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Use of Enclosure Space by Captive Lion-Tailed Macaques (*Macaca silenus*) Housed in Indian Zoos

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Captive nonhuman animals use enclosure space differentially. Enclosure features strongly influence this. This study recorded both the enclosure space used by 47 captive lion-tailed macaques housed in 13 zoos across India and the behavior of the macaques. The exhibition of abnormal behaviors, food-related behaviors, and social interactions correlated significantly with the use of the edge zone (the part of the enclosure closest to the visitor area). Animals housed in barren enclosures used the edge zone to a significantly greater percentage than did those housed in complex exhibits. Percentages of autogrooming, social interactions, and food-related behaviors significantly correlated with the use of the enrich zone. Space use studies assist in rec-

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ognizing areas within the enclosure, which captive animals actively use. Conversely, the studies can identify areas infrequently used and show how to make maximum use of these enclosure areas. Further studies targeting both the increase in percentages of natural behaviors exhibited and use of the enrich zone used the current study on captive lion-tailed macaques for their design.

Several environmental factors influence the behavior (Mallapur, 2005a; Mallapur & Choudhury, 2003; Mallapur, Waran, & Sinha, 2005; Marriner & Drickamer, 1994); reproduction (Harvey, DeFalco, & Lindburg, 1995, 2001; Harvey, DeFalco, Vasseaur, & Lindburg, 1998; Johnson, Petto, & Sehgal, 1991; Mallapur, Sinha, & Waran, in press); and health (Hubrecht, 1996; Roberts, 1995; Volf, 1999; Ziegler, 2001) of primates in zoos. One of these factors is enclosure space (Clarke, Juno, & Maple, 1982; Hebert & Bard, 2000; Kessel & Brent, 1996; Little & Sommer, 2002). Nonhuman primates require sufficient, usable space that provides necessary sensory input to exhibit species-specific behavioral patterns (Mallinson, Smith, Darwent, & Carroll, 1994). Animals housed in unnaturally barren environments or small exhibits are deprived of appropriate stimuli for the expression of a natural behavioral repertoire (Reinhardt, 1997; Reinhardt, Liss, & Stevens, 1996). It has been observed that individuals housed in suboptimal environments develop a wide range of abnormal behavioral patterns (Clarke et al., 1982; Goerke, Fleming, & Creel, 1987; O'Neill, Novak, & Suomi, 1991) and that individuals housed in smaller, indoor enclosures are less active than those housed in larger, outdoor enclosures (Macedonia, 1987).

To exhibit behaviors they are motivated to perform, captive animals use enclosure space differentially, spending more time in certain areas and less time in others (Baldwin, 1985; Mallapur, Qureshi, & Chellam, 2002). Nonhuman primates housed in enclosures having an access to the vertical dimension tend to use the higher reaches of their enclosure more than they use the floor (Hebert & Bard, 2000; Kessel & Brent, 1996; Malone, 1998; Neveu & Deputte, 1996). Likewise, a study on felids in captivity showed that the study animals spent more than 75% of their time in less than half their enclosure space. Baldwin observed that felids most frequently rested toward the rear of their exhibits.

This article records the use of enclosure space by captive lion-tailed macaques housed in 13 zoos across India. The purpose of a study such as this is to recognize areas within the enclosure actively used by the captive macaques. By doing so, infrequently used areas of the enclosure also can be identified along with the probable reasons behind the low levels of their use. Such studies provide baseline information required for renovating and redesigning enclosures to improve the welfare of the captive animals housed in the enclosures. The current study on captive, lion-tailed macaques was used to design further applied behavioral studies to improve the welfare of lion-tailed macaques in captivity.

METHOD

Behavioral and Space Use Methods

A behavioral and space use study (Mallapur, 2005b) was conducted on 47 captive, lion-tailed macaques housed in 13 Indian zoos; see Table 1. Observations were conducted between July and December 2002. At each zoo, all individuals exhibited to the public were studied for a period of 9 hr during the day between 0830, when the zoo opened in the morning and 1730, when it closed for the day. Behavior (states) and space use were recorded every 15 min as instantaneous scans for all the individuals in the group. The sampling period lasted for durations of 3 hr; a minimum of two sampling periods of 3 hr each (0830h to 1130h, 1130h to 1430h, 1430h to 1730h) were covered per observation day. Details of the enclosure occupied by the study animals were gathered from zoo records, enclosure measurements, and from observations made at each study zoo. Details of the enclosures—including trees, shrubs, shelters, and other structural features found within the enclosures—were marked on a representative map of the enclosure.

To study the space use of the enclosure by an animal, the enclosure was partitioned on paper into four zones (Figure 1):

1. Edge zone—the part of the enclosure closest to the visitor area;
2. Back zone —the part of the enclosure furthest from the visitor area;

TABLE 1
Thirteen Zoos in India Used in Behavioral Use Space Study Conducted on 47 Lion-tailed Macaques

Name of Zoo	*Location in India*
Arignar Anna Zoological Park	Chennai, Tamil Nadu
Guindy Children's Park	Chennai, Tamil Nadu
Jaipur Zoo	Jaipur, Rajasthan
Mahendra Chaudhury Zoological Park	Chandigarh, Punjab
Maitri Baagh Zoo	Bhilai, Chhattisgarh
Mini Zoo	Kodanad, Kerala
Mini Zoo	Thattekkad, Kerala
Nandankanan Biological Park	Bhubaneshwar, Orissa
National Zoological Park	New Delhi, Delhi
Sanjay Gandhi Biological Garden	Patna, Bihar
Chamarajendra Zoological Gardens	Mysore, Karnataka
State Museum and Zoo	Thrissur, Kerala
Thiruvananthapuram Zoo	Thiruvananthapuram, Kerala

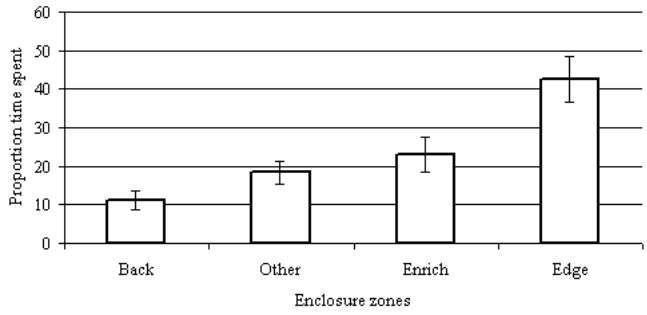

FIGURE 1 Proportions of enclosure space used by captive lion-tailed macaques in Indian zoos.

3. Enrich zone—the part of the enclosure containing structures such as trees, sleeping platforms, sheds, logs, and elevated bars (including any enrichment devices); and
4. Other zone—the parts of the enclosure that do not fall into any of the above categories.

These zones were marked on the base map, and this procedure was followed for all individuals at all 13 zoos. The four zones were mutually exclusive. Although the edge and back zones were positioned similarly across all the enclosures housing lion-tailed macaques in the study zoos, enrich and other zones were not. Because the enrich zone included trees, shrubs, water body, enrichment devices, logs, and elevated bars, the zone varied in position across enclosures.

Data Analyses

The use of enclosure space, as recorded in the instantaneous scans, has been expressed as percentage time spent in these particular states of the total time that an individual was observed. Behavioral and space use data for the 47 individuals were pooled at the end of the observation period to obtain group averages (26 groups) to maintain social independence of data points. The pooled behavior and space use data were used for analyses. For the purpose of examining the influence of the selected environmental factors on the performance of different behaviors by the study animals, the factors were quantitatively ranked on individual arbitrary scales (Table 2).

The Friedman's test was used to analyze differences across the different enclosure zones used by captive, lion-tailed macaques. The test helped to identify zones the macaques used most frequently. Spearman's correlation test was used to test if percentages of behavior exhibited correlated with space use data (Siegel &

Castellan, 1988). Because several factors (Table 2) seemed to influence behavior simultaneously, partial correlations were conducted to control for certain factors and study the individual influence of competing factors on the use of enclosure space (Siegel & Castellan, 1988). All p values that have been reported are two-tailed. SPSS (Version 7.5) was used to conduct the statistical analyses.

TABLE 2
Ranks for Factor Categories Used to Compare Behavioral Data Across Captive Lion-Tailed Macaques Housed in 13 Indian Zoos

Factor	*Categories*	*Sample Size*	*Ranks*[a]
Zoo category	Small	11	0
	Medium	0	1
	Large	15	2
Rearing history	Wild caught (acquired from the wild in the last 5 yr)		0
	Captive reared (acquired from wild but in captivity for > 5 yr)	1	1
	Zoo born (born in zoos)	11	2
	Confiscated (confiscated from unrecognized zoos or circuses)	14	3
Group composition	1 male: 2 or more females	0	0
	1 male: 1 female	4	1
	Single adult with young	2	2
	Males: females and young	2	3
	> 1 male: >1 female (no young)	3	4
	Single-sex groups	2	5
	Singly housed	13	6
Enclosure size	< 30 m^2	7	0
	30 to 60 m^2	9	1
	60 to 90 m^2	4	2
	> 90 m^2	5	3
Enclosure type	Cage (an enclosure without a moat, only bars)	19	0
	Wet moat	5	1
	Dry moat	2	2
Enclosure complexity	Barren	9	0
	Barren but enriched	10	1
	Complex	7	2
Substrate	Hard	17	0
	Soft	8	1
Vertical dimension	Cannot climb to elevated areas within enclosure	8	0
	Can climb to elevated areas within enclosure	18	1

[a]These ranks were only used for statistical analyses to study the influence of the factors listed above on behavior.

RESULTS

Of all the zones, the percentage of time spent using the area of the enclosure closest to the visitor side (edge zone, 42.6 ± 5.9%, $N = 26$) by captive lion-tailed macaques was the highest, followed by the enriched areas of the enclosure (enrich zone, 22.9 ± 4.5%); rest of the enclosure (other zone, 18.3 ± 3.0%); and the area farthest away from the visitor side (Figure 1, back zone, 11.2 ± 2.5%) Friedman Test, $\chi^2(3, N = 26) = 30.2$, $p < .001$.

Use of the Edge Zone

The performance of abnormal behavior (Table 3) was positively correlated, and food-related behavior and social interactions were negatively correlated with the use of the edge zone (Spearman's Correlation Test; SPT): abnormal behavior, $P = .560$, $p < .005$; food-related behavior, $P = –.547$, $p < .005$; and social interactions, $P = –.527$, $p < .05$. Zoo category was negatively correlated with the use of the edge zone, suggesting that lion-tailed macaques used the edge zone more in smaller zoos than in larger zoos, corrected for rearing history, $P = –.5321$, $p < .01$; $U = 19.500$; $N = 11$ (small zoos) and 15 (large zoos); $p < .001$. (See Table 4 for other partial correlations.) The percentage of time spent in the edge zone also was negatively correlated with enclosure complexity: Animals housed in barren enclosures used the edge zone more than did those housed in complex exhibits (Figure 2), corrected for rearing history, $P = –.6296$, $p < .005$, Table 4;

TABLE 3
Behaviors Recorded During the Behavioral and Space Use Conducted in 13 India Zoos

Behavior	*Definition*[a]
Abnormal	Behavioral pathologies that occur under conditions of captivity such as stereotypic pacing, plucking hair, and floating limb
Natural	Behaviors that are naturally exhibited in the wild; this category includes behaviors that are exhibited at comparable levels by both free range and captive individuals
Food related	Behaviors involved in searching for food and feeding
Social interactions	Behaviors directed by one individual (actor) towards another (target), the latter being a member of the captive group, an animal housed in the neighboring enclosure, zoo staff, observer, visitor or any feral animal in the vicinity; this category includes allogrooming, mating, playing, and suckling
Autogrooming	Individuals groom any part of their own body actively looking for fragments of dirt, insects, ectoparasites, and other foreign particles in the hair
Active	Continuous movement in a particular direction on any substratum by the individual. Active behaviors include climbing, running, and walking

[a]For definitions of behaviors such as stereotypic pacing, climbing, running refer to Mallapur (2005b).

TABLE 4
Partial Correlations of Enclosure Zone Use to Different Individual Characteristics and Captivity Factors

Correlation	*Correlation Coefficient*	*p Value*	*Constant Factor*
Edge—Zoo category	–.5385	.005	Housing
Edge—Zoo category	–.5321	.006	Rearing history
Edge—Zoo category	–.4861	.014	Sex
Edge—Zoo category	–.5200	.008	Vertical access
Edge—Zoo category	–.5192	.005	Enclosure substrate
Edge—Zoo category	–.4528	.023	Enclosure complexity
Edge—Enclosure complexity	–.6296	.001	Rearing history
Edge—Enclosure complexity	–.6153	.001	Zoo category
Edge—Enclosure complexity	–.5837	.002	Sex
Edge—Enclosure complexity	–.3960	.05	Vertical access
Edge—Enclosure complexity	–.5596	.004	Enclosure substrate
Edge—Enclosure complexity	–.6002	.002	Enclosure type
Edge—Enclosure complexity	–.6179	.001	Housing
Enrich—Vertical access	.6086	.001	Rearing history
Enrich—Vertical access	.5875	.002	Zoo category
Enrich—Vertical access	.5767	.003	Sex
Enrich—Vertical access	.6492	.000	Enclosure substrate
Enrich—Vertical access	.6589	.000	Enclosure type
Enrich—Vertical access	.3941	.05	Enclosure complexity
Enrich—Vertical access	.6027	.001	Housing

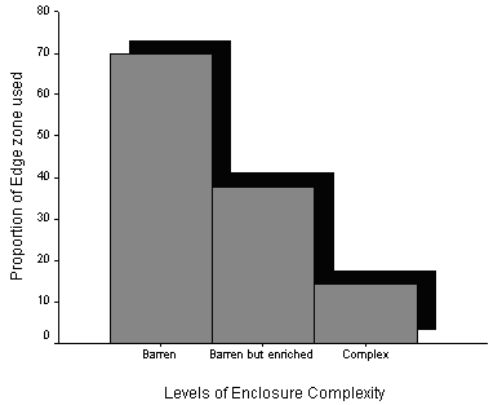

FIGURE 2 Influence of enclosure complexity on the proportion of edge zone used in captive lion-tailed macaques.

Kruskal–Wallis, $\chi^2(2, N = 9) = 12.84$, (barren), 10 (barren-but-enriched), 7 (complex), $p < .005$.

Use of the Enrich Zone

The exhibition of autogrooming, social interactions, and food-related behaviors were correlated positively with the use of the enrich zone by the study individuals (SPT, autogrooming, $P = .555$, $p < .005$; food-related behavior, $\rho = .433$, $p < .05$; social interactions, $P = .484$, $p < .01$). The use of the enrich zone also was correlated positively with access to the vertical dimension. Thus, animals housed in enclosures with access to the vertical dimension used the enrich zone more than did those housed in enclosures that had no access, corrected for rearing history, $P = .6086$, $p \leq .001$, Table 4; $U = 4.00$, $N = 8$ (no vertical access) and 18 (vertical access), $p < .001$.

Use of the Back and Other Zones

Food-related behaviors were correlated positively, and active behaviors were correlated negatively with the use of the other zone (food-related behavior, $P = .508$, $p < .01$; active behavior $P = –.475$, $p < .005$). Animals housed in enclosures that were 10 to 20m^2 in size used the back zone in significantly greater percentages than did those housed in enclosures less than 10 m^2 in size, corrected for zoo code; $P = .4051$, $p < .05$, Table 4; Kruskal–Wallis, $\chi^2(3, N = 7) = 12.77$ (< 30m^2 in size), 9 (30 to 60m^2), 4 (60–90m^2), 5 (> 90m^2), $p < .01$.

DISCUSSION

Primarily because of the presence of appropriate environmental stimuli, animals are motivated to perform a variety of behavioral patterns. Certain environmental factors, specific to a given area, stimulate the animal to exhibit certain behaviors or specific behavioral sequences. Similarly, in captive environments, certain areas within the enclosure probably stimulate the animal to exhibit particular behavioral patterns. In this study, individuals were observed to use certain enclosure zones to exhibit specific behavioral patterns: Abnormal behaviors were exhibited predominantly in the edge zone. There could be several probable explanations for this. The first author observed that animals in the edge can maximize visitor interaction—including being fed by the visitors—by spending more time in this zone closest to the visitors. Also, an animal trying to escape an enclosure tries to do so from the edge. When unable to escape from one location, an animal tries from other locations—walking or running up and down along the edge of the enclosure, trying to get out (Mason, 1991).

It has been suggested that the incidence of stereotyped behaviors in several species of primates is linked to an environmental deficit (Redshaw & Mallinson, 1991). Modern captive facilities such as Jersey Zoo, Channel Islands, United Kingdom, have recognized the need to maximize movement and natural behaviors. This has resulted in little or no stereotyped movements being exhibited by the animals housed in their enriched primate exhibits. Lack of such enrichment could give rise to abnormal behaviors such as stereotypic pacing.

The macaques in this study exhibited higher levels of social interactions and food-related behaviors in the enrich zone; they displayed lower levels of active behaviors in the back zone. The enrich zone usually consisted of features such as sleeping platforms, trees, bushes, or even a water body. The safe, upper reaches of a tree or even a sleeping platform could motivate individuals to forage and interact with one another. Similarly, free-ranging lion-tailed macaques primarily used intermediate trees and branches for foraging and feeding, although the canopy was preferred while surveying surrounding areas (Raghavan, 2001). The back zone was the area of the enclosures in front of the gate connecting to the off-exhibit enclosures where the animals usually were fed. In this area, captive lion-tailed macaques sat and waited in anticipation of being fed, leading to low levels of behavioral activity.

The edge was the most frequently used zone, with animals spending as much as 43% of their time in this zone. Individuals housed in smaller, barren cages tended to use the edge more than did those housed in large, naturalistic enclosures. The absence of appropriate environmental stimuli—which provide the necessary sensory input to develop species-specific behavior patterns—probably lead captive individuals housed in small, barren cages to depend on an external stimulus such as visitor interaction. Naturalistic enclosures, however, provide animals with an ideal environment to exhibit species-typical behavior. Animals in these enclosures spent more time in the enriched portions of the enclosure that typically included features such as trees, bushes, and water bodies (trees were not planted along the edges of the enclosures because animals can escape through the overhanging branches). Similar observations were made in a study on captive carnivores: These studies showed that large cats spent two-thirds of their time along the periphery of their enclosures (Baldwin, 1985).

CONCLUSIONS

In this study, it is evident that captive lion-tailed macaques used the edge zone—the space closest to the visitor area—when their captive environments were deficient in appropriate environmental stimuli. That the captive, lion-tailed macaque population in this study largely used the edge zone to display their behaviors suggests that primate exhibit design in Indian zoos may need to be assessed and upgraded. Several modern zoos have recognized the need for natural-

istic exhibit design. This recognition has lead to the construction of larger, more complex enclosures for several taxa—including nonhuman primates such as orangutans, gorillas, and chimpanzees. Including natural features—trees, bushes, sleeping platforms, or water bodies—provides access to the vertical dimension at varied and appropriate levels and allows movement and increasing locomotor activity in arboreal primates without their needing to use the ground.

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