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Zoo visitors as a source of enrichment to reduce abnormal behavior in captive rhesus macaques (*Macaca mulatta*) in the Central Zoo, Kathmandu, Nepal

Shailendra Sharma[a] | **Laxman Khanal**[a*] | **Smriti Shrestha**[a] | **Naresh Pandey**[a] | **Rita U. Bellanca**[b] | **Randall C. Kyes**[c]

[a]Central Department of Zoology, Institute of Science and Technology, Tribhuvan University, Kathmandu 44618, Nepal.
[b]Washington National Primate Research Center, University of Washington, Seattle, WA 98195, USA.
[c]Departments of Psychology, Global Health, and Anthropology, Center for Global Field Study, and Washington National Primate Research Center, University of Washington, Seattle, WA 98195, USA.

[*]*Corresponding author: lkhanal@cdztu.edu.np*

Abstract Overexpression of abnormal behavior among captive primates indicates poor management practices. The type, frequency, and contributing factors of abnormal behaviors vary highly across individual animals in captive settings. This study explored if sex, rearing history, the number of visitors, and type of visitor-monkey interactions affected the behaviors of captive rhesus macaques (*Macaca mulatta*) housed at the Central Zoo in Kathmandu, Nepal. Behavioral observations of six adult rhesus macaques (ages 4–12 years; two were rescued from the wild, and four were born in the zoo) were conducted using the focal animal sampling method. Observations were collected daily in two conditions (7:00–10:00 AM, without visitors present; and 10:00 AM–1:00 PM, with visitors present). During the visitor presence condition, instantaneous scan sampling also was implemented every 10 minutes to record the number of visitors and the type of visitor-monkey interaction. Resting, feeding and grooming were the most prevalent activities, and abnormal behavior ranked fifth throughout the observation period. Significant differences were observed in abnormal or stress-related behavior by sex and rearing history: females engaged in abnormal behavior more than the males, and rescued monkeys engaged in more abnormal behavior than the captive born. Abnormal behavior decreased, begging behavior increased as the number of zoo visitors and the extent of visitor-monkey interaction increased. We conclude that captive rhesus macaques respond to zoo visitors as a source of enrichment, and visitors' presence helps decrease abnormal or stress-related behavior levels.

Keywords: abnormal behavior, captivity, coping mechanism, pacing behavior, rhesus monkeys

1. Introduction

Over the decades, monkeys have been placed in captive settings for various purposes. In zoos, it is to achieve the goals of entertainment, education, conservation, animal welfare, and research (Anderson et al 2003; Fernandez et al 2009; Carr and Cohen 2015). Rhesus macaques (*Macaca mulatta*) are the second most commonly used primate species in laboratory-based research (Carlsson et al 2004). Housing conditions and behavior are important indicators of well-being and may affect research outcomes. They may also impact visitors' perceptions about the animals or their environment in a zoo setting (Westlund et al 2012). The behavioral assessment of captive monkeys is crucial to validate scientific research, promote proper management and animal welfare, whether in a laboratory environment or in zoos.

Animals in captivity may experience different types of stress compared to animals in the wild, thus increasing the concern for their health and welfare (Morgan and Tromborg 2007). Animals in a captive setting show a broad spectrum of stress-related behaviors differing from their wild counterparts. These behaviors may be referred to broadly as abnormal/stereotypic behavior (Liu et al 2006) which often includes frequent, repetitive movements such as pacing, rocking, etc. These abnormal behaviors persist among different species of animals and may indicate poor management practice (Pomerantz et al 2013). It may be a way to cope with an adverse situation, or impairment of the central nervous system during the animal's early development (Mason 2006; Roth and Cords 2020) or a result of unavoidable stress (Mason 2013; Roth and Cords 2020). Motor stereotypic behavior (MSB) is a type of full-body repetitive behavior (pacing, bouncing, flipping, twirling, swinging, head twisting, rocking) that may be due to simultaneous or overlapping factors, including past survival experiences (e.g., rearing history), intrinsic factors (e.g., temperament, origin), and current circumstances (e.g., socialization status, enrichment status), etc. (Mallapur and Choudhury 2003; Gottlieb et al 2015; Polanco et al 2021). In

captive primates, pacing is highly correlated with the length of their daily path, whereas hair plucking is highly correlated with the natural group size (Pomerantz et al 2013). Hence, primates with a larger natural range and a gregarious societal structure might be more susceptible to developing abnormal/stereotypic behavior in captivity.

In captivity and/or in the wild, different primates engage in a broad spectrum of behaviors to cope with unwanted disturbance and pressure. Primates perform pacing, stereotypic grooming, urine drinking (Khan 2013), reduced social behavior (Marty et al 2019), aggression (Chamove et al 1988), hair plucking (Reinhardt 2005), self-biting, rocking, bouncing, self-injurious behavior (Polanco et al 2021), alertness, depressive-like behavior, displacement (Troisi 2002), avoidance behavior, and self-scratching, etc. (Maréchal et al 2011; Marechal et al 2016). Accurate assessment of abnormal behaviors in captivity can help promote a healthy population of animals. Because abnormal or stress-related behaviors may indicate poor management strategies, behavioral evaluations may guide the development of improved management protocols. While studies have been conducted on different aspects of rhesus macaque behavior and ecology in the wild (e.g., diet, distribution), the assessment of abnormal or stress-related behaviors of these primates in Nepal has yet to be published.

The Central Zoo in Lalitpur, Nepal, is home to a wide diversity of wild animals. The zoo receives more than a million visitors annually (NTNC 2021). Among the many animals on exhibit at the zoo is a small group of rhesus macaques that have been one of the mainstay attractions for visitors. This study was designed to assess the prevalence of abnormal behavior in this group and to determine factors contributing to the behavior. We defined abnormal behavior broadly using the following definition: "Abnormal behavior has been observed in a wide variety of primate species housed in zoos, laboratories and sanctuaries. Behaviors can be considered abnormal if they are qualitatively different (i.e., occur in captivity but not typically in the natural setting) or quantitatively different (i.e., occur significantly more or significantly less than what is observed in the natural setting). Although abnormal behavior does not generally cause an animal harm, it can be an indicator of suboptimal environments, either past or present. Therefore, abnormal behavior is often used as a measure of wellbeing in captive nonhuman primates." (NPRC-BMC 2023). We aimed to i) identify the types and extent of abnormal behavior in these zoo-housed rhesus macaques, ii) determine if sex or rearing history has an effect, iii) examine any possible effects that the number of zoo visitors and the type of visitor-monkey feeding interactions may have on the expression of abnormal behavior.

2. Materials and Methods

2.1. Study area and study animals

The Central Zoo in Lalitpur, Kathmandu, Nepal, covers an area of 0.06 km^2 (Figure 1). It supports 38 species of mammals, 50 species of birds, 10 species of reptiles, and 15 species of fish (as of 14 July 2022). The Central Zoo, under the management of the National Trust for Nature Conservation, Kathmandu, Nepal, aims to entertain visitors and motivate researchers to conduct *ex-situ* wildlife research and expand conservation education (NTNC 2021).

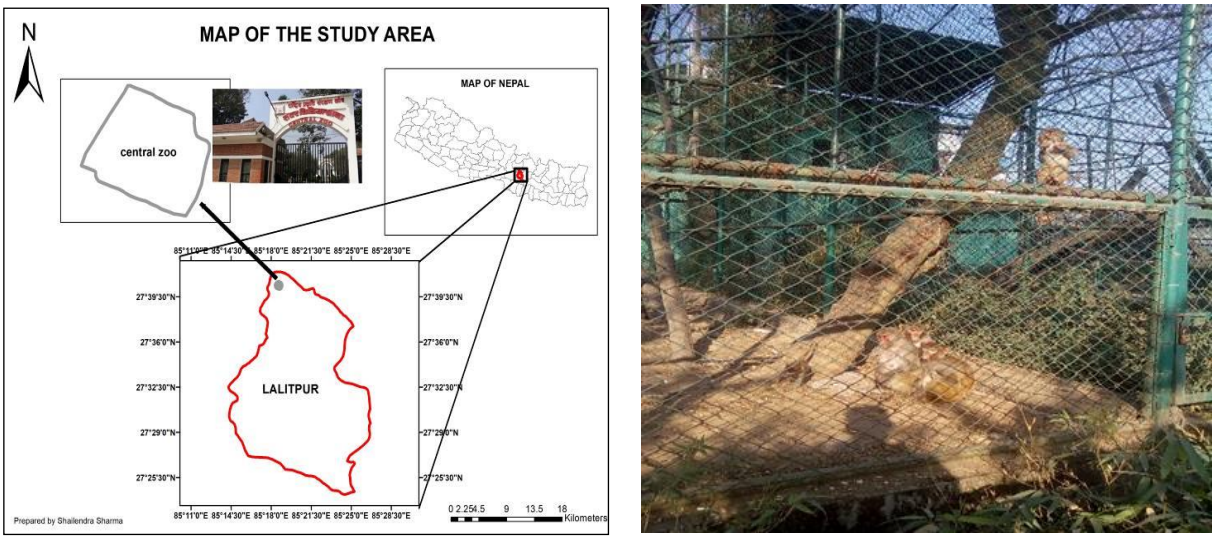

Figure 1 Map of the study area and photograph of the study site showing the enclosure for the rhesus macaques.

2.2. Rhesus macaques in the Central Zoo, Kathmandu

A group of eight rhesus macaques was housed in a fenced enclosure of about 10×20 m^2. The enclosure was constructed of iron wire fencing. Inside the enclosure, fallen logs of different species of trees with varying diameters and hanging ropes of cotton fibres having diameter of about 2 cm were provided as sources of enrichment. In the front and right sides of the cage, (the space between rhesus and landur cage), there were herbaceous plants (*Urtica diosa* and *Arundinaria* spp.), and inside the enclosure there was a wild

pear (*Pyrus pashia*) tree. The macaques were observed feeding opportunistically on fruits of the wild pear and leaves and stems of herbaceous plants. The enclosure was exposed on two sides; the front was exposed to the zoo visitors while the left side was restricted to staff access. Langurs were housed on the right side, and a concrete house comprised the back of the cage, providing a shelter for the macaques. The group of rhesus macaques included two adult males, four adult females, and two infants (Table 1). The rearing history of the macaques was divided into two categories: captive-born and rescued. Macaques born and raised inside the zoo were categorized as captive-born, while those born in the wild but raised in captivity were placed in the rescued category. Two adult females (F2 and F8) were rescued as infants, all others were captive-born (Table 1). The ages of the adults ranged from 4–12 years, and both infants were 3–4 months of age. F2 was the mother of M1 and F6; F4 was the mother of M3, and F8 had no maternal relation to any other group member. Zoo staff fed the macaques three times a day (morning, afternoon, and evening), water was provided *ad libitum*, and the enclosure was cleaned per the requirement (~3–4 times a week).

Table 1 Age/sex status of rhesus macaques with number of focal samples per individual.

ID	Sex	Rearing history	N	Identification characters
F2	Female*	Rescued	73	Adult lactating female, back with little fur and short tail.
F8	Female	Rescued	75	Adult female with Scar on her forehead and amputated tail tip.
F4	Female*	Born in captivity	74	Adult lactating female with dark brown fur.
F6	Female	Born in captivity	74	Adult female and very healthy-looking female.
M1	Male	Born in captivity	74	Adult male with tail amputated.
M3	Male	Born in captivity	73	Adult male with tail.

ID: Identification number, N: Number of focal samples, * Lactating females

2.3. Behavioral data collection

Eleven general behaviors and nine abnormal behaviors (Table 2) were recorded. Seven abnormal behaviors (pace, bounce, hair plucking, self-sucking, withdrawal, self-biting, and self-injurious behavior) were selected and revised by Polanco et al (2021), and two (Head upside-down posture and scratching) were added during the preliminary study. Behavioral observations were conducted between 7:00 AM and 1:00 PM from 01 December 2020 to 23 February 2021. The rhesus macaques were observed for three hours in the morning (7:00 AM – 10:00 AM) when no visitors were present and again for three hours (10:00 AM – 1:00 PM) when visitors were present. The peak of the number of visitors present at the enclosure typically occurred around 12:00 PM. Observations were conducted using the focal animal sampling method (Altmann 1974) with a 30-minute observation period. A focal animal was selected randomly through a lucky draw method, and at least two focal samples were collected per individual animal per day (one in the absence of visitors and one in the presence of visitors). When visitors were present, at the end of every 10 minutes, instantaneous scan sampling was used to record the number of visitors near the enclosure and the type of interaction category (Table 3). The start and end time of each predefined behavioral state performed by the focal animal were recorded using a stopwatch. The behavioral observation was terminated if the focal animal was lost from view for more than 10 minutes. When zoo staff provided food to the animals in the enclosure's indoor facilities (inside the shelter) during observation, the behavior of the focal animal was scored as feeding. Animals were provided food directly without any kind of enrichment strategy inside the enclosure. The behavior of each infant was fully dependent on its mother and other group members, therefore, they were excluded from the behavioral sampling.

2.4. Interaction categories in response to the number of visitors around the enclosure

Interaction categories were defined by the number of visitors and the probability that they would provide supplemental food during a preliminary study (five days before actual behavioral sampling started) (Table 3). The probability of the visitor-monkey feeding interactions was calculated by dividing total number of feeding interactions within a specific range of visitors around the cage and the total number of interactions throughout the focal observation period during the preliminary study. Three range classes of visitor-monkey interactions were identified- i) first quartile to median (low interaction), ii) median to mean (medium interaction), and iii) above mean (high interaction).

$$\text{Interaction Probability (P)} = \frac{\text{Number of interactions within specific range of visitors}}{\text{Total number of interactions}}$$

2.5. Statistical analysis

Initially, the data were checked for normality by implementing 'QQ' plot and the Shapiro test. The behavioral data were found to be non-normal in distribution, so non-parametric tests were employed in R version 4.2.1 (R Core Team 2022) for the complete data analysis. These data were presented as mean and standard error (Mean ± SE) of duration in minutes. A Mann–Whitney U test was used to evaluate the potential effects of sex (male and female) and rearing history (captive born and rescued) on abnormal behavior. The Kruskal–Wallis one-way ANOVA was used to analyze any differences in abnormal behavior, begging behavior, and general behavior in response to different levels

of visitor-monkey interaction (zero interaction, low interaction, medium interaction, and high interaction). The Kruskal–Wallis one-way ANOVA also was used to evaluate individual animals and the expression of abnormal behaviors. A Spearman's rank correlation coefficient was calculated to assess any potential associations between abnormal behavior and begging behavior with the number of visitors near the enclosure.

Table 2 An ethogram of general and abnormal behaviors recorded in the study.

Behavioral categories	Behavior	Description of the behavior
General behavior	Foraging	State of searching for food in the surroundings for at least 15 seconds.
	Feeding	Anything palatable is put in their mouth, hands engaged, and chewing for a considerable amount of time, at least 15 seconds.
	Playing	Teasing, pulling, pushing, and grabbing activities in between two animals or state of playing with other non-palatable material (modifier) inside the fenced enclosure for at least 10 seconds.
	Autogroo-ming	Cleaning or manipulating the hair or skin of own body for at least five seconds.
	Grooming to other	Cleaning or manipulating the hair or skin of another's body at least five seconds.
	Aggression behavior	Scream, facial expressions, bite, chase, vocal threat, flight, at least five seconds. Note: This category includes the behaviors of the aggressor and the recipient. Facial expressions included: open mouth threat, lip smacking, and bared teeth display.
	Begging	Animal sitting near fence in the presence of a visitor with one or both hands reaching out of the fence to beg for food; or sitting and looking at visitors for at least 30 seconds.
	Moving	Covering some distance in a purposeful manner or in response to other animals inside the fenced enclosure.
	Resting	Sitting or lying down without engaging in other activities for at least 15 seconds.
	Groomed	Cleaning or manipulating the hair or skin own's body by others group members for at least five seconds.
	Lactation	State of mother breast feeding to her infant for at least 15 seconds.
Abnormal behavior	Pace	Walking back and forth or in a circular pattern for at least five seconds.
	Bounce	Moving jerkily, usually up and down, for at least five seconds.
	Hair Pluck	Excessive pulling of one's hair; often leading to an over-groomed appearance.
	Self-Suck	Sucking various parts of one's body including digits, tail, and male genitalia.
	Withdrawn	Animal sitting away from group, usually acting socially withdrawn, for at least 30 seconds.
	Self-Bite	Biting oneself; usually involves bites to the arms, legs, shoulders or genitals.
	Self-Injurious Behavior	Self-biting, scratching, or some other form of self-mutilation which results in injury. If the self-biting incident did not result in injury, then it was categorized as 'self-biting'.
	Scratch	Using limbs in a rapid motion to get rid of anything on its body surface for at least five seconds.
	Head Upside-down Posture	Subject's body in upside down position, making at least a 60-degree angle between head and perch or floor for at least five seconds.

Table 3 Probability of visitor-monkey interaction observed during the preliminary study.

Interaction category	Number of visitors (range) around the enclosure	Description
Zero interaction (A)	Absence of visitors (before 10:00 AM)	Zoo opens at 10:00 AM, before that no visitors allowed.
Low interaction (LI)	0 – 3 visitors	P = 11.392 chance of visitor-monkeys interaction.
Medium interaction (MI)	4 – 9 visitors	P = 35.443 chance of visitor-monkeys interaction.
High interaction (HI)	10 or more	P = 53.165 chance of visitor-monkeys interaction.

3. Results

3.1. Abnormal behavior and activity budget of captive rhesus macaques

Throughout the observational period, the captive rhesus macaques engaged in normal behavior for 87.36% of time while 12.64% of time involved in abnormal or stress-related behavior. Out of 20 recorded behavioral states, resting accounted for the highest proportion (35.34%), followed by feeding/foraging (20.43%), grooming (15.05%), and moving (13.0%). Abnormal behavior (12.64%) ranked fifth followed by begging (2.48%), aggression (0.74%) and play (0.32%).

Nine types of abnormal or stress-related behavior were identified. Of the total abnormal behavior, pacing accounted for the highest proportion (55.61%), followed by withdrawal (27%), hair plucking (9.20%), scratching (4.12%), and self-suck (1.15%). Other observed abnormal behaviors included bounce, head upside-down, self-biting, and self-injurious behavior (Figure 2).

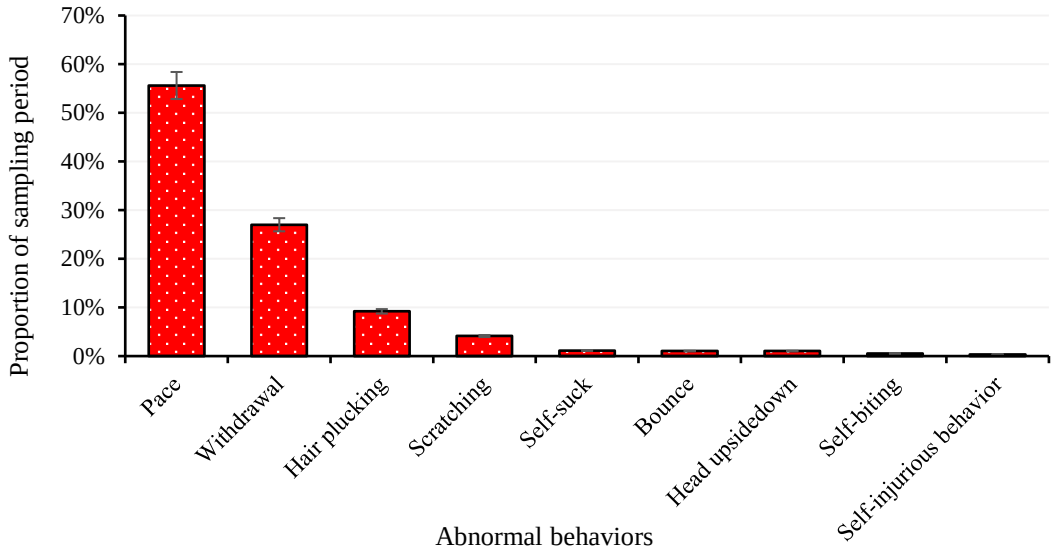

Figure 2 Abnormal behavior repertoire in captive rhesus macaques.

3.2. Abnormal behavior as a function of sex and rearing history

The Mann-Whitney U test revealed a statistically significant sex difference in overall abnormal behavior (U = 29168, $P < 0.05$). Females (4.79 ± 0.353) performed more abnormal behavior than males (1.78 ± 0.310, Figure 3a). Pacing, hair plucking, head upside-down, withdrawal, and bounce were observed significantly more in females (Table 4), while self-injurious behavior was observed more in males. Self-bite was observed solely by the females, and self-suck was observed only by the males.

Table 4 Sex-wise differences in abnormal behavior (Mean ±SE duration per focal animal sample bout of 30 minutes).

S.N.	Abnormal behavior	Male	Female	Mann Whitney U test
1	Pacing	1.28 ± 0.297	2.52 ± 0.30	U = 25325, P < 0.01
2	Hair plucking	0.0637 ± 0.0637	0.491 ± 0.0992	U = 24239, P < 0.01
3	Scratching	0.171 ± 0.0128	0.127 ± 0.0101	U = 23507, P > 0.05
4	Head upside-down	0.00148 ± 0.0014	0.0579 ± 0.0118	U = 24915, P < 0.01
5	Withdrawal	0.0605 ± 0.0298	1.50 ± 0.221	U = 25464, P < 0.01
6	Self-bite behaviors	0.00 ± 0.00	0.0298 ± 0.0168	U = 22050, P > 0.05
7	Bounce	0.0120 ± 0.0059	0.0939 ± 0.0211	U = 13134, P < 0.01
8	Self-suck	0.132 ± 0.0651	0.00 ± 0.00	U = 19388, P < 0.01
9	Self-injurious behavior	0.0229 ± 0.0213	0.0077 ± 0.0077	U = 21538, P > 0.05

Abnormal or stress-related behavior also differed significantly as a function of rearing history (U = 9609, P < 0.05). Rescued animals engaged in more abnormal behaviors (7.21 ± 0.54) than their captive-born counterparts (2.08 ± 0.23, Figure 3b).

There was a significant difference in the performance of abnormal or stress-related behavior by individual mcaques ($\chi 2 = 119.99$, df = 5, $P < 0.05$, Figure 4). Female, F2 (7.36 ± 0.81) and F8 (7.07 ± 0.71) engaged in significantly more abnormal behaviors than the rest of the group, constituting 63.52% of total abnormal behavior. Both individuals were rescued. The majority of the pacing behavior was performed by the F2 (55.94%) followed by F4 (23.64%), while female F8 performed the majority of withdrawal (most of the time she

self-isolated from the group, 92.39%), scratching (24.66%), hair plucking (46.62%) and self-biting behaviors (92.64%).

3.3. Abnormal behavior in response to the number of visitors and interaction categories

There was a negative correlation between abnormal or stress-related behavior and the number of visitors at the enclosure (r_s = -0.128, Figure 5a). A Kruskal–Wallis one-way ANOVA test revealed a significant difference in abnormal behavior by interaction category. A majority of abnormal behavior was performed during the 'visitors' absence (A) and under the low interaction (LI) category (Figure 5b).

Begging behavior was performed more during high interaction categories followed by medium and low interaction categories and was positively correlated (r_s = 0.382) with the number of visitors (Figure 6).

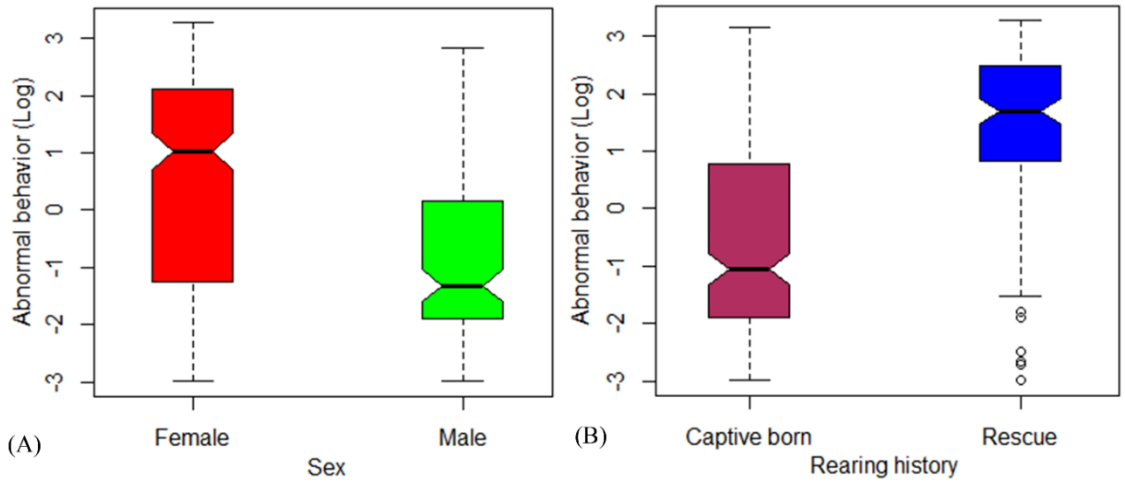

Figure 3 Abnormal behavior in response to the a) sex and b) rearing history of captive rhesus macaques.

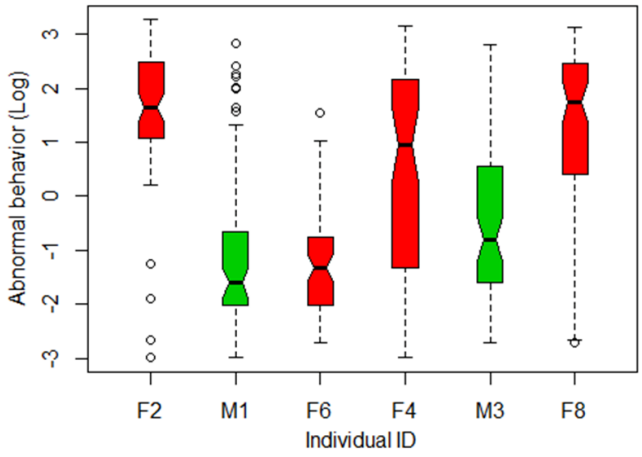

Figure 4 Abnormal behavior performed by individual rhesus macaques (Individual ID as provided in Table 1).

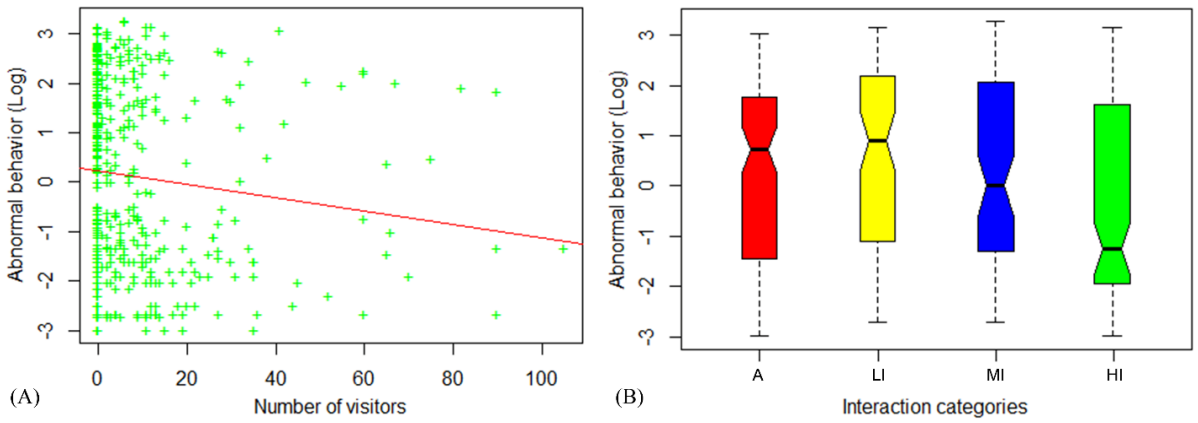

Figure 5 Abnormal behavior with a) Number of visitors around the enclosure; and b) Different interaction categories. A-visitors absent (before 10:00 AM), LI-low interaction category, MI-medium interaction category, HI-high interaction category.

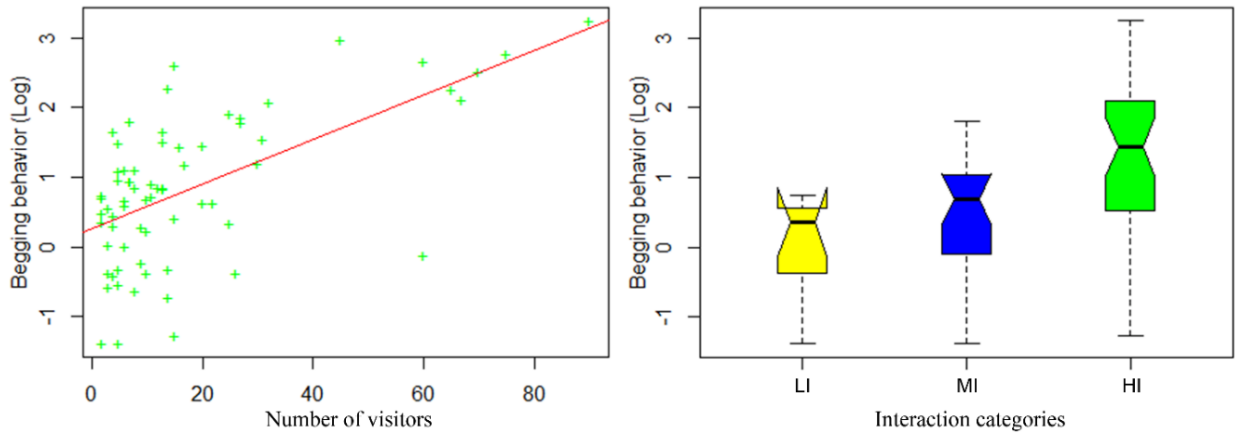

Figure 6 Begging behavior with a) Number of visitors around the enclosure and b) Under different interaction categories. Begging was only possible in the visitors' presence. LI-low interaction category, MI-medium interaction category, HI-high interaction category.

4. Discussion

The activity budget of the rhesus macaques in the Central Zoo, Kathmandu, consisted mainly of resting behavior followed by feeding/foraging, grooming, moving, abnormal or stress-related behavior, begging, aggression, and play. The higher proportion of resting versus foraging behavior could reflect a behavior adjustment to life in captivity (Jaman and Huffman 2008). Behavior in a zoo setting is related to several different factors, such as the substrate upon which the animals are living, zoo location (urban or rural), food availability (supplemented food), interaction with visitors, and the age and sex of the monkeys (Jasso Del Toro et al 2020). Jaman and Huffman (2008) reported higher resting and foraging in urban Japanese macaques (*Macaca fuscata*) related to regular supplemental food provisioning that provided a high amount of energy within a shorter span of time. Rhesus macaques engaged more feeding/foraging when a grassy substrate was provided than a gravel substrate (Beisner and Isbell 2008). In the Central Zoo, there was a lack of grassy substrate. In addition, the zoo staff and visitors supply high-energy food to the animals. Zoo management provided different types of fruits and vegitables (apple, orange, banana, carrot, cabbage, sugarcane, spinatch), nuts (peanut), bakery products (white bread), legumes (chickpea) while visitors illicitly provided highly processed packaged items (crackers, potato chips, candies, oranges, peanuts, cheeseballs, popcorn, banana, noodles etc.). These supplements might be directly associated with a higher resting rate. When monkeys inside the zoo become satiated in a shorter period, they tend to rest and groom more. According to Horwich (1980), resting in proximity facilitates social grooming.

The rhesus macaques in this study performed less aggression which might be attributed to close kinship between the group members. Kinship has been explained as a significant component in reducing aggressive interactions between group members in Vervet monkeys (*Chlorocebus pygerythrus*) (Cheney and Seyfarth 1986). Group members who are closely related tend to engage in less aggression with each other. Another reason for the lower rates of aggression might be related to the smaller number of females and the varied maturation levels among them. Samuels and Henrickson (1983) witnessed high aggression among female rhesus macaques at the California Primate Research Center when a large group of the females gained sexual maturation simultaneously during the breeding season. Multiple studies on aggression in captive primates suggested that less aggression could be due to the fact that primates do not need to worry about territory, and have scheduled food resources available to them in good quality and quantity, in small and clumped size, which leads to less competition (Isbell and Pruetz 1998, Isbell et al 1998, Mathy and Isbell 2001, Chancellor and Isbell 2008).

Among the different types of abnormal or stress-related behavior performed by this group of captive rhesus macaques, pacing, a type of motor stereotypic behavior (MSB), accounted for the highest proportion. Small housing size and a lack of proper enrichment might be the reason for the higher expression of pace behavior. Gottlieb et al (2015) and Pomerantz et al (2012) concluded that MSB was the most commonly observed abnormal behavior performed by captive primates, and inadequate enrichment resulted in the development of MSB. In this study, individuals did not perform withdrawal or scratching behavior equally. One of the adult females, F8, outperformed the others with her withdrawal and scratching behavior. Such behavior might be related to the fact that she spent most of her time self-isolating from other group members. One possible explanation for the withdrawal behavior in F8 might be related to her early rearing experience (Marriner and Drickamer 1994), given that she was rescued before coming to the zoo. Dell'Anna et al (2022) reported that individuals spending more time isolated from their group perform scratching behavior more frequently than the other members. Hair plucking in captive rhesus macaques may be correlated with rearing history and sex (Brand and Marchant (2018). Females engaged in more hair-plucking behavior than the males, and those wild-born macaques raised in the zoo engaged in more hair-plucking than captive-born primates. The two females in this study (F2 and F8) who engaged in the highest rate of hair plucking were wild-born rescues.

The female rhesus macaques engaged in more abnormal or stress-related behavior than the males. Comparable results were reported by De la Barrera Cardozo et al (2021) in female capuchins (*Sapajus* spp.) who engaged in more frequent abnormal behaviors than males. Two of the four adult female rhesus macaques in the Central zoo were rescued as infants, and two were born inside the zoo setting. Adverse experiences in infancy might have contributed to the development of abnormal behavior in these females. Supporting evidence states that the rearing method, early life experiences, and social deprivation are strongly associated with the development of abnormal behavior in zoo primates (Mallapur and Choudhury 2003; Crast et al 2014; Laméris et al 2021). The exhibition of abnormal behavior significantly differed among the six individuals, possibly due to disparate levels of early life adversity.

The negative correlation between the number of visitors and abnormal or stress-related behavior in this study might be related to behavioral diversity. As the number of visitors increased around the enclosure, the probability of visitor-monkey interaction increased. Consequently, the macaques engaged in more diverse behaviors than during the no visitors condition leading to reduced abnormal behaviors. A study on captive Diana monkeys (*Cercopithecus diana*) emphasized that monkeys engaged in more diverse behaviors when there were larger groups of visitors (Todd et al 2007).

The rhesus macaques at the Central Zoo may respond to visitors as a source of enrichment, and enrichment substantially reduces the expression of abnormal behavior in captive mammals (Shyne 2006). Cairo-Evans et al (2022) reported that as the number of visitors around the cage increased, monkeys' distance from the edge of the cage significantly decreased, suggesting that captive primates prefer to approach visitors. Captive animals may receive stimulation or enrichment from the visitor's interaction (Hosey 2008, 2013). Another study by Line et al (1991) concluded that responsive enrichment could reduce abnormal behavior in aged captive rhesus macaques more than other non responsive enrichments. Visitors might be taken as an active and responsive enrichment source, thus minimizing abnormal behavior levels in captive rhesus macaques. A study on captive chimpanzees (*Pan troglodytes*) by Baker (2004) reported that positive human-animal interactions in captivity significantly reduced the levels of abnormal behavior.

We observed that begging behavior was positively associated with the number of visitors and the high visitor-monkey interaction category. Comparable results were presented in captive lion-tailed macaques (*Macaca silenus*) by Mallapur et al (2005), who concluded that begging behavior is directly associated with the number of visitors near the cage (i.e., begging behavior significantly increased during high visitors' presence compared to during visitors' absence). Our results contradict those of Wells (2005) who emphasized that the number of visitors near the cage excites captive primates and drives them to perform more abnormal behaviors. Another study by Hashmi and Sullivan (2020) concluded that visitors and visitors' noise negatively influenced captive primates' welfare. Specifically, the number of visitors and noise significantly increased the abnormal behavior in captive primates.

Our findings were based on the behavioral observation of a small group of rhesus macaques housed in the Central Zoo. Nevertheless, it provides an important insight on the behavioral adaptations of captive macaques exposed to many visitors. Further assessments with larger sample sizes will be helpful to fully understand the mechanisms by which macaques cope with abnormal or stress-related behavior in resource-limited situations inside captive settings.

5. Conclusions

Resting constituted the highest proportion of diurnal activity in the time budget of captive rhesus macaques in the Central Zoo, followed by feeding and grooming. Abnormal behavior ranked fifth out of the total behaviors observed. Females engaged in more abnormal behavior than males. Wild-born rescued animals engaged in more abnormal behavior than their captive-born counterparts. Abnormal behavior decreased and begging behavior increased as the number of zoo visitors and the extent of visitor-monkey interaction increased. We conclude that captive rhesus macaques respond to zoo visitors as a source of enrichment, and visitors' presence helps decrease abnormal or stress-related behavior.

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Ethical considerations

This study involved non-invasive behavioral observation conducted by the first author (SS) outside the animal's enclosure. Approval for this study was provided by the Central Zoo (reference number: 327/077/078).

Conflict of Interest

The authors declare no conflict of interest.

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References

Altmann J (1974) Observational sampling study of behavior: Sampling methods. Behavior 49:227–265.

Anderson US, Kelling AS, Pressley-Keough R, Bloomsmith MA, Maple TL (2003) Enhancing the zoo visitor's experience by public animal training and oral interpretation at an otter exhibit. Environment and Behavior 35:826–841. https://doi.org/10.1177/0013916503254746.

Baker KC (2004) Benefits of positive human interaction for socially-housed chimpanzees. Animal Welfare 13:239–245.

Beisner BA, Isbell LA (2008) Ground substrate affects activity budgets and hair loss in outdoor captive groups of rhesus macaques (*Macaca mulatta*). American Journal of Primatology 70:1160–1168. https://doi.org/10.1002/ajp.20615.

Brand CM, Marchant LF (2018) Prevalence and characteristics of hair plucking in captive bonobos (*Pan paniscus*) in North American Zoos. American Journal of Primatology 80:e22751. https://doi.org/10.1002/ajp.22751.

Cairo-Evans A, Wierzal NK, Wark JD, Cronin KA (2022) Do zoo-housed primates retreat from crowds? A simple study of five primate species. American Journal of Primatology 84:e23386. https://doi.org/10.1002/ajp.23386.

Carlsson HE, Schapiro SJ, Farah I, Hau J (2004) Use of primates in research: A global overview. American Journal of Primatology 63:225–237. https://doi.org/10.1002/ajp.20054.

Carr N, Cohen S (2015) The public face of zoos: Images of entertainment, education and conservation. Anthrozoös 24:175–189. https://doi.org/10.2752/175303711x12998632257620.

Chamove AS, Hosey GR, Peter S (1988) Visitors excite primates in zoos. Zoo Biology 7:359–369. https://doi.org/10.1002/zoo.1430070407

Chancellor RL, Isbell LA (2008) Punishment and competition over food in captive rhesus macaques, *Macaca mulatta*. Animal Behaviour 75:1939–1947. https://doi.org/10.1016/j.anbehav.2007.11.007

Cheney DL, Seyfarth RM (1986) The recognition of social alliances by vervet monkeys. Animal Behaviour 34:1722–1731. https://doi.org/10.1016/S0003-3472(86)80259-7

Crast J, Bloomsmith MA, Perlman JE, Meeker TL, Remillard CM (2014) Abnormal behaviour in captive sooty mangabeys. Animal Welfare 23:167–177. https://doi.org/10.7120/09627286.23.2.167

De la Barrera Cardozo M, Chiba de Castro WA Aguiar LM (2021) Stress behaviors in captive robust capuchins: Effects of humidity, visitors, management and sex. American Journal of Primatology 83:e23265. https://doi.org/10.1002/ajp.23265

Dell'Anna F, Schino G, Aureli F (2022) Anxiety in Geoffroy's spider monkeys (*Ateles geoffroyi*): Can scratching be used as an indicator? American Journal of Primatology 84:e23373. https://doi.org/10.1002/ajp.23373

Fernandez EJ, Tamborski MA, Pickens SR, Timberlake W (2009) Animal–visitor interactions in the modern zoo: Conflicts and interventions. Applied Animal Behaviour Science 120:1–8. https://doi.org/10.1016/j.applanim.2009.06.002

Gottlieb DH, Maier A, Coleman K (2015) Evaluation of environmental and intrinsic factors that contribute to stereotypic behavior in captive rhesus macaques (*Macaca mulatta*). Applied Animal Behavior Science 171:184–191. https://doi.org/10.1016/j.applanim.2015.08.005

Hashmi A, Sullivan M (2020) The visitor effect in zoo-housed apes: The variable effect on behaviour of visitor number and noise. Journal of Zoo and Aquarium Research 8:268–282. https://doi.org/10.19227/jzar.v8i4.523

Horwich RH (1980) Behavioral rhythms in the Nilgiri langur, *Presbytis johnii.* Primates 21:220–229. https://doi.org/10.1007/bf02374035

Hosey G (2008) A preliminary model of human–animal relationships in the zoo. Applied Animal Behaviour Science 109:105–127. https://doi.org/10.1016/j.applanim.2007.04.013

Hosey G (2013) Hediger revisited: How do zoo animals see us? Journal of Applied Animal Welfare Science 16:338–359. https://doi.org/10.1080/10888705.2013.827916

Isbell LA, Pruetz JD (1998) Differences between vervets (*Cercopithecus aethiops*) and patas monkeys (*Erythrocebus patas*) in agonistic interactions between adult females. International Journal of Primatology 19:837–855. https://doi.org/10.1023/a:1020393329574

Isbell LA, Pruetz JD, Young TP (1998) Movements of vervets (*Cercopithecus aethiops*) and patas monkeys (*Erythrocebus patas*) as estimators of food resource size, density, and distribution. Behavioral Ecology and Sociobiology 42:123–133. https://doi.org/10.1007/s002650050420

Jaman MF, Huffman MA (2008) Enclosure environment affects the activity budgets of captive Japanese macaques (*Macaca fuscata*). American Journal of Primatology 70:1133–1144. https://doi.org/10.1002/ajp.20612

Jasso Del Toro C, Mondragon-Ceballos R Gutierrez-Garcia G (2020) Potential food availability influences social interactions of young individuals in a Neotropical primate (*Alouatta palliata*). Folia Primatologica 91:31–47. https://doi.org/10.1159/000501408.

Khan BN (2013) Impact of captivity on social behaviour of chimpanzee (*Pan troglodytes*). The Journal of Animal and Plant Sciences 23:779–785.

Laméris DW, Staes N, Salas M, Matthyssen S, Verspeek J, Stevens JMG (2021) The influence of sex, rearing history, and personality on abnormal behaviour in zoo-housed bonobos (*Pan paniscus*). Applied Animal Behaviour Science 234:105178. https://doi.org/10.1016/j.applanim.2020.105178

Line SW, Morgan KN, Markowitz H (1991) Simple toys do not alter the behavior of aged rhesus monkeys. Zoo Biology 10:473–484. https://doi.org/10.1002/zoo.1430100606

Liu J, Chen Y, Guo L, Gu B, Liu H, Hou A, Liu X, Sun L, Liu D (2006) Stereotypic behavior and fecal cortisol level in captive giant pandas in relation to environmental enrichment. Zoo Biology 25:445–459. https://doi.org/10.1002/zoo.20106

Mallapur A, Choudhury BC (2003) Behavioral abnormalities in captive nonhuman primates. Journal of Applied Animal Welfare Science 6:275–284. https://doi.org/10.1207/s15327604jaws0604_2

Mallapur A, Sinha A, Waran N (2005) Influence of visitor presence on the behaviour of captive lion-tailed macaques (*Macaca silenus*) housed in Indian zoos. Applied Animal Behaviour Science 94:341–352. https://doi.org/10.1016/j.applanim.2005.02.012

Marechal L, MacLarnon A, Majolo B, Semple S (2016) Primates' behavioural responses to tourists: Evidence for a trade-off between potential risks and benefits. Scientific Reports 6:32465. https://doi.org/10.1038/srep32465

Maréchal L, Semple S, Majolo B, Qarro M, Heistermann M, MacLarnon A (2011) Impacts of tourism on anxiety and physiological stress levels in wild male barbary macaques. Biological Conservation 144:2188–2193. https://doi.org/10.1016/j.biocon.2011.05.010

Marriner LM, Drickamer LC (1994) Factors influencing stereotyped behavior of primates in a zoo. Zoo Biology 13:267–275. https://doi.org/10.1002/zoo.1430130308

Marty PR, Beisner B, Kaburu SSK, Balasubramaniam K, Bliss-Moreau E, Ruppert N, Sah SAM, Ismail A, Arlet ME, Atwill ER, McCowan B (2019) Time constraints imposed by anthropogenic environments alter social behaviour in longtailed macaques. Animal Behaviour 150:157–165. https://doi.org/10.1016/j.anbehav.2019.02.010

Mason G (2006) *Stereotypic behaviour in captive animals: Fundamentals and implications for welfare and beyond*. In: G. Mason and J. Rushen (Eds.) Stereotypic animal behaviour: Fundamentals and applications to welfare. CAB International New York, NY 10016 USA,. pp 325–356.

Mason G (2013) Why do polar bears and other captive carnivores perform stereotypic behavior? Canada Research Chair in Animal Welfare, University of Guelph, Ontario, Canada. pp:5.

Mathy JW, Isbell LA (2001) The relative importance of size of food and interfood distance in eliciting aggression in captive rhesus macaques (*Macaca mulatta*). Folia Primatologica 72:268–277. https://doi.org/10.1159/000049948

Morgan KN, Tromborg CT (2007) Sources of stress in captivity. Applied Animal Behaviour Science 102:262–302. https://doi.org/10.1016/j.applanim.2006.05.032

National Primate Research Centers Behavioral Management Consortium (2023) BMC – Abnormal Behavior Ethogram. Available online at:

https://nprcresearch.org/primate/behavioral-management/abnormal-behavior-ethogram.php. Accessed on: January 18, 2023.

NTNC (2021) Annual Report 2021. National Trust for Nature Conservation, Kathmandu, Nepal. https://www.ntnc.org.np/publication/annual-report-2021. Accessed on: October 19, 2022.

Polanco A, McCowan B, Niel L, Pearl DL, Mason G (2021) Recommendations for abnormal behaviour ethograms in monkey research. Animals 11:1–23. https://doi.org/10.3390/ani11051461

Pomerantz O, Meiri S, Terkel J (2013) Socio-ecological factors correlate with levels of stereotypic behavior in zoo-housed primates. Behavioural Processes 98:85–91. https://doi.org/10.1016/j.beproc.2013.05.005

Pomerantz O, Paukner A, Terkel J (2012) Some stereotypic behaviors in rhesus macaques (*Macaca mulatta*) are correlated with both perseveration and the ability to cope with acute stressors. Behavioral Brain Research 230:274–280. https://doi.org/10.1016/j.bbr.2012.02.019

Reinhardt V (2005) Hair pulling: A review. Laboratory Animals 39:361–369. https://doi.org/10.1258/002367705774286

Roth AM, Cords M (2020) Zoo visitors affect sleep, displacement activities, and affiliative and aggressive behaviors in captive Ebony langurs (*Trachypithecus auratus*). Acta Ethologica 23:61–68. https://doi.org/10.1007/s10211-020-00338-7

Samuels A, Henrickson RV (1983) Outbreak of severe aggression in captive *Macaca mulatta*. American Journal of Primatology 3:277–281. https://doi.org/10.1002/ajp.1350050314

Shyne A (2006) Meta-analytic review of the effects of enrichment on stereotypic behavior in zoo mammals. Zoo Biology 25:317–337. https://doi.org/10.1002/zoo.20091

Todd PA, Macdonald C, Coleman D (2007) Visitor-associated variation in captive Diana monkey (*Cercopithecus diana diana*) behaviour. Applied Animal Behaviour Science 107:162–165. https://doi.org/10.1016/j.applanim.2006.09.010

Troisi A (2002) Displacement activities as a behavioral measure of stress in nonhuman primates and human subjects. Stress 5:47–54. https://doi.org/10.1080/102538902900012378

Wells DL (2005) A note on the influence of visitors on the behaviour and welfare of zoo-housed gorillas. Applied Animal Behaviour Science 93:13–17. https://doi.org/10.1016/j.applanim.2005.06.019

Wessling EG, Kuhl HS, Mundry R, Deschner T, Pruetz JD (2018) The costs of living at the edge: Seasonal stress in wild Savanna-dwelling chimpanzees. Journal of Human Evolution 121:1–11. https://doi.org/10.1016/j.jhevol.2018.03.001

Westlund K, Fernstrom AL, Wergard EM, Fredlund H, Hau J, Spangberg M (2012) Physiological and behavioural stress responses in cynomolgus macaques (*Macaca fascicularis*) to noise associated with construction work. Laboratory Animals 46:51-58. https://doi.org/10.1258/la.2011.011040