ENVIRONMENTAL INFLUENCES ON SPACE UTILISATION AND THE ACTIVITY BUDGET OF CAPTIVE LEOPARDS (*Panthera pardus fusca*) IN FIVE ZOOS IN SOUTHERN INDIA

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Over the last six months, I worked with zoo people from five different zoos and am grateful to them for their support and assistance:

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My best friend Anupama for the good times we spent together
Anand, for being there every time needed him
Wobbles for the long chats and all the football games
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SUMMARY

A behavioural study was conducted on leopards in five zoos situated in Thiruvananthapuram, Chennai, Mysore and Bangalore between November 1998 and March 1999. Twenty six leopards were studied in five zoos of which sixteen were singly housed and ten were housed in groups. There were 16 males and 10 females. Only three of the 26 animals were captive born, 10 were captive reared and 13 were wild caught. Fourteen singly housed leopards were studied in on-exhibit and off-exhibit enclosures on days with visitor presence and also on zoo holidays, two singly housed leopards were studied in the off-exhibit enclosures only. The group of ten at Bannerghatta Zoological Gardens, Bangalore was studied only in the on-exhibit enclosure.

Scan sampling method was used to record the behavioural patterns in leopards. The ethogram, which consists of all behaviour observed in five zoos lists 12 behavioural states and 29 behavioural events. The leopard enclosures were divided into imaginary blocks and the utilisation of these grids by the leopard was recorded alongwith behaviour at five-minute intervals. The grids were further categorised into “edge”, “back”, “enrich” and “rest” zones. Each leopard was studied for two days on-exhibit, two days off-exhibit and one zoo holiday. The leopard at Childrens' Park, Guindy as also studied for two excess visitor days during the Pongal festival. Information on each leopard was obtained from zoo records.

No significant difference in behaviour was observed between males and females, and wild caught and captive-reared individuals. The behavioural repertoire of female leopards was significantly associated with their period of anoestrum. Stereotypic pacing was found to increase with enclosure size. Leopards housed in larger enclosures exhibited higher levels of activity and stereotypy behaviour.

Smaller enclosures housed leopards that rested for longer proportions of time. Activity and resting behaviour peaks in the daily activity budget of the leopards were due to their crepuscular nature. The peaks in stereotypic behaviour in the daily activity budget were influenced by zookeepers' presence. Food-anticipatory behaviour was observed in all leopards before and during feed time. Individuals that were studied on-exhibit and off-exhibit exhibited higher levels of stereotypic behaviour off-exhibit and higher levels of activity behaviour on-exhibit. The presence of visitors also influences the behaviour repertoire of captive leopards. All singly housed leopards studied on days with visitor presence and zoo holidays exhibited higher levels of activity on zoo holidays and higher levels of resting behaviour on days with the presence of visitors. Six individuals were studied singly and then as pairs. The proportion of activity and resting behaviour exhibited when they were housed in pairs was higher and stereotypic behaviour, though not statistically significant, was lower than when they were singly housed. The utilisation of space differed between singly and group-housed leopards. Singly housed individuals utilised the "edge" and "back" zones of their enclosures more and the structurally "enrich" zone less than group-housed leopards. Most of the leopards utilised the "edges" of their enclosure for stereotyping, the "back" zone for resting and the "rest" of the enclosure for activity behaviour. The structural features found within the enclosures that housed leopards were of two categories; sleeping platforms, trees and sheds that stimulated resting behaviour and logs, snags and tree trunks that stimulated activity behaviour. In enclosures that were structurally enriched with sleeping platforms, sheds or trees, leopards utilised the "enrich" zone of the enclosure for resting instead of the "back" zone. Enclosures having logs and snags, the "enrich" zones is utilised to exhibit activity behaviour. The utilisation of

the structurally enriched zones of the enclosures was positively correlated with enclosure complexity. Leopards in structurally enriched enclosures exhibited higher levels of activity and lower levels of resting than the barren enclosures. The factors that were found to influence the behavioural repertoire of captive leopards have been taken into consideration while recommending environmental enrichment techniques for the renovations of old enclosures and the construction of new ones.

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larger enclosures exhibited higher levels of activity and stereotypy behaviour. Smaller enclosures housed leopards that rested for longer proportions of time. Activity and resting behaviour peaks in the daily activity budget of the leopards were due to their crepuscular nature. The peaks in stereotypic behaviour in the daily activity budget were influenced by zookeepers' presence. Food-anticipatory behaviour was observed in all leopards before and during feed time. Individuals that were studied on-exhibit and off-exhibit exhibited higher levels of stereotypic behaviour off-exhibit and higher levels of activity behaviour on-exhibit. The presence of visitors also influences the behaviour repertoire of captive leopards. All singly housed leopards studied on days with visitor presence and zoo holidays exhibited higher levels of activity on zoo holidays and higher levels of resting behaviour on days with the presence of visitors. Six individuals were studied singly and then as pairs. The proportion of activity and resting behaviour exhibited when they were housed in pairs was higher and stereotypic behaviour, though not statistically significant, was lower than when they were singly housed. The utilisation of space differed between singly and group-housed leopards. Singly housed individuals utilised the "edge" and "back" zones of their enclosures more and the structurally "enrich" zone less than group-housed leopards. Most of the leopards utilised the "edges" of their enclosure for stereotyping, the "back" zone for resting and the "rest" of the enclosure for activity behaviour. The structural features found within the enclosures that housed leopards were of two categories; sleeping platforms, trees and sheds that stimulated resting behaviour and logs, snags and tree trunks that stimulated activity behaviour. In enclosures that were structurally enriched with sleeping platforms, sheds or trees, leopards utilised the "enrich" zone of the enclosure for resting instead of the "back" zone. Enclosures having logs and

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1. INTRODUCTION

1.1. General Introduction

The welfare of animals in the context of their management and exploitation has currently become the focus of scientific attention. A large number of animal welfare studies have been conducted on the biological and psychological impacts of captive environments on farm, laboratory and zoo animals (Wiepkema & Koolhaas, 1993; Bernard & Hurst, 1996; Kessler & Turner, 1997). Conditions in captivity were found to decrease the animals' general reactions and alter their behavioural patterns (Kiley & Worthington, 1977).

Behaviour is influenced by the motivational states of an individual. These motivations are in turn influenced by the internal physiological state of the individual, external stimuli and conditions, and by the consequences of the behaviour (Kolter, 1995). The behaviour exhibited by an animal in its natural habitat, is the product of many generations of natural selection and environmental conditions (Carlstead, 1996).

A wide range of species of wild animals is maintained in laboratories and zoos in barren, unstimulating environments of a sub-optimal level (Kirkwood, in press; Maple, 1979). Captive environments as these, biologically and spatially restrict the animal from performing its species-specific behaviour. Such an inability to adapt to their captive environments results in an exhibition of abnormal behaviour (Carlstead & Seidensticker, 1991).

Behaviour that are exhibited as a result of the effects of captivity and not represented in the animal’s natural behavioural repertoire is abnormal behaviour. Primates and carnivores are particularly affected by behavioural disturbances (Boorer, 1972). Some examples of abnormal behaviour exhibited by felids in captivity are

reingestion, regurgitation, coprophagy, stereotypic pacing and over-grooming (Lyons et al. 1997).

Felids in captivity are found to exhibit locomotor stereotypies such as stereotypic pacing most frequently (Shepherdson et al. 1993; Lyons et al. 1997). Stereotypy is a characteristically repetitive behaviour, invariant in form and has no obvious goal or function (Carlstead, in press; Carlstead et al. 1993a). It may be an idiosyncratic expression of some primary behaviour that is prevented from being completed functionally due to captivity (Carlstead & Seidensticker, 1991). Stereotypy is environmentally induced developing in situations where the animal is normal but the environment in which it lives in is some way less than optimal. This is often referred to as "cage-stereotypy" (Kolter, 1995).

Stereotypy is a good indicator of sub-optimal environments (Mallinson, 1995). It is influenced by several factors of captivity such as enclosure size and complexity (Keulen & Kromhout, 1976; Lyons et al. 1997), visitor presence (Glatson et al. 1984; O'Donovan et al. 1993) and social deprivation in singly housed social animals and social dominance in solitary living animals that are housed in groups. Enclosures that deprive an animal of the opportunity to perform its natural daily processes, are barren environments of a suboptimal level. Animals housed in these enclosures are under stress. This results in a reduction in exploratory and social behaviour (Kiley & Worthington, 1977; Buchanan-Smith, 1996; 1997), and in an exhibition of stereotypy in most cases (Boorer, 1972). In an attempt to solve these problems, some zoos have turned to environmental enrichment techniques (Markowitz, 1982; Wilson, 1982; Carlstead & Shepherdson, 1991; Forthman & Bakeman, 1992; Forthman et al. 1992; Powell, 1995).

The technique of environmental enrichment seeks to meet the behavioural needs of zoo animals by providing them with naturalistic surroundings. This method is utilised to enrich the environment in suboptimal confinements, so as to reconstruct the animal's natural habitat (Markowitz, 1982; Clevenger, 1987). Animals housed in enriched environments utilise areas of the enclosure that are more naturalistic (Baldwin, 1985; Neveu & Deputte, 1996). Animals housed in larger more environmentally complex enclosures exhibit lower levels of stereotypy than animals housed in small barren enclosures (Keulen & Kromhout, 1976).

This study addresses the effects of captivity on the behaviour of a solitary-living felid species; the leopard (*Panthera pardus fusca*). I focus on stereotypic pacing and food anticipatory behaviour. The major factors measured are visitors' presence, enclosure size, social enrichment and complexity.

1.2. Literature Review

1.2.1. Stereotypy and stress in captive animals

A large number of species maintained in zoos exhibit abnormal behaviour. Confinement of these wild animals in zoos causes acute stress, resulting in the exhibition of abnormal behaviour such as stereotypy (Mason, 1991; Weipkema & Koolhaas, 1993). Stereotypy is considered a form of atypical behaviour and indicates that an animal's psychological welfare is at a suboptimal level (Boorer, 1972; Marriner & Drickamer, 1994). Stereotypy has been widely studied in carnivores and primates (Clarke et al. 1982; Wilson, 1982; Carlstead, 1991; Wechsler, 1991; Forthman & Bakeman, 1992; Carlstead et al. 1993b; Inges et al. 1997). A behavioural study on polar bears revealed that a considerable proportion of the time budget of the bears was occupied by stereotypic behaviour (Wechsler, 1991). Stereotyping pacing

in polar bears were fixed both spatially and temporally. Stereotypy is caused by various factors related to captivity such as enclosure size (Keulen & Kromhout, 1976; Macedonia, 1987; Lyons et al. 1997) social deprivation (Maple, 1979), feeding time (Lyons et al. 1997; Carlstead, 1998), period of anoestrus (Bennett & Mellen, 1983) and barren environments (Redshaw & Mallinson, 1991; Zucker et al. 1991; Braastaad, 1996).

A study conducted on captive bears has shown that animals in smaller enclosures exhibited more stereotypy than animals in larger enclosures (Keulen & Kromhout, 1976). Restrictive captive environments were also found to be associated with abnormal behaviours other than stereotyped movement such as inactivity, depression, self-aggression and coprophagy (Clarke et al. 1982).

Enclosure design also plays an important role in the daily activity budget of animal in captivity (Seidensticker & Doherty, 1996; Reinhardt et al. 1996; Monte & Pape, 1997; Seidensticker & Forthman, 1998). A study on captive Sifakas (*Propithecus verreauxi*) had shown that those housed outdoors were more active, spending less time resting and more time in locomotion, playing and feeding than sifakas housed indoors (Macedonia,1987).

Female felids in oestrus exhibit higher proportions of stereotypic behaviour than in the anoestrus condition. A study on a pair of sand cats revealed significantly higher pacing levels and locomotion in the female during oestrus periods (Bennett & Mellen, 1983).

Food-anticipatory behaviour has been observed in captive environments. Food anticipation is an abnormal behaviour exhibited by captive animals as they learn to predict the feeding time each day. This results in stereotypy in anticipation of being fed (Baldwin, 1985; Ramanan, 1995).

1.2.2. Space utilisation by captive animals

Carnivores in captivity spend more than 75 % of their time in less than half their enclosure space (Baldwin, 1985). His study observed felids resting most frequently towards the rear of their exhibits. The space most frequently utilised in the enclosure by the felids was used for resting. Thus, the availability of areas suitable for resting on-exhibit influenced the distribution of space use. Lyons et al.'s (1997) study on captive felids and their utilisation of space showed that enclosure design and the management regime influence the behaviour of captive felids. The size of the enclosure did not affect the pacing behaviour, but the edges of the enclosures were particularly used for stereotypic pacing. In another study by Kessel & Brent (1996) on the utilisation of space by captive-born baboons (*Papio* spp.), eight baboon groups were monitored before and after the provision of structural enrichment which was in the form of a galvanised ladder suspended horizontally by chains and a plastic drum hung from the ladder. The baboons spent most of their time on the floor and the bench and this did not change with the addition of the new structures. Keulen & Kromhout's (1976) study on captive bears recorded stereotyped and begging behaviour of captive polar, brown and Himalayan black bears in relation to various landforms that featured in their enclosure. Polar, brown and Himalayan black bears preferred levelled surfaces without terraces and uneven floors. Brown and Himalayan black bears were less inhibited by a confined space than polar bears and did not seem to be disturbed by relatively small enclosures. Unlike polar bears they tend to behave actively on a surface interspersed with rocks and boulders.

1.2.3. Activity patterns in captive felids

Baldwin (1985) in his behavioural study on captive carnivores recorded the daily activity patterns of felids in captivity. A strong morning peak in activity was observed, followed by decreasing activity. A small afternoon peak was also observed in some seasons. Morning activity peaks occurred slightly before, or coincided with feeding time and were larger, longer in duration, and less variable seasonally than afternoon peaks. This suggests that morning activity was focused on feeding time.

Temperature has a significant effect on the behaviour of leopards in captivity; activity levels have been found to be inversely related with temperature (Baldwin, 1985).

1.2.4. Social interactions in captive solitary felids

Most felids are solitary living except for the lion *(Panthera leo)* which lives in social groups called prides (Eisenberg, 1986). Intraspecific interactions occur during territorial fights and during breeding season (Eisenberg, 1986; Bothma, 1998). A study of a pair of sand cats in captivity showed a temporal distribution in the utilisation of space by the sand cats within the enclosure (Bennett & Mellen, 1983). Temporal division of the enclosure is an adaptation by the sand cats to communal living. The study showed that when one cat was active, the other tended to be inactive. When both cats exhibited periods of inactivity simultaneously, the enclosure was spatially segregated into male and female sleeping areas. A study on of eight adult pairs of snow leopards recorded the behavioural differences between pairs successful and unsuccessful breeding pairs, and between males and females (Freeman, 1983). Snow leopard pairs have a high degree of tolerance for each other and exhibit little aggressive behaviour. A high degree of synchrony between paired snow leopards

was observed, resulting in within-pair consistency. Unsuccessful males continued to pace during the female oestrus cycle, while males whose mates became pregnant showed a dramatic drop in their pacing behaviour during the oestrus time-block.

1.2.5. Leopard studies

Leopards are the most adaptable and widespread of big cats (Muckerhirn & Eisenberg, 1972; Bailey, 1993). Though not extensively studied, information on the behavioural ecology of the leopard does exist (Muckerhirn & Eisenberg, 1972; Norton & Lawson, 1985; Bailey, 1993). Solitary and occasionally arboreal, leopards prefer elevated rest areas and are frequently sighted on trees and rocky outcrops (Muckenhirn & Eisenberg, 1972; Schaller, 1972; Santiapillai et al. 1982; Seidensticker et al. 1984; Bailey, 1993). Studies on free-ranging leopards (*Panthera pardus fusca)* in the Indian sub-continent have documented prey selection and habitat use but none of these studies have recorded the daily activity budget of this species (Johnsingh, 1983; Karanth, 1991; Karanth & Sunquist, 1995; Edgaonkar & Ravi Chellam, 1998). The distribution of leopards in India and its morphology has been well documented (Prater, 1980). A few studies have recorded the behaviour of leopards in captivity (Baldwin, 1985; Lyons et al. 1997). Baldwin's study (1985) showed an influence of the time of day on the activity budget of the leopards in his study. Leopard behaviour was also found to be strongly influenced by the presence of visitors. Lyon's et al. (1997) in his study on the utilisation of space by captive felids found that leopards alongwith the rest of the felids studied predominantly used the edges of their enclosures. Elevated areas were used as surveillance points to examine the surrounding regions.

Though the effects of captivity on the behaviour of wild animals has been studied extensively across many species, the behavioural changes due to confinement in captive leopards or any other species maintained in Indian zoos has not yet been documented. This study aims to record the behaviour of leopards in five zoos in southern India.

1.3. Objectives

This study was conducted to achieve the following objectives:

- To determine the factors that influence the activity patterns exhibited by leopards in captivity
- To determine the factors that influence the frequency of stereotypy exhibited by the study animals
- To study the utilisation of space by leopards in captivity and to determine the influence of the following parameters on space-utilisation by the study animals
    - Enclosure size and complexity
    - Visitors' presence
- To determine the changes in the behaviour of the study animals caused by the following parameters :
    - Enclosure size and complexity
    - Visitors' presence
    - Social enrichment

2. STUDY SITES

Five zoos in southern India were chosen to conduct a behavioural study on leopards in captivity.

2.1. Thiruvananthapuram Zoological Gardens1, Thiruvananthapuram :

2.1.1. Study Area

The Thiruvananthapuram Zoological Gardens is located within the city of Thiruvananthapuram. It forms a part of the Museum and Zoo complex which includes the museum, art gallery, snake house, botanical gardens and the zoo. The zoo extends over 30 to 40 acres. It was constructed in the early 1850's in the traditional European style. Five hundred thousand to eight hundred thousand people visit this small city zoo every year. The zoo houses a large variety of animals from giraffes, mithun, rhinos, hippos to tigers, lions, leopards and macaques. It is open to the public from 09:30 to 17:30 hrs.

2.1.2. Exhibit Area

The leopards are exhibited in one wing of the cat-house which also houses tigers and lions. The two leopards are exhibited as a pair. The leopard-house is flanked by the tiger enclosure on the left and the lion enclosure on the right at a distance of 1.5 m.

The leopard enclosure is 3.6 m wide and 7.2 m long, the front of the enclosure being hemispherical (Figure 2.1; the zones mentioned in the all the enclosures have been defined in 3.2.8). It has a concrete flooring walled in by wrought-iron bars that merge at a height of 3.6 m to form a dome-shaped structure. A long wooden

[1] **Thiruvananthapuram Zoological Gardens** shall be referred to as Thiruvananthapuram Zoo through the rest of the text and as Trivandrum Zoo in the figures and tables

log is the only form of structural enrichment found within the enclosure. There is a water trough within the enclosure. The on-exhibit enclosure is connected to the off-exhibit enclosure by a door situated at the extreme end of the enclosure. A fence running around the cat-house maintains the visitor-distance at 1.8 m. Visitors are able to observe the leopards almost at eye level as the on-exhibit enclosure is elevated by 0.6m. The exhibit is completely devoid of any visual screens, this maximises the visitors' ability to sight the animal. The maximum distance that the animal can recede to in the enclosure is only 10 m (from the posterior end of the enclosure to the visitor area).

The off-exhibit enclosure is 4.5 m long and 3 m wide (Figure 2.1). It is nearly as large as the on-exhibit enclosure but is completely devoid of light. Three of its walls are made of brick while the fourth is of wrought-iron bars that run all the way up to the ceiling. This enclosure has a concrete flooring. Each on-exhibit enclosure is connected to an off-exhibit enclosure. All the off-exhibit enclosures are connected to the adjacent enclosures by doors. The big cats are frequently shifted to neighbouring enclosures during cleaning and health inspections. A high fence and gate ensures that the visitors maintain a distance of 9 m from the off-exhibit enclosures thus reducing the disturbance caused by the visitors to a minimum. The cat-house is surrounded by *Samanea saman and Tamarindus indica* trees. The enclosures are well shaded and sunlight reaches only a part of the enclosure at noon.

The animals at Thiruvananthapuram zoo were the first to be studied between the 23rd of November and the 7th of December, 1998. The mean ambient temperature and the humidity recorded in this study was

1) morning at **07:30** hrs : temperature : **25.5^{o}C** , humidity : **98.5%**
2) noon at **12:30** hrs : temperature : **29.5^{o}C**, humidity : **90%**
3) evening at **16:30** hrs : temperature : **27.5^{o}C**, humidity : **91.6%**

There were also a few rain showers during the end of November in Thiruvananthapuram.

2.1.3. Study Animals

The Thiruvananthapuram Zoological Gardens houses two leopards. The male was caught near a village close to Kannur in 1993 while the female was born in the Veermata Jijabai Bhosle Udyan and Zoo, Mumbai. She was brought to Thiruvananthapuram in 1992. Both animals are between 6 and 8 years in age. The leopards have not suffered from any serious ailments in the past except for a severe case of dermatitis, which the female still suffers from.

2.1.4. Husbandry practices

There are three zookeepers in charge of the cat-house. The enclosures are cleaned on the arrival of the zookeepers. At 09:00 hrs the first zookeeper arrives and he disposes all the left-over meat from the previous day's meal. Enclosures are hosed down with the animals on-exhibit at 09:30 hrs when the rest of the zookeepers arrive. The enclosures are cleaned with a non-toxic cleanser called Benzyl konium chloride or commonly as "germi-clean" in zoos. At 08:00 hrs the sweepers clean the area surrounding the enclosure. The off-exhibit areas are swept by the zookeepers. The leopards are fed at 11:30 hrs every day (3.5 kg of beef). Slabs of meat are thrust between the wrought-iron bars every day except on Mondays which is the fasting day for the carnivores as well as the zoo holiday. The leopards are given milk and eggs at 16:00 hrs everyday except on Mondays.

2.2. Arignar Anna Zoological Park[2], Chennai:

2.2.1. Study Area

The Arignar Anna Zoological Park is located on the eastern side of the Grand Southern Trunk Road, south of Chennai city. It lies in the Vandalur Reserve Forest of Kanchipuram District. The Zoological Park is located at a distance of 32 km from the Central Railway Station. The Madras zoo was shifted to Vandalur in 1979 and was opened to the public in 1985 as the Arignar Anna Zoological Park. It is one of the biggest zoos in south-east Asia extending over 510 ha.

The Zoological Park houses numerous species of animals. The animals are mostly maintained in open wet or dry moated enclosures. These enclosures have been built within pockets of dry evergreen forests. The zoo is open to the public from 08:00 to 17:00 hrs. Large numbers of people visit the zoological park in the month of January during the Harvest festival and in May during the summer holidays. In 1998, 86,860 people visited the zoo in January and 95,153 in May. Through the rest of the year, about 30,000 to 40,000 people visit the zoological park every month.

2.2.2. Exhibit Area

The Zoological Park has 8 leopards, which it maintains in two enclosure complexes. Each enclosure complex consists of a large on-exhibit enclosure, a much smaller on-exhibit enclosure and 4 off-exhibit enclosures that house 4 leopards. A distance of 200 m, which is partially forested, separates the two enclosure complexes.

The first leopard enclosure complex consists of a large on-exhibit enclosure, which is connected to a smaller on-exhibit enclosure and two off-exhibit enclosures through doors. The two off-exhibit enclosures are connected to two other off-exhibit enclosures. The off-exhibit enclosures are located within a room, which has a narrow

[2] **Arignar Anna Zoological Park** shall be referred to as Vandalur Zoo through the rest of the text

service-area. The front wall of the room consists of wrought-iron bars in the form of a gate, which is permanently locked and only opened during cleaning and health inspections. These walls force the visitors to maintain a distance of 1.8 m from the enclosures.

The large on-exhibit enclosure (7 m x 14 m) is completely meshed with a soft floor of mud and grass. The outer surface of the enclosure is curved giving it a hemispherical appearance. There are a few bamboo clumps along with one or two *Tamarindus indica* and *Azadirachta indica* saplings. A water tank that is permanently dry extends along the anterior end of the enclosure. The right portion of the enclosure has two to three wooden slabs erected one against another so as to form climbing posts. The posterior face of the enclosure consists of a brick wall. The wall has shelters that project out at a height of 1.2 m and 4.5 m from the ground. A part of the enclosure gets intense light at noon, the rest of the enclosure being otherwise completely shaded.

The smaller on-exhibit enclosure and the off-exhibit enclosure are located behind this enclosure. It consists of two small on-exhibit enclosures which effectively function as one enclosure. The entire on-exhibit enclosure is 8 m long, 4.85 m wide and has a sandy floor. The two posterior walls are of brick while the anterior faces are meshed. Two doors at the posterior end of the enclosure connect it with the larger on-exhibit enclosure and the off-exhibit enclosure. There is also a service entrance at the posterior end of the enclosure, which is locked permanently. There is a water-trough at the left edge of the enclosure and two wooden logs placed at the posterior end of the enclosure. These logs serve as climbing equipment. The hind wall has shelters at 1.2 m and 1.8 m respectively. The roof of the enclosure is completely covered with metal sheets. The enclosure receives sunlight at its edges from the midday sun. A fence running around the entire enclosure complex maintains the visitor distance at

1.3 m. the larger on-exhibit enclosure has many trees, clumps of grass and bamboo, which act as visual screens reducing visitors' ability to observe the animals. The smaller on-exhibit enclosure has no visual barriers. This makes it easier for the visitors to see in this enclosure.

There are 4 off-exhibit enclosures in this enclosure complex two of which are connected to the larger on-exhibit enclosure while the third is connected to the smaller on-exhibit enclosure (Figure 2.2). The off-exhibit enclosures (1.6 m x 2 m and 2.6 m x 2 m) or holding areas have concrete floors and their posterior wall is made of brick, the other three faces consist of wrought-iron bars. Each off-exhibit enclosure is connected to the neighbouring off-exhibit enclosures by doors, 0.9 m high. These enclosures are completely devoid of light. All the off-exhibit enclosures have a water-trough that is placed at the left edge of the enclosure. These enclosures are within a room, which has a narrow service passage.

The second enclosure complex is fairly similar to the first in having one large on-exhibit enclosure, two small on-exhibit enclosures and 4 off-exhibit enclosures. The larger on-exhibit enclosure (8 m x 14 m) has a soft floor of mud and grass. The outer surface of the enclosure is curved giving it a hemispherical appearance. The enclosure consists of a few clumps of bamboo and *Tamarindus indica* and *Azadirachta indica* saplings. A water-tank runs along the anterior end of the enclosure and is maintained dry. Bushes and plants from the adjoining forest patch have inter-

twined into the enclosure's meshing making the outer right edge of the enclosure dense with greenery. It forms a hideout for the leopards reducing the public's visibility. The anterior wall is of brick while the rest of the enclosure is meshed. The posterior wall has two shelters at a height of 1.2 m above the two doors that connect it with the off-exhibit enclosures. The entire enclosure is well shaded and intense sunlight reaches only a portion of the enclosure at noon.

The smaller on-exhibit enclosures have a floor of sand. One of these enclosures (3.8 m x 4.2 m) houses a leopard while the other is left empty permanently (Figure 2.3). These enclosures are situated behind the larger on-exhibit enclosure. Their posterior walls are of brick while the other faces are of mesh. The first enclosure that houses the leopard is connected to the off-exhibit enclosure through a door in the posterior wall. There are two poles placed at the rear end of the enclosure at a height of 0.9 m. These poles serve as scratch posts. The second on-exhibit enclosure is connected to the first by a door in its side-wall. The roof is of metal sheets placed on the meshing. Little light reaches the enclosure floor. The entire enclosure complex is fenced and this maintains the visitor distance at 1.5 m. The smaller on-exhibit enclosure is completely devoid of visual barriers.

The holding areas are located in a room, which consists of three off-exhibit enclosures (2.8 m x 3.7 m) and a squeeze cage (2.8 m x 3.7 m). All 4 enclosures including the squeeze cage periodically house leopards, but the squeeze cage is reduced to 1.6 m x 2.35 m in area by moving the sliding wrought-iron wall face (Figure 2.3). The squeeze cage is connected to the smaller on-exhibit enclosure. Two of the three off-exhibit enclosures are connected to the larger on-exhibit enclosure through doors. The 4 holding areas are also interconnected through doors 0.9 m high. The corner holding areas have two of their posterior walls made of brick while the enclosures at the centre have only one brick face. The rest of the faces are of wrought-

iron bars. These enclosures have a concrete flooring and are completely devoid of light.

All the off-exhibit enclosures have a water-trough that is placed at the left edge of the enclosure. These enclosures are found within a room, which has a narrow service passage. These walls force the visitors to maintain a distance of 1.8m from the enclosures. Trees and bushes surround the two enclosure complexes.

The animals at Vandalur Zoo were studied between the 16th of December, 1998 and the 21st of January, 1999. This site was further visited on one occasion: the 8th of March 1999. The mean ambient temperature and the humidity recorded here were

1. morning at **07:30** hrs : temperature : **22.5°C**, humidity : **98.5%**
2. noon at **12:30** hrs : temperature : **27°C**, humidity : **68.3%**
3. evening at **16:30** hrs : temperature : **25.5°C**, humidity : **79.5%**

2.2.3. Study Animals

The Vandalur Zoo houses 8 leopards, 6 males and 2 females. The two females are wild-caught from the Nilgiris. They are between 7 and 9 years in age. Three of the males are cubs (1.5 years old); one was born in the zoo while the others were brought from the wild to the zoo when they were a few weeks old. Two of the adult males are 5 to 6 years old. Both were brought to the zoo from the wild, one as an adult and the other as a cub. The eighth leopard is an old male from Amrithi Zoo who is approximately 15 years old.

2.2.4. Husbandry practices

The zookeepers arrive between 08:30 and 09:30 hrs every morning. The leopards are left into the on-exhibit enclosures after the enclosures are cleaned.

The larger on-exhibit enclosures are cleaned less frequently. Leopards housed in these enclosures are given complete access to the off-exhibit enclosures by opening the door connecting the off-exhibit to the on-exhibit enclosure open, from 17:30 to 09:30 hrs the next day. The interconnecting door is closed at 09:30 hrs on the arrival of the zookeepers. The smaller on-exhibit enclosures are swept before the leopards are let in at 09:30 hrs on the arrival of the zookeepers. The off-exhibit enclosures are also swept and cleaned with water. The off-exhibit enclosures are regularly cleaned with bleaching powder and phenyl. The leopards are fed at 16:30 hrs in the off-exhibit enclosures. Each leopard gets 5 kg of beef every day except on Tuesdays which is the fast day for the zoo carnivores. It is also the zoo holiday. The leopards occasionally get chicken as a substitute.

2.3. Children's' Park, Guindy:

2.3.1. Study Area

The Childrens' Park is situated in the city of Chennai in Guindy. The park extends over 25 acres. It is flanked by the Madras Snake Park and the Guindy National Park that are 1.6 acres and 2.73 sq. km respectively. The leopard house is situated at the posterior end of the Park. The Childrens' Park opens at 09:00 and closes at 17:30 hrs everyday. The park is visited by 1,000 to 2,000 people every except during the Tamil Harvest Festival when the park is visited by 14,000 to 15,000 people each day. The park also exhibits other species such as tortoises, a pair of hyaena, rhesus macaques and a large number of birds.

2.3.2. Exhibit Area

The leopard house consists of one on-exhibit enclosure and three off-exhibit enclosures. The large on-exhibit enclosure (9 m x 7 m) is completely meshed with a soft floor of mud. The outer surface of the enclosure is curved giving it a hemispherical appearance. There is a long wooden log placed roughly at the centre of the enclosure. There is a concrete water body located to the left side of the enclosure The posterior face of the enclosure consists of a brick wall. The wall has a shelter that projects out at a height of 0.6 m from the ground. The entire on-exhibit enclosure is covered by a creeper that hangs down along the side-walls of the enclosure. This overhanging plant filters the light reaching the enclosure floor with only the anterior portion of the enclosure getting intense light at noon.

The off-exhibit enclosures (2.2 m x 2.65 m) are located behind the on-exhibit enclosure and are not accessible to the public, as the entire off-exhibit area is fenced. The three off-exhibit enclosures are situated adjacent to one another and are interconnected by doors 0.75 m high. Their floors are of concrete\granite. These enclosures are devoid of light. The second off-exhibit enclosure is connected to the on-exhibit enclosure by a door in its back wall, which is 0.75 m high. The off-exhibit enclosures have their hind wall made of brick while the other three faces are of wrought-iron bars. The off-exhibit enclosures are housed in a room that also has a narrow service passage which ends in a door, which is permanently locked. The on-exhibit enclosure has a concrete wall, 1 m high that maintains the visitor distance at 1.5 m. The area between the wall and the enclosure forms a flower-bed.

The animal at Guindy was studied between the 4th and 8th, and 14th and 19th of January 1999. This site was further visited on one occasion: the 26th of January 1999. The mean ambient temperature and the humidity recorded here were

1. morning at **07:30** hrs : temperature :**22°C**, humidity : **96%**
2. noon at **12:30** hrs : temperature :**28.6°C**, humidity : **64%**
3. evening at **16:30** hrs : temperature :**25°C**, humidity : **75.5%**

2.3.3. Study Animal

The leopard house at Guindy has a single adult male. He was brought to the park from the Arignar Anna Zoological Park in 1995. The animal is more than 15 years old. There are no records of his acquisition at the Vandalur Zoo.

2.3.4 Husbandry practices

The zookeeper arrives between 08:30 and 09:30 hrs every morning. The on-exhibit enclosure is swept and the water body is cleaned and filled. The leopard is then left into the on-exhibit enclosure. The off-exhibit enclosures are cleaned after the leopard is left into the on-exhibit enclosure. The leopard is left on-exhibit till 17:30 hrs each day and then taken into the off-exhibit enclosure. The animal is taken into the off-exhibit enclosure at 14:30 hrs for feeding and is left out onto the on-exhibit enclosure at 15:00 hrs. The leopard gets 5 kg of beef every day except on Tuesdays which is the fast day for the zoo carnivores. It is also the zoo holiday. The leopard occasionally gets chicken as a substitute.

2.4. Shri. Chamarajendra Zoological Gardens[3], Mysore:

2.4.1. Study area

The Chamarajendra Zoological Gardens is located within the city of Mysore at a distance of 1 km from the city bus stand.

In 1892, the zoo was first established as the "palace zoo" in a small area of 10.2 acres by the Maharaja of Mysore, Shri Chamarajendra Wodeyar. In 1906, another 6.22 acres were added to the zoo area. The Chamarajendra Zoological Gardens now extend over 100 acres. The Karanji tank, which occupies another 150 acres, and the Chamundi Hill Safari that also extends over 150 acres surround it.

The Mysore Zoo exhibits numerous species being the only Indian zoo to exhibit three species of rhinos. They also exhibit lions, tigers, leopards, tapirs, otters, giraffes and many species of primates and ungulates.

Large numbers of people visit the Mysore Zoo during the Ugadi festival (1,74,500 people in October) and in the holiday season which is during the months of January (1,10,277 people), April (1,14,500 people) and May (1,78,700 people). It is open to the public from 09:00 to 17:00 hrs. Exhibits alternate with patches of manicured lawns and gardens. There are a large number of shade trees of the dry deciduous type.

2.4.2. Exhibit Area

The Mysore Zoo maintains 10 leopards in captivity. They are housed in four enclosure complexes that are located next to each other in the posterior end of the zoo. There are four on-exhibit enclosures that lie next to each other attached to the neighbouring enclosure by the side-wall. The on-exhibit enclosures have a mud and

[3] **Shri Chamarajendra Zoological Gardens** shall be referred to as Mysore Zoo through the rest of the text

grass floor. The on-exhibit area is connected to a sprinkler system, which runs over the roof of the enclosures. The posterior wall is made of brick while the front and side-walls are meshed. The off-exhibit enclosures are located behind the on-exhibit enclosure and are not accessible to the public.

The first enclosure complex houses two leopards that are exhibited as a pair. It consists of one on-exhibit (Figure 2.4) enclosure and 2 off-exhibit enclosures. The on-exhibit enclosure (7.7 m x 13.8 m) is connected to the one off-exhibit enclosure through a door in its posterior wall. In front of the door there is a small area with a concrete flooring which is at a higher elevation where the leopards prefer to rest. A log has been placed roughly at the centre of the enclosure, which serves as a climbing and scratching post. There is a water-trough at the left posterior edge of the enclosure.

The off-exhibit enclosures (2.4 m x 4.8 m) are adjacent to one another and are inter-connected by a door. They have a concrete flooring and are completely devoid of light. The side-walls are made of brick while the front and back faces are made of wrought-iron bars. The off-exhibit enclosures also have doors in the front through which the zookeeper enters to clean the enclosures. These doors are permanently locked. There is a wooden bench in each off-exhibit enclosure that runs along the side-wall. Water troughs are placed at the anterior left end of the enclosure.

The second enclosure complex houses two leopards that are exhibited as a pair. It is bigger than the first and has one large on-exhibit (Figure 2.5) and four off-exhibit enclosures at the back. The second on-exhibit enclosure (17 m x 10.5 m) is attached to the first along its left side-wall. It has a floor of mud and grass. A *Samanea saman* is located roughly to the centre of the enclosure. The leopards were observed to prefer resting on the tree's branches than resting at ground level. The posterior wall is made of brick while the three other faces are of mesh. The on-exhibit enclosure is connected to all four off-exhibit enclosures by doors at regular intervals

in the posterior wall. There is a water-trough at the left posterior edge of the enclosure.

The off-exhibit enclosures (3 m x 4.8 m) are located behind the on-exhibit enclosure and inaccessible to the visitors. These holding areas have their back and side-walls made of brick while the front face consists of wrought-iron bars. The off-exhibit enclosures are interconnected by doors in their side-walls. They also have doors in the front through which the zookeeper enters to clean these enclosures. Two leopards occupy the last two holding areas. The second enclosure has the squeeze cage while the first is empty. These enclosures receive very little sun-light only at midday when the front portion of the enclosure is lit. The third and fourth enclosures have a water-trough at the anterior end of the enclosure towards the side-wall. The off-exhibit enclosures have a wooden bench each that is located at posterior right end of the enclosure along the side-wall.

The leopards housed in the third enclosure complex were not studied. The fourth enclosure complex houses three sub-adults that are largely exhibited as a group of three. It consists of one on-exhibit enclosure (Figure 2.6) and three small off-exhibit enclosures. The fourth on-exhibit enclosure is L-shaped having an area of 224.5 sq.m. and is connected to the third on-exhibit enclosure along its left side-wall and the third is connected to the second in the same fashion. This enclosure is completely meshed except for the posterior face, which is of brick. The floor is of mud and grass. This enclosure is devoid of any form of structural enrichment. The leopards are permanently at ground level as there are no higher elevation points in this enclosure. The on-exhibit enclosure is connected to the three off-exhibit enclosures through doors in the posterior wall. There is a water trough at the posterior end of the left side-wall of the enclosure. The fourth on-exhibit enclosure is not as well shaded as the other three and at noon, most of the enclosure gets intense light.

The off-exhibit enclosures (1.9 m x 2.5 m) in the fourth enclosure complex are much smaller than the other three enclosure complexes. Doors interconnect them. The posterior and side-walls are of brick, while the front face is of wrought-iron bars. The front face of each holding area also has a door through which the zookeeper enters to clean these enclosures. These doors are permanently locked. The holding areas have a concrete/stone floor and the entire enclosure is devoid of light. Each enclosure has a wooden bench placed at the posterior end of the enclosure next to the door that links the off-exhibit enclosure to the on-exhibit enclosure. A water trough is maintained at the anterior end of the enclosure along the side-wall.

A fence runs around the front of the entire leopard house and forces the visitors to maintain a minimum distance of 1.5 m. The mesh walls have been cemented to a height of 0.6 m to reduce animal teasing by the visitors. The off-exhibit area is cut-off from the public area by a high barbed-wire fence. This area is inaccessible to the visitors. *Samanea saman, Tamarindus indica* and other avenue trees border the front of the leopard house sheltering the on-exhibit enclosures and the visitor areas from sunlight. The off-exhibit area has clumps of bamboo growing between the enclosure complexes. There are a few *Tamarindus indica* and *Azadirachta indica* trees present in this area.

The animals at Mysore Zoo were studied between the 3rd and the 23rd of February, 1999. The ambient temperature and the humidity recorded in this study were

1) morning at **07:30** hrs : temperature : **20.5^{o}C**, humidity : **89.5%**
2) noon at **12:30** hrs : temperature : **28.5^{o}C**, humidity : **55%**
3) evening at **16:30** hrs : temperature : **30^{o}C**, humidity : **45.6%**

2.4.3. Study Animals

The Mysore Zoo houses 10 leopards of which 7 were studied. There are 4 females and 6 males. Of the three that weren't studied, two males were handicapped and one (female) refused to come on-exhibit. Four of the study animals (two males and two females) are between 10 and 12 years of age. They were all brought from the wild, one male and one female were brought as cubs while the other two were adults. The other three are 3 years and 7months old (one female and two males). They were brought to the zoo as cubs from the wild.

2.4.4. Husbandry Practices

The zookeepers' daily routine of cleaning and disposal of waste starts at 09:30 hrs at the leopard - house. Two zookeepers are in charge of the leopard house. The leopards are left on-exhibit at 09:30 hrs and then the off-exhibit enclosures are cleaned. The sprinkler system is switched on at 09:30 hrs on the arrival of the zookeepers. It is allowed to run for 30 to 60 minutes every day. The area in front of the leopard house and behind it is swept twice a week. The leopards are taken into the off-exhibit enclosures at feed-time, which is at 16:30 hrs and are only left on-exhibit the next day at 09:30 hrs. The leopards are fed at 16:30 hrs in the off-exhibit enclosures. Each leopard is fed 5 kg of beef every day except on Tuesdays which is the carnivore fast-day.

2.5. Bannerghatta Zoological Gardens[4], Bangalore:

2.5.1. Study Area

The Bannerghatta Zoological Gardens is situated at a distance of 25 km from Bangalore city. The Safari Park and the Bannerghatta National Park flank the zoological gardens.

2.5.2. Exhibit Area

The Bangalore Zoo houses 14 leopards in a single leopard house that includes one large on-exhibit enclosure and three off-exhibit enclosures. The leopards are exhibited in groups of 10 and 4. The zookeeper segregates the leopards into two groups of 10 and 4, separating the individuals that fight excessively. The group of 10 leopards is exhibited from 09:30 to 15:00 hrs. At 15:00 hrs, the first group is taken into the off-exhibit enclosure and the second group of four is left into the on-exhibit enclosure. The second group is taken into the off-exhibit enclosure at 17:00 hrs. The leopard-house is situated at the end of the zoo.

The on-exhibit enclosure (35.4 m x 24 m) has only its posterior wall made up of bricks while the rest of the enclosure is completely meshed. The floor consists of mud and grass. There are numerous *Tamarindus indica*, *Tabebuia* spp. and *Azadirachta indica* saplings and trees within the enclosure. There are several shelters, sleeping dens and rocks that are the resting-places of the leopards. There are two small water bodies of which one is permanently dry. Through the posterior wall, the on-exhibit enclosure is connected to the three off-exhibit enclosures by doors. The on-exhibit enclosure is shaded from sunlight by shade trees bordering the leopard-house. A portion of the enclosure gets intense light only from the midday sun.

The off-exhibit enclosures lie behind the on-exhibit enclosure and are completely walled in and fenced. The three holding areas are inter-connected by

[4] **Bannerghatta Zoological Gardens** shall be referred to as Bangalore Zoo through the rest of the text

doors. Their posterior wall is made of brick while the front and sides are of wrought-iron bars. The holding areas are housed in a room, which also has a narrow service passage which ends in a door, which is permanently locked. The front walls of the off-exhibit enclosures also have a door through which the zookeeper enters to clean these enclosures. The floor is of granite/concrete. The squeeze cage is attached to the side-wall of the third off-exhibit enclosure. A water trough is maintained at the anterior right end of each enclosure. The enclosures are completely devoid of light. There is a fence running around the leopard-house that forces the visitors to maintain a distance of 1.5 m from the enclosure.

The animals at Bangalore Zoo were studied between the 3rd and 29th of March, 1999. The ambient temperature and the humidity recorded in this study were

1. morning at **07:30** hrs : temperature : **22.5°C**, humidity : **94.5%**
2. noon at **12:30** hrs : temperature : **31.5°C**, humidity : **67.5%**
3. evening at **16:30** hrs : temperature : **31°C**, humidity : **71%**

2.5.3. Study Animals

Bangalore Zoo houses three adult females, five male cubs and one female cub, and five adult male leopards. Four male cubs were born in captivity. One male and one female cub were brought to the zoo when they were a few weeks old from the wild. They are two years old and are of the same litter. Three of the adult males are between eight and twelve years of age and were caught from the wild. The last two males are between three and five years old and they were both brought to the zoo as cubs from the wild. The three females are three to four years old, two of which were brought to the zoo as cubs from the wild, while the third was born in captivity. The three year-old male and one of the three year-old females are from the same litter.

2.5.4. Husbandry Practices

The leopards are let into the on-exhibit enclosure at 09:30 hrs on the arrival of the zookeeper. The zookeeper exhibits the leopards in two groups. The first group of leopards is fed at 15:00 hrs when they are taken into the off-exhibit enclosures while the second group is fed at 17:00 hrs. The leopards are fed 5 kg of beef everyday except on Tuesdays, which is the fast day for the carnivores. It is also the zoo holiday. The off-exhibit enclosures are cleaned after the leopards are left into the on-exhibit enclosure at 09:30 hrs.

3. METHODS

3.1. Field Methods

3.1.1. Behavioural Sampling Methods

The activity budgets of zoo leopards were studied in five zoos in southern India from November 1998 to March 1999. An *adlibitum* sampling was conducted initially for a period of 15 hours to standardise the behavioural patterns exhibited and to develop an ethogram. This study broadly distinguishes behavioural patterns into behavioural events and behavioural states as defined by Martin & Bateson, (1994).

- **behavioural events:** are those behavioural patterns that are of relatively short duration, such as discrete body movements or vocalisations, which can be approximated as points in time. The frequency of their occurrence can be quantified using the instantaneous sampling technique.
- **behavioural states:** are those behavioural patterns that are of relatively long duration, such as prolonged activities or body postures. The duration (total duration or the proportion of time spent performing the activity), of these behavioural states can be quantified using continuous recording sampling technique.

An ethogram was prepared (appendix I), which was later modified (addition of behavioural states and events) at each site.

The leopards were exhibited singly, in pairs or in groups across the five zoos. In Thiruvananthapuram, the two leopards were exhibited as a pair. The male and female were studied singly and as a pair. At Vandalur Zoo, the eight leopards were housed singly and exhibited on a rotational basis. Six leopards were studied singly Vandalur except for a pair of cubs who were studied as a group of two. The zoo at Mysore exhibited its seven leopards as two groups of two and one group of three. The groups

were separated as the study was looking at the behaviour of singly housed leopards. The groups of two were studied both singly and in pairs (as social enrichment). The Bangalore Zoo exhibited its leopards in two groups, of ten and four, the individuals that fight excessively being separated by the zookeeper. The group of ten leopards was exhibited from 09:30 to 15:00 hrs. At 15:00 hrs, the first group was taken into the off-exhibit enclosure and the second group of 4 was left into the on-exhibit enclosure. The second group was taken into the off-exhibit enclosure at 17:00 hrs. The group of four that were usually exhibited between 15:00 and 17:00 hrs were exhibited at 09:00 to 15:00 hrs on the days they were studied from morning to evening. The daily activity budget was recorded as single animal scans and group scans for singly housed individuals and individuals housed in groups respectively, as given by Altmann, (1974).

The leopards that were singly housed were studied for a period of five to seven days. Each day, the behaviour exhibited by the study animal was scanned (Altmann, 1974; Martin & Bateson, 1994) after a sampling interval of five minutes for a period of six or ten hours. The ten-hour sampling period was further divided into sampling blocks the duration of which varied across zoos. This was due to reasons that were not under my control. A period of two days was spent near the study animals at each site to enable them to adapt to my presence. Each individual was studied for

- **Control days:** two control days for a period of ten hours each day (the second day being a pseudo-replicate of the first) in the on-exhibit enclosure. A special note was made if the control day fell on a week-end or on the day after the animal had fast.
- **Off-exhibit days:** two days in the off-exhibit enclosures for a period of six hours each day (the second day being a pseudo-replicate of the first). A special note was

made if the off-exhibit day fell on a weekend or on the day after the animal had fast.

- **Visitor-absence day:** one day when the zoo is closed to the public for a period of ten hours.
- **Social enrichment days:** for those individuals that were also exhibited as male-female pairs as in Thiruvananthapuram and Mysore, the pairs were scanned for a period of six hours for two days (the second day being a pseudo-replicate of the first).

This routine for sampling behaviour was followed in the first four sites, which were Thiruvananthapuram, Mysore, Vandalur and Childrens' Park at Guindy, where animals were either housed singly or in pairs.

All behavioural observations were recorded between 06:00 and 18:00 hrs. The ten hours of sampling time on control days and visitor-absence days ran between 06:00 and 18:00 hrs, the start and end-time being different at each zoo. This was due to reasons that were not under my control.

In Thiruvananthapuram, the ten sampling hours was divided into two blocks of 2.5 and 7.5 hrs respectively while in Chennai and Mysore, the ten sampling hours was divided into two blocks of 4.5 and 5.5 hrs. On off-exhibit days and social enrichment days, behaviour is recorded continuously for 6 hours between 06:00 and 18:00 hrs.

During the study at Bangalore, the leopards were scanned individually and as a group while on-exhibit. All behavioural recordings were made continuously for a period of eight hours. Ten individuals were studied between 07:00 and 15:00 hrs while the remaining four were studied from 09:00 to 17:00 hrs. The eight hours was divided into two-hour sampling units and the study animals were changed after the completion of each sampling unit. The behavioural state and events exhibited by the study animals were recorded at five-minute sampling intervals. The entire group on-

exhibit, were scanned at 15 minute sampling intervals through the eight hours. Group scans and single animal scans are carried out simultaneously at 15 and five-minute intervals respectively. Group scans included all animals on-exhibit except the animal that was being scanned singly for the same time period. While all 14 leopards were included in the group scans, the four cubs in the group were not scanned singly, as individual identification posed a problem. At Bangalore, the leopards were neither studied off-exhibit nor on zoo holidays.

Alongwith the behavioural data that was recorded every five minutes for singly housed animals and those housed in pairs and every 15 minutes for animals housed in groups, orientation of the animal with respect to location of the public-area and any causes of disturbance, were also noted.

Data recorded every five minutes was pooled day-wise for comparisons such as visitor-absence to visitor-presence days or off-exhibit to on-exhibit days. For comparisons between different periods of the day, the data was pooled for the specified time period (the pooling of data for these time periods have been mentioned in 3.2 for each comparison).

3.1.2. Documentation of data from the zoo records with respect to each animal under study

Data on the history of the leopards was collected from the records maintained by the zoo staff. The following information was collected:

- **Age and sex of the animal:**

  Animals were categorised according to their age into

  Cubs: below the age of three years

  Adults: between the age of three and 12 years

  Old: over 12 years of age

- **Wild-caught, captive-born or captive reared:**

  Wild-caught : caught from the wild as an adult (above the age of three years)

  Captive-reared: brought to the zoo from the wild as cubs (below the age of three years) or were brought from another zoo with no previous records of birth or acquisition.

  Captive-born: born in captivity

Information on the region in which the animal was found with respect to wild-caught and captive-reared animals was recorded. Information on animals born in other zoos was also noted.

- health records: information of any illnesses the animal had had in the past or any particular ailments the animal is prone to was recorded.
- diet and other information on the feeding regime for each animal to be studied.
- Information on each individual animal (behaviour patterns typical to the animal in question) was collected by talking to the zookeepers in each zoo. Records on husbandry methods practised at each zoo site were also maintained.

3.1.3. Determination of space utilisation with respect to enclosure features

Details of the enclosure occupied by the study animal were gathered from the zoo records, from measurements and from observation made at each zoo. These enclosure details were gridded on a representative map. Trees, plants, shelters and other forms of structural enrichment found within the enclosure were plotted on the base map.

The location of the enclosure with respect to the zoo i.e. distance from the entrance and exit and the positioning of the enclosure (centre, back, front or to the side of the zoo) was noted. The size of the enclosure, structural features such as materials used for the walls, substrate, roof, presence of trees etc. was documented. Information on the animal housed in the neighbouring enclosure was also recorded

To study the space utilisation of the enclosure by an animal, the enclosure was partitioned on paper into various zones. These zones were marked on the base map for all on-exhibit and off-exhibit enclosures in the five, which had the features of the enclosure mapped on it zoos (Figures 2.1 to 2.6). Every day, a copy of this base map of the enclosure housing the animal to be studied was taken to the field site and used during scan sampling. The animal's position was noted alongwith the behavioural data. This procedure was followed for all individuals at all the five.

3.1.4. Temperature, humidity and other environmental factors

The dry and wet thermometer's readings were noted in the morning, at noon and in the evening on every sampling day. Information on rain and strong winds were noted. The time of day when intense sun-light reached the floor was noted. The degree of sunlight available to the enclosure was broadly categorised into brightly-lit, partially-lit and dimly-lit.

3.2. Statistical Analysis

To minimise categories of behavioural states, the behaviour were broadly classified into resting, activity and stereotypic behaviour i.e., of the 11 behaviour states exhibited by the singly housed leopards behaviour such as sleeping, sitting, sitting erect and lying down were grouped under resting behaviour while walking, standing, rolling, running and jumping were grouped under activity behaviour.

Behavioural data of leopards housed at Bangalore Zoo (housed in groups) was segregated from the other zoos (where leopards were singly housed) and analysed separately. The group-housed leopards exhibited climbing behaviour which was not observed at the other sites. Climbing was included under activity behaviour for the leopards at Bangalore.

Frequencies of the behaviour scanned at five minute intervals were summed on a daily basis for each leopard. These frequencies were converted to proportion time spent in exhibiting each behaviour (percentages).

3.2.1. Analysis of behavioural differences in life history and across sex

Differences in proportion time spent in exhibiting resting, activity and stereotypic behaviour were tested by using Kruskall-Wallis test (Zar, 1984). Differences in proportion time spent in exhibiting each behaviour between males and females, and captive-reared and wild-caught individuals were tested using Mann-Whitney U-Wilcoxon Rank Sum W Test (Zar, 1984). Analysis was carried out separately for singly housed leopards and those housed in groups.

The singly housed females were further categorised into anoestrus and females in oestrus. This data was analysed by using chi-square test for independent samples (2 $\times$ 2 contingency tables).

3.2.2. Analysis of behavioural differences across visitor-presence and visitor-absence days

Each leopard was studied for two visitor-presence days and one visitor-absence day. The differences in proportion time spent in exhibiting each behaviour on visitor-presence and visitor-absence (holidays) days were tested using Wilcoxon Matched-pairs Signed-ranks Test for singly housed leopards. Sampling days were

differentiated into week-days (average number of visitors), week-ends (higher number of visitors) and day after fast day (24 hours after the last meal). The differences in proportion time spent in exhibiting each behaviour on these days were tested using Mann-Whitney U-Wilcoxon Rank Sum W Test. Behavioural data of singly housed leopards and those housed in groups were segregated for analysis.

3.2.3. Analysis of behavioural differences exhibited on-exhibit and off-exhibit

Each leopard was observed for two days in the on-exhibit enclosures and two days in the off-exhibit enclosures. The differences in proportion time spent in exhibiting each behaviour on-exhibit and off-exhibit were tested using Wilcoxon Matched-pairs Signed-ranks Test (Lehner, 1996) for singly housed leopards.

3.2.4. Analysis of behavioural differences between pre-feeding and an average sampling hour

Food anticipatory behaviour was measured by comparing any hour (13 behavioural sampling-points in one hour) of behaviour sampling in the day with the sampling hour immediately before feed-time. In most zoos, the leopards were fed between 16:00 hrs and 17:00 hrs when they were taken off-exhibit for the night. Hence, pre-feeding hours could not be compared with the post feeding hours. An hour was randomly chosen from the first six sampling hours of the day for zoos that fed their leopards in the evening and this sampling hour was compared with the pre-feeding hour of sampling. In Thiruvananthapuram, where the leopards were fed at 11:30 hrs, an hour from the last six sampling hours of the day was randomly chosen and compared with the prefeeding hour of sampling. Though a comparison between the pre-feeding and post-feeding hours was possible with the behavioural data from Thiruvananthapuram, an hour was chosen randomly to maintain uniformity across

zoos. The differences in proportion time spent in exhibiting each behaviour between the randomly chosen sampling hour and the hour before feeding were tested using Wilcoxon Matched-pairs Signed-ranks Test. Behavioural data of singly and group-housed leopards were analysed separately.

3.2.5. Analysis of differences in the activity budget of leopards before and during social enrichment

Six leopards (two at Thiruvananthapuram and four at Mysore) were exhibited as pairs. Their behaviour were recorded when they were singly housed and when they were exhibited as pairs. The behaviour exhibited under these two conditons was compared by using Wilcoxon Matched-pairs Signed-ranks Test.

3.2.6. Analysis of behavioural differences across time in a sampling day

The hours of behavioural observation in a sampling day were broadly segregated into three categories (Table 3.1). The sampling hours were divided into three categories based on the arrival of zoo staff and visitors and also on time of day. The differences in proportion of time spent in exhibiting each behaviour between the three categories were tested using Kruskall-Wallis test (Zar, 1984). The three categories were tested separately for visitor presence and visitor absence days for singly housed leopards and only visitor presence days were tested for those housed in groups. Using Kolmorogrov-Smirnov Goodness of Fit test tested the difference in behaviour exhibited on visitor presence and visitor absence days. The Kruskall-Wallis test was also used to test the differences in the proportion of behaviour with time of day. Behaviour exhibited on each sampling day was segregated hour-wise and behaviour was compared across hours of observation. Analysis was carried out separately for singly and group-housed leopards.

Table 3.1. Categories for the hours of behavioural observations on a sample day for singly housed leopards across four zoos.

Categories	Description
Category 1 : first hour of sampling in the day	Includes sampling hours before the arrival of visitors and zoo staff
Category 2 : second to the ninth hour of sampling in the day	Includes sampling hours during the day when visitors and zoostaff are present within the zoo premises
Category 3 : the last hour of sampling in the day	The last sampling before the leopard is taken into the off-exhibit enclosure.

3.2.7. Calculation and analysis of behavioural diversity

The Shannon-Weiner diversity index (Magurran, 1988) was used to calculate the behavioural diversity exhibited by each animal. The diversity index was calculated for behaviour exhibited on-exhibit and off-exhibit for each animal that was singly housed and only for those behaviour exhibited on-exhibit for those housed in groups. All behavioural states were utilised for the calculation of **Shannon-Weiner index (*H*)** :

$$H = \sum p_i \log (1 / p_i)$$

where p_i is the proportion of time engaged in the i^{th} behaviour. The value of the index depends partially on the number of behaviour in the sample, and partially on the equitability of time spent between behaviour. Larger values of *H* indicate greater diversity.

Behavioural diversity was calculated for visitor absence days, for visitor presence days, on-exhibit and off-exhibit for singly housed leopards. Leopards were observed in the on-exhibit enclosures on visitor-absence days. The diversity in behaviour exhibited on visitor-absence and days with visitors presence (leopards observed on-exhibit), and between on-exhibit and off-exhibit days were compared by using Wilcoxon Matched-pairs Signed-ranks Test. Differences in behavioural diversity exhibited by singly housed leopards and those housed in groups were also tested by using Wilcoxon Matched-pairs Signed-ranks Test.

3.2.8. Calculation and analysis of diversity in the utilisation of space within an enclosure

The frequency of grid-usage by each leopard was summed up on a daily basis for each enclosure. These frequencies were converted into proportion time spent in each grid within the enclosure. The grids were broadly categorised into four zones: “edge”

(grids that bordered the outer edge of the enclosure and were the closest to the visitor area[5]), "back" (grids at the posterior end of the enclosure that are farthest from the visitor-area) and the "enrich" (environmentally enriched portions of the enclosure). The grids that did not fall into the first 3 categories were included in the "rest" zone. The differences in the proportion time spent in each zone were tested by the Kruskall-Wallis test. The proportion time spent in each zone was correlated with the proportion time spent in exhibiting each behaviour by using the nonparametric Spearman Rank Correlation Coefficient Test for each enclosure. Twelve correlations of the proportion of behaviour exhibited to the proportion of space utilised were conducted as there were four zones and three behaviour states. These correlations were calculated for each on-exhibit and off-exhibit enclosure separately. The comparisons that were significantly correlated were later tabulated for each zoo.

A spread of Participation Index (SPI) was calculated for each animal for the on-exhibit and off-exhibit enclosures, to give a measure of space utilisation (Shepherdson et al 1993; Lyons et al. 1997).

$$SPI = [\, M (n_a - n_b) + (F_a - F_b) \,] / 2(N - M)$$

Where N = total number of observations of the subject ; M = mean frequency of observations in all of the enclosure zone subdivisions M (N divided by number of zone subdivisions in the enclosure) ; n_a = number of zone subdivisions with a frequency greater than M ; n_b = number of zone subdivisions with a frequency less than M ; F_a = total number of observations in zone subdivisions with frequencies greater than M; F_b = total number of observations in zone subdivisions with frequencies less than M. The calculated SPI varies between 0 and 1 ; 0 indicates all zone subdivisions within the enclosure were used equally ; and 1 indicates that the subject animal spent all of the observed time in one zone subdivision.

[5] **the "edge" zone of** one on-exhibit enclosures in Chennai had some of its outermost grids farthest from the visitor area

Diversity in the utilisation of space was calculated using spread of participation index for the utilisation of different zones on visitor absence days, for visitor presence days on-exhibit and off-exhibit for singly housed leopards. Differences in diversity in the utilisation of space on visitor-absence and on-exhibit days, and between on-exhibit and off-exhibit days were tested by using Wilcoxon Matched-pairs Signed-ranks Test. Diversity in the utilisation of space by singly housed leopards and those housed in groups were also tested by using Wilcoxon Matched-pairs Signed-ranks Test.

3.2.9. Analysis of the differences in behaviour patterns exhibited in structurally enriched and barren enclosures

The differences in behaviour exhibited in structurally enriched and barren enclosures were tested by using Mann-Whitney U-Wilcoxon Rank Sum W Test. This test was carried out separately for on-exhibit and off-exhibit enclosures.

3.2.10. Correlation of enclosure complexity and various other parameters

The enclosures were comparatively graded according to their complexity (Table 3.2).

Table 3.2. Complexity grades for enclosures housing leopards singly in four zoos

Grades	Complexity
1	Enclosures that are barren (**no trees, logs etc.,**)
2	Partially barren enclosures (**logs present**)
3	Enclosures with **sleeping platforms**
4	Enclosures with **trees, clumps of bamboo and/or waterbodies**

Enclosure complexity was correlated with behavioural diversity and the diversity in space utilisation by using Partial Correlation Coefficient Test by correcting for enclosure size. Enclosure complexity was also correlated with the proportion of time spent in the "enriched" zone and with the proportion of time spent in exhibiting resting behaviour by each leopard. Behavioural diversity and the diversity in space utilisation were also correlated with enclosure complexity by using Partial Correlation Coefficient Test. The test was corrected for enclosure size.

3.2.11 Analysis of the differences in various parameters across zoos

The differences in proportions of behaviour exhibited between zoos were tested by using the Kruskall-Wallis test. The same test was used to test

1) the differences in proportion time spent in each zone
2) the differences in proportion time spent in exhibiting resting, activity and stereotypic behaviour.

3.2.12. Analysis of the differences in various parameters between singly and group-housed leopards

The differences in the activity budgets and in the utilisation of space between singly and group-housed leopards was tested by using Mann-Whitney U-Wilcoxon Rank Sum W Test.

Statistical test results were considered significant at $P \leq 0.1$ for all the tests conducted. χ^2 values have been reported for Kruskall-Wallis tests and Z values for Mann Whitney U-Wilcoxon Rank Sum W Test and Wilcoxon Matched-pairs Signed-ranks Test.

4. RESULTS

Twenty-six leopards were studied in five zoos of which sixteen were singly housed and ten were housed in groups (Table 4.1.). There were 16 males and 10 females. Only three of the 26 animals were captive-born, 13 were captive-reared and 10 were wild-caught. Fourteen singly housed leopards were studied in on-exhibit and off-exhibit enclosures and on holidays, two singly housed leopards were studied in the off-exhibit enclosures only. The group of ten at Bangalore was studied only in the on-exhibit enclosure.

Eleven behaviour states (Table 4.1 and 4.2) and 29 behavioural events were recorded while observing singly housed leopards in four zoos (excluding Bangalore Zoo). Seven of these behaviour states were exhibited by leopards housed in all four zoos. In Bangalore Zoo, the group-housed leopards exhibited 12 behaviour states (Table 4.2 and 4.3) i.e., climbing which was not observed in any of the other zoo, was exhibited by some group housed leopards.

The differences in the proportions of activity, resting and stereotypic behaviour exhibited by leopards in captivity were compared. The proportion of resting behaviour exhibited was significantly higher than activity and stereotypic behaviour for singly housed (Kruskall Wallis, χ^2 = 57.00, df = 2, p= 0.001[1]) and group-housed leopards (Kruskall Wallis, χ^2 = 20.43, df = 2, p= 0.0001).

4.1. Differences in activity budget with sex and history

The differences in the proportions of activity, resting and stereotypic behaviour exhibited by leopards in captivity were compared across sex and history for singly and group-housed leopards. There was no significant difference in the proportion time spent

[1] All p values are two tailed significance unless otherwise specified

Table 4.1. *Details of sex and history of leopards studied in captivity in five zoos (Nov' 98-Mar'99)*

Zoological Park	Total	Males	Females	Captive reared	Captive-born	Wild caught
Trivandrum Zoo	2	1	1	0	1	1
Vandalur Zoo	6	4	2	2	1	3
Childrens' Park	1	1	0	1	0	0
Mysore Zoo	7	4	3	5	0	2
Bangalore Zoo	10	6	4	5	1	4

Table 4.2. Frequencies of resting behaviour for leopards in captivity in five zoos (Nov'98-Mar'99)

Behaviour	**Trivandrum Zoo (%) n=2**	**Vandalur Zoo (%) n=6**	**Childrens' Park (%) n=1**	**Mysore Zoo (%) n=7**	**Bangalore Zoo (%) n=10**
Lying Down	2.72	3.77	12.13	3.28	2.54
S.E (±)	1.34	2.67	-	0.56	1.25
Sitting	45.69	38.09	36.40	23.52	36.53
S.E (±)	9.88	5.01	-	2.81	6.26
Sitting Erect	4.47	6.96	4.50	5.37	4.55
S.E (±)	2.77	1.02	-	1.77	1.68
Sleeping	37.21	18.21	26.03	32.41	30.10
S.E (±)	5.60	3.31	-	4.24	12.11
Resting Behaviours	**90.09**	**67.03**	**79.06**	**64.58**	**74.02**
Not Visible	0.00	6.53	11.94	3.59	0.05
S.E (±)	-	1.27	-	0.39	0.10

n= one day 910 hours of observation) for each leopard sampled at the given site

Table 4.3. *Frequencies of activity and stereotypic behaviour for leopards in captivity in five zoos (Nov'98-Mar'99)*

Behaviour	**Trivandrum Zoo (%) n=2**	**Vandalur Zoo (%) n=6**	**Childrens' Park (%) n=1**	**Mysore Zoo (%) n=7**	**Bangalore Zoo (%) n=10**
Walking	3.21	5.20	4.31	5.50	7.98
S.E (±)	1.12	1.36	-	0.60	3.25
Standing	2.91	4.43	1.76	8.59	6.05
S.E (±)	2.55	1.50	-	4.03	2.29
Running	0.00	0.67	0.20	0.28	0.59
S.E (±)	-	0.12	-	1.11	0.50
Jumping	0.00	0.26	0.00	0.00	0.11
S.E (±)	-	0.05	-	0.12	0.13
Rubbing / Rolling	0.10	0.51	0.00	0.53	0.11
S.E (±)	0.14	0.10	-	0.00	0.20
Climbing	0.00	0.00	0.00	0.00	0.11
S.E (±)	-	-	-	-	0.13
Activity Behaviours	**6.22**	**11.06**	**6.26**	**14.9**	**14.94**
Stereotypic Behaviours	**3.69**	**15.38**	**2.74**	**16.93**	**10.98**
S.E (±)	1.30	2.93	-	4.03	8.29

n= one day (10 hours of observation) for each leopard sampled at the given site

in exhibiting activity, resting and stereotypic behaviour across sex (Mann Whitney-U, activity behaviour, Z= -0.651, N= 16, p=0.52; resting behaviour, Z= -0.978, N= 16, p=0.33; stereotypic behaviour, Z= -0.434, N= 16, p=0.67) and history (Mann Whitney-U, activity behaviour, Z= -1.55, N= 14, p=0.12; resting behaviour, Z= -1.55, N= 14, p=0.12; stereotypic behaviour, Z= 0.259, N= 14, p=0.8) (between wild-caught and captive-reared individuals) for singly housed leopards. The behaviour exhibited by leopards housed in groups were not significantly different across sex (Mann Whitney-U, activity behaviour, Z= -1.06, N= 10, p=0.28; resting behaviour, Z= -0.213, N= 10, p=0.91; stereotypic behaviour, Z= 0.433, N= 10, p=0.66) but resting and stereotypic behaviour were significantly different with history (wild-caught and captive-reared). Wild-caught leopards exhibited higher proportions of resting behaviour than captive-reared individuals (Mann Whitney-U, Z= -1.96, N = 10, p= 0.05) and lower proportions of stereotypic behaviour (Mann Whitney-U, Z = -1.74, N = 10, p= 0.081). Activity behaviour did not show any significant difference with history in group-housed individuals (Mann Whitney-U, Z = -1.47, N = 10, p= 0.141). As the leopards were housed in a group, factors such as territoriality and dominance hierarchy could have influenced the activity budget. These factors were not measured during the course of this study.

The proportion of time spent in exhibiting activity, resting and stereotypic behaviour by female leopards was found to be significantly associated with period of anoestrus (χ^2 = 15.09, df = 5, p= 0.005). Females in oestrus exhibited higher levels of activity and stereotypic behaviour and lower levels of resting behaviour when compared to anoestrus females.

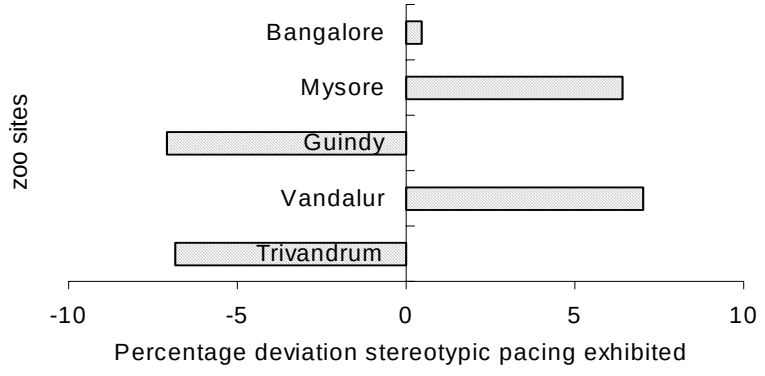
4.2. Stereotypic pacing

All singly housed leopards exhibited stereotypic pacing. Six of the ten individuals housed in groups exhibited stereotypic pacing. Mean stereotypic pacing levels were calculated for each zoo. The mean stereotypic level for each zoo was categorised according to their deviation from the overall mean (10.52%). The deviations (positive or negative) from the mean were plotted for each zoo (Figure 4.1). Leopards at Trivandrum Zoo and Childrens' Park paced below the average pacing level while individuals at Mysore Zoo and Vandalur Zoo paced above the average pacing level. The leopards at Bangalore Zoo were near average pacers.

4.3. Activity budget and zoos

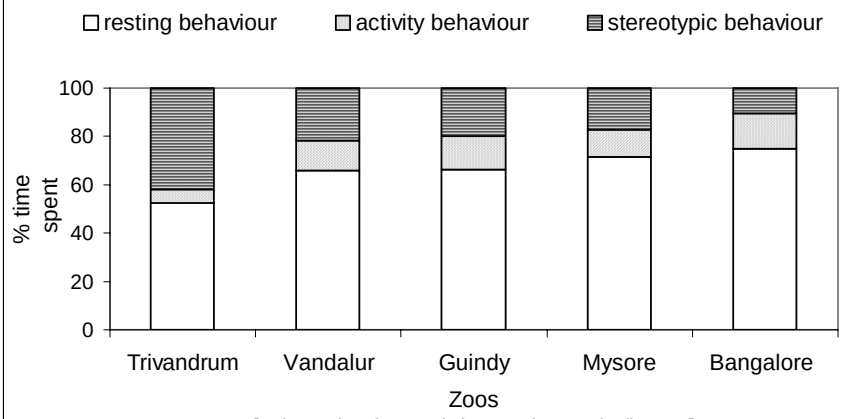
The differences in the proportions of activity, resting and stereotypic behaviour exhibited by singly housed leopards were compared across zoos (Figure 4.2). Activity behaviour significantly differed across zoos (Kruskall Wallis, $\chi^2 = 7.00$, df = 3, p=0.072). Activity levels exhibited by the leopards housed at Mysore and Vandalur Zoos were significantly higher than Trivandrum Zoo and Childrens' Park, Guindy. Though resting (Kruskall Wallis, $\chi^2 = 5.97$, df = 3, p=0.113) and stereotypic behaviour (Kruskall Wallis, $\chi^2 = 3.78$, df = 3, p=0.287) showed no significant difference across zoos, levels of resting behaviour exhibited at Trivandrum Zoo and Childrens' Park were higher than Mysore and Vandalur Zoos, and stereotypic pacing levels were higher at Mysore and Vandalur Zoos in comparison to Trivandrum Zoo and Childrens' Park.

Figure 4.1. *Deviation from the mean level of stereotypy exhibited by leopards in five zoos (Nov'98-Mar'99)*



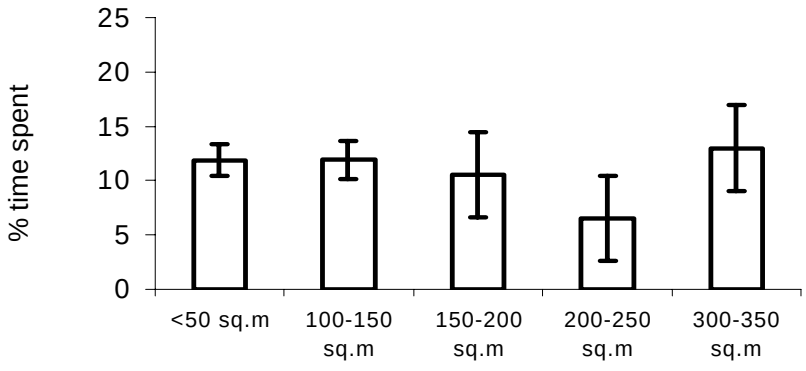
[n (one day for each leopard sampled) = 26]

Figure 4.2. *Activity budget of singly and group-housed leopards in five zoos (Nov'98-March'99)*



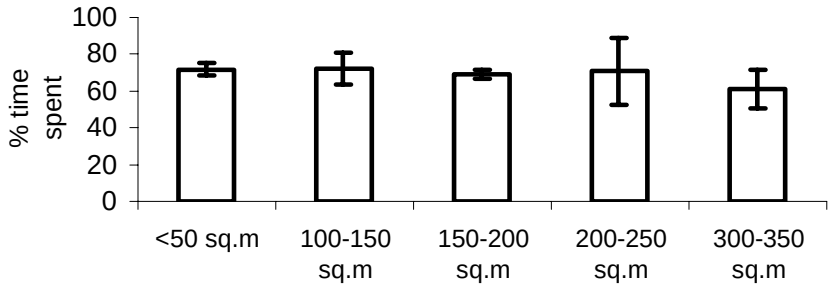
[n (one day for each leopard sampled) = 26]

Figure 4.3. *Differences in activity behaviour with enclosure size for singly housed leopards in 4 zoos (Nov'98-March'99)*



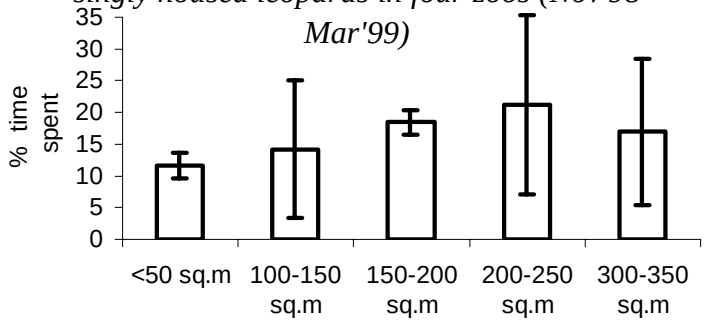
[n (one day for each leopard sampled) = 16]

Figure 4.4. *Differences in resting behaviour with enclosure size for singly housed leopards in four zoos (Nov'98-March'99)*



[n (one day for each leopard sampled) = 16]

Figure 4.5. *Differences in levels of stereotypic behaviour with enclosure size for singly housed leopards in four zoos (Nov'98-Mar'99)*



[n (one day for each leopard sampled) = 16]

4.4. Activity budget and enclosure size

There were no significant differences in behaviour with the increase in enclosure size of the on-exhibit enclosures, but proportions of resting behaviour exhibited decreased and activity levels increased marginally with an increase in enclosure size (Kruskall-Wallis, activity behaviour , $\chi^2 = 2.229$, df = 4, p=0.694; resting behaviour, $\chi^2 = 2.83$, df = 4, p=0.586) (Figure 4.3 and 4.4). Activity levels were higher for individuals housed in medium sized enclosures (150 to 250 sq.m) than individuals housed in large enclosures (250 to 300 sq.m). The proportion of activity exhibited in enclosures greater than 300 sq.m was found to be the highest. Levels of resting behaviour exhibited were marginally lower for leopards housed in enclosures belonging to the 150-200 and 300-350 sq.m classes.

Stereotypic pacing levels, though not significant, was found to increase with the enclosure size of the on-exhibit enclosures (Kruskall-Wallis, $\chi^2 = 1.46$, df = 4, p=0.834). The proportion of time spent in stereotypic pacing increased with the size of the enclosure, but decreased marginally for enclosures greater than 300 sq.m in size (Figure 4.6).

4.5. Daily Activity Budget

The activity budget of the singly housed leopards showed two peaks in activity (Figure 4.6 and 4.7). Activity levels were high at 07:00 to 08:00 hrs in the morning and gradually decreased through the day only to peak at 18:00 hrs again. Higher proportions of resting behaviour were exhibited in the afternoon at 13:00 hrs. Stereotypic pacing peaked during the third hour on- exhibit (at 09:00 hrs) and before feed-time (at 16:00 to 17:00 hrs).

Figure 4.6. *Daily Activity Budget for singly housed leopards in four zoos (Nov'98-Mar'99)*

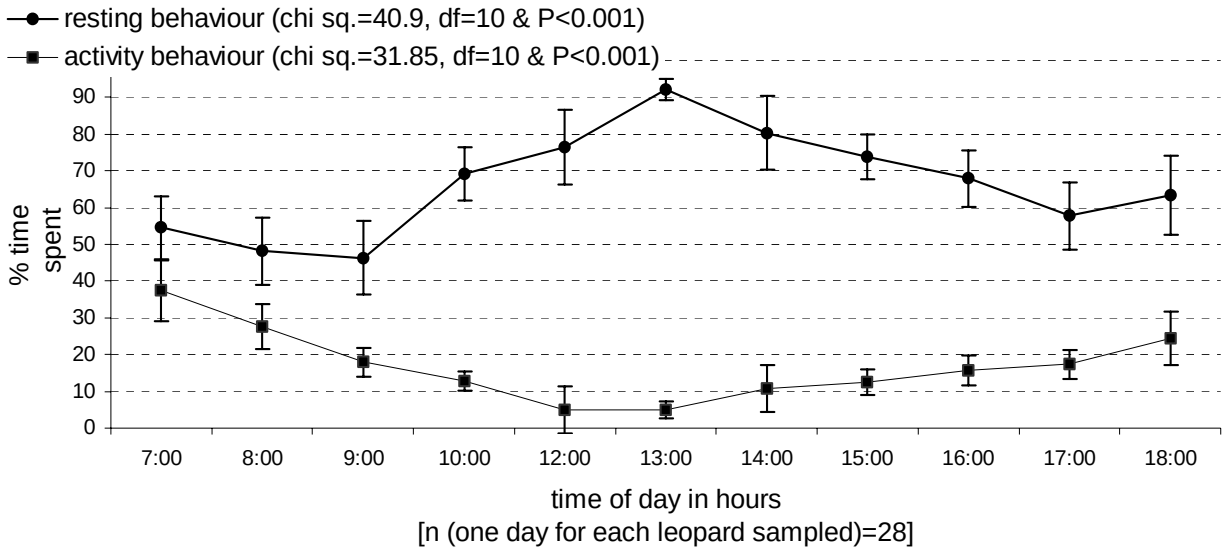


Figure 4.7. *Daily Activity Budget for singly housed leopards in four zoos (Nov'98-Mar'99)*

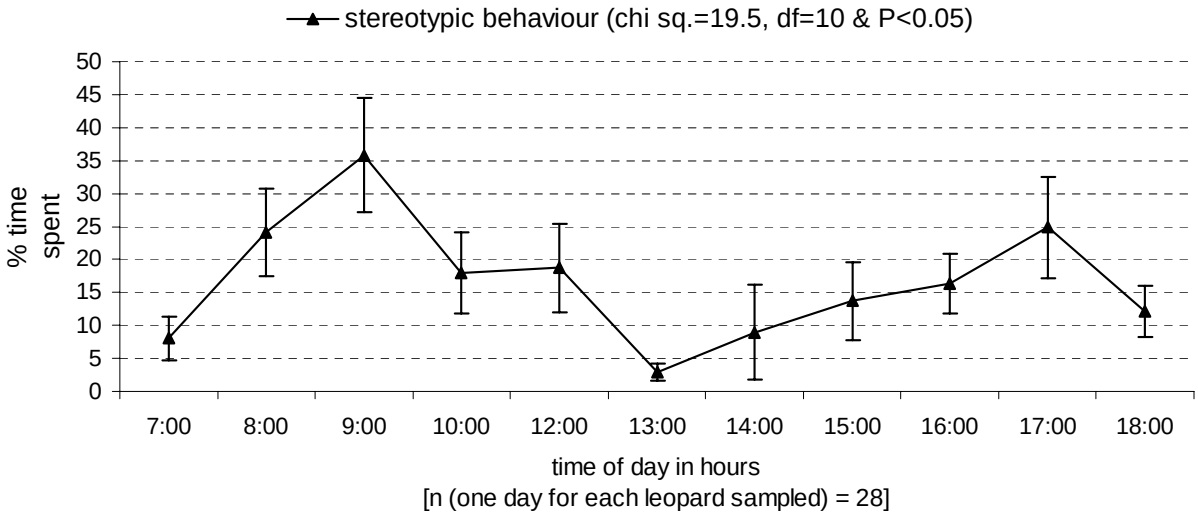


Figure 4.8 *Differences in behaviour in relation to feeding time for singly housed leopards (Nov'98-Mar'99)*

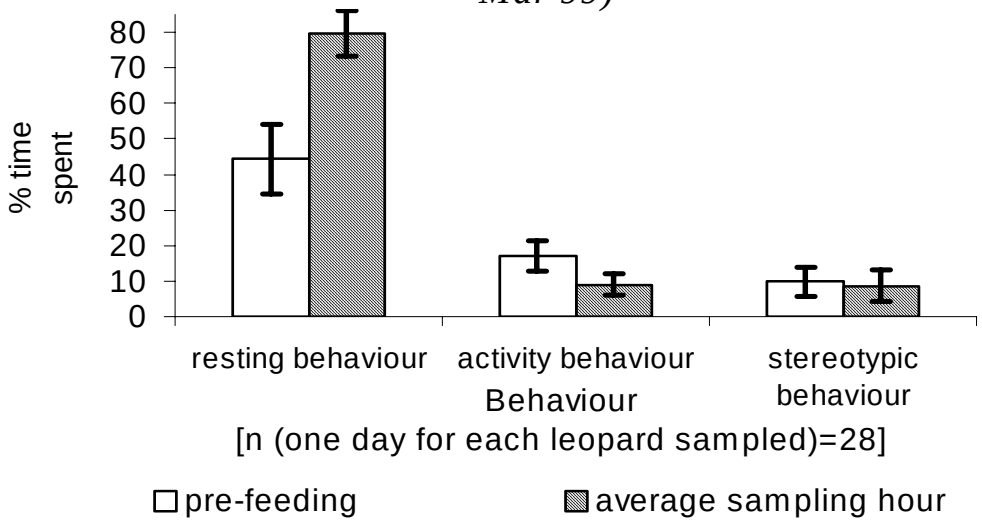
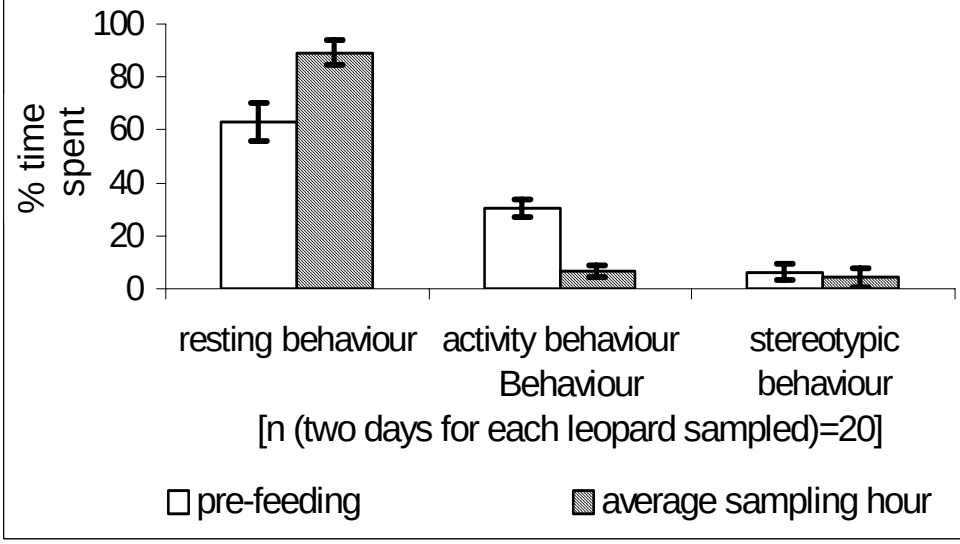


Figure 4.9 *Differences in behaviour in relation to feeding time for group housed leopards (Mar'99)*



4.6. Feed time and activity budget for singly and group-housed leopards

The differences in the proportions of activity, resting and stereotypic behaviour exhibited before feeding time and during an average sampling hour were compared for singly and group-housed leopards (Figure 4.8 and 4.9). There was a significant difference in the proportion of activity and resting behaviour exhibited before feeding and during an average sampling hour for singly (Wilcoxon, activity behaviour, Z = -1.8553, N = 28, p=0.064; resting behaviour, Z = -3.62, N = 28, p=0.0003) and group-housed leopards (Wilcoxon, activity behaviour, Z = -3.26, N = 20, p=0.061; resting behaviour, Z = -3.0770, N= 20, p=0.002). Singly and group-housed leopards exhibited significantly lower levels of resting behaviour and higher proportions of activity behaviour before feeding to normal sampling hours. There was no significant difference in the stereotypic pacing levels between pre-feeding and normal sampling hours for singly and group housed leopards (Wilcoxon, singly housed leopards, Z = -0.384, N= 28, p=0.70; group-housed leopards, Z = -0.24, N= 20, p=0.813).

4.7. Activity budget and enclosure type

The type of the enclosure housing the leopards was found to influence their activity budget. The differences in the proportions of activity, resting and stereotypic behaviour exhibited in the on-exhibit and off-exhibit enclosures by singly housed leopards were compared (Figure 4.10, 4.11 and 4.12). Activity and stereotypic pacing levels exhibited in the on-exhibit and off-exhibit enclosures were significantly different (activity behaviour, Z = -2.94, N = 28, p=0.003; stereotypic behaviour, Z = -2.52, N = 28, p=0.0116). Higher levels of activity behaviors were exhibited on-exhibit while higher levels of stereotypic pacing were exhibited off-exhibit. There was no significant difference in the proportion of resting behaviour exhibited on-exhibit and off-exhibit by singly housed leopards.

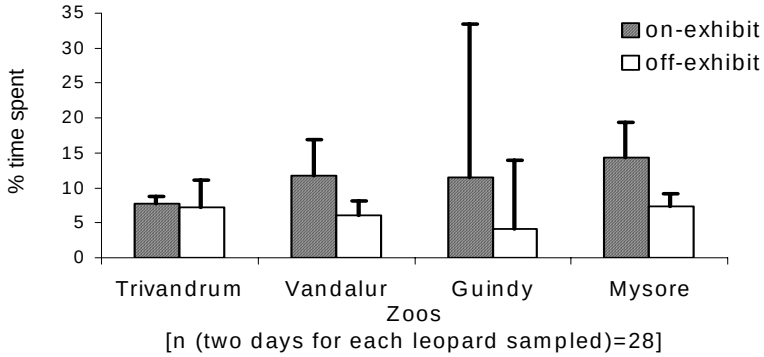
4.8. Activity budget and visitor presence

The differences in the proportions of activity, resting and stereotypic behaviour exhibited on zoo holidays in the on-exhibit and off-exhibit enclosures by singly housed leopards were compared (Figure 4.12, 4.13 and 4.14). There was a significant difference in the level of activity and resting behaviour exhibited by singly housed leopards on visitor absence (zoo holidays) and visitor presence days (activity behaviour, Z = -1.96, N = 14, p=0.05; resting behaviour , Z = -2.39, N = 14, p=0.0171). Visitors influenced the exhibition of higher levels of resting behaviour. The leopards were found to be more active on zoo holidays. Though the difference in the proportion of stereotypic pacing exhibited between visitor presence and absence days was insignificant (Z = -1.54, N = 14, p=0.124), stereotypic behaviour exhibited on zoo holidays were slightly higher than when visitors were present.

There was a significant difference in the activity behaviour with an increase in visitor numbers (χ^2 = 8.18, df = 3, p=0.042). Higher levels of activity were recorded on zoo holidays while activity patterns decreased significantly on weekdays, weekends and excess visitor days (on occasions such as festivals). Though there was no significant difference in resting (χ^2 = 2.95, df = 3, p=0.4) and stereotypic behaviour (χ^2 = 3.26, df = 3, p=0.353) with the number of people visiting the zoo, stereotypic behaviour increased drastically on festivals when visitor numbers were considerably higher.

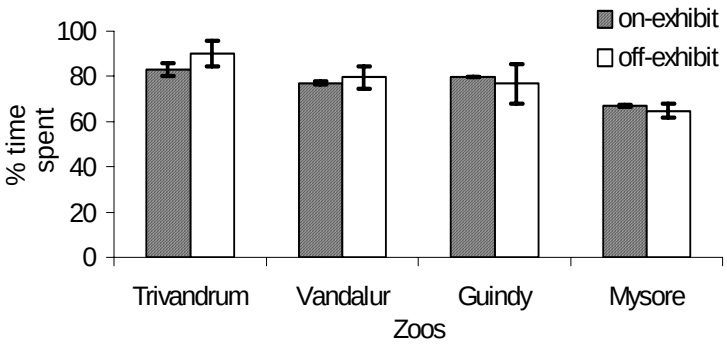
Comparisons were made between the morning, noon and evening hours on zoo holidays and on the days with visitor presence to check for differences in the proportion of behaviour exhibited during the day (Table 3.1). There was a significant difference in the proportion of activity and resting behaviour exhibited between the morning, noon and evening hours on days with visitor presence (activity behaviour, χ^2 = 16.3, df = 2, p=0.001; resting behaviour, , χ^2 = 14.05, df = 2, p=0.001) and zoo holidays (activity

Figure 4.10. *Activity behaviour exhibited in the enclosure type by singly housed leopards (Nov'98-Mar'99)*



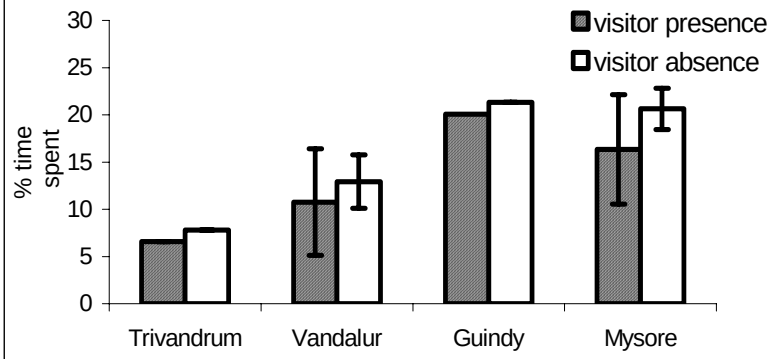
[n (two days for each leopard sampled)=28]

Figure 4.11*. Differences in resting behaviour with enclosure type for singly housed leopards across four zoos (Nov'98-March'99)*



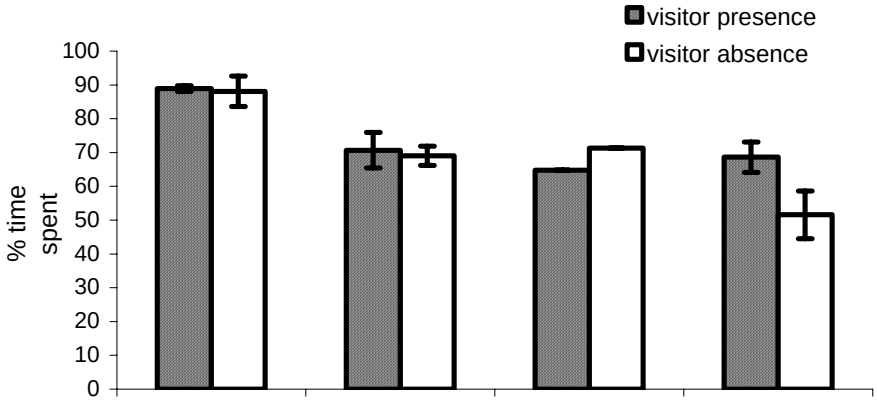
[n (two days for each leopard sampled)=28]

Figure 4.12. *Differences in activity behaviours with visitor presence for singly housed leopards across four zoos in southern India (Nov'98-March'99)*



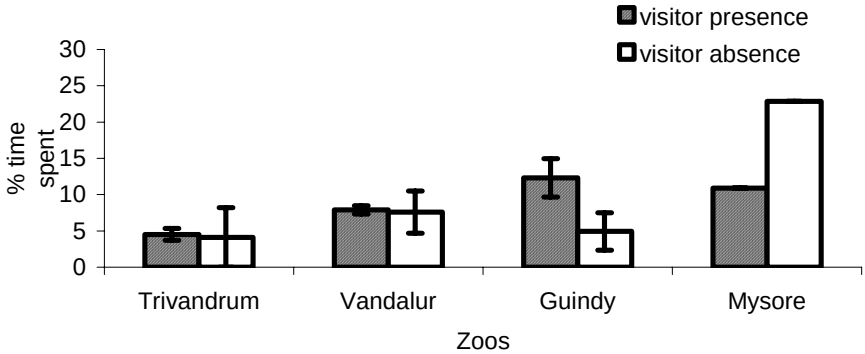
[n (one day for each animal sampled)=14]

Figure 4.13. *Differences in resting behaviour with visitor presence for singly housed leopards across four zoos (Nov'98-March'99)*



[n (one day foreach leopard sampled)=14]

Figure 4.14. *Differences in stereotypic behaviour and visitor presence for singly housed leopardsacross four zoos (Nov'98-March'99)*



[n (one day for each leopard sampled)=14]

behaviour, χ^2 = 8.23, df = 2, p=0.016; resting behaviour, χ^2 = 4.62, df = 2, p=0.099). Resting behaviour was significantly higher in the afternoons on days with visitor presence and on zoo holidays while activity levels were higher in the mornings and evenings. There was no significant difference in the proportion of stereotypic pacing exhibited during the morning, noon and evening hours on days with visitor presence (χ^2 = .741, df = 2, p=0.690) and on zoo holidays (χ^2 = 1.52, df = 2, p=0.467). The distribution of activity, resting and stereotypic behaviour between the days with visitor presence and zoo holidays were compared, but no significant difference was found (activity behaviour, Z=0.655, p=0.785, N=42;. resting behaviour, Z=0.546, p=0.927, N=42; stereotypic behaviour, Z=0.546 p=0.927, N=42). This suggested that there was no difference in the behaviour pattern exhibited through the day between the days with visitor presence and zoo holidays.

4.9. Activity budget and social enrichment (as a treatment)

Significant differences were found in the levels of activity and resting behaviour exhibited by 6 leopards before and during social enrichment (activity behaviour, Z = -2.201, N = 6, p=0.028; resting behaviour, Z = -2.201, N= 6, p=0.028). The leopards exhibited higher proportions of activity and lower proportions of resting behaviour when exhibited as pairs (Figure 4.15). Though, there was no significant difference in the proportion of stereotypic behaviour exhibited before and during social enrichment (stereotypic behaviour, Z = -1.15, N= 6, p=0.249), stereotypic pacing level was found to be slightly higher when the leopards were singly housed.

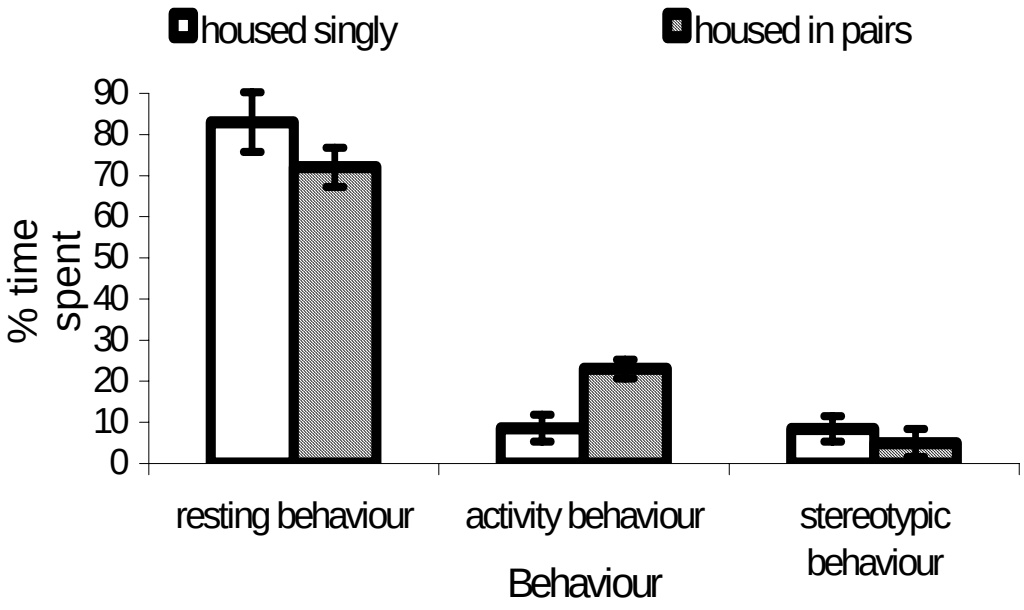
4.10. Activity budget and group size

On comparing the activity budgets of singly and group-housed leopards, a significant difference was found in the proportion of activity and resting behaviour exhibited (activity behaviour, Z = -4.22, N= 26, p=0.001; resting behaviour, Z = -4.22, N= 26, p=0.001). Leopards housed singly exhibited higher levels of activity behaviour while the leopards housed in groups exhibited significantly higher levels of resting behaviour. There was no significant difference in the level of stereotypic pacing levels (Z = -0.384, N= 26, p=0.700) exhibited by singly and group-housed leopards.

4.11. Activity budget and utilisation of space

The differences in the utilisation of enclosure zones were tested for singly housed leopards. Leopards were found to use the edges of their enclosure more than any other portion of the enclosure (χ^2 = 42.00, df = 3, p=0.001). Leopards housed in groups used the structurally enriched portions of the enclosure to a greater extent (χ^2 = 12.78, df = 3, p=0.005).

Figure 4.15 *Differences in behaviour with social enrichment for singly housed leopards (Nov'98-Mar'99)*



[n (one day for each leopard sampled)=6]

The enclosures grids were categorised into four zones; the “edge”, “back”, “rest” and enrich” zone. Utilisation of these zones were compared across sex and history (wild-caught and captive-reared) for singly and group-housed leopards. Singly housed leopards showed a significant differences across sex ($Z = -2.08$, $N= 27$, $p=0.037$) and history ($Z = -3.00$, $N= 27$, $p=0.002$) in their utilisation of the “rest” zone. Males and captive-reared leopards utilised the “rest” zone more than females and wild-caught individuals respectively. Wild-caught leopards housed in groups utilised the “rest” zone more than the captive-reared individuals ($Z= -2.034$, $N = 10$, $p=0.042$). There was no significant difference in the utilisation of “edge”, “enrich” and “back” zones across sex and history for singly and group-housed.

The “edge” zone of the on-exhibit enclosure in Trivandrum was significantly correlated with the stereotypic pacing levels (Table 3.4.). Resting behaviour were exhibited significantly higher in the “back” zone. The “rest” of the enclosure was significantly correlated with activity behaviour. The “enrich” zone was positively correlated with activity behaviour and negatively correlated with resting behaviour. The zones of the off-exhibit enclosure were not significantly correlated with any behaviour.

Table 3.4. Correlation between the utilisation of space and the behaviour exhibited in the on-exhibit (T1) and off-exhibit (T2) enclosure by captive leopards (using Spearman Rank Correlation Coefficients) in Trivandrum Zoo.

Correlations between the percentage time spent in different enclosure zones ("enrich", "back", "rest" and "edge") and the percent time spent in exhibiting activity (Abp), resting (Rbp) and stereotypic behaviours (Sbp) for enclosures T1 and T2

Enclosure identity		***Edge (sbp)***	***Back (rbp)***	***Rest (abp)***	***Enrich (rbp)***	***Enrich (abp)***	***N***
Trivandrum Zoo (T1)	**rho**	0.741	0.799	0.571	-0.679	0.586	22
	P	**0.0001**	**0.0001**	**0.005**	**0.001**	**0.004**	
Trivandrum Zoo (T2)	**rho**	0.373	0.311	-0.229	-	-	14
	P	**0.189**	**0.278**	**0.431**	**-**	**-**	

N (number of sampling days) = one day (in hours) for each study animal exhibited in that enclosure

In Vandalur, the “rest” zone of the three on-exhibit enclosures were found to be significantly correlated with activity behaviour (Table 3.5.). Of the two structurally enriched enclosures, the first enclosure’s “enrich” zone was positively correlated with resting behaviour and negatively correlated with activity behaviour. The second enclosure showed no correlation. In the third enclosure, the “edge” was positively correlated with the exhibition of stereotypic behaviour. In the second enclosure, the “edge” zone was negatively correlated with stereotypic behaviour. Of the five off-exhibit enclosures at Vandalur, one showed a positive correlation between its “edge” zones and the exhibition of stereotypic behaviour, another showed a negative correlation and in the rest of the enclosures there was no correlation. The “back” zone was positively correlated with resting behaviour for one of the enclosures while it was negatively correlated for another. The other enclosure did not show any significant correlation. The “rest” zones were not significantly correlated with activity behaviour for the off-exhibit enclosures. All the off-exhibit enclosures in Vandalur did not have an “enrich” zone, as they were barren enclosures.

In Guindy, the “edge” zone was positively correlated with stereotypic pacing levels in the on-exhibit enclosure (Table 3.6). The “enrich” zone was found to be positively correlated with resting behaviour and negatively correlated with activity behaviour. The “back” and “rest” zone were not significantly correlated with resting and activity behaviour respectively. The off-exhibit enclosure did not show any significant correlation between its zones and the behaviour exhibited in them.

In Mysore, of the three on-exhibit enclosures, two showed a positive correlation between their “edge” zones and the exhibition of stereotypic behaviour (Table 3.7.). Activity behaviour were positively correlated with “rest” zone for two enclosures. Of the two on-exhibit enclosures that were structurally enriched, one showed a positive

Table 3.5. Correlation between the utilisation of enclosure zones and the behaviour exhibited in each on-exhibit (V1,V3,V6) and off-exhibit (V2,V4,V5,V7,V8) enclosure (using Spearman Rank Correlation Coefficients) in Vandalur Zoo

Correlations between the percentage time spent in different enclosure zones ("enrich", "back", "rest" and "edge") and the percent time spent in exhibiting activity (Abp), resting (Rbp) and stereotypic behaviours (Sbp) for enclosures V1, V2, V3, V4, V5, V6, V7, V8 and V9

Enclosure identity		***Edge (sbp)***	***Back (rbp)***	***Rest (abp)***	***Enrich (rbp)***	***Enrich (abp)***	***N***
Vandalur Zoo (V1)	**rho**	0.404	-0.190	0.663	0.901	-0.853	11
	P	**0.218**	**0.576**	**0.026**	**0.0001**	**0.001**	
Vandalur Zoo (V2)	**rho**	-0.152	0.941	0.399	-	-	6
	P	**0.774**	**0.005**	**0.434**	-	-	
Vandalur Zoo (V3)	**rho**	-0.370	-0.471	0.426	-0.186	0.054	22
	P	**0.090**	**0.027**	**0.048**	**0.407**	**0.811**	
Vandalur Zoo (V4)	**rho**	0.853	0.435	-0.265	-	-	6
	P	**0.031**	**0.389**	**0.612**	-	-	
Vandalur Zoo (V5)	**rho**	0.358	0.293	0.115	-	-	6
	P	**0.486**	**0.573**	**0.828**	-	-	
Vandalur Zoo (V6)	**rho**	0.807	0.945	0.757	-	-	11
	P	**0.003**	**0.0001**	**0.0001**	-	-	
Vandalur Zoo (V7)	**rho**	0.257	-0.353	-	-	-	6
	P	**0.623**	**0.492**	-	-	-	
Vandalur Zoo (V8)	**rho**	-0.886	-0.754	-0.058	-	-	6
	P	**0.019**	**0.084**	**0.913**	**-**	**-**	

N (number of sampling days) = one day (in hours) for each study animal exhibited in that enclosure

Table 3.6. Correlation between the utilisation of enclosure zones and the behaviour exhibited in each on-exhibit (G1) and off-exhibit (G2) enclosure (using Spearman Rank Correlation Coefficients) at Childrens' Park, Guindy

Correlations between the percentage time spent in different enclosure zones ("enrich", "back", "rest" and "edge") and the percent time spent in exhibiting activity (Abp), resting (Rbp) and stereotypic behaviours (Sbp) for enclosures G1 and G2

Enclosure identity		***Edge (sbp)***	***Back (rbp)***	***Rest (abp)***	***Enrich (rbp)***	***Enrich (abp)***	***N***
Childrens' Park (G1)	**rho**	0.802	-0.155	0.236	0.764	-0.688	11
	P	**0.003**	**0.650**	**0.485**	**0.006**	**0.019**	
Childrens' Park (G2)	**rho**	-0.250	0.234	-0.107	0.286	0.037	7
	P	**0.589**	**0.613**	**0.819**	**0.542**	**0.937**	

N (number of sampling days) = one day (in hours) for each study animal exhibited in that enclosure

Table 3.7. Correlation between the utilisation of enclosure zones and the behaviour exhibited in each on-exhibit (M1, M3, M6) and off-exhibit (M2, M4, M5, M7) enclosure (using Spearman Rank Correlation Coefficients) at Mysore Zoo

Correlations between the percentage time spent in different enclosure zones ("enrich", "back", "rest" and "edge") and the percent time spent in exhibiting activity (Abp), resting (Rbp) and stereotypic behaviours (Sbp) for enclosures M1, M2, M3, M4, M5, M6 and M7

Enclosure identity		***Edge (sbp)***	***Back (rbp)***	***Rest (abp)***	***Enrich (rbp)***	***Enrich (abp)***	***N***
Mysore Zoo (M1)	**rho**	0.059	0.304	0.472	0.197	0.065	22
	P	**0.793**	**0.121**	**0.027**	**0.379**	**0.774**	
Mysore Zoo (M2)	**rho**	-0.225	0.104	-0.002	0.055	-0.359	14
	P	**0.440**	**0.725**	**0.994**	**0.851**	**0.208**	
Mysore Zoo (M3)	**rho**	0.855	-0.135	0.425	0.677	-0.685	22
	P	**0.0001**	**0.551**	**0.048**	**0.0001**	**0.0001**	
Mysore Zoo (M4)	**rho**	0.855	-1.09	-0.248	0.473	-0.452	7
	P	**0.014**	**0.815**	**0.592**	**0.284**	**0.308**	
Mysore Zoo (M5)	**rho**	-	0.449	-0.431	0.428	-0.255	7
	P	-	**0.312**	**0.334**	**0.338**	**0.582**	
Mysore Zoo (M6)	**rho**	0.408	0.008	-0.055	-	-	33
	P	**0.019**	**0.963**	**0.759**	**-**	**-**	
Mysore Zoo (M7)	**rho**	0.804	0.622	-.345	-0.071	-0.087	21
	P	**0.0001**	**0.003**	**0.125**	**0.761**	**0.707**	

N (number of sampling days) = one day (in hours) for each study animal exhibited in that enclosure

correlation between its “enrich” zone and proportion of resting behaviour exhibited. None of the enclosures showed any significant correlation between the “back” zone and resting behaviour. Of the four off-exhibit enclosures, two showed a positive correlation between their “edge” zones and stereotypic pacing levels. Resting behaviour were positively correlated with the “back” zone for one off-exhibit enclosure. The “enrich” zones of the four enclosures were not significantly correlated with either resting or activity behaviour exhibited.

In Bangalore, the group-housed leopards were only observed on-exhibit. The “edge” zone of the on-exhibit enclosure in Bangalore was significantly correlated with stereotypic pacing levels (Table 3.8). Resting behaviour were positively correlated with “back” and “enrich” zones. The “enrich” zone was negatively correlated with activity behaviour and the “rest” zone was significantly correlated with activity behaviour.

There were nine on-exhibit enclosures and 11 off-exhibit enclosures across the five zoos. Of the nine on-exhibit enclosures (Tables 3.4, 3.5, 3.6, 3.7 and 3.8), six showed a positive correlation of stereotypic behaviour with the "edge" zone and one showed a negative correlation. Three enclosures showed a positive correlation between "back" zone and resting behaviour while two enclosures showed a negative correlation. The "rest" of the enclosure was significantly used to exhibit activity behaviour in seven of the nine enclosures. Of the nine on-exhibit enclosures, only seven were environmentally enriched. Of these, four enclosures had their "enrich" zones positively correlated with resting behaviour and negatively correlated with activity behaviour while one has its "enrich" zone positively correlated with activity behaviour and negatively correlated with resting behaviour.

Of the 11 off-exhibit enclosures (Tables 3.4, 3.5, 3.6, 3.7 and 3.8), four had their "edge" zones correlated with stereotypic behaviour and one was negatively correlated. Two enclosures showed a positive correlation between their "back" zones and resting

Table 3.8. Correlation between the utilisation of enclosure zones and the behaviour exhibited in each on-exhibit (B1) (using Spearman Rank Correlation Coefficients) at Bangalore Zoo

Correlations between the percentage time spent in different enclosure zones ("enrich", "back", "rest" and "edge") and the percent time spent in exhibiting activity (Abp), resting (Rbp) and stereotypic behaviours (Sbp) for enclosure B1

Enclosure identity		***Edge (sbp)***	***Back (rbp)***	***Rest (abp)***	***Enrich (rbp)***	***Enrich (abp)***	***N***
20(on)	**rho**	0.6177	0.452	0.211	0.44	-0.415	78
	P	**0.0001**	**0.0001**	**0.064**	**0.0001**	**0.0001**	

N (number of sampling days) = one day (in hours) for each study animal exhibited in that enclosure

Table 3.9. Correlation between enclosure complexity and the behavioural diversity of captive leopards in four zoos

Correlating enclosure complexity (comp) with the behavioural diversity indices corrected for enclosure size (using Partial Correlation Coefficients).

Pair	***Partial Correlation***	***2-tailed P***	***N***
Comp (div)	0.4755	0.086	16

N = number of sampling days (one day for each study animal)

Table 3.10. Correlations between enclosure complexity and the utilisation of the “enrich” zone by leopards in four zoos

Correlating enclosure complexity (comp) with the utilisation of the "enrich" zone and activity (abp), resting behaviours (rbp) for off-exhibit (off-ex) and on-exhibit enclosures (on-ex) (using Partial Correlation Coefficients)*.

Pair	***Partial Correlation***	***2-tailed P***	***N***
Comp (enrich) **(on-ex)**	0.593	0.033	29
Comp (enrich) **(off-ex)**	0.676	0.008	29
Comp (rbp) **(off-ex)**	-0.5759	0.031	29
Comp (abp) **(off-ex)**	0.7360	0.003	29

N = number of sampling days (one day for each study animal)

* activity, resting and stereotypic behaviour were correlated with enclosure complexity for on-exhibit and off-exhibit enclosures. Only significant results have been tabulated

behaviour. Four of the ten off-exhibit enclosures were structurally enriched but none of them showed a positive correlation between the "enrich" zone and resting or activity behaviour.

4.12. Behavioural diversity

The differences in equitability of behaviour exhibited were tested across the four zoos that housed leopards singly. On comparing each individuals' behavioural diversity on-exhibit and off-exhibit, a significant difference was found (Z= -4.110, N = 28, p=0.001). The behavioural diversity for the on-exhibit enclosures was significantly higher than the off-exhibit. There was no significant difference in the behavioural diversities on visitor presence and visitor absence days (Z= -0.541, N = 51, p=0.589). The behavioural diversities of singly and group-housed individuals were compared and a significant difference was found. Behavioural diversity was significantly higher for singly housed leopards. A comparison of behavioural diversities across zoos showed a significant difference (χ^2 = 9.177, df = 3, p=0.027).

Behavioural diversity was correlated with enclosure complexity using Partial Correlations. The data was corrected for enclosure size. Beahvioural diversity was tested for on-exhibit enclosures and off-exhibit enclosures separately. Behavioural diversity was positively correlated with enclosure complexity grades for off-exhibit enclosures only (Table 3.9).

4.13. Diversity of space utilisation

The differences in equitability of space utilisation were tested across the four zoos that housed leopards singly. The difference in the diversity of space utilised between visitor presence and absence days was insignificant (Z= -0.157, N = 14, p=0.875). The

on-exhibit and off-exhibit enclosures did not show any significant difference in the diversity of space utilised by the leopards housed in them (on-exhibit, $\chi^2 = 1.90$, df = 3, p=0.593; off-exhibit, $\chi^2 = 0.945$, df = 3, p=0.815).

4.14. Enclosure type and their structural features

On comparing the proportion of time spent in exhibiting activity, resting and stereotypic behaviour between structurally enriched and barren on-exhibit enclosures, activity levels were found to be significantly higher and resting behaviour were significantly lower in structurally enriched enclosures (activity behaviour, Z= -2.780, N = 15, p=0.004; resting behaviour, Z= -2.199, N = 15, p=0.029). There was no significant difference in the proportion of stereotypic behaviour exhibited in the structurally enriched and barren enclosures (Z= -1.273, N = 15, p=0.232). There was no significant difference in behaviour exhibited in structurally enriched and barren off-exhibit enclosures (activity behaviour, Z= -0.141, N = 15, p=0.945; resting behaviour, Z= -1.414, N = 15, p=0.188; stereotypic behaviour, Z= -0.283, N = 15, p=0.839).

4.15. Enclosure complexity, behaviour and space use

Enclosure complexity was correlated with leopard behaviour and enclosure zones by using Partial Correlations. The data was corrected for enclosure size. The correlations were conducted for on-exhibit enclosures and off-exhibit enclosures separately. Complexity was positively correlated with activity behaviour and negatively correlated with resting behaviour for off-exhibit enclosures (Table 3.10). The utilisation of the "enrich" zone was positively correlated with enclosure complexity for on-exhibit and off-exhibit enclosures (Table 3.10).

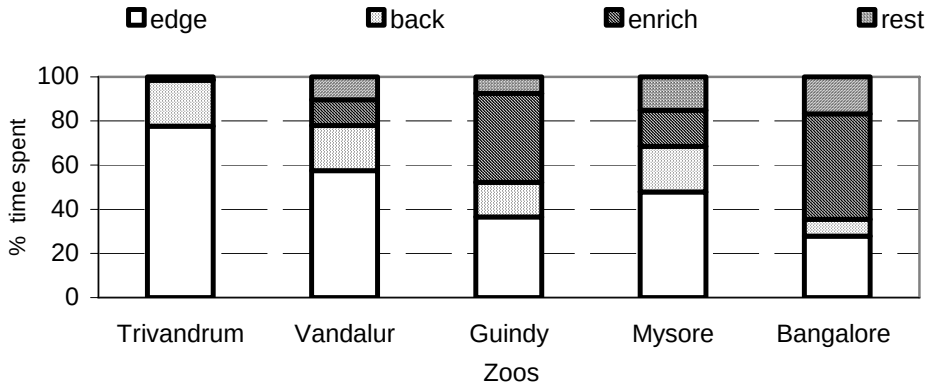
4.16. Space utilisation and group size

On comparing utilisation of enclosure space by singly and group housed leopards, group-housed individuals' utilisation of the "enrich" zone was found to be significantly higher (Z= -3.150, N = 39, p=0.001) while utilisation of "edge" and "back" zones was considerably lower ("edge" zone, Z= -2.412, N = 39, p=0.015; "back" zone, Z= -2.477, N = 39, p=0.012). There was no significant difference in "rest" zone utilisation between singly and group-housed individuals (Z= -1.029, N = 39, p=0.316).

4.17. Space utilisation and zoos

The differences in the proportions of time spent in the "edge", "back", "enrich" and "rest" zones by singly housed leopards were compared across zoos (Figure 4.16). There was a significant difference in the utilisation of the "enrich", "back" and "rest" across zoos ("enrich" zone, χ^2 = 7.94, df = 3, p=0.047;"back' zone, χ^2 = 9.1, df = 3, p=0.027; "rest" zone, χ^2 = 9.17, df = 3, p=0.027). There was no significant difference in the utilisation of "edge" zones across zoos (χ^2 = 4.47, df = 3, p= 0.215).

Figure 4.16. *Space utilisation by singly and group-housed leopards across five zoos (Nov'98-March'99)*



[n (one day for each leopard sampled)=26]

5. DISCUSSION

As habitat destruction accelerates the decline of wildlife throughout the world, activities such as captive propagation of endangered species become a focus of attention (Hutchins et al. 1984). Zoos begin to play an important role in conservation, and new techniques in creating artificial habitats and management programmes to meet the animals' psychological and physical needs become highly significant.

The behaviour of wild animals is considerably altered by captivity, and abnormal behaviour such as stereotypic pacing have become a regular feature in confined environments (Boorer, 1972; Hutchins et al. 1984).

5.1. Stereotypic pacing

Stereotypies develop in a wide variety of situations and across a broad range of species. Some types of stereotypies are environmentally induced, developing as a result of an abnormal organism-environment interaction (Carlstead, 1998). In most zoo animals, stereotypic activity arises from primary behaviour patterns that over a period of time the animal has been repeatedly motivated to perform. These primary behaviour are often appetitive, i.e., the activities the animal performs in a natural environment when it is looking for some particular external stimulus for example, foraging for food, searching for a mate, escaping to a safe place or seeking distance or space from conspecifics (Carlstead, 1998). Stereotypic pacing is wide-spread in carnivores and common in captive felids (Boorer, 1972). Of the 26 leopards studied across five zoos, 22 exhibited stereotypic pacing. The leopards spent 2 to 11% of the time pacing.

Stereotypic pacing levels are influenced by a number of factors such as rearing history (Forthman & Bakeman, 1992), enclosure size (Keulen & Kromhout, 1976), enclosure complexity (Goerke et al. 1987; Neveu et al. 1996).

In this study, sex and history did not influence stereotypic pacing in singly housed leopards. Sex did not affect pacing levels in group-housed leopards but differences did occur with history. Rearing history was found to strongly influence stereotypic pacing in captive sloth bears, where mother-reared individuals exhibited lower bouts of stereotypy than hand-reared sloth bears (Forthman & Bakeman, 1992). Such a difference in behaviour due to history of the animal was seen in the leopards housed in a group.

Wild caught leopards housed in groups exhibited higher levels of resting behaviour than captive reared individuals. This could be due to several reasons. Wild caught animals are less adapted to the presence of humans. A large number of people visit zoos and as enclosures are surrounded by visitor areas, wild caught leopards tend to use the posterior or the structurally enriched portions of their enclosures that are farthest from the visitor area. Leopards housed in a group utilised the “enrich” and “back” zones for exhibiting resting behaviour. These two zones were farthest from the visitor area and were utilised by wild-caught individuals for resting.

Captive-reared leopards exhibited higher levels of stereotypic behaviour than wild-caught leopards. In certain situations stereotypy is motivated by the need to escape or maintain distance from conspecifics e.g., two of the captive-reared leopards housed in a group exhibited high levels of stereotypy in fear of other individuals housed in the same enclosure. This could be triggered by social dominance, which comes to play when solitary-living species are housed in groups. Lyons et al.’s (1997) study on captive felids found that edges were utilised to exhibit stereotypic pacing

while posterior portions and structural features such as sheds and sleeping dens were utilised for resting. Similar behaviour patterns were observed in the leopards housed in groups.

5.2. Restlessness

The activity budgets of female leopards depend on their period of anoestrus. Isolated females in oestrus exhibited high levels of stereotypy and activity behaviour. Females in oestrus, stereotyped along the enclosure's edge closest to the neighbouring males enclosure from where they could see the male. When the male came into view, the female would rub her head and body against the enclosure grill or roll on the floor. Rubbing and rolling was often accompanied by vocalisations. These vocalisations were typical to the oestrus condition.

Restlessness or increased activity and pacing has been cited as a sign of oestrus in several felid species such as snow leopards, caracals, fishing cats, and north and European lynx (Seager & Demorest, 1978). Vocalisations have been associated with oestrus in some of these species for example, snow leopards, caracals and fishing cats. Similar increase in pacing and activity levels was seen in a female sand cat at Washington Park Zoo (Bennett & Mellen, 1983).

5.3. Daily Activity Budget

The activity budget of the leopards in this study consisted of two peaks in stereotypy, one at 09:00 hrs and the other at 16:00 to 17:00 hrs. Both peaks in stereotypy coincided with zookeeper activity. The leopards stereotyped considerably

at 09:00 hrs when the zookeepers cleaned the off-exhibit enclosures. The late afternoon peaks coincided with feeding time and were of a longer duration.

Baldwin (1985) in his study on captive carnivores recorded a strong morning peak and a small late afternoon peak in activity in the daily activity pattern of felids. The morning peak in activity coincided with feeding time and was larger and longer in duration.

Activity behaviour peaked early morning at 07:00 to 08:00 hrs gradually regressing through the day only to peak again at 18:00 hrs. Resting behaviour peaked at noon (13:00 hrs) and gradually decreased through the rest of the day. The gradual rise and fall in the proportions of behaviour exhibited remained unchanged with the presence and absence of visitors (zoo holidays). Leopards in the wild are crepuscular by nature, being active in the early mornings and late evenings, and resting through the hotter hours of the day (Bailey, 1993; Santiapillai et al, 1982; Schaller, 1972). These peaks in activity and resting behaviour observed in the daily activity budget of captive leopards were due to its crepuscular nature.

5.4. Food anticipatory behaviour

The activity budget before and during a normal sampling hour was compared for leopards in captivity. Higher levels of activity behaviour and lower levels of resting behaviour were exhibited before feeding time by the captive leopards in this study. Stereotypic pacing also occurred but was not significantly different from the level exhibited during the rest of the day. Leopards stereotyped along the edges of the enclosures from where they could clearly see the zookeeper approaching the enclosure during feeding time.

Carnivores devote a large amount of time to hunting behaviour in the wild (Shepherdson et al. 1993). In captivity, there is little opportunity to express hunting behaviour while the strong motivation remains. Stereotypic pacing in captive carnivores is thought to be a result of this high level of motivation to express appetitive behaviour, particularly in the pre-feeding period (Mason, 1991).

Captive animals are on a predictable feeding regime in most zoos and are fed at the same time everyday six days a week. They learn to predict the inter-food interval and anticipate food arrival by exhibiting food-anticipatory stereotypies, which occur mainly prior to and during the hours that zookeepers' place food in the enclosure (Carlstead, 1998). The stereotypic pacing levels exhibited by leopards in this study depended on the predictability of the feeding time.

5.5. Stereotypic pacing and the visitor numbers

The presence of visitors influenced the activity budget of the captive leopards in this study. The leopards exhibited higher levels of activity behaviour on zoo holidays and higher levels of resting behaviour on visitor presence days. On festivals when the number of people who visited the zoo drastically increased, proportion of time spent in exhibiting stereotypic pacing increased considerably. Most of the leopard enclosures had visitor areas on three or all four sides of the enclosures. High levels of activity on zoo holidays signify the increase in resting behaviour as a maintenance of visitor distance by the leopards on visitor presence days. During the presence of visitors, leopards used the centre and back areas of the enclosure. Leopards housed in enclosures that were surrounded on three sides by visitor areas or those enclosures having visibility barriers were found to use a small proportion of the enclosure's edge for their daily activity.

Visitors are a source of stressful excitement to animals in captivity (Chamove et al, 1988). They disrupt the behaviour repertoires of these animals housed in zoos (Glatson, 1984; O' Donovan, 1993). In a study, O'Donovan (1994) observed captive cheetahs to utilise the posterior portion of their enclosure for resting (farthest from the visitor area) during visitor presence. Proximity of humans also has a profound influence on the social and reproductive behaviour of certain species e.g., cotton-topped tamarins (Glatson, 1984).

The presence of visitors was found to influence the behavioural repertoire and the utilisation of enclosure space of leopards in captivity. The proportion of stereotypic pacing exhibited depends on visitor presence and number.

5.6. Social enrichment

Six leopards were studied singly and as pairs. Social enrichment stimulated an increase in the level of activity and resting behaviour exhibited by these leopards. Leopards are solitary-living species and the male only comes in contact with the female when she is in heat. Being housed as a pair could become very interesting for the two individuals housed together. New odours and scent markings are a form of enrichment by itself (Law & Tartner, 1998). A greater proportion of time spent exhibiting in activity behaviour like running, sniffing, jumping, and stalking.

The anoestrus conditon of the female also influences the distance she maintains from the male. Of the 3 females studied as pairs, the female in oestrus was found to utilise the grid closest to grid utilised by the male. This ultimately led to mating. Two of the three pairs consisted of anoestrus females. In these cases, the males and females were found to rest in separate grids. If one got too close to the other, it would result in a fight. A similar study was conducted by Bennet and Mellen

(1983) observed the males and female sand cats to utilise different areas of the enclosure. They was also found that the when one sand cat was active the other would remain sedentary.

5.7. Behavioural diversity

The leopards exhibited higher levels of behavioural diversity on-exhibit in comparison to the off-exhibit enclosures. Off-exhibit enclosures are usually small in size and barren, a typical unstimulating environment. Leopards are not motivated in these environments to exhibit a variety of behaviour. Higher proportions of stereotypy and resting behaviour are invariably exhibited. On-exhibit enclosures are large, complex environments that are structurally enriched with logs, snags, sleeping platforms or trees. These structures stimulate activity and resting behaviours such as climbing, rubbing and rolling, scratching and sitting. Higher proportions of activity and resting behaviour are coupled with lower in stereotypic levels in the on-exhibit enclosures. Complex enclosures such as these stimulate the exhibition of a wider spectrum of behaviour.

5.8. Stereotypic pacing and housing condition

The design of the housing is a major factor in the welfare of all wild animals in captivity (Kirkwood, in press). An impoverished environment leads to a decrease in social behaviour and is also known to affect the reproductive success of many species in captivity (Buchanan-Smith, 1996). The reproductive success of certain species has been found to be negatively correlated with the husbandry practices followed (Mellen, 1991). Most species of felids are characterised by major anatomical and behavioural adaptations to a three dimensional arboreal environment (Reinhardt et al. 1996). To

stimulate these behaviour, animal holding facilities are now looking into a number of areas in which modifications would ultimately benefit the captive individuals (Mallinson et al. 1994; Brent & Stone, 1996; Reinhardt et al. 1997); some such areas being environmental enhancements and enclosure complexity.

5.8.1 Enclosure size

An important parameter of enclosure design is enclosure size which varies from species to species (Dickie, 1997). Adequate space needs to be provided for the normal functioning of the animal in an captive environment. It has been suggested that once cage reaches a 'critical size' then any extra space that is added by renovating the enclosure is redundant. The natural history of wild animals provides the guidelines for creating and maintaining optimal environments for their captive counterparts. Captive environments improve significantly by increasing the environmental complexity along with the size of the enclosure, especially by using objects that would stimulate the animals natural behaviour repertoire (Wilson, 1982). Studies conducted by various zoo-biologists have suggested that minimum size of enclosures that exhibit felids (refer to A.Z.A stipulations for housing felids in captivity, Appendix II).

Pacing was found to vary with size of the on-exhibit enclosures for leopards in captivity. Individuals at Vandalur Zoo and Mysore Zoo were above average pacers while those at Bannerghatta Zoological Gardens were near average pacers. Leopards at the Childrens' Park and The Trivandrum Zoo were considered well below average pacers. Vandalur Zoo and Mysore Zoo are also the zoos with the largest enclosures housing leopards singly. The enclosure at The Childrens' Park is medium in size and the enclosure at The Trivandrum Zoo is the smallest. The enclosure at Bannerghatta

that houses 10 leopards is the largest enclosure. Stereotypic pacing levels was found to increase with the increase in enclosure size. Smaller enclosures have shorter visitor distances and lack hideouts and visibility barriers. In smaller enclosures captive cheetahs were found to utilise the back portion farthest from the visitor (O'Donovan, 1993). Activity and stereotypic levels are reduced in these enclosures while resting behaviour predominate. Larger enclosures have several visibility barriers and these areas that are hidden from the publics view were utilised by the leopards for activity and stereotypic behaviour. Stereotypic pacing levels exhibited by leopards housed in enclosures greater than 250 sq.m was lower than those of intermediate size. Larger enclosures were found to be more complex having several structural features that stimulated activity and resting behaviour. Hence, this sudden decrease in pacing levels is influenced by the combined effect of enclosure size and enclosure complexity.

On comparing behaviour across zoos, leopards housed at the Trivandrum Zoo and The Childrens' Park exhibited higher lower levels of activity and stereotypic behaviour and higher levels of resting behaviour than the Vandalur Zoo and the Mysore Zoo. Though the differences in activity and stereotypic behaviour were not significant, a gradual gradation in activity, resting and stereotypic behaviour is observed with enclosure size across zoos.

Enclosure size influences behaviour patterns in felids but total size of enclosures does not significantly alter pacing activity (Lyons et al. 1997). In this study Lyons et al (1997) found that cats in relatively larger enclosures had higher levels of relative movement. Keulen & Kromhout (1976) studied ursids across different enclosure sizes and found that some species of bear were less prone to develop stereotyped behaviour in larger sized zoo enclosures.

5.8.2. Stereotypic pacing and enclosure type

The activity budgets of leopards in captivity were compared in the on-exhibit and off-exhibit enclosures. The leopards exhibited higher levels of stereotypy off-exhibit and higher proportions of activity behaviour on-exhibit. Size and complexity of the enclosures segregates off-exhibit enclosures from the on-exhibit enclosures. The on-exhibit enclosures are larger than the small, barren off-exhibit enclosures. Animals housed in the off-exhibit enclosures permanently, for long periods of time, are invariably over-sensitised to noises and disturbance factors such as visitors and zoo staff. Activity behaviours are exhibited on-exhibit due to the presence of structural features such logs, snags and trees. These features do not occur in the small, barren off-exhibit enclosures. This leads to the exhibition of lower levels of activity levels in the off-exhibit enclosures and higher levels in the on-exhibit enclosures.

Housing condition and enclosure type influences the behaviour repertoires of captive animals. On-exhibit enclosures are large spacious enclosures that are highly complex compared to off-exhibit enclosures that are small in size, devoid of light and barren. A questionnaire survey detailing exhibit spaces and husbandry procedures (Carlstead, 1991) sent to 62 zoos housing fennec foxes reported more behavioural problems in indoor than outdoor exhibits. A study on Sifakas by Macedonia (1987) revealed higher levels of locomotion, feeding and playing and lower levels resting behaviour by sifakas housed out-doors than by those housed in-doors.

5.8.3. Enclosure complexity

The activity budgets of leopards housed in enriched and barren enclosures were compared. The captive leopards in this study exhibited higher levels of activity behaviour in structurally enriched on-exhibit enclosures than the barren enclosures.

They tended to rest for longer periods of time in these barren on-exhibit enclosures. Structurally enriched off-exhibit enclosures did not influence the proportion of behaviour exhibited and individuals housed in structurally enriched and barren off exhibit enclosures exhibited similar proportions of activity, resting and stereotypic behaviour.

Larger and more complex enclosures having visibility barriers and hiding places influence the activity budgets of animals housed in them (Keulen & Kromhout, 1976). Complex environments stimulate the exhibition of natural behaviour repertoires. Utilisation of the structurally enriched areas on exhibit increased as the level of enclosure complexity increased from completely barren enclosures to those that had logs and snags, to sleeping platforms and then to enclosure with trees. Presence of these structural features stimulates an increase in the use of these areas. Off-exhibit enclosures in Mysore Zoo and The Childrens' Park had a sleeping platform each. These sleeping platforms stimulated an increase in activity behaviour and a reduction in resting behaviour.

A major consequence of zoo exhibits is the reduction of space and complexity compared to the animals' natural habitat. This reduction in complexity includes both the physical environment, which is relatively unchanging and spatially limited in captivity, and the complexity of the behavioural repertoire exhibited. Abnormal behaviour such as stereotypy and lethargy are some of the behavioural problems exhibited by captive wild animals maintained in barren unstimulating environments. Housing conditions in laboratories and a large proportion of enclosures in zoos are barren and sub-optimal. Clarke et al (1982) in his study on a juvenile chimpanzee who transferred from a laboratory environment to a naturalistic manmade island, observed a dramatic reduction in stereotyped and self-directed behaviour within 22 weeks after

the transfer. In their natural habitats, certain arboreal species of felids rest at elevated points so as to get a good view of the surroundings and also to escape from danger. At the Seattle Zoo, caracals were observed to spend over 80% of their time in their structurally enriched on-exhibit enclosure as opposed to the small, barren adjacent enclosure in which they where fed (Hutchins et al. 1984). More than 75% of all their activity behaviour took place in the on-exhibit enclosure.

5.9. Utilisation of enclosure space

The different enclosure zones ("edge", "back", "rest" and "enrich") were correlated with activity, resting and stereotypic behaviour to check if the zones are utilised for the exhibition of a particular behaviour pattern. The leopards utilised the edges of the enclosure for stereotypic pacing. In enclosures that were not structurally enriched, the "back" was utilised for resting. Enclosures that were structurally enriched, the enriched zones were utilised for resting or activity behaviour. Resting behaviour were exhibited in the "enrich" zone of enclosures containing objects that stimulate activity behaviour such as logs and snags. Baldwin (1985) in his study on captive carnivores observed on-exhibit resting occurred either at the rear of the exhibit (farthest away from the visitor viewing area, closest to off-exhibit den) if no sheltered areas were available and towards the front if sheltered resting sites were available. The structurally enriched areas of these enclosures stimulated activity behaviour and resting behaviour was rarely exhibited in these grids. The structural features were segregated into two types; those e.g., logs, snags and trees that stimulate the exhibition of activity behaviour and others e.g., sleeping platforms, sheds and trees that stimulate the exhibition of resting behaviour. Leopards housed in enclosures containing trees, sheds and sleeping dens utilised these areas for resting. These

structural features stimulated resting behaviour. Activity behaviour was rarely exhibited in these areas. Leopards tended to utilise the entire enclosure during peak activity periods.

The diversity of space use did not change with enclosure type. The use of different zones by leopards within an enclosure was compared across zoos. Though not statistically significant, utilisation of “back” and “edge” zones was greater by leopards in The Trivandrum Zoo and The Childrens’ Park while leopards at The Vandalur Zoo and Mysore Zoo utilised the “enrich” and “rest” zones to a greater extent. The enclosures at The Trivandrum Zoo and The Childrens’ Park are smaller than the enclosures at The Vandalur Zoo and Mysore Zoo.

Aspects of enclosure design such as size and complexity influence the performance of stereotypic behaviour (Koolhaas & Weipkema, 1997; Macedonia, 1987). Lyons et al. (1997) in their study on the effects of physical characteristics of the environment and feeding regime of captive felids determined the enclosure space utilised by the felids and the relationship between pacing and cage size. They also examined the potential importance of enclosure edges. Edges of captive environments constitute an enforced territorial boundary (Lyons et al. 1997). There is also the source of several forms of stimulation as edges permit the view of the visitor-area and the zookeepers’ approach for feeding and cleaning. The edges of the enclosure were utilised more than the central areas by the fields.

In this study, I found that stereotypy in captive leopards in 5 zoos was influenced by a variety of factors such as enclosure size, enclosure complexity, visitor presence, housing condition, anoestrus condition in females and rearing history. The addition of structural objects such as logs, snags, sleeping platforms and sheds stimulated the animals to exhibit activity and resting behaviours. Hence, enrichment

such as these that influence an increase in activity and resting behaviour and a decrease in pacing could be used to reduce the proportion of abnormal behaviour exhibited by animals housed in captivity.

5.10. Conclusion

This study found that the factors of captivity such as enclosure size and complexity, visitors' presence, enclosure type and the presence of structural features influences the activity budget of leopards in captivity.

- There was no significant difference in behaviour across males and females in singly and group housed leopards though, the activity budget was significantly associated with their period of anoestrus for singly housed females.
- Wild-caught and captive-reared singly housed leopards exhibited similar levels of activity, resting and stereotypic behaviour. The behaviour exhibited by group housed leopards significantly differed with history. Wild-caught individuals exhibited significantly higher levels of resting behaviour while captive-reared leopards exhibited considerably higher levels of stereotypy.
- Stereotypic pacing was influenced by enclosure size. Stereotypic pacing increased with the size of the on-exhibit enclosure upto 250 sq.m and decreased for those greater than 250 sq.m.
- The peaks in activity and resting in the daily activity budget of singly housed leopards was due to the crepuscular nature of the animal while stereotypy peaked during zookeeper activity
- The presence of visitors caused an increase in resting behaviour. The leopards were more active on zoo holidays.

- Higher pacing levels were exhibited in off-exhibit enclosures by singly housed leopards. Individuals housed in the on-exhibit enclosures showed higher activity levels.
- Higher proportions of activity behaviour time and lower levels of resting behaviour were exhibited before feeding in comparison to the rest of the day.
- During social enrichment, leopards exhibited higher proportions of activity and lower levels of resting behaviour.
- On comparing the behaviour of single and group-housed leopards, singly housed leopards were found to exhibit higher proportions of activity and lower proportions of resting behaviour.
- Leopards were found to use edges for exhibiting stereotypic pacing, the back of the enclosure for resting and the rest of the enclosure was used to exhibit activity behaviour.
- Structural features were found to be of two types: sleeping platforms, trees and sheds that stimulated resting behaviour and logs, snags and tree trunks that stimulated activity behaviour.
- In enclosures that were structurally enriched with sleeping platforms, sheds or trees, leopards utilised the "enrich" zone of the enclosure for resting instead of the "back" zone. Enclosures having logs and snags, the "enrich" zones are utilised to exhibit activity behaviour.
- Higher proportions of activity behaviour and lower levels of resting behaviour are exhibited in structurally enriched enclosures in comparison to barren enclosures.
- Singly housed leopards utilised the “edge” and “back” zones significantly more and the “enrich” zone significantly less than group-housed leopards

Stereotypic behaviour is a good indicator that an environment is suboptimal for an individual. The viewer would perceive the exhibition of stereotypic pacing by the leopard as an outcome of boredom or stress. Stereotypic pacing in leopards and other captive wild animals can be reduced or eliminated by gaining a proper understanding of the nature of the species in order to design and introduce species-specific environmental enrichment techniques. Hence, there is an increasing need for animal welfare studies in Indian zoos.

5.11. Management Implications: design of species compatible enclosures with reference to the leopard

Observations of the behavioural repertoire of the species in the wild gives clear indications about the needs of their counterparts in captivity (Maple & Finley, 1987; Kleiman et al. 1996). In designing an enclosure for a particular species e.g., leopard, certain behavioural patterns need to be observed such as the pace and style of movement, the variety of locomotor activity, and the habitat levels and substrates used by the animal. These factors would affect the compatibility of the enclosure of the animal, which is to be housed in it. The size and complexity of the enclosure also plays an important role in the welfare of the species. Enclosures should provide enough room for normal postures and movements on the ground (Carlstead et al. 1991; Caine & Boyle, 1992). Its space should be sufficiently used and should be complex to allow species-specific behavioural patterns (Reinhardt et al. 1996).

Ideally, a captive environment should be a true simulation of a species' natural habitat. This is not always possible, as many zoos have inherited inadequate facilities from the past and cannot afford to replace them immediately. In any case, essential characteristics of the physical and social environment should be incorporated, but

these changes in the enclosure should only be thought of as interim solutions until new enclosures can be constructed.

Some of the significant features that need to be addressed while designing or renovating an enclosure are:

- **greater cage volume** : The enclosure size and complexity influences the level of stereotypic pacing exhibited by leopards. Pacing levels in large complex environments are significantly less than in small, barren enclosures. Off-exhibit enclosures, which are small, increased the proportions of stereotypy exhibited. Leopards in off-exhibit enclosures exhibited higher levels of pacing than those on-exhibit. In zoos, where a surplus number of a single species, results in some animals being housed off-exhibit on a permanent basis, stereotypic levels increase considerably and occupy a major portion of the activity budget. Felids in larger enclosures make better use of the space allotted to them and have higher levels of average movement. Larger, more complex enclosures would stimulate the leopard to exhibit a greater variety of behaviour patterns. This could diminish the overall proportion of abnormal behaviour exhibited by the animal (refer to AZA guidelines for standardised enclosures sizes for captive felids, Appendix II).

- **enclosure furnishing and complete use of the enclosure volume** : the leopard is an semi-arboreal species and restricting them to the ground could only affect their behaviour repertoires adversely. A multidimensional network of arboreal pathways in the enclosures would provide adequate climbing opportunities and considerably increase the effective size of the enclosure (Sambrook & Buchanan-Smith, 1997). Addition of sleeping, platforms, sleeping dens, sheds, trees and benches would increase the use of the vertical space as well as the horizontal

space thus increasing the overall utilisation of the enclosure. Inclusion of these elevated locations in leopard enclosures is a simple and inexpensive technique of structurally enriching the environment. This will allow the leopard to rest, view their surrounding and watch potential prey**.**

- **Visitor disturbance and visitor-distance:** Visitor distance needs to be maintained to reduce the disruption of natural behaviour repertoires of these animals (Hosey & Druck, 1987; Fa, 1992). Increasing the height of the enclosures would give arboreal species such as the leopard an access to utilise the vertical dimension and at the same time increase the distance between them and the viewers. Lowering public walkways is another option to reduce the disturbance caused by visitors.
- **Predictable feeding regimes and food anticipatory behaviour:** Predictable feeding regimes cause the anticipation of food in captive animals leading to the exhibition of food-anticipatory behaviour. A change or irregurality in the feeding time would reduce anxiety and levels stereotypic behaviour exhibited before feed-time (Lindburg, 1988). Feeding enrichment techniques have also been recorded to reduce levels of stereotypic behaviour (Markowitz & La Forse, 1987; Forthman et al. 1992; Powell, 1995).

Enriching a leopard's enclosure would not only help the animal to identify itself with its surroundings but will also give the visitor an opportunity to appreciate the animal's place in nature. The significance of this approach is that it does not require a technical educational programme to be effective; the impact on the public is immediate and strong. It is this natural approach to zoo management that will characterise the zoos of the future.

LITERATURE CITED

ALTMANN, J. 1974. Observational study of behaviour: sampling methods. *Behaviour* 49:227-267

BAILEY, T. N. 1993. *The African Leopard : A Study of the Ecology and Behaviour of a Solitary Felid*. Columbus University Press, New York

BALDWIN, C. F. 1985. *Behaviour of Carnivores in Outdoor Exhibits at the National Zoological Park*. Masters thesis submitted to Colby College, George Mason University, Fairfax, Virginia

BENNETT, S.W AND MELLEN, J. D.1983. Social interactions and solitary behaviours in a pair of captive sand cats (*Felis margarita*). *Zoo Biology* 2:39-46

BERNARD, C. J AND HURST, J. L. 1996. Welfare by design : the natural selection of welfare criteria. *Animal Welfare* 5: 405-433

BOORER, M. K. 1972. Some aspects of stereotyped patterns of movement exhibited by zoo animals. *International Zoo Yearbook* 12: 164-168

BOTHMA, J. P. 1998. *Carnivore Ecology in Arid Lands.* Springer-Verlag Berlin Heidelberg, New York.

BRAASTAD, B. O. 1996. Behaviour of silver foxes in traditional breeding boxes with an entrance tunnel. *Animal Welfare* 5:155-166

BRENT, L AND STONE, A. M. 1996. Long-Term Use of Televisions, Balls, and Mirrors as Enrichment for Paired and Singly Caged Chimpanzees. *American Journal of Primatology* 39:139-145

BUCHANAN-SMITH, H. M.1996. Enriching the lives of marmosets and tamarins in captivity. *Shape of Enrichment* 5(4): 3-5

BUCHANAN-SMITH, H. M.1997. Environmental control: an important factor of captive callithrichid environments. In **Pryce, C; Scott, L and Schnell, C**

(eds). *Marmosets and Tamarins in Biological and Biomedical Research*. 47-53.

CAINE, N. G AND BOYLE, V. J. 1992. Cage design and forms of play in red-bellied tamarins, *Saguinus labiatus*. *Zoo Biology* 11:215-220

CARLSTEAD, K. 1991. Husbandry of the fennec fox, *Fennecus zerda*: environmental conditions influencing stereotypic behaviour. *International Zoo Yearbook* 30: 202-207

CARLSTEAD, K. 1996. Effects of captivity on the behaviour of wild mammals. In **Kleiman, D.G; Allen, M.E; Thompson, K. and Lumpkin, S** (eds). *Wild Mammals in Captivity: Principles and Techniques*. University of Chicago Press, Chicago and London

CARLSTEAD, K. in press. Determining the causes of stereotypic behaviours in zoo carnivores: towards developing appropriate enrichment strategies. In **Shepherdson, D. J; Mellen, J and Hutchins, M** (eds). *Second Nature Environmental Enrichment for Captive Animals.* Smithsonian Institute Press, Washington, D.C

CARLSTEAD, K AND SEIDENSTICKER, J. 1991. Seasonal variation in stereotypic pacing in an American black bear (*Ursus americanus).* *Behavioural Processes* 25:155-161

CARLSTEAD, K AND SHEPHERDSON, D. 1991. Effects of environmental enrichment on reproduction. *Zoo Biology* 13: 447-458

CARLSTEAD, K., SEIDENSTICKER, J AND BALDWIN, R. 1991. Environmental enrichment for zoo bears. *Zoo Biology* 10:3-16

CARLSTEAD, K., BROWN, J. L AND SEIDENSTICKER, J. 1993a. Behavioural and adrenocortical responses to environmental changes in leopard cats *(Felis bengalensis*). *Zoo Biology* 12:321-331

CARLSTEAD, K., BROWN, J. L AND STRAWN, W. 1993b. Behavioural and physiological correlates of stress in laboratory cats. *Applied Animal Behaviour Science* 38: 143-158

CHAMOVE, A. S., HOSEY, R. G AND SCHAETZEL, P. 1988. Visitors excite primates in zoos. *Zoo Biology* 7:359-369

CLARKE, A. S., JUNO, C. J AND MAPLE, T. L. 1982. Behavioural effects of a change in the physical environment: a pilot study of captive chimpanzees. *Zoo Biology* 1:371-380

CLEVENGER, S. A. 1987. Utilising natural history and behaviour in exhibit design: coatis (*Nasua nasua*) at National Zoological Park. *American Association of Zoological Parks and Aquariums Regional Proceedings.* 82-89

DICKIE, L. A. 1997. Environmental Enrichment in Captive Primates. *Zoo Outreach Organization Z* Information Exchange Network* XII: 10

EDGAONKAR, A AND RAVI CHELLAM. 1998. A preliminary study on the ecology of the leopard (*Panthera pardus fusca*), in Sanjay Gandhi National Park, Maharashtra.

EISENBERG, J. F. 1986. Life history strategies of the felidae: variations on a common theme. In **Miller S. D. and Everett D. D.** (eds). *Cats of the World: Biology, Conservation, and Management*. National Wildlife Federation, Washington, D.C. pp 293-304

FA, J. E. 1992. Visitor-directed aggression among the gibralter macaques. *Zoo Biology* 11:43-52

FORTHMAN, D. L AND BAKEMAN, R. 1992. Environmental and social influences on enclosure use and activity patterns of captive sloth bears (*Ursus ursinus*). *Zoo Biology* 11:405-415

FORTHMAN, D. L., ELDER, S. D., BAKEMAN, R., KURKOWSKI, T.W., NOBLE, C.C AND WINSLOW, S.W. 1992. Effects of Feeding Enrichment on Behaviour of Three species of captive Bears. *Zoo Biology* 11:187-195

FREEMAN, H. 1983. Behaviour in adult pairs of captive snow leopards (*Panthera uncia*). *Zoo Biology* 2: 1-22

GLATSON, A. R., SOETEMAN, E. G., PECEK, E. H AND HOOFF, 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

GOERKE, B., FLEMING, L AND CREEL, M. 1987. Behavioural changes of a juvenile gorilla after a transfer to a more naturalistic environment. *Zoo Biology* 6:283-295

HOSEY, G.R AND DRUCK, P.L. 1987. The influence of zoo visitors on the behaviour of captive primates. *Applied Animal Behaviour Science* 18:19-30

HUTCHINS, M., HANCOCKS, D AND CROCKETT, C. 1984. Naturalistic solutions to the behavioural problems of captive animals. *Zoologique Garten* 54: 28-42

INGES, R., WARAN, N.K AND YOUNG, R.J. 1997. Effect of wood-pile feeders on the behaviour of captive bush dogs (*Speothos venaticus*). *Animal Welfare* 6:145-152

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

KARANTH, K. U. 1991. Ecology and management of tigers in Tropical Asia. In **Maruyama N; Bobek B., Ono Y; Regelin W; Bartos L and Ratcliffe, R** (eds). *Wildlife Conservation: Present trends and perspectives for the 21st Century*. Japan Wildlife Research Center, Tokyo. 156-159.

KARANTH, K. U AND SUNQUIST, M. E. 1995.Prey Selection by Tiger, Leopard and Dhole in Tropical Forests. *Journal of Animal Ecology* 64:1-11

KESSEL, A. L AND BRENT, L. 1996. Space utilization by captive-born baboons (*Papio* spp.) before and after provision of structural enrichment. *Animal Welfare* 5:37-44

KESSLER, M. R AND TURNER, D. C.1997. Stress and adaptation of cats (*Felis silvestris catus*) housed singly, in pairs and in groups in boarding catteries. *Animal Welfare* 6: 243-254

KEULEN, G. N AND KROMHOUT. 1976. Zoo enclosures for bears their Influence on captive behaviour and reproduction. *International. Zoo Yearbook* 18 :177-186

KILEY, M AND WORTHINGTON. 1977. Behavioural problems of farm animals. Stockfield : Oriel Press.

KIRKWOOD, J. K. in press. Design for the accommodation for wild animals: how do we know when we have got it right? *Proceedings 5th international Zoo design Conference*. Paignton, 17-20th May 1998.

KLEIMAN, D.G., ALLEN, M.E., THOMPSON, K. AND LUMPKIN, S. 1996. Wild mammals in captivity: principles and techniques. University of Chicago Press, Chicago and London

KOLTER, L. 1995. Regulation of behaviour and the development of abnormal behaviour patterns. **Ganslober, U; Hodges, J.K and Kaumanns, W** (eds). *Research and Captive Propagation.* Filander Verlag GmbH

LAW, G AND TARTNER, P. 1998. Behaviour of a captive pair of clouded leopards (*Neofelis nebulosa*): introduction without injury. *Animal Welfare* 7:57-76

LEHNER, P. H. 1996. *Handbook of ethological methods*. II Ed. Cambridge University Press, Cambridge

LINDBURG, D. G. 1988. Improving the feeding of captive felines through application of field data. *Zoo Biology* 7:211-218

LYONS, J., YOUNG, R. J AND DEAG, J. M. 1997. The effects of physical characteristics of the environment and feeding regime on the behaviour of captive felids. *Zoo Biology* 16:71-83

MACEDONIA, J. M. 1987. Effects of housing differences upon activity budgets in captive sifakas (*Propithecus verreauxi*). *Zoo Biology* 6:55-67

MAGURRAN, A. E. 1988. Ecological diversity and its measurements. Croon Helm Ltd, London

MALLINSON, J. J. C., SMITH, J. D., DARWENT, M AND CARROLL, J. B. 1994. The design of the sumatran orangutan, *Pongo pygmaeus abelii* 'home-habitat' at the Jersey Wildlife Preservation Trust. *Dodo Journal Wildlife Preservation Trust* 30:15-32

MALLINSON, J. J. C. 1995. Zoo breeding programmes : balancing conservation and animal welfare. *Dodo, Journal Wildlife Preservation Trusts* 31: 66-75

MAPLE, T. L. 1979. Great apes in captivity: the good, the bad and the ugly. In **Maple, T. L; Erwin, J and Mitchell, G**. (eds). *Captivity and Behaviour: Primates in Breeding Colonies, Laboratories and Zoos*. Van Nostrand Reinhold, New York

MAPLE, T. L AND FINLEY, T. W. 1987. Post-occupancy evaluation in the zoo. *Applied Animal Behaviour Science* 18:5-18

MARKOWITZ, H. 1982. *Behavioural Enrichment in the Zoo*. Van Nostrand Reinhold, New York

MARKOWITZ, H AND LA FORSE, S. 1987. Artificial prey as behaviour enrichment devices for felines. *Applied Animal Behaviour Science* 18:31-43

MARRINER, L. M AND DRICKAMER, L. C. 1994. Factors influencing stereotyped behaviour of primates in a zoo. *Zoo Biology* 13:267-275

MARTIN, P AND BATESON, P. 1994. *Measuring Behaviour: An Introductory Guide*. II Ed. Cambridge University press, Cambridge

MASON, G. 1991. Stereotypies: a critical review. *Animal Behaviour* 41:1015-1037

MELLEN, J. D., HAYES, M. P AND SHEPHERDSON, D. J. in press. Captive environments For small felids. *Environmental Enrichment for Captive Animals*. **Shepherdson, D.J; Mellen, J and Hutchins, M** (eds). Smithsonian Institute Press, Washington, D.C.

MELLEN, J. D. 1991. Factors influencing reproductive success in small captive exotic felids (*Felis* spp.): a multiple regression analysis. *Zoo Biology* 10:95-110

MELLEN, J. D. 1998. Optimal environments for captive felids. *Husbandry Manual for Small Cats*. American Zoo and Aquarium Association. Felid Taxon Advisory Group. pp 284-393

MONTE, M AND PAPE, G. 1997. Behavioural effects of cage enrichment in single-caged adult cats. *Animal Welfare* 6:53-66

MUCKERHIRN, N. A AND EISENBERG, J. F. 1972. Home ranges and predator of the Ceylon leopard (*Panthera pardus fusca*). in **Eaton**, **R. L.** (ed). *The World's Cats*. World Wildlife Safari, Winston, Oregon. 1: 142-175

NORTON, P. M AND LAWSON, A. B. 1985. Radio tracking of leopards and caracals in the Stellenbosch area, Cape Province. *South African Journal of Wildlife Research* 15: 17-24

NEVEU, H AND DEPUTTE, B. L. 1996. Influence of availability of perches on the behavioural well-being of captive, group-living mangabeys. *American Journal of Primatology* 38: 175-185

O'DONOVAN, D., HINDLE, J.E., MCKEOWN, S AND DONOVAN, S.O. 1993. Effect of visitors on the behaviour of female cheetahs and cubs. *International Zoo Yearbook* 32:238-244

O'GRADY, R. J. P., LAW, G., BOYLE, H; MACDONALD, A AND JOHNSTONE, J.1990. Himalayan black bear *Selenarctos thibetanus* exhibit at Glasgow zoo. *International Zoo Yearbook* 29:233-240

PRATER, S.H. 1980. *Book of Indian Mammals*. Bombay Natural History Society, Bombay

POWELL, D.M. 1995. Preliminary evaluation of environmental enrichment techniques for African lions (*Panthera leo*). *Animal Welfare* 4:361-370

RAMANAN, A. V. 1995. Feeding regimes in non-domestic captive felids. Submitted to Tamil Nadu Veterinary and Animal Science University

REDSHAW, M. J AND MALLISON, J. J. C. 1991. Learning from the wild: improving the psychological and physical well-being of captive primate. *Dodo, Journal of Jersey Wildlife Preservation Trust* 27:18-26

REINHARDT, V., LISS, C AND STEVENS, C. 1996. Space requirement stipulations for caged non-human primates in the United States: a critical review. *Animal Welfare* 5:361-372

REINHARDT, V AND ROBERTS, A. 1997. Effective Feeding Enrichment for Non-Human Primates: A Brief Review. *Animal Welfare* 6: 265-272

SAMBROOK, T. D AND BUCHANAN-SMITH, H. M. 1997. Control and complexity in novel object enrichment. *Animal Welfare* 6:207-216

SANTIAPILLAI, C., CHAMBERS, M. R AND ISHWARAN, N. 1982. The leopard *Panthera pardus fusca* (Meyer, 1794) in the Ruhuna National Park, Sri Lanka and observation relevant to its conservation. *Biological Conservation* 5-14

SCHALLER, G. B. 1972. The Serengeti lion : a study of predator-prey relations. *The University of Chicago Press*, Chicago and London

SEAGER, S. W. J AND DEMOREST, C. N. 1978. Reproduction of captive wild carnivores. **Fowler, M** (eds). *Zoo and Wild Animal Medicine*. 667-682

SEIDENSTICKER, J., SUNQUIST, M.E AND MCDOUGAL, C. 1984. Leopards living at the edge of the Royal Chitawan National Park, Nepal

SEIDENSTICKER, J AND FORTHMAN, D. L.1998. Evolution, ecology and enrichment: basic considerations for wild animals in zoos. In **Shepherdson, D.J., Mellen, J.D and Hutchins, M** (eds). *Second Nature, Environmental Enrichment for Captive Animals*. Smithsonian Institution Press, Washington D.C

SHEPHERDSON, D. J., CARLSTEAD, K., MELLEN, J. D AND SEIDENSTICKER, J. 1993. The influence of food presentation on the behaviour of small cats in confined environments. *Zoo Biology* 12:203-216

WECHSLER, B. 1991. Stereotypies in polar bears. *Zoo Biology* 10:177-188

WIEPKEMA, P. R AND KOOLHAAS, J. M. 1993. Stress and animal welfare. *Animal Welfare* 2:195-218

WILSON, S. F. 1982. Environmental influences on the activity of captive apes. *Zoo Biology* 1:201-209

ZAR, J. H. 1984. *Biostatistical Analysis*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey

ZUCKER, E. L., DEITCHMAN, M AND WATTS, E. 1991. Behavioural evaluation of exhibit modifications designed to accommodate an aged Diana monkey. *Zoo Biology* 10:69-74

APPENDIX I

ETHOGRAM : this ethogram consists of 13 behavioural states and 29 behavioural events which were recorded across 5 south Indian zoos.

BEHAVIOUR	**DESCRIPTION**
BEHAVIOURAL STATES	behavioural patterns of relatively long duration
SLEEPING	lying or sitting, head down and eyes closed
LYING DOWN	Lying, head down and eyes open
SITTING	as implied
SITTING ERECT	Sitting, fore limbs straight as in standing
WALKING	as implied
STEREOTYPIC PACING	Repetitive pacing along the same path
STANDING	as implied
RUNNING	as implied
JUMPING	as implied
ROLL\RUBBING	Rolling and rubbing on the ground
MATING	Male mounts the female and copulates
CLIMBING	Movement along a tree trunk
NOT VISIBLE	as implied
BEHAVIOURAL EVENTS	behavioural patterns of relatively short duration
ALERT	lying or sitting with head up and eyes open and focused

BEHAVIOUR	DESCRIPTION
BODY MOVEMENT	Movement of the body while sitting, lying down or sleeping
FACE RUB	Rubbing face with fore paw
PANTING	breathing heavily with mouth open and tongue hanging
SNIFFING	smelling inanimate objects or other individuals
LICKING ONESELF	Licking various body parts
LICKING OBJECT	Licking an inanimate object
LICKING OTHER	Licking another individual
SCRATCHING ONESELF	Scratching various body parts
BITING ONESELF	Biting various body parts
SCRATCHING/BITING OBJ.	Scratching or biting inanimate object
PLAYING	playing, wrestling with inhibited paw strikes with low or no vocalisation
DEFECATING	as implied
URINATING	as implied
HORIZONTAL MARKING	Spraying or scent marking
FLEHMEN	a grimace with mouth open, wrinkled nose, retracted lips and tongue that may not protrude past the lips
CALLING UNDER BREATH	Low vocalisations that that last for a second

BEHAVIOUR	DESCRIPTION
CALLING	Loud vocalisations that last more than 5 seconds
HUNTING\STALKING	run upto or stalk objects or animals within or outside the enclosure
GROWLING	Loud vocalisation, with grimacing and teeth baring
CHEWING	Biting an inanimate object repeatedly
RUBBING	Brushing parts of the body against another individual
RUBBING AGAINST OBJECT	Brushing parts of the body against an inanimate object
FALL-OFF	sudden drop from a higher elevation to a lower elevation due to lack of control on reflexes
EATING GRASS	as implied
EATING	chewing or ingesting any form of food
DRINKING WATER	as implied
SCRAPING SOIL WITH PAWS	Digging out soil within the enclosure with hind or fore paws
AGGRESSION	fighting between two or more individuals

APPENDIX II

Studies conducted by various zoo-biologists have suggested that minimum size of for enclosures that exhibit felids (Mellen, 1998).

According to the American Association of Aquariums, universities and Zoos(AZA) :

1) an animal lesser than 10 kg would require an enclosure of the minimum size 2.0 * 2.0 * 2.4 cu. m per cat.
2) an animal lesser than 20 kg would require an enclosure of the minimum size 4.0 * 2.0 * 2.4 cu. m per cat.
3) large felids would require a minimum area of 200 sq. ft and an additional 50% for each additional animal(this rule would hold for the following species of big cats : *Panthera onca, Panthera pardus, Uncia uncia, Puma concolor, Neofelis nebulosa)*
4) very large felids would require a minimum area of 6.7 * 4.5 *4.8cu. m and an additional 50% for each additional animal(this rule would hold for the following species of big cats : lion(*Panthera leo), tiger(Panthera tigris*))