help them to share the resources without much competition if they occur in the same area.

CHAPTER 1

INTRODUCTION

Distribution of ungulate species shows that most of the habitats are used by more than one species. Such species are known as sympatric. It has been found worth examining how these sympatric ungulate species are sharing the resources. If there is competition for a keystone resource between two species it could lead to one species expelling the other. But this does not occur. Among a few pioneer studies on habitat use by Lamprey's (1963) works on sympatric ungulates and their habitat Tarangaire Game Reserve in Tanzania. He had concluded that each species has its own niche and competition is being avoided by differences in spatial and temporal distribition and by the use of different feeding levels, which was comfirmed by Field and Laws, 1970 and Blankenship and Field, 1972).

Later on, a number of studies have been undertaken on this aspect (Hirst, 1975). In a recent study, Scogings <u>et al.</u> (1990) studied the habitat use by 10 mammal species ranging from impala to bruchellis zebra in Jack Scott Nature Reserve, South Africa and concluded that each species avoid competition by using different combinations of various habitat parameters. Thus it can be concluded that competition by sympatric species is usually avoided by one way or other.

Selection of preferred habitats could essentially be a behavioral process of keying into structural habitat features so that interspecific competition is minimized and opportunities for habitat exploitation maximized. This had been demonstrated to be the case with birds (Lack, 1933; MacArthur et al. 1962; Klopfer, 1969) and ungulates (Lamprey, 1963; Jarman, 1974).

Besides the use of behavioural adaptations the use of a particular habitat by an ungulate species is further limited by its basic morphological and physiological features. Social energetics and risk factors further limit overall use of habitat. Since these constraints must be reflected in each animals pattern of space utilization by a species, such patterns may be considered diagnostic of an animal's response to its environment (Ford and Krumme,1979).

It would mean that habitat use by a particular species can be best understood by monitoring its movement which ultimately would reflect its behaviour or response to the habitat (Rongstad and Tester, 1969; Shea et al., 1990) or understanding internal structure and overlap of home ranges (Georgii, 1980; Horner and Powell, 1990). With the advent in technology it is possible to keep track of the animal continuously by using telemetry in habitat use studies. Most of the earlier habitat use studies were based on monitoring the animals during day time as it is easy and as it can be done with certain species even without telemetry (Hirst, 1975; Cairns and Telfer, 1980). But in recent years, scientists are becoming more keen to know differential use of habitat between day and night. Recent studies conducted on this aspect are on black bear, sambar, white tailed deer, mule deer and big horn sheep (Shea et al., 1990; Flynn et al., 1990; Horner and powell, 1990).

Most of the wildlife habitats in India are shared by a number of ungulate species. In some habitat the size of the species vary from mouse deer to elephant. But not many studies have been done to understand the ecological separation of these sympatric herbivores. The two studies done are on Himalayan ungulates (Green, 1987) and ungulates of Kanha National Park (Schaller, 1967).

Three sympatric ungulate species viz. sambar, chital and nilgai which differ morphologically and physiologically from one another, were selected for the present study. Both the deer are water dependent and among these sambar is forest dwelling and a browser whereas, chital is a grazer browser. Nilgai is less dependent on water than the deer species and has food habits similar to chital. All the three species were radio collared which made it easier to track them to understand their differential habitat use.

Therefore, the study was framed, to collect information on spacio-temporal use of the habitat during day and night by sambar, chital and nilgai in Sariska National Park in Rajasthan.

1.1 STUDY HYPOTHESIS

The major aim of the study was to examine the spacio-temporal use of habitat by radio-collared chital (*Cervus axis*) sambar (*Cervus unicolor*) and nilgai (*Boselaphus tragocamelus*) and their diurnal and nocturnal activity patterns.

Following null hypothesis (Ho) were set for study:

1. There is no difference in habitat use by these ungulates between seasons (winter and summer),
2. There is no difference in activity by these ungulates between day and night time and between seasons,
3. There is no variation between the nocturnal and diruna] home ranges and between the season.

1.2 REVIEW OF LITERATURE

1.2.1 Radiolocation of animals:

Error and bias in radiotracking:

Few investigators who have used radio triangulation have reported on the bias and sampling error involved (Springer, 1979). Heezen and Tester (1967) defined system error to be the angle between the system determined bearing and the true bearing of the animal. It could be caused by a number of factors such as wind twisting the antennas, temperature changes, and inaccurate referring of the antenna. Inglis *et al.*, (1968) tested both the precision and accuracy of their system to a target and called this bearing accuracy. They attempted to lessen or eliminate system error with the use of beacons. Inglis et al., (1968) also used bearing from different pairs of antennas to a target at a known location to determine positional accuracy of their system. They found errors in the positional accuracy of their system to be a function of the interaction of bearing accuracy, distance from the tracking station to the transmitter, and the angle between the bearing.

Heezen and Tester (1967) showed that the error of a determined location fix has an area which was termed an error polygon. Springer (1979) defined this error polygon as the intersection of error sectors from the radio tracking towers formed by appropriate confidence intervals. The size and shape of the error polygons changed from one location to another in relation to the towers. Macdonald and Amlaner (1980) described these inaccuracies as errors imposed by the geometry of triangulation. They stated that while the system error does not increase with distance, the triangulation error does. Errors also can be made in reading and recording bearings (Heezen and Tester, 1967; Macdonald and Amlaner, 1980). Delays in the time taken between taking bearings at the two antenna towers to pinpoint an animals ,position will cause movement error (Tester and Siniff, 1965; Deat et al., 1980; Macdonald and Amlaner, 1980). The magnitude of this error depends on the time lag involved, the speed at which the animals move, and its position in relation to the antenna towers.

Topographical error, error due to reflections of signals off thick or wet vegetation, valleys, hillsides, or buildings can cause inaccuracies in determination of an animals location (Macdonald and Amlaner, 1980). These errors are more serious at higher frequencies (200-500 Mhz). They can be lessened by using the null system to radio track, knowing the individual features of the landscape and how they affect radio signals, taking alternative bearings, and keeping alert for nonsensical bearings.

Indices such as distance travelled by an animal can be affected by sampling interval (Heezen and Tester, 1967). A large sampling interval may miss movements made by an animal between times when radio location fixes are taken especially if the animal moves in a non-linear, zig-zag pattern. However, the smaller the sampling interval, the greater the effect of the overall location error, especially on an index such as total distance travelled in a given time interval (Heezen and Tester, 1967). An animal may not move at all, but due to the location error the radio location fixes detect movement. Springer (1979) suggested that if error polygons overlap, no detectable movement has occurred at a specific level of statistical significance.

1.2.2 Determination of home range:

Though the techniques for locating and observing animals have been improving, there has not been a concomitant evolution of method of analysis for interpreting the data acquired (Sandreson, 1966). Frequently analysis only involves determination of area or shape of area used by an animal (Voight and Tinline, 1980).

Sanderson (1966) suggests that sizes and shapes of species home range have little significance in themselves and that researchers should concentrate more on ecological studies. Jewell (1966) felt that the concept of home range was important in the interpretation of the restricted area within which individual or groups live and the manner in which they use their living space.

The concept that individuals of many species confine their movements to a limited area has long been known. One of the earliest expression of this is by Seton (1909) in reference to mammals: "No wild animal roam at random over the country; each has a home region....". A widely used definition of home range is that of Burt (1943) "that area around the established home which is traversed by the animal in its normal activities of food gathering, mating and caring for the young...".

Most of the earlier work for calculating various indices of home range was based on trapping and marking techniques. These methods of analysis have carried over to analysis of radio telemetry data.

Typical descriptive properties of home range include computation of (1) center of activity (Hayne, 1949) (2) distribution of activity radii (Tester and Siniff, 1965), and (3) an index of the magnitude of home range (Anderson, 1982).

Mohr and Stumpf (1966)suggested calculating the area and shape of home ranges on the basis of a minimum convex polygon in which the outer most location points are connected by straight lines. A related procedure is obtained by dropping the requirement that the polygon be convex (Stickel, 1954). Both procedures suffer from sample size bias, especially from outliers (Jenrich and Turner, 1969). The polygon methods still have a wide range of use (Bowen, 1982; Schweinsburg, 1971; Bailey, 1974; Martinsen, 1968; Kurz and Marchinton, 1972).

Several probabilistic home range models have been proposed (Hayne, 1949; Calhoun and Casby, 1958; Jennrich and Turner, 1969; Mazurkiewicz, 1969; Dunn and Gipson, 1977). Hayne (1949) suggested the concept of a geometrical center of activity with a circular home range . Calhoun and Casby (1958) used a circular home range model in which a bivariate normal model with a covariance term equal to 0 was applied. These methods of analysis assuming circular home ranges can yield misleading estimates if used with data exhibiting significant linearity (Stumpf and Mohr, 1962).

Jenhrich and Turner (1969) and Mazurkiewiz (1969) also assumed a bivariate normal distribution but with the more general case of dropping the restriction that the covariance equal zero. Their model then could be used to analyse data that suggested a "tilted elliptical home range. Jenhrich and Turner (1969) failed to point out other useful information which could be obtained from this model besides area of home range, including lengths of major and minor axes (principal components) and the orientation of the ellipse with respect to environmental gradients. Mazurkiewiez (1971) assumed that the orientation of the ellipse was an index of the preferred direction of movement with the ratio of the axes being an index of the degree of preference for this direction. Van

Winkle (1975) compared these and several other probabilistic models and concluded that the bivariate normal distribution without the restriction of circularity provides a more general and flexible probabilistic home range model. Though the assumption of bivariate normality is unlikely to be realistic since the resources governing the pattern of animal movement are in many cases not normally distributed in space, Macdonald et al (1980), Jennrich and Turner (1967), Van Winkle (1985) and Koeppl et al. (1975) favour this technique which they consider to be statistically robust.

Dunn & Gipson (1977) proposed a model in which the utilization of space by the animal still is assumed to be bivariate normal, but with recognition of the fact that in radio tracking there usually is correlation between successive fixes along the animal route. The model used, the Ornstein Uhlenbech Diffusion model, assumes a stable home range and the route taken by the animal to be Markonian. Macdonald et al. (1980) pointed out that a consequence of this model is that the animals movements have a centralising tendency and that this assumption of a tendency to move towards the center of a home range has no obvious biological basis. Analysis of various data sets by Macdonald et al. (1980) comparing the Jennrich and Turner (1969) model to that of Dunn and Gipson (1977) showed that the former's assumption of independene of location fixes gives home range areas and shapes only slightly different from those of the latter provided that the sample size is large. Macdonald et al. (1980) showed that if an animal movement do not have a genuine centralizing tendency towards the middle of its home range than the Ornstein-Uhlenbeck model can introduce errors which depart even further from reality than the Jennrich and Turner (1969) model.

Grid-square methods have been advocated to investigate internal anatomy of a home range (Adams and Davis, 1967). Voight and Tinline (1980) described methods of computing home range size by analysing a grid system and adding the area of all squares containing locations. They also described systems that allow used squares to weight their neighbours and for linking squares through which an animal logically must have travelled between two sightings, even if the animal was not followed while doing so. This method gives no measure of the distribution of locations and is influenced by the size of grid square chosen. Tester and Siniff (1965) compared fitting a truncated geometric and a truncated poisson distribution to the frequency distribution of squares continuing 1, 2, 3.....radio fixes. They found that the geometric distribution gave a better estimate for their data set, but that there was notable disagreement at both ends of the distribution.

The frequency distribution of locations can be effected seriously be grid square size. Cooper (1978) suggested that the size of the grid square should be no smaller than the limitation in the accuracy of the tracking system. Macdonald <u>et al.</u> (1980) used grid square sizes described by proportions of the total range size so that comparisons of the pattern of use of home ranges using frequency values for different individuals could be made. If this is not done, comparisons can be made only between ranges of identical sizes as the number of cells influences the frequency distribution data.

Rasmussen and Rasmussen (1979) developed an index of range use which is helpful in distinguishing between home ranges where the frequencies of grid square use for different animals home ranges have the same distribution but where the pattern of use differs such as where heavily used squares are clumped together rather than regularly spaced. The index involves summing the number of fixes in each pair of grid squares and dividing this by the distance between them. The index takes on greater values when intensively used squares are clumped together.

New techniques for estimating home range size and space-use patterns recently have been introduced (Anderson, 1982; Ford and Krumme, 1979). These methods describe home range in a probabilistic sense but make no assumption about the underlying distributions, and hence are non parametric. Anderson (1982) used a procedure based upon an existing nonparametric technique for density estimation which uses the Fourier transform. Ford and Krumme (1979) developed a method for calculating a probability of location distribution for an average individual member of a population which requires no assumptions about the shape of the distribution. They termed this distribution, the population utilization distribution or PUD.

1.2.3 Determination of habitat selection:

Radio tracking data not only provides record of animal movement and activity but also of the utilization of the habitat by the instrumented animals. Locations taken for each animal can be classified as to the habitat type in which they occured. Thus an estimate can be developed for the percentage of time each animal had spent in a particular habitat type.

The methodology to determine the habitat type of a radiotracking location varies from simple to complex. The habitat type can be recorded in the field, either at the time the location is taken or at later time when the observer travels to the location. A second approach is to physically plot the location on a habitat map and record the habitat from the map.

Availability:

Availability of each habitat type is usually determined from specific areas on a habitat map. Availability consists of the amount of area of each habitat type that is available to the members of a population (White and Garrdt, 1990).

Measurement of the size of each habitat on a map can be performed in a number of ways. One standard method is to use a planimeter to measuer the map to obtain areas of each habitat.

If the map has been digitised for computer processing, numerous computer programs are available to estimate the size of each habitat type, including commercially available GIS systems.

According to Marcum and Loftsgaarden (1980) estimates of the area of each habitat type can be determined from random points placed on the map. But this method has a sampling error associated with the habitat area estimate and therefore the statistical analysis would be treated differently.

Utilization:

As availability can be measured from the maps, the habitat type of a radio location can also be determined from maps. In general, the polygon approach is preffered, in that the distance to the nearest habitat boundary can be determined and, hence the probability of the location's being misclassified can be estimated.

Preference:

The question of preference is really whether the animal selects some habitat types more than others and thus spends more time in these habitat (and hence less time in the other habitats) than would be expected based on the availability of each habitat type. If a habitat is prefered, then more time would be spent there than expected by chance alone. thus, if one habitat type is prefered, then one or more of the remaining habitat types must be avoided because of constraints on time.

Use of radio telemetry techniques to locate free ranging animals for the purpose of determining habitat use is a common technique in wildlife reasearch and management. Recent papers have included grizzly bears (Ursus arctos horribilis) (Servheen, 1983), ring-necked pheasants (Phasianus colchicus) (Whiteside and Guthery, 1983).

The most common statsisticsl test to detect selection of > 1 of habitat type by radioed animals is the Chi-square goodness of fit test of observed use data to expected habitat availability as measured by abundance.

CHAPTER 2

STUDY AREA

The present study was undertaken in Sariska Tiger Reserve, one of the 19 Tiger Reserves of India situated in semi-arid part of Rajasthan.

2.1 Location, Topography and Climate:-

Sariska Tiger Reserve (STR) 27' 20'N and 76' 25'E in south eastern Rajasthan, is located in the undulating plateau lands, and wide valleys of the Aravalli hill ranges. STR covers an area of 800 sq.km, and the study area was located in Sariska National Park of STR, covering an area of 288 sq.km. between Sariska gate and Kalighati (Fig.1).

The tract in the study area is mainly hilly with two big plateaus (Kankawari and Kiraska) having undulating ground and numerous narrow valleys. Major part of the area is occupied by rocks of the Delhi system and Aravalli system comprising of quartzites, conglomerates, grits, limestone, phyllites, granites and schists. Evidence of lava conglomerates is also occasionally met with. Soil differs depending on the underlying rocks with gneisses and schists etc. are generally covered by red sandy soils.

The climate of this tract is sub-tropical characterised by distinct winter, summer and monsoon, spring as else where in north India, is short. Winter season commences from November. In winter the temperature has been observed to drop to sub-zero during nights. Summer season commences from middle of March and continues till end of June (Mercury touches 47'C on some hot summer days).

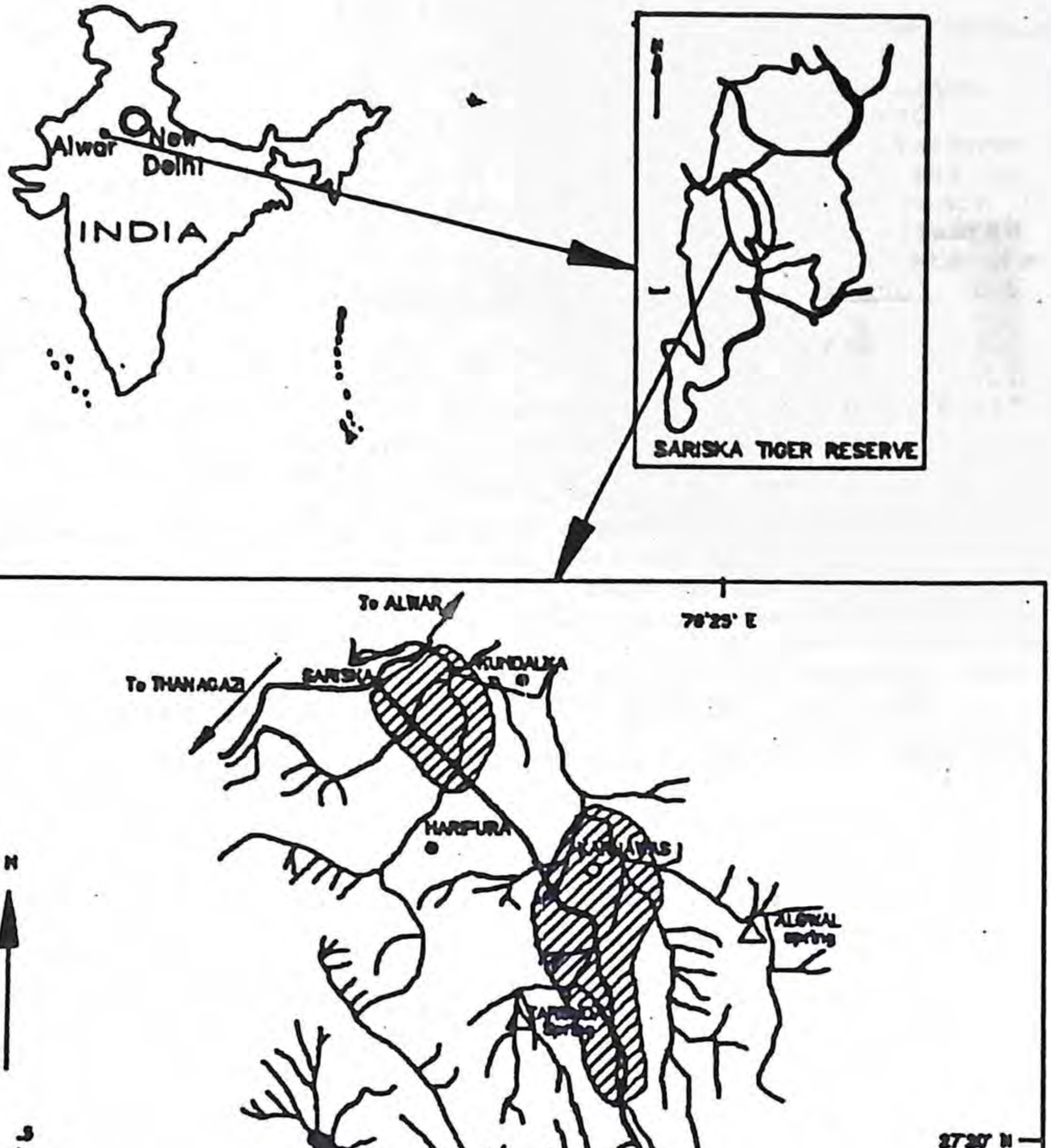


Fig.1 Map of study area (Hatched)

Rainy season commences late june and continues till middle of October.

The average rainfall is 650 mm, the precipitation being from south-east monsoon in July, August and september. Winter rains, if any are very few.

2.2 VEGETATION:

According to Champion and Seth (1968) the vegetation of STR is of Tropical Dry Deciduous and Tropical Thorn forest.

Anogessius pendula is the dominant tree species in the undulating areas and on the hills, covering over 90% area of the forests, Boswellia serrata and Lannea coromandelica grow on rocks and dry slopes while Acacia catechu is common in valleys. Dendrocalamus strictus is extremely limited and is found along well drained reaches of the streams and moist and cooler parts of the hills. Albizia lebbeck, Diospyros melanoxylon, Holoptelia integrifolia, and Ficus spp. are found in moist localities and attain large size both in crown spread and height. Butea monosperma grows gregariously, where valleys fan out and become flat and wide (Parmar, 1985).

On the basis of their composition, Parmar (1985) classified forests of Sariska national park of STR as follows -

1. Anogessius pendula forest,
2. Boswellia serrata forest,
3. Acacia catechu forest, and
4. Miscellaneous type of forest, which can further be divided into three categories namely -

a. Butea monosperma forest,

b. Forests along nullahs, and

c. Scrub forest.

2.2.1 Anogeissus pendula forest:

The type is largely determined by the presence of Anogeissus pendula which forms nearly pure crops, often quite well stocked, about 6mm, high and 70-80 cm girth, but branched from about 1-1.5m above the ground. The associated forest species are those of the southern dry deciduous type with more and more of the thorn forest species as the habitat is drier. The forest is leafless from March to June. There is a thin shrub and grass undergrowth but no bamboo.

This type usually occurs on the lower and gentler slopes and tops of low hills (Boswellia serrata or Sterculia urens occupying the higher ridges and crests) within the 240-600 m altitudinal range.

2.2.2 Boswellia forest:

An open forest in which Boswellia forms an overwood to stunted trees and shrubs of dry deciduous forests. It is ordinarily 12-15 m. exceptionally 18-20 m high and 1.2 to 1.8 m in girth. The only tree equally it in size often being Sterculia urens. It is leafless from February to May. There is low grass, scanty undergrowth and the forests are usually burnt. Regeneration is usually absent.

2.2.3 Acacia catechu forest:

It is a deciduous forest, the canopy is light but usually fairly complete and 18-20 m height. The older woods have more less definite understorey, which is mainly composed of young trees. The woods have one marked feature in which they resemble the moist more than the dry deciduous in that they come early into leaf (March and are in full leaf throughout the hot weather).

2.2.4 Butea forest:

On flat ground this type presents a savannah appearance with scattered stunted and very malformed trees or thickets standing over short grass or bare ground; on lower hill slopes almost pure consociations are found on screes and gravel derived from basic rocks and yielding clayey soils. In Sariska it is seen in association with Zizyphus mauritiana, Capparis sepiaria, C. decidua and Acacia leucophloea.

2.2.5 Forest along nullahs:

In Sariska, forest along nullahs which represent more of wet conditions, Phoennix sylvestris, Ficus glomerata, with association with Zizyphus mauritiana are seen.

2.2.6 Scrub forest:

A low broken soil cover of shrubby growth 3 to 6 m high including some tree species reduced to similar conditions, usually many stemmed from the base. There may be localities in which the soil and climate are such as to permit of the development of a dry deciduous low forest in which tree growth in the narrower sense is scarce, but as seen in most of the cases, they owe their stunted condition to maltreatment, usually directly or indirectly connected with felling, lopping, grazing and frequent fires. In Sariska valley the main composition of this forest type seen are *Zizyphus numularia*, *Balanitis aegyptica*, *Rus mysorensis*, *Mayetenus emarginatus* and scrub near villages.

2.3 FAUNA

Besides chital (*Cervus axis*), sambar (*Cervus unicolor*) and nilgai (*Boselaphus tragocamelus*) the other wild herbivores [illegible] found are wild boar (*Suscrofa cristatus*), chousingha (*Tetracerous quadricornis*), porcupine (*Hystrix indica*) etc. . Among carnivores Tiger (*Panthera tigris*), leopard (*Panthera pardus*), caracal (*Felis caracal*) jungle cat (*Felis chaus*), palm civet (*Paradoxurus hermaphroditus*), striped hyaena (*Hyaena hyaena*), Indian fox (*Vulpes bengalensis*). Primates are represented by the common langur and macaque. About 94 species of birds are found in the reserve (Sariska management plan 1990-91).

CHAPTER 3

MATERIALS AND METHODS

3.1 Species and number radio instrumented:

A stag and a doe of sambar and chital and a hind of nilgai were chemically immobilized and radio collared between 25th and 26th of March 1990. The present study was based on the habitat use by sambar, chital and nilgai hinds between November 1990 and April 1991. These animals were monitored for obtaining data on diet movement and activity patterns, and independent locations for estimation of home range and habitat use.

3.2 Seasons :

The study covered two seasons viz. summer (March-April) and winter (November-February).

3.3 Movement Pattern and home range :

3.3.1 Collection of animal location data:

Radio tracking leading to direct sighting has one disadvantage of disturbing the animals (Inglis et al.1968; MacDonald et al.1980 and Deat et al.1980). Therefore, triangulation technique (Tester and Siniff, 1957; Heezen and Tester, 1967 and Springer, 1979) was adopted during this study for collecting location data.

Fixed well known locations or points on a map, (scale 1:50,000), preferably elevated points, in each habitat type were selected. Radio locations of each animal were made from triangulation using compass bearing from at least three different stations or locations. (This was done to maximize chances of getting at least two bearings without bounce or funneling of signals). So as to avoid errors due to animal movement all the three locations were made within < 30 m. Telonics Model TR-2 Receiver (Telonics, Inc., Mesa, Arizona) and a hand held 'H' type directional antenna was used for tracking.

One day and one night independent radio locations were made every day beacons were used to detect mechanical bias in the tracking system.

A cartesian coordinate grid system was established on a topographical map of the study area and the locations were plotted on the grided map.

3.3.2 Diel Activity Patterns :

Diel activity patterns for each animal was measured in terms of the range linearity and continuous monitoring of active and non active phases of each animal (Kurz and Marchinton (1972).

Range linearity :

Range linearity or the linear distance moved from one location to the successive locations over a certain time interval (6 hourly) was monitored continuously for a day (24 hrs.).

Each hind was located atleast once during sampling periods of 0600-0800;1200-1400; 1600-1800; 1800-2000; 0000-0200;0400-0600 IST(Indian Standard Time) for a period of six days for each season.

Thus, three radio fixes during day (one in the morning, afternoon and evening) and at night (one in the evening, midnight and early morning) for each animal were recorded. Using consecutive locations linear distance travelled in meters was calculated one as described by Kurz and Marchinton (1972).

Activity types:

During this period the animal was approached till the signal was strong and therefore, the activity was monitored by using a Telonics Model- TDP-1 Digital processor (plate.1). The activity of an animal was considered either inactive or active. Activity was recorded continuously for 24 hrs for each radio collared animal for six days when the animal was found within a km. range of telemetry receiver. The antenna mounted on a 3 m pole was fixed in the ground to monitor change in the signal amplitude. Animals were considered inactive if the signal amplitude maintained an equilibrium level. The activity event was recorded at an interval of 5 min. The definition of inactivity had been previously used with tip-switch radio collars by Garshellis et al. (1982). (<2 changes/minute).

3.3.3 Estimation of home range:

With the advent of radio tracking techniques there has been a considerable increase in the amount of data that can be collected and used to analyse home-range size, shape and internal configuration (Harris,et al. 1990). As a result in addition to a purely spatial representation of home range, it has become possible to define it in statistical terms. The various analytical techniques have been reviewed by MacDonald, et al. (1980), and more recently by Jaremovic and Croft (1987) and Worton (1987).

In the present study minimum convex polygon technique was chosen for home range calculation (Mohr, 1947; Southwood, 1966). This method seems to be most appropriate for a quick estimate of home range size (Anderson, 1982). An advantage of the minimum convex polygon is that it is the only technique that is strictly comparable between studies globally, and its inclusion as one or two or more of methods of range calculation is therefore valuable. It is also one of the few methods to give comparable results between grid trapping and telemetry data (Jones, 1983).

Although it is more robust than other techniques when the number of fixes, is low, it does have a number of disadvantages. The range boundary encompasses all the fixes including occasional fixes well beyond the main area of activity. This means that the range size is strongly influenced by peripheral fixes, and the range area can include large areas which are never visited. In addition, there is no indication of the intensity of range use. Some of these disadvantages can be reduced by using concave polygon, e.g. Clutton-Brock et al. (1982) and Kenward (1987), or by correcting minimum convex polygon ranges by manipulative adjustments such as restricted polygons (Wolton, 1982; Mills and Gorman, 1987). Such approaches may be useful in certain situations, but the assumptions are seldom valid in others and the techniques are thus not comparable between studies.

The area of error polygon and home range was estimated by using a planimeter.

3.4 Determination of habitat use by radio instrumented animals:

The availability-utilization approach (Neu, et al., 1974) has been used to study the habitat use by each radio instrumented animal. Habitat characteristics for each species have been broadly identified based on terrain and vegetation.

Terrain was classified into flat, gentle slope and steep slope types. Under vegetation availability of vegetation types, tree density, shrub density, grass cover, and herb cover were quantified.

3.4.1 Availability:

After determining different terrain types various vegetation characteristics available to each animal was estimated for each season. The study area was divided into 250 x 250 m grid. This grid size was selected to contain 89.2% of telemetry polygon error. Horner and Powell (1990) working on black bears in the mountains of north Carolina have selected grid size which contains approximately 80% of telemetry error. Each grid was numbered and 30% of the total grids were randomly selected to determine habitat characteristics separately for each species.

Along a diagonal transect in the selected grid at intervals of 50 m the following parameters were quantified :

Terrain types:

Each sampling point was classified with respect to terrain types such as flat, gentle slope and steep slope.

Tree density:

The number of trees (GBH > 20cm) with respect to species were counted in a circular plot of 10 m laid at each sampling point. The height and the canopy cover of each tree were ocularly estimated.

Shrub density:

Plants less than 20 cm. of GBH were considered as shrubs. A circular plot 5 m was used to count the species and their number at each sampling point. Volume of each species was estimated by measuring the length, breadth and the height.

Ground layer:

The percent herb cover and grass cover was estimated ocularly in a quadrat of 0.25 m^2 at each sampling point. Only two major herb and two grass species were monitored seasonally.

3.4.2 Utilization:

Radio locations obtained through triangulation were transferred on the grided map. The grid which contained the radio locations was considered to collect data on utilization.

Habitat parameters as used for availability estimation were quantified for the grids used by each radio instrumented animals to obtain utilization data. Similar methods used for availability estimation were used for utilization.

3.5 Statistical analysis:

Statistical tests *viz.* 't' test, analysis of variance, correlation coefficient, Chi-square test were done in the present study (Sokal and Rohlf, 1981).

In order to see the significance in distance moved with the time periods, a one-way analysis of variance of test was done, with respect to seasons and species. A correlation regression test was done to see the relation between distance moved and activity of the radio instrumented animals. All the above tests were done through a SPSS program in a IBM computer.

CHAPTER-4

Results

4.1 Error polygon:

Total number of random radio locations obtained for each species in each season were as follows:

	winter	summer
Nilgai (hind)	154	129
Chital "	154	129
Sambar "	138	126

From the locations obtained by triangulation of the radio instrumented animals and the beacons, error polygons were constructed which formed due to the intersection of 3 points. The area of polygon has ranged from 110 to 130 ha for nilgai hind, 130 to 150 ha for chital hind and 77 to 90 ha for sambar hind during both seasons (Table-1). polygon error did not differ statistically ('t' test) between the two season in all three species.

4.2 Diel Activity Patterns:

4.2.1 Range linearty :

Daily movement parameter or the range linearty was determined as linear distance moved by the animal between two consequent locations. Fig. 2 indicates that distance travelled between two consequent locations at different times of the day ranged from 100 to 500 m in nilgai, 100 to 1000 m in chital and 100 to 600 m in sambar. On an average nilgai, chital and sambar hinds moved 220 m, 245 m and 270 m during winter, and 300 m, 333 m and 308 m during summer respectively.

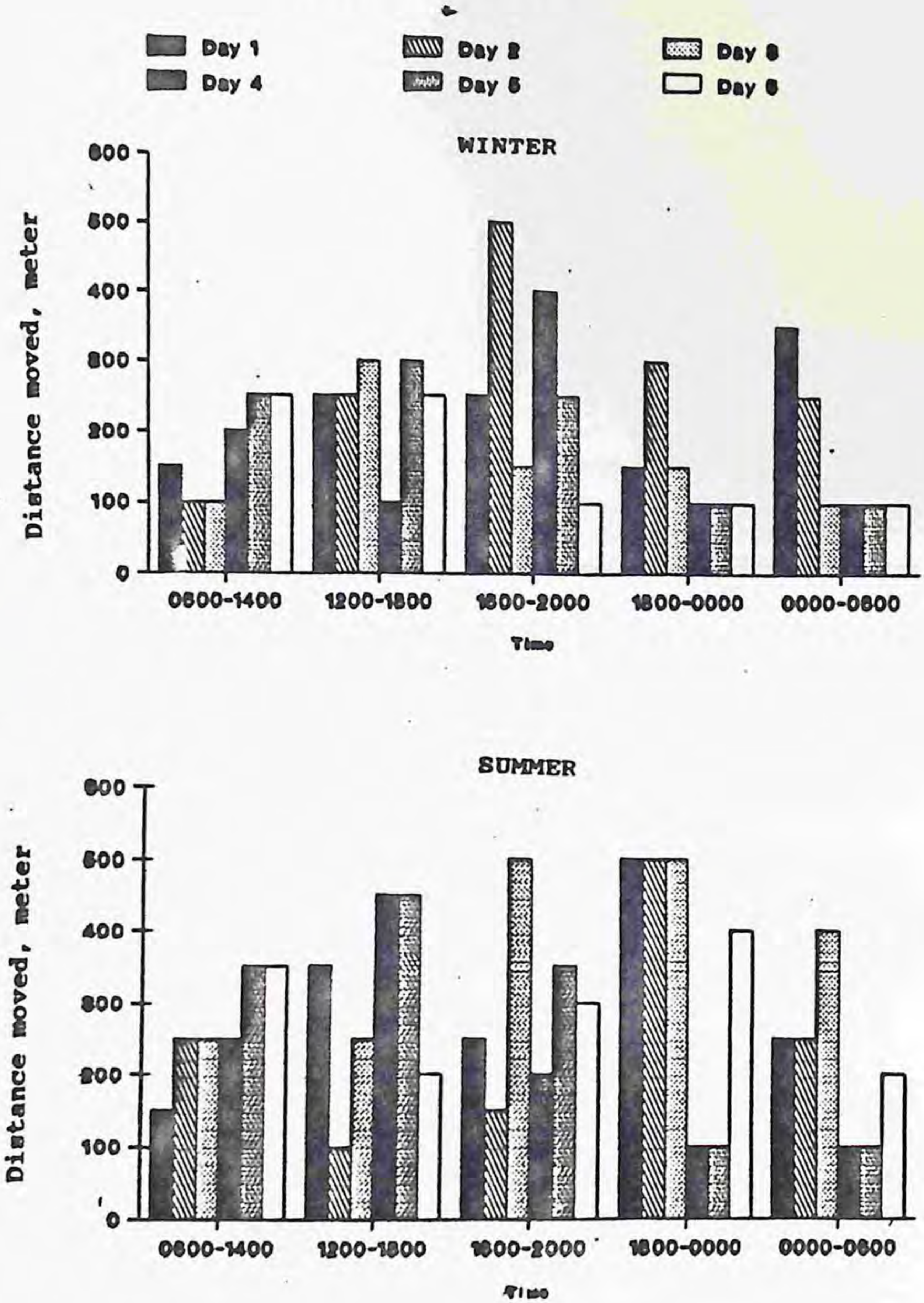
Comparision of distance travelled during day and at night revealed that the animals moved shorter distances at night than day in both the seasons (Fig. 2).

Table- 1. Convex error polygon area in three ungulate species

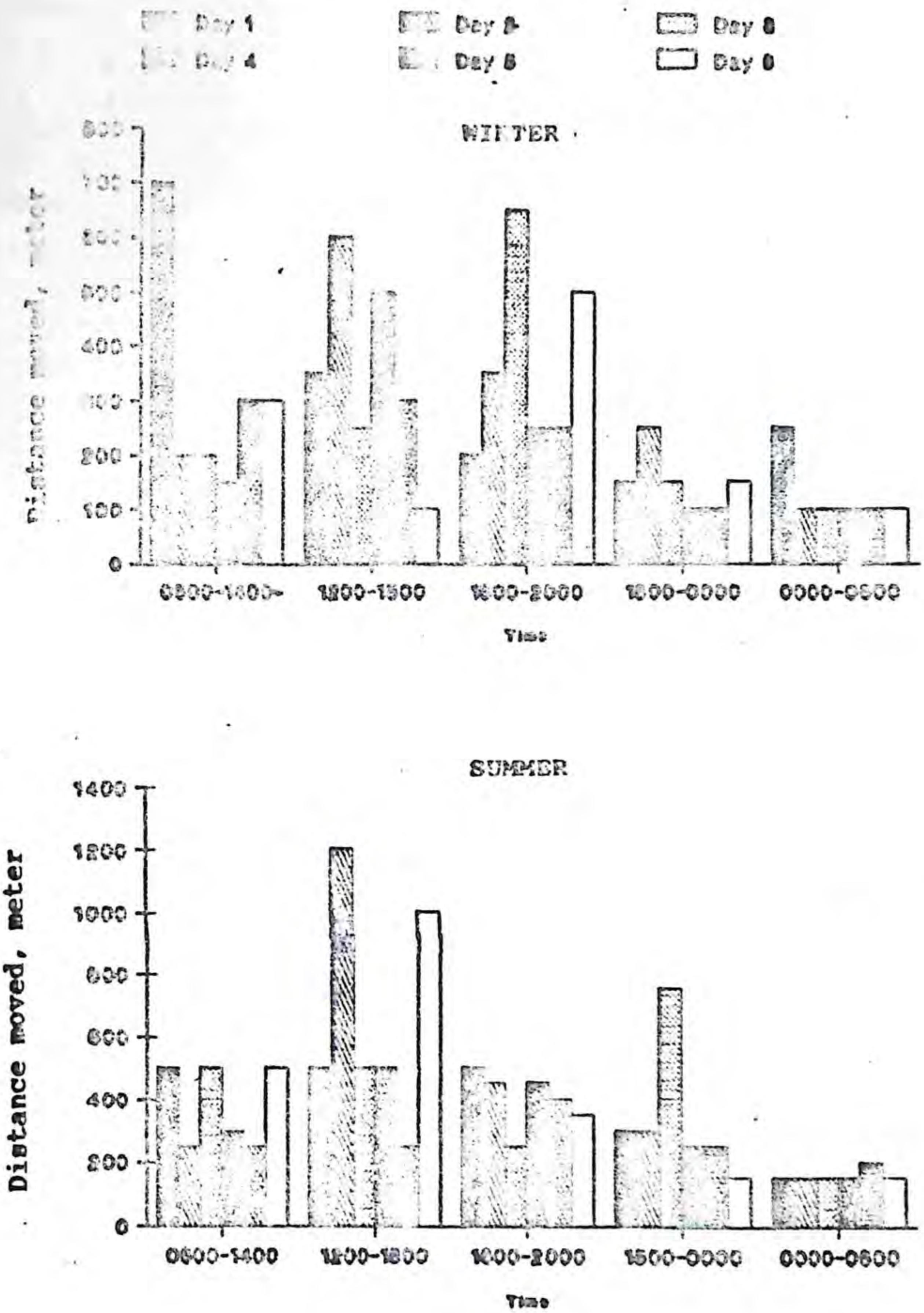
Species	WINTER		SUMMER	
	Mean (ha)	S.E.	Mean (ha)	S.E.
Nilgai	110	±34	130	±40
Chital	150	±39	130	±40
Sambar	77	±15	90	±20

Figure. 2. Day and night movement patterns of three ungulate species during winter and summer.

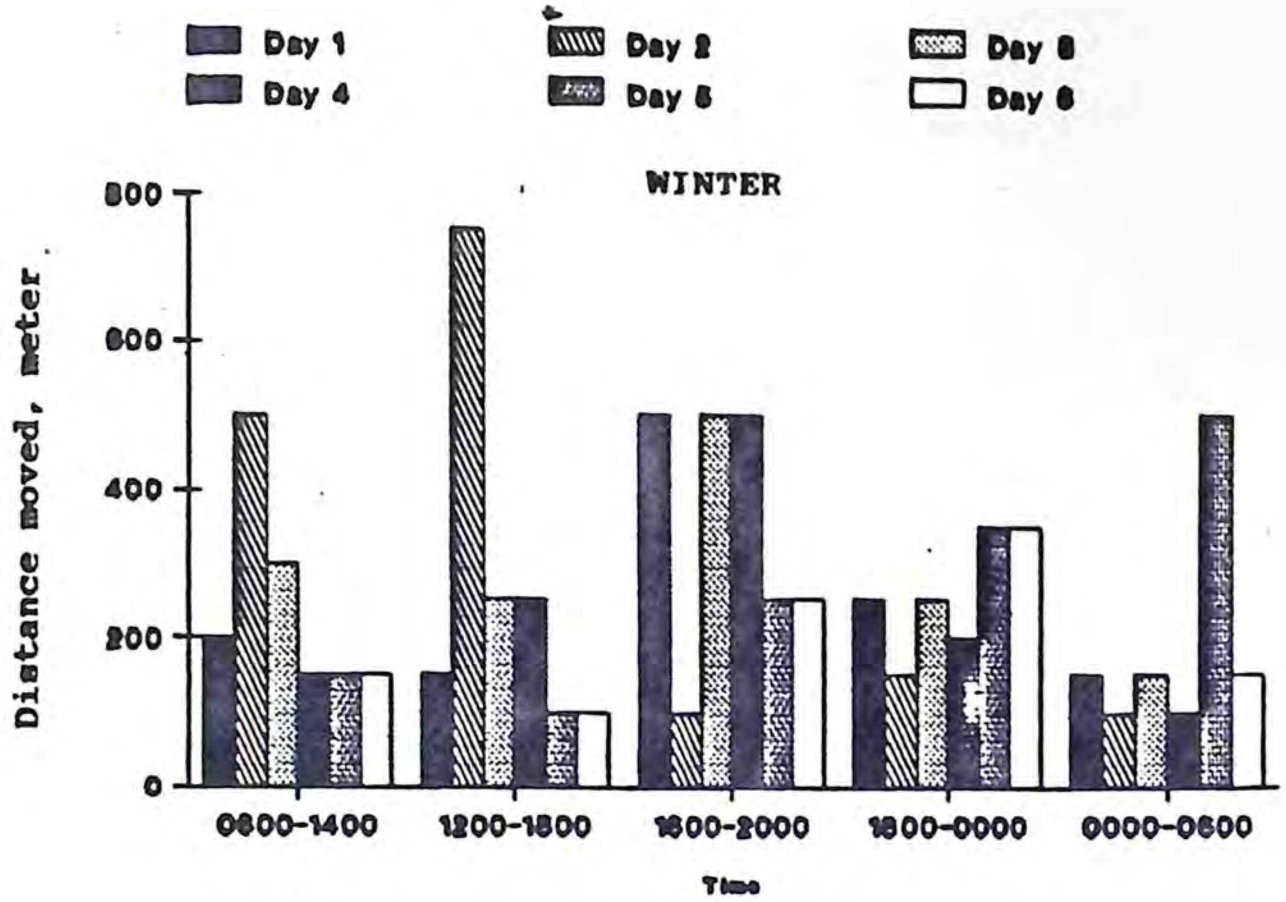
(a) NILGAI


Day 1
Day 4
WINTER
Distance moved, meter
Time
SUMMER
Distance moved, meter

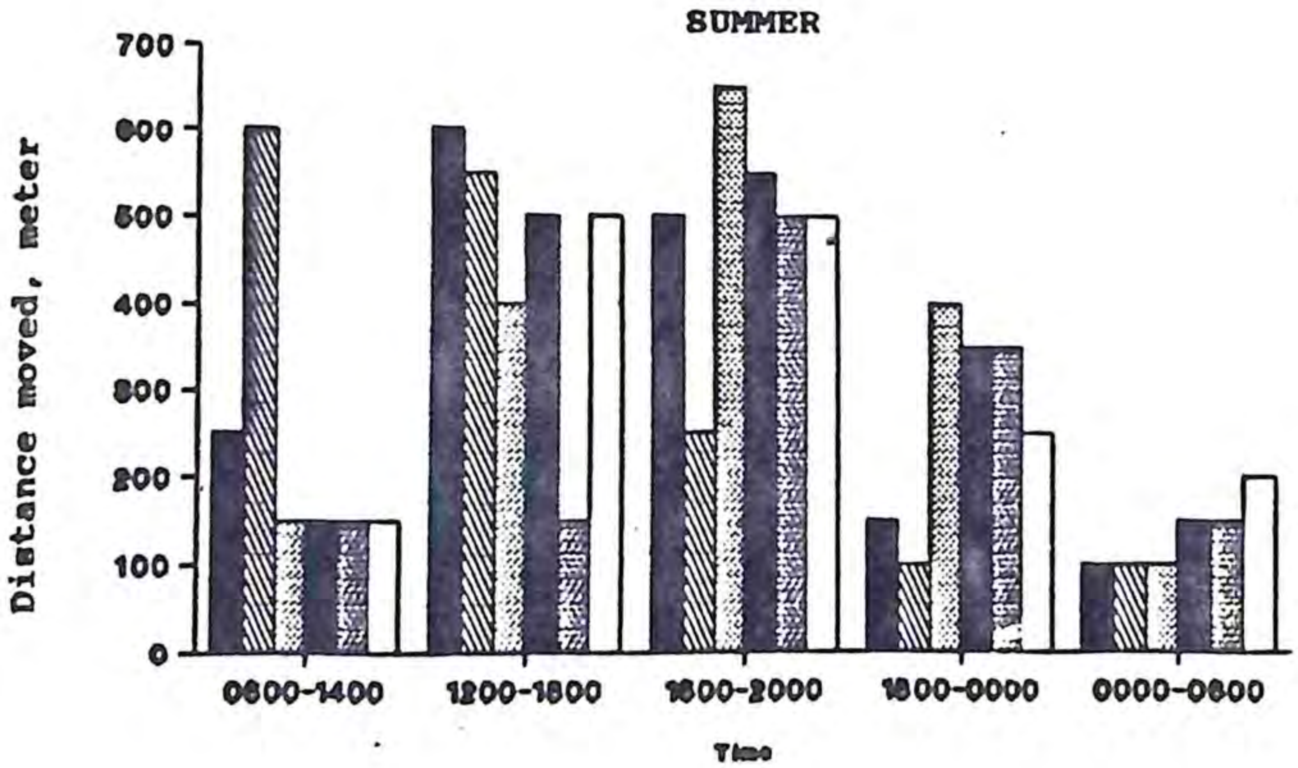
(b) CHITAL


WINTER
Time
SUMMER
Distance moved, meter
1400
1200
1000
600
400
200
0
0600-1400
0000-0600
Time

(c) SAMBAR



Day 1
Day 2
Day 4
WINTER
Distance moved, meter
400
200
0
Time



SUMMER
Distance moved, meter
700
500
400
200
100
0
Time

From the one-way analysis of variance test, nilgai didn't show any significant difference in distance moved at day or night whereas chital and sambar hinds showed significant difference (P < .001) in distance moved at day and night (Table-2).

4.2.1 Diel activity types:

Diel activity pattern - as percent active in an hour has been shown in Fig. 3. Nilgai showed uni-modal activity pattern during winter and were found more active during early morning hours (0600-0800) and during afternoon to late evening hours (1300-2200). The peak activity period was around 1800-1900 hours. During summer, nilgai was found active (>50% of an hour) throughout day except during 0200-0400 hours when the activity dropped to <40%. The peak activity periods were during 0800-0900, 1900-2000 and 0500-0600 hours.

Comparison of seasonal mean diurnal movements and mean nocturnal movements showed that nilgai was more active during day in winter and more in night during summer.

Chital showed tri modal activity patterns with peak activity periods falling around 0900-1000 hours, 0500-0700 hrs. and 0300-0400 in both season. The mean dirunal and nocturnal activity showed that chital was more active during day than at night in winter and summer.

During winter sambar was active throughout day and night without any clear cut peak activity periods except from 0300 to 0600 hrs. During summer, sambar showed bi-modal activity pattern with peaks around 0600-0700 and 1800-2000 hours. The mean diurnal movements showed that sambar were more active at night during winter and summer.

An average distance moved in a particular time interval period by all three species was strongly correlated (r = 0.85-0.95) with mean percentage activity of that period.(Table-3).

4.3 HOME RANGE:

Home range of the radio instrumented chital, sambar and nilgai hind was calculated by the minimum area method. The relationship

Table-2. 'ANOVA' between distance moved and time of the day

(a) Nilgai

Source of variation	Df	SS	MS	F ratio	F pro
Between groups	4	48916.6667	12229.1667	.7152	.585
Within groups	55	940416.667	17098.4848		
Total	59	989333.3333			

(b) Chital

Source of variation	Df	SS	MS	F ratio	F pro.
Between groups	4	458310.0000	114577.5000	5.2431	.001
Within group	55	1201908.333	21852.8788		
Total	59	1660218.333			

(c) Sambar

Source of variation	Df	SS	MS	F ratio	F pro.
Between groups	4	505583.3333	126395.8333	4.8494	.002
Within groups	55	1433541.667	26064.3939		
Total	59	1939125.00			

Table-3. Percent activity and mean distance (in metres) travelled by ungulate species.

(a) Nilgai

SEASON	TIME	DISTANCE	% ACTIVITY
Winter	0600-0800 /1200-1400	175	41.6
	1200-1400 /1600-1800	241	62.8
	1600-1800 /1800-2000	275	78.4
	1800-2000 /0000-0200	150	34.2
	0000-0200 /0400-0600	166	42
Summer	0600-0800 /1200-1400	266	51.8
	1200-1400 /1600-1800	300	65.6
	1600-1800 /1800-2000	291	64.8
	1800-2000 /0000-0200	350	79.5
	0000-0200 /0400-0600	250	42.8

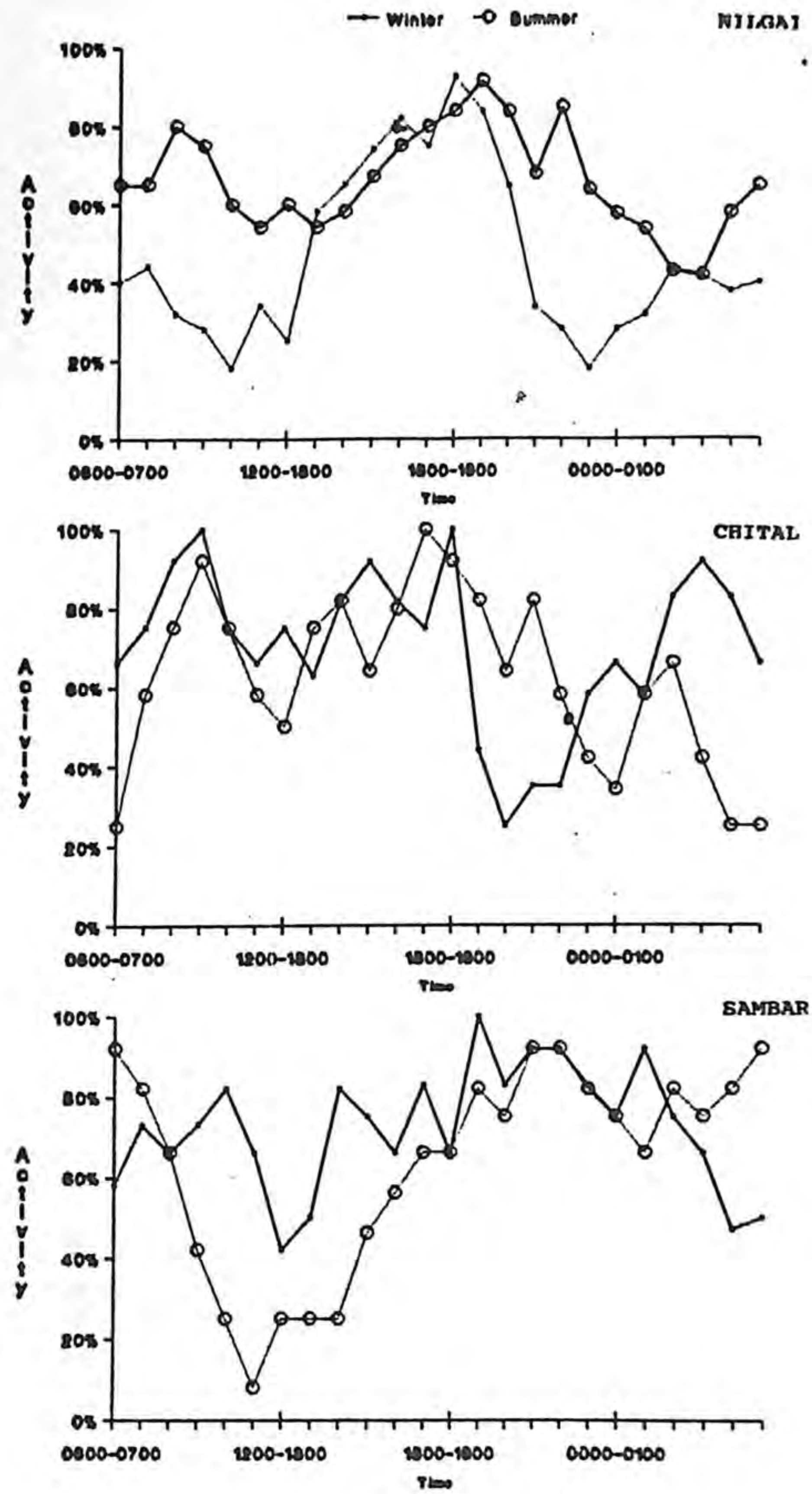
(b) Chital

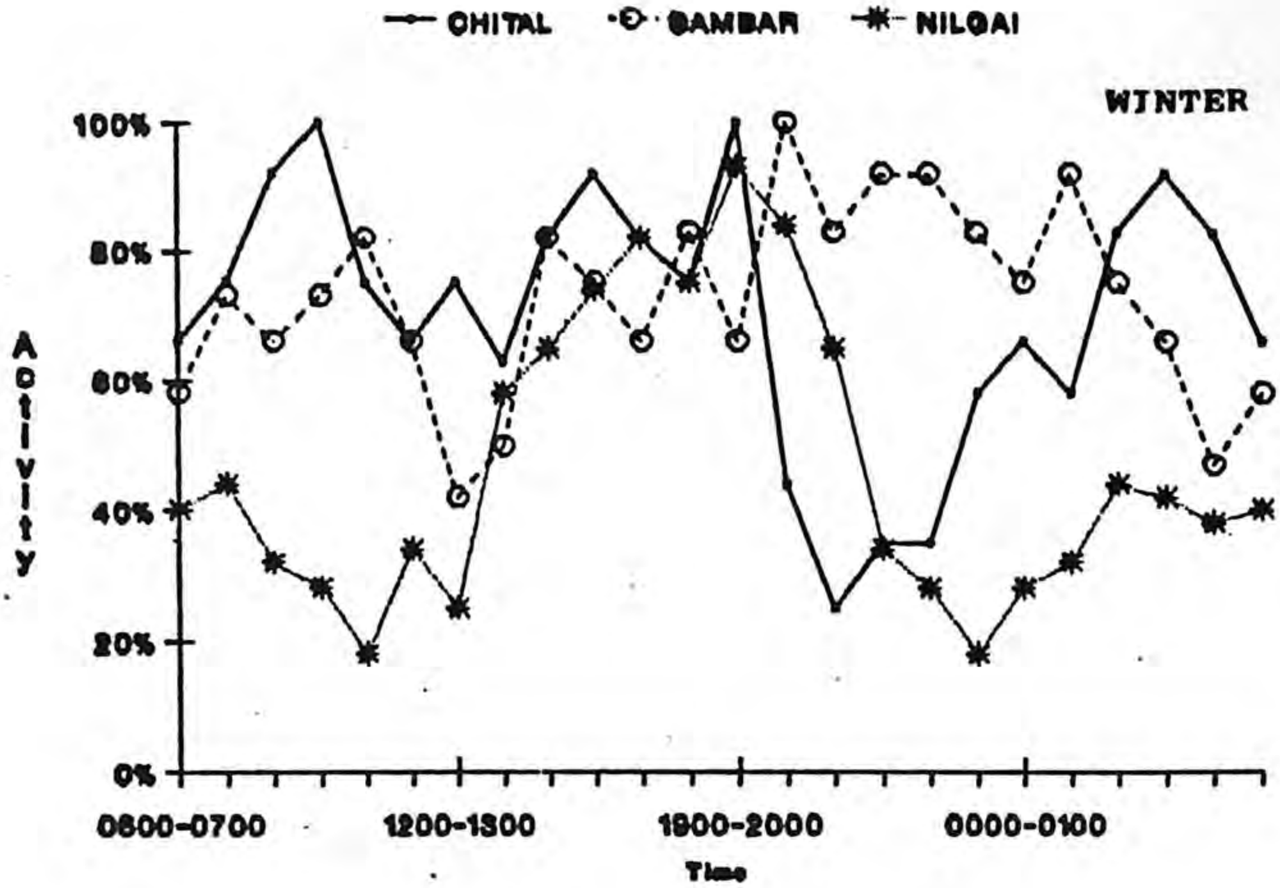
SEASON	TIME	DISTANCE	% ACTIVITY
Winter	0600-0800 /1200-1400	308	74.6
	1200-1400 /1600-1800	350	76.5
	1600-1800 /1800-2000	366	78.1
	1800-2000 /0000-0200	158	49.5
	0000-0200 /0400-0600	125	34.2
Summer	0600-0800 /1200-1400	383	70
	1200-1400 /1600-1800	508	88.5
	1600-1800 /1800-2000	400	75.1
	1800-2000 /0000-0200	333	63.5
	0000-0200 /0400-0600	158	41.5

(c) Sambar

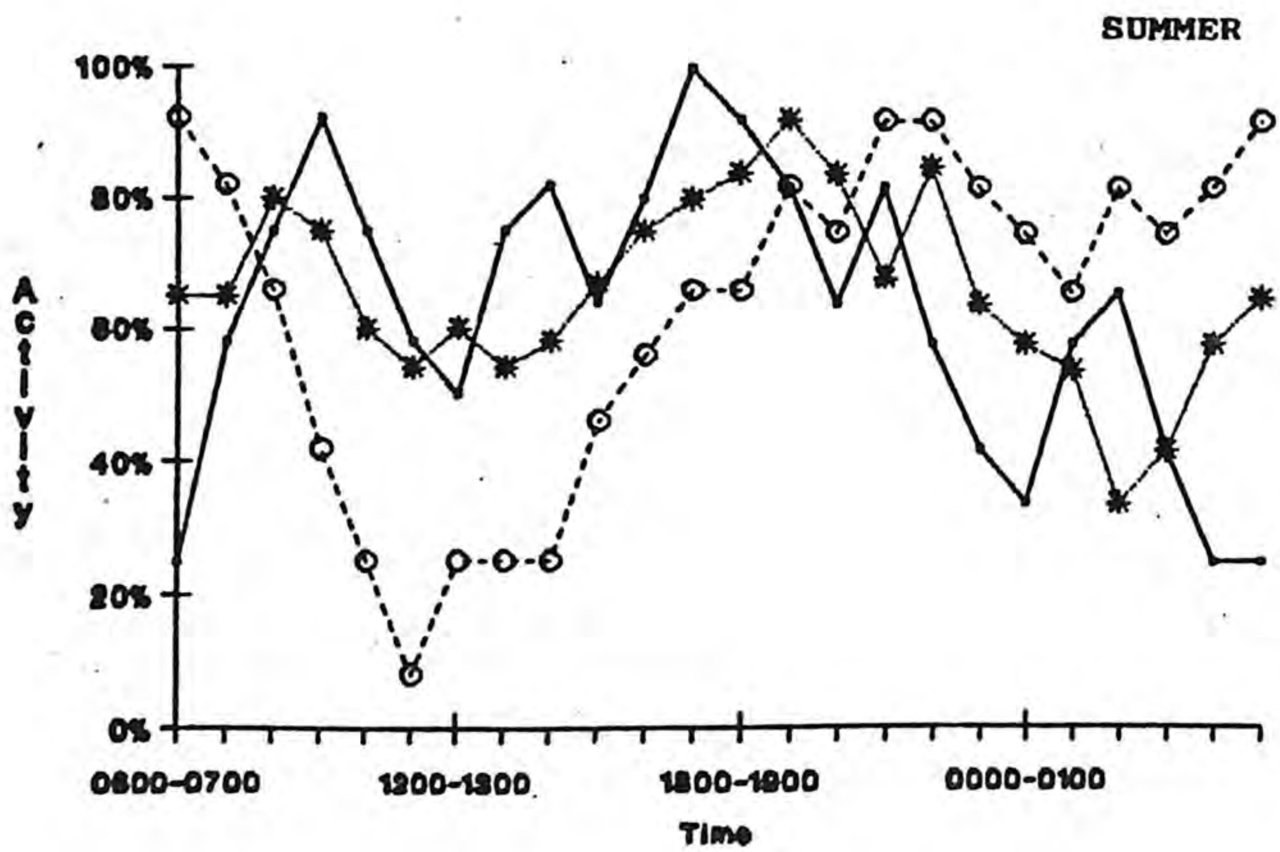
SEASON	TIME (Hrs.)	DISTANCE	% ACTIVITY
Winter	0600-0800 /1200-1400	266	63.7
	1200-1400 /1600-1800	266	66.3
	1600-1800 /1800-2000	350	86
	1800-2000 /0000-0200	258	68.8
	0000-0200 /0400-0600	191	40.5
Summer	0600-0800 /1200-1400	241	45.6
	1200-1400 /1600-1800	450	78.6
	1600-1800 /1800-2000	491	81.5
	1800-2000 /0000-0200	300	67.5
	0000-0200 /0400-0600	125	40.5

Figure 3. Diel activity pattern of three radio-collared ungulate species


Winter
Summer
NILGAI
100%
80%
60%
40%
20%
0%
Activity
0600-0700
1200-1800
1800-1900
0000-0100
Time
CHITAL
100%
80%
60%
40%
20%
0%
Activity
0600-0700
1200-1800
1800-1900
0000-0100
Time
SAMBAR
100%
80%
60%
40%
20%
0%
Activity
0600-0700
1200-1800
1800-1900
0000-0100
Time



CHITAL
SAMBAR
NILGAI
WINTER
100%
80%
60%
40%
20%
0%
Activity
0600-0700
1200-1300
1900-2000
0000-0100
Time



SUMMER
100%
80%
60%
40%
20%
0%
Activity
0600-0700
1200-1300
1800-1900
0000-0100
Time

between home range and number of locations reveal that minimum 24 locations are needed for establishing home ranges for radio collared nilgai, chital and sambar (Fig. 4).

Home range calculated on using one day and one night independent location revealed that summer home ranges of nilgai and sambar are 20-21% smaller than winter home ranges. Winter home range of chital was 18% larger in summer than in winter (Fig. 5).

Dirunal home range of nilgai in summer and winter remained almost constant whereas nocturnal home range decreased by 35% in summer than in winter. In case of chital, diurnal and nocturnal home ranges during summer were 5.25% smaller than winter. In summer sambar had a decrease of 28% in dirunal home range and 55% decrease in nocturnal home range compared to winter.

Internal structure of home range for each species has indicated that animals have not used the area randomly (Fig. 6) as most of the locations are clumped. It would mean that some areas have been used relatively more than the other in all three species during both seasons.

There was a significant seasonal home range overlap in nilgai (X^2 = 3.26, d.f. = 1, $P < 0.001$) and sambar (X^2 = 3.52, d.f. = 1, $P < 0.001$), whereas chital didn't show any significant seasonal home range overlap (Fig. 6).

4.4 Habitat use:

Habitat in which the locations were obtained were classified into vegetational classes, with indicative species (described in chapter 3, sec. 3.4).

Nilgai showed a proportional use of flat terrain in both winter and summer. *Acacia* scrub was more preferred during winter, whereas *Zizyphus numularia* scrub was preferred during summer. Nilgai has preffered the grids having 0-50 trees/ha during winter while in summer, the animal preferred grids with high tree density (50-100 trees/ha), shrub density preferred were in the classes of S2(400-600 nos/ha) and S3(600-800 nos/ha) during both seasons.

Table 4. Day and night home ranges of three ungulate species during winter and summer.

SUMMER

(a) Nilgai

TIME PERIOD	NUMBER OF LOCATIONS	AREA	% ACTUAL VALUE
0600-0800 /1200-1400	24	160	88
1200-1400 /1600-1800	21	130	72
1600-1800 /1800-2000	30	80	44
1800-2000 /0000-0200	28	90	50
0000-0200 /0400-0600	26	80	44

(b) Chital

TIME PERIOD	NUMBER OF LOCATIONS	AREA	% ACTUAL VALUE
0600-0800 /1200-1400	28	50	33
1200-1400 /1600-1800	26	90	60
1600-1800 /1800-2000	30	70	47
1800-2000 /0000-0200	28	100	67
0000-0200 /0400-0600	26	100	67

(c) Sambar

TIME PERIOD	NUMBER OF LOCATIONS	AREA	% ACTUAL VALUE
0600-0800 /1200-1400	28	100	84
1200-1400 /1600-1800	22	100	84
1600-1800 /1800-2000	28	90	76
1800-2000 /0000-0200	24	60	50
0000-0200 /0400-0600	24	30	25

(a) Nilgai

TIME PERIOD	NUMBER OF LOCATIONS	AREA	% OF ACTUAL VALUE
0600-0800 /1200-1400	28	100	60
1200-1400 /1600-1800	30	80	48
1600-1800 /1800-2000	30	90	54
1800-2000 /0000-0200	30	90	54
0000-0200 /0400-0600	26	50	30

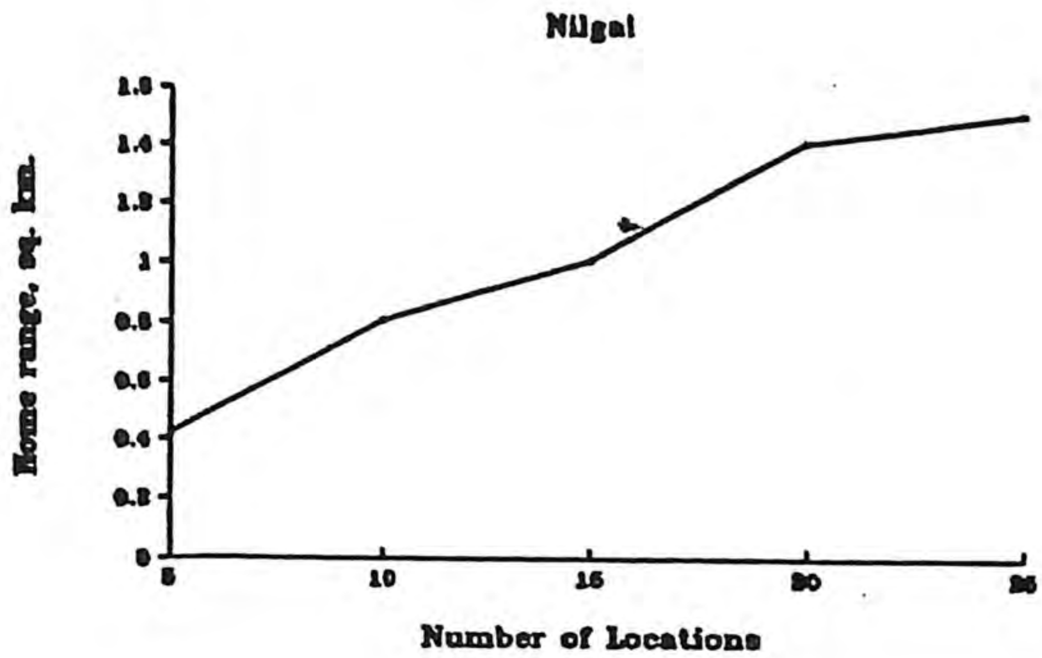
(b) Chital

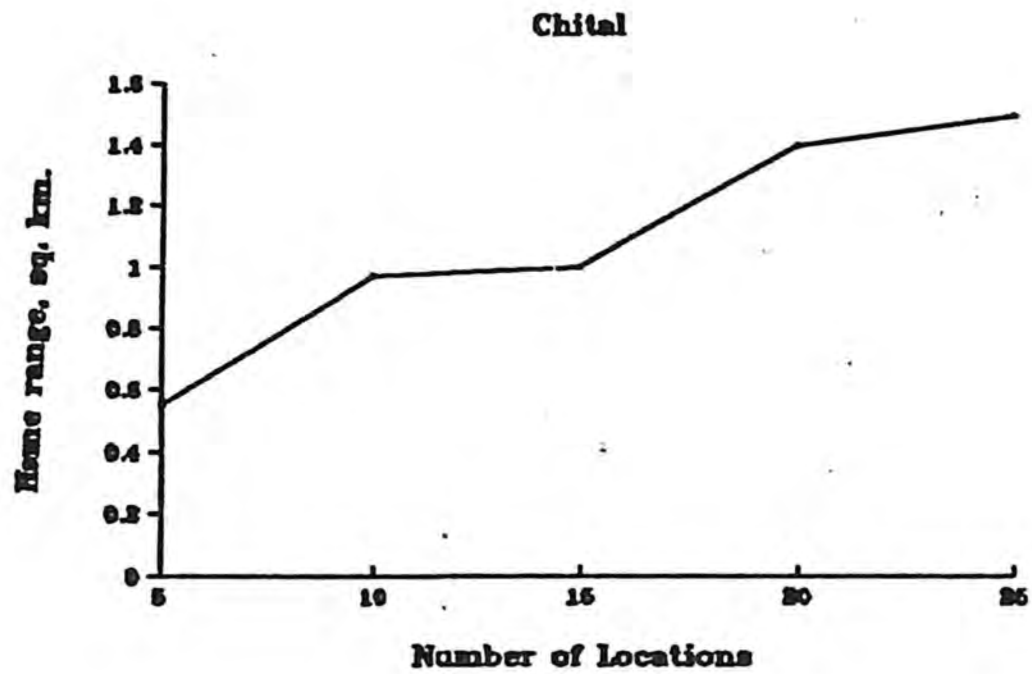
TIME PERIOD	NUMBER OF LOCATIONS	AREA	% OF ACTUAL VALUE
0600-0800 /1200-1400	24	80	53
1200-1400 /1600-1800	21	100	66
1600-1800 /1800-2000	30	90	60
1800-2000 /0000-0200	28	30	20
0000-0200 /0400-0600	26	40	26

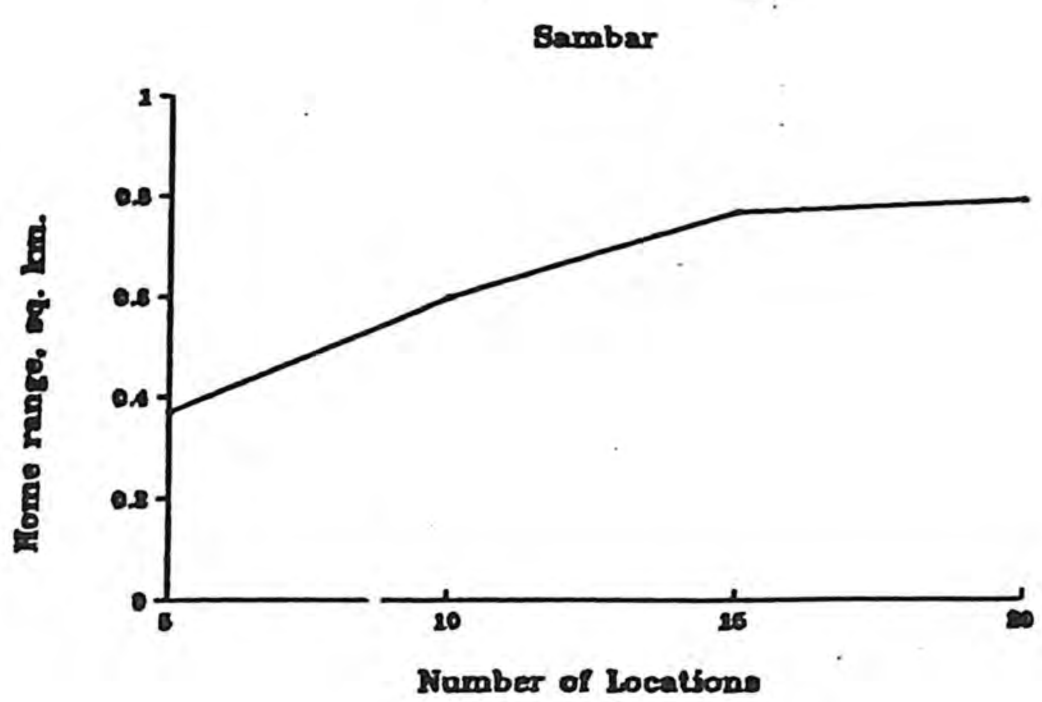
(c) Sambar

TIME PERIOD	NUMBER OF LOCATIONS	AREA	% OF ACTUAL VALUE
0600-0800 /1200-1400	28	200	70
1200-1400 /1600-1800	30	200	70
1600-1800 /1800-2000	30	90	31
1800-2000 /0000-0200	30	100	35
0000-0200 /0400-0600	26	80	28

Figure 4. Minimum sample size required to calculate home range of three ungulate species.


Nilgai
Home range, sq. km.
Number of Locations
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
5
10
15
20
25


Chital
Home range, sq. km.
Number of Locations
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
5
10
15
20
25


Sambar
Home range, sq. km.
Number of Locations
0
0.2
0.4
0.6
0.8
1
5
10
15
20

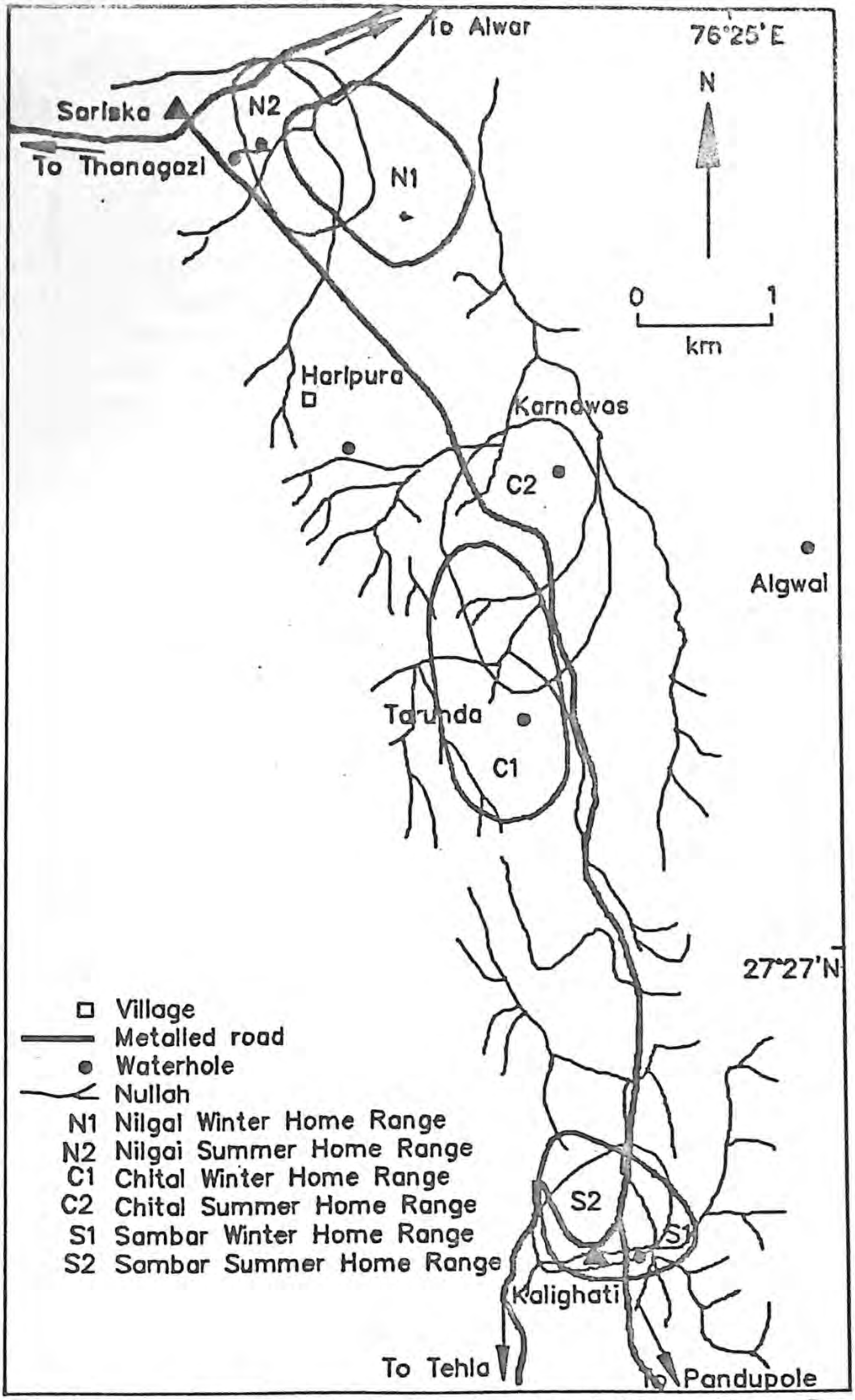


Fig.5 Map of study area showing Summer & Winter Home Range of radio-collared Nilgai, Chital and Sambar

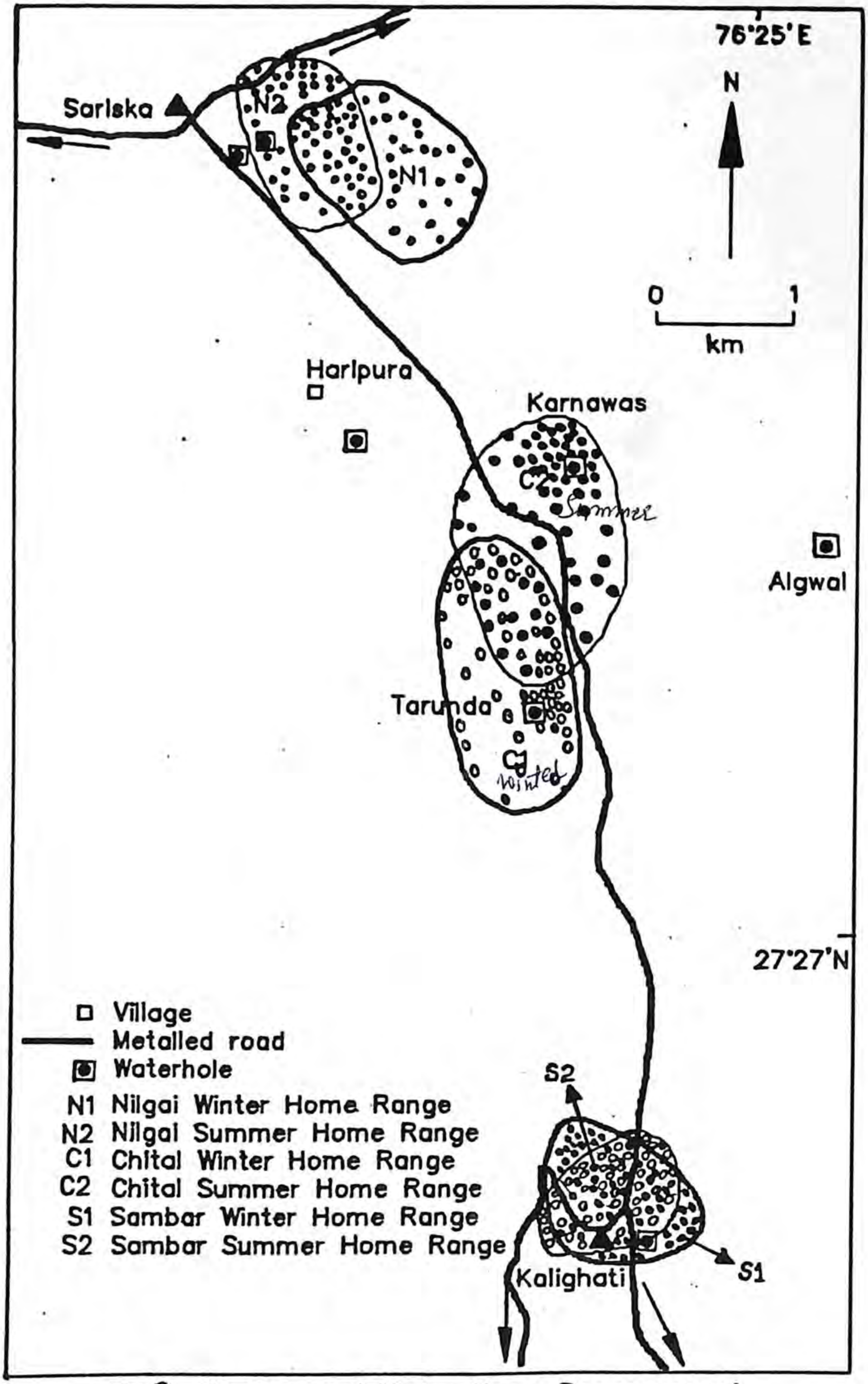


Fig.6 Summer and Winter Home Range use of radio-collard Nilgui, Chital and Sambar

Grass cover preferred was in the class of G2(25-50%) during winter, and preference was shown for H1(0-25%) class of herb cover, whereas in summer no such preference was shown for grass cover or herb cover(Table-5.a).

Chital showed preference for flat terrain in both winter and summer seaons. *Zizyphus* mixed vegetation type was preferred during the winter, whereas animal preferred *Acacia* mixed scrub during summer. Chital showed preference for the tree density of T2(50-100 trees/ha) class in winter but summer preference varied between T2(50-100 trees/ha) and T3(100-150 trees/ha) classes. There was no particular selection of shrub density class, both in winter and summer, preferred grass cover during winter was G3(50-75%) class, whereas in summer it was G2(25-50%, cover) & G3(50-75%, cover) classes. The herb classes preferred during winter was of H2 (25-50%) and H3(50-75%) class and in summer preference for H3 class was observed (Table-5.b).

Sambar showed a clear preference for the steep slopes both during the winter and summer period. In the vegetation category during winter it showed a preference for the *Anogeissus* mixed type. No such preference was shown in summer and the vegetaton was used proportionately as per availability. Preference for T5(200-250 trees/ha) and T4(250-300 trees/ha) and S1(200-400 trees/ha) class, of tree density and shrub density were observed during winter period, but in summer animal showed preference for higher tree and shrub density zones (Class T6 and Class T7) (Table 6). In grass and herb cover preference was showed towards G3(50-75) and H2(25-50), H3(50-75) in winter, and in summer G3 was prefered in the grass cover category, whereas no preference was shown towards herb cover (Table-5.c).

Table 5 (a) : Selection of habitat categories by radio-collared Nilgai in Sariska National valley of STR

Ungulate Type	Season	Terrain Type			Vegetation Type			Tree Density							Shrub Density				% Grass cover				% Herb cover			
		F	G.S.	S.S.	SAm	Sz	So	T1	T2	T3	T4	T5	T6	T7	S1	S2	S3	S4	G1	G2	G3	G4	H1	H2	H3	H4
Nilgai	Winter	*	*		+	*	-	+	*	-	-	-	-	-	*	+	+	-	*	+	*		+	*	-	-
	Summer	*			*	+	*	*	+	*	-	-	-	-	*	-	-	+	-	*	*					

Terrain Type

F = Flat terrain.
G.S. = Gentle slope.
S.S. = Steep slope.

Vegetation Type

So = Open scrub.
Sz = Zizyphus nummularia scrub
SAm = Acacia mixed scrub.

Tree Density

T1 = 0-50
T2 = 50-100
T3 = 100-150
T4 = 150-200
T5 = 200-250
T6 = 250-300
T7 = > 300

Shrub Density

S_1 = 200-400
S_2 = 400-600
S_3 = 600-800
S_4 = >800

% Grass Cover

G1 = 0-25
G2 = 25-50
G3 = 50-75
G4 = 75-100

% Herb Cover

H1 = 0-25
H2 = 25-50
H3 = 50-75
H4 = 75-100

+ = Observed use > expected use.
- = Observed use < expected use.
* = No significant difference between observed and expected use.

Table 5 (b) : Selection of habitat categories by radio collared Chital in Sariska Valley of STR

Ungulate Type	Season	Terrain Type			Vegetation Type			Tree Density							Shrub Density				% Grass cover				% Herb cover			
		F	G.S.	S.S.	SAm	Zm	Zw	T1	T2	T3	T4	T5	T6	T7	S1	S2	S3	S4	G1	G2	G3	G4	H1	H2	H3	H4
Chital	Winter	+	-		-	+	*	-	+	*	-	-	-	-	-	+	*	-	-	*	+	*	-	+	+	*
	Summer	+	*		+	*	-	-	+	+	*	-	-	-	*	+	*	*	-	+	+	-	-	*	+	*

Terrain Type

F = Flat terrain.
G.S. = Gentle slope.
S.S. = Steep slope.

Vegetation Type

Zm = Zizyphus mixed.
Zw = Zizyphus woodland.
SAm = Acacia mixed scrub.

Tree Density

T1 = 0-50
T2 = 50-100
T3 = 100-150
T4 = 150-200
T5 = 200-250
T6 = 250-300
T7 = > 300

Shrub Density

S_1 = 200-400
S_2 = 400-600
S_3 = 600-800
S_4 = >800

% Grass Cover

G1 = 0-25
G2 = 25-50
G3 = 50-75
G4 = 75-100

% Herb Cover

H1 = 0-25
H2 = 25-50
H3 = 50-75
H4 = 75-100

+ = Observed use > expected use.
- = Observed use < expected use.
* = No significant difference between observed and expected use.

Table 5 (c) : Selection of habitat categories by radio collared Sambar in Sariska Valley of STR

Ungulate Type	Season	Terrain Type			Vegetation Type			Tree Density							Shrub Density				% Grass cover				% Herb cover			
		F	G.S.	S.S.	Zm	Am	Aw	T1	T2	T3	T4	T5	T6	T7	S1	S2	S3	S4	G1	G2	G3	G4	H1	H2	H3	H4
Sambar	Winter	-	*	+	-	+	*	-	-	-	*	+	+	*	+	-	-	*	*	-	+	*	-	+	+	*
	Summer	*	-	+	*	*	-	-	-	-	*	*	+	+	-	*	+	*	-	*	+	*	*	*	*	-

Terrain Type

F = Flat terrain.
G.S. = Gentle slope.
S.S. = Steep slope.

Vegetation Type

Zm = Zizyphus mixed.
Am = Anogeissus mixed.
Aw = Anogeissus woodland.

Tree Density

T1 = 0-50
T2 = 50-100
T3 = 100-150
T4 = 150-200
T5 = 200-250
T6 = 250-300
T7 =) 300

Shrub Density

S_1 = 200-400
S_2 = 400-600
S_3 = 600-800
S_4 =)800

% Grass Cover

G1 = 0-25
G2 = 25-50
G3 = 50-75
G4 = 75-100

% Herb Cover

H1 = 0-25
H2 = 25-50
H3 = 50-75
H4 = 75-100

+ = Observed use) expected use.
- = Observed use (expected use.
* = No significant difference between observed and expected use.

CHAPTER-5

DISCUSSION

5.1 Error polygon:

Investigators who have used radio triangulation have reported on the bias and sampling error involved. Bias and precision of bearings to beacons are the most common descriptors of performance of radio tracking systems (Macdonald and Amlaner, 1980). Besides, factors such as vegetation density, distance and angle of radio instrumented animal from the antenna are the main factors affecting error (Heezen and Tester, 1967). Deat et al. (1980) found a larger error with bearings of locations in dense vegetation than with locations in open vegetation. One of the important aspect in radio triangulation is size and shape of the polygon error (Springer, 1979).

In the present study, polygon error was < 1.5 ha for all three species and did not differ seasonally. We made all possible attempts to get minimum size of polygon error by taking three compass bearings. Over 95% of the locations of radio instrumented animals in my study were within 2 kilometre of the animal, which could be the reason for small error polygons achieved in different locations (Table-1). The Dry-deciduous open vegetation of the study area would have helped in getting smaller polygon error. Radio signals were appreciably louder and clearer both during day and night in both the seasons.

One can get minimum size of polygon during triangulation, if some criteria are followed. Heezen and Tester, (1967) examined the effect of distance and angle on estimated distance moved by radio instrumented animals and found no significant effect until distances exceeded 1 1/2 miles (2 km) at a 45' angle from the baseline of the towers. Horner (1986) suggested that locations < 0.5 km should be accepted; locations 0.5-3 km should be accepted only if the angle of intersection of compass bearing are between 45' and 135' and locations > 3 km should not be used.

5.2 <u>Diel activity pattern and home range:</u>

As expected, sambar in a dry deciduous habitat was found active through out the day during winter without any particular activity pattern (Fig. 3). During summer the diurnal activity reduced drastically and showed a bi-modal activity pattern. Sambar being a forest dwelling species is seem to be more succeptible to ambient temperature fluctuation. This would probably be the reason for the bi-modal activity pattern during summer with a peak around 0600-0700 and 1800-2000 hrs, as ambient temperature goes above 40' C during day time. Shea <u>et al.</u> (1986) has reported crepuscular activity pattern for sambar in Vincent Park, Florida throughout the year.

Nilgai showed a unimodal pattern of activity during winter with a peak activity bettween 1800 hrs and 2000 hrs (Fig.4). In summer, the peak activity occured early morning (0500-0600 hrs) and evening (1900-2000 hrs). The mean diurnal and nocturnal movements showed that nilgai was more active during day in winter and at night in summer. This change in activity could be due to high day time ambient temperature.

A tri-modal peak activity was observed for chital during both the seasons, and the mean diurnal and mean nocturnal movement showed that chital was more active during day in winter as well as in summer. This may be due to it use of a habitat with a fairly closely canopy providing suitable ambient temperature for day time activity. Another factor which could have influenced its day time activity is its food habits which is discussed in a section 5.3.

A general pattern of nocturnal activity of white-tailed deer has been described by Montgomery (1963). The deer generally grazed in fields until 2400 hrs, then bedded, in fields, and became active in upper woodlands 1-2 hours before sunrise. White-tailed deer in Oklahoma moved almost exclusively at night during the summer (Ockenfels and Bissonette, 1982).

Mule deer in Washington had summer and fall day/night time activity ratios of 1/2.22 and 1/2.03 for males and females, respectively, with activity peaks between 1800 and 2000 hours during both seasons (Kammermeyer and Marchinton, 1977). A similar kind of activity was observed by Taber and Dasmann (1988) in their study on Columbian black-tailed deer (O.h. columbianus) in northern California, which fed throughout the night during summer.

It seems that all the three species in Sariska are relatively more active at night than during day in summer, as reported in other ungulate species like mule deer, white-tailed deer and black-tailed deer (Robinnette, 1966; Truett, 1972; Wallamo, 1981; Leopold and Krausman, 1987) to avoid the high ambient temperature and insolation during day time (Fig. 3).

Significant correlation was found between linear distance travelled and mean percent activity (Table-3). Similar relationship has also been reported in white-tailed deer (Montgomery, 1963; Ockenfels and Bissonette, 1982 Holzenbein and Schwede, 1988).

I report that a minimum of 25 locations were needed in establishing home ranges for radio instrumented nilgai, chital and sambar. All the three species should respond to varying resource conditions over the year as do other animals (Carpenter and MacMillen, 1976; Kodric-Brown and Brown, 1978) and this would reflected in home range size and extent of overlap between seasons. Thus shape and size of home range might probably be used as an indicator of the availability - use of resources, as suggested by the definition of Burt (1943).

Sambar and nilgai showed a significant home range overlap between the two seasons whereas the home range overlap in chital was not significant. Home range size and extent of overlap among three species were in the following order : sambar < nilgai < chital and sambar> nilgai> chital respectively.

Browse resources fluctuate less spacio-temporally than grass and herb. All three species consume browse in the order of sambar < nilgai < chital (Schaller, 1967). This might probably the reason why sambar, a browser, had the least home range size and larger range overlap than the other two species. The home range size and overlap are inversely and directly related respectively to the order of browse constituents eaten.

The concept of non-random use of a home area by an animal is not noval and clumped use within home ranges would indicate use of certain areas more than others (Fig. 6). Home range area would be underestimated if an independent location is taken during a particular time of the day (Table-4). Therefore random locations for home range calculation should be taken at different times of the day.

5.3 Habitat use:

Nilgai and chital showed a proportional use of flat terrain during both winter and summer, while sambar preferred steep slopes both the seasons (Table-5).

Differential use of terrain types by sympatric ungulates has been reported by Green (1987) during his study on Himalyan ungulates. Scogings *et al.* (1990) observed that there was a differential use of terrain types by 10 ungulate species in Jack Scott Nature Reserve, South Africa. Nilgai showed a clear preference for *Acacia* mixed scrub vegetation in winter whereas *Zizyphus numularia* scrub vegetation during summer. This might probably the reason of reduced diurnal activity periods during summer as this habitat does not have much tree cover but provide good fodder. *Zizyphus numularia* leaves are rich in nutrient contents and contain crude protien of about 12 to 14% (Goyal, unpublished data).

Chital showed distinct preference for *Zizyphus* mixed type of vegetation in winter and *Acacia* mixed scrub vegetation in summer.

Sambar had distinct preference of *Anogeissus* mixed vegetation during winter, no such preference was seen in summer (Table-5. c). This may be because sambar feed on fallen Anogeissus leaves during winter and till March.

Nilagi during winter showed a preference for a habitat Acacia mixed scrub with a low tree density class (0-50 /ha), where as in summer it was observed to prefer the habitat Zizyphus scrub with a medium tree density class (50-100 /ha). There was no difference in the selection of shrub density classes between winter and summer habitat. Preference for low grass cover was shown during winter whereas no such preference was ovserved in summer. Similarly a preference for low herb cover was observed in winter but no such preference was observed in summer. Since most of the ground layer had dried up during summer, Zizyphus nummularia scrubland was preferred which provided nutritious fooder. Nilgai showed preference for high tree density zones within this habitat possibly to avoid high summer insolation.

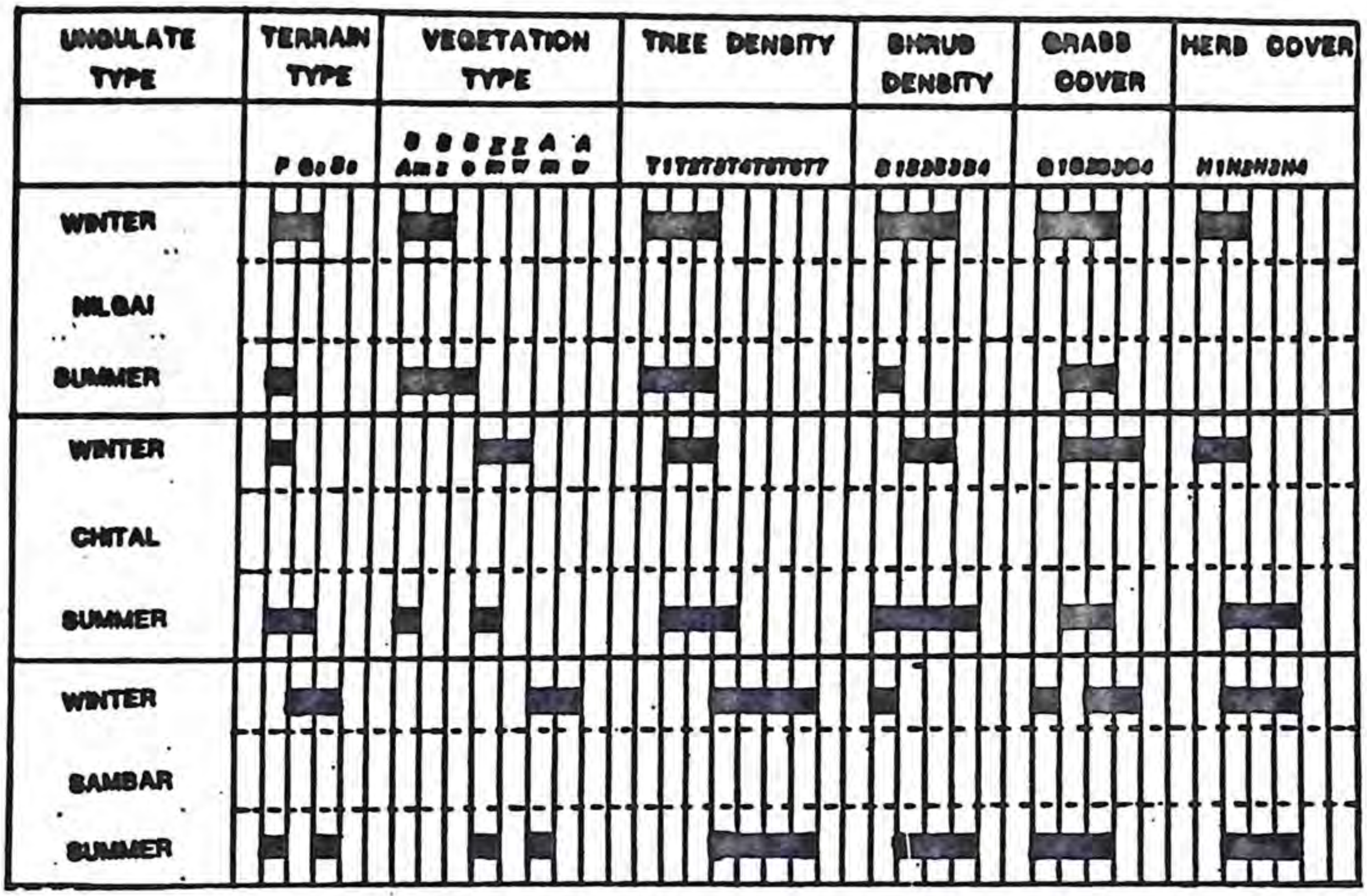
Chital preferred a habitat of zizyphus maruritiana mixed with medium tree density (50-100/ha) in winter whereas in summer it showed a preference for a habitat Acacia mixed scrub of tree density (100-150/ha) (Table-5. b). There was no preference of shrub density classes between the seasonal habitats. Medium grass cover and herb cover preference was observed in winter and summer which suggests high dependence on herbs and grasses to meet food nutrients. This might be one of the reasons why chital was active through out day and night to get the preferred food items from the sparsely distributed grasses and herbs. The reason for less seasonal home range overlap in chital could be due to selection of foraging area close to water. Water in Tarunda water hole (Fig. 5) which was located in the winter home range dried up in the first week of March. Thereafter most locations were obtained near the Karnawas water hole which is 2.5 km north-east of Tarunda. This suggests that water is one of the crucial habitat parameter for chital. Sambar is also heavily dependent upon water but a such a water related change in sambar home range was not seen as the water hole used by it (Kalighati) did not dry up.

A medium to high tree density area was preferred by sambar during both the seasons. Similarly preference for medium to high grass cover and herb cover was observed in winter and summer. Sambar's preference for heavy cover has already been recorded by Schaller (1967), Whitehead (1972) and Johnsingh (1983). Day and night habitat of sambar differed. Sambar preferred to stay in the hills during day and came down to the valley during evening hours and remained there almost through out the night. These differences could be attributed to sambars' tendency to avoid disturbed areas (valleys near roads in Sariska) in day time and seeking shelter in the relatively undisturbed hills.

The above findings indicate that the three ungulates in Sariska have the ability to use the terrain and vegetation types spatially and temporally (Fig.7). Such an adaptation would help them to share the resources without much competition if they occur in the same area. Lamprey (1963) has highlighted these features even three decades ago.

Figure 7. Habitat selection by three ungulate species

(a) Habitat use



Tree Density

T1 = 0-50
T2 = 50-100
T3 = 100-150
T4 = 150-200
T5 = 200-250
T6 = 250-300
T7 = > 300

Terrain Type

F = Flat terrain.
G.S. = Gentle slope.
S.S. = Steep slope.

% Grass Cover

G1 = 0-25
G2 = 25-50
G3 = 50-75
G4 = 75-100

Vegetation Type

So = Open scrub.
Sz = Zizyphus numularia scrub
SAm = Acacia mixed scrub.
Zm = Zizyphus mixed.
Zw = Zizyphus woodland.
SAm = Acacia mixed scrub.
Aw = Anogeissus woodland.

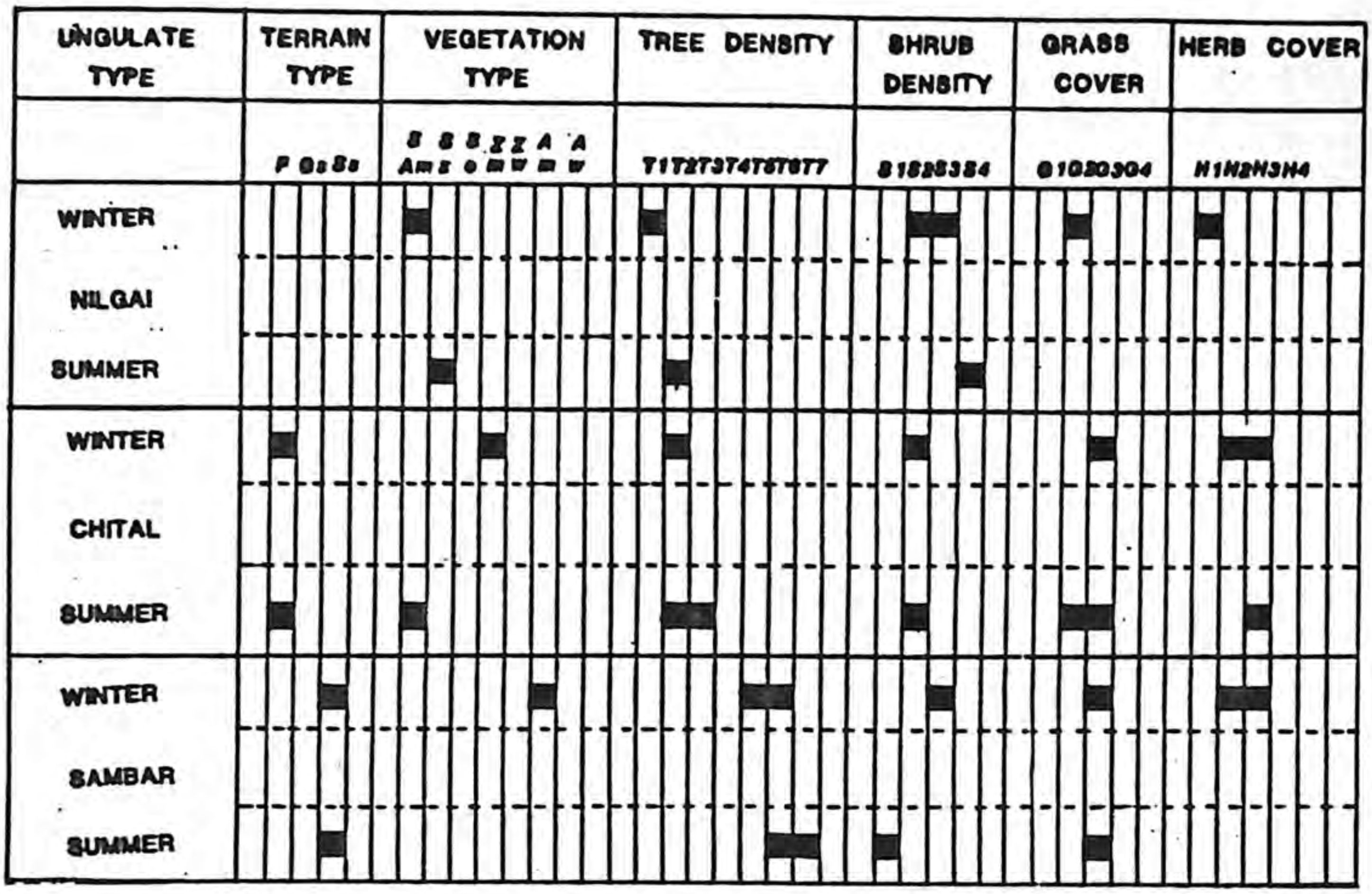
% Herb Cover

H1 = 0-25
H2 = 25-50
H3 = 50-75
H4 = 75-100

Shrub Density

S_1 = 200-400
S_2 = 400-600
S_3 = 600-800
S_4 = >800

(b) Habitat preference (Neu et al., 1974)



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Terrain Type

F = Flat terrain.
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Vegetation Type

So = Open scrub.
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H4 = 75-100

Shrub Density

S_1 = 200-400
S_2 = 400-600
S_3 = 600-800
S_4 = >800

CHAPTER 6

CONCLUSION

Minimum polygon error might be acheived by following certain guide lines just as taking bearings within two km of the animal. A minimum twenty five locations were needed to calculate the home range of all the three species.

Uni-modal activity pattern was found in nilgai and sambar during summer and winter. Sambar did not show any activity peak during winter. A tri-modal activity pattern was seen in chital during summer and winter. Reduction in dirunal activity periods of nilgai and sambar during summer suggests that both the species seem to be more susceptible to day time ambient temperature. Chital was active throughout the day during summer and winter. This might be attributed to its habit of sparsely distributed and preference of a habitat with good canopy cover.

The home range size and overlap in all the three species was related to the extent of browse species constituting the diet. Samallest home range and highest overlap in sambar might be attributed to its greater dependence on the browse.

Browse species fluctuate relatively less spatio-temporally over season than grass which constitute a major diet of chital.

Steep slopes were mostly preferred by sambar whereas, chitaland nilgai showed preference for the flat to moderate slope terrain types. Among the three species, only nilgai and chital showed preference for different vegetation types between summer and winter. Sambar preferred medium to high tree density classes in both the seasons whereas high tree density class was preferred by nilgai during summer to avoid high dirunal insolation.

All three species used resources differently and this suggest that all the three species occur in a same area, they might avoid competition by using resources spatio-temporally.

The first null hypothesis that there is use of same habitat in both the seasons was rejected except for sambar.

The second and third null hypothesis that there does not occur any change in activity during day and night and seasons, was also rejected as activity changed between day and night and seasons.

REFERENCES

Adams, L & Davis, S.D. (1967). The internal anatomy of home range. Journal of Mammalogy, 48, 529-536.

Administrative & Management plan (1989-1990). Sariska Tiger Reserve, Alwar district,Rajasthan.

Anderson, J. (1982). The home range: A new nonparametric estimation technique. Ecology, 63, 103-112.

Bailey, T.N. (1974). Social organization in a bobcat population. Journal of Wildlife Management, 38, 435-446.

Blakenship, L.H. & Field, C.R. (1972). Factors affecting the distribution of wild ungulates on a ranch in Kenya. Preliminary report. Zool. Afr, 7, 281-302.

Bouliere, F & Hadley, M. (1970). The ecology of the tropical savannahs. Annu. Rev.Ecol. Syst., 1, 125-152.

Bowen, W.D. (1982). Home range and spatial organization of coyotes in Jasper National Park, Alberta. Journal of Wildlife Management, 46, 201-206.

Burt, W.H. (1943). Territoriality and home range concepts as applied to mammals. Journal of Mammalogy, 24, 346-352.

Cairns, A.L. (1976). Distribution and food habits of moose, wapiti, deer, bison and snow shoe hare in Elk Island National Park, Alberta. M.Sc. Thesis, Univ. Calgary, Alberta, 169 pp.

Cairns, A.L. & Telfer, E.S. (1980). Habitat use by four sympatric ungulates in Boreal mixed wood forest. J. Wildlife. Management, 44, 849-857.

Calhoun, J.B. & Casby, J.U. (1958). Calculation of home range and density of small mammals. U.S. Dept. of Health, Education, and Welfare, Public Health Monograph No.55.

Carpenter, F.L. & MacMillen, R.E. (1976). Threshold model of feeding territoriality and test with a Hawaiian honeycreeper. Science, 194, 634-642.

Champion, H.G. & S.K. Seth (1968). The forest types of India. pp.404.

Clutton-Brock, T. H; Guinness, F.E. & Alben, S.D. (1982). Red Deer: Behavior and Ecology of Two sexes. Edinburg Univ. Press, Edinburg.

Cooper, W.E. (1978). Home range criteria based on temporal stability of areal occupation. Journal of Theoretical Biology, 73, 687-695.

Deat, A., Mauget, R., Maurel, D. & Sempere, A. (1980). The automatic, continuous fixed radio tracking system of the Chize forest. In C.J. Amlaner and D.W.Macdonald, editors. A handbook on biotelemetry and radio tracking. Permagon Press, Oxford.

Dunn, J. & Gipson, P. (1977). Analysis of radio telemetry data in studies of home range. Biometrics, 33, 85-101.

Field, C.R & Laws, R.M. (1978). The distribution of the larger herbivores in the Queen Elizabeth National Park, Uganda. J. Appl. Ecol.7, 273-294.

Flynn, L.B; Shea, S.M; Leeis, J.C. and Marchintan, R.L. (1990). population status, health and habitat use. In Ecology of Sambar deer on st. Vincent National Wildlife Refuge, florida. Bulletin No. 25. Tall timber research station, Talloahassee, Florida. 63-96 N.

Ford, R.G. & Krumme, D.W. (1979). The analysis of space use patterns. Journal of Theoretical Biology, 76, 125-155.

Garshelis, D.L.; Quigley, H.B.; Villarubia, C.R. & Pelton, M.R. (1982). Assessment of telemetric sensors of motion sensors for activity. Can. J. Zoo. 60:1800-1805.

Georgii, B. (1980). Home range patterns of female red deer (Cervus elaphus.L) in the Alps. Oecologia (Berlin), 47, 278-285.

Green, M.J.B. (1987). Ecological separation in Himalayan ungulates. Journal. Zoology. London, 1, 693-719.

Harris, S; Cresswell, W.J; Forde, P.G; Trewhella, W.J; Woollard, T & Wray, S (1990). Home-range analysis using radio-tracking data- review of problems and techniques particularly as applied to the study of mammals. Mammal Rev., 20,97-123.

Hayne, D. (1949). Calculation of size of home range. Journal of Mammalogy, 30, 1-18.

Heezen, K.L. & Tester, J.R. (1967). Evaluation of radio tracking by triangulation with special reference to deer movements. Journal of Wildlife Management, 31, 124-141.

Hirst, S.M. (1975). Ungulate habitat relationship in a South African woodland/savanna ecosystem. Wildlife Monograph. 44, 60pp.

Holzenbein, S & Schwede, G. (1988). Activity and movement of female white-tailed deer during rut. Journal of wildlife management, 53.219-223.

Horner, M.A & Powell, R.A. (1990). Internal structure of home range of Black bears and analysis of home range overlap. Journal of Mammology, 71(3), 402-410.

Inglis, J.M., Sittler, O.D. & Kirby, J.D.(1968). A fixed station radio tracking system. Southwestern Naturalist, 13, 433-443.

Jaremovic, R.V. & Croft, D.B. (1987). Comparison of techniques to determine eastern grey Kangaroo home range. Journal, of wildlife.Management: 51, 921-930.

Jarman, P.J. (1974). The social organization of antelope in relation to their ecology. Behavior-XLVIII-3-4 215-267.

Jennrich, R.I. & Turner, F.B. (1969). Measurement of non-circular home range. Journal Theoretical Biology, 22, 227-237.

Jewell, P.A. (1966). The concept of home range in mammals. Symposium of the Zoological Society of London, 18, 85-109.

Johnsingh, A.J.T. (1983). Large mammalian prey predators in Bandipur. Journal of Bombay Natural, History, Society, 80(1),1-57.

Johnson, D.H (1980). The comparison of usage and availability measurements for evaluation of resource preference, Ecology 61, 65-71.

Jones, E.N. (1983). A comparison of meadow vale home ranges derived from grid trapping and radio telemetry. Journal of wildlife Management, 47, 558-561.

Kammermeyer, K.F & Marchinton, R.Z. (1977). Seasonal change in circadian activity of radio monitored deer. Journal of wildlife Management, 41, 315-317.

Kelton, S.D. (1981). Biology of sambar deer (Cervus unicolor Kerr, 1792) in New Zealand with particular reference to diet in a Manuwata flax swamp. Master's Thesis, Massey University, Palmerston North, New Zealand.

Kenward, R. (1987). Wildlife Radio Tagging: Equipment, Field Techniques and Data Analysis. Academic Press, London.

Klopfer, P.A. (1969). Habitats and territories. Basic Books, New York, N.Y. 117pp.

Kodric-Brown, A & Brown, J.H. (1978). Influence of economics, interspecific competition, and sexual dimorphism on territoriality of migrant rufos humming birds. Ecology, 59,285-296.

Koeppl, J.W. Slade, N.A. & Hoffmann, R.S. (1975). A bivariate home range model with possible application to ethnological data analysis. Journal of Mammalogy, 56, 81-90.

Kurz, J.C. & Marchinton, R.C. (1972). Radiotelemetry studies of feral hogs in South Carolina. Journal of Wildlife Management, 36, 1240-1248.

Lack, D. (1983). Habitat selection in birds with special reference to the effects of afforestation on the Breckland avifauna. Journal of Animal Ecology, 2, 239-262.

Lamprey, H.F. (1963). Ecological separation of the large mammal species in Tarangire Game Reserve, Tanganyiaka. East African wildlife Journal, 1:1-30.

Leopold, B.D & Krausman, P.R. (1987). Dirunal activity of desert mule deer in relation to temperatures. Texas Journal of Science 39,49- 53.

MacArthur, R.H.; MacArthur, J.W & Preer, J. (1962). On bird species diversity. II, Predictions of bird census from habitat measurements. American Naturalist, 96,167-174.

Macdonald, D.W., Ball, F.G. & Hough, N.G. (1980). The evaluation of home range size and configuration using radio tracking data. In C.J. Amlaner and D.W. Macdonald, editors. A handbook on biotelemetry and radio tracking. Pergamon Press, Oxford.

Macdonald, D.W. & Amlaner, C.J. (1980). A practical guide to radio tracking. In C.J. Amlaner and D.W. Macdonald, editors. A handbook on biotelemetry and radio tracking. Pergamon Press, Oxford.

Marcum, C.L. & Loftsgaarden, D.O. (1980). A non-mapping technique for studying habitat preferences. Journal of wildlife Management, 44, 963-968.

Martinka, C.J.(1968). Habitat relationships of white tailed and mule deer in northern Montana. J. wildlife Management, 32, 558-565.

Martinsen, D.L. (1968). Temporal patterns in the home ranges of chipmunks, (Eutamias). Journal of Mammalogy, 49, 83-91.

Mazurkiewicz, M. (1969). Elliptical modification of the home range pattern. Bulletin de L'Academie Polonaise des Sciences, 17, 427-431.

Mazurkiewicz, M. (1971). Shape, size and distribution of home ranges of Clethrionomyz glareolus (Schreber, 1780). Acta Theriologica, 16, 23-60.

Mills, M.G.L. & Gorman, M.L. (1987). The scent marking behavior of the spotted hyena (Crocuta crocuta) in the southern Kalahari. Journal of Zoology, 212-483-497.

Mohr, C.O. (1947). Table of equivalent populations of North American small mammals. American Midland Naturalist, 37, 223-249.

Mohr, C.O. & Stumpf, W.A. (1966). Comparison of methods for calculating areas of animal activity. Journal of Wildlife Management, 30, 293-304.

Montgomery, G.G. (1963). Nocturnal movements and activity rhythms of white tailed deer. Journal of wildlife Management. 27, 422-427.

Neu, C.W; Byers, C.R; Peck, J.M. & Boy, V (1974). A technique for analysis of utilization - availability data. Journal of Wildlife Management. 38, 541-545.

Ockenfels, R.A. & Bissonette, J.A. (1982). Estimate of white tailed deer activity levels in Oklahoma, Proceedings Annual South East Association. Game Fish Agencies, 36, 445-453.

Orday, L.L. (1985). Habitat use by desert mule deer. M.S. thesis. Univ. Arizona, Tucson, 32 pp.

Parmar, P.J. (1985). A contribution to the flora of Sariska Tiger Reserve, Alwar district, Rajasthan. Bulletine. Bot Survey., India, 27, 29-40.

Rasmussen, D.R. & Rasmussen, K.L. (1979). Social ecology of adult males in a confined troop of Japanese macaques (Macaca fuscata). Animal Behavior, 27, 434-445.

Robinette, W.L. (1966). Mule deer home range and dispersal in Utah. Journal of Wildlife Management, 30, 335-339

Rongstad, O.J & Tester, J.R. (1969). Movements and habitat use of white-tailed deer in Minnesota. Journal of Wildlife Management. 33,366-379.

Sanderson, G.C. (1966). The study of mammal movements-a review. Journal of Wildlife Management, 30, 215-235.

Schaller, G.B. (1967). The deer and the Tiger. Univ of Chicago Press. Illinois.

Schweinsburg, R.E. (1971). Home range, movements, and herd integrity of the collared peccary. Journal of Wildlife Management, 35, 455-460.

Scogings, P.F.; Theron, G.K. & Bothma, J.U.P. (1990). Two quantitative methods of analyzing ungulate data. South African Journal of Wildlife Research, 20(1), 9-13.

Seton, E.T. (1909). Life-histories of northerh animals....Charles X's Sons, New York.

Sevheen, C. (1983). Grizzly bear food habits, movements, and habitat selection in the Mission mountains, Montana. Journal wildlife management, 47: 1026-1035.

Shea, S.M (1986). The ecology of sambar deer, social behavior, movement ecology, and food habits. Master's Thesis, Univ. of Georgia, Athens.

Shea, S.M.; Flynn, B.L; Marchinton, R.L. & Lewis, J.C. (1990). Social behavior, movement ecology, and food habits. In Ecology of Sambar deer on St. Vincent national Wildlife Refuge, Florida. Bulletin no.25, Tall timbers research station tallahesse, Florida.

Sokal, R.R. & Rohlf, F.J. (1981). Biometry 2nd ed. Freeman, San Francisco, CA. 859pp.

Southwood, T.R.E. (1966). Ecological Methods. Methuen, London, United Kingdom.

Springer, J.T. (1979). Some sources of bias and sampling error in radio triangulation. Journal of Wildlife Management , 43, 926-935.

Stickel, L.F. (1954). A comparison of certain methods of measuring ranges of small mammals. Journal of Mammalogy, 35, 1-15.

Stumpf, W.A. & Mohr, G.O. (1962). Linearity of home range of California mice and other animals. Journal of Wildlife Management, 26, 149-154.

Tester, J.R. & Siniff, D.B. (1965). Aspects of animal movement and home range data obtained by telemetry. Transactions of the North American Wildlife and Natural Resources Conference, 30, 379-392.

Taber, R. D. and Dasmann, R.R. (1958). The black tailed deer of the chaparral. Its life history and management in the North Cost Range of California. Calif. Dept. Fish and Game bull. 8.

Truett, J.C. (1972). Ecology of desert mule deer (Odocoileus heminous crooki) in southeast Arizona, Ph.D. Thesis, Univ. Arizona, Tucson 66 pp.

Van Winkle, W. (1975). Comparison of several probabilistic home-range models. Journal of Wildlife Management, 39, 118-123.

Voigt, D.R. & Tinline, R.R. (1980). Strategies for analyzing radio tracking data. In C.J. Amlaner and D.W. Macdonald, editors. A handbook on biotelemetry and radio tracking. Pergamon Press, Oxford.

Wallmo, O.C. (1981). Mule and black-tailed deer distribution and habitats. In O.C. Wallmo ed. Mule and black-tailed deer of North America. Univ. Nebraska press, Lincoln.

Western, D. (1973). The structure, dynamics and changes of the Amboseli ecosystem Ph.D. Dissertation. Univ. Nairobi, Kenya, 222pp.

White, G.R. & Garrdt, R.A. (1990). Analysis of Radio Tracking data. Academic Press, New York.

Whitehead, G.K. (1972). Deer of the world. Constable and Co. Ltd., London, U.K.

Whiteside, R.W. and Guthery, F.S. (1983). Ring necked pheasant movement home range, and habitat use in west Taxas. Journal of wildlife management.47: 1097-1104.

Wolton, R.J. (1982). The social ecology of the wood mouse (Apodemus sylvaticus). Ph.D. thesis, Univ. of Aberdeen.

Worton, B.J. (1987). A review of models of home range for animal movement. Ecological modelling, 38, 277-298.