

**DENSITY RELATED BEHAVIOUR OF SELECT
UNGULATE SPECIES IN FOUR ZOOS OF SOUTHERN
INDIA**

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

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JUNE 2003**

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1. INTRODUCTION

1.1. General introduction

Zoos with the responsibility of *ex-situ* conservation of wildlife are striving to meet as much as of the ecological and biological needs of the species in their exhibit. In spite of all the efforts being put forth, zoos face a lot of criticism in the upkeep of animals. One of the major problems in most Indian zoos (as per the CZA guidelines) are the surplus number of individuals of certain species. Though this has been much debated upon, very little work has been done in this regard (Annon, 1999; Ganslober 1995).

Before dealing with the problem at hand, the first step in addressing the surplus problem is to define the terms by which an animal acquires this status. Zoos can then begin to systematically identify the problem's dimensions. No one really knows what number of individuals of a species is involved, or how they change from year to year. Allocation of precious space to animals that are no longer essential to breeding and the cost required for breeding add on to the already minimal budgetary of zoos. Currently, zoos face, the problem of indiscriminate breeding of animals that ends up as surplus to their space availability. Accidental pregnancies, inadvertent breeding of hybrids, and the birth of congenitally disadvantaged individuals lead to surplus animals in a zoo (Anon 1999).

Surplus problem is most often seen in large carnivores, primate and ungulates. Though studies have been conducted on carnivores and primates, not many studies, however, have been carried out on density related behaviour and

the management problems on ungulate species in Indian zoos. Consequently it is essential to address the problem for developing an alternative to the ongoing crisis in Indian zoos.

The target species for the present study were chital (*Axis axis*), blackbuck (*Antelope cervicapra*) and sambar (*Cervus unicolor*). The stock book of ungulates (Inventory of animals of CZA, 1999-200, 2000-2001) by itself reflects the surplus of these three species housed in almost all the Indian zoos. Most of the zoos struggling with the constraint of finance do not have any increase in area while face with increase in number of individuals each year (Bettinger 1994; Goosen, 1999). As a consequence of increased densities, some species show more aggressiveness than their free ranging conspecifics (Anon 1994). In certain species, territoriality in a constricted space further leads to infighting (Stine *et al.* 1982). Hence, the size of the enclosure housing a particular number of individuals of a single or a variety of species needs thorough consideration. The management of these species needs special attention to minimise the chances of aggression related injuries, disease prevalence, fight for accessibility to food, space and females.

A study on the behavioural pattern of these species is highly needed at this stage when the importance of these species has been overshadowed by the charismatic species. The social behaviour of these species in the wild would be considered as normal behavior of the group. The study was taken up to reflect if the density of these three species in an enclosure is likely to have any effect on their behaviour.

1.2. Review of literature

Chital (*Axis axis*), black buck (*Antelope cervicapra*) and sambar (*Cervus unicolor*) are maintained in almost all the zoos of the country (Inventory of animals of CZA, 1999-200, 2000-2001). But the prolific rate at which the three species breed is creating a concern for their effective management (CZA guidelines, Inventory of animals of CZA, 1999-2000, 2000-2001). Though the studies of these species in the wild are numerous (Schaller, 1967; Russ 1970; Chaplin, 1977; Mungall, 1978; Krishnan, 1982; Dougherty, 1982; Krishnan, 1984; Wemmer, 1987; Bhatnagar, 1991; Chakrabarty, 1991; Mungall, 1994; Sankar 1994; Raman *et al.*, 1995; Raman *et al.*, 1996), to name a few not many studies have been conducted on them under captive conditions (Paulraj and Naidu, 1987). Studies have recorded the behaviour of animals to differ in captive conditions (Bennett, 1983).

1.2.1. Hierarchy

Among mammals there is usually an increased frequency of aggressive interactions when the population density increases both in wild and in captivity (Nieuwenhuijsen, 1982; Patton, *et al*, 2001). The general behaviour of males in this respect follows a typical pattern (Schaaf, 1984; Enciso *et al.* 1999): larger individuals dominate smaller ones, and older individuals dominate younger ones, unless the physical condition of the older individuals hinders their capability to do so. Among ungulates it has been documented that hard-antlered males normally dominate those with velvet antlers (Huntingford, 1984). Ranjit Singh (1989) recorded the horn size, colour and age to be major factors in the determination of

inter-se male hierarchy in mixed group. In black buck, males with larger horns and lighter pelage than the dominant male accept a lower status to that of dominant male. Apart from their size, the shapes and type of horns and antler helps the establishment of preeminence in social hierarchy. In both chital and sambar, a wide spread antler is an advantage but only amongst males of the same antler size class.

Studies on black bucks in wild have corroborated that after adult and subadult males, the adult females are next in hierarchy followed by yearlings and lastly the fawns (Schaller, 1967; Mungall, 1978; Ranjitsinh 1989). In chital and sambar, the adult males hold the social apex followed by adult females, subadult males, subadult females and then by the fawns. Agonistic behaviour in females is not as pronounced as in males (Ranjitsigh, 1989). But, aggressive behaviour within females or that between females and males were nonetheless, aggravated by increased density within their enclosures (Ables *et al.*, 1978; Zucker, 1987).

Aggressive behaviour of an individual, in general, is related to several factors like restricted space (Nieuwenhuijsen, 1982; Goff, 1994; Casinello and Pieters 2000), increased group size or group densities (Hutchins *et al.*, 1991), dispute over food (Popp 1984), competition for space (Duce and Brannian 1990) and access to females during mating (Munagall, 1978). For example, Casinello and Pieters (2000) found that, in captive male dama gazelles (*Gazella dama mhorr*) social ranks were determined by age. Smaller enclosures are generally associated with a higher rate of aggression and a higher rate of interactions between individuals (Casinello and Pieters 2000). In a study of tree kangaroos,

females directed more aggression towards males than towards other females, contrary to their behaviour in the wild (Hutchins *et al.*, 1991). Even the Bolivian squirrel monkey (*Saimiri boliviensis*) followed a similar pattern (Williams and Abee 1988) under captivity. In direct contrast to these studies however, Nieuweonhuijsen (1982) found no increase in the intensity of aggressive acts due to crowding. Instead, submissiveness increased during crowded periods. This possibly had the effect of counteracting the increase of aggressiveness and perhaps the behaviour is used to regulate aggression (Patton, *et al* 2001).

1.2.2. Activity pattern

Several studies have examined the activity patterns of different species in captivity but none have directly documented that of these ungulate species. Stoinski *et al.* (2001) for example examined the behavioural profiles of two captive male gorilla groups in Atlanta and Santa Barbara zoos and found no significant change in the overall social behaviour between the two groups. Studies in the wild have shown that the feeding activity peaks during early morning and late evening hours. When the day is cooler resting peaks around midday, which is the hottest part of the day. (Schaller, 1967).

1.2.3. Visitor Influence

The presence of visitors *per se* has been shown to affect the behavioural repertoire of several mammalian species in captivity (Thompson, 1989; Mallapur, 1999). The interaction of these species with visitor, however vary, depending on several factors like design of the enclosure (Wood 1998), type of species involved (Marcellini and Jensen, 1988), environmental influences, the activity of

visitors (Chamove *et al.*, 1988), the time spent by the visitor in front of the enclosure (Price *et al.* 1994) and the location of the cage (Mitchell *et al.*, 1990) in the zoo.

1.3. Objectives

1. To determine the relationship between density of individuals and different behavioural responses.
 - (i) Is the activity pattern of animals influenced by density?
 - (ii) Is the pattern of aggressive behaviour influenced by density?
 - (iii) Is the activity pattern of the species influenced by the presence of visitors?
 - (iv) Is the hierarchical order among the sexes influenced by density?

2. To examine the level of accessibility to food by different age-sex class
 - (i) Does dominance play a role in accessing the food?

2. STUDY AREA

The zoos selected for the study were Chamarajendra Zoological Garden in Mysore, Arignar Anna Zoological Park in Chennai, Nehru Zoological Park in Hyderabad and Indira Gandhi Zoological Park in Vizag (Fig. 2.0). The selection was based on the logistic ease with which this study can be conducted here, given the short time frame. These four zoos provided a varied range of densities of the target species under study. Besides, all these zoos being located in the same geographical zone had almost similar temperature regimes from the month of November to April when the study was conducted.

2.1. Mysore Zoo, Chamarajendra Zoological Garden (CZG)

The zoo is located within the city of Mysore a kilometer away from the city bus stand. The Maharaja of Mysore, Sri Chamarajendra Wodiyar, established this in 1862. Though the zoo was set up with 10.2 acres during its inception, presently the zoo spreads over an area of 100 acres.

The zoo exhibits include both indigenous and exotic species. The zoo is open to public from 9am to 5pm. During the study period in this zoo the maximum visitation was in the month of December during the (festivals of Id-ul-fitar, Christmas and New Year).

2.1.1. Black buck enclosure

CZG exhibits black buck in two adjacent enclosures (Figs.2.1 and 2.2). The two enclosures are located adjacent to each other. The enclosures are meshed on all sides while open on the top.

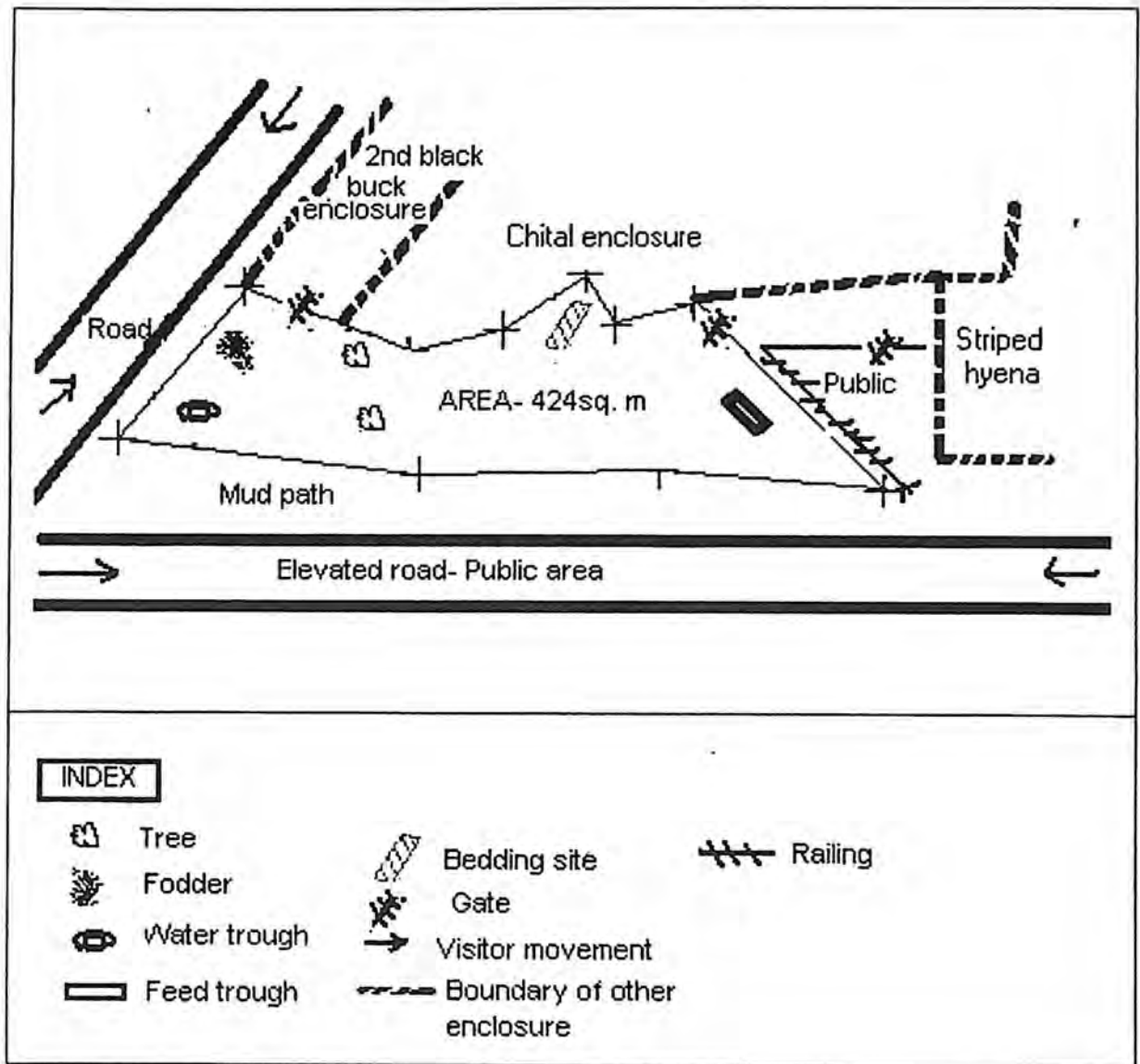


Fig. 2.1. Enclosure-1 of black buck at the Mysore zoo

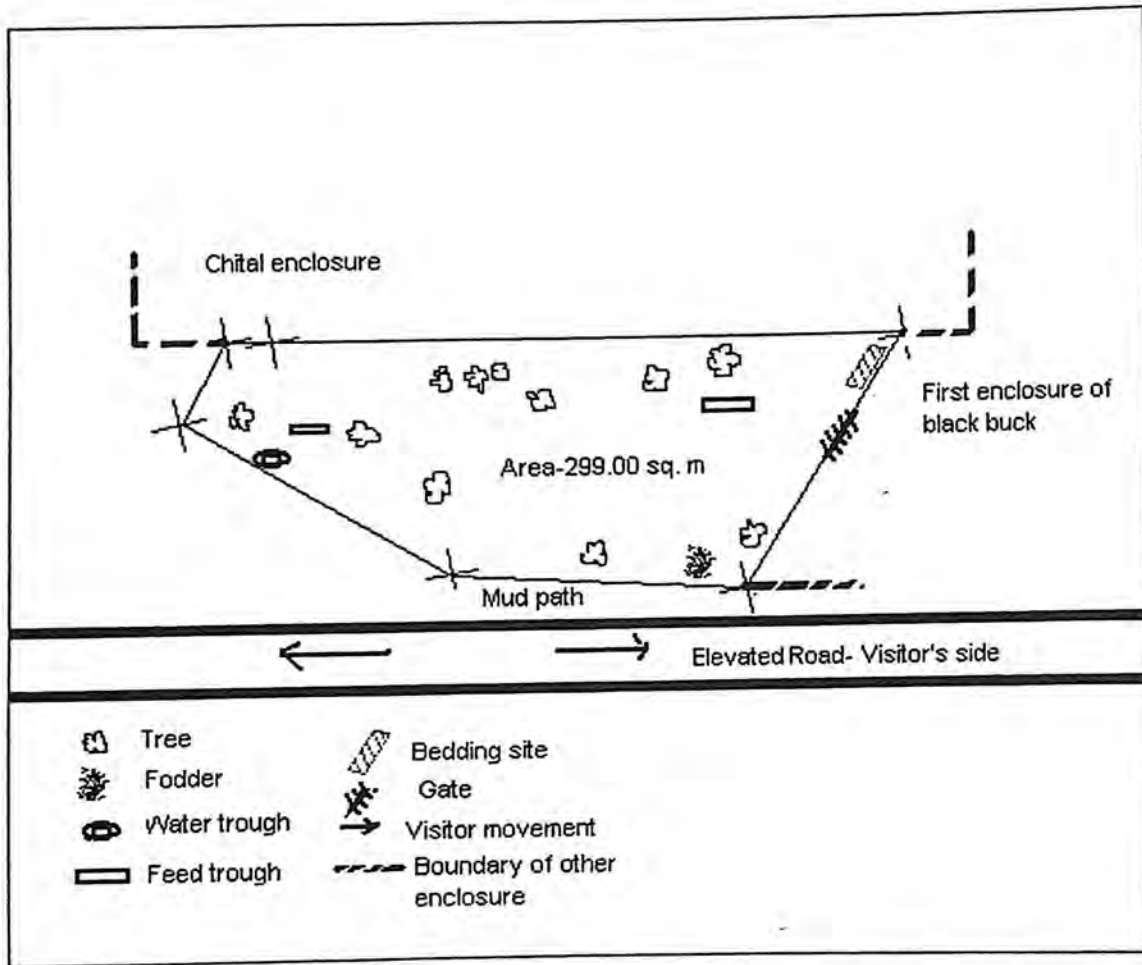


Fig. 2.2. Enclosure-2 of black buck at Mysore zoo

The enclosure 1 has 35 individuals in an area of 484m² (Appendix-1, Table2.1) while enclosure 2 covers an area of 299m² with 30 individuals. The front side of the first enclosure is three meter below the visitor's observation area. The fence forms a barrier of two meter high from the enclosure's ground level. Outside the enclosure, 0.5m to the right side of the enclosure, a railing runs to minimise visitor disturbance. Five meters from the railing the enclosure of striped hyena (*Hyaena hyaena*) is located.

A three-meter high chain-linked fences surround the second enclosure 2 (Appendix-1, Table2.1). The front side of the enclosure is 0.5m below the visitor's point of observation. The backside of the enclosure adjoins the chital enclosure and the right side with that of enclosure 1. Few coconut trees and bamboo clumps are dispersed and the enclosure is relatively shadier than the first enclosure I.

2.1.2. Chital enclosure

There are two enclosures of chital which are nearly 300m apart from each other. The enclosure1 (Fig. 2.3) maintains 100 individuals in an area of 6825m² (Appendix-1, Table2.1). The exhibit has a plain earthen surface. The enclosure is partitioned into three sections by mesh fencing, but the entire area is available for use by animals. The section to the left of the enclosure has grasses growing. Two mesh gates connect this section with the other two sections of the enclosure. The front portion of the enclosure is made of brick wall and is two meter below the visitor's area. Along the front side of the enclosure a visitor stand off runs at a distance of one meter from the exhibit while the other three

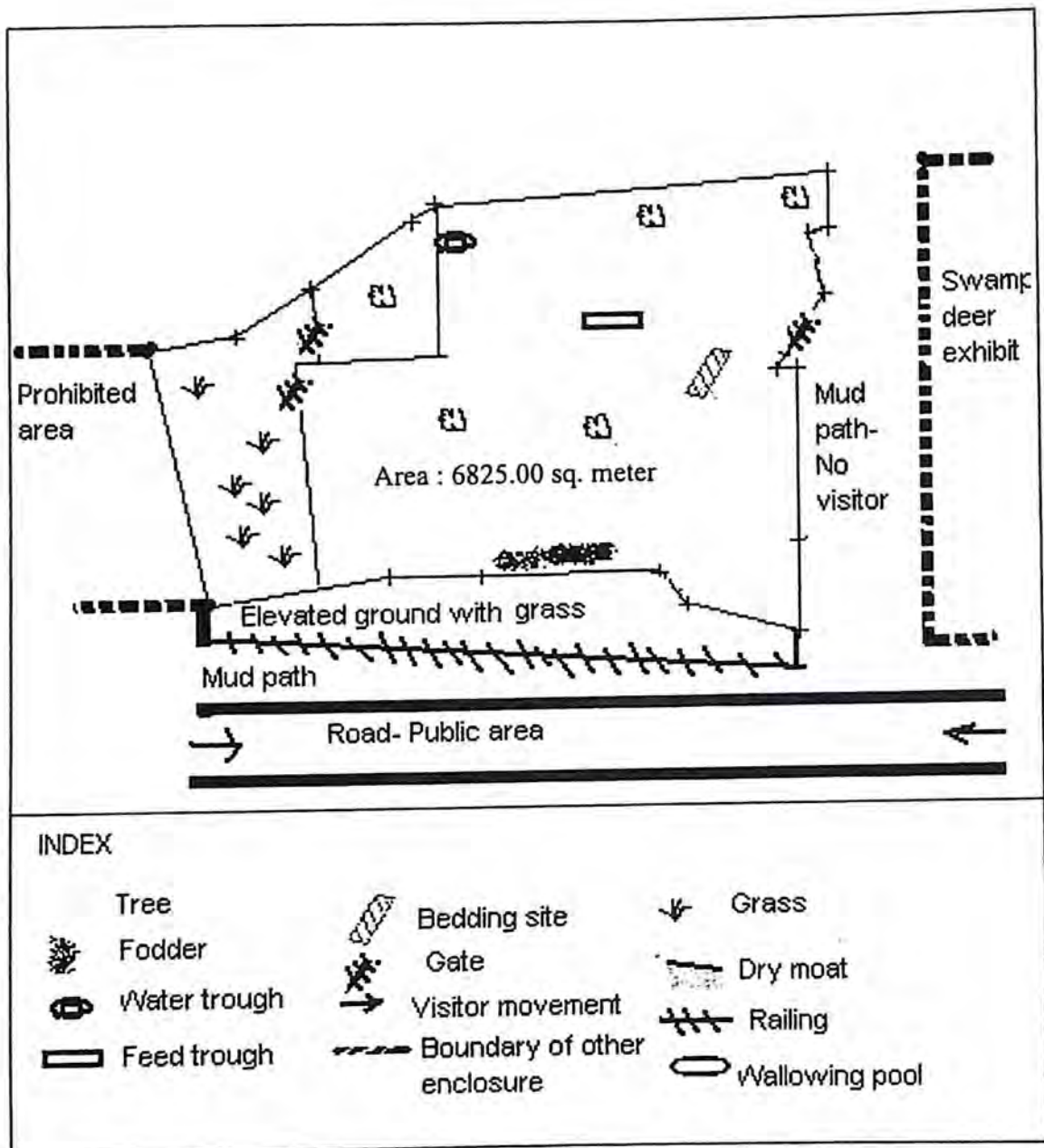


Fig. 2.3. Enclosure-1 of chital at Mysore zoo

sides are not open to the visitors. On the right at a distance of five meter is the enclosure of swamp deer (*Cervus duvaucelii*). The right and the backside has concrete wall raised to a height of 0.5m upon which chain link fence of two meters high continues. The right side has a gate for the entry of the animal keeper. Outside, at the back of the enclosure lot of trees grow which provide shade to the back portion of the enclosure. Left side of the enclosure has a high concrete wall of three meters high forming a partition between the enclosure and the visitor's restricted area of the zoo. A small food trough is placed right next to the gate and the second larger food trough is nearly 10m away from the gate. Water trough is placed at the back of the enclosure form where the water overflows to the length of 10m. The animals were seen to drink water from the ground. Few coconut trees are interspersed in the enclosure. The back portion receives shade in forenoon and the animals were seen to take the most advantage of it.

The enclosure-2 (Fig.2.4) shares its boundary with the two black buck enclosures. It houses 83 individuals in an area of 3317m² (Appendix-1, Table2.1). Visitors view the enclosure from the front and right side thereby increasing the chance of disturbance. These two sides have a stand off barrier one meter away from the enclosure to minimise the disturbance by visitors. Half the length of left side adjoins the enclosure for striped hyena (*Hyaena hyaena*). Followed by this, there is gate to the storeroom of haystacks from where the animal keeper enters. It then continues with the enclosure 1of black buck. This side has a concrete wall of one meter from where it shares the chain-linked fence

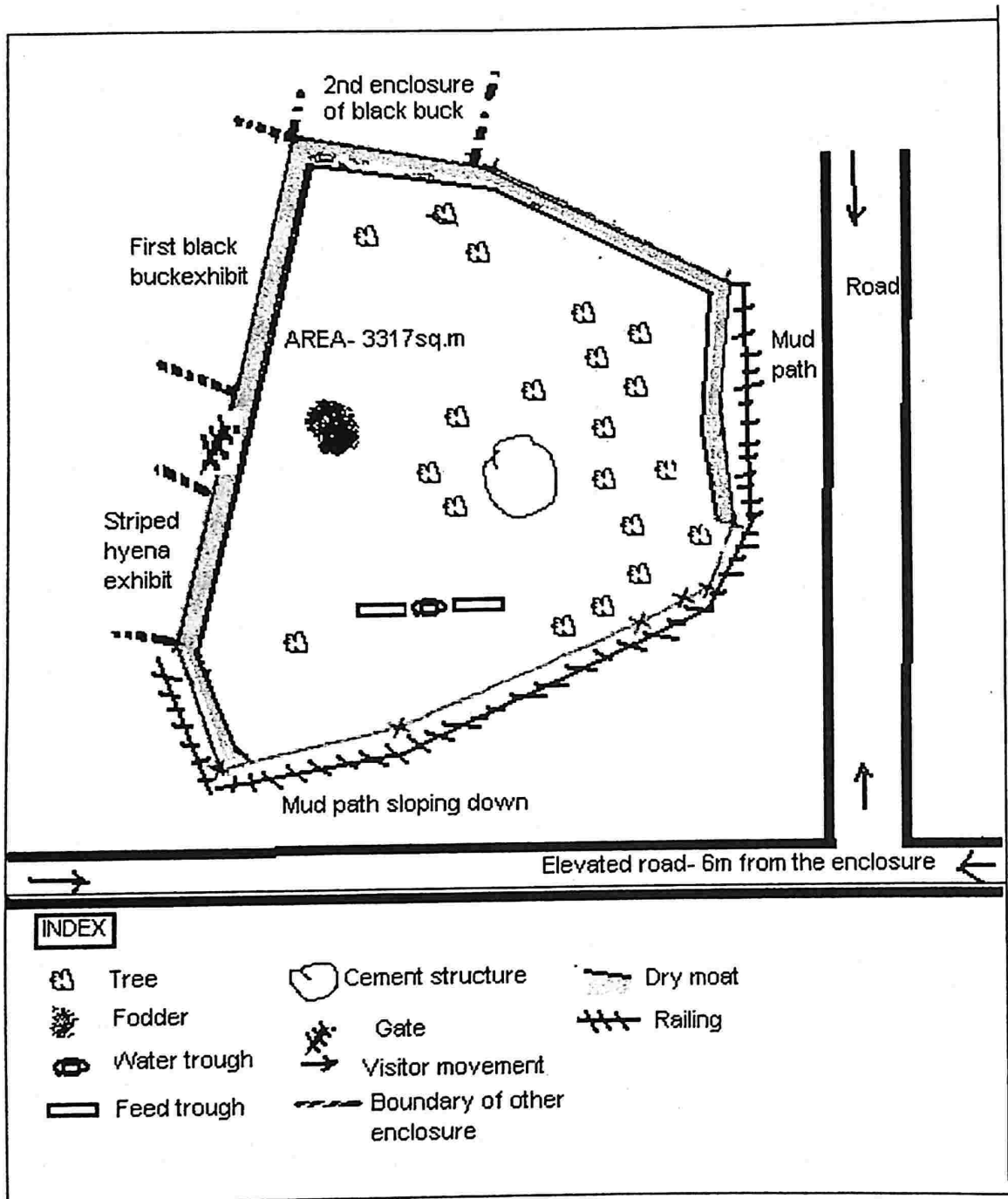


Fig. 2.4. Enclosure-2 of chital at Mysore zoo

of the neighbouring enclosures. The backside of the enclosure is continuous with the enclosure 2 of black buck. The wall rises to one meter high from where it is continuous with the chain link fence of the second black buck enclosure. Except for the front portion a dry moat of two meters width extends in rest three sides of the enclosure. Two food troughs lie next to each other in the middle of the enclosure and the water trough is in between the two troughs. There are few trees growing in the enclosure. But the back of the enclosure receives lot of shade in the forenoon from trees present just outside the enclosure.

The males in the first enclosure were found to shed their antlers within a few days of observation. A subadult male had deformed antler, one of the spike growing downward. An adult male, which had been castrated, failed to shed its 4m antler and was seen to lose out in most of the fights. Although the overall stock was healthy, a few individuals ended up in getting injured and limping quite frequently.

By the second day of sampling, in enclosure 2, most males had started losing their antlers. Few females were pregnant during the course of the study and two fawns were born two days after the end of sampling of this enclosure.

2.1.3. Sambar enclosure

This enclosure (Fig.2.5) maintains 38 individuals in an area of 2609m² (Appendix-1, Table2.1). To the front of the enclosure, which is the only side accessed by visitors, there are two enclosures for primates. The walls are two meters high and concrete to the level of visitor's standing area, while concrete walls of two meter encircle the rest three sides also. The railings in the front side

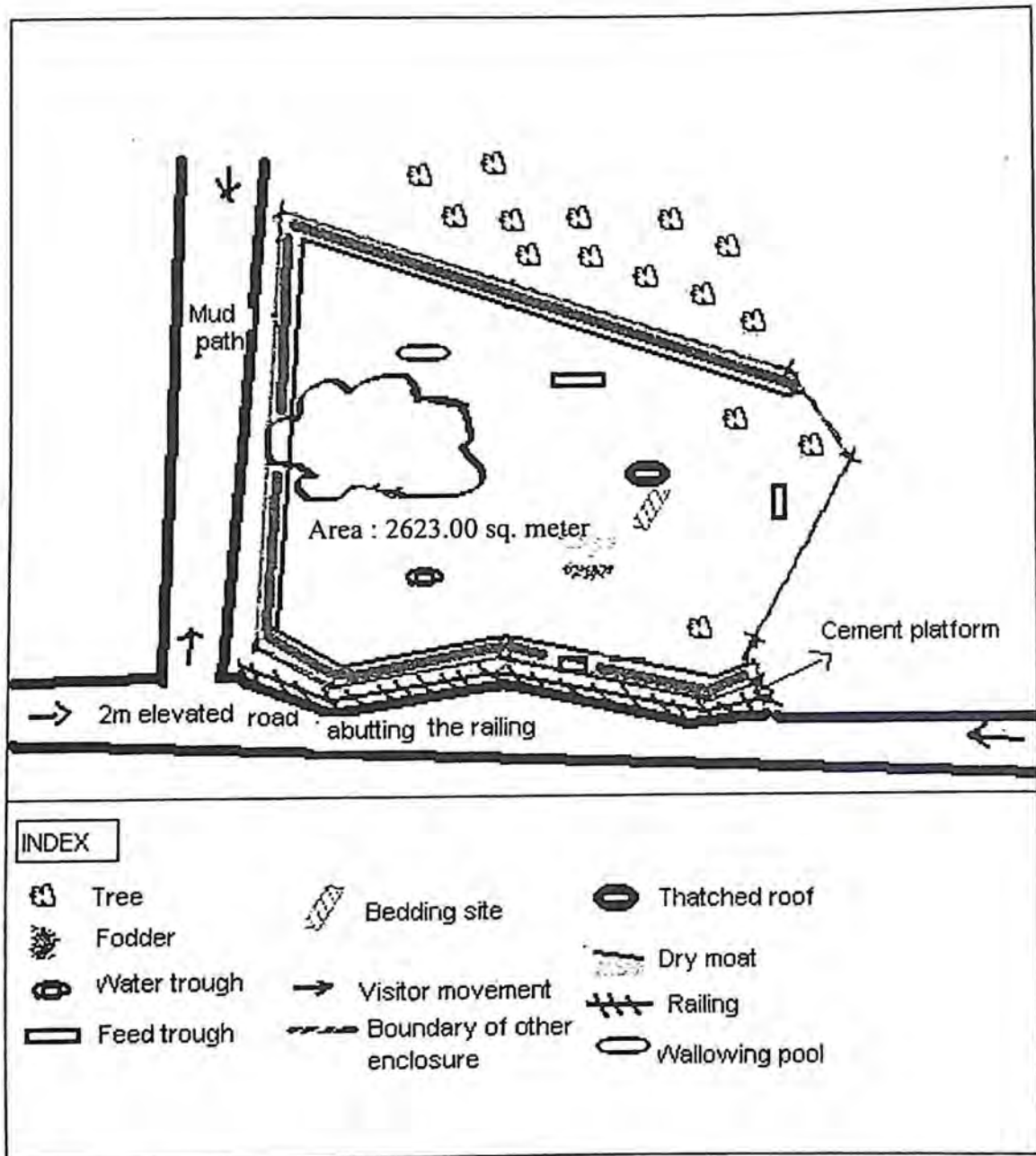


Fig. 2.5. Sambar enclosure at Mysore zoo

maintain the visitor's at a distance of 0.3m. A dry moat of three meters wide and 0.5m depth surrounds the enclosure on three sides barring the right side. The enclosure has an undulating surface. There is a huge tree on the left of the enclosure, which shades almost half of the enclosure. The trees behind the enclosure also provide shade in the backside of the enclosure. There is a wallowing pool in the left side of the enclosure. The food trough is located 10m to the right of the pool and the water trough 10m to its front. The second food trough is to the right of the enclosure. A thatched roof held by four bamboos is erected in the middle of the enclosure to provide shade during summer. Several small branches of neem (*Azadiractia inidica*) and peepal (*Ficus spp.*) trees were erected at the foot of coconut tree to place the browse on them.

All the individuals of the stock were captive bred. Of the fourteen adult males ten males were castrated. Few of the adult males had injuries in their body, which got aggravated by continuous crow bites.

2.2. Chennai Zoo, Arignar Anna Zoological Park (AAZP)

AAZP is located on the outskirts of the Chennai city a km away from the Vandalur Railway Station. The Madras zoo was established in 1855, was shifted to the present site at Vandalur in 1979 and was opened to the public from 1985. The zoo sprawls in an area of 1275 acres of which 400 acres have been used to display enclosures.

The zoo is one of the biggest zoos in South East Asia and displays the largest number of animals and birds in India. The forest environ of the enclosures are conducive for the animals and gives a natural appearance about their habitat

to visitors. The zoo remains open to the public from 08:00hrs to 17:00 hrs. The maximum visitation during the study was (festival of Pongal) in January.

2.2.1. Black buck enclosure

The enclosure (Fig.2.6) for this species, holds 75 individuals and covers an area of 5107m² (Appendix-1, Table2.2). Only the front portion of the enclosure is open to the visitors. Adjacent and on the right is the enclosure for barking deer (*Muntiacus muntjak*) while on the left side is the enclosure of moufflon (*Ovis musimon*) enclosure. Backside has a muddy path where visitor's entry is prohibited. The front and the backside of the enclosure are of concrete of three meters height from the ground to the visitor's standing area. The 0.5m wall towards the visitor's side has pieces of glass stuck on them to prevent visitors from entering. The stand off barrier of vegetation and railing at a distance of 0.5m in the front portion wards off the visitor vandalism. The ground is flat but filled with leaf litter. The front and back portions have a dry 2m wide and 0.5m deep dry moats. There are numerous trees with low canopy cover providing enough shade for the animals. Two food troughs are present in the back portion of the enclosure. A water tank is located to the right side of the enclosure. All the individuals were captive bred and had a good health status.

2.2.2. Chital enclosure

This enclosure (fig.2.7) spreads over an area of 3936m² and with 21 individuals (Appendix-1, Table2.2) during January 2003. The number increased to 23 when it was visited during March 2003, for summer season sampling. It lies next to the moufflon (*Ovis musimon*) enclosure in the right side and the left side

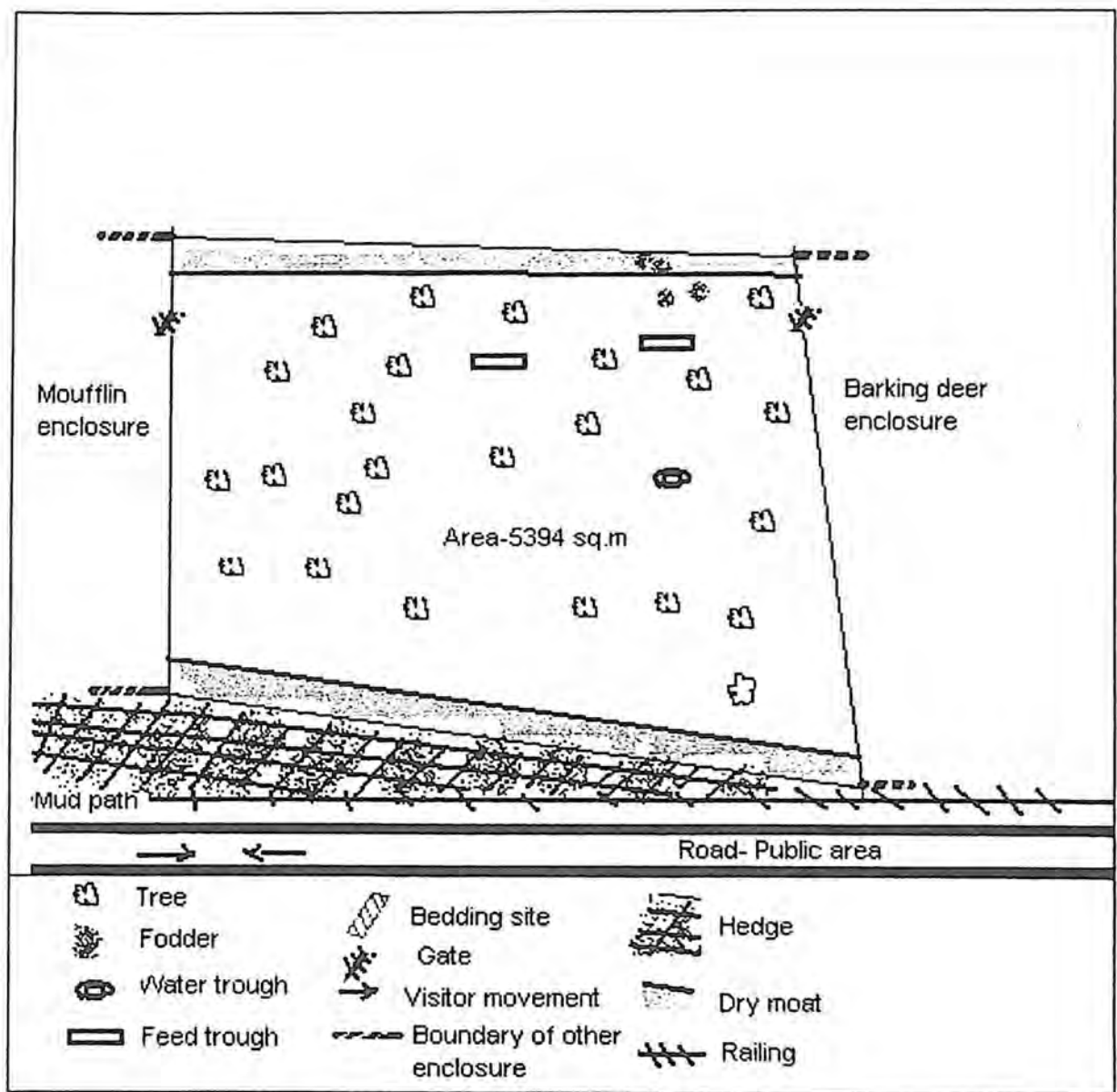


Fig. 2.6. Black buck enclosure at Chennai zoo

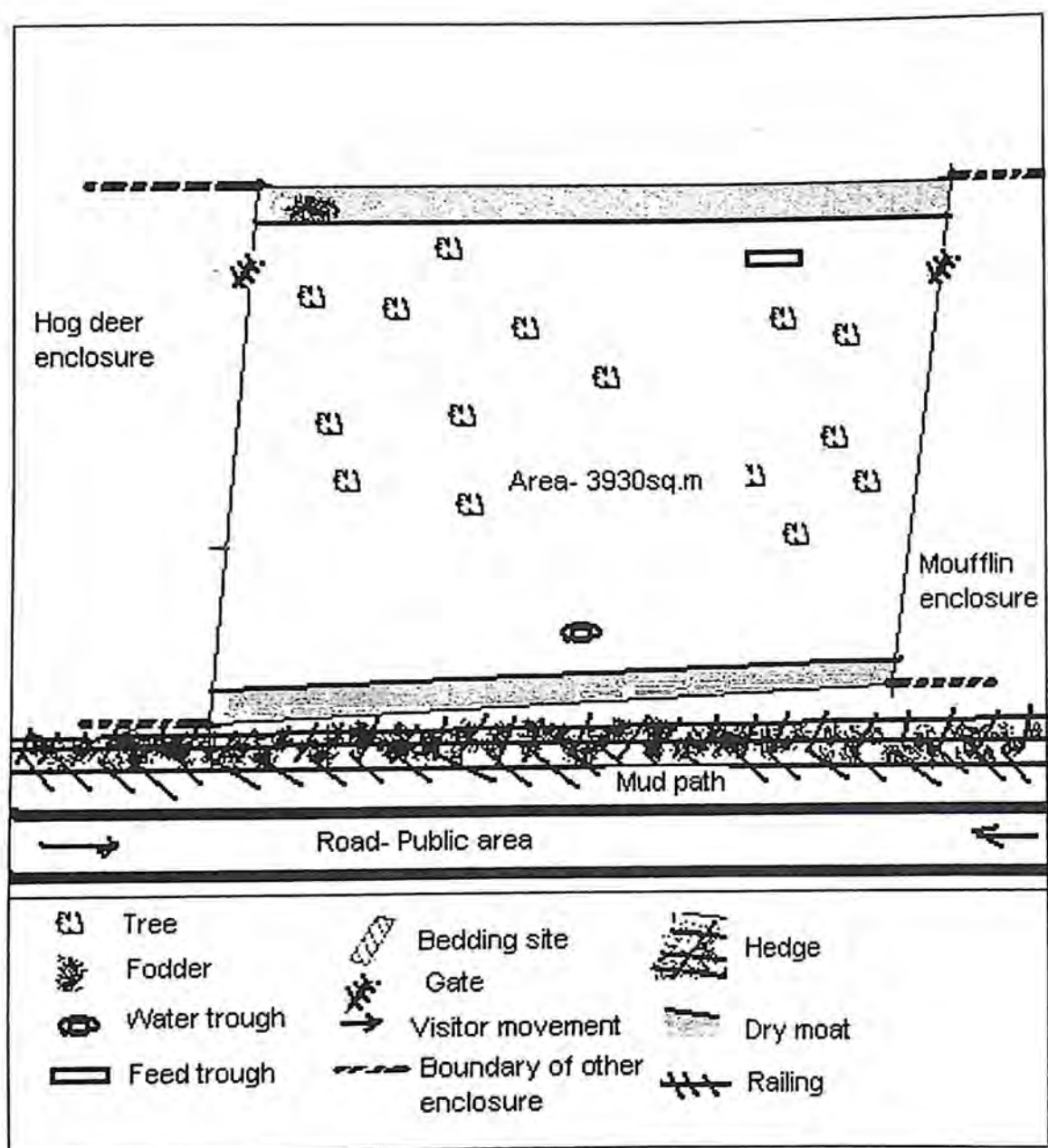


Fig. 2.7. Chital enclosure at Chennai zoo

abuts with that of hog deer (*Axis porcinus*) exhibits. The front and back walls are concrete (2.5m) from ground to visitor's standing area but the two sides have chain-link fencing of four meters. There are two mesh gates at the back portion of the two sidewalls for the access to the two neighbouring enclosure by the animal keeper. The viewing portion is limited to the front side only. However, vegetation and railing at a distance of 0.5m restricts the viewers at a distance of 1m from the enclosure. A dry moat of 2m wide and 0.5m deep is present in the front and back portion of the enclosure. The ground is slightly undulating with leaf litter and small samplings. Food trough is present at the back of the exhibit and the pool of water towards the front portion. Lot of trees grow in the enclosure ensuring a cool summer to the animals.

2.2.3. Sambar enclosure:

This enclosure (Fig.2.8) built on the concept of predator-prey relationships, is located next to a tiger enclosure. The number of individuals increased from 42, in January 2003, to 45 when sampling was repeated two months later in March 2003. The exhibit spreads over an area of 4099m² (Appendix-1, Table2.2). The gradient of the enclosure increases towards the enclosure of the tiger. The terrain is rocky and undulating. Walls of concrete extend on three sides to a height of 1.5 m from the ground. The back portion has mesh fencing to a height of 2.5 m. The front and side portions are two meters below the viewing platform, restricting the public by a stand off area at a distance of 0.5 m. One food trough is toward the left of the enclosure and the second is located 10 m to its right. A wallowing pool is present between the two food

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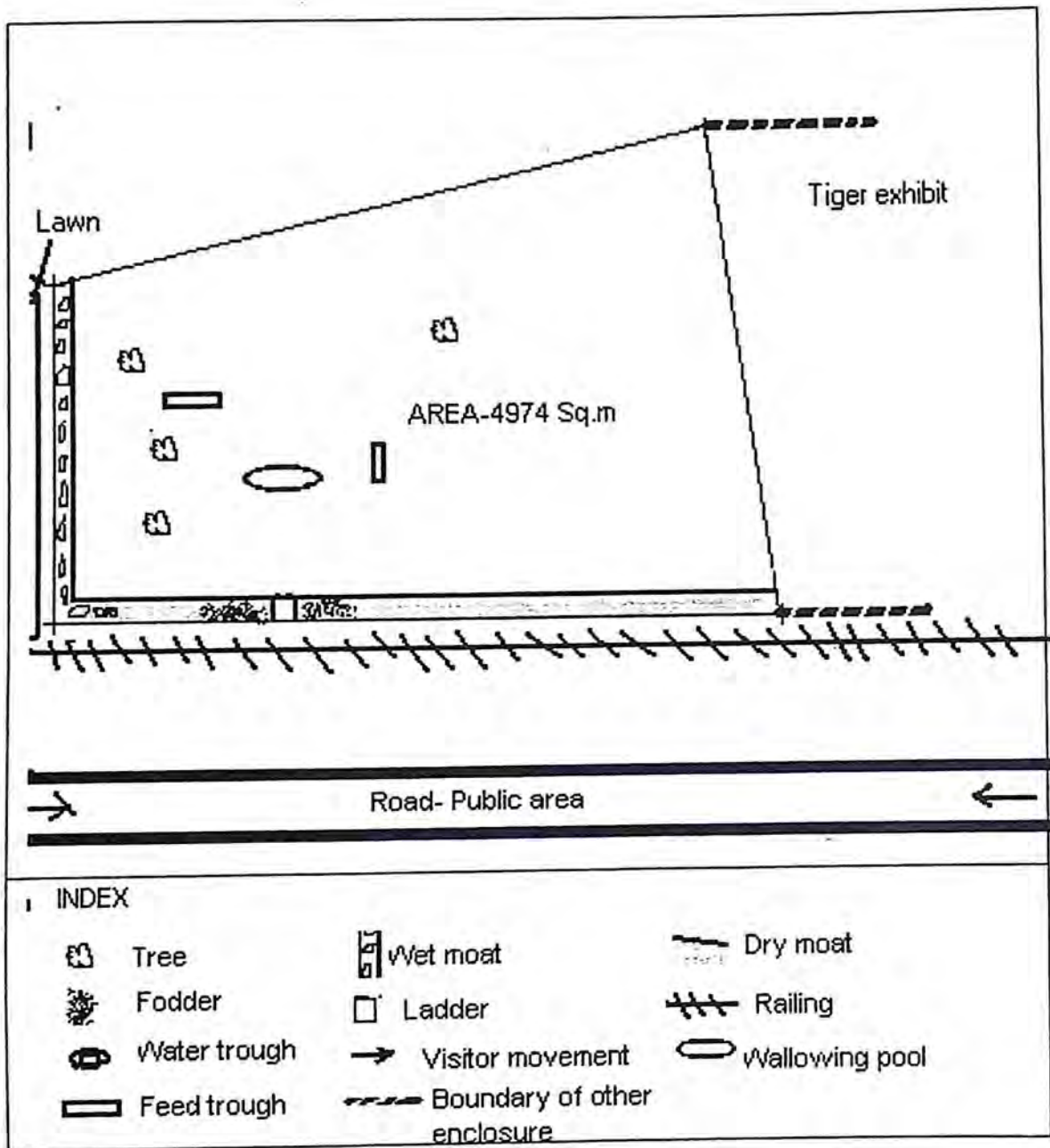


Fig. 2.8. Sambar enclosure at Chennai zoo

trenches. The front side has a 1.5m dry moat and the moat of the left side has little water for the animals to wallow. The exhibit has a ladder in the front side for the animal keeper to enter. No big trees are found but plants have been planted with mesh fencing to prevent damage by the species. Few small saplings were found to grow.

The animals were of poor health and were infected with fungal skin disease. Several injury patterns were marked on the body of few individuals as a result of infighting. Some individuals were noticed to have problem with their eyes too.

2.3. Hyderabad Zoo, Nehru Zoological Park (NZP):

NZP is located on the brink of Hyderabad city 4km from the Hyderabad Railway Station. The inception of the zoo dates back to the year 1963. This zoo is one of the largest zoos in India spreading over an area of 300 acres.

The zoo holds special importance for its prehistoric dinosaur park, primate sections, parrots, the nocturnal animal house and the Felid safaris. The zoo remains open to public from 09:00hr to 17:00hr. During the course of the study maximum visitation was seen on general public holidays.

2.3.1. Black buck enclosure:

The enclosure covers an area of 5827m² (Appendix-1, Table2.3) with 14 individuals. The enclosure (fig.2.9) is open to visitors from all sides. A brick wall of three meters from the ground to visitor's standing area encircles the entire enclosure. The surface is plain with lot of leaf litters. The exhibit is divided into two sections. A night enclosure of chain-link fencing of dimension of 2m x 10m is

situated in one of the section to prevent predation by wild cats and stray dogs at night. A wet moat of two meters width runs around this section of the enclosure. The other section has a dry moat of two meters width adjoining the boundary. Vegetation barrier of 0.5m width creates a visitor stand off all round the enclosure. There are numerous trees in this section of with lot of leaf litter. Concentrate feed in morning is supplied on the rocks present on the section of the enclosure having night enclosure.

2.3.2. Chital enclosure:

This enclosure (Fig. 2.10) sprawls over an area of 36,040m² (Appendix-1, Table2.3) and houses 22 individuals. The three sides of the enclosure are of brick walls 3.5m high and the backside is of chain-link fence two meters high from the ground to the visitor's standing area. This enclosure is an ideal illustration of the natural habitat of the species. It has numerous trees where the animals take rest in the afternoon. Most part of the enclosure has lush green grass meadows, with rocks at different points. A moat was created on the three sides of the enclosure with certain amount of water in it. The left portion of the enclosure had soft mud due to water logging. The visitors from the front and right side can view the animals from a distance of one meter from the vegetation stand off and 3.5m above the enclosure. The other two sides are inaccessible to public. Eight meters to the right of the enclosure the enclosure of canids are displayed. There was no food and water trough in the enclosure.

The animals were seen to be healthy and utilised the entire part of the enclosure. Though they remained in groups individual spacing was also noticed

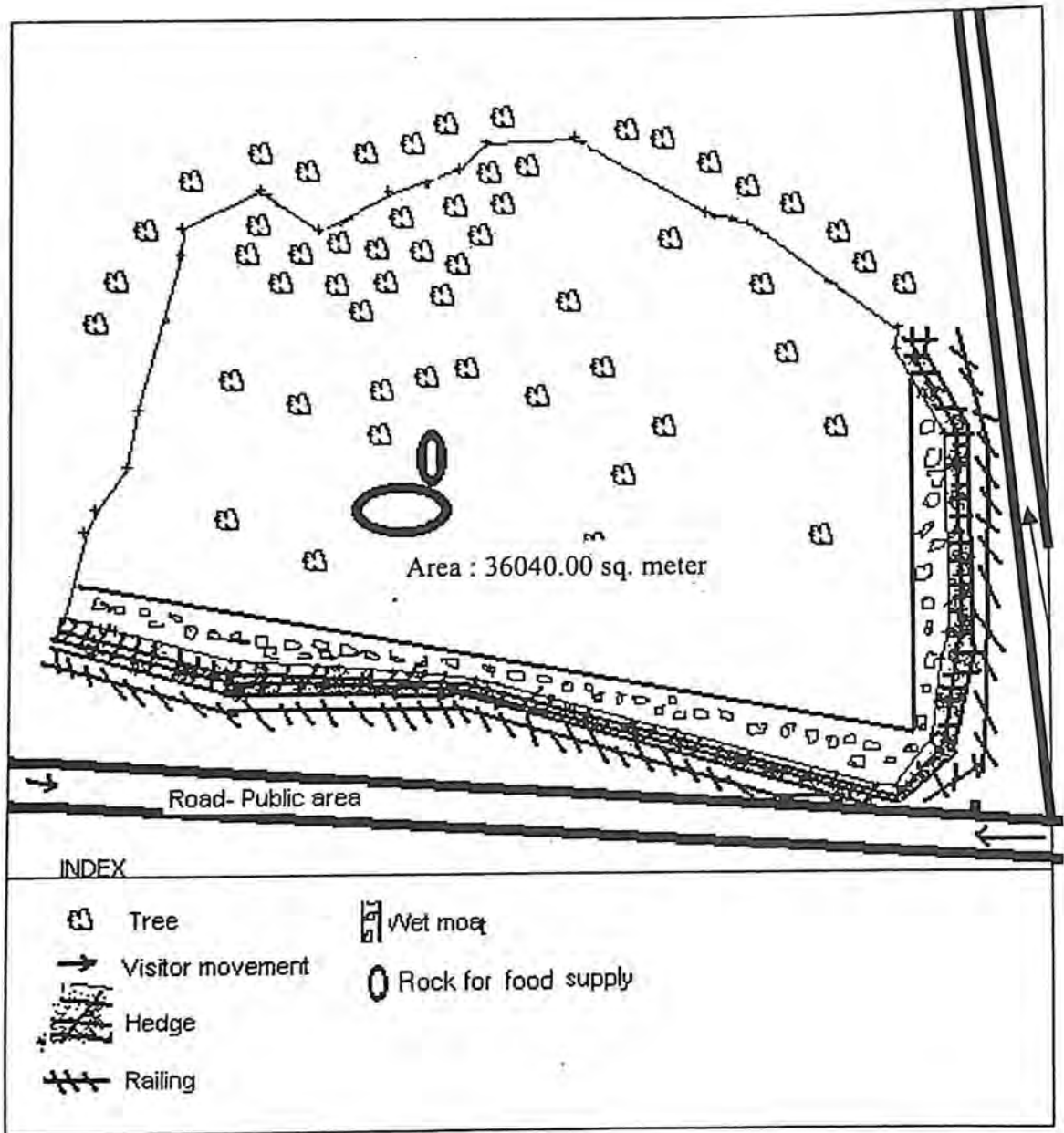


Fig. 2.10. Chital enclosure at Hyderabad zoo

in this enclosure. The animals in this herd were not seen to crowd at the time of food supply, but seen to feed leisurely when desired on the concentrate supplied.

2.3.3. Sambar enclosure

This enclosure (Fig. 2.11) is in front of the black buck enclosure situated on the other side of the road. It houses 16 individuals in an area of 4359m² (Appendix-1, Table2.3). The right side of the enclosure abuts with that of nilgai (*Boselaphus tragocamelus*) enclosure and the left side with that of wild ass. The enclosure has an undulating terrain the right half of it being rocky ground. The other half of the ground is having numerous trees of *Acacia catechu*. The pods of these trees were greatly relished by the animals. A chain-link fence of two meters height encircles the enclosure by the two sides and the back portion. A rock wall of three meters high stands to a width of 10m in middle of the chain-link fence in the backside of the exhibit. A wire mesh gate is attached to the rocky structure making way to the night enclosure. The front portion is of brick wall 0.5m high from the viewing area. A 2.5m water moat in the front portion separates the animals from the outside area. Small grass patches on the brink of the water moat create good foraging and resting site. One meter from the front brick wall a barrier of vegetation minimizes visitor disturbance to the species.

In the first day of sampling a few days old fawn died due to lack of milk availability from its mother. The animals were seen to be very affinitive towards the animal keepers.

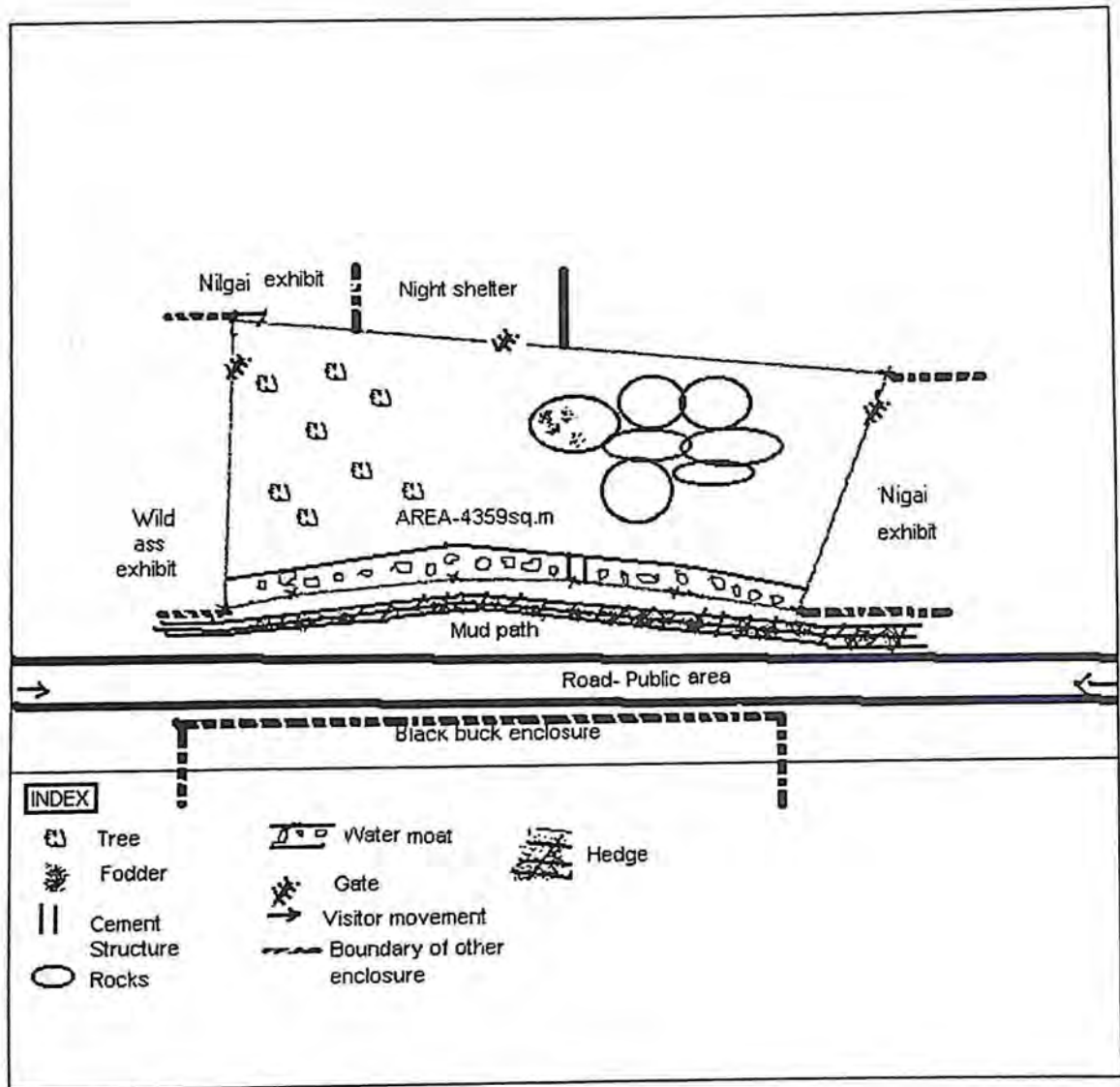


Fig. 2.11. Sambar enclosure at Hyderabad zoo

2.4. Vizag Zoo, Indira Gandhi Zoological Park (IGZP)

This zoo is situated in the outskirts of the city of Vishakhapatnam on the National highway towards Vizianagram, 6km away from the city bus stand. It is flanked by hills on either sides and the back of the zoo faces the Bay of Bengal. Though the park was set up in the year 1972 the park was open to the public in the year 1977. IGZP covers an area of 625 acres. It remains open to public from 09:00hr- 17:30hr. Maximum visitation was seen only on Sundays.

2.4.1. Black buck enclosure

This is the only enclosure (Fig. 2.12) exhibiting mixed species. The enclosure is shared by 14 chital and 18 black buck. But the study was restricted to black bucks due to short time span of the study. It covers an area of 11,533.15m² (Appendix-1, Table 2.4). The surface is plain with lot of litters. Brick wall of three meters from the ground to visitor's standing area surrounded all the four sides. A dry moat of three meters width and 0.5 m deep extends in front and the two sides of the enclosure. A small wooden food trough is present for food supply. The right side of the enclosure has separate night enclosures for the two species. 10 m to the right of this enclosure, is located the white tiger exhibit which receives lot of visitors. Several tree species grow in the enclosure and the enclosure is slightly undulating. Few saplings also grow which is grazed by both the species. A fawn was added onto the herd by the third visit to the zoo.

2.4.2. Sambar enclosure

This zoo displays two exhibits of sambar. The enclosure 1 (Fig. 2.13) resembles a scrub forest environ with lot of trees and saplings growing

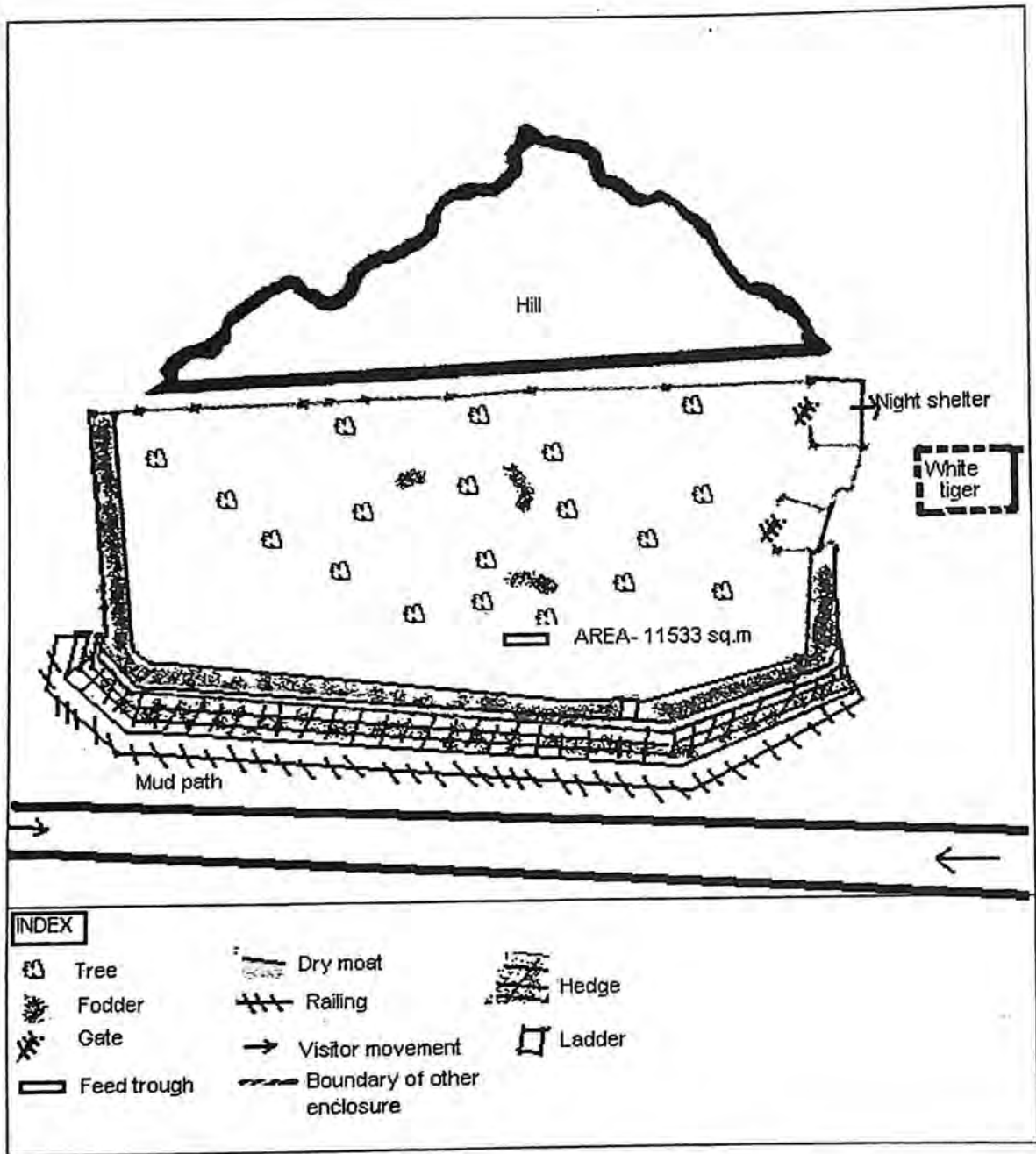


Fig. 2.12. Black buck enclosure at Vizag zoo

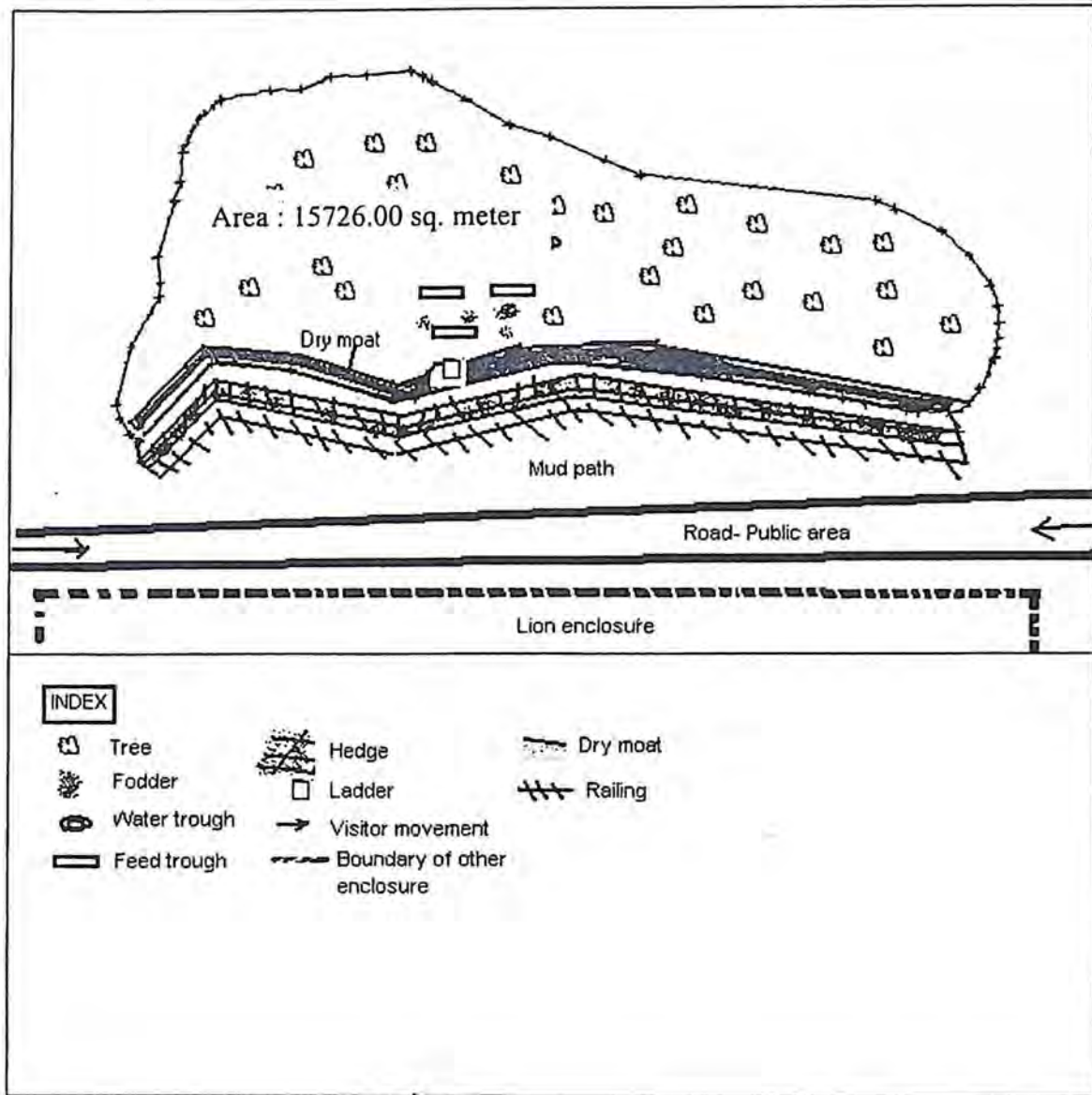


Fig. 2.4.13. Enclosure-1 of Sambar at Vizag zoo

throughout the enclosure. Covering an area of 15,726m² (Appendix-1, Table2.4) the enclosure maintains a stock of 13 individuals. The enclosure has an undulating terrain. Brick walls of 2-2.5 m from the ground to visitor's standing area border the four sides. A dry moat of two-meter width and 1m depth runs in the front portion of the enclosure. Three small food troughs were located in the front portion of the exhibit. The enclosure on the other side of the road was for lions and no other exhibit was located near this enclosure.

The enclosure 2 (Fig. 2.14) has a population of 25 individuals in an area of 8933m² (Appendix-1, Table2.4). It is located next to gaur (*Bos gaurus*) enclosure on the right and thamin deer (*Cervus eldi*) enclosure to the left. The enclosure has brick walls of two meters from ground to visitors standing area in all the sides, the back wall being continuous with a hill. The enclosure is plain with a slight gradient to the back of the enclosure. A huge *Ficus* spp tree was located in the middle of the enclosure providing shade to the central portion of the enclosure. This part of the enclosure was seen to be preferred by the herd in forenoon. The growth of saplings grow gives a greener appearance to the enclosure. Three food troughs were distributed at different locations and a water trough was in the middle of the enclosure. The water overflowing from the trough formed a small pool that was used for wallowing by few individuals.

The animals were of slightly poor health during the winter, but the health deteriorated conspicuously during the summer season data collection in April 2003.

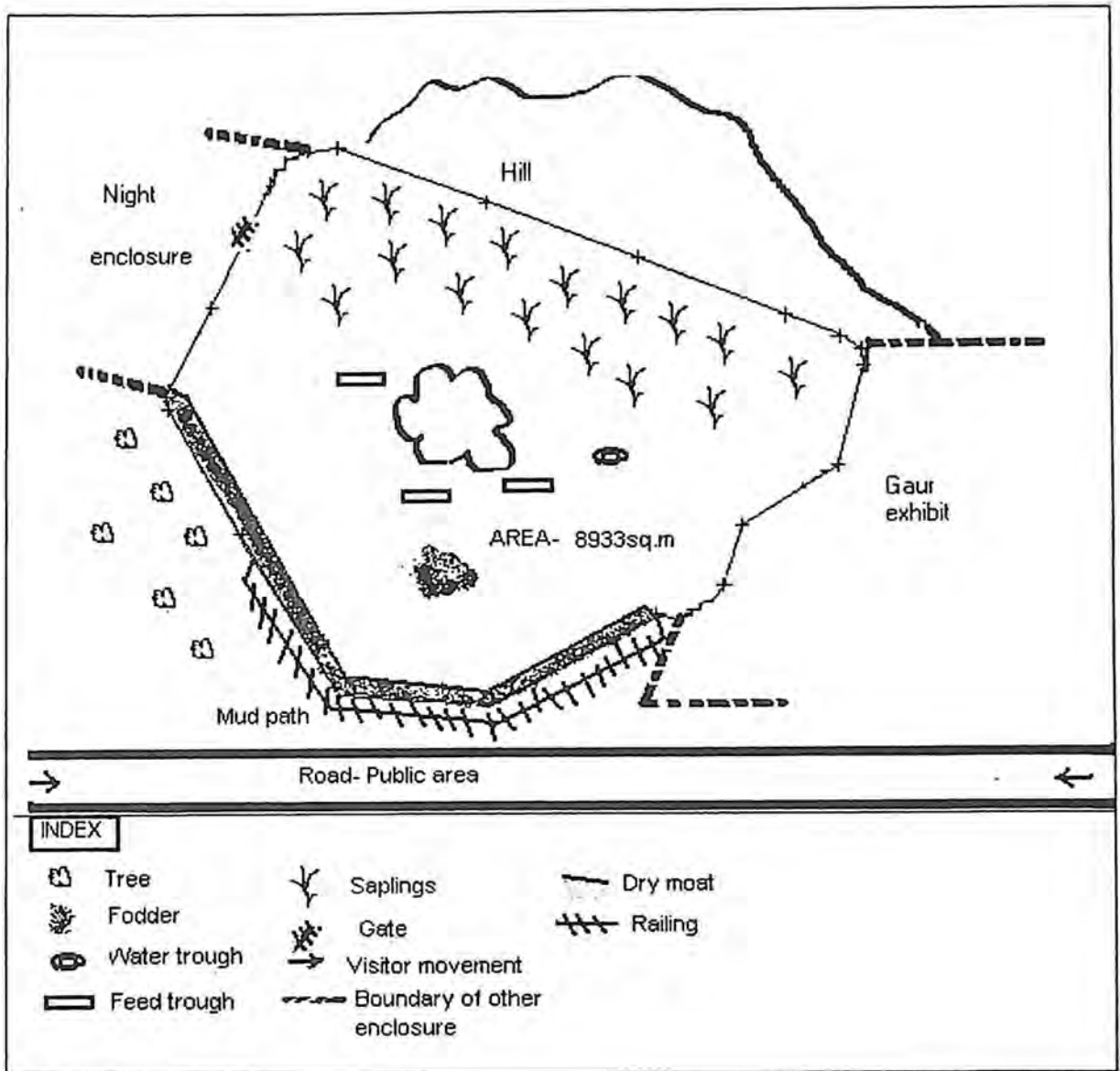


Fig. 2.14. Enclosure-2 of Sambar at Vizag zoo

3. METHODOLOGY

The study of the target species of ungulates was carried out for a period of 155 days between November 2002 to April 2003. The month of November, 2002 was spent in reconnaissance which was followed by the systematic data collection between December 2002 to April 2003 (Fig. 3.1)

3.1. Reconnaissance survey

The four zoos were visited for a duration of three days each at the initiation of the study in November 2002. This was to get a fair idea of the zoo and collect preliminary information on the species and their enclosures. During this period, the number of animals of the target species in each enclosure was enumerated. The population structure was classified into five different categories viz. adult male, adult female, subadult male, subadult female and fawn. The enclosures were surveyed using a compass and a measuring tape to get the area and shape of the enclosure. The manually drawn map was replaced by plotting the map in the 'Civil Design and Survey' software. The area was calculated by using 'Autocad'. The physical structures and the trees present in the enclosure were plotted manually based on the rough sketch. From the total area estimated, the space available for each individual was calculated by dividing the area of the enclosure with the total number of individuals in the enclosure. The area was then standardized across the enclosures by deducing the density of animal per 100m².

The behaviour (Manning, 1979) of the species was recorded using scan and focal sampling (Lehner and Philip, 1940; Altman, 1974; Lehner 1979) was

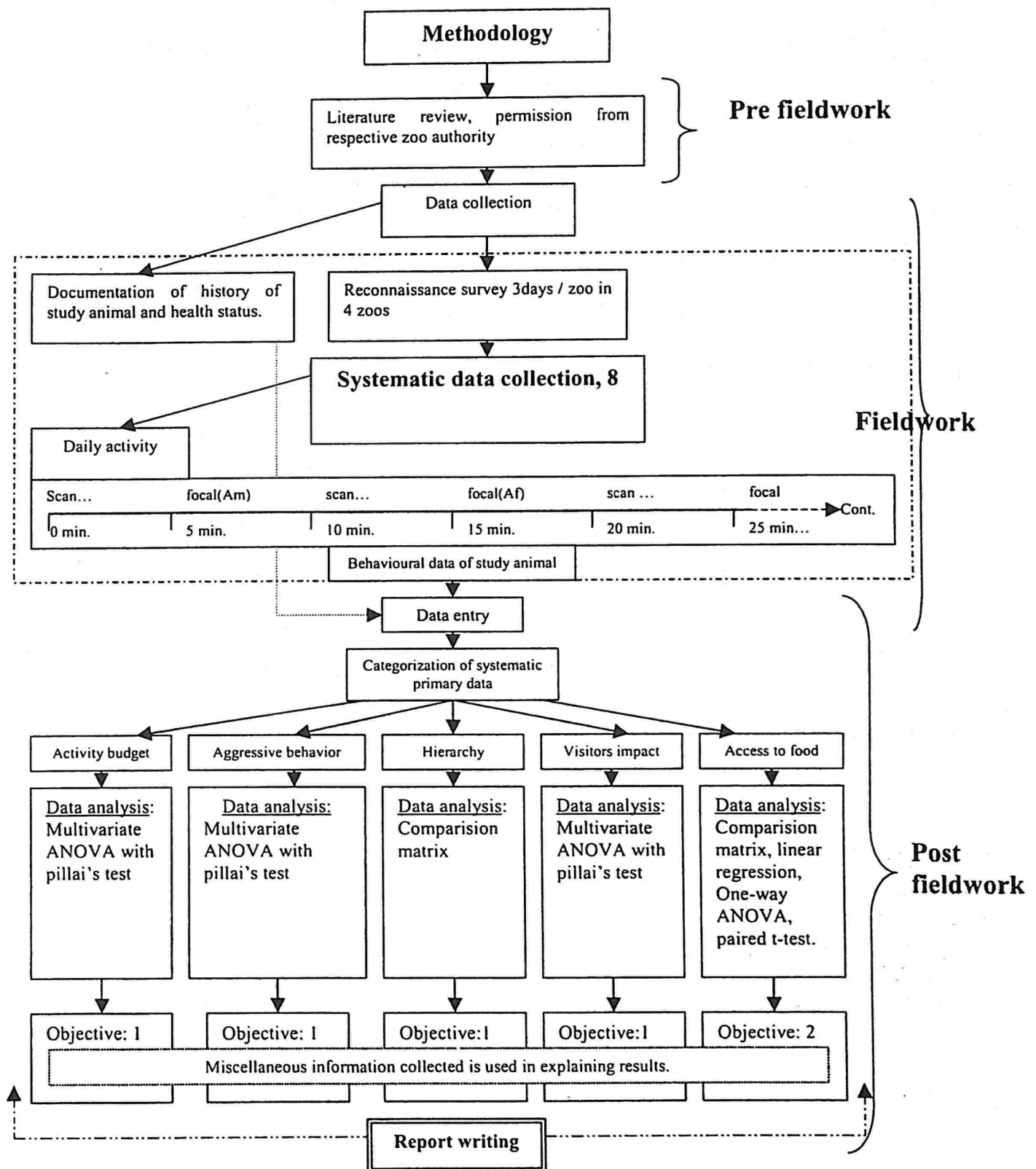


Figure: Flow chart of research methods followed in density related behavior study of ungulates.

opted. In each zoo a combination of the two sampling methods for six to eight hours was done for the first two days of the reconnaissance period, on any two different species. This was carried out to get used to the two said sampling methods and to accustom the observer to the routine. For both scan and focal samplings, both the behavioural state (behavioral activity of longer duration) and events (momentary behaviour where the patterns are of shorter duration) were recorded. An ethogram was developed during this period and it was refined as the study progressed.

3.2. Secondary data collection

3.2.1. Documentation of history of animals from zoo records

The zoo records were looked into the pedigree of the observed animals (captive bred, acquired from other zoos, received as gifts or captured from the wild). The information on the breeding records of the stock (total number of individuals in an enclosure) in captivity depicted the rate of proliferation of the species contributing to their density in the enclosure. The mortality record of each of the species was also looked into to determine the cause of mortality (infighting, disease or any other factors).

3.3. Primary data collection

The sampling period in Chennai, Hyderabad and Vizag zoos were divided into two seasons— winter and summer. In each season the data for each enclosure of a species was collected for a period of four days. This was to avoid the bias to the behavioural change in response to difference in temperature in the two seasons. In CZG zoo the sampling of black buck and chital was not done in

two seasons but the entire sampling for both the species was completed during in winter season (December 2002, first week of January 2003). The study of sambar was taken up in the month of April 2003 for eight consecutive days. This was done as the zoo had plans to shift chital and black buck enclosure after January. Behavioural sampling was done in each enclosure from 08:30hr to 17:00hr with a half an hour break was taken in the afternoon from 12:30hr to 13:00hr. To avoid the repetition of the same pattern of behaviour every day, the enclosure of a species of the same zoo was studied on a rotational basis.

3.3.1. Activity budget

On a daily basis, scan sampling (Altman, 1974; Lehner 1979) with a sampling period of 5min and a sampling interval of 5min was done for the entire herd from 8:40 to 16:55hr with a break of half hour in the afternoon. The instantaneous behaviour of each individual in the enclosure was noted down in that particular enclosure. Eight hours of sampling resulted in forty scans every day. The behaviour of adult male, adult female, subadult male and subadult female and fawn were recorded. This was done with the objective of finding the frequency of individuals of each sex category exhibiting a particular activities viz. standing, feeding, moving, lying, interacting, aggressive and submissive behaviours (Kumar, 1987; Mallapur, 1999).

3.3.2. Aggressive pattern

Aggressive interactions were categorised into three categories viz. mild (where no contact with the recipient was involved), moderate (aggression of very short duration inflicting minute distress to the recipient) and intense (aggression

directed for a longer duration inflicting severe distress and sometimes leading to injury of the recipient) form of aggression. The aggressive behaviour were categorised in the three categories. From the scan recordings, aggressive behaviour was gleaned. This was to find out the frequency of different form of aggression exhibited by different sex category in enclosures of varying area and densities.

3.3.3. Impact of visitors on behaviour

The visitor off day was selected and similar behavioural sampling was done for 8hr between 08:40-16:55hr on that day. This information represented the behaviour repertoire of ungulates in the absence of visitors. Behaviour of the animals on visitor maximum days (Sundays or local and national festivals), from 08:40-16:55hr, was compared with that of behaviour on visitor off days to analyse the difference in behaviour of the target species in response to visitors.

3.3.4. Hierarchy

The social hierarchy of the species in the wild was used as the normal hierarchical order from which the extant ranking of the populations in the enclosure studied was compared. In blackbuck, adult males were considered to be the most dominant in the herd followed by subadult males. Adult females ranked below the subadult males followed by subadult females. Fawns ranked the least in the stock (Ranjitsingh 1989). In sambar and chital, adult males were most dominant followed by adult females who in turn dominated the subadult males. Subadult females ranked below the subadult males and fawns were the least in the ranking order.

For the study, the sex categories of interest were adult male, adult female, subadult male and subadult female. Focal sampling (Altman, 1974) with a sampling period of five minutes was done to deduce the hierarchical order of the species in the enclosure. The first focal sampling began by randomly choosing an adult male from the herd and noting its activity and behaviour for a period of five minutes. During this period both behaviour states and events were recorded along with. During the focal sampling, the time duration for each state as well as events for any interactive behaviour, the initiator of the behaviour, its action, the recipient and its response was noted down with the duration of time expended for that interaction.

3.3.5. Hierarchy based on access to food

In all the zoos concentrate feed was supplied to the animals in the morning and green fodder in the evening. Focal or scan sampling during the time of food supply was opted out owing to the difficulty in carrying out either of the sampling procedure. The time of food supply was noted down. All aggressive interactions in the duration of thirty minutes from the time of food supply were recorded. The aggressor and mode of its aggression, the recipient and its response was noted down. The time duration for each aggressive interaction was also recorded. This was done to get an overview of hierarchical order, proportion of time spent and rate of aggressive interaction for access to food supply.

3.3.6. Behaviour and space usage in relation to adjoining exhibit

Information of animal housed next to the enclosure and its distance from the exhibit of the species under study was documented. This was to see if there

was any aberration to the behaviour and space usage of the enclosure in relation to the neighbouring animal/s.

3.4. Data analysis

3.4.1. Categorisation of data

A repertoire of 82 behavioural states and events were generated to record the behaviour of the three species throughout the study period. For statistical simplicity and better perspective the entire set was pooled under 7 broad categories *viz* standing, feeding, lying, moving, interaction, aggression and submission (Appendix-2, Table 3.1)

3.4.2 Statistical analysis

3.4.2.1. Seasonal difference

At the end of the study, the eight days data collected for each enclosure was separated out for the two seasons. The difference in the activity pattern for winter and summer season was tested for different sex categories using Man Whitney-U test.

3.4.2. 2. Analysis of difference in behaviour across the densities

At the end of 40 scans every day the number of individuals for each scan in the seven broad categories were summed up. To standardize the number of individuals across the enclosures, the actual number of individuals showing particular activity/ behaviour was converted to proportions or percentages. Arcsine transformation of the proportion was done as a means to normalise the data. The difference in the proportion of individuals exhibiting a particular activity across the different densities of enclosure we tested by Multivariate ANOVA with

Pillai's test (Sokal and Rohlf 1969; Zar, 1984). Difference in proportion of individuals showing a particular activity across the densities were tested separately for the four categories of adult male, adult female, subadult male, subadult female for all the three species.

3.4.2.2. Analysis of difference in aggressive pattern across the density of the enclosure

The proportions of individuals exhibiting mild/ moderate and intense form of aggression were calculated. Arcsine transformation of the data was done. Multivariate ANOVA with Pillai's test (Zar, 1984) was done to find if there was any difference between the three patterns of aggression across the densities. The differences in the proportions of individuals exhibiting the aggressive pattern were calculated for adult female, adult male, subadult males and subadult female for the three species.

3.4.2.3. Analysis of difference in behaviour between visitor off day and visitor maximum day

The proportion of individuals at the end of 40 scans for both visitor off and maximum day was calculated and arcsine transformation of the data was done to normalise the data. Multivariate ANOVA was done to test the difference in the proportion of individuals showing the seven different activity/ behaviour between visitor off day and visitor maximum day (Zar, 1984). Difference in proportion of individuals showing a particular activity or behaviour between visitor off day and visitor maximum day were tested separately for the four categories of adult male, adult female, subadult male, subadult female for the three species.

3.4.2.4. Analysis of time spent per individual for aggression across density

The time spent by each individual in aggression within 30min from the time of food supply was calculated by dividing the total time spent in aggression with that of the number of individuals in the herd. The differences in the time spent in aggression per individual were tested by one-way ANOVA for both morning and evening sessions. In chital, as the variance was not homogenous the differences in the time spent in the aggression per individual to have an access to food supply were tested using non-parametric Kruskal-Wallis test (Siegel, 1956) both for morning and evening sessions. A comparison of the time spent per individual in aggression for access to food supply in the morning and evening session separately was done by paired-t test (Zar, 1984). The tests were carried out for black buck and chital.

3.4.3. Descriptive analysis

3.4.3.1. Analysis of hierarchy in the enclosure

A cross tabulation of initiator and the response of the recipient was carried out for each day. The response of the recipient was differentiated as ignoring, losing and retaliating. A comparison matrix (Appenix-3) of the initiator and recipients losing out to the initiator was deduced from the total response to test the sex category winning the most of the aggressive interactions. The hierarchy of the population in each enclosure was inferred from the matrix based on the ranks received from the percentage of wins in an aggressive interaction. The sex category on the left side of the table (Appenix-3) indicates the initiators and the ones on the top of the table depict the recipients. The sex category to the left of

the sign (<, >, ~) is the initiator and to the right is the recipient. The numerical value to the right of the relationship obtained indicate the percent of times an initiator has won over the recipient in an aggressive encounter thus gaining its rank in the social status.

3.4.3.2. Hierarchy in the population to an access to food

The hierarchy of the population to access food during morning food supply in each enclosure was inferred from the matrix based on the ranks received from the percentage of wins in an aggressive interaction (as discussed in the previous analysis). The hierarchy matrix (Appendddix-4) was also made for the aggressive interactions in the evening session food supply. The difference in the hierarchy pattern of the stock population to that of the hierarchy to an access to food in the morning and evening food session was compared. A note was made of the difference in hierarchical pattern of the herd to gain an access to the food between the morning and evening sessions.

3.4.3.3. Analysis of rate of aggression for access to food across the density

The number of aggressive interactions at the end of 30 min from the time of food supply was divided by the number of individuals in the stock to compute the rate of aggression during that time period. Simple linear regression was done to find he relation between the rates of aggression across the densities. The rate of aggression across the densities for access to food was worked out for the evening session also. Graphical comparison was made between the rate of aggressions for both the morning and evening sessions. A similar relationship was computed for all the three species across the densities.

4. RESULTS

4.1 Difference in the activity pattern between two seasons

The data collected in the two seasons for each enclosure were compared for all the sex classes.

There was no significant difference in the activity pattern of the three species when compared between two seasons. Hence the data for two seasons were pooled together for data analysis.

4.2. Difference in activity pattern across the densities

In **blackbuck**, activity pattern differed across density (adult female Pillai's trace value = 0.502, $p < 0.001$; adult male Pillai's trace value = 0.956, $p < 0.001$; subadult male Pillai's trace value = 0.779, $p < 0.001$; subadult female Pillai's trace value = 0.725, $p < 0.001$ and fawn Pillai's trace value = 0.39, $p < 0.001$). The species was found to spend more time in feeding when the density was low but as the density increased the feeding activity gradually receded. The frequency of individuals standing, and moving did not show any particular trend with the increase in density of the population. Though lying did not show a particular trend across density it was common after feeding. Adult females (Fig. 4.1) and fawns (Fig. 4.5) were found less interactive as the density increased. The males (Fig. 4.2) became more aggressive to females and the frequency of submission amongst the females increased in attempts to defend them. When the density of the stock increased the subadult females (Fig. 4.4) of Mysore1 enclosure (8.35 ind/100sqm) became more aggressive to the adult females and subadult males (Fig. 4.3). Fawns (Fig. 4.5) were found to lie down most of the time and kept

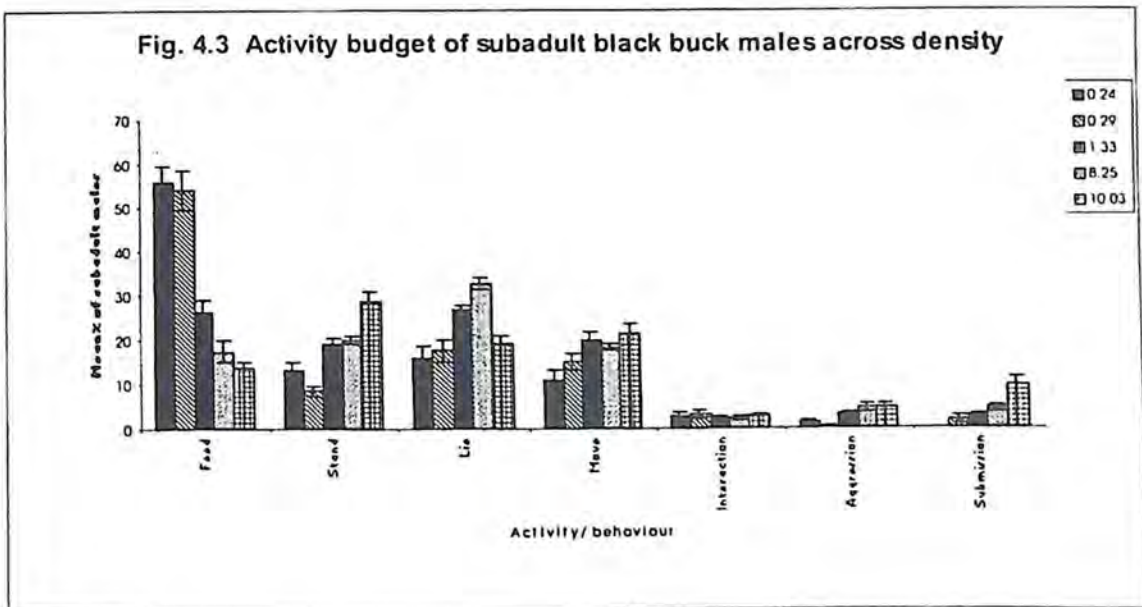
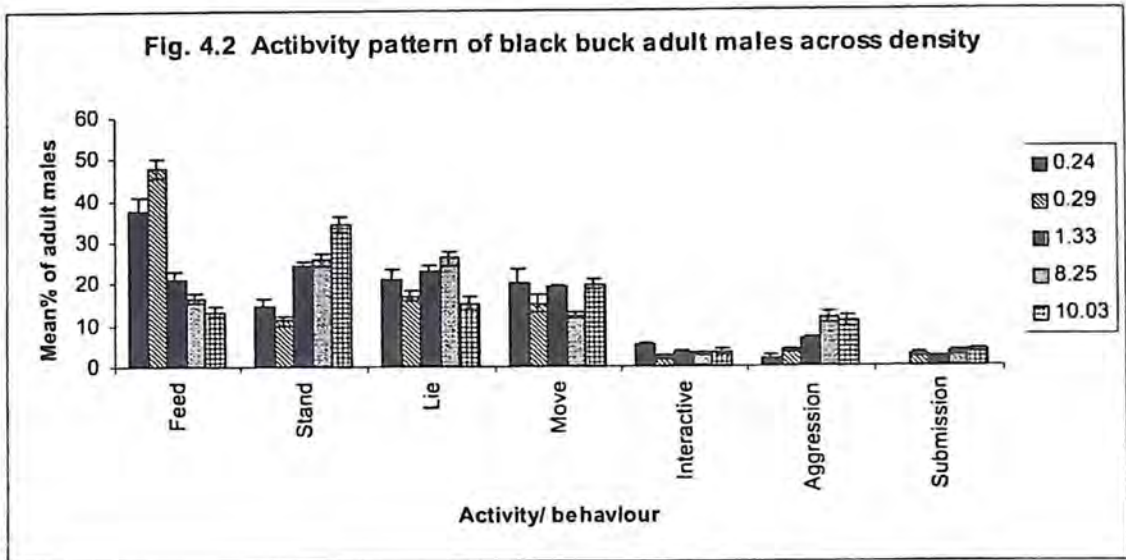
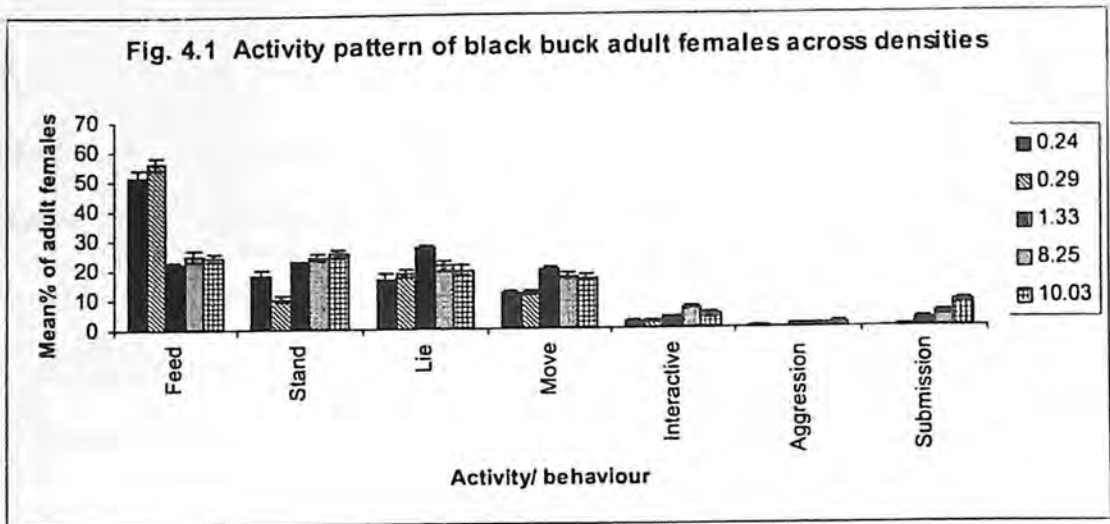


Fig. 4.4. Activity budget of black buck subadult females across density

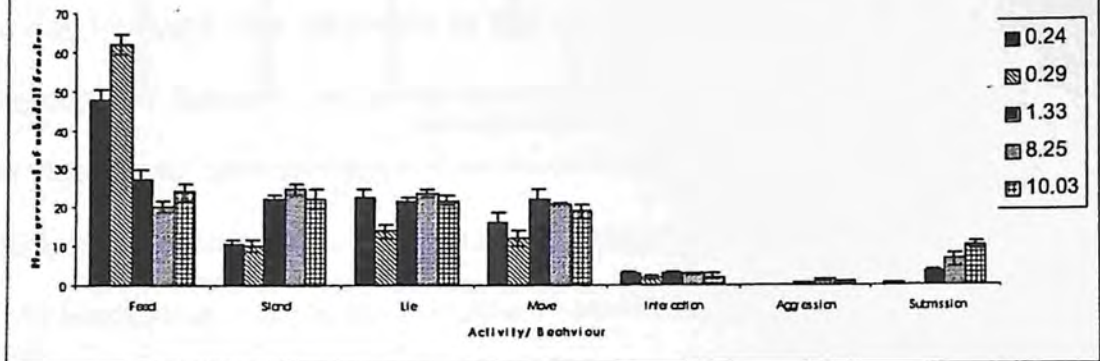
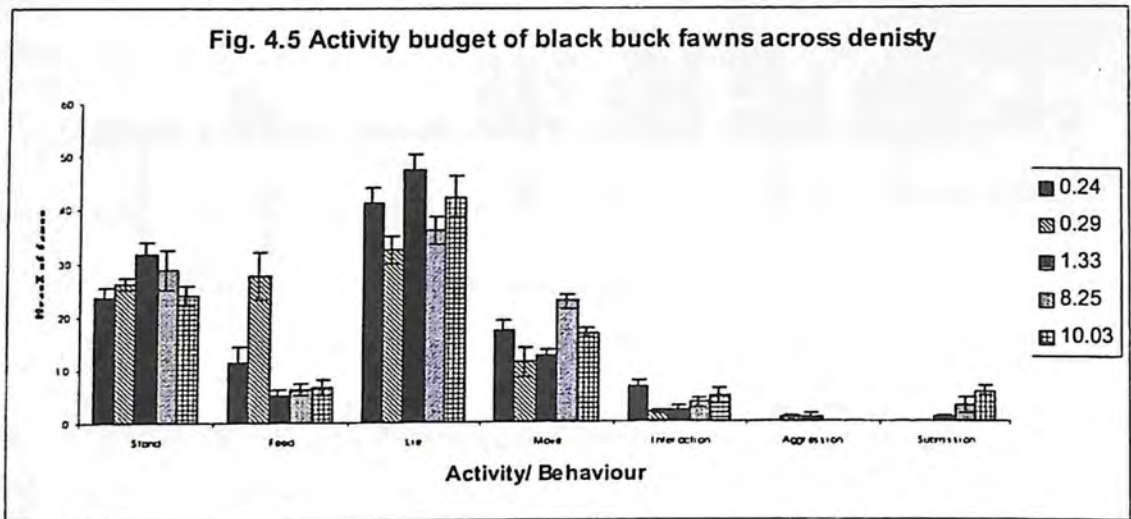


Fig. 4.5 Activity budget of black buck fawns across density



away from the other herd members. They were spared from the aggressive encounters in enclosures with low density but as the density of the enclosures increased they were seen to bear the brunt of the aggression of older individuals.

In **sambar**, the activity pattern showed a gradient of change as the density changed (adult female Pillai's trace value = 0.214, $p < 0.001$; adult male Pillai's trace value = 0.738, $p < 0.001$; subadult male Pillai's trace value = 1.248, $p < 0.001$; subadult female Pillai's trace value = 0.544, $p < 0.001$ and fawn Pillai's trace value = 0.15, $p < 0.001$) (Fig. 4.6, Fig. 4.7, Fig. 4.8, Fig. 4.9, Fig. 4.10). The frequency of standing increased with the increase in the density. No trend was seen in the proportion of lying, moving and interacting as density changed. Though frequency of aggression in the population increased with the increase in density, the stock of Mysore enclosure (highest density) did not respond to the change. The aggressive level of adult males of this enclosure decreased even though there was a constraint of space. These males were instead found to allogroom each other, which is a very rare behaviour of the sex category. This might be due to the reason that 10 of the 14 adult males present in the enclosure were castrated. The submissive behaviour in other four enclosures increased with an increase in density owing to the intensity of the fights encountered. The herd of this enclosure was found spending more time in lying. As a consequence of increased aggression, submission and lying activities the time spent in feeding decreased with the increase in density of the enclosure.

In **chital**, the populations showed a range of variation in the activity pattern with the change in density of the species in different enclosures (adult

Fig. 4.6 Activity budget of Sambar adult females across density

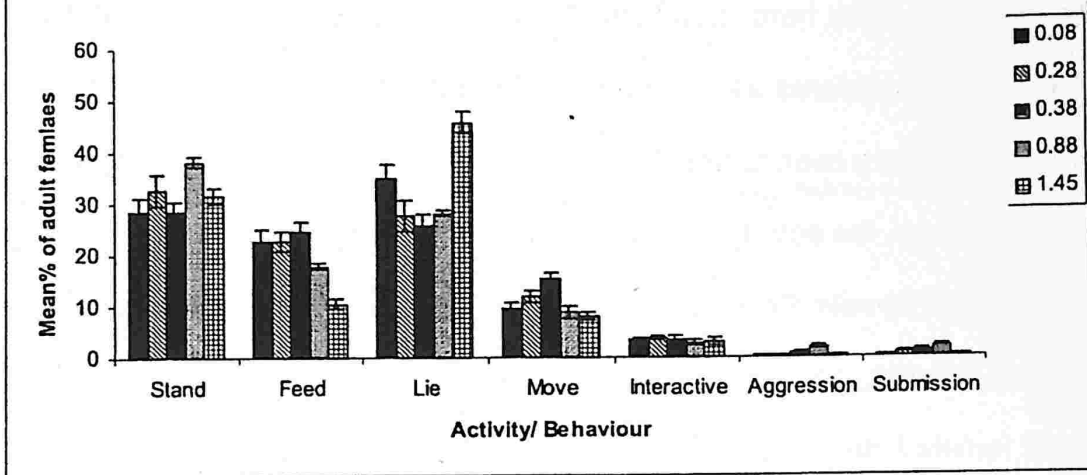


Fig. 4.7 Activity budget of Sambar adult males across density

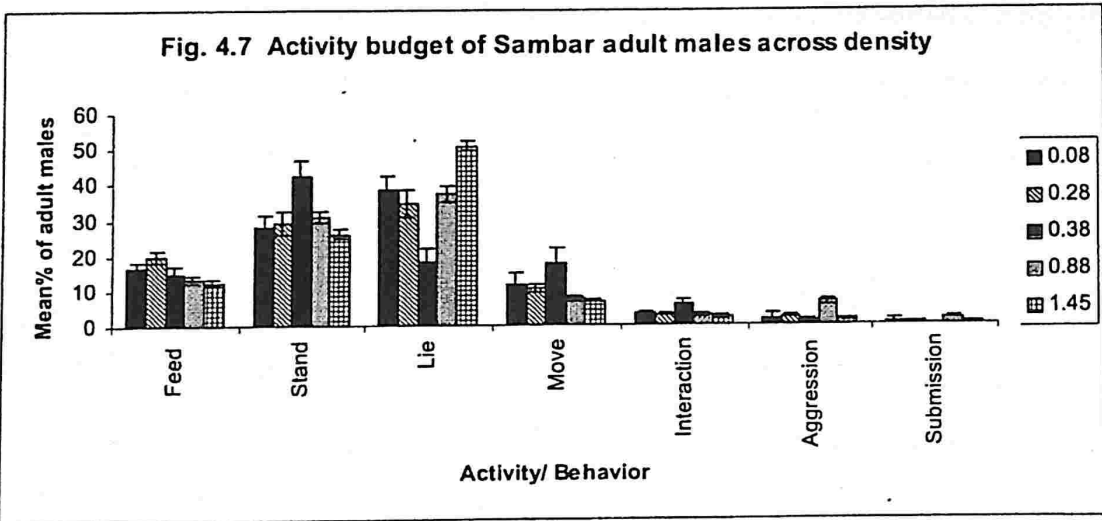
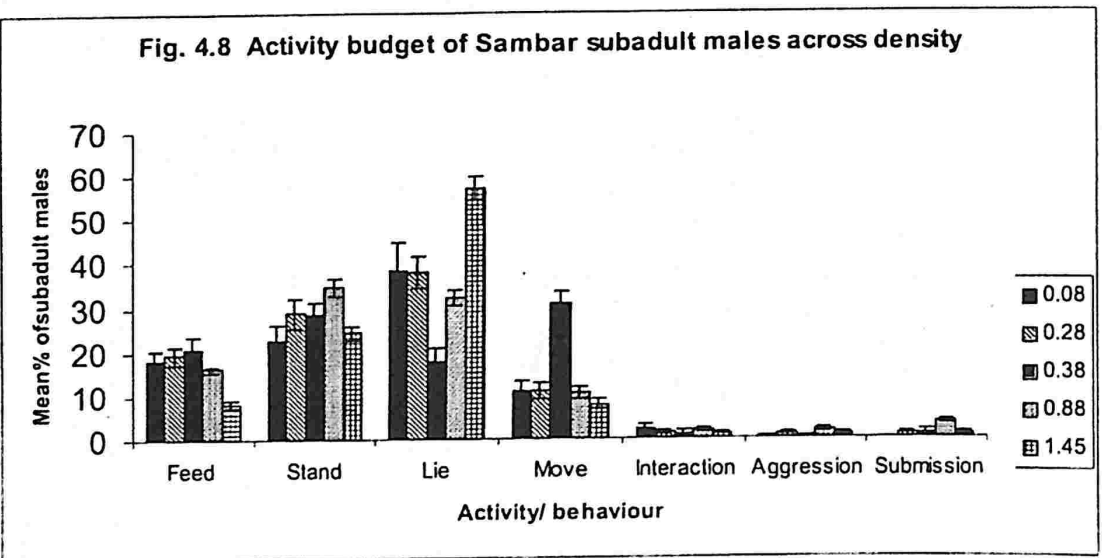
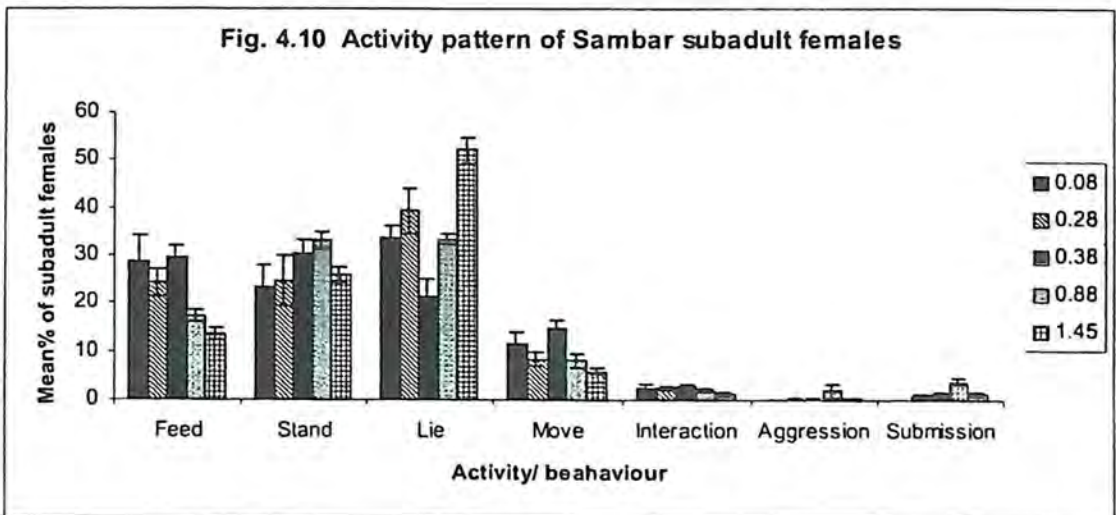
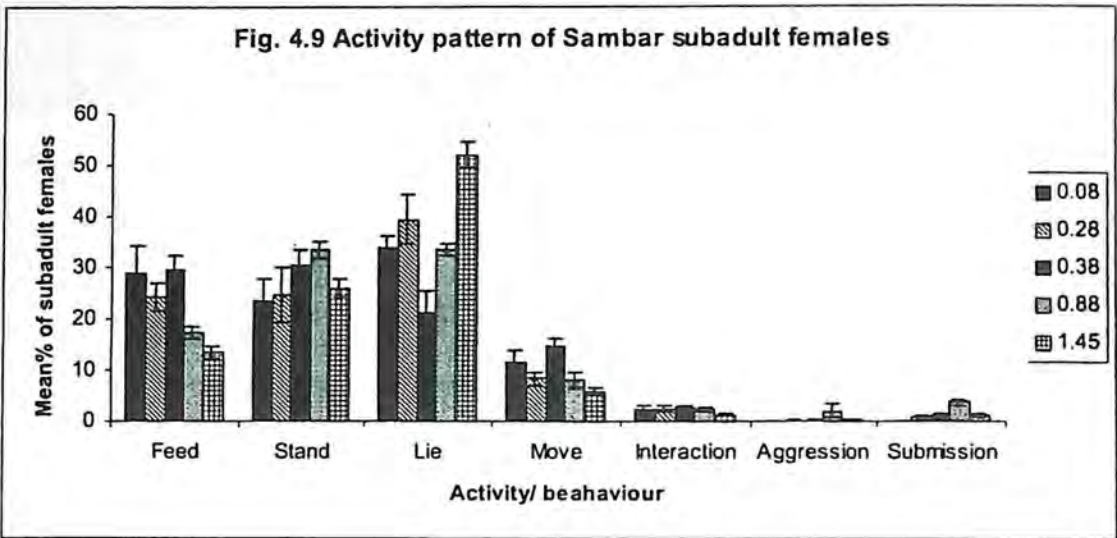


Fig. 4.8 Activity budget of Sambar subadult males across density

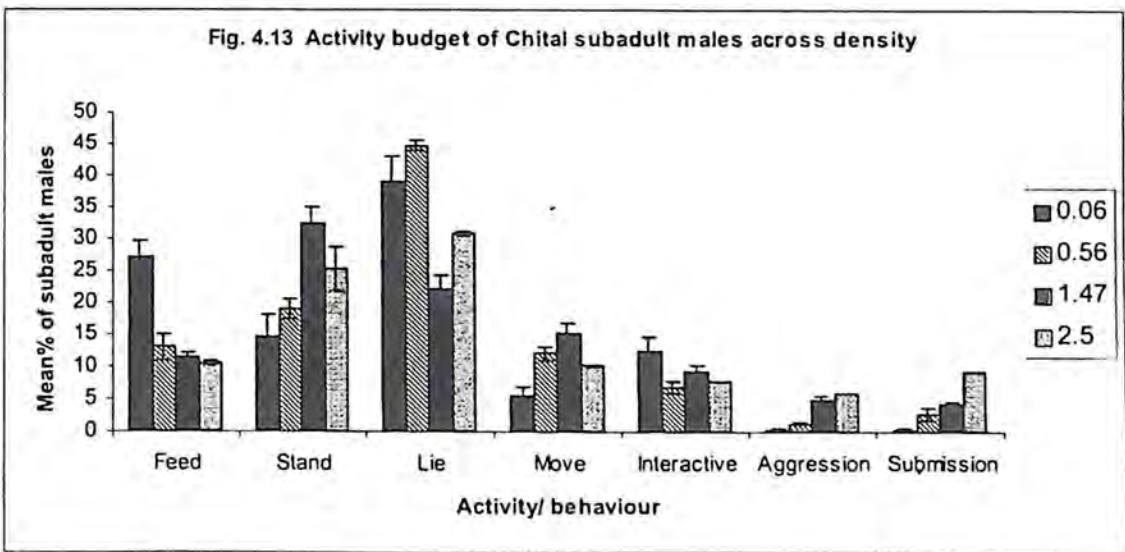
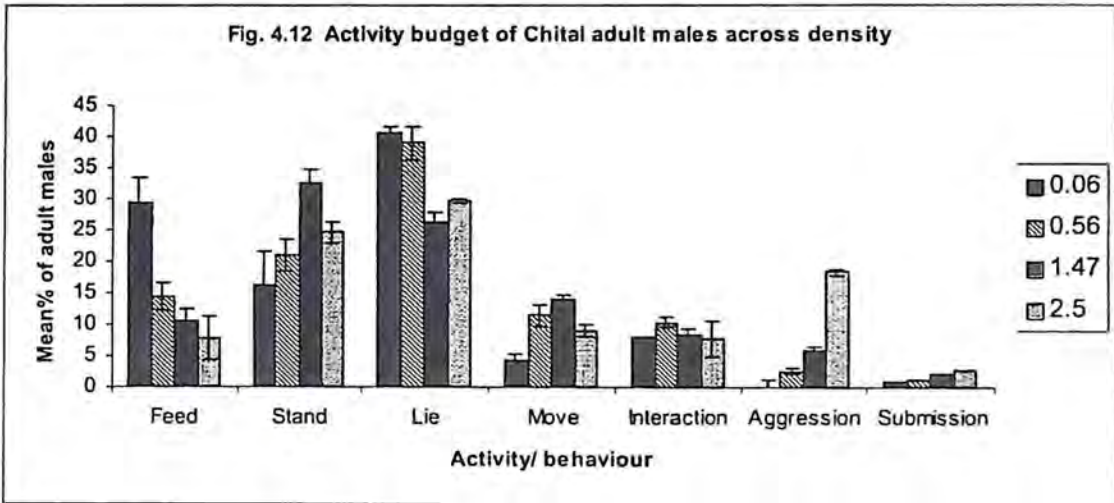
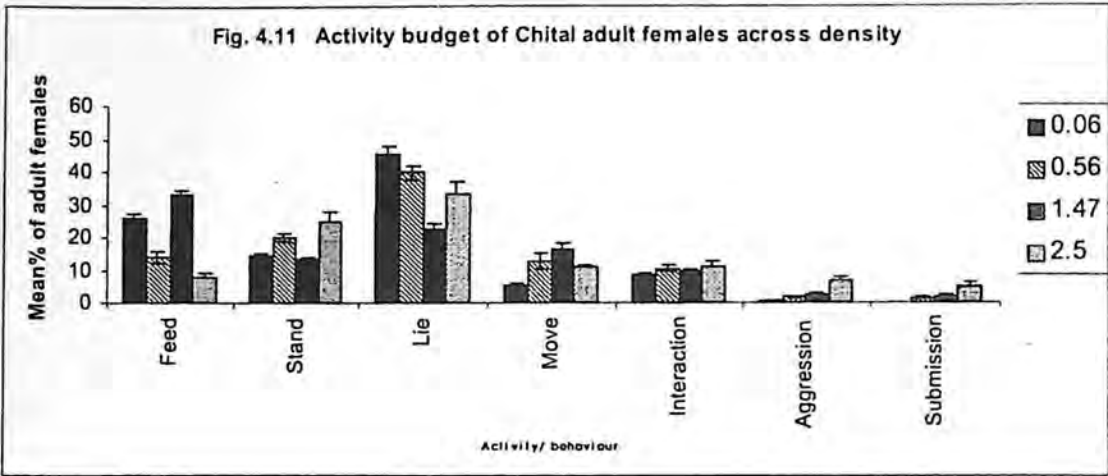


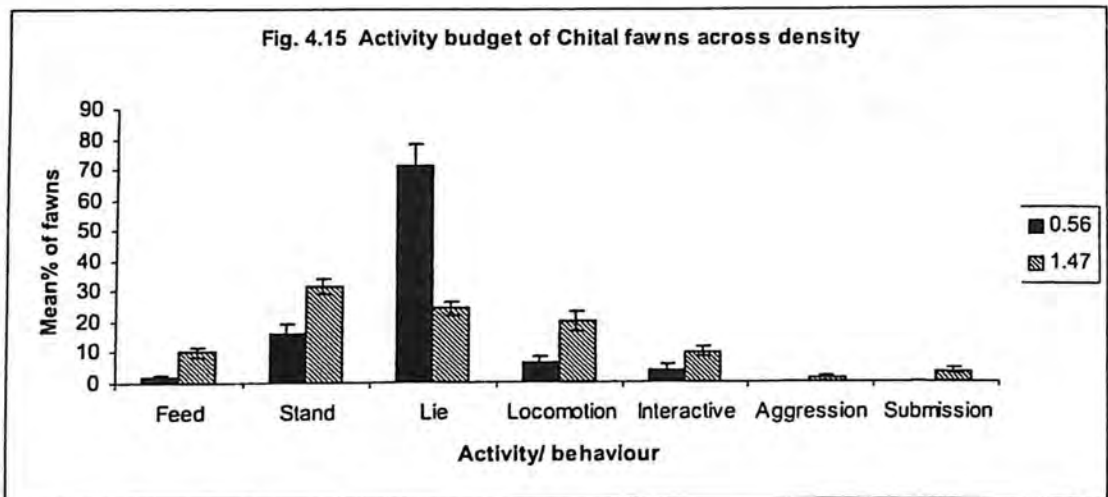
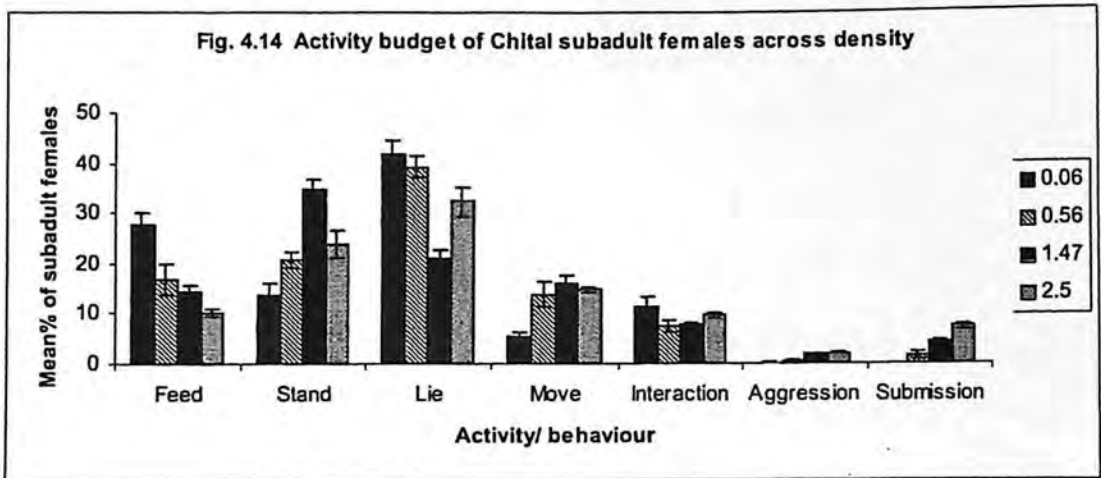


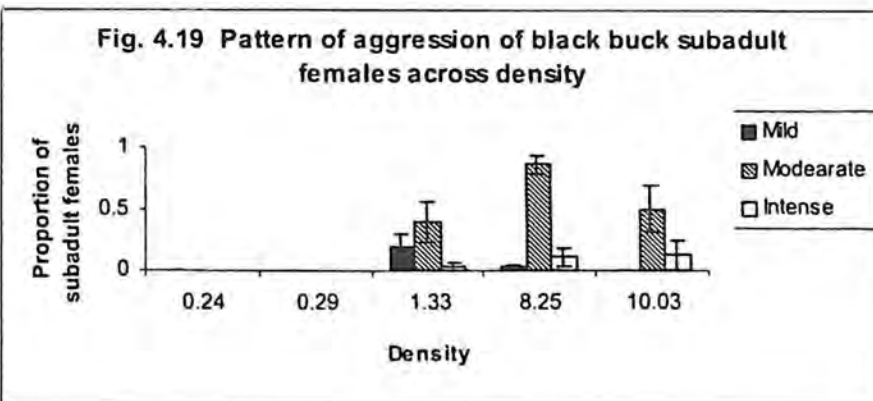
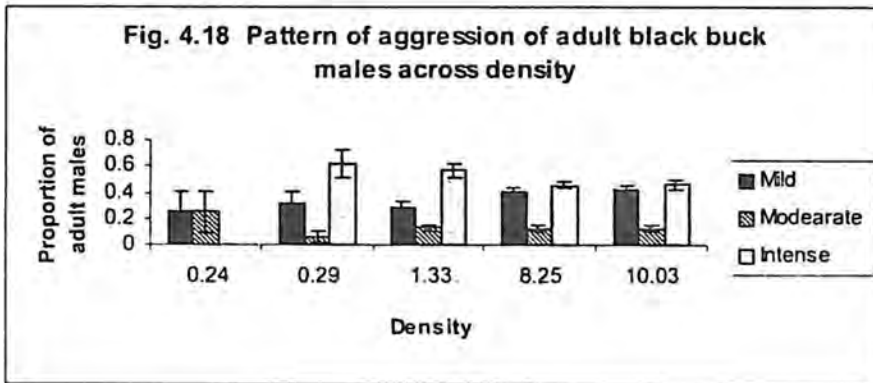
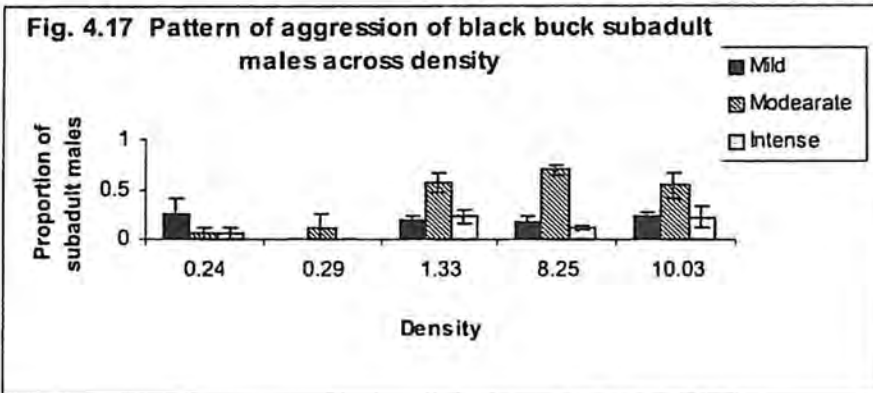
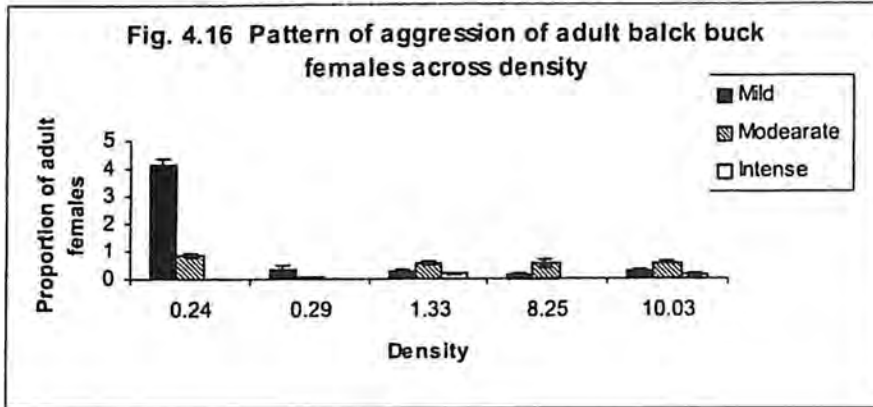
female Pillai's trace value = 0.584, $p < 0.001$; adult male Pillai's trace value = 0.533, $p < 0.001$; subadult male Pillai's trace value = 0.519, $p < 0.001$; subadult female Pillai's trace value = 0.652, $p < 0.001$ and fawn Pillai's trace value = 0.518, $p < 0.001$) (Fig. 4.11, Fig. 4.12, Fig. 4.13, Fig. 4.14, Fig. 4.15). No pronounced pattern was found in the standing, moving and interaction in the sex categories across different densities of the species in different enclosures. As the density increased aggression by the dominant section and submission by the weaker section in the other populations increased leading to a decrease in the feeding and lying time of the stock. The stock of Hyderabad enclosure (least density- 0.06 individual/100 sq. m) exhibited an activity pattern very similar to that of wild population. They were found to forage in morning hour and rest in as the heat of the day increased. Foraging in this enclosure peaked again in the evening hour. Aggression was seen the least in this enclosure.

4.3. Difference in aggressive pattern across the density

In **black buck**, pattern of aggression varied in different enclosures [adult female (Pillai's trace = 0.917, $p < 0.001$), adult male (Pillai's trace = 0.593, $p < 0.001$), subadult male (Pillai's trace = 0.779, $p < 0.001$), subadult female (Pillai's trace = 0.408, $p < 0.001$)]. Though mild form of aggression was exhibited at the same frequency in all the enclosures amongst females, moderate and intense form of aggression varied (Fig. 4.16, Fig. 4.19). Adult black buck males (Fig. 4.18) in low density of species did not resort to intense aggression. But encounters became more intense as the density of the individuals in the



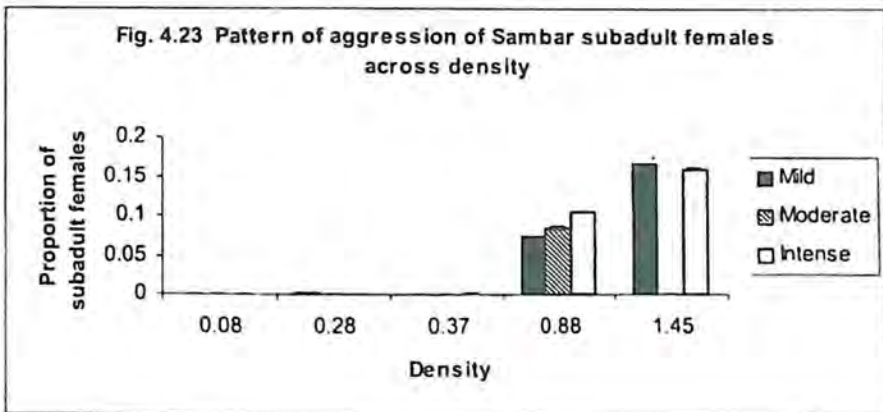
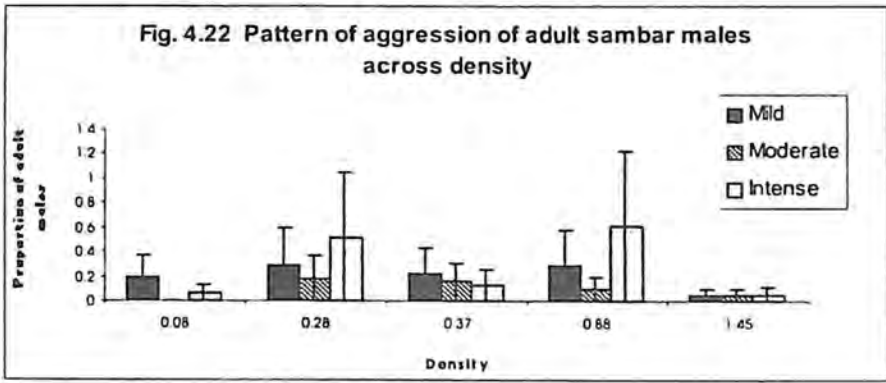
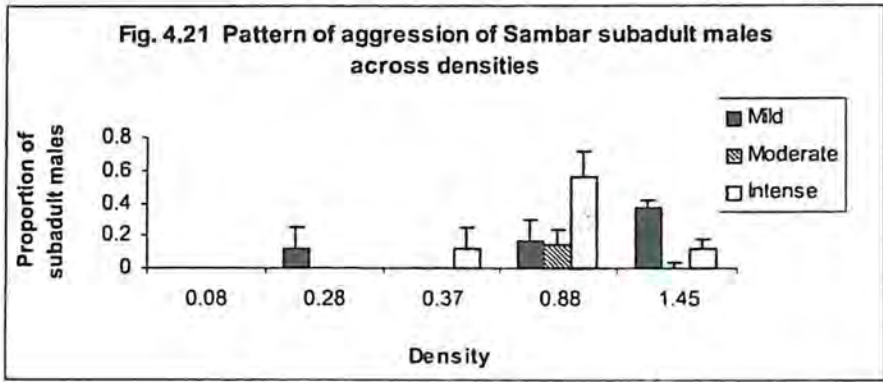
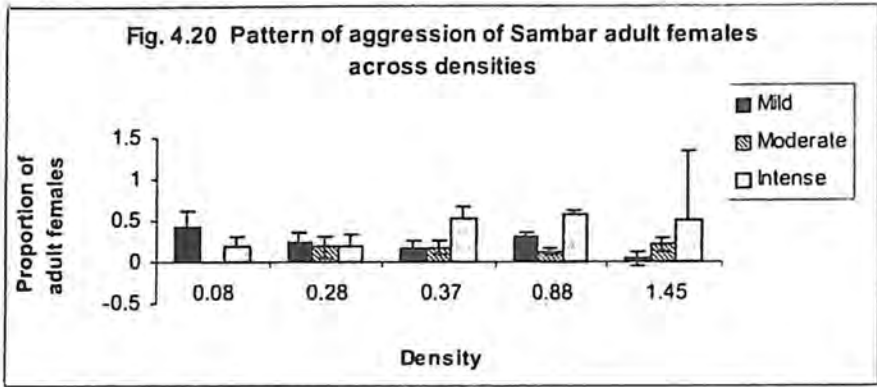


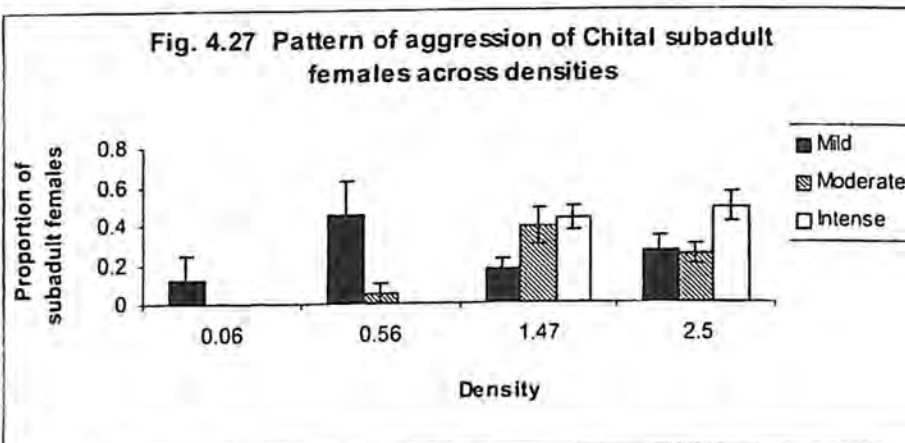
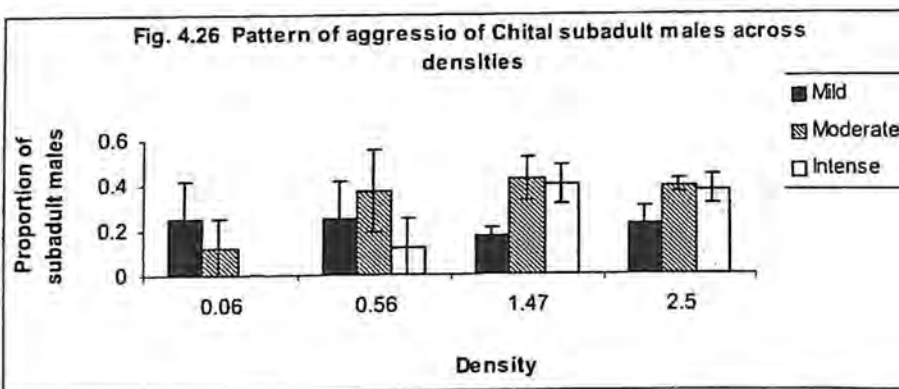
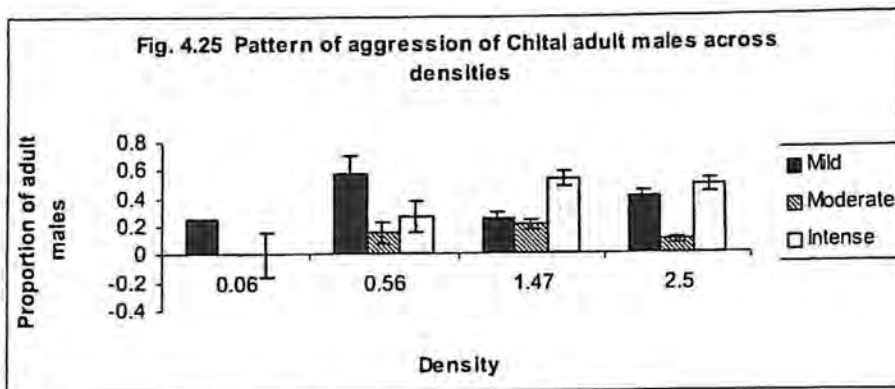
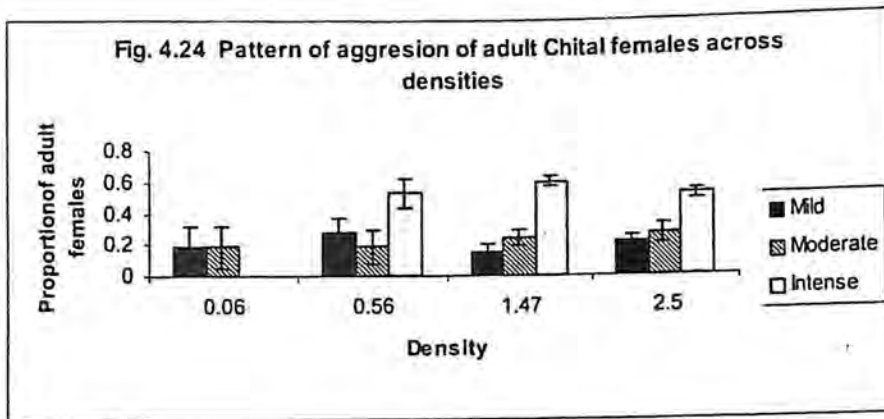


enclosures increased. Though the intensity of aggression in subadult males (Fig. 4.17) increased with an increase in density of the individuals, they resorted to moderate form of aggression. An interesting finding in the enclosure of Vizag was the adult males (Fig.4.18) exhibiting intense aggression in spite of having a low-density.

In **sambar**, aggressive patterns varied across densities of the species in different enclosures [adult female (Pillai's trace =0.337, $p<0.001$), adult male (Pillai's trace =0.662, $p<0.001$), subadult male (Pillai's trace =1.086, $p<0.001$), subadult female (Pillai's trace =0.609, $p<0.001$)]. The species did not exhibit variation in the frequency of mild and moderate form of aggression in adult male (Fig. 4.22) and females (Fig. 4.20, Fig. 4.23). With the increase in density adult females became aggressive to adult males resulting in intense aggression. Adult males were more intense in their aggression when the number of males increased in the enclosure rather than the density of individuals in an enclosure was more. In low density, the adult male and females subdued subadult males and females. But when density increased these weaker sections (Fig. 4.21) retaliated with greater intensity. The most interesting finding was in the enclosure of Mysore where the adult males exhibited aggression to a significantly low level in spite of having the highest density.

In **chital**, aggressive pattern varied in females and adult males [adult female (Pillai's trace =0.773, $p=0.002$), adult male (Pillai's trace =0.895, $p<0.001$), subadult female (Pillai's trace =1.107, $p<0.001$)] (Fig. 4.24, Fig. 4.25, Fig.4.27). Though the species did not exhibit intense aggression in low-density





population the intensity enhanced to a greater magnitude with an increase in density of individuals in an enclosure. Subadult males did not show a change in the aggressive pattern across density of species in enclosures (Pillai's trace =0.398, $p < 0.189$) (Fig. 4.27). Chital was found to be extremely aggressive species and all the sex categories fought with each other with an increase in intensity all the sex categories.

4.4. Visitor influence

Black buck, in most of the enclosures did not show a significant change in the activity pattern in response to the presence of visitors. A significant difference was found in the behavioural response of the species only in Chennai zoo [adult female (Pillai's trace value = 0.378, $p < 0.001$), adult male (Pillai's trace value = 0.286, $p = 0.001$), subadult male (Pillai's trace value = 0.325, $p < 0.001$) and subadult female (Pillai's trace value = 0.373, $p < 0.001$). Visitors influenced the exhibition of higher level of standing and moving behaviour in most of the enclosures. The species was found to be more active on visitor maximum day. More number of visitors enhanced the standing activity of adult females (Fig. 4.28) in the enclosure of Vizag (density-0.29) [$F(1,78) = 9.639$; $p = 0.003$]. Interaction [$F(1,78) = 4.43$; $p = 0.039$] and aggressive [$F(1,78) = 6.11$; $p = 0.16$] behaviour of the adult females decreased due to the presence of visitors.

Adult males (Fig. 4.29) of Chennai enclosure were more submissive [$F(1,78) = 6.524$; $p = 0.013$] on presence of more number of visitors. Though the proportion of lying and moving exhibited by the adult male did not show any

Fig. 4.28 Visitor influence on the activity pattern of black buck adult females

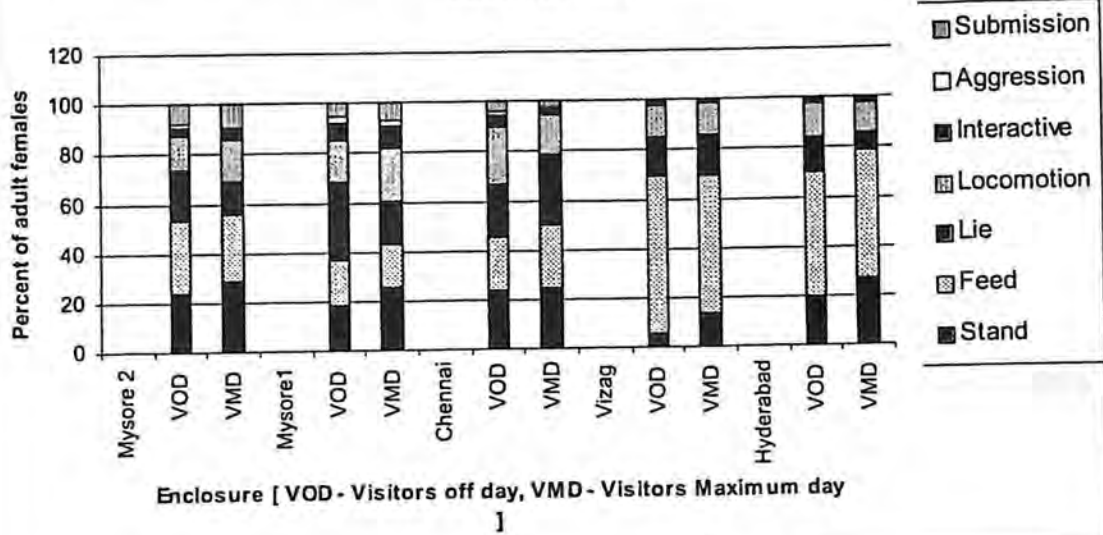
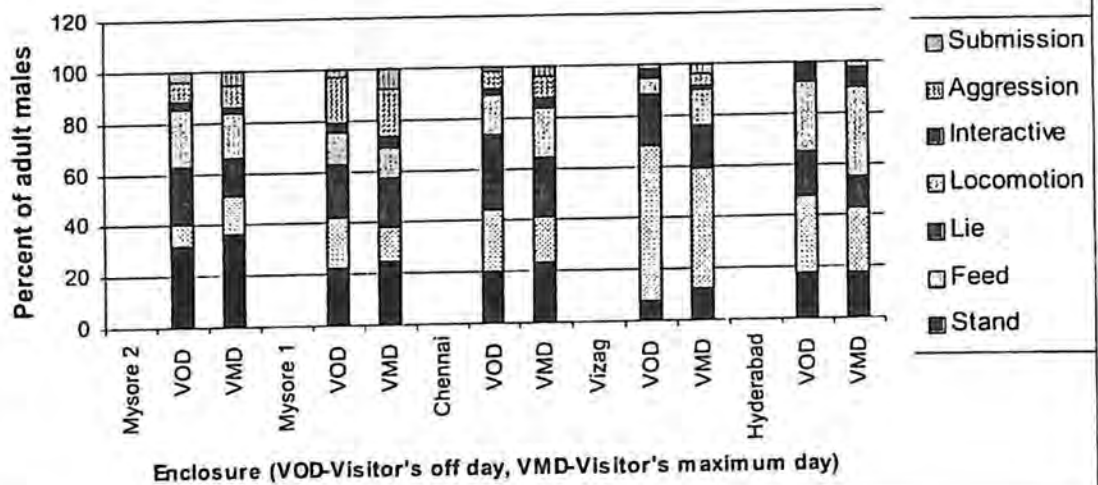


Fig. 4.29 Visitor influence on activity pattern of black buck adult males



significant difference adult males were found to lie less and fight more on visitor maximum day.

Subadult males (Fig. 4.30) were found to be moving [$F(1,78)=13.804$; $p<0.001$] and **interacting** [$F(1,78)=7.485$; $p=0.008$] less on zoo holiday in Chennai enclosure. The sex category exhibited higher frequency of lying in the enclosure-2 of Mysore on zoo holiday [$F(1,78)=6.5$; $p=0.013$].

The frequency of standing [$F(1,78)=$] increased in subadult females (Fig. 4.31) as a consequence to visitor influence.

In **sambar**, activity pattern was not significantly affected by the presence of visitors. The only enclosure where visitors induced a change in the activity pattern was the enclosure-2 of Vizag [adult female (Pillai's trace value = 0.378, $p<0.001$), adult male (Pillai's trace value = 0.311, $p<0.001$), subadult male (Pillai's trace value = 0.325, $p<0.001$) and subadult female (Pillai's trace value = 0.373, $p<0.001$).

In the enclosure-2 of Vizag, adult females (Fig. 4.32) were found to **feed** and **lie** more on zoo holidays. But the **moving** activity increased considerably when the presence of visitors was more in the zoo. The adult males (Fig. 4.33) though exhibited higher proportion of lying [$F(1,78)=7.981$; $p=0.006$] the visitors had a mild influence on enhancing the exhibition of aggression [$F(1,78)=3.663$; $p=0.059$] of adult males. Visitors contributed to higher level of lying in subadult males (Fig.4.34) [$F(1,78)= 8.265$; $p=0.005$] and subadult females (Fig. 4.35) [$F(1,78)=11.408$; $p=0.001$] in the enclosure-2 of Vizag. Consequently the frequency of standing in these sex categories [subadult male $F(1,78)=4.376$;

Fig. 4.30 Visitor influence on the activity pattern of black buck subadult males

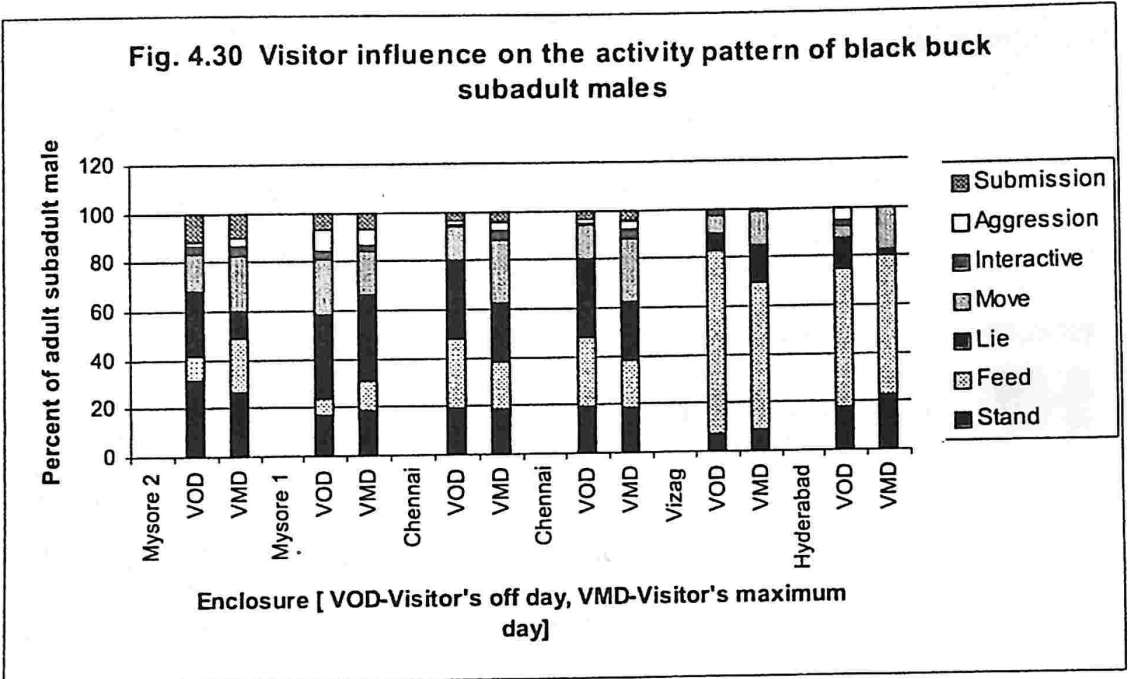


Fig. 4.31 Visitors influence on the activity pattern of black buck subadult female

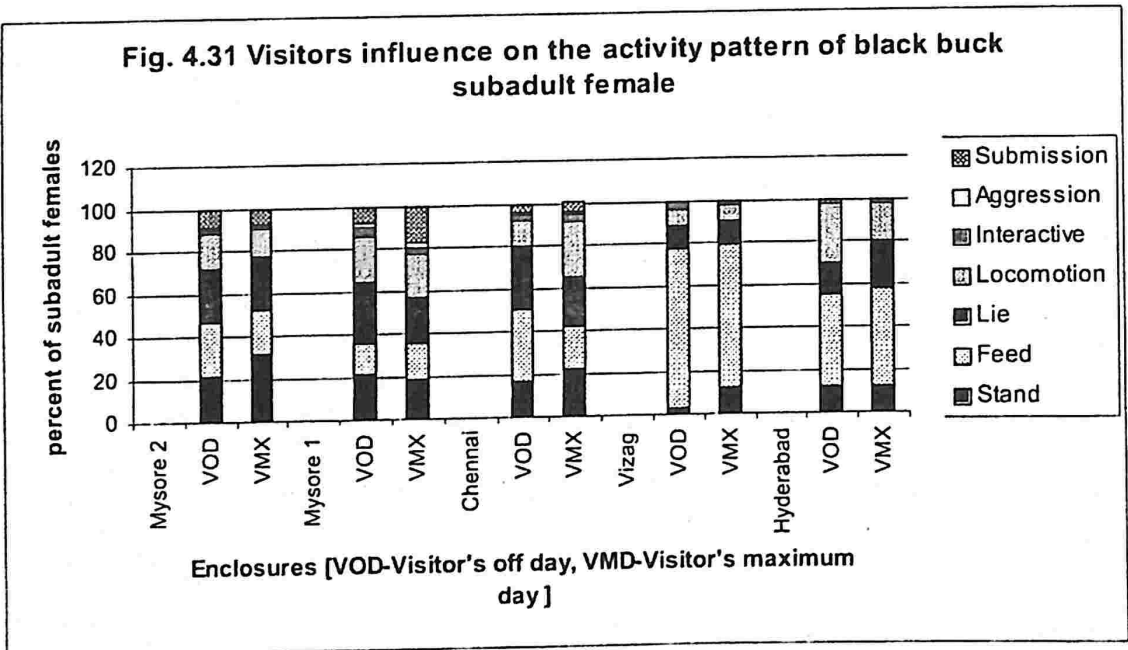


Fig. 4.32 Visitors influence on the activity pattern of Sambar adult females

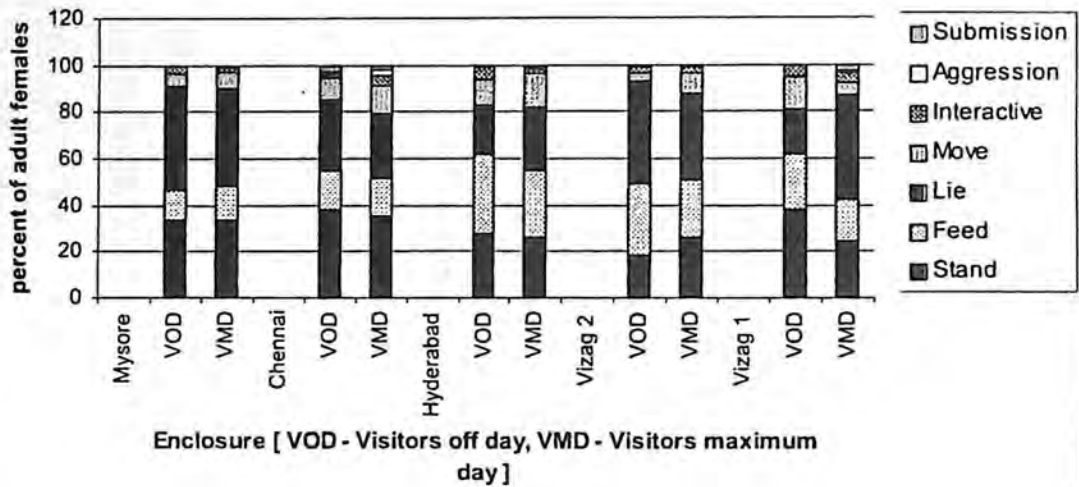


Fig. 4.33 Visitors influence on the activity pattern of sambar adult male

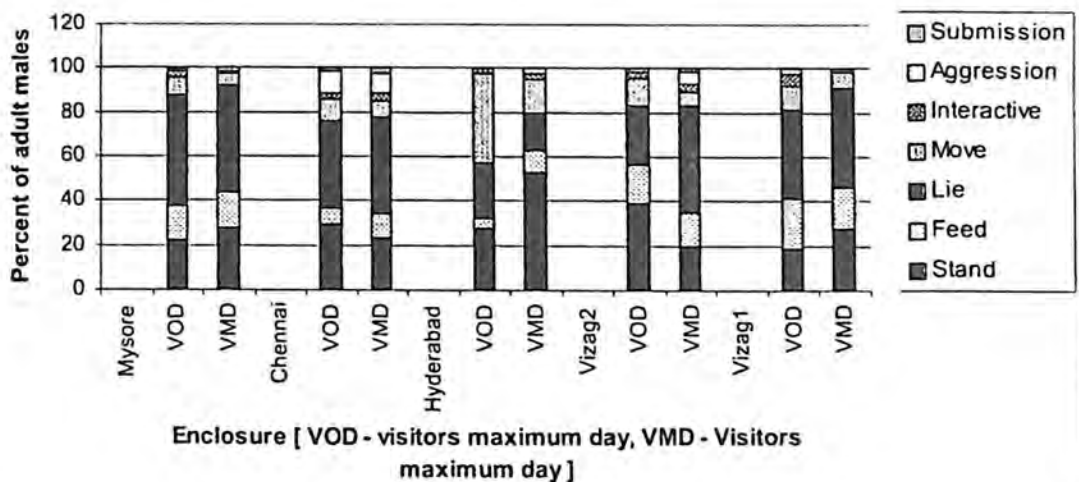


Fig. 4.34 Visitor influence on the pattern of sambar subadult male

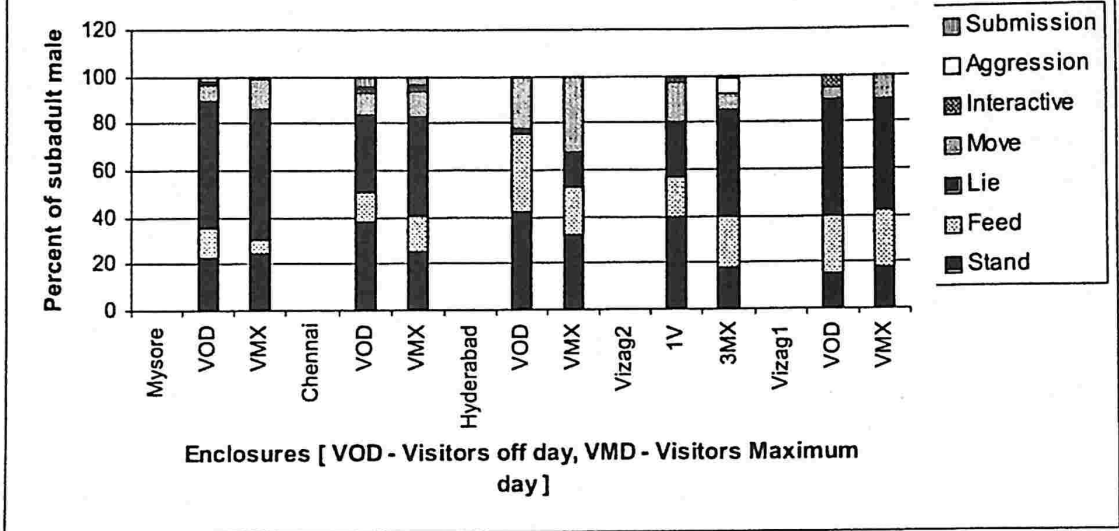
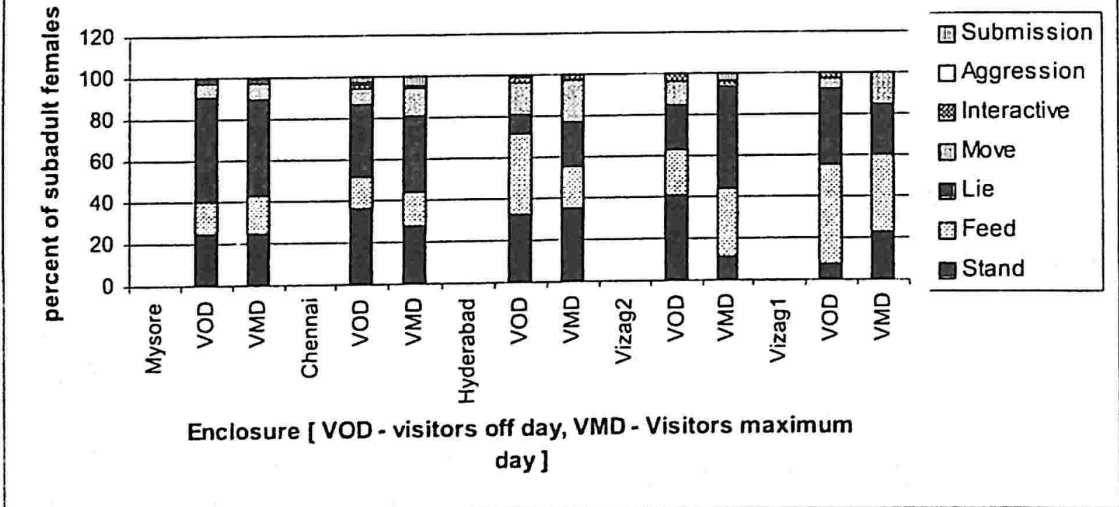


Fig. 4.35 Visitors influence on the activity pattern of sambar subadult females



$p=0.04$, subadult females $F(1,78)=16.245$; $p<0.01$] recedes on visitor maximum day.

In **chital** visitors altered the activity pattern in all the enclosures. Visitors were found to have an influence [Hyderabad (Pillai's trace value = 0.019, $p=0.004$, Mysore-1 (Pillai's trace value = 0.414, $p<0.001$) and Mysore-2 (Pillai's trace value = 0.171, $p=0.0015$] on the activity pattern of the adult females (Fig. 4.36) to a considerable level. In the enclosure of Hyderabad adult females were found to be more active on zoo holidays and resting more on the visitor maximum day [lying $F(1,94)=5.716$; $p=0.019$]. But in the enclosures of Mysore [Mysore1 ($F(1,78)=9.339$; $p=0.003$), Mysore2 ($F(1,78)=11.191$; $p=0.001$)] the animals exhibited lying activity to a lower level with the increase in the number of visitors. Aggression by the adult females enhanced as an influence of visitor presence [Mysore-1 $F(1,78)=2.394$; $p=0.126$; **Mysore-2**].

In adult males (Fig. 4.37) while lying activity increased in the enclosure of Hyderabad [$F(1,94)=11.314$; $p=0.001$] it decreased in the enclosures of Mysore [Mysore-1 ($F(1,78)=8.74$; $p=0.004$) and Mysore-2 ($F(1,78)=5.624$; $p=0.02$)] in the presence of visitors. A greater proportion of adult males were seen interacting [Chennai $F(1,78)=13.012$; $p=0.001$ and Mysore-2 $F(1,78)=5.757$; $p=0.019$] among each other on visitor maximum day.

Subadult males (Fig. 4.38) exhibited higher frequency of lying on zoo holidays in the enclosures of Mysore [Mysore1 $F(1,78)=8.404$; $p=0.005$ and Mysore2 $F(1,78)=33.065$; $p<0.001$].

Fig. 4.36 Visitors influence on the activity pattern of chital adult females

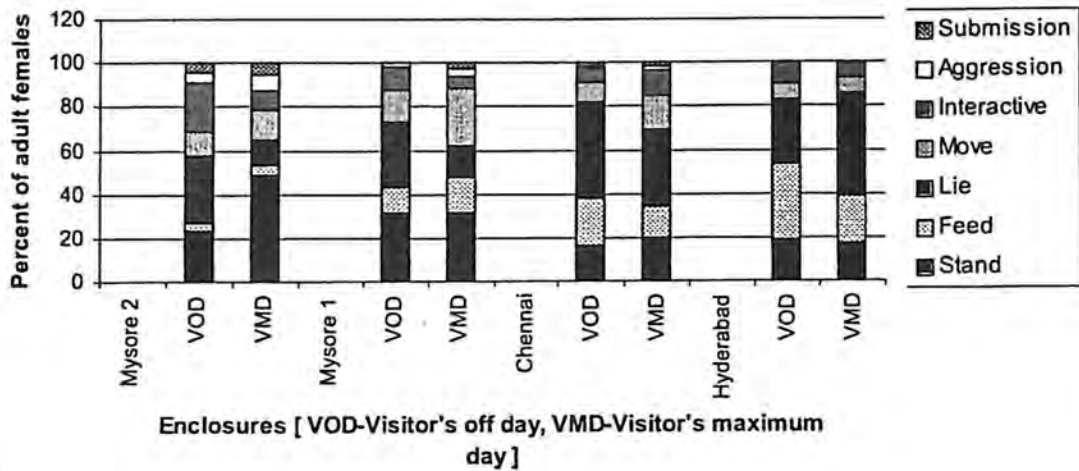


Fig. 4.37 Visitors influence on the activity pattern of chital adult males

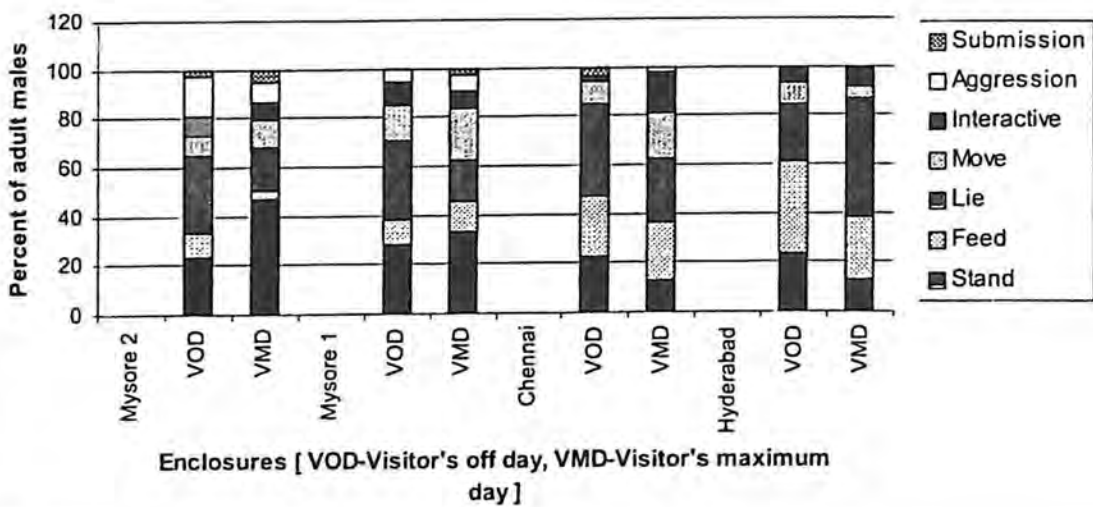


Fig. 4.38 Visitor influence on the activity pattern of chital subadult male

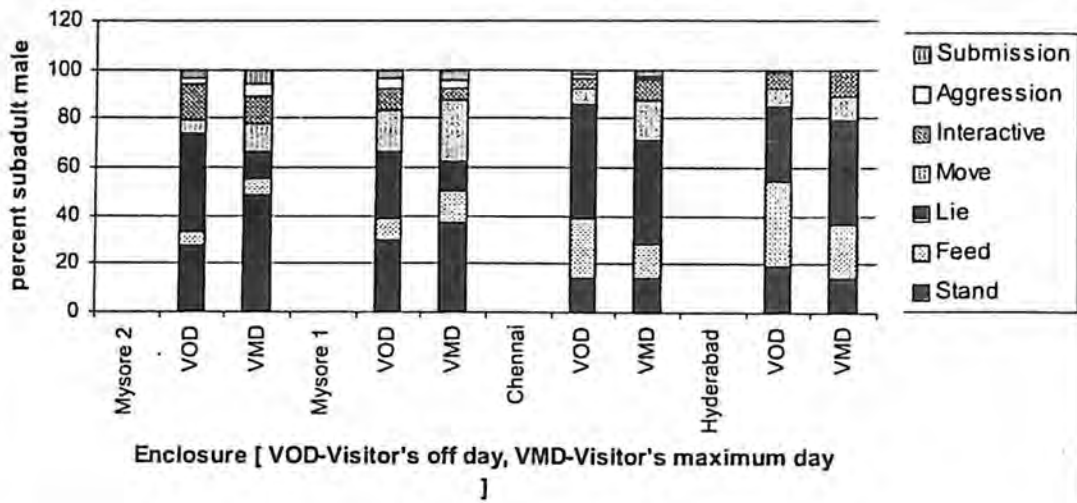
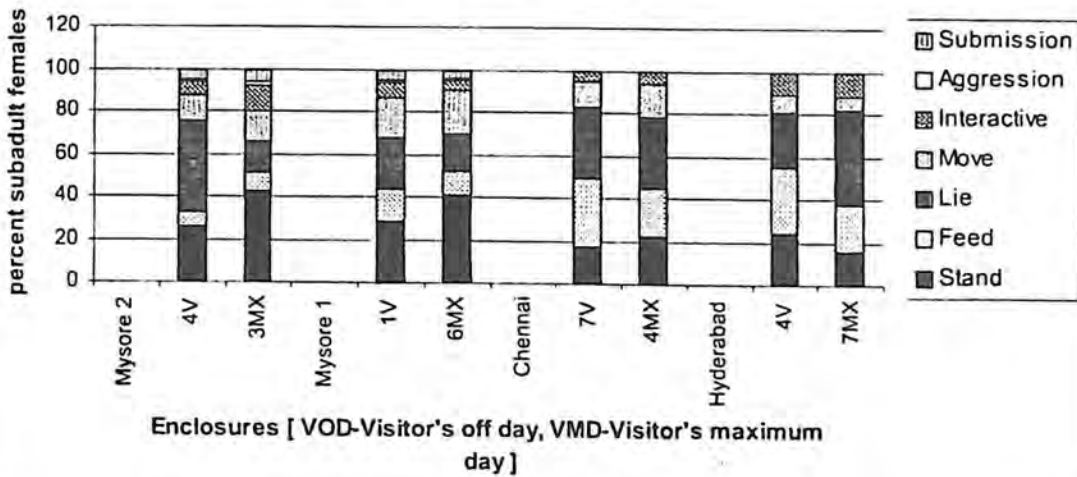


Fig. 4.39 Visitors influence on the activity pattern of chital subadult female



There was a significant difference in the standing activity subadult females (Fig. 4.39) in the enclosures of Mysore. Low level of standing behaviour was recorded on zoo holidays while it increased to a higher proportion on visitor maximum day.

4.5. Analysis of hierarchy in the enclosure

The hierarchical rank of various populations in the enclosure was compared.

4.5.1. Black buck:

Hyderabad enclosure (0.24 individual per 100sq.m):

The ranks (Appendi-3, Table 4.4.1) of the sex categories on the basis of the win-loss percentages was AM>AF, AM>SM, AM>SF, SM>AF, SM>SF, AF=SF (where AM= Adult male, AF= Adult female, SM= Subadult male, SF= Subadult female)

The summarised hierarchical status of the population was

$$\boxed{AM>SM>AF=SF}$$

Adult males were the most dominant followed by subadult males. The aggressive interaction between the adult and subadult females were almost similar, both holding similar hierarchical status in the population.

Vizag zoo (0.29 individual per 100sq.m):

The ranks (Appendi-3, Table 4.4.2) of the sex categories on the basis of the win-loss percentages was AM>AF, AM>SM, AM>SF, SM>AF, SM~SF, AF~SF

The summarised hierarchical status of the population in this enclosure was

AM>SM>AF~SF

The males were found to be more dominant than the females. The subadult males ranked second in the hierarchical ranking next to that of adult male. The dominance relation among the female were not too pronounced.

Chennai zoo (1.33 individual per 100sq.m):

The ranks (Appendi-3, Table 4.4.3) of the sex categories on the basis of the win-loss percentages was

AM>AF, AM>SM, AM>SF, SM>AF, SM>SF, AF>SF

The summarised hierarchical status of the population was

AM>SM>AF>SF

Males retained their hierarchy as that of the previous enclosures. Adult females though ranked low to the subadult males in the hierarchical order exhibited a higher level of aggression in comparison to the adult females of Hyderabad and Vizag enclosures. Adult females were positioned at a higher rank than the subadult females.

Mysore1 enclosure (8.25 individual per 100sq.m):

The ranks (Appendi-3, Table 4.4.4) of the sex categories on the basis of the win-loss percentages was

AM>AF, AM>SM, AM>SF, SM>AF, SM>SF, SF>AF

The summarised hierarchical status of the population was

AM>SM>SF>AF

The hierarchical order of the population of enclosure-1 of Mysore (density-8.25) deviates from the standard norm. The males exhibited similar pattern of dominance ranks but the level of adult males losing out to other sex categories increased in this enclosure. The subadult females surpassed the adult females and were found to hold a higher dominance status in comparison to the adult females.

Mysore 2 enclosure (10.03 individual per 100sq.m):

The ranks (Appendi-3, Table 4.4.5) of the sex categories on the basis of the win-loss percentages was AM>AF, AM>SM, AM>SF, SM>AF, SM>SF, AF>SF

The summarised hierarchical status of the population was

AM>SM>AF>SF

Though the hierarchical order in the enclosur-2 of Mysore follows the normal pattern of that of wild but the subadult male and adult females were found to lose out to the adult males to a lesser extent. The subadult females were seen to pose a tougher competition to the subadult males in the aggressive encounters.

4.5.2. Sambar

Vizag1 enclosure (0.08 individual per 100sq.m):

The ranks (Appendi-3, Table 4.4.6) of the sex categories on the basis of

the win-loss percentages was AM>AF, AM>SM, AM~SF, AF>SM, AF~SF, SM~SF

The summarised hierarchical status of the population was

AM>AF>SM~SF

Adult males were found to be most dominant in the population. The adult females ranked over the subadult males. But the hierarchical order between subadult male and female was not pronounced.

Vizag2 enclosure (0.28 individual per 100sq.m):

The ranks (Appendix - 3, Table 4.4.7) of the sex categories on the basis of the win-loss percentages was AM>AF, AM>SM, AM>SF, AF>SM, AF~SF, SM~SF

The summarised hierarchical status in the population was

AM>AF>SM~SF

The adult males topped in the dominance ranking. The adult females asserted a higher position in the social status of the herd. But the aggression level between the subadult males and females were too inconspicuous to reach to a conclusive ranking.

Hyderabad enclosure (0.38 individual per 100sq.m):

The ranks (Appendix - 3, Table 4.4.8) of the sex categories on the basis of the win-loss percentages was

AM>AF, AM>SM, AM>SF, AF=SM, SF>AF, SM>SF

The summarised hierarchical status in the population was

AM>SM>SF>AF

Adult males were ranked on top of the hierarchical order. The subadult male and subadult females surpassed the adult females in the social hierarchy.

Chennai enclosure (0.88 individual per 100sq.m):

The ranks (Appendix - 3, Table 4.4.9) of the sex categories on the basis of the win-loss percentages was AM>AF, AM>SM, AM>SF, AF>SM, AF>SF, SF>SM

The summarised hierarchical status in the population was

AM>AF>SF>SM

The hierarchical order deviated from the normal pattern in this enclosure. Though the adult males significantly ranked higher in the population, the adult females also proved out to be a tougher opponent in the aggressive encounters. The subadult females scored higher rank in the social hierarchy in comparison to subadult males.

Mysore enclosure (1.45 individual per 100sq.m):

The ranks Appendix - 3, Table 4.4.10) of the sex categories on the basis of the win-loss percentages was

AM>AF, SM>AM, AM>SF, AF>SM, AF>SF, SF~SM

The summarised hierarchical status in the population was

No pattern

No clear cut dominance ranking was seen in this stock.

4.5.3. Chital

Hyderabad enclosure (0.06 individual per 100sq.m):

The ranks (Appendix - 3, Table 4.4.11) of the sex categories on the basis of the win-loss percentages was

AM>AF, AM>SM, AM>SF, AF>SM, AF>SF, SM>SF

The summarised hierarchical status in the population was

AM>AF>SM>SF

The adult males were the most dominant ones. The adult females ranked above the subadult males. The subadult females ranked the least in the dominance hierarchy.

Chennai enclosure (0.56 individual per 100sq.m):

The ranks (Appendix - 3, Table 4.4.12) of the sex categories on the basis of the win-loss percentages was AM>AF, AM>SM, AM>SF, AF>SM, AF>SF, SM>SF

The summarised hierarchical status in the population was

AM>AF=SM>SF

Adult males were the most dominant ones in the herd. Adult females and subadult males shared the hierarchical status in the enclosure. Subadult females were the least dominant ones in this stock.

Mysore1 enclosure (1.47 individual per 100sq.m):

The ranks (Appendix - 3, Table 4.4.13) of the sex categories on the basis of the win-loss percentages was AM>AF, AM>SM, AM>SF, SM>AF, AF>SF, SM>SF

The summarised hierarchical status in the population was

AM> SM>AF>SF

The subadult males ranked second in the hierarchical order next to that of adult males. Adult female were found to be more dominant than the subadult females.

Mysore2 enclosure (2.5 individual per 100sq.m):

The ranks (Appendix - 3, Table 4.4.14) of the sex categories on the basis of the win-loss percentages was AM>AF, AM>SM, AM>SF, SM>AF, AF>SF, SM>SF

The summarised hierarchical status in the population was

AM> SM>AF>SF

The hierarchical order was similar to that of enclosure-1 of Mysore. But the level of aggression was found to be higher in adult females and subadult males in comparison to the individuals of the former enclosure. The aggressive encounters of subadult females were more severe than the first enclosure of Chital in Mysore.

4.6. Analysis of hierarchy to access to food:

The hierarchy of the species to have an access to food both for morning and evening session was compared to the existing hierarchy of the population.

4.6.1. Black buck

Hyderabad zoo

The ranks (Appendix-4, Table 4.5.1) of the sex categories on the basis of the win-loss percentages in Hyderabad zoo was as follows:

Morning: AM>AF, AM>SM, AM~SF, SM>AF, SM~SF, AF~SF

The summarised hierarchical status in the population was

AM>SM>AF=SF

Evening: AM>AF, AM>SM, AM>SF, SM=AF, SM>SF, AF~SF

AM>SM=AF>SF

The hierarchy of adult males was above the subadult male. The adult females and subadult females had the same ranking to get an access to food during the food supply in morning hours. No difference in the hierarchical status was observed for access to food between morning and evening sessions.

Vizag zoo

The ranks (Appendix-4i, Table 4.5.3) of the sex categories on the basis of the win-loss percentages in the enclosure of Vizag was

Morning: AM>AF, AM>SM, AM~SF, SM>AF, SM~SF, AF>SF

The summarised hierarchical status in the population was

AM>SM>AF>SF

Evening: AM>AF, AM>SM, AM~SF, SM>AF, AF~SF

The summarised hierarchical status in the population was

AM>SM>AF~SF

The hierarchical pattern of the stock of Vizag enclosure was similar to that of the stock in Hyderabad zoo up to the level of hierarchy in males. The adult females gained over the subadult females to gain an access to food in the morning hours. But no overall difference in the hierarchical status was observed for access to food between morning and evening sessions.

Chennai zoo

The ranks (Appendix-4, Table 4.5.5) of the sex categories on the basis of the win-loss percentages in the enclosure of Vizag was

Morning: AM>AF, AM>SM, AM>SF, SM>AF, SM>SF, AF>SF

The summarised hierarchical status in the population was

AM>SM>AF>SF

Evening: AM>AF, AM>SM, AM>SF, SM>AF, SM>SF, AF~SF

The summarised hierarchical status in the population was

AM>SM>AF~SF

There was a linear hierarchical order among the sex and age class in this enclosure to have an access to food during the morning session. Adult males get the maximum chances of getting food followed by subadult males. The adult females are dominant over the subadult females to get an access to food. No overall difference in the hierarchical status was observed for access to food between morning and evening sessions.

Mysore1 zoo

The ranks (Appendix-4, Table 4.5.7) of the sex categories on the basis of the win-loss percentages in the first enclosure of Mysore was

Morning: AM>AF, SM>AM, AM>SF, SM>AF, SM>SF, SF>AF

The summarised hierarchical status in the population was

SM>AM>SF>AF

Evening: AM>AF, SM>AM, AM>SF, SM>AF, SM>SF, AF~SF

The summarised hierarchical status in the population was

AM>SM>AF~SF

The subadult males outnumbered the adult males and subfemales of this exhibit were found to outnumber the adult females from the feeding site in the morning hour. The hierarchical order changed almost completely during the evening session of food in this enclosure. The males gained their dominance rank and the ranking between females were not pronounced.

The hierarchy altered for access to food between morning and evening session.

Mysore-2 zoo

The ranks (Appendix-4, Table 4.5.9) of the sex categories on the basis of the win-loss percentages in the second enclosure of Mysore was

Morning: AM>AF, AM=SM, AM>SF, SM=AF, SM>SF, AF>SF

The summarised hierarchical status in the population was

No pattern

Evening: AM>AF, AM=SM, AM>SF, SM=AF, SM>SF, AF>SF

The summarised hierarchical status in the population was

No pattern

The fight for access to food became very intense both in morning and evening session. The Subadult males fought with an equal intensity as that of adult males and adult females to win over chances of getting the food. The subadult females also equally participated in aggression with subadult males for chances of procurement of food. No clear-cut social hierarchy could be obtained for the stock to access to food both in morning and evening sessions.

4.6.2. Sambar

Vizag1 zoo

The ranks (Appendix-4, Table 4.5.11) of the sex categories on the basis of the win-loss percentages in the first enclosure of Vizag was

Morning: AM>AF, AM>SM, AM~SF, AF~SM, AF~SF

The summarised hierarchical status in the population was

AM>AF~SM~SF

Evening: AM>AF, AM>SM, AM~SF, AF~SM, AF~SF

The summarised hierarchical status in the population was

AM>AF~SM~SF

The hierarchical order was not so pronounced in this enclosure. The adult males were found to dominate over the feeding site. But the dominance rank in the other sex categories was not discernible.

No overall difference in the hierarchical status was observed for access to food between morning and evening sessions.

Vizag2 zoo

The ranks (Appendix-4, Table 4.5.13) of the sex categories on the basis of the win-loss percentages in the second enclosure of Vizag was

Morning: AF>AM, AM>SM, AM>SF, AF>SM, SM>SF

The summarised hierarchical status in the population was

No pattern

Evening: AM>AF, AM>SM, AM~SF, AF>SM, AF~SF

The summarised hierarchical status in the population was

AM>AF>SM~SF

The hierarchical order of the population in the morning session of food supply did not show any fixed pattern whereas a linear hierarchy existed in evening hour for access to food.

Hyderabad zoo

The ranks (Appendix-4, Table 4.5.15) of the sex categories on the basis of the win-loss percentages in Hyderabad zoo was

Morning: AM>AF, AM>SM, AM>SF, AF>SM, AF>SF

The summarised hierarchical status in the population was

AM>AF>SM~SF

Evening: AM>AF, AM>SM, AM>SF, AF>SM, AF>SF

The summarised hierarchical status in the population was

AM>AF>SM~SF

The adult male dominated over the feeding area and was seen to displace the rest of the herd members from his vicinity. The adult female followed the adult male in the dominance rank. The subadult males and females were not seen to exhibit any aggression for access to food. Similar hierarchical pattern was observed in both morning and evening sessions for access to food.

Chennai zoo

The ranks (Appendix-4, Table 4.5.17) of the sex categories on the basis of the win-loss percentages in Chennai zoo was

Morning: AM=AF, SM>AM, AM>SF, AF=SM, AF>SF, SM>SF

The summarised hierarchical status in the population was

No pattern

Evening: AM=AF, AM>SM, AF>SF, AF>SM, AF>SF, SM>SF

The summarised hierarchical status in the population was

AM=AF>SM>SF

There was no similarity in the hierarchical pattern obtained for access to food in morning and evening sessions. No hierarchical ranking could be ascertained in the morning session due to intense aggression by all sex classes. Adult males and adult females fought with equal intensity in the evening hour for getting access to food. Subadult males and females followed the adults in the hierarchical set up.

Mysore zoo

The ranks (Appendix-4, Table 4.5.19) of the sex categories on the basis of the win-loss percentages in Mysore zoo was

Morning: AF>AM, AM>SM, AM~SF, AF~SM, AF>SF, SM~SF

The summarised hierarchical status in the population was

AF>AM>SM~SF

Evening: AM=AF, AM~SM, AM>SF, AF~SM, AF>SF, SM~SF

The summarised hierarchical status in the population was

AM=AF>SM~SF

While adult males and adult females were found to fight with an equal intensity for food access both in the morning and evening, subadult males receded in their hierarchical rank in the evening.

Chital

Hyderabad Zoo

Though concentrate feed was provided in the morning session the stock of this enclosure was not seen to congregate at that particular time and feed on the supplied food. They were found to pay very little attention to the concentrate feed supplied but were seen to feed on the natural forage present in the enclosure. Hence the hierarchy of the population of this population to access food was not accessed.

Chennai zoo

The ranks (Appendix-4, Table 4.5.21) of the sex categories on the basis of the win-loss percentages in Chennai zoo was

Morning: AM>AF, AM>SM, AM>SF, AF>SM, AF>SF, SM=SF

The summarised hierarchical status in the population was

AM>AF>SM=SF

Evening: AM>AF, AM>SM, AM>SF, AF>SM, AF=SF, SM>SF

The summarised hierarchical status in the population was

No pattern

Adult males won over the rest of the age and sex classes in getting an access to food. Adult females positioned themselves at a higher hierarchical level than the

subadult males and females. But the subadult males and females shared the hierarchical status both. Such a distinct pattern was not observed in the evening session.

Mysore-1 enclosure

The ranks (Appendix-4, Table 4.5.23) of the sex categories on the basis of the win-loss percentages in the first enclosure of Mysore zoo was

Morning: AM>AF, SM>AM, AM>SF, SM>AF, AF=SF, SM>SF

The summarised hierarchical status in the population was

SM>AM>AF=SF

Evening: AM>AF, AM>SM, AM>SF, SM>AF, AF>SF, SM>SF

The summarised hierarchical status in the population was

AM>SM>AF>SF

Adult males lost to subadult males but defeated the adult females in fights to accessibility to food in the morning hour. But the adult males gained back their dominance ranking in the evening supply of food in the evening session of food supply.

Mysore-2 enclosure

The ranks (Appendix-4, Table 4.5.25) of the sex categories on the basis of the win-loss percentages in the first enclosure of Mysore zoo was

Morning: AM>AF, AM>SM, AM>SF, AF>SM, AF>SF, SM>SF

The summarised hierarchical status in the population was

AM>AF>SM>SF

Evening: AM>AF, SM>AM, AM>SF, AF=SM, AM>SF, SM>SF

The summarised hierarchical status in the population was

No pattern

Though a linear hierarchy was observed in the population stock to have an access to food in the morning hour, no pattern was observed in the evening session for access to food as the aggression to access food intensified.

4.7. Analysis of rate of aggression to access to food across density:

The rate of aggression by the individuals to access to food was compared to that of increase in density.

4.7.1. Black buck

The number of aggressive interactions exhibited by an individual in the enclosure was compared across different densities of species in the enclosures during morning and evening food supply. In the morning session, a positive relation was found between the rate of aggression (y) and the density (x) of the black buck in the enclosures (Linear regression, $y = 0.1319x + 0.2713$, $R^2 = 0.7332$). A stronger relation (Linear regression, $y = 7.9891x - 1.5311$, $R^2 = 0.8831$) was found in the evening session as the species exhibited aggression to a higher level with the increase in density of individuals in the enclosure.

A graphical comparison (Fig. 4.40) of rate of aggression between morning and evening supply of food was made. The rate of aggression was found to have reduced slightly in comparison to the rate of aggression in the morning food supply.

4.7.2. Sambar

The relationship of rate of aggression to access to food across density both for morning and evening sessions were compared. Comparison was made separately with and without the inclusion of castrated males of Mysore enclosure. When the enclosure with the castrated males was excluded from the analysis, a moderate relation (Linear regression, $y = 0.9793x - 0.0934$, $R^2 = 0.4559$) was found between the rate of aggression to access to food and density of the species. But the relationship weakened as the enclosure with castrated males was included in the analysis (Linear regression, $y = 0.2286x + 0.7162$, $R^2 = 0.0093$). A very weak relation (Linear regression, $y = 1.0494x + 0.0064$, $R^2 = 0.2757$) existed when the rate of aggression to access to food was compared to density in the evening supply of food, with the exclusion of enclosure with castrated males. No relation (Linear regression, $y = 0.0974x + 0.5771$, $R^2 = 0.0008$) was found when the rate of aggression to access to food was compared across density (of species in the respective enclosures) taking the enclosure with castrated males into consideration.

The rate of aggression to access food was compared graphically (Fig. 4.41) between morning and evening supply of food. An overall decrease in the level of aggression was found in the evening hour of food supply.

4.7.3. Chital

No relation was observed between the rate of aggression to access to food with that of density in Chital during both and morning (Linear regression, $y =$

-1.57x + 2.3052, $R^2 = 0.1552$) and evening (Linear regression, $y = -1.0256 + 1.9973x$, $R^2 = 0.0747$) supply of food.

A graphical representation (Fig. 4.42) of the rate of aggression to access to food during and morning and evening supply of food revealed no difference in the rate of aggression during both the sessions.

4.8. Analysis of time spent per individual for aggression across density of species

The time spent in aggression to access to food was compared across density.

4.8.1. Black buck

The time spent by black buck in aggression to get an access to food differed significantly (Fig. 4.44) across the five enclosures during the morning ($F(4,35) = 39.394$, $p < 0.001$) and evening hours ($F(4,35) = 102.269$, $p < 0.001$) of food supply. Black buck in all the five enclosures (Hyderabad enclosure- $t = 1.037$, $N = 8$, $p = 0.334$, Vizag enclosure- $t = -1.77$, $N = 8$, $p = 0.865$, Chennai enclosure- $t = 0.79$, $N = 8$, $p = 0.455$, Mysore-1 enclosure- $t = -1.433$, $N = 8$, $p = 0.291$, Mysore-2 enclosure- $t = 0.587$, $N = 8$, $p = 0.576$) were found to spend almost equal time in exhibiting aggression at both morning and evening hour of food supply.

4.8.2. Sambar

Sambar exhibited a difference (Fig. 4.45) in the time spent in aggression to get an access to food in the morning hour of food supply ($F(4,35) = 24.011$,

Fig 4.40 Coparision of mean rate of aggression to access to food between morning and evening supply of food in black buck

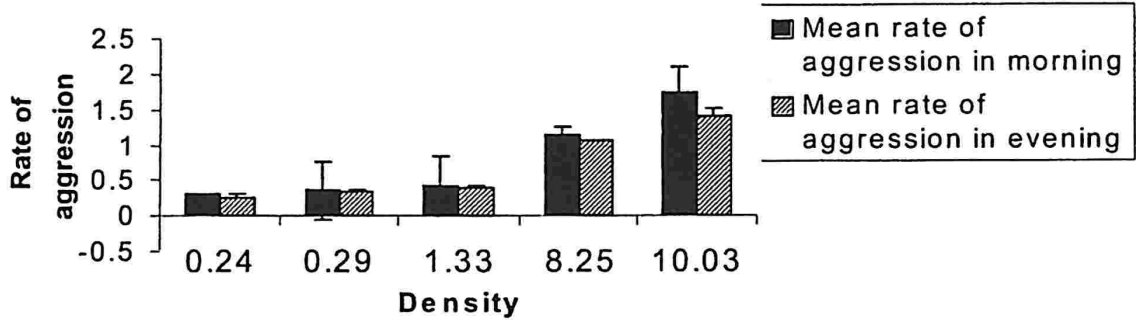


Fig. 4.41 Coparision of mean rate of aggression to access to food between morning and evening supply of food in sambar

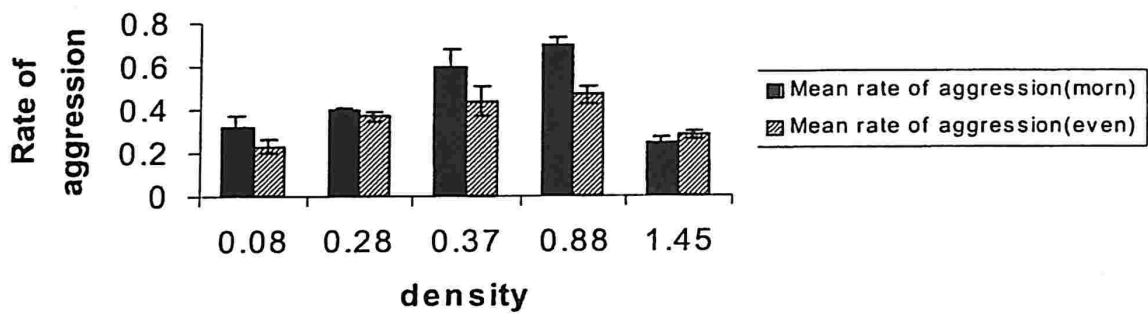
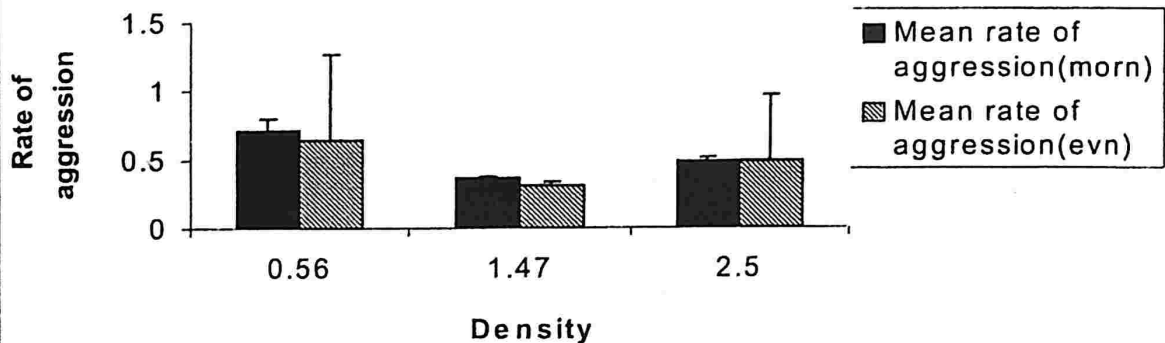


Fig. 4.42 Coparision of mean rate of aggression to access to food between morning and evening supply of food in Chital



$p < 0.001$). A similar trend was exhibited in the evening hour of food supply where a significant difference in time spent was found for an access to food ($F(4,35) = 8.426$, $p < 0.001$). The comparison of morning and evening hour of time spent in aggression to accessibility of food showed no significant difference in the enclosures of Vizag-1 ($t = 1.688$, $N = 8$, $p = 0.135$), Vizag-2 ($t = -0.589$, $N = 8$, $p = 0.579$) Hyderabad ($t = 1.687$, $N = 8$, $p = 0.135$) and Mysore ($t = -1.159$, $N = 8$, $p = 0.284$). However, in the Chennai enclosure, sambar showed a significant difference ($t = 8.233$, $N = 8$, $p < 0.001$) in the time spent in aggression to get an access to food between morning and evening session of food supply.

4.8.3. Chital:

As the data did not show homogeneity non-parametric test Kruskal Wallis was preferred to find the difference in the time spent across the density of species for access to food. The three enclosures of Chital showed a significant difference (kruskal Wallis, $\chi^2 = 11.54$, $df = 2$, $p = 0.003$) in the time spent in aggression to access food in the morning hour (Fig. 4.43). There was a significant difference in time spent in getting an access to food in the evening hour of food supply. The time spent in aggression by the species both in morning and evening period of food supply did not differ at all (Chennai- $t = 0.555$, $N = 8$, $p = 0.596$, Mysore1- $t = 1.227$, $N = 8$, $p = 0.26$, Mysore2- $t = -0.487$, $N = 8$, $p = 0.641$).

Fig 4.45 Mean time spent by chital to access to food across density

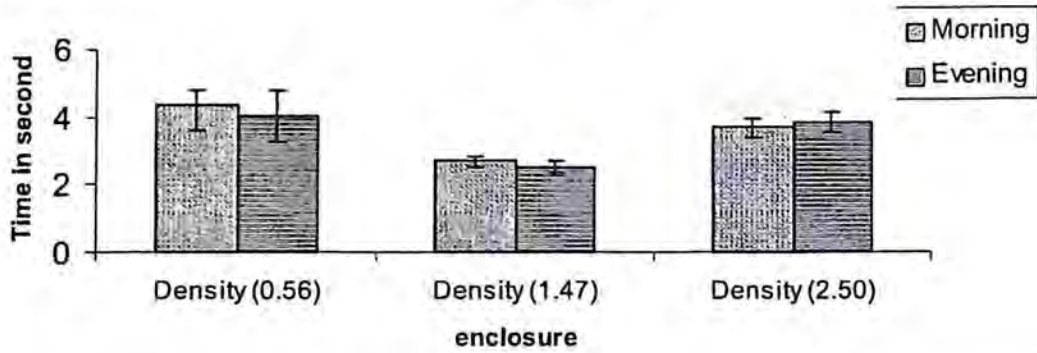


Fig 4.43 Mean time spent by black buck to access to food across density

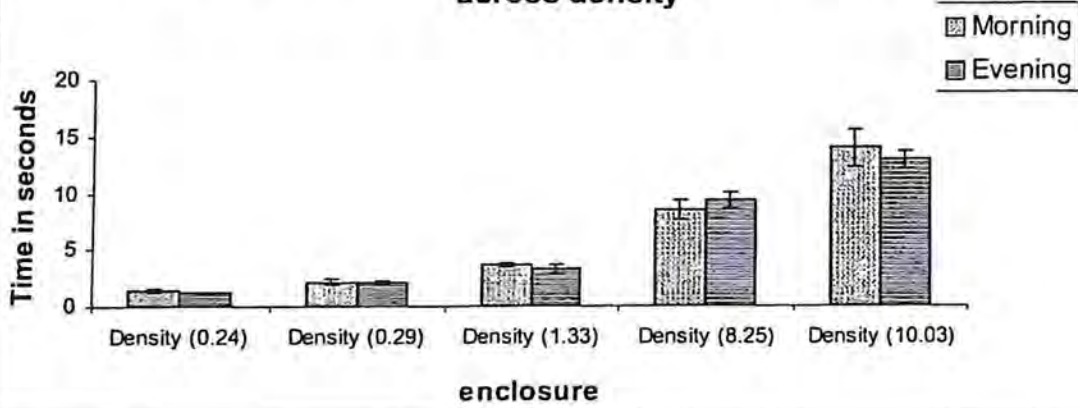
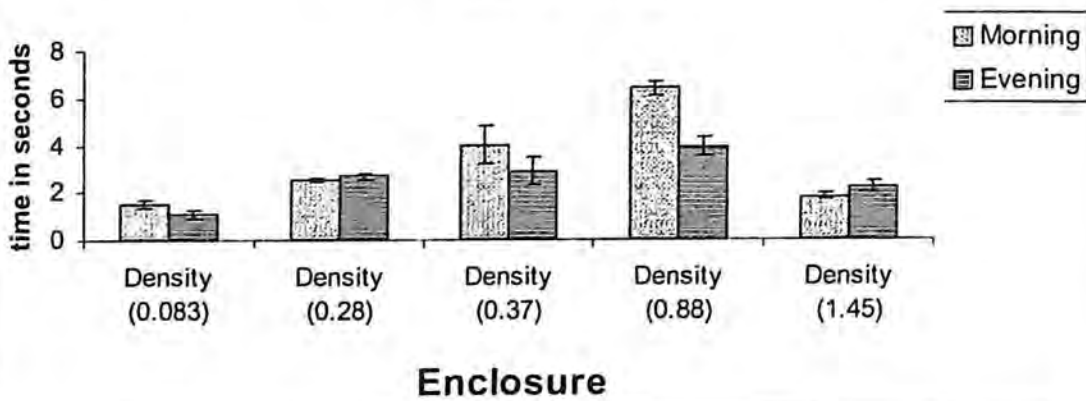


Fig.4.44 Mean time spent by sambar to access to food across density



5. DISCUSSION

5.1. Seasonal difference

Except adult females and adult males of Chennai enclosure no other species showed any variation in their activity pattern when compared for winter and summer seasons. This could be because the entire study was carried out in a very short time frame to actually be differentiated into two distinct seasons. Moreover, the four zoos being located in the same geographical zone showed similar temperature regimes. Consequently no influence of season was noticed on the behaviour repertoire of the species.

5.2. Activity pattern

Most of the studies on Indian ungulates in the wild confer to the findings that the activity patterns are highly correlated with the time of dawn and dusk and show peaks of feeding activity (Schaller, 1967; Russ, 1970; Tak and Lamba, 1984). The three species usually concentrate on their feeding activity from morning till noon and again in the evening. The activity pattern of a species in captivity cannot be compared with that of wild population, as the entire pattern is dependent on the supply of food in a confined space. But in captivity, the density of the species in the enclosure had a role to play in their activity pattern.

Black buck:

At low densities (of species in the enclosure) the species were seen to space out and spend more time in feeding. But with an increase in densities this pattern was found to change. The adult males became more aggressive to the adult females and the subadult sex classes. The recipients diverted their time

from feeding schedule to submission to escape from the aggression inflicted on them by the adult males. With increase in density the competition for both space and food increased. The resources (shade, water, food) being limited in a restricted space the fight for access increased. Subadult males and females too participated in aggressive encounters to win over these resources. The maternal relationship (Murdock; *et al.*, 1983) between adult females and fawns was also seen to be altered in all enclosures, as the adult females in their attempts to escape from the aggressive encounters were found to spend less time with fawns.

Hyderabad Zoo

At this density the species was seen to disperse in the entire enclosure and spend a greater amount of time in feeding. Though the stock moved about in-group they were seen to space out from each other and forage. In the afternoons, except the adult male the rest of the stock huddled in the back of the enclosure, where visitor disturbance was minimal and took rest. Aggression was minimal in this enclosure as the stock had only one adult male and a subadult male.

Vizag Zoo

Though the species was housed with chital in the same enclosure, the enclosure was spacious enough for the stock to space out. The proportion of individuals feeding was almost the highest in this enclosure in comparison to the rest of the black buck enclosures studied. Lying activity peaked in the afternoon. The females were rarely seen to participate in aggression. One of the three adult

males present in the enclosure dominated the rest of the individuals. To prevent other males from accessing food or females this male frequently chased the other males. Aggression between black buck males and chital was evident as a pressure of interspecies mixing for access to food and space.

Chennai enclosure

This enclosure in spite of having a natural setting for the species with lot of trees and shade was crowded with 75 individuals. One adult male dominated the entire herd. But aggression was not restricted to that single male. The space and food constraint intensified in this enclosure and the directionality of aggression was from all sex and age class. Hence the frequency of feeding reduced in this enclosure. In the afternoons though the species was seen to take rest the weaker individuals were seen to be displaced from their resting site by the stronger individuals. The bachelor group occupied one part of the enclosure and fights between them to establish dominance was intense.

Mysore1 and Mysore2 enclosure

These two enclosures were extremely small in size with large number of individuals thus having the highest density of species. The frequency of feeding receded conspicuously and individuals were seen to move about much in the enclosure. The weaker sections preferred the corners of the enclosure to prevent interactions with the other individuals and spent more time in standing there. Aggression in this enclosure was at the peak and each individual fought with the other to get access to food or space throughout the day. The weaker sections of

the population were under immense stress and were even scared to urinate peacefully.

Sambar:

Activity patterns of sambar also altered with different densities of species in the enclosures. No trend in moving and interaction were recorded. As the space per individual decreased the individuals were found mostly standing to a greater extent. This was because only particular portion of the enclosure received shade and had water to wallow. As only few members of the population occupied those resources, the fight intensified for an access to those resources.

Vizag1 enclosure

This is a huge enclosure having the least density of sambar of the 5 enclosures studied. The individuals preferred to take rest most of the time. Though feeding activity was high and individuals spaced from each other avoiding contact for most of the time. Allgrooming was frequent between adult male and females as well as between adult females and fawns. The interesting factor noted in this enclosure was though this enclosure was located in front of the lion enclosure they utilised even the front portion of the enclosure facing the lion enclosure (Fig. 2.13). This could be because the road that passed between the two enclosures was utilised by human beings, which eradicated the fear of the species to utilise that part of the enclosure.

Vizag2 enclosure

Though this enclosure was smaller than the first enclosure and had larger number of individuals, the individuals had enough area to space out. Lying

activity peaked in the enclosure. Feeding was mostly restricted to the time of feed supply. The individuals preferred to stand in shadier areas. Interaction between adult females and fawns was evident. Aggression though was there in all sex categories were exhibited at a lower frequency.

Hyderabad enclosure:

Hyderabad enclosure:

This enclosure had only one adult male, which dominated over the entire herd. The species apart from feeding on the feed supplied were seen to feed on the pods of *Acacia* spp. that fell from the tress growing in the enclosure. The subadult male avoided any form of aggression and stayed away from the rest of the herd members. Aggression between the females was evident. The fight for space to lie down in the shadier portion of the enclosure was seen among the adult sections.

Chennai enclosure:

This enclosure was almost barren with little shade and cover for the species. The enclosure had only two small wallowing areas to utilise in the hot afternoons. Hence the fight to avail those spaces increased among all the sex classes. Feeding and lying activity reduced in this enclosure and aggression increased in this enclosure.

Mysore enclosure

Though the aggressive behaviour showed a positive trend with increase in density, the trend deflected in this enclosure in spite of having the highest density. The entire herd was seen to huddle up together under the shady region

at the back of the enclosure. Aggression was not much directed for access to wallowing pool also. The adult males exhibited affiliative behaviour towards each other, which is a rare phenomenon. This might be due to the fact that 10 of the 14 adult males present in the enclosure were castrated. Owing to the greater frequency of fights with increase in density of individuals the frequency of feeding decreased in all the enclosures.

Chital:

The activity pattern of chital was strongly influenced by difference in the density of individuals. At low density individuals were seen to spend more time in feeding and less of aggression. But as the density increased the fight amongst the herd members showed a positive trend in attempts to get access to resources present. No pattern was observed for the rest of the activities. Other form of interaction like autogrooming was observed to the maximum in this species.

Hyderabad enclosure

Otherwise known as the 'maidan enclosure' this enclosure covers an area of 36,040sq.m. housing 22 chital. The stock was found to forage in morning hours. But as the day progressed they took rest under the trees. Though concentrate feed was supplied in morning the species preferred to graze on the natural grass present in the enclosure. The herd was found to take rest almost till late afternoon. Hence aggression was exhibited to an insignificant level in the enclosure.

Chennai enclosure

The proportion of individuals feeding in this enclosure receded drastically from that of Hyderabad enclosure. The stock spent more time in lying on the periphery of the enclosure to avoid disturbance by visitors. They foraged on the fallen leaves of the numerous trees present in the enclosure. But the frequency of aggression for availing food and space enhanced to a considerable level.

Mysore-1 and Mysore-2 enclosures

Both these enclosures had extremely high density of chital residing in the enclosures. The individuals were seen to stay close together and move in groups. But the constraint of space played a major role in the elicitation of their behaviour. In spite of the adult males losing their antlers during the period of study the level of aggression was to a greater extent. The weaker section of the population also resorted to fights in competition for access to space and food.

No literature in captive condition on the activity pattern of the species under study could be found to substantiate the findings. But literature does exist in primates and felids in finding the difference between activity patterns both in wild and captivity (Evans, 1983; Freeman, 1983; Glatston, 1984; Kumar, 1987; Geoffrey, 1988; Hosey, 1988, Mitchell 1989; Raghavan, 2001; Stoinki *et al.* 2001) in different enclosures.

5.3. Aggressive pattern

At low densities, ranks established for dominance, access to resource and females involve limited use of antler or horn. Disputes tend to be resolved by aggressive display or mild form of trials of strength (Putman, 1988, Miller, 1997;

Penfold *et al.*, 2002). Females exhibited stamping of legs or hard look at the opponent. These behaviours were used only against clearly inferior opponents. Adult males avoided contact with the weaker section of the population and drove them by pointing antler, threatening or following them from a distance (Miura *et.al.*, 1993) . This might be to reduce the cost of energy being exerted by the dominant individual to dominate the opponent. With increase in density aggressive encounters intensified in the different sex categories. Intense aggression in males is likely for two reasons. Firstly because males are more interactive than females (Popp, 1984) and secondly, males have a greater ability to inflict injuries. Actual fighting is observed in either sex, only during the initial resolution of the hierarchy or when individuals wish to challenge their position in relation to others (Putman, 1988). Hence the subadult males exhibited higher frequency of aggression as density of individuals increased. But they resorted to moderate fighting because of the small body size.

Male aggressiveness varies not only intraspecifically but also interspecifically (Popp, 1984; Popp and Bunkfeldt-Popp, 1985, Inglett *et al.*, 1989). The frequency of aggression in adult black buck males of Vizag (Density- 0.29 ind per 100 sq. m.) enhanced in spite of having an almost similar density of Hyderabad (0.24 ind per 100 sq. m). Less intense form of aggression in Mysore enclosure was due to low surge of testosterone in the castrated males.

Black buck:

Hyderabad enclosure

The level of aggression in this enclosure was minimal. The adult and the subadult male resorted to slight pushing, or threatening and avoided any other form of physical contact. The adult females resorted to threatening whereas the subadult females did not participate in any form of aggression.

Vizag enclosure

Though this enclosure had almost similar density of species as that of Hyderabad enclosure but the level of aggression by adult males was quite high in comparison to Hyderabad enclosure. This could be due to the presence of chital also in the enclosure. The rest of the sex categories avoided any form of fights.

Chennai enclosure

The intensity of aggression in this enclosure enhanced owing to greater density of species in this enclosure. The females restricted the fights to mild and moderate form. But to establish dominance in the population the fights among the males intensified. The adult and subadult males fought for gaining access to space and food. The fight (locked horn) between the adult males and subadult males also continued for a considerably longer duration.

Mysore-1 and Mysore-2 enclosures

The space being too small for the large number of individuals housed in both the enclosures the fights for food and space intensified among all the sex and age categories. The females also fought back when they were cornered.

With increased intensity of fight the entire stock remained under stress and were busy the entire day fighting for the resource or avoid the stronger opponent.

Sambar:

Vizag-1 enclosure

Aggression in this stock was to a negligible level. The weaker section of the population did not initiate any form of aggression and the adults directed mild form of aggression.

Vizag-2 enclosure

Aggression intensified in case of adult males as the number of adult males (7) was more in this enclosure. The adult females also resorted to biting to drive away the subadults from gaining access to the resource of the enclosure. The subadult males and females avoided fights.

Hyderabad enclosure

Frequency of aggression in the subadult section remained the same as that of previous enclosure. But the intensity of aggression by adult male decreased in this enclosure. There being only one adult male in the enclosure it dominated over the rest of the stock. Hence the adult male resorted to intense form of aggression only to adult females who defied the adult male in giving him the shadier space, which he wanted to access.

Chennai enclosure

The intensity of aggression was highest in this enclosure. The number of individuals being large in the small space and the resource (wallowing area and shady places) being limited the fights intensified to gain access to those

resources. The fights were not limited to the adults but the weaker section of the population also retaliated back with greater intensity to win over their rights.

Mysore enclosure

Interestingly, aggression directed by adult males of the population was of the lesser intensity in this enclosure. Females mostly initiated the fights that occurred. Only one subadult male initiated aggression. This could be due to surge of testosterone in this male, which has realised the castrated adult males in remaining docile.

Chital:

Hyderabad enclosure

Intense form of aggression was not seen in this enclosure. Males being overtly dominant over the rest of the stock resorted to only aggressive approach or head up/ down display. The adult females and subadult males initiated mild and moderate form of aggression. Subadult females very rarely directed mild form of aggression.

Chennai enclosure

The intensity of aggression enhanced in this enclosure. Adult females were resorted to biting each other to a greater extent. The fight for space and food increased and all the sex categories were seen to fight for gaining these resources. But the subadult females avoided moderate and intense form of aggression.

Mysore-1 and Mysore-2 enclosures

The intensity of aggression by these large numbers of individuals in both the enclosures was at the peak. All the age and sex categories fought with each other with maximum intensity to establish their dominance over the other to gain access to the resources.

5.4. Visitor influence

The presence of visitors did not affect the activity pattern of captive ungulates in most of the enclosures. Black bucks exhibited higher level of activity when the visitor number increased and were found lying more on zoo holidays. In Chennai the species was affected the most as the visitor maximum day was on the festival of Pongal when the zoo received a visitation of 60,000 people. This led to severe restlessness in the species and they were seen to move to a considerably higher level. As this enclosure had only the front portion open to the public the animals were seen to restrict themselves in the middle and back portion of the enclosure. The females were found to stand in secluded places and became less interactive among the herd members. As a consequence of this the frequency of aggression decreased. Though the level of aggression in males did not recede, the frequency of submission enhanced. The recipient did not resort to long fights or did not retaliate back to the aggressive action directed at him. This could be due to the stress involved in the animals as an effect of visitor disturbance. The subadult males avoided all sort of interaction and were found to lie down considerably high in the back portion of the enclosure away from the

visitors. Subadult females did not get much opportunity to feed and were seen to move about in the back portion of the enclosure.

Sambar did not respond to the presence of visitors in most of the enclosures. The enclosure-2 of Vizag was the only enclosure, which showed a change in the activity pattern of the species as an effect of visitor presence. The species was found to lie more and feed less on visitor maximum day. This could be because sambar are predominantly forest animal and avoid open space (Schaller 1967). Being shy of human presence the species was found to lie in the back portion of the enclosure when the presence of visitors was more in the zoo. Though males did not move about more in the presence of visitors, they exhibited higher level of aggression to their conspecifics as a consequence to the stress induced due to visitor presence.

Almost all the enclosures of Chital were affected by the presence of visitors. In Hyderabad the enclosure was open to visitors on two sides. The species being extremely shy of human beings avoided the front part of the enclosure and preferred to lie down under the shady trees. But a reverse trend was seen in the enclosures of Mysore where the number of the animals in the enclosure was quite high. This caused an excitement among the visitors who gathered around the enclosure for a considerable longer period. This could be the reason of exhibiting lower level of resting by the species in the enclosure. The females exhibited higher level of aggression and were seen to bite others to a greater extent.

Visitors cause stress (Thompson, 1989) and excitement in animals in captivity (Chamove *et al.* 19988; Mallapur, 1999; Dutta 2002). They disrupt the behavioural pattern of the animals housed in zoos (Fa, 1992; Price *et al.*, 1994). Most of the enclosures did not show an alteration in the behaviour of the species, as visitors do not spend much time in front of the enclosure of ungulates. In the black buck enclosures of Mysore where visitor disturbance was more (due to greater portion of the enclosure open to public and location of the enclosure in the center of the zoo), the density of the animals in those enclosures was also quite high. Hence the animals already in a tremendous state of stress did not show any alteration in their behaviour even in the absence of visitors. The presence of visitors was found to influence activity pattern of animals only when the visitors induced disturbance to the animals directly. But when the density of the individuals in the enclosures exceeds to a greater magnitude the animals already in a state of stress are not affected by visitor's presence.

5.4. Hierarchy

Hierarchy in a population is based on the dominance ranks, which depends on body size, colour, age and antler/ horn size (Clutton-Brock, 1982; Ranjitsinh, 1989).

Black buck

In black buck, hierarchical order in different populations followed almost a similar pattern of hierarchical status to that of wild. The adult male was the social apex of the stock. After the adult and subadult males the adult females are the next in

hierarchy, followed by subadult females (Schaller, 1967; Mungall, 1978; Ranjitsinh 1989). But close observations revealed that the case was not that simple and unidirectional (Stine *et al.*, 1982). With low density the females did not exhibit aggression and the females of different age classes enjoyed a similar hierarchical status. But with increasing density aggressive encounters between different dyads (adult males vs subadult males, adult females vs subadult males) enhanced. Subdult females of the first enclosure of Mysore (high density) were extremely aggressive and succeeded in overthrowing the adult females from their hierarchical rank and gaining a higher status in the competition for food and space.

Sambar

Adult males ranked top in the herds. In low density, adult females ranked higher than the subadult males owing to their greater body size (Mac Donald *et al.*, 2000). Subadult females ranked the least in the social hierarchy. But with increasing density the hierarchical order varied because the formerly subordinate individuals managed to achieve a higher social status (Baker 2000). Biting among the females increased towards subadult males and females in high density who retaliated back and managed to overpower the adult female's social ranking. It was interesting to note that the subadult male of the enclosure of Mysore (highest density) constantly initiated fights with adult males and displaced them of their ranks. One reason behind this could be the castration of the adult

males in the stock and the surge of testosterone in the uncastrated subadult male.

Chital

Several studies have argued that age (Baker 2000) and antler size and complexity exerts an important influence on the dominance rank of the adult males (Clutton-Brock, 1982; Schaff, 1984; Enciso *et al.* 1999). The findings of the present study too substantiated this fact. But a significant finding was in the enclosures of Mysore (highest densities) where the adult males after shedding their antlers became less aggressive and avoided conflicts (Bartos and Hyaneck, 1982). Though the aggression by the conspecifics to adult males increased (Ables, *et al.*, 1978; Zucker 1987) they managed to retain their social rank. With a gradual increase in density the subadult males surpassed the females in the hierarchical ranking. This could be due to increased group size in a restricted space, (Duce and Brannia, 1990; Goff, 1994; Cassinello and Pieters 2000) which puts a strain on the individuals for access to the resources within the enclosure.

5.6. Hierarchy and access to food

Food supplies when clumped together create hierarchies in the population to have an access to the resource (Clutton-Brock *et al.* 1982). In low density, the hierarchy of the population for access to food did not vary from the hierarchy initially obtained for the stock. This indicates that even though there is limited supplies of food in restricted space individuals follow the social hierarchy, as they got enough area to space out in low dense populations. But the pattern changes

with increase in the density where the population hierarchy is again disrupted leading to intense fight and injuries to get the priority to the resource available.

5.7. Rate of aggression to access to food supply

Conflict over food is a leading cause of aggression. Aggression is greatest when food is provided at one location. The frequency at which fights occur to access food should logically depend on the number of animals around the food trough. The rate of aggression would then be influenced by the density of the species around the perimeter of the food trough than the density of the species in the enclosure. Study on five mixed species of ungulates (Popp, 1984) found providing food at several locations reduce aggression but will not eliminate aggression. In black buck, though the rate of aggression to access food showed a positive trend with the increase in density, the result is not so clearly defined. It is noteworthy here to see the enclosure of Chennai with a stock of 72 individuals had two food troughs, where the use was separated between the bachelor groups in one food trough and the females and subadult males in the other. This gives the individual to shuttle between the food troughs resulting in low rate of aggression. Similarly in chital enclosure of Chennai though the density was low a high rate of aggression to access food was seen when the food was supplied in one trough. But the theory of the number of animals around the food trough does not hold ground for long. In sambar, in spite of the food being supplied at different locations the rate of aggression showed a positive trend with increase in density of individuals in the enclosures. The trend differed only in the enclosure of Mysore (highest density), which might be due to the presence of castrated

males in the herd who did not involve in serious fights. The rate of aggression to food in the evening session was found to recede. This might be because the individuals may have been satiated to a certain extent after feeding in morning.

5.8. Time spent in aggression to access to food

The time devoted for aggression would depend on the density of the species in the enclosure to a greater extent. As the food in the trough gets exhausted within a short time frame it pays for the individual to incur more energy to aggressive encounters. At low density where the hierarchy is already established aggression is directly addressed to the clearly inferior classes of the stock. The subordinate individual predominantly avoids conflict and makes way for the dominant ones to have access to food. But with increase in density as the hierarchy keeps shuffling the subdominant classes accept the challenge directed at them leading to fights of longer duration.

No literature in this aspect was available to corroborate the findings of the study.

5.9. Conclusion

This study found that the density of a species in an enclosure influences:

1. The activity pattern of all the sex categories showed a significant difference as densities of the species in the enclosures increased.
2. Aggressive pattern intensified in the captive populations as the density of the species increased in the enclosures.
3. Visitor's impact did not have a significant influence on the behaviour repertoire of the species.

4. The hierarchy of the stock population in low density in nature simulated enclosures resembled to the social ranking of wild condition. But as density increased a disruption in the hierarchical set up was observed.
5. At low density, hierarchy of the stock density accessing to food remained similar to the hierarchy that existed in the population at other times. But the hierarchical ranking changed temporarily from the extant hierarchical pattern of the population as density of species increased.
6. The rate of aggression for accessing food though increased with increase in density of the species. However, the frequency of aggressive encounters was more dependent on the number of adult males in the stock rather than the density of the species.
7. Time spent in aggression for access to food increased with an increase in density of the species in an enclosure. The altered hierarchical order at high-density resulted in increased aggressive encounters among all age and sex classes each incurring a higher cost of energy to get access to resources of the enclosure.
8. The interaction between adult females and fawns decreased as density of the species increased putting an ambiguity on the survivorship of the fawns. Because of the decreasing time of association with fawns the adult females became more susceptible to non-required mating which may result in increased density of the species further in the enclosure.

From this study it is imperative to look at

- (i) The stage at which the aggression tends to increase from individuals at the top of the hierarchy to other individuals
- (ii) The point of time animals tend begin spending less time from resting to restlessness
- (iii) Crowding at feeding and wallowing areas
- (iv) Occurrence of injuries particularly with adult females as they are the breeding animals.

These factors are the tell-tale indicators of density related problems that needs to be looked at immediately.

5.10. Management implications

It would be only a utopian dream for every zoo in India to have extremely low density of ungulates even though the CZA guideline clearly states that the number of ungulates in a large deer park or zoo enclosure should not exceed twenty. But that is because most of the zoos have a constraint of space and are not even in a position to shift surplus animal elsewhere. In any case, with increased breeding animal density increase and eventually become moderate and high density. The key to understand when the situation is not ideal is to see when initiation of aggression is not restricted from the alpha male to the adult males but are also directed from adult male to subadult male to adult female to subadult female. When the other section of the stock start to become victims as well as aggressors, then the management needs to realise that the density is impacting all sex classes. The management needs to keep an watch on the sex and size class categories that are joining in aggressive cohorts.

Aggression and hierarchy can also be significantly altered by creating moderate size mini territories by providing multiple food troughs, larger water troughs, multiple wallowing areas and several fodder places and multiple shaded areas. This would minimise aggression and put less pressure on the resources of the enclosures. However, this may also result in increased breeding, as larger number of males will contribute to breeding.

Castration of adult males can prove out to be one of the alternatives to minimise aggression in the stock when the management intends not to have an increase in the population. The low surge of testosterone reduces and alters the behaviour of adult males making them more docile. However, castration results in changes in colour, abnormality in horns and antlers and such animals are a taboo for exhibition in a zoo.

Visitor distance needs to be maintained to reduce the disruption of natural behaviour repertoires of these animals. Planting vegetation and other stand off barrier before the visitor's viewing area with strict vigilance by the animal keepers would reduce the disturbance caused by visitors. As visitor disturbance from the viewing area pushes the animal towards the backside of the enclosures the effective density increases from the actual density.

Adjoining predator enclosures next to the ungulate enclosures also reduces the utilisation of significant portion of the enclosure, thereby reducing the effective space utilisation and increasing actual density. While predator prey display theme is ideal care should be taken to space them apart.

Based on the findings of the present study the fourteen enclosures for the three species can be classified into two categories *viz.* medium and high density based on the CZA guidelines for space allocation for ungulates (Appendix-5, Table, 5.1). The enclosures with low density ranging from (0.06-0.29 individual/100 sq. m.) reflected an ideal environ for the peaceful coexistence of the individuals but low probability of sighting by visitors. At medium density (0.03-0.05 individuals per 100 sq. m. aggressions and changes in behaviour repertoire begins to appear though visitor satisfaction is ideal. However, densities above 0.5 animals per 100 sq. m. in all studied species of ungulates, results in higher incidence of aggression and distress to the animals. From the visitor point of view also there is a negative satisfaction value as agonistic fights, injuries, poor health condition of victims surface up. It is therefore, imperative for the zoo managers to adhere to the low-density regime for ungulate exhibit. But from managerial perspective, a much more important point would be to detect where aggression related behaviour appear within the population and a low density enclosure shifts into a moderate density enclosure thereby necessitating alternative plans for reducing density.

Management recommendations for diiferent zoos:

Mysore Zoo:

Black buck enclosures

1. Reduce the number of animals.
2. Increase the distance of stand off barrier.
3. Increase the height of mesh wire in black buck enclosure-1.

4. Multiple feeding troughs at different sites.
5. Reduce the number of males.
6. Increase the size of the enclosures.
7. Natural vegetations needs to be planted.

Samabr enclosure

1. Reduce the number of animals.
2. Multiple feeding sites and drinking sites.
3. Castration of all males.
4. Treatment of injured individuals.

Chital-1 enclosure

1. Reduce the number of animals.
2. More number of feeding troughs at different places.
3. More shaded areas

Chital-2 enclosure

1. Reduce the number of animals.
2. More number of feeding troughs at different places.
3. Visitor distance needs to be maintained by increasing the stand off barrier distnace.

Hyderabad enclosure:

Black buck enclosure

1. Reduce the number of sides of visitor viewing.
2. Maintain the population sie.

3. Increase the quantity of feed.

Samabr enclosure

1. Multiple feeding sites.
2. Provide artificial shaded areas on the rocky places.
3. Browse needs to be supplied.
4. Increase the quantity of feed.

Chital enclosure:

1. Repair of fence in the back side of the enclosure.
2. Widening and increasing the depth of moat in the right side of the enclosure.
3. Supply of water in the moat.

Chennai Zoo:

Black buck enclosure

1. Reduce the number of animals.
2. Clip the low canopy to increase visibility of animals.
3. Interspecies mixing of animals needs to be avoided.
4. Increase the quantity of feed.
5. Timely supply of feed.
6. Feeding in the front portion of the enclosure.
7. Few more feed troughs at different places.

Samabr enclosure

1. Reduce the number of animals.
2. More browse needs to be supplied.

3. Skin disease of teh animals needs to be checked.
4. More trres and wallowing areas needs to be provided.
5. Increase the quantity of feed.
6. Timely supply of feed.
7. Predation and prey concept needs to be assessed.

Chital enclosoure:

1. keep the population in check.
2. Interspecies mixing avoided.
3. Mesh wire of teh enclosoures should not be left with opening for teh stock to escape from their enclosoure and animals of neighbouring enclosures to stray into the chital enclosoure.
4. More number of feed troughs at different places.
5. Increase the quantity of feed.
6. Timely supply of feed.

Viag Zoo:

Black buck enclosure

1. Interspecies mixing avoided.
2. Concentrate feed need to be supplied in teh morning.
3. Increase the quantity of feed.

Samabr enclosoure-1

1. Browse needs to be provided.
2. Increase the quantity of feed.

Samabr enclosure-2

1. Reduce the number of animals.
2. Browse needs to be provided.
3. Visitor stand off area needs to be increased.
4. Increase the quantity of feed.

REFERENCE:

Ables, E.D., Fuchus, E.R., Galvin, T.J., Jones, L.P., Robinson, R.M., Russ, W.B., Smith, J.C., 1978. The axis deer in Texas. The Caesar Kleberg Research program in wildlife Ecology and Department of Wildlife fisheries Sciences. The Texas Agricultural Experiment Station. The Texas A&M University System.

Altmann, J. 1974. Observational study of behaviour; Sampling methods. *Behavior*. 49:227-267.

Baker, K.C. 2000. Advanced age influences chimpanzee behavior in small social groups. *Zoo Biology* 19: 111-119.

Bartos, L and Hyaneck, J. 1982. Social position in the red deer stag. I. The effect on developing antlers. In., Brown, R.D, ed. *Antler development in cervidae*. Caesar Kleberg wildlife research institute, Kingsville, TX.

Bartos, L and Hyaneck, J. 1982. Social position in the red deer stag. II. The relationship with developed antlers. In., Brown, R.D, ed. *Antler development in cervidae*. Caesar Kleberg wildlife research institute, Kingsville, TX.

Bennett, S.H and Mellen, J.D; 1983. Social interactions and solitary behaviors in a pair of captive sand cats (*Felis margarita*). *Zoo Biology* 2: 39-46.

Bettinger, T., Wallis, J., Carter, T. 1994. Spatial selection in captive adult female chimpanzees. *Zoo Biology*. 13: 167-175.

Bhatnagar, Y.V, 1991. *Habitat preference of Sambar (Cervus unicolor) in Rajaji national park*. M.Sc, Dissertation, Wildlife Institute of India. Pp 51.

Cassinello, J., Pieters, I. 2000. Multi-male captive groups of endangered dama gazelle: Social rank, aggression and enclosure effects. *Zoo Biology*. 19(2): 121-129.

Chakrabarty, B. 1991. *Habitat use by radio instrumented Chital, Sambar and Nilgai in sariska tiger reserve*. M.Sc, Dissertation, Wildlife Institute of India. Pp 44.

Chaplin, R.E. 1977. *Deer*. Blandford Press. Pp 218

Chamove, A.S., Hosey, G.R., Schaetzel, P. 1988. Visitors excite primates in zoos. *Zoo Biology*. 7: 359-369.

Clutton – Brock, T.H *et al.*, 1982. *Red deer*. The university of Chicago press. Pp. 198-231.

CZA guidelines.

Dougherty, 1982. *Black buck antelope in India: perspective on the management of a threatened species*. B.S Dissertation, Dr. Raymond F. Dasmann and the environmental studies B card. Pp110.

Duce, S and Brannian J. 1990. Social behaviour of the Guianan cock-of-the-rock (*Rupicola rupicola*) in captivity. *Zoo Biology*. 9:223-232.

Dutta, T. 2002. *A study of visitor's attitude towards zoo and zoo animals at peshwe zoo, pune*. M.Sc, Dissertation, Univerity of Pune. Pp 73.

Enciso, A.E., Calcagno, J.M., Gold K.C., 1999. Social interactions between captive adult male and infant lowland gorillas: Implications regarding kin selection and zoo management. *Zoo Biology*.18: 53-62.

- Evans, S. 1983. Breeding of the cotton – top Tamarin *Saguinus odipus odipus*: A comparison with the common marmot. *Zoo Biology* 2: 47-54.
- Fa, J.E. 1992. Visitor directed aggression among the Gibraltar macaques. *Zoo Biology*. 11:43-52.
- Freeman.H, 1983. Behavior in adult pair of captive snow leopards (*Panthera uncia*). *Zoo Biology* 2: 1-22.
- Ganslober, U., Hodges, J.K., Kanmanns, W. 1995. Research and captive propagation. Filander Verlag.
- Geoffrey R. Hosey, 1988. Behavior of the mayotte lemur, *Lemur fulvus mayottensis*, in captivity. *Zoo Biology*.
- Glatston, A.R., Geilvoet-Soetman, E., Hora-Pecek, E., Hoff, J.A.R.A.M.V. 1984. The influence of the zoo environment on social behaviour of groups of cotton-topped tamarins, *Saguinus oedipus Oedipus*. *Zoo Biology*. 3:241-253.
- Goff, C., Howell, S.M., Fritz, J., Nankivell, B. 1994. Space use and proximity of captive chimpanzee (*Pan troglodytes*) mother/ offspring pairs. *Zoo Biology*. 13(1): 61-68.
- Goff. C. *et al.* 1994. Space use and proximity of captive chimpanzee (*Pan troglodytes*) mother/offspring pairs. *Zoo biology* 13(1): 61-68.
- Goosen, C., Schrama, A., Brinkhof, H., Schonk, J., Hoek, L.A.V.1999. Housing conditions and breeding success of chimpanzees at the primate centre TNO. *Zoo Biology*. 2: 295-302.

Hosey, G.R. 1988. Behavior of the Mayotte lemur, *Lemur fulvus mayottensis*, in captivity. *Zoo Biology*. 1: 27-35.

Huntingford, F. 1984. The study of animal behaviour. Chapman and Hall.

Hutchins, M., G.M. Smith, D.C. Mead, S. Elbin and J. Steenberg. 1991. Social behaviour of Matschie's tree kangaroos (*Dendrolagus matschiei*) and its implications for captive management. *Zoo Biology*. 10(2): 147-154.

Inglett, B.J., J.A. French, L.G. Simmons, K.W. Vires. 1989. Dynamics and intrafamily aggression and social reintegration in lion tamarins. *Zoo Biology*. 8:67-78

Inventory of animals 1999-2000. Central Zoo Authority.

Inventory of animals 2000-2001. Central Zoo Authority.

Krishnan, B. 1984. India's wildlife in 1959-70. An ecological survey of the larger

Krishnan, M. 1982. The handbook of India's wildlife. Nagras & Co., Madras.

Kumar, A. 1987. *The ecology and population dynamics of the lion-tailed macaque (Macaca silensis) in south India*. Dissertation. University of Cambridge. Pp 174.

Lehner, P.N. 1996. Handbook of ethological methods. Second edition. Cambridge University Press.

Lehner, Philip.N, 1940. Ethological methods. Cambridge university press.

Mac Donald, D.W., P.D. Stewart, P. Stopka, N. Yamaguchi. Measuring the dynamics of mammalian societies: An ecologist's guide to ethological methods. Boitani, L. and Todd k. Fuller (Eds), 2002. Research techniques in animal ecology. Columbia University Press. Pp.353.

Mallapur, A. 1999. *Environmental influences on space utilization and activity budget of captive leopards (Panthera pardus fusca) in five zoos of Southern India*. MSc. Dissertation. Wildlife Institute of India. Pp 111.

Mammals of Peninsular India. Bombay Natural History society.

Manning, A. 1979. An introduction to animal behaviour. Edward Arnold (Publishers) Ltd. 31:161-192.

Marcellini, D.L. and T.A. Jenssen. 1988. Visitor behaviour in the national Zoo's reptile house. *Zoo Biology*. 7: 329-338.

Miller, Karl.V and Ozoga, John.J. 1997. In, McShea, William.J et al, ed., The science of over abundance – Deer ecology and population management. Smithsonian Institution press, Washington and London. Pp 402.

Mitchell, G., Obradovich, S., Sumner, D., DeMorris, K., Lofton, L., Minor, J., Cotton, L., Foster, T. 1990. Cage location effects on visitor attendance at three Sacramento zoo mangabey enclosures. *Zoo Biology*. 9(1): 55-63.

Mitchell, Robert .W. 1989. Function and social consequence of infant – adult male interaction in a captive group of low land gorillas (*Gorilla gorilla gorilla*). *Zoo Biology* (8): 125-137

Miura.S *et al*, 1993. Social organization and mating behavior of white- lipped deer in the qinghai-Xizang plateau, China. *Deer of China*, Elsevier science publishers Pp 220-233.

Mungall, E.C and Sheffield W.S., 1994. Exotics on the range. The Texas example. Texas A&M University Press: College Station.

Mungall, E.C. 1978. The Indian blackbuck antelope: A Texas view. The Caesar Kleberg Research program in wildlife Ecology and Department of Wildlife fisheries Sciences. The Texas Agricultural Experiment Station. The Texas A&M University System. Pp 183.

Murdock, G.K., W.W. Stine, T.L. Maple. 1983. Observations of maternal-infant interactions in a captive herd of sable antelope. *Zoo Biology*. 2: 215-224.

Nieuwenhuijsen.k and Frans B.M.de waal, 1982. Effects of spatial crowding on social behavior in a chimpanzee colony. *Zoo Biology* (1): 5-28.

Patton, M.L., White, A.M., Swaisgood, R.R., Sproul, R.L., Fetter, G.A., Kennedy, J., Edwards, M.S., Rieches, R.G., Lance, V.A. 2001. Aggression control in a bachelor herd of fringe-eared Oryx (*Oryx gazelle callotis*), with melengestrol acetate: Behavioural and endocrine observations. *Zoo Biology*. 20(5): 375-387.

Paulraj, S and Naidu, S.S. 1987. Population dynamic, breeding cycle and social behavior of captive black buck in Aringar Anna zoological park, madras. Aringar Anna zoological park, madras.

Penfold, L.M, R. Ball, I. Burden, W. Jochle, S.B. Citino, S.L.Monfort, N. Wielebnowski. 2002. Case studies in antelope aggression control using a GnRH agonist. *Zoo Biology* (21): 435 – 448.

Popp, J.W. 1984. Interspecific aggression in mixed ungulate species exhibits. *Zoo Biology*. 3(3): 211-219.

Popp, J.W. 1985, L. Bunkfeldt-Popp. Interspecific aggression among female ungulates. *Zoo Biology*. 3(12): 197-200.

Price, E.C., Ashmore, A., Mcgovern, A. 1994. Reactions of zoo visitors to free ranging monkeys. *Zoo Biology*. 13: 355-373.

Putman, R. 1988. The natural history of Deer. Christopher Helm (Publishers) Ltd.
Pp.

Raghavan, R. 2001. Social behavior and communication among wild lion-tailed macaque (*Macaca Silenus*) in the Indira Gandhi wildlife Sanctuary, Tamil Nadu. M.Sc, Dissertation, Wildlife Institute of India. Pp 95.

Raman, T.R., R.K.G. Menon, R. Sukumar. 1995. Decline of black buck (*Antelope cervicapra*) in an insular nature reserve: The Guindy National Park, Madras. *Current Science*. 68(6): 578-580

Raman, T.R., R.K.G. Menon, R. Sukumar. 1996. Ecology and management of chital and black buck in Guindy National Park, Madras. *Journal, Bombay Nat.His.Society*. 93(2):179-191

Ranjitsinh, M.K. 1989. The Indian black buck. Natraj publishers. Dehradun. Pp 155.

Russ, W.B. 1970. Reproductive biology and population structure of the axis deer, *Axis axis*, on the powder horn ranch, Calhoun County, Texas. M.S Dissertation. Texas A & M university. Pp74.

Sankar.K. 1994. *The ecology of three large sympatric herbivores (Chital, Sambar and Nilgai) with special reference for reserve management in sariska tiger reserve, Rajasthan*. PhD Thesis. Saurashtra University. Pp 190.

Schaaf, C.D. 1984. Animal behaviour and the captive management of wild mammals: A personal review. *Zoo Biology*. 3(4): 373- 377.

Schaller, G.B. 1967. The deer and the tiger. A study of wildlife in India. The University of Chicago Press.

Sibley, R.M and R.H. Smith. 1985. Behavioural ecology. Ecological consequences of adaptive behaviour. Edition. Oxford Blackwell Scientific Publications.

Siegel, S. 1956. *Nonparametric statistics for the behavioural sciences*. McGraw – hill international book company. Pp 312.

Sokal, R.R and Rohlf, F.J (1995). Biometry. The principles and practice of statistics in biological research. Third Edition, W.H. Freeman and Co., New York, Pp.887.

Stine, W.W., Howell, L.L., Murdock, G.K., Newland, M.C., Conradsen, L., Maple, T.L. 1982. The control of progression order in captive herd of sable antelope (*Hippotragus niger*). *Zoo Biology*. 1:89-110.

Stoinski, T.S., Hoff, M.P., Lukas, K.E., Maple, T.L. 2001. A preliminary behavioural comparison of two captive all- male gorilla groups. *Zoo Biology*. 20(1): 27-40.

Tak, P.C., B.S. Lamba. 1984. Ecology and ethology of the spotted deer *Axis axis axis* (Erxleben) (Artiodactyla. Cervidae). Records of Zoological Survey of India.

Thompson, V.D. 1989. Behavioural response of 12 ungulate species in captivity to the presence of humans.

Wemmer, C.M. 1987. Biology and management of the cervidae. Smithsonian Institution Press. Washington DC, London. Pp 577.

Williams, Leader.N, 1988. Reindeer on South Georgia: the ecology of an introduced population. Cambridge university press.

Williams, L.E and Abee, C.R, 1988. Aggression with mixed age- sex groups of Bolivian squirrel monkeys following single animal introductions and new group formations. *Zoo Biology* (7): 139-145.

Wood, W. 1998. Interactions among environmental enrichment, viewing crowds, and zoo chimpanzees (*Pan trogoodytes*). *Zoo Biology*. 17:211-230.

Zucker, E.L.1987. Control of intragroup aggression by a captive male orangutan. *Zoo Biology*. 6: 219-223.

Zar, J.H. 1984. *Biotatistical Analysis*. Prentice – Hall, Inc., Englewood Cliffs, New Jersey. Pp 747.

Appendix- 1

Table. 2.1. Density and population structure at Mysore Zoo (Chamarajendra Zoological Garden)

Species	Total area (m ²)	Total no. of animals	Space available / individual (m ²)	Density of animal per 100 (m ²)	Sex ratio (Female :Male)	AM	AF	SM	SF	F
Black buck1	424	35	12.11	8.25	1.5:1	7	15	6	5	2
Black buck2	299	30	9.96	10.03	0.75:1	12	10	4	2	2
Chital1	6825	100	68.25	1.47	2.8:1	18	39	13	20	10
Chital2	3317	83	39.96	2.50	2:1	12	31	16	24	0
Sambar	2623	38	69.03	1.45	1.2:1	14	13	3	5	3

Table. 2.2. Density and population structure at Chennai Zoo (Arignar Anna Zoological Park)

Species	Total area (m ²)	Total no. of animals	Space available per individual	Density of animal per 100 m ²	Sex ratio	AM	AF	SM	SF	F
					Female:Male					
Black buck	5394	72	74.92	1.33	1:1	23	27-1	12	9	2
Chital	3930	21+2	178.64	0.56	2.3:1	3	9	3	5	1+2
Sambar	4074	42+3	113.05	0.88	1.6:1	7	16	7	7	5+3

Table. 2.3. Density and population structure at Hyderabad Zoo (Nehru Zoological Park)

Species	Total area (m ²)	Total no. of animals	Space available per individual	Density of animal per 100 m ²	Sex ratio	AM	AF	SM	SF	F
					Female:Male					
Black buck	5827	14	416.21	0.24	5.5:1	1	10	1	1	1
Chital	36040	22	1638.18	0.06	2:1	12	6	2	2	0
Sambar	4359	16	272.44	0.36	5:01	1	7	1	3	4

Table. 2.4. Density and population structure at Vizg Zoo (Indira Gandhi Zoological Park)

Species	Total area (m ²)	Total no. of animals	Space available per individual	Density of animal per 100 m ²	Sex ratio	AM	AF	SM	SF	F
					Female:Male					
Black buck	11533	18+15	349.48	0.29	2.4:1	3	10	2	2	0-1
Sambar1	15726	13	1209.69	0.083	2.3:1	2	6	1	1	2
Sambar2	8933	25	357.32	0.28	1.2:1	7	9	2	2	5

Appendix – 2

Categorisation of standing activity

Sl. No.	Activity	Description
1	Standing	As implied
2	Vocalising	Making sound under breath
3	Snorting	Dominant black buck adult male making sound with a greater pressure to the other individual
4	Sneezing	Expulsion of air from nostril
5	Stretching body	Gets up and stretches the body with hind and forelimbs apart
6	Defecating	As implied
7	Urinating	As implied
8	Licking mouth	Moving tongue over the muzzle
9	Raising tail	As implied
0	Shaking tail	As implied
11	Moving ear	As implied
12	Looking to the side	Looking at right or left side
13	Looking down	Head down looking to at a level lower than the eye level of the individual
14	Looking up	Head up looking to at a level lower than the eye level of the individual

15	Alert	Stands with erect ear and stiff body
16	Moving head	Moving head in any of the direction
17	Rubbing body with inanimate object	Brushing parts of the body against inanimate objects
18	Rubbing antler/horn on the tree	Rubbing the tip of the antler on the bark of a tree
19	Rubbing antler/horn on the ground	Rubbing the tip of the antler on the ground
20	Shaking body	Standing and shaking the body vigorously for 3-5 seconds

Categorisation of feeding activity

Sl. No.	Activity	Description
1	Feeding	As implied
2	Foraging	Feeding on food other than supplied by the zoo authority
3	Browsing	Standing on hindlegs, neck extended to feed on the tree leaves
4	Drinking	As implied
5	Chewing	As implied
6	Nibbling	Taking small bites of the forage
7	Suckling	Act of drinking milk from the adult female

Categorisation of lying activity

Sl. No.	Activity	Description
1	Lie	Resting on the ground with eyes open
2	Cud chewing	Lying and chewing the regurgitated food
3	Lying and moving head	As implied
4	Lying and moving ear	As implied
5	Getting up	As implied

6	Sitting	Resting with forelimbs folded and the entire weight of the body resting on the forelimbs
7	Sitting erect	Sitting with body erected
8	Sitting down	Attempt to sit- folding the forelimbs and touching the back portion of the body first on the ground and sitting down with forelimbs folded
9	Sleeping	Resting with eyes closed
10	Wallowing	Lying in water

Categorisation of moving activity

Sl. No.	Activity	Description
1	Sniffing ground	Looking down with the muzzle almost touching the ground, nostrils being raised and lowered at repeated frequencies
2	Walking	As implied
3	Searching	Walking with head lowered, head moving slightly in all direction in quest of forage other than the food supplied by the zoo authority
4	Running	As implied
5	Playing	Two individuals playfully chasing one another
6	Jumping	As implied

Categorisation of interaction behaviour

Sl. No.	Activity	Description
1	Licking genital	Individual flicking tongue over the anal region of the recipient
2	Sniffing genital	Individual puts the muzzle near the anal region of the recipient and smells the region
3	Sniffing	Sniffs any other body part of the recipient
4	Sniffing urine	Sniffs urine of other individual as the other individual is urinating or after the other individual has left the spot
5	Flehmen	Licks the urine the individuals and curls up the tongue with head slightly raised and mouth slightly open
6	Scratching body	Raises one of the forelimb with the body slightly lowered and the head twisted slightly too scratch the neck and head with the raised forelimb
7	Autogrooming	Grooming the whole body except neck and head body using tongue, teeth or antler
8	Lying and grooming	As implied

9	Allogrooming	Licking the body of the other individual
10	Soliciting allogrooming	Individual who is soliciting to be groomed and
11	Not soliciting allogrooming	Individual on being approached for grooming showing negative response
12	Rubbing body with another individual	Brushing the body part with another individual

Categorisation of submission behaviour

Sl. No.	Activity	Description
1	Moving slightly away	Moving back ward on approach of dominant individual
2	Walking away displaced	Neck extended and walking away from the aggressor
3	Running away displaced	Running away in being threatened
4	Getting up displaced	Getting up and moving away from the place on being threatened
5	Standing scared	Neck S shaped position with muzzle pointed towards the ground. Ears laid back one flashing back and forth exposing white hairs
6	Sitting scared	Neck extended with muzzle parallel to the ground. Ears laid back

Categorisation of aggression behaviour

Sl. No.	Activity	Description
1	Hard look	Standing stiffly and looking directly into the eyes of another individual with lowered ears
2	Stamping leg	Standing without looking directly at the opponent, raising one of the forelimbs and stamping it on the ground repeatedly
3	Aggressive approach	Walking directly towards the opponent with head slightly raised high
4	Pushing	Head of the aggressor touches the body of the opponent and the opponent is pushed back
5	Butting	Head of aggressor at the butt of the opponent pushing the recipient back
6	Biting	Bite at neck/shoulder/rump

7	Chasing	Chase while striking with forefeet.
8	Chasing and biting	As implied
9	Locking antler/horn	Without any display, interlock antlers and push each other aggressively
10	Pointing antler/horn	Neck arched, ears laid back, eyes rolled, tail below horizontal
11	Poking antler/horn	Head extended and the antler poked at the body of the opponent
12	Pressing head	Ram each other with lowered head, thumping the ground
13	Jumping and hitting with forelegs	Jumps on the back of the opponent and hitting the butt region with the forelegs
14	Threatening	Head bobbing up and down with chest directed at the opponent
15	Standing on the hind legs and hitting	Both the individual stand on hind legs and hit each other with forelegs
16	Kicking	Hit the opponent with the hind leg
18	Following	Walks behind the individual
19	Head up display	Erect posture with muzzle pointed upwards.
20	Striking antler/horn	Jerking head downward or sideways to point the tip of antler briefly.
21	Hitting antler/horn	Jerking head downward hitting the opponent on the back

APPENDIX-3

Table 4.4.1. Hierarchical ranking of black buck in the enclosure of Hyderabad

AM- adult male, AF- Adult female, SM- Subadult male, SF- Subadult female,
>, Higher dominance rank; <, Lower dominance rank; ~, Hierarchical rank not defined; =, Similar hierarchical ranking.

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 100%	AM~SF, 0%
Adult female	AF<AM, 0%		AF~SM, 0%	AF=SF, 50%
Subadult male	SM<AM, 0%	SM>AF, 75%		SM>SF, 100%
Subadult female	SF<AM, 0%	SF~AF, 0%	SF~SM, 0%	

Table 4.4.2. Hierarchical ranking of black buck in the enclosure of Vizag

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 100%	AM>SF, 100%
Adult female	AF<AM, 0%		AF=SM, 50%	AF~SF, 0%
Subadult male	SM<AM, 0%	SM>AF, 78%		SM~SF, 0%

Table 4.4.3. Hierarchical ranking of black buck in the enclosure of Chennai

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 98%	AM>SM, 85%	AM>SF, 100%
Adult female	AF<AM, 0%		AF<SM, 41%	AF>SF, 95%
Subadult male	SM<AM, 14%	SM>AF, 89%		SM>SF, 100%
Subadult female	SF<AM, 0%	SF<AF, 0%	SF~SM, 0%	

Table 4.4.4. Hierarchical ranking of black buck in the Mysore-2 enclosure

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 87%	AM>SM, 91%	AM>SF, 97%
Adult female	AF<AM, 46%		AF>SM, 71%	AF>SF, 61%
Subadult male	SM<AM, 66%	SM>AF, 94%		SM>SF, 98%
Subadult female	SF<AM, 0%	SF>AF, 88%	SF=SM, 50%	

Table 4.4.5. Hierarchical ranking of black buck in Mysore-2 enclosure

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 93%	AM>SF, 100%
Adult female	AF>AM, 60%		AF=AM, 50%	AF>SF, 100%
Subadult male	SM<AM, 47%	SM>AF, 92%		SM>SF, 87%
Subadult female	SF<AM, 0%	SF~AF, 0%	SF>SM, 69%	

Table 4.4.6. Hierarchical ranking of Sambar in Vizag-2 enclosure

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 56%	AM>SM, 67%	AM-SF, 0%
Adult female	AF<AM, 0%		AF>SM, 100%	AF-SF, 0%
Subadult male	SM-AM, 0%	SM-AF, 0%		SM-SF, 0%
Subadult female	SF-AM,0%	SF-AF, 0%	SF-SM, 0%	

Table 4.4.7. Hierarchical ranking of Sambar in Vizag-1 enclosure

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 85%	AM>SM, 75%	AM>SF, 100%
Adult female	AF-AM, 0%		AF>SM, 100%	AF-SF, 0%
Subadult male	SM<AM, 16%	SM-AF, 0%		SM-SF, 0%

Table 4.4.8. Hierarchical ranking of Sambar in the enclosure of Hyderabad

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 71%	AM>SM, 98%	AM>SF, 90%
Adult female	AF=AM, 50%		AF>SM, 100%	AF>SF, 75%
Subadult male	SM-AM, 0%	SM>AF, 100%		SM>SF, 100%
Subadult female	SF-AM,0%	SF>AF, 100%	SF>SM, 67%	

Table 4.4.9. Hierarchical ranking of Sambar in the enclosure of Chennai

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 92%	AM>SM, 95%	AM>SF, 90%
Adult female	AF>AM, 83%		AF>SM, 73%	AF>SF, 92%
Subadult male	SM-AM, 0%	SM<AF, 11%		SM>SF, 88%
Subadult female	SF-AM,0%	SF-AF, 0%	SF>SM, 100%	

Table 4.4.10. Hierarchical ranking of Sambar in the enclosure of Mysore

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 75%	AM<SM, 47%	AM>SF, 100%
Adult female	AF<AM, 38%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM<AM, 33%	SM>AF, 58%		SM-SF, 0%
Subadult female	SF-AM,0%	SF-AF, 0%	SF>SM, 100%	

Table 4.4.11. Hierarchical ranking of Chital in the enclosure of Hyderabad

Hierarchy-Mysore2	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 100%	AM>SF, 100%
Adult female	AF-AM, 0%		AF>SM, 100%	AF>SF, 89%
Subadult male	SM-AM, 0%	SM-AF, 0%		SM>SF, 100%

Table 4.4.12. Hierarchical ranking of Chital in the enclosure of Chennai

Hierarchy-Mysore2	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 95%	AM>SM, 86%	AM>SF, 100%
Adult female	AF-AM, 0%		AF>SM, 100%	AF>SF, 96%
Subadult male	SM-AM, 0%	SM>AF, 100%		SM>SF, 100%
Subadult female	SF-AM, 0%	SF=AF, 50%	SF<SM, 0%	

Table 4.4.13. Hierarchical ranking of Chital in Mysore-1 enclosure

Hierarchy-Mysore2	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 82%	AM>SM, 70%	AM>SF, 90%
Adult female	AF-AM, 0%		AF>SM, 91%	AF>SF, 93%
Subadult male	SM<AM, 40%	SM>AF, 80%		SM>SF, 71%
Subadult female	SF-AM, 0%	SF<AF, 36%	SF<SM, 25%	

Table 4.4.14. Hierarchical ranking of Chital in Mysore-2 enclosure

Hierarchy-Mysore2	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 75%	AM>SM, 74%	AM>SF, 89%
Adult female	AF<AM, 39%		AF>SM, 64%	AF>SF, 98%
Subadult male	SM>AM, 56%	SM>AF, 73%		SM>SF, 79%
Subadult female	SF-AM, 0%	SF<AF, 38%	SF>SM, 56%	

APPENDIX-4

Table 4.5.1. Hierarchical ranking of black bucks to access to food in Hyderabad Zoo in morning

Zoo in morning

AM- adult male, AF- Adult female, SM- Subadult male, SF- Subadult female,
>, Higher dominance rank; <, Lower dominance rank; ~, Hierarchical rank not defined; =, Similar hierarchical ranking.

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM100%	AM~SF, 0%
Adult female	AF~AM, 0%		AF~SM, 0%	AF>SF, 100%
Subadult male	SM~AM, 0%	SM>AF, 100%		SM~SF, 0%

Table 4.5.2. Hierarchical ranking of black bucks to access to food in Hyderabad Zoo in evening

Zoo in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM100%	AM>SF, 100%
Adult female	AF~AM, 0%		AF>SM, 100%	AF~SF, 0%
Subadult male	SM~AM, 0%	SM>AF, 100%		SM>SF, 100%

Table 4.5.3. Hierarchical ranking of black bucks to access to food in Vizag Zoo in morning

morning

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM100%	AM~SF, 0%
Adult female	AF~AM, 0%		AF~SM, 0%	AF>SF, 100%
Subadult male	SM~AM, 0%	SM>AF, 67%		SM~SF, 0%

Table 4.5.4. Hierarchical ranking of black bucks to access to food in Vizag Zoo in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM100%	AM~SF, 0%
Adult female	AF~AM, 0%		AF~SM, 0%	AF~SF, 0%
Subadult male	SM~AM, 0%	SM>AF, 100%		SM~SF, 0%

Table 4.5.5. Hierarchical ranking of black bucks to access to food in Chennai Zoo to access to food in morning

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 77%	AM~SF, 0%
Adult female	AF~AM, 0%		AF~SM, 0%	AF>SF, 100%
Subadult male	SM~AM, 0%	SM>AF, 96%		SM>SF, 100%

Table 4.5.6. Hierarchical ranking of black bucks to access to food in Chennai Zoo to access to food in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM100%	AM>SF, 100%
Adult female	AF~AM, 0%		AF~SM, 0%	AF~SF, 0%
Subadult male	SM~AM, 0%	SM>AF, 100%		SM>SF, 100%

Table 4.5.7. Hierarchical ranking of black bucks to access to food in Mysore-1 enclosure in morning

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 90%	AM>SF, 100%
Adult female	AF~AM, 0%		AF~SM, 0%	AF>SF, 80%
Subadult male	SM>AM, 0%	SM>AF, 98%		SM>SF, 100%
Subadult female	SF~AM, 0%	SF>AF, 100%	SF~SM, 0%	

Table 4.5.8 Hierarchical ranking of black bucks to access to food in Mysore-1 enclosure in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 76%	AM>SF, 100%
Adult female	AF~AM, 0%		AF~SM, 0%	AF~SF, 0%
Subadult male	SM<AM, 25%	SM>AF, 100%		SM>SF, 94%

Table 4.5.9. Hierarchical ranking of black bucks to access to food in Mysore-2 enclosure in morning

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 100%	AM>SF, 100%
Adult female	AF~AM, 0%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM>AM, 100%	SM>AF, 100%		SM>SF, 80%
Subadult female	SF~AM, 0%	SF~AF, 0%	SF=SM, 50%	

Table 4.5.10. Hierarchical ranking of black bucks to access to food in Mysore-2 enclosure in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 97%	AM>SM, 97%	AM>SF, 100%
Adult female	AF~AM, 0%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM>AM, 100%	SM>AF, 73%		SM>SF, 100%
Subadult female	SF~AM, 0%	SF<AF, 33%	SF~SM, 50%	

Table 4.5.11. Hierarchical ranking of Sambar to access to food in the Vizag-1 enclosure in morning

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 88%	AM>SM, 100%	AM~SF, 0%
Adult female	AF~AM, 0%		AF~SM, 0%	AF~SF, 0%

Table 4.5.12. Hierarchical ranking of Sambar to access to food in the Vizag-1 enclosure in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 100%	AM~SF, 0%
Adult female	AF~AM, 0%		AF~SM, 0%	AF~SF, 0%

Table 4.5.13. Hierarchical ranking of Sambar to access to food in the Vizag-2 enclosure in morning

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 92%	AM>SM, 100%	AM>SF, 100%
Adult female	AF>AM, 100%		AF~SM, 0%	AF>SF, 100%
Subadult male	SM~AM, 0%	SM>AF, 100%		SM>SF, 100%

Table 4.5.14. Hierarchical ranking of Sambar to access to food in the Vizag-2 enclosure in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 100%	AM>SF, 100%
Adult female	AF~AM, 0%		AF>SM, 100%	AF~SF, 0%

Table 4.5.15. Hierarchical ranking of Sambar to access to food in Hyderabad Zoo in morning

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 100%	AM>SF, 100%

Table 4.5.16. Hierarchical ranking of Samr to access to food in Hyderabad Zoo in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 100%	AM>SF, 100%
Adult female	AF~AM, 0%		AF>SM, 100%	AF>SF, 100%

Table 4.5.17. Hierarchical ranking of Sambar to access to food in Chennai Zoo in morning

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 87%	AM>SF, 100%
Adult female	AF>AM, 100%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM>AM, 100%	SM>AF, 100%		SM>SF, 100%

Table 4.5.18. Hierarchical ranking of Sambar to access to food in Chennai Zoo in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM>SM, 83%	AM>SF, 100%
Adult female	AF>AM, 100%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM~AM, 0%	SM~AF, 0%		SM>SF, 60%

Table 4.5.19. Hierarchical ranking of Sambar to access to food in Mysore Zoo in morning

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 83%	AM~SM, 0%	AM~SF, 0%
Adult female	AF>AM, 100%		AF~SM, 0%	AF>SF, 100%
Subadult male	SM<AM, 25%	SM~AF, 0%		SM~SF, 0%

Table 4.5.20. Hierarchical ranking of Sambar to access to food in Mysore Zoo in evening

Hierarchy	Adult male	Adult female	Subadult male	Subadult female
Adult male		AM>AF, 100%	AM~SM, 0%	AM~SF, 100%
Adult female	AF>AM, 100%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM~AM, 25%	SM~AF, 0%		SM~SF, 0%

Table 4.5.21. Hierarchical ranking of Chital to access to food Chennai Zoo in morning

Adult male		AM>AF, 100%	AM>SM, 92%	AM>SF, 100%
Adult female	AF~AM, 0%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM~AM, 0%	SM~AF, 0%		SM>SF, 100%
Subadult female	SF~AM, 0%	SF~AF, 0%	SF>SM, 100%	

Table 4.5.22. Hierarchical ranking of Chital to access to food Chennai Zoo in morning

Adult male		AM>AF, 100%	AM>SM, 100%	AM>SF, 100%
Adult female	AF~AM, 0%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM~AM, 0%	SM~AF, 0%		SM>SF, 100%
Subadult female	SF~AM, 0%	SF>AF, 100%	SF~SM, 0%	

Table 4.5.23. Hierarchical ranking of Chital to access to food in the Mysore-1 enclosure in morning

Adult male		AM>AF, 100%	AM>SM, 94%	AM>SF, 100%
Adult female	AF~AM, 0%		AF=SM, 50%	AF>SF, 100%
Subadult male	SM>AM, 100%	SM>AF, 100%		SM>SF, 100%
Subadult female	SF~AM, 0%	SF>AF, 100%	SF~SM, 0%	

Table 4.5.24. Hierarchical ranking of Chital to access to food in Mysore-1 enclosure in evening

Adult male		AM>AF, 100%	AM>SM, 94%	AM>SF, 100%
Adult female	AF~AM, 0%		AF>SM, 80%	AF>SF, 100%
Subadult male	SM<AM, 33%	SM>AF, 100%		SM>SF, 94%

Table 4.5.25. Hierarchical ranking of Chital to access to food in the Mysore-2 enclosure in morning

Adult male		AM>AF, 100%	AM>SM, 97%	AM>SF, 100%
Adult female	AF~AM, 0%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM>AM, 66%	SM>AF, 88%		SM>SF, 96%
Subadult female	SF~AM, 0%	SF>AF, 67%	SF~SM, 0%	

Table 4.5.26. Hierarchical ranking of Chital to access to food in the Mysore-2 enclosure in evening

Adult male		AM>AF, 100%	AM>SM, 93%	AM>SF, 100%
Adult female	AF>AM, 75%		AF>SM, 100%	AF>SF, 100%
Subadult male	SM>AM, 100%	SM>AF, 100%		SM>SF, 100%
Subadult female	SF~AM, 0%	SF~AF, 67%	SF~SM, 0%	

APPENDIX-5

Table 5.1. CZA recommended guidelines for space allocation for ungulates

Species	Density of individual per acre	Density of individual per 100 sq. m.
Black buck	3 animals/ acre	0.72
Chital	2 animals/ acre	0.05
Sambar	1 animals/ acre	0.02

Categorisation of enclosures based on the density of individuals of a species

Species	Within CZA recommended density (individual per 100 sq. m.)	Medium density (individual per 100 sq. m.)	High density (individual per 100 sq. m.)
Black buck	Hyderabad (0.24) Vizag (0.29)	-	Chennai (1.33) Mysore-1 (8.25) Mysore-2 (10.03)
Chital	Hyderabad (0.06)	Chennai (0.56)	Mysore-1 (1.47) Mysore-2 (2.5)
Sambar	Vizag-1 (0.08) Vizag-2 (0.28)	Hyderabad (0.38)	Chennai (0.88) Mysore (1.45)