

Enclosure Design and Space Utilization by Indian Leopards (*Panthera pardus*) in Four Zoos in Southern India

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Enclosure design and the use of enclosure space influence the activity budget of captive leopards. The study laid out in grids all enclosures on the base map and segregated these grids into 4 zones. Every 5 min, the study recorded the proportion of time spent in these zones with the leopards' behavior. Captive leopards most frequently used the "edge" zone. Almost all leopards used the edge zone for stereotypic pacing, the "back" zone for resting, and the "other" zone for activity. The study positively correlated the proportion of time spent in the "enriched" zone with activity levels exhibited by leopards housed in some enclosures and with resting in others. Thus, the study segregated structural objects in the enriched zone into activity-related features (e.g., logs) and rest-related features (e.g., trees and sleeping platforms). Compared with individuals housed in barren enclosures, leopards housed in structurally enriched on-exhibit enclosures exhibited higher levels of activity. Enclosure design was found to be an important factor influencing the welfare of leopards in captivity.

Laboratories and zoos maintain a wide range of species of wild animals for the purpose of research, education, and conservation. The inability of several of these wild animals to adapt to their captive environments causes acute stress, resulting in the exhibition of abnormal behavior such as stereotypic pacing, excessive inactivity, deviant sexual behavior, and abnormal maternal care (Carlstead, 1991; Mason, 1991; Wiepkema & Koolhaas, 1993).

Behavior patterns exhibited by wild animals in captivity and not by their free-ranging counterparts are termed *abnormal behavior* (Boorer, 1972). The pres-

ence of such behaviors in an animal's behavioral repertoire is an indication that the animal's psychological welfare is at a suboptimal level (Erwin & Deni, 1979; Kirkwood, 2000). With the growing need for a better understanding of captive settings, scientists have investigated several aspects of enclosure design, such as size and complexity, and found that they influence the proportion of abnormal behavior exhibited by confined animals (Keulen & Kromhout, 1976; Kirkwood, 2000; Macedonia, 1987; Maple, 1979). Barren and sterile captive environments restrict animals both biologically and spatially from performing their species-specific behaviors, giving rise to abnormal behavior such as stereotypic pacing. *Stereotypic pacing* is a characteristically repetitive behavior, invariant in form, and has no obvious goal or function (Carlstead, 1998; Carlstead, Brown, & Seidensticker, 1993).

Enclosure design also influences the activity budget of animals in captivity (Monte & Pape, 1997; Reinhardt, Liss, & Stevens, 1996; Seidensticker & Forthman, 1998). A study on captive Sifakas (*Propithecus verreauxi*) showed that individuals housed outdoors were more active than those housed indoors (Macedonia, 1987).

Baldwin's (1985) study on carnivores in captivity demonstrated that they spent more than 75% of their time in less than half their enclosure space. He observed that felids rested most frequently toward the rear of their exhibits and that the resting space was the one felids used most frequently. Thus, the availability of areas suitable for resting on exhibit influenced the distribution of space use. Lyons, Young, and Deag's (1997) study on captive felids and their space demonstrated that enclosure design and the management regime influence the behavior of captive felids. The size of the enclosure did not affect the pacing behavior, but the felids used edges of the enclosures in particular for stereotypic pacing.

Research efforts in recent years have examined the effects of improvements in captive environments on animal behavior. Increasing both horizontal and vertical space has been proposed as a way of improving the environment for great apes (Hebert & Bard, 2000; Maple, 1979) and arboreal felids (Hutchins, Hancocks, & Crockett, 1984).

In this study, we examined the areas of the enclosure used by captive leopards. Leopards are the most adaptable and widespread of big cats (Bailey, 1993; Muckerhirm & Eisenberg, 1972). They are solitary and occasionally arboreal (Bailey, 1993; Muckerhirm & Eisenberg, 1972; Santiapillai, Chambers, & Ishwaran, 1982; Schaller, 1972; Seidensticker, Sunquist, & McDougal, 1984). Although not extensively studied, information on the behavioral ecology of the leopard does exist (Bailey, 1993; Muckerhirm & Eisenberg, 1972; Norton & Lawson, 1985). Studies on free-ranging leopards (*Panthera pardus fusca*) in the Indian subcontinent 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). The distribution of leopards in India and its morphology has been well documented (Prater, 1980). A few studies have

recorded the behavior of leopards in captivity (Baldwin, 1985; Lyons et al., 1997). In this study we also present the influence of environmental enrichment and enclosure design on the activity budget of leopards in captivity.

MATERIALS AND METHOD

Subjects and Study Area

We conducted a behavioral study on 16 singly housed leopards (see Table 1) in four zoos located in Thiruvananthapuram, Chennai, and Mysore between November 1998 and March 1999. Fourteen of the leopards were studied on exhibit and off exhibit; 2 were studied in off-exhibit enclosures only. All on-exhibit enclosures were outdoors; all off-exhibit enclosures were indoors. The Thiruvananthapuram Zoo (Trivandrum) maintained the leopards in a cathouse that housed other big cats.

The leopards housed at Trivandrum were fed at 11:30 a.m. Those at Arignar Anna Zoological Park (Vandalur), Guindy Children's Park, and Chamarajendra Zoological Gardens (Mysore) were fed at 2:30 p.m., 2:30 p.m., and 4:30 p.m., respectively. All were fed 6 to 8 kg of red meat per animal per day. The leopards were fasted once a week and occasionally were fed chicken.

Method

We gathered details of the enclosure occupied by animals from zoo records, measurements, and from observations made at each zoo. Details of the enclosures were laid out on grids on a representative map (see Figure 1), including trees, shrubs, shelters, and other structural features found within the enclosures (see Table 1).

To study an animal's space utilization, we partitioned the enclosure on paper into various zones. These zones were marked on the base map for all on-exhibit and off-exhibit enclosures in the four zoos. The base map also had enclosure features marked on it. A copy of the appropriate map was taken to the enclosure to be used during scan sampling. The animal's position along with the behavioral data were noted. This procedure was followed for all individuals at the four zoos.

To standardize the recording of behavioral patterns exhibited by the leopards and to develop an ethogram, we initially conducted ad libitum sampling for a period of 15 hr on two leopards at Trivandrum. Eleven behaviors were recorded and classified into activity, resting, and stereotypic behaviors for comparison and analysis (see Table 2).

Each animal was scanned every 5 min, and the animal's behavior was recorded (Altmann, 1974; Martin & Bateson, 1994) for a period of 6 to 10 hr. All behavioral observations were recorded between 6:00 a.m. and 6:00 p.m. Sampling was conducted as follows.

TABLE 1
Details of Captive Leopards Studied in Four Zoos

<i>Zoological Park</i>	<i>On Exhibit</i>			<i>Off Exhibit</i>			<i>Males</i>	<i>Females</i>	<i>Total</i>
	<i>Environment No.</i>	<i>Size^a</i>	<i>Enriched With</i>	<i>Environment No.</i>	<i>Size^a</i>	<i>Enriched With</i>			
Trivandrum	1	3.6 × 7.2	Log	1	4.5 × 3.0	Barren	1	1	2
Madras	1	10.0 × 24.0	Trees	1	2.8 × 3.7	Barren	1		6
	2	8.0 × 24.0	Sleeping platform and trees	2	2.8 × 2.7	Barren	1		
				3	2.6 × 2.0	Barren	1	1	
	3	3.8 × 4.2	Barren	4	2.6 × 2.0	Barren	1		
Guindy	1	9.0 × 7.0	Sleeping platform	5	1.6 × 2.0	Barren		1	
Children's Park				1		Sleeping platform	1		1
Mysore	1	(18.3 × 10.4) + (8.0 × 4.4)	Barren	1	1.9 × 2.5	Sleeping platform	2	1	7
	2	17.0 × 10.5	Tree	2	3.0 × 4.8	Sleeping platform	1	1	
	3	7.7 × 13.8	Log	3	2.4 × 4.8	Sleeping platform	1	1	
Total		8			11		10	6	16

Note. Animals were housed singly in all zoos during this part of the study and alternatively were left in the on-exhibit enclosures. November 1998 to March 1999.

^aGiven in meters.

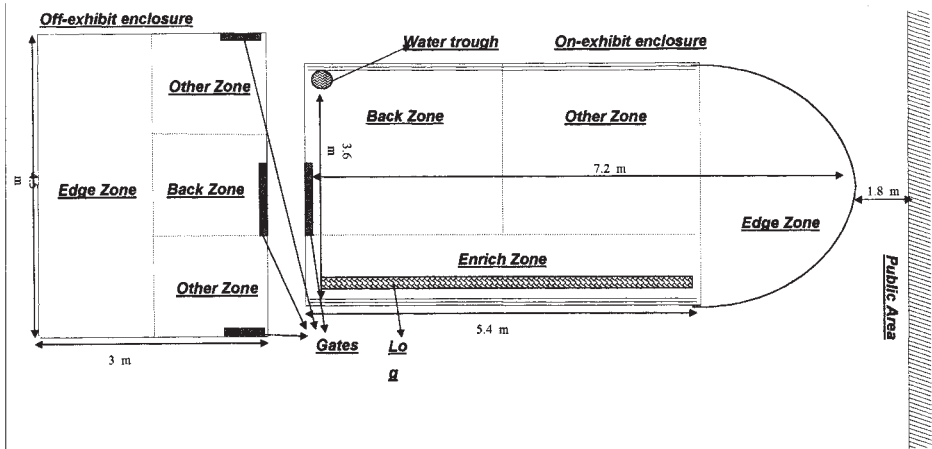


FIGURE 1 On- and off-exhibit enclosures for leopards at Trivandrum Zoo, India.

TABLE 2
Ethogram for Leopards Housed in Four Indian Zoos

<i>Behavior Observed</i>	<i>Descriptions</i>	<i>Behavior Category</i>
Sleeping	Lying or sitting: head down and eyes closed	Resting
Sitting	As implied	Resting
Sitting erect	Sitting: fore limbs straight as in standing	Resting
Lying down	Lying: head down and eyes open	Resting
Running	As implied	Activity
Climbing	As implied	Activity
Jumping	As implied	Activity
Standing	As implied	Activity
Walking	As implied	Activity
Rubbing/rolling	Rolling and rubbing on the ground or on inanimate object	Activity
Stereotypic pacing	Repetitive pacing along the same path	Stereotypic pacing

1. On-exhibit days: two control days for a period of 10 hr each day (the second day being a pseudoreplicate of the first) in the on-exhibit enclosure. A special note was made if the control day fell on a weekend or on the day after the animal fasted. Visitors were present on on-exhibit days.

2. Off-exhibit days: two days in the off-exhibit enclosures for a period of 6 hr each day (the second day being a pseudoreplicate of the first). Although visitors were present on off-exhibit days, they did not have access to the study animals because all off-exhibit enclosures were indoors. Because of poor lighting during the early morning and evening hours, animals were studied for only 6 hr in the off-exhibit enclosures.

This routine for sampling behavior was followed at all four sites. Frequencies of behaviors scanned at 5-min intervals were summed on a daily basis for each leopard. We converted these frequencies to proportion of time spent exhibiting each behavior (percentages). Replicates were pooled for each animal for each condition.

Analyses

We used the Kruskal–Wallis test (Zar, 1984) to test the differences in the proportion of time spent in each zone. We correlated the proportion of time spent in each zone with the proportion of time spent in exhibiting each behavior for each enclosure using the nonparametric Spearman rank correlation coefficient test. We conducted 12 correlations between the proportion of behavior exhibited and the proportion of time spent in each zone because there were four zones and three behavior states. We calculated these correlations for each on-exhibit enclosure. Because they were small—rarely consisting of more than two zones—off-exhibit enclosures were not included.

The enclosures were graded comparatively according to their complexity (see Table 3). We correlated enclosure complexity with the proportion of time spent in the enriched zone using the partial correlation coefficient test corrected for enclosure size. We conducted the test separately for on- and off-exhibit enclosures.

We used the Mann–Whitney *U*–Wilcoxon rank sum *W* test (Zar, 1984) to examine differences in behavior exhibited between structurally enriched and barren enclosures. We conducted this test separately for on- and off-exhibit enclosures.

RESULTS

Activity Budget and Enclosure Size

There were no significant differences in activity and resting with the increasing enclosure size of the on-exhibit enclosures, Kruskal–Wallis: activity behavior, $\chi^2(4, N = 16) = 2.23, p = .694$; resting behavior, $\chi^2(4, N = 16) = 2.83, p = .586$.

TABLE 3
Complexity Grades for Enclosures Housing Leopards Singly in Four Zoos in Southern India

<i>Grade</i>	<i>Complexity</i>
1	Enclosures that are barren (no trees, logs, or other enrichment devices)
2	Partially barren enclosures (logs present)
3	Enclosures with sleeping platforms or trees
4	Enclosures with trees, clumps of bamboo, and/or bodies of water

Activity Budget and Space Utilization

We analyzed the correlations between the proportion of time spent exhibiting a particular behavior and the proportion of time spent in a particular zone. Of the eight on-exhibit enclosures in four zoos (see Table 1), stereotypic pacing exhibited by leopards housed in five of these enclosures showed a significant positive correlation with the proportion of time they spent in the edge zone (Trivandrum Zoo, Environment 1 [T1]: $\rho = .741, p \leq .0001$; Madras Zoo, Environment 3 [M3]: $\rho = .807, p \leq .05$; Guindy Children's Park, Environment 1 [G1]: $\rho = .802, p \leq .05$; Mysore Zoo, Environment 1, $\rho = .408, p \leq .05$; Mysore Zoo, Environment 2 [M2]: $\rho = .855, p \leq .0001$; see Figure 2). Leopards housed in four of the eight enclosures exhibited resting levels that correlated positively with the proportion of time spent in the back zone (T1: $\rho = .799, p \leq .0001$; M1: $\rho = .471, p \leq .05$; M3: $\rho = .945, p \leq .0001$; G1: $\rho = .764, p \leq .006$).

Activity exhibited by leopards housed in six of the eight on-exhibit enclosures positively correlated with the time spent in the "other" zone (T1: $\rho = .571, p \leq .005$; M1: $\rho = .426, p \leq .05$; M2: $\rho = .663, p \leq .05$; M3: $\rho = .757, p \leq .0001$; My2: $\rho = .425, p \leq .05$; My3: $\rho = .472, p \leq .05$). Five of the eight on-exhibit enclosures had an enriched zone. The proportion of time spent in the enriched zone by leopards housed in two of these five enclosures positively correlated with resting (M2: $\rho = .901, p \leq .0001$; My2: $\rho = .677, p \leq .0001$). Leopards housed in these two enclosures did not use the back zone for resting. The proportion of time spent in the enriched zone by leopards housed in the Trivandrum Zoo enclosure was found to correlate positively with activity (T1: $\rho = .586, p \leq .004$).

Figure 3 plots the average number of significant Zone \times Behavior correlations against enclosure size. The scale on the y axis varies between 1, when all correlations are significant, and 0, when all the correlations conducted for that particular enclosure size class are not significantly correlated. The figure shows that enclosures of small sizes have a higher average significant correlation value than the larger enclosures. Enclosures of $< 50 \text{ m}^2$ in size have significant p values for all five behavior-space use correlations, whereas enclosures of 200 to 250 m^2 in size have .6 significant correlations.

The proportion of time spent in the enriched zone positively correlated with enclosure complexity for leopards in their on-exhibit and off-exhibit enclosures (see Table 4).

ENCLOSURE TYPES AND THEIR STRUCTURAL FEATURES

A comparison of the proportion of time spent in exhibiting activity, resting, and stereotypic behavior between structurally enriched and barren on-exhibit enclosures

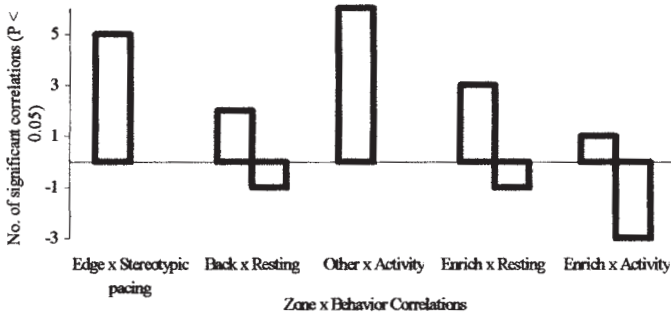


FIGURE 2 Significant Zone x Behavior correlations for captive leopards in four zoos in southern India (November 1998 to March 1999). Enrich = enriched.

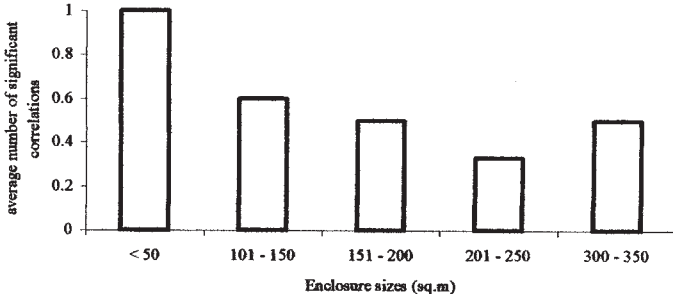


FIGURE 3 Average number of significant Zone x Behavior correlations exhibited by captive leopards (November 1998 to March 1999).

TABLE 4
Complexity x Enrich Zone Partial Correlations Correcting for Enclosure Size Leopards Housed On- and Off-Exhibit in Four Zoos in Southern India

Exhibit Type	Pair	Partial Correlation	<i>p</i> ^a	<i>N</i> ²
On exhibit	Complexity x Enrich zone	.593	.033	10
Off exhibit	Complexity x Enrich zone	.676	.008	11

^aTwo tailed.

revealed that activity levels were significantly higher in structurally enriched enclosures (Mann-Whitney *U*: $Z = -2.780, N = 15, p = .004$; see Figure 4). There was no significant difference in the proportion of stereotypic behavior exhibited in the structurally enriched and barren enclosures (Mann-Whitney *U*: $Z = -1.273, N = 15, p = .232$). There was no significant difference in behavior exhibited in structurally enriched and barren off-exhibit enclosures (Mann-Whitney *U*: activity behavior, $Z =$

$-0.141, N = 15, p = .945$; resting behavior, $Z = -1.414, N = 15, p = .188$; stereotypic behavior, $Z = -0.283, N = 15, p = .839$).

DISCUSSION

Use of Enclosure Space

Leopards used particular zones within the enclosure to exhibit specific behavioral patterns. In on-exhibit enclosures, they used the edges of the enclosure for stereotypic pacing and the rear of the enclosure for resting. Leopards housed in structurally enriched enclosures used this zone to exhibit either active or resting behaviors. There was a distinct difference between the enriched areas used to exhibit activity and those used to exhibit resting behaviors. By closely studying the two types of enriched zones, we could segregate them into those containing activity-related devices (e.g., logs) and rest-related devices (e.g., trees and sleeping platforms). Leopards in the two enclosures who used the enriched zone of their enclosures for resting did not use the back zone to exhibit these behaviors. The rest-related devices were a tree in Environment 2 of the Mysore Zoo and an elevated sleeping platform in Environment 2 of the Madras Zoo. Both used elevated rest sites as enrichment. Solitary and occasionally arboreal leopards prefer elevated rest areas and in the wild frequently are sighted on trees and rocky outcrops (Bailey, 1993; Muckerhirm & Eisenberg, 1972; Santiapillai et al., 1982; Schaller, 1972; Seidensticker et al., 1984). Leopards housed in smaller enclosures seemed to exhibit a clear pattern in their use of enclosure space to exhibit specific behaviors. There could be several reasons for this pattern in enclosure space use. Smaller enclosures are usually devoid of visibility barriers and hide-outs for the animals. They also have shorter flight and visitor distances and,

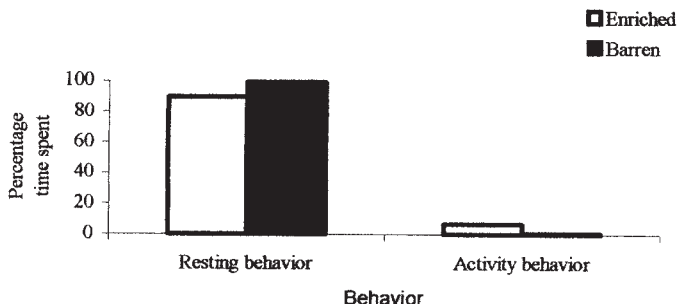


FIGURE 4 Influence of structural features on the activity budget of captive leopards (November 1998 to March 1999).

hence, they use the rear of the enclosure for resting to maintain maximum visitor distance and the edges to liberate stress by stereotypic pacing. Large enclosures, however, also tend to be more naturalistic and complex. They also have more visibility barriers and structurally enriched features that stimulate their occupants to exhibit species-specific behavioral patterns. Used primarily for activity, the “other” zone tends to be greater in the larger enclosures. Lyons et al.’s (1997) study found that captive felids housed in relatively larger enclosures exhibited relatively higher levels of activity.

Leopards used the edges more than any other part of their enclosure. They used the edges for stereotypic pacing. All leopards in the study paced (Mallapur & Chellam, in press) and used the edges of their enclosures to do so. Captive environments constitute an enforced territorial boundary (Lyons et al., 1997). Lyons et al. also explained how the edges of the enclosure can be the source of several forms of stimulation: For example, they permit the view of the visitor area and the zookeepers’ approach for feeding and cleaning. The felids that they observed also used the edges of their enclosures more than the central areas.

Aspects of enclosure design such as size and complexity influence the performance of stereotypic behavior (Boorer, 1972; 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 used by the felids and the relationship between pacing and cage size. In this study we found that enclosure complexity influenced the proportions of stereotypic pacing exhibited by captive leopards in the four zoos. The addition of structural objects, such as logs, sleeping platforms, and sheds, stimulated the animals to exhibit activity or resting behaviors. Hence, enrichment items such as these that increase activity and resting and reduce stereotypic pacing, should be used to reduce the proportion of abnormal behavior exhibited by leopards housed in captivity.

Enclosure Complexity

The captive leopards in this study exhibited higher levels of activity in structurally enriched on-exhibit enclosures than in the barren enclosures. They tended to rest for longer periods in barren on-exhibit enclosures. Larger and more complex enclosures that had visibility barriers and hiding places influenced the activity budgets of animals housed in them. Complex environments stimulated the exhibition of natural behavioral repertoires. In this study, the use 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 enclosures with trees. The presence of these structural features influences an increase in the use of these areas. Leopards housed in enclosures that were more complex spent more time in the enriched zone than those housed in less complex or even barren enclosures. Structurally

enriched off-exhibit enclosures did not influence the proportion of behavior exhibited, and individuals housed in structurally enriched and barren off-exhibit enclosures exhibited similar proportions of activity, resting, and stereotypic behavior. Further research is needed to understand the preferential use of enclosure space by this species.

A major consequence of zoo exhibits is the reduction of space and complexity compared with 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 behavioral repertoire exhibited. Abnormal behavior such as stereotypic pacing is a behavioral problem exhibited by captive wild animals maintained in barren, unstimulating environments. Conditions in captive environments in laboratories and a large proportion of zoos are barren and suboptimal. Clarke, Juno, and Maple (1982), in their study on a juvenile chimpanzee who was transferred from a laboratory environment to a naturalistic manmade island, observed a dramatic reduction in stereotyped and self-directed behavior within 22 weeks after the transfer. In their natural habitats, certain arboreal species of felids rest at elevated points not only to get a good view of the surroundings but also to escape from danger. At the Seattle Zoo, caracals were observed to spend more than 80% of their time in their structurally enriched on-exhibit enclosure as opposed to the small, barren, adjacent enclosure in which their food was provided (Hutchins et al., 1984). More than 75% of all their activity behaviors took place in the on-exhibit enclosure.

CONCLUSIONS

This study recorded the influence of enclosure size, complexity, and the space utilization on the activity budget of leopards in captivity:

1. Leopards used edges or edge zone for exhibiting stereotypic pacing, the rear of the enclosure or back zone of the enclosure for resting, and the rest of the enclosure or other zone for activity.
2. Structural features were of two types: (a) rest-related devices (e.g. sleeping platforms and trees) and (b) activity-related devices (e.g., logs).
3. In enclosures that were structurally enriched with sleeping platforms or trees, leopards used the enriched zone instead of the back zone of the enclosure for resting. In enclosures with logs, they used the enriched zones for activity.
4. Leopards exhibited higher proportions of activity and lower levels of resting in structurally enriched on-exhibit enclosures than in barren enclosures.
5. Leopards housed in enclosures that were more complex spent more time in the enriched zone of their enclosures than did individuals housed in comparatively less complex or even barren enclosures.

IMPLICATIONS FOR WELFARE

By demarcating the enclosure into zones, we established that different zones were used to exhibit different behavioral patterns by the leopards. To increase the use of certain enclosure zones, or to reduce the levels of abnormal behavior exhibited by the leopards, zones could be structurally enriched or visibility barriers and hideouts incorporated for privacy. Activity-related or rest-related enrichment devices or structures could increase activity or resting behaviors in an enclosure zone. The most commonly used activity-related and rest-related enrichment devices are logs, trees, and sleeping platforms.

Certain studies suggest that boredom influences the exhibition of abnormal behavior patterns such as stereotypic pacing. Enriching barren enclosure areas could increase levels of activity and resting exhibited by leopards and reduce undesirable behaviors such as stereotypic pacing. In this study, leopards housed in enriched enclosures were more active than those housed in comparatively barren enclosures.

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