

Understanding the efficacy of enrichment intervention from
behavioural responses in captive Sloth Bears

by

Mukul Sudhakar
Enrolment no: 50BB22A73012

Dissertation Thesis

Submitted to Academy of Scientific and Innovative Research

For the partial fulfilment for the degree

Master of Science
in
Wildlife Science

Under the supervision of

Supervisor: Dr. Lallianpuii Kawlni,
Scientist-D

Co- Supervisor: Dr. Sutirtha Dutta
Scientist - E



भारतीय वन्यजीव संस्थान
Wildlife Institute of India



July 2024

DECLARATION

I hereby declare that the work conducted under the thesis entitled “Understanding the efficacy of enrichment intervention from behavioural responses in captive Sloth Bears”, is a record of original and independent research work done by me and subsequently submitted for the award of the degree of Master’s in Wildlife Science at the Academy of Scientific and Innovative Research. This research work has been carried out under the guidance and supervision of Dr. Lallianpuii Kawlni, Scientist-D, and co-supervision of Dr. Sutirtha Dutta, Scientist-E of Wildlife Institute of India, Dehradun. The work has not formed the basis for the award of any other degree, diploma, or any other qualification. I also declare that the thesis embodies my own work, analysis, observation, understanding and the particulars given in it are true to the best of my knowledge.



Mukul Sudhakar

Enrolment No: 50BB22A73012

Place: Dehradun

Date: 30/06/2024



Dr. Lallianpuii Kawlni
Supervisor



Dr. Sutirtha Dutta
Co-supervisor

CERTIFICATE

This is to certify that the thesis by Mukul Sudhakar entitled “Understanding efficacy of enrichment intervention through behavioural responses in captive sloth bears” is an original and independent research work submitted to the Academy of Scientific and Innovative Research, for the award of the degree of Master’s in Wildlife Science.

Mukul Sudhakar has put one semester of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.



Dr. Lallianpuii Kawlni

Supervisor



Dr. Ruchi Badola

Dean

Faculty of Wildlife Science

CERTIFICATE OF PLAGIARISM CHECK

It is certified that the Master's dissertation thesis titled "Understanding efficacy of enrichment intervention through behavioural responses in captive sloth bears" submitted by Mukul Sudhakar has been examined by us for plagiarism check as per UGC (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations. The following inferences are drawn from this check:

- a) Thesis has significant new work/knowledge as compared to already published work or work under consideration for publication elsewhere.
- b) No sentence, equation, diagram, table, paragraph or section is found to have been copied verbatim from previous work unless it was placed under quotation marks and the source was duly cited.
- c) The work presented is original work of the author (i.e. there is no plagiarism) and there is no fabrication of data or result by manipulating research materials, equipment or processes, or by changing or by omitting data or results such that the research is not accurately represented.

The similarity indices for the individual chapters as reported by the software iThenticate are as follows:

S. No	Chapter	iThenticate similarity index
1.	Chapter 1: Introduction	7 %
2.	Chapter 2: Methods	0%
3.	Chapter 3: Objectives	0%
4	Chapter 4: Results	0%
Overall		5%



Dr. Manohar Pathak

Librarian



Dr. Lallianpuii Kawlni

Supervisor

ACKNOWLEDGEMENT

I am deeply grateful to my supervisor, Lallian ma'am, whose guidance and support were pivotal in shaping this research. Your insightful feedback and encouragement have been instrumental in every stage of this study.

I extend my heartfelt thanks to Sutirtha sir for their valuable advice, insights and explanations, and constructive criticism that helped refine this research and broaden its scope.

I would like to acknowledge and appreciate the contributions of my peers, all 20 of them whose collaboration and discussions enriched my understanding and perspective on sloth bear enrichment practices.

Special thanks go to the Mumbai Zoo and Delhi Zoo for granting me access to their facilities and for their cooperation and assistance during data collection, without which this study would not have been possible. Special thanks to Abhishek Satam, Sanjay Tripathi, Manoj Kumar and Abhishek Sir for their unwavering support and enthusiasm during and after the work.

I am indebted to my family for their unwavering support, understanding, and patience throughout this academic journey. Their encouragement and belief in me kept me motivated during challenging times.

Lastly, I express my gratitude to my friends for their encouragement, understanding, and for being a source of positivity and laughter, which provided much-needed balance during intense periods of research.

Each of these individuals and organisations has played a crucial role in the completion of this dissertation on sloth bear enrichment, and for that, I am profoundly thankful.

Table of Contents

EXECUTIVE SUMMARY	11
INTRODUCTION	13
A. Target Species	14
B. Background and Context	15
C. Welfare	16
D. Literature Review	18
OBJECTIVE	20
A) To understand the effect of novel enrichment intervention on behavioural repertoire of captive sloth bears.	20
B) To measure the changes in enclosure utilisation of the targeted species with respect to pre- and post- novel enrichment interventions.	20
C) To understand how behavioural response affects welfare in captive sloth bears.	20
METHODOLOGY	20
A) Sampling Methods	21
B) Scan Sampling.	22
C) Study design	24
D) Study Area	26
ANALYSIS	30
A. Species behaviour diversity:	30
B. Enclosure usage diversity:	30
C. Behavioural response on Welfare:	31
RESULT	32
I. Behaviour Diversity	32
II. Enclosure usage	34
III. Activity Budget	38
VI. Welfare	43
DISCUSSION	50
REFERENCE	56

List of Figures

Fig: 1 Pitfall feeder for feeding enrichment.....	22
Fig: 2 Sloth Bear enclosure, Mumbai Zoo	26
Fig: 3 Feed for Enrichment, Mumbai Zoo.....	26
Fig: 4 Hind – Rest, Proximal line, Shiva.....	30
Fig: 5 Comparison of mean and 95% CI (error bars) of Shannon Diversity index computed on daily frequency of behaviours across individual Sloth bears between control (red) and enrichment (cyan) phases.....	31
Fig: 6 Comparison of mean and 95% CI (error bars) for enclosure utilization computed on daily frequency of zones across individual Sloth bears between control (red) and enrichment (cyan) phases in Delhi.....	35
Fig: 7 Comparison of mean and 95% CI (error bars) for enclosure utilization computed on daily frequency of zones across individual Sloth bears between control (red) and enrichment (cyan) phases in Mumbai.....	35
Fig: 8 Fig: 8 Heatmap -The following columns reflect the various enclosure zones. The values in each column indicate the proportion of scans for each individual in each zone for the specific individual one for TRT 1 (enrichment) and another for TRT 0 (control) in Delhi.....	37
Fig: 9 Heatmap -The following columns reflect the various enclosure zones. The values in each column indicate the proportion of scans for each individual in each zone for the specific individual one for TRT 1 (enrichment) and another for TRT 0 (control) in Mumbai.....	38

Fig: 10 Activity budget for Delhi	41
Fig: 11 Activity Budgets for Mumbai site for each individual in control and treatment respectively	45
Fig: 12 Biplot, PC1 and PC2 The original variables and principal components are shown in a biplot. The original variables are represented by the arrows, while the observations are represented by the points. The arrows' length and direction show how each variable contributes to the principal components.....	46
Fig:13 Linear Mixed Model showing the effect of treatment and group (Zoo) on PC2 Scores, with individual sex as a random effect.	47
Fig: 14 Predicted probability of inactivity in both zoo in absence of enrichment and individual = 0.....	49
Fig: 15 Predicted probability of Stereotypy in both zoo in absence of enrichment and individual = 0.....	50

List of Tables

TABLE: 1 Comparison of mean and 95% CI of Shannon Diversity index computed on daily frequency of behaviours across individual Sloth bears between control and enrichment phases.....	33
TABLE: 2 Comparison of mean and 95% CI of Proportion of behaviors – Active, Inactive and and Stereotypy computed on daily frequency of behaviours across individual Sloth bears between control and enrichment phases.....	40
TABLE: 3 This table represents the principal component analysis (PCA) loadings for five behavioral parameters (Active, Stereotypy, Inactive, Shannon, and behavior_diversity) across five principal components (PC1 to PC3).....	46
TABLE: 4 Inactivity Models consisting individual traits as a random effect and zoo and Treatment as fixed effects	48
TABLE: 5 Inactivity Model Selection – Interactive effect of both enrichment and zoo and individual as a random effect.....	48
TABLE: 6 Stereotypy Models consisting individual traits as a random effect and zoo and Treatment as fixed effects.....	49
TABLE: 7 Stereotypy Model Selection – Additive effect of both enrichment and zoo and individual as a random effect.....	50

List of Maps

MAP: 1 Delhi zoo layout, (Reference – CZA.nic.in).....24

MAP: 2 Mumbai Zoo, Layout.....25

EXECUTIVE SUMMARY

In this study, I tried to understand how enrichment activities affect the behavior and well-being of captive sloth bears. The study aimed to determine if enrichment intervention helps bears exhibit more natural behaviors and reduce stress-related behaviors, improving their overall welfare.

Six Sloth bears were studied in two zoos, Delhi and Mumbai, and were observed before and after introducing enrichment intervention in the form of Pitfall feeder. These Feeders, helps in providing novel feeding methods and interactive object, and were designed to encourage the bears to engage in natural behaviors like exploring, digging and foraging etc. The study used various parameters to track changes in the bears' behavior, including different activity levels such as Proportion of time Active, Inactive and Stereotypic, usage of different zones of their enclosures, and behavior diversity. A comprehensive welfare index was computed from these parameters using Principal Component Analysis.

The results showed that enrichment activities had some positive effect on the bears' behavior. The bears became more active and explored more areas of their enclosures after the enrichment activities were introduced. However, the response varied among individual bears, with few showing a decline in stress-related behaviors, while others did not exhibit significant changes or even showed an increase in such behaviors. This variability highlights the need for tailored enrichment plans that cater to the unique needs of each bear.

The study also found differences between the two zoos, wherein markers of behavioural well-being were better in Mumbai Zoo compared to Delhi Zoo. This was attributed to better management practices and more complex enclosures in Mumbai. Thus, factors such as long-term management practices and the overall complexity of the enclosures play a crucial role in the well-being of captive sloth bears.

In conclusion, while enrichment activities are beneficial for captive sloth bears, their design and implementation should be tailored to the individual needs of each bear to maximise their positive impact on well-being. This research supports the importance of regular and varied enrichment intervention in zoos to increase the wellbeing of captive animals. However, it also underscores the need for comprehensive management practices that ensure the long-term welfare of these animals consisting of enrichment plans and studies to be incorporated in the management plan of the zoos.

INTRODUCTION

India is a country with rich biodiversity; home to numerous mega-vertebrates that thrive in its national parks and attract international and local tourists seeking to experience its natural ecosystems. Despite this, a significant portion of the Indian population resides in rapidly expanding urban areas, where their primary encounters with biodiversity occur in zoos. These zoos, many of which were established by British colonial rulers in the 19th century, play a pivotal role in wildlife conservation, education, research, and recreation for local communities (Kevin Hannam, 2010).

Captive institutions offer a controlled environment for management, study, and understanding of various species including their behaviour, nutrition, and health (Brown et al., 2017). For example, studies and breeding programs are being conducted by the Smithsonian's National Zoo and Conservation Biology Institute to ensure the sustainability of sloth bear populations and make the public aware of their ecological significance and conservation status. These programs are vital as they maintain genetically diverse captive populations, raise awareness, and address challenges faced by sloth bears in both wild and captivity (Brown et al., 2017).

In recent years, the wellbeing of animals in captivity has become a significant concern. These captive environments vary encompassing zoological institutions, laboratory environments, rescue and rehabilitation centres and private ownerships. Enrichment plays a vital role in the well-being of captive animals by stimulating their natural behaviours and enhancing their overall quality of life. Understanding the efficacy of enrichment interventions in these settings is crucial for improving the welfare of animals and ensuring their conservation. This thesis aims to explore the behavioural responses of sloth bears to enrichment interventions, and shedding light on the effectiveness of these measures in promoting their well-being and informing future conservation strategies.

A. Target Species

The Sloth bear belongs to the family Ursidae in India along with four species of bear, i.e. the Asiatic black bear, the Himalayan brown bear, and the Sun bear. *Ursine* have an omnivorous diet comprising fruits, insects, and small vertebrates. (Smith et al., 2015). Sloth bears are solitary, native to the Indian subcontinent (Akhtar et al., 2004). In the wild they lack stereotypic behaviour and they showcase a diverse range of behaviours such as denning, scavenging, foraging and climbing (Joshi et al., 1999). Sloth bears' unique dietary habits include using their large, flexible lips to suck up insects, a behaviour not seen in other bear species (Williams et al., 2015). This dietary flexibility underscores their critical ecological roles, such as seed predation and dispersal, which are vital for maintaining forest ecosystems (Johnson et al., 2017).

Bears have excellent memory, which helps them in tracking food sources throughout the year (Thompson et al., 2016). This foraging behaviour often results in conflict with humans, especially in regions where their habitats overlap with human-dominated landscapes comprising agricultural fields or settlements (Kumar et al., 2018). Among these four species, the sun bear, because of its more secluded habitat preferences, generally avoids human conflict; the other three species frequently encounter humans, leading to potential conflicts (Anderson et al., 2019).

The sloth bear, in particular, is identifiable by its shaggy coat and distinctive V-shaped mark on its chest (Patel et al., 2014). The average-sized bear weighs from 60 to 100 kilograms, with sexual size dimorphism meaning males are larger in size when compared to females, sometimes reaching up to 140 kilograms (Patel et al., 2014). The sloth bear's appearance has earned it comparisons to the sloth, although the two are not closely related.

B. Background and Context

Historically, there has been a significant increase in the number of sloth bears in captive environments, primarily zoos, rehabilitation centres, and other housing facilities. Sloth bears have been exploited in circuses and by street performers known as *madaris* in India, where they were forced to perform tricks for entertainment (Rao et al., 2010) and growing threats like human – bear conflict. As dim-sighted animals, sloth bears can become aggressive when alarmed, standing on their hind legs and using their sharp claws and canines to bite. This defensive behaviour contributes to human-wildlife conflict. The rise in captive sloth bears is a growing welfare concern, as they are removed from their natural habitats and often exhibit behavioural and physiological responses in the form of stereotypic behaviours like pacing and head bobbing, indicative of stress and boredom (Francois et al., 2016). These behaviours usually are expressed due to confinement and barren environments in captivity.

Enrichment intervention is a valuable approach to aid the welfare of animals inhabiting a captive environment. These interventions are any manipulations that provide opportunities to engage in natural behaviours and experience diverse stimuli, including physical, social, and cognitive engagement, to improve welfare and be as close as possible to their wild counterparts. Such intervention could be as simple as a novel object and as complex as providing a natural habitat as observed in the wild settings. All of these natural behaviours, and the factors that cause these behaviours to manifest in a species in the wild should be replicated as closely as possible to the wild when designing enclosures or enrichment. (LaFollette, 2023).

There is increasing literature on enrichment and its positive impacts on the behaviour of sloth bears in captivity. For example, studies show enrichment positively impacts behavioural and physiological stress in captive animals, enhancing well-being (Loraine et al., 2007). Ongoing enrichment may also reduce stereotypical behaviours in the long term (Ewa Galaj et al., 2020). By providing opportunities for natural, instinctive behaviours and

alleviating boredom, enrichment benefits sloth bear welfare (Goswami et al., 2016). Current evidence indicates that enrichment promotes natural, active behaviours in sloth bears (Mindy et al. et al., 2023). However, their specific needs and preferences should direct enrichment program design. Further research is required to evaluate enrichment's impacts on sloth bears and determine optimal enrichment types for the species.

For sloth bears specifically, introducing devices like honey logs, underground food pipes, and wobbling boxes increased active behaviours and decreased abnormal behaviours. Studies on enrichment preferences have shown that bears preferred the honey-log enrichment (M. Veeraselvam et al., 2013). These and similar findings indicate that enrichment interventions are effective tools against captivity.

C. Welfare

Animal welfare as a concept has evolved over time, especially with regard to captive animals. In the past, the main purpose of zoos was entertainment and display with no regard for welfare (Maple & Perdue, 2013). The traditional definition of animal welfare focused on the absence of negative indicators such as pain, discomfort, and disease, which is not a comprehensive definition. With changing times and advancements, the focus has shifted towards conservation, research, and education, emphasising the primary objective of ensuring animal welfare.

Captivity frequently impairs welfare due to small, barren enclosures that lack natural complexity and stimulation, eliciting repetitive behaviours. To address the impacts of captivity on animals. Evaluating and enhancing animal welfare in captivity is crucial and requires immediate attention and it is imperative that methods used should assess both positive and negative welfare indicators (Wolfensohn et al., 2018).

The current definition of welfare also emphasises its relation to the individual, which means that welfare can differ among different members of the same species, even when they are exposed to the identical conditions (Hosey et al., 2009).

Individuals in zoo animals, who often come from very diverse backgrounds, may differ greatly in their previous life experiences, which can influence their ability to cope with certain challenges; by using each animal as its own control, an individual's welfare can be tracked in response to changes in its environment, and thus, an individual's welfare can be measured. (Sonya P. Hill et al 2009).

- Various aspects of welfare include:

Physical Health: This includes proper nutrition, veterinary care, and an environment that allows for the expression of natural behaviours. According to the Five Freedoms framework stated by Mellor - “Animals should be free from hunger, thirst, discomfort, pain, injury, and disease”. (Mellor, 2016).

Natural Behaviour Expression: Ensuring animals can exhibit behaviours typical of their species, such as foraging, socialising, and mating. Providing an environment that mimics their natural habitat as closely as possible is essential for this aspect of welfare (Carlstead & Shepherdson, 2000).

Freedom from Fear and Distress: Ensuring that the animals do not experience unnecessary fear or distress, which can be achieved by minimising stressful interactions and disturbances (Broom, 1991).

This study evaluates the animal welfare indices by determining the efficacy of enrichment intervention through behaviour response in Captive Sloth Bears.

D. Literature Review

The Captive environment can cause significant challenges for the welfare of the animal. This often leads to expression of abnormal behaviours termed as stereotypies (Carlstead et al., 1991; Forthman & Bakerman, 1992). The use of enrichment intervention has become a crucial aspect in captive facilities to tackle such abnormal behaviours and promote natural behaviour in captive animals (Gupta et al., 2013). This literature review helps in examining the efficacy of enrichment interventions through behavioural responses in species which started to receive attention due to its unique characteristics and increasing population in captive facilities.

Feeding enrichment is a component of environmental enrichment in which captive animals are provided with the feed in a manner which instigate their natural behaviour with an objective to influence mental and physical activity. Similarly for sloth bears, a species known for its unique foraging behaviour and diet, feeding enrichment can play an important role.

Numerous research has looked at the effects of various enrichment interventions on the behaviour of captive sloth bears. One of the most prevalent enrichments is the implementation of novel feeding methods such as honey-filled wooden logs which greatly reduced stereotypic pacing while stimulating investigatory and exploratory behaviours in captive sloth bears such as American black bears (*Ursus americanus*), and brown bears (*Ursus arctos*) (Carlstead et al. (1991). Similarly, Forthman and Bakeman (1992) reported that the introduction of ice blocks consisting of diverse food items such as fish, peanuts, bread, raisins, peanut butter, and sunflower seeds influenced the behaviour positively for captive sloth bears. The Asiatic black bear (*Ursus thibetanus*) and the Malayan sun bear (*Helarctos malayanus*) are also have been studied concluding that feeding-based enrichment reduces stereotypic behaviours and promotes more natural foraging activities (Vickery & Mason, 2004; Babitz et al., 2023).

Importance of Feeding Enrichment

Sloth bears possess unique foraging habits, utilising their long claws and flexible lips, along with the ability to voluntarily close their nostrils, to extract insects and food items from hard-to-reach places like crevices. (Altman, 1999). Hence introducing feeding enrichment to bears in captivity provides an opportunity to carry out natural behaviours. The inability to perform these behaviours in captivity can lead to stress, boredom and the development of stereotypic behaviour. The objective of feeding enrichment is to present challenges which are similar to and associated with natural foraging, which can directly affect both mental and physical activity. (Veeraselvam et al., 2001)

Gaps in Existing Knowledge

1. The abundant numbers of sloth bears in the wild and captivity do not attract the same novelty of studies as other charismatic species. It is necessary to study animal welfare, especially in captivity, due to the inflating numbers of individuals in zoological institutes by numerous factors such as HWC and performing industries. (Brij K. Gupta et al. 2005).
2. While certain captive establishments in India adhere to elevated criteria, most others do not meet the equivalent level of distinction as global establishments. To guarantee the welfare of animals that have been removed from their natural habitat, employing scientific study to enhance captive establishment management is essential.
3. Numerous studies present captivity and its effects on animals through behavioural responses and are limited by it. Most studies on animal welfare in captivity rely on the absence of stereotypical behaviour, which does not necessarily indicate the animal's health. Various indices, including behavioural patterns, frequencies, contexts, and physiological measures, should be examined together (Sonya P et al.,2009) (Ceara Byrne et al.,2020).

4. Abundant studies focus on behavioural responses such as behaviour diversity and stereotypy separately on a single variable such as enclosure usage, visitation of public, etc. (Marina et al. et al., 2018).
5. Few studies utilising more than one animal welfare index are on species like the Asiatic Lion (Goswami et al., 2021). In contrast, some studies on ursids are present on captive sun bears in Malaysia (Siti Sarayati et al., 2016).

OBJECTIVE

A) To understand the effect of novel enrichment intervention on behavioural repertoire of captive sloth bears.

B) To measure the changes in enclosure utilisation of the targeted species with respect to pre- and post- novel enrichment interventions.

C) To understand how behavioural response affects welfare in captive sloth bears.

METHODOLOGY

Selecting appropriate sampling techniques is essential based on the observer's objective in the behaviour ecology field, as it is relatively difficult to observe and record every behaviour of every individual with utmost precision. Sampling techniques aid in providing the answer to such complications; according to the objective or question to be answered, the sampling method is selected, varying in the interest of behaviour. In general, behaviour can be categorised and recorded in two ways-

1. Behavioural states - Behaviours spanning for some duration and usually mutually exclusive. Example - Rest and Locomotion are mutually exclusive and could be classified as either of one at a given time for a single animal. These are often timed and represented as a proportion of time an observer witnessed an animal exhibit a behaviour when contrasted with total time sampling for all behaviour states. For example, from 100 hours of behavioural data on domestic cats, 38% is recorded as

Locomotion, 12% as foraging and 50% as Rest. To answer the question, "Are cats inherently inactive?" Here, selecting behaviour states for the objective is appropriate.

2. Behavioural events - Behaviours that are brief, rare and tend to occur less frequently. Hence, the probability of missing such behaviours when sampling for a larger number of individuals is evident. The usual representation of behaviour event data comprises count and is expressed in rate. Example: Change in rate of auto groom in primates when compared in protected and tourism zones.

A) Sampling Methods

Behaviour Sampling:

a. Ad-libitum sampling:

Ad - libitum is a sampling technique utilised to study species' behaviour in which all occurrences of the expressed behaviours by the target species in an observational period are recorded without a systematic approach. This sampling technique allows the observer to sample multiple individuals at the same time to determine different behavioural states by recording an individual's behaviour that appears relevant to the observer. It is often used during the initial phase of descriptive studies and during reconnaissance observations to create an ethogram for the species. (Lehner, 1979). Hence this sampling was selected to construct the ethogram of the study animal.

No.	Behavior State	Code	Description
1	Locomotion	LOC	Movement from one location to another including run and walk inside its enclosure quadrupedally.
2	Agnostic	AGN	Social behaviors related to conflict, including aggression and submission.
3	Stereotypy	STY	Repetitive, abnormal behavior patterns with no apparent goal or function - Head Bobbing and Pacing.
4	Play	PLY	Including social and solitary play for activities engagement for enjoyment and recreation.
5	Climbing	CLM	Moving upward or downward on a structure or tree.
6	Rest	RST	Periods of inactivity such as sleeping, resting on hind or belly where the animal is not engaging in other behaviors.
7	Foraging	FRG	Obtaining food and feeding.
8	Vigilant	VIG	Alert and attentive to the surroundings.
9	Standing	STD	Being upright quadrupedally without moving.
10	Exploratory	EXP	Investigating the surroundings and finding food.
11	Bipedal	BIP	Standing or moving on two legs.
12	Autogroom	AUT	Self-cleaning behaviors.
13	Mating	MAT	Behaviors associated with reproduction.
14	Maintenance	MNT	Behaviors related to the upkeep of self such as drinking.

Table: 1 Ethogram of behaviour states

B) Scan Sampling.

In a day sampling was conducted to observe the activity of two animals (one male and one female) within an enclosure. Forty scans were performed in four sets of ten observations each, with eight-minutes of intervals separating between each scan. These scans captured the behaviour of both animals. This observation procedure was repeated for twelve consecutive days, to sample for control phase and similarly was replicated for the enrichment phase of the study for a zoo. This also accounts for observer bias by taking readings at fixed time intervals, to eliminate the tendency to focus on behaviours which are more interesting compared to others. Providing broad coverage to understand the change in behaviour with the introduction of enrichment intervention when compared between control and treatment. Also, scan sampling can help in comparing the welfare to enrichment and other covariates such as Shannon

evenness index, behaviour diversity etc. across two different zoos, and can find variations between various housing systems.

Behavioural Parameters for sampling include:

- a. **Species-Typical Behaviour Diversity:** The range of behaviours an animal exhibits in captivity are measured by species-typical behaviour diversity. The frequency of distinct behaviours exhibited by the animal is referred to as richness, relative frequency of each behaviour is termed as evenness.
- b. **Aberrant Repetitive Behaviour:** A wide range of abnormal behaviours which are repetitive in nature that animals may display in captivity are collectively referred to as aberrant repetitive behaviour or ARB. These actions, which usually have no apparent function or objective, may be a sign of underlying stress or boredom. ARBs can show up in animals as coprophagy, head bobbing, pacing, rocking, self-mutilation, etc. (Mason & Latham, 2004). Proportion of scans in a day animal observed performing stereotypic behaviour was recorded in an enclosure.
- c. **Enclosure Usage:** The enclosure was divided according to the resources, named after features within the enclosure, such as tree, water trough, cave, and ramp. The scans were used to record the location (zones) of the individuals performing a certain behaviour. Enclosure utilization is a significant factor in the evaluation of animal welfare, The homogenous usage is considered as an indication of a novel and complex enclosure design, which is more advantageous for animal well-being compared to a mere increase in enclosure size (Tyagi et al., 2016). The usage of enclosures can also be influenced by characteristics such as clean water trough, presence of trees, climbing structures, dens or caves as shelters, all of which can ultimately impact animal well-being.

C) Study design

This study employs a comparative methodology to analyse the impact of novel enrichments on the behavioural responses of sloth bears in two zoo facilities. Behavioural data was collected pre-enrichment and, during, enrichment phase across multiple individuals, and zoos, to account for inherent variability of the system, thereby supporting the evaluation of the impacts of the enrichment interventions.

As previously mentioned, the study was carried out in two phases:

- a) Baseline Period (12 days): Prior to the introduction of novel enrichment, termed as control when ($trt = 0$), behavioural parameters were documented to establish baseline measures for each individual through scan sampling. This baseline data served as a benchmark for assessing changes in behaviour during enrichment.
- b) Treatment Period (12 days): During the treatment period, monitoring of behavioural responses was conducted for 12 days while the feeding enrichment was being provided to the individuals which were displayed in the arena. This intensive phase of data collection offered comprehensive insights into the responses to novel enrichments on bear welfare.

Enrichment Protocol

To ensure consistency and uniformity in the application of enrichments, a standard enrichment, i.e., pitfall feeder, was used at both sites belonging to the class of feeding enrichment. These pitfall feeders were made from bamboo, for animal safety and biodegradability. The novel feeders for sloth bears were selected due to enrichment history, with no probability of habituation at both zoos. These enrichments were randomly distributed in the enclosure.

The enrichment was filled every morning with zoo feed for the sloth bear before the display of bears out in the enclosure. The feeders were expected to stimulate the bears' natural behaviour, such as exploratory, foraging, digging, and sometimes playing.



Fig: 1 Pitfall feeders for feeding enrichment

Site Selection:

Two zoos were shortlisted for the study: Delhi and Mumbai Zoo. Secondary data was collected for these zoos from CZA or personal communication with the zoological staff.

All factors that could influence bear behaviour, such as the presence of enriching elements (small waterfall - Mumbai), structural characteristics, and overall size of the enclosures. Moreover, the design and layout of the enclosures plays an important role in influencing enclosure utilization, with the presence of structurally complex elements in the enclosure such as trees, bamboo culms, water bodies and so on has a significant effect on enclosure utilization by captive animals. The size of the enclosures can be a factor when assessing complexity, as smaller enclosures may exhibit different levels of complexity compared to larger ones.

D) Study Area

National Zoological Park, Delhi - The national zoological park, also known as Delhi Zoo, is located in the heart of the country's capital, sharing proximity with significant landmarks such as India Gate, Old Fort, and others. The zoo was established in 1959. The area is highly visited by tourists, and the national zoological park also attracts a steady stream of visitors. The Central Zoo Authority of India manages the zoo, which, although located in the city centre, spans over 172 acres. It accommodates diverse wildlife from around the world, with a focus on species native to India.

Sloth Bear Enclosure: This Enclosure was constructed to house Malayan Sun Bear, but after the death of Malayan Sun Bear, Sloth bear is exhibited in the enclosure. According to CZA – It doesn't fulfil CZA' norms of containment requirement. (Master Plan, National Zoological Park, 2012-2031)

Open-air dry moated enclosure – The enclosure arena comprises the area of 674 sqm. These are usually designed with dry moat on the viewing side of the enclosure which act as a barrier between the animal and the visitors so the bear does not escape. Also, there is no requirement for high fences which might obstruct the display for the animal and visitors. (Mellen & MacPhee, 2001).

The enclosure is an open-air space covered on three sides by a stone wall and a deep moat. Consisting of 4 cubicles and a single passage and wallowing pool. (Master Plan, National Zoological Park, 2012-2031).

The enclosure consists of a single tree, several logs, and a ramp for climbing. It also consists of 3 shallow troughs, usually one filled at all times but maintenance is inconsistent which can cause a concern for cleanliness and usability, necessary for the animal to cool off in the hot temperature. The substrate of the enclosure includes a mix of patchy grass and rocky terrain with many potholes due to the bear's digging behaviour, even in the cave substrate,

which is concrete. An artificial cave is present at the distal portion of the enclosure parallel to the visitor pavement, providing shelter to retreat from the elements and rest. This cave mimics the natural dens utilised by bears for either sleep or protection.



Map:1 Delhi Zoo layout, (Reference - cza.nic.in)

Veermata Jijabai Bhosale Udyan, Mumbai - Veermata Jijabai Bhosle Udyan is one of the oldest zoos, established in 1861. The zoo is spread across 48 acres and houses around 400 animals, contributing to 70 species (Zoo Authority of India, 2023). The zoo is involved in many studies relating to biodiversity, including behavioural studies. It is located in the urban settlement of the bustling City of Mumbai and welcomes an annual visitor of about 2 million.

The zoo consists of artificial inputs mimicking a natural habitat, delivering the fauna with naturalistic environmental enrichment. As the name suggests, it is a Udyan zoo consisting of native and exotic trees making up the botanical garden. Brihanmumbai Municipal Corporation manages the zoo.



Fig: 2 Sloth Bear Enclosure, Mumbai Zoo

Feed—The Sloth bears are fed twice a day. Once released into the arena, they receive porridge containing Suji, honey, egg, milk, and jaggery. The diet provided later in the day comprises mixed fruits and vegetables when the animal is returned to the Krall.



Fig: 3 Feed for enrichment, Mumbai Zoo

The male is brought from rescue and rehabilitation Gorewada, Nasik, and the female from the Surat Zoo. Only females show signs of stereotypy in the form of head bobbing. They are mostly affiliated with a site in the enclosure at the left extreme distal end, which serves the farthest distance from the viewing glass panels. The zoo consists of free ranging Indian Grey Mongoose entering into different enclosures providing social enrichment.

ANALYSIS

A. Species behaviour diversity:

The frequency of each behavioural state in a sampled day (proportion of scans when it occurred) was computed for an animal. Using this data, Shannon diversity index was computed for each phase of the study i.e., Control (trt=0) and treatment (trt = 1) to estimate behaviour diversity of the individual. Shannon diversity index was calculated as:

$$H' = - \sum [\text{Frequency of behaviour } i) * \ln (\text{Frequency of behaviour } i)].$$

B. Enclosure usage diversity:

Similarly, frequency of use of each zone (proportion of scans where the animal was observed in the zone) of the enclosure was calculated for an animal for a sampled day, using the formula:

$$H' = - \sum [\text{Frequency use of zone } i) * \ln (\text{Frequency use of zone } i)].$$

The maximum Shannon diversity index (H' max) occurs when all zones are equally used. This is given by

$$H' \text{ max} = \ln(Z)$$

Ln = Natural log

Z = Number of zones.

This index was estimated for each phase of the study. Aberrant repetitive behaviours such as head bobbing and pacing are mostly site or zone specific considered as a negative cue for determining welfare which makes the enclosure utilization heterogeneous in usage by the animals as some zones gets utilized more than the rest, which ultimately lowers the values for Shannon Evenness index estimating lower welfare.

Also, stereotypical behaviour are aberrant repetitive behaviours as they do not qualify to be species-specific behaviours.

C. Behavioural response on Welfare:

We used the following metrics to represent behavioural welfare: Proportions of time spent in active behavioural states (positive marker of behavioural welfare), inactive and stereotypic states (negative marker of behavioural welfare), behavioural diversity and enclosure utilisation diversity (positive marker of behavioural welfare). Thereafter, these variables were analysed using Principal Component Analysis, to extract fewer synthetic variables that surrogate behavioural welfare. Subsequently, Generalised linear mixed models were used to examine the response of the principal component surrogating behavioural welfare, on zoo and enrichment (as fixed effects) and individual (as random effect).

RESULT

I. Behaviour Diversity

It was observed that Shannon index of behavioural diversity increased after introduction of feeding enrichment only for Mayra and remained similar for other individuals across zoos.

(Fig 5).

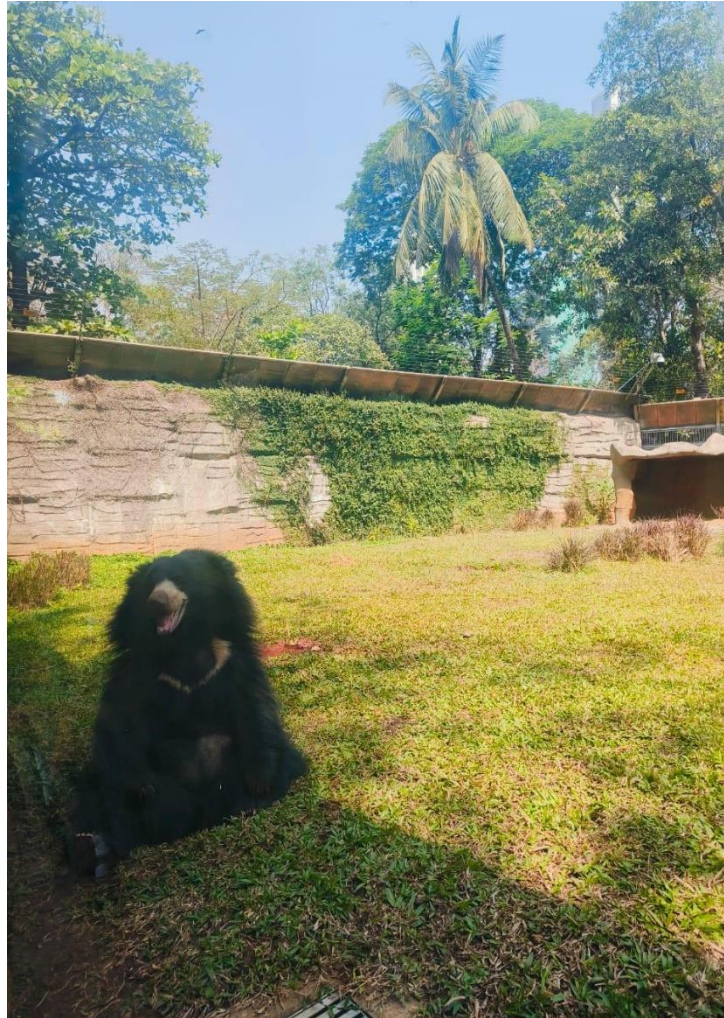


Fig: 4 Hind - Rest, Proximal line, Shiva

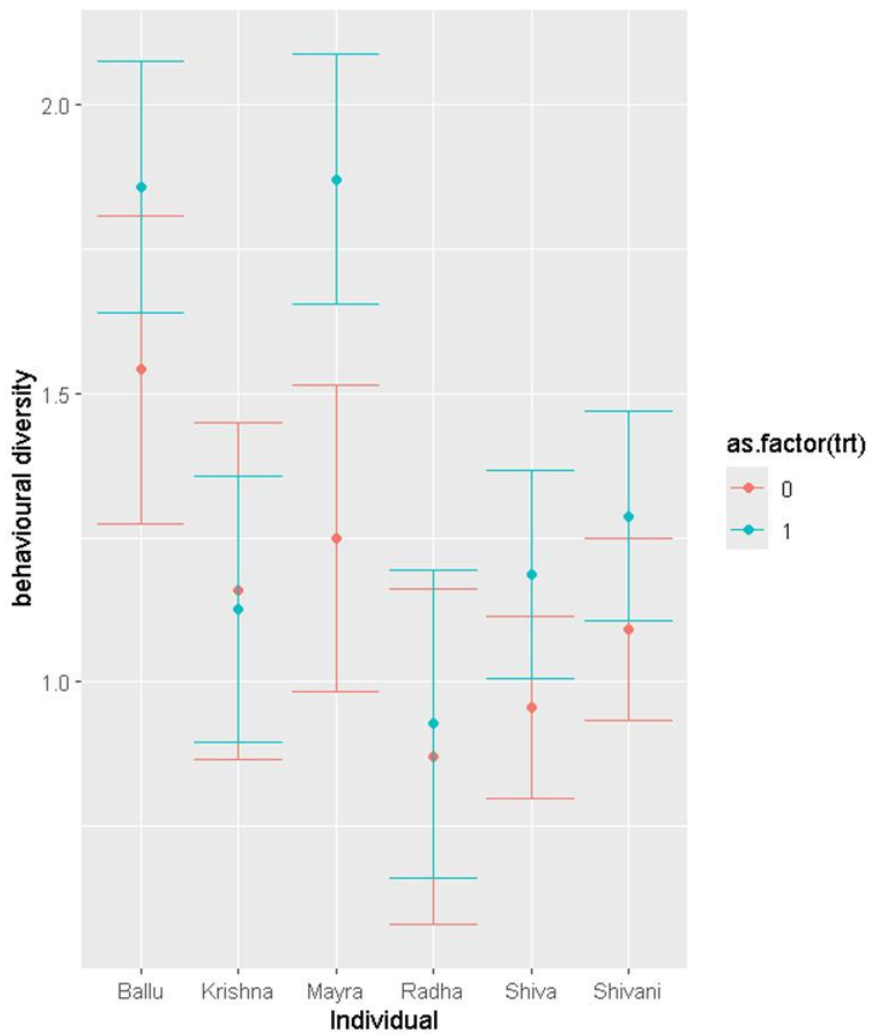


Fig: 5 Comparison of mean and 95% CI (error bars) of Shannon Diversity index computed on daily frequency of behaviours across individual Sloth bears between control (red) and enrichment (cyan) phases.

II. Enclosure usage

For all individuals (Ballu, Krishna, Mayra, Radha, Shivani, Shiva), there was a positive trend in enclosure use diversity after enrichment in both zoos, but the difference was not statistically significant.

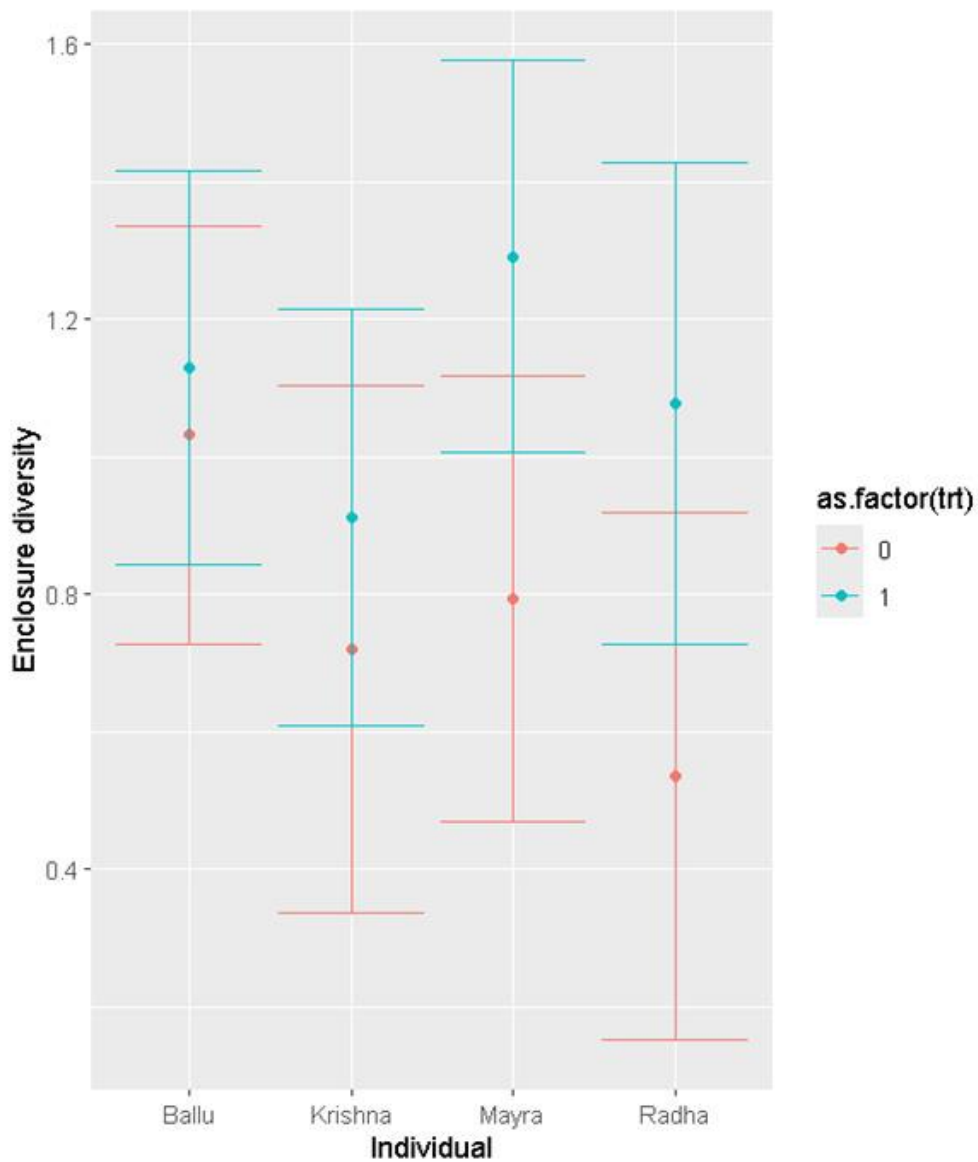


Fig: 6 Comparison of mean and 95% CI (error bars) for enclosure utilization computed on daily frequency of zones across individual Sloth bears between control (red) and enrichment (cyan) phases in Delhi

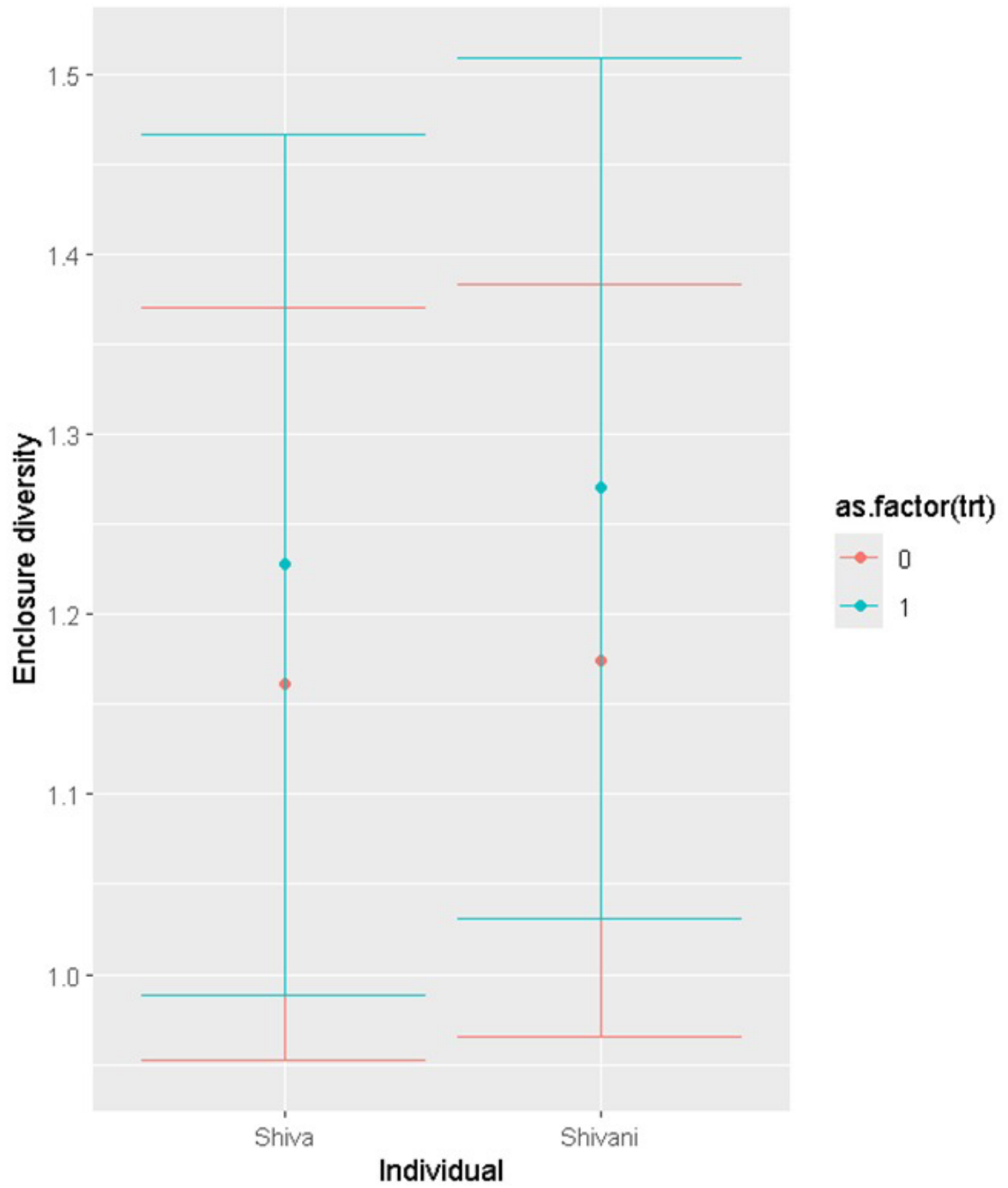


Fig: 7 Comparison of mean and 95% CI (error bars) for enclosure utilization computed on daily frequency of zones across individual Sloth bears between control (red) and enrichment (cyan) phases in Mumbai

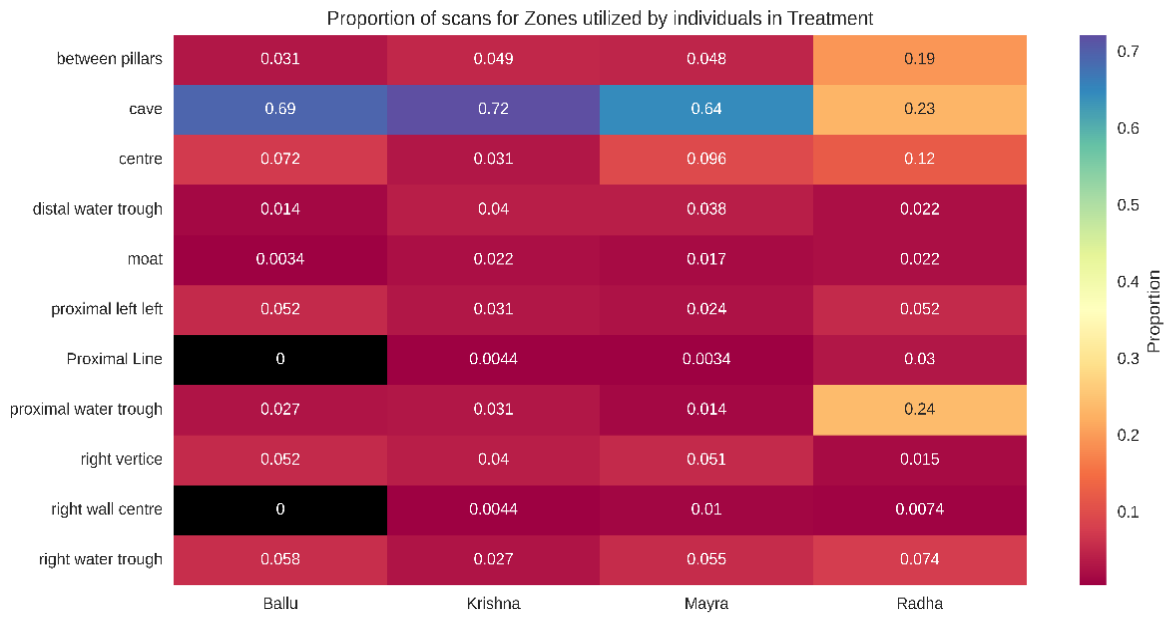
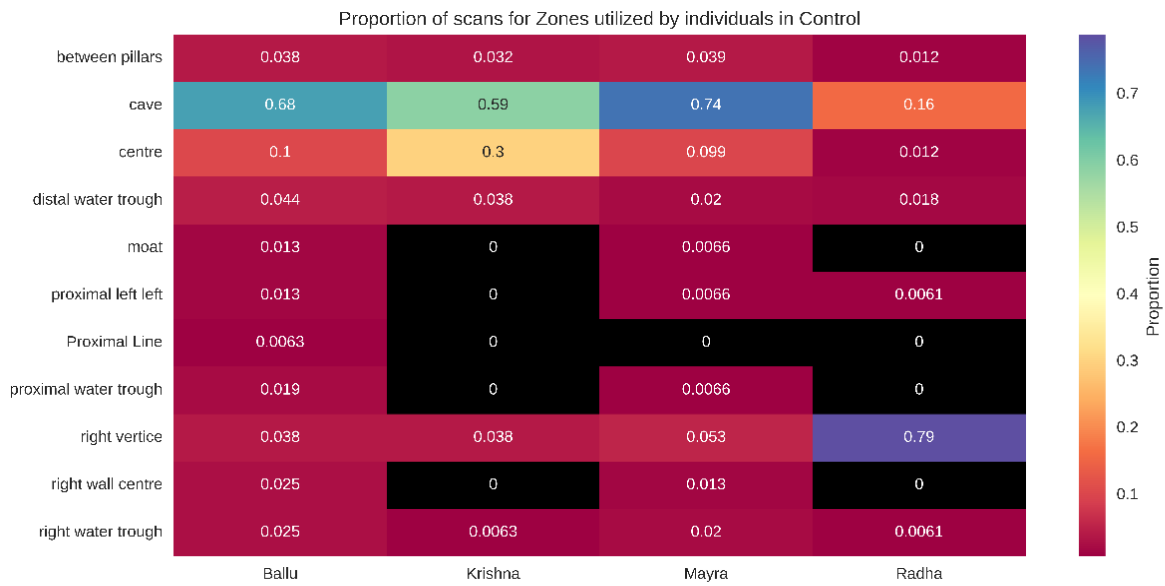


Fig: 8 Heatmap -The following columns reflect the various enclosure zones. The values in each column indicate the proportion of scans for each individual in each zone for the specific individual one for TRT 1 (enrichment) and another for TRT 0 (control) in Delhi

The Tree and Left Grill areas are favoured by Shiva and Shivani, respectively, for different behaviour repertoire associated with the zone, such as Rest for Shiva and Stereotypic behaviour - Head bobbing for Shivani.

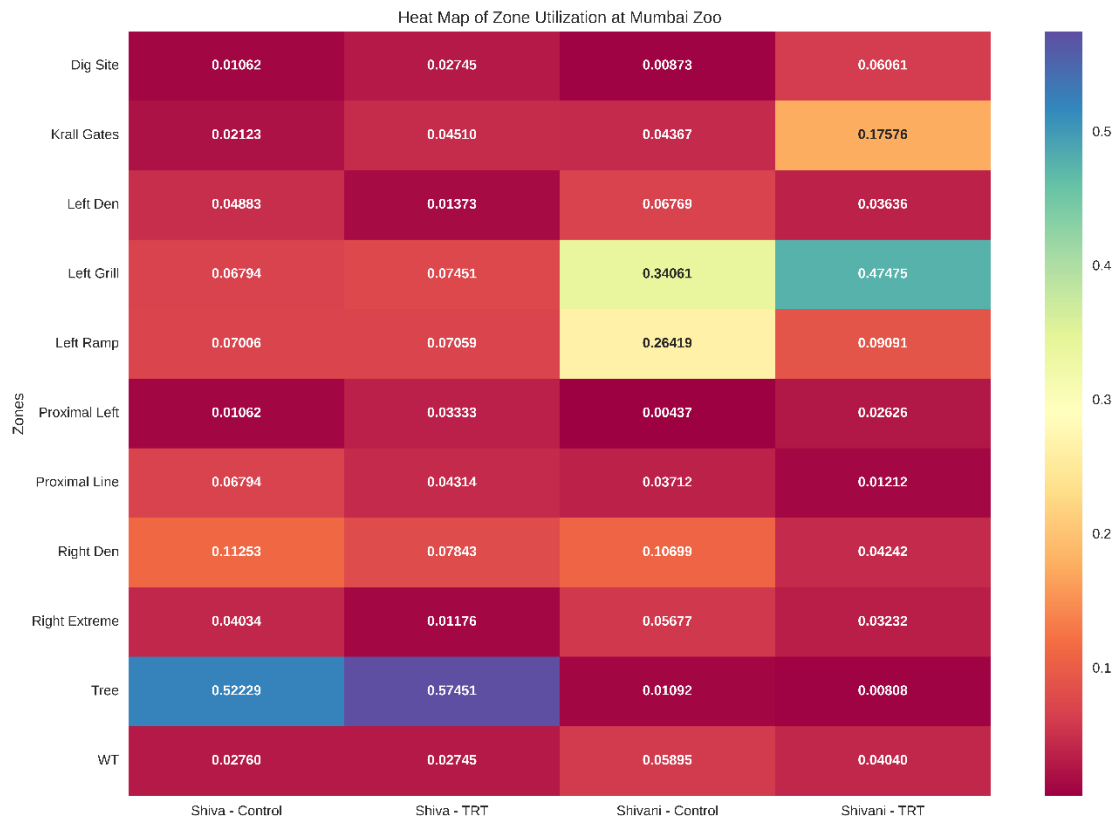


Fig: 9 Heatmap -The following columns reflect the various enclosure zones. The values in each column indicate the proportion of scans for each individual in each zone for the specific individual one for TRT 1 (enrichment) and another for TRT 0 (control) in Mumbai

III. Activity Budget

In the Control Condition (TRT 0), Stereotypy levels are notably elevated for Mayra and relatively high for Ballu, implying a potential stress response or lack of stimulation. Resting behavior is significantly high for Radha and Krishna, suggesting a probable lack of engagement or stimulation. Among the subjects, exploratory behavior is relatively evenly distributed, with Mayra exhibiting the highest ratio. Locomotion remains consistent across the individuals, with Ballu having the highest and Radha the lowest. (Table 6)

In the Enrichment Condition (TRT 1), Stereotypy declines for Mayra, while it drastically rises for Krishna and Radha, whereas it remains steady for Ballu. This indicates that the enrichment had diverse effects on their stress levels or repetitive behaviors. (Table 6)

Resting behavior decreases for most individuals, particularly for Radha, who displays a decline in trend, potentially suggesting a more beneficial impact of the enrichment on her. Similar observations were noted for Krishna, whose levels decreased. (Table 6) Exploratory behaviors witness an increase across most individuals, with a significant rise in Radha's exploratory behavior increased except for ballu which decreases. This implies that enrichment generally encourages more active behaviors. The evaluation of activity budgets under both conditions demonstrates that enrichment typically boosts positive behaviors, diminishes negative indications of inactivity or monotony, and increases in exploratory behaviors. However, the varying responses to enrichment among individuals underscore the necessity of customising enrichments to suit the particular requirements and preferences of each individual to optimise their effectiveness. (Table 6)

ACTIVE			
Zoo	Individual	Control	Enrichment
Delhi	Ballu	0.68 (0.28)	0.59 (0.2)
Delhi	Krishna	0.24 (0.12)	0.43 (0.15)
Delhi	Mayra	0.53 (0.27)	0.59 (0.26)
Delhi	Radha	0.17 (0.07)	0.46 (0.21)
Mumbai	Sivani	0.34 (0.09)	0.39 (0.11)
Mumbai	Shiva	0.39 (0.1)	0.38 (0.1)
STEREOTYPE			
Zoo	Individual	Control	Enrichment
Delhi	Ballu	0.26 (0.1)	0.24 (0.08)
Delhi	Krishna	0.17 (0.09)	0.5 (0.18)
Delhi	Mayra	0.35 (0.18)	0.14 (0.05)
Delhi	Radha	0.2 (0.09)	0.15 (0.07)
Mumbai	Sivani	0.1 (0.02)	0.1 (0.03)
Mumbai	Shiva	0 (0)	0 (0)

INACTIVITY			
Zoo	Individual	Control	Enrichment
Delhi	Ballu	0.06 (0.02)	0.17 (0.06)
Delhi	Krishna	0.59 (0.3)	0.33 (0.18)
Delhi	Mayra	0.42 (0.19)	0.28 (0.13)
Delhi	Radha	0.34 (0.29)	0.34 (0.2)
Mumbai	Sivani	0.35 (0.18)	0.3 (0.17)
Mumbai	Shiva	0.61 (0.16)	0.55 (0.13)

Table 2: Comparison of mean and 95% CI of Proportion of behaviors – Active, Inactive and and Stereotypy computed on daily frequency of behaviours across individual Sloth bears between control and enrichment phases

1. **Active:** There is no significant difference in active behavior levels within individuals between the Control and Enrichment conditions.
2. **Stereotype:** There is no significant difference in stereotypic behavior levels within individuals between the Control and Enrichment conditions.
3. **Inactive:** There is no significant difference in inactivity levels within individuals between the Control and Enrichment conditions.

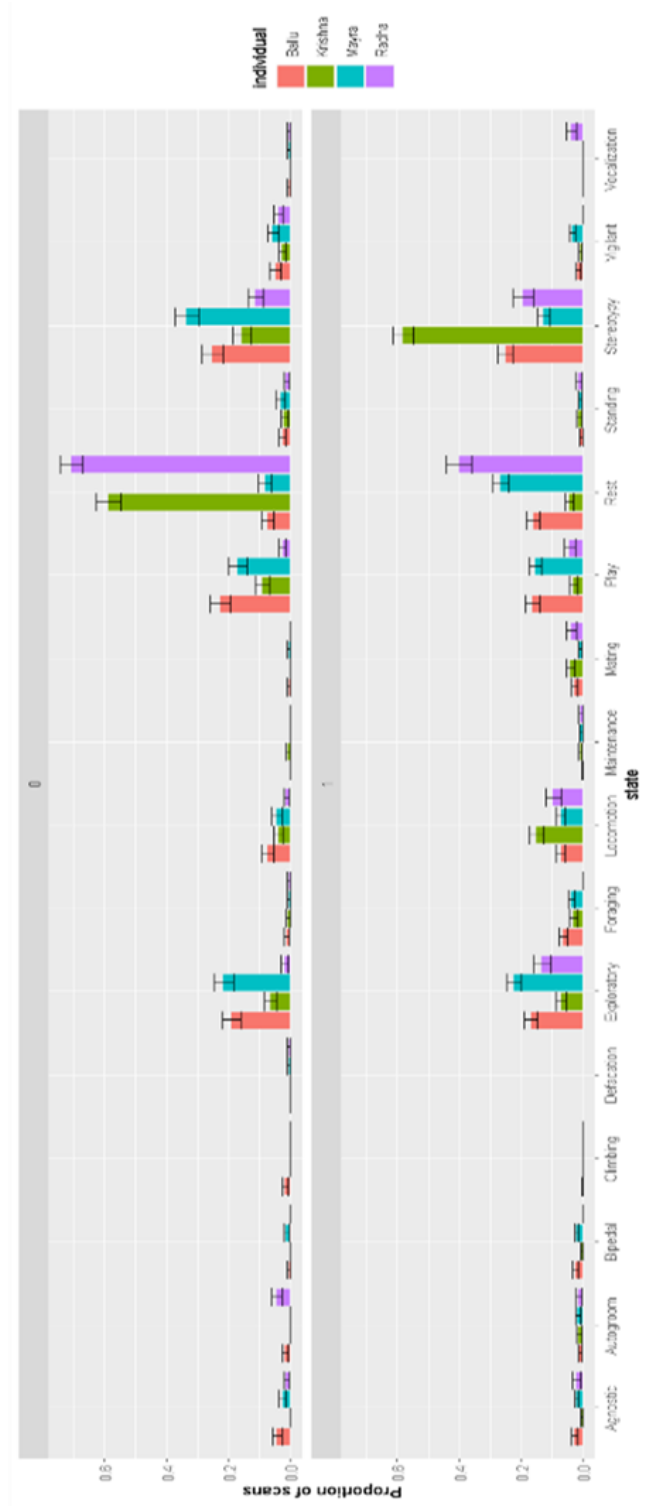


Fig: 10 Activity budget for Delhi

Changes in Activity Budgets

I. Increased Exploratory behavior: In enriched settings, both female and male subjects displayed a notable rise in exploratory behavior. The percentage of time spent in exploration increased for both individuals, indicating that the pitfall feeder introduced novel stimuli that prompted the animals to actively investigate their surroundings. (Fig: 10)

II. Increased Foraging Behavior: Foraging activities also experienced a significant boost due to enrichment. Both individuals increased their foraging duration. The introduction of feeding enrichment elements required the animals to search for food and engage in feeding, thereby fostering natural foraging behaviors. (Fig: 10)

III. Increased Locomotion: Both individuals displayed an increase in locomotion, or movement within the enclosure, under enriched conditions. Both individuals increased. This surge suggests that the enriched setting provided more opportunities and motivation for physical activity as feeders were dispersed throughout the enclosure, which is vital for maintaining physical well-being. (Fig: 10)

IV. Reduced Resting Behavior: Conversely, the time spent resting decreased under enriched conditions. Resting duration for both individuals declined. This decline in resting time is likely a direct consequence of increased engagement in other activities such as exploration, foraging, and locomotion. (Fig: 10)

V. Decreased Play Behavior: Interestingly, play behavior declined with enrichment for both the individual. This shift may be attributed to the animals dedicating more time to other enriched activities, thereby reducing the available time for play. (Fig: 10)

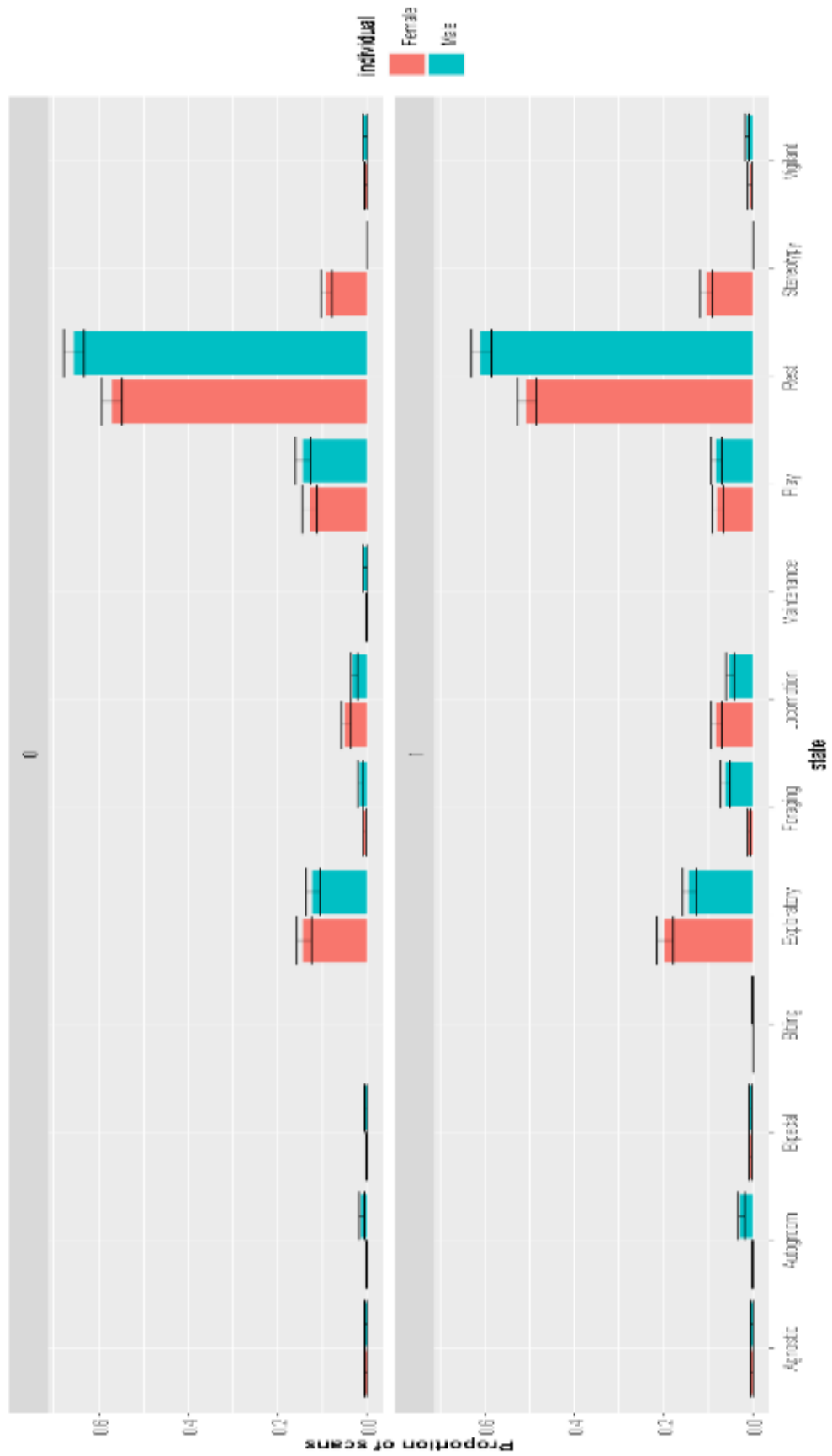


Fig: 11 Activity Budgets for Mumbai site for each individual in control and treatment respectively

VI. Welfare

For the Welfare Index we performed Principal component analysis of 5 variables - Active, Stereotypy, Inactive, Enclosure utilization, and Behaviour diversity.

Principal Components:

PC1: The first principal component explains approximately 39.86% of the variance.

PC2: The second principal component explains approximately 33.11% of the variance.

PC3: The third principal component explains approximately 18.45% of the variance.

The first two principal components account for approximately 72.97% of the total variation, indicating that they account for the majority of the variability in the data.

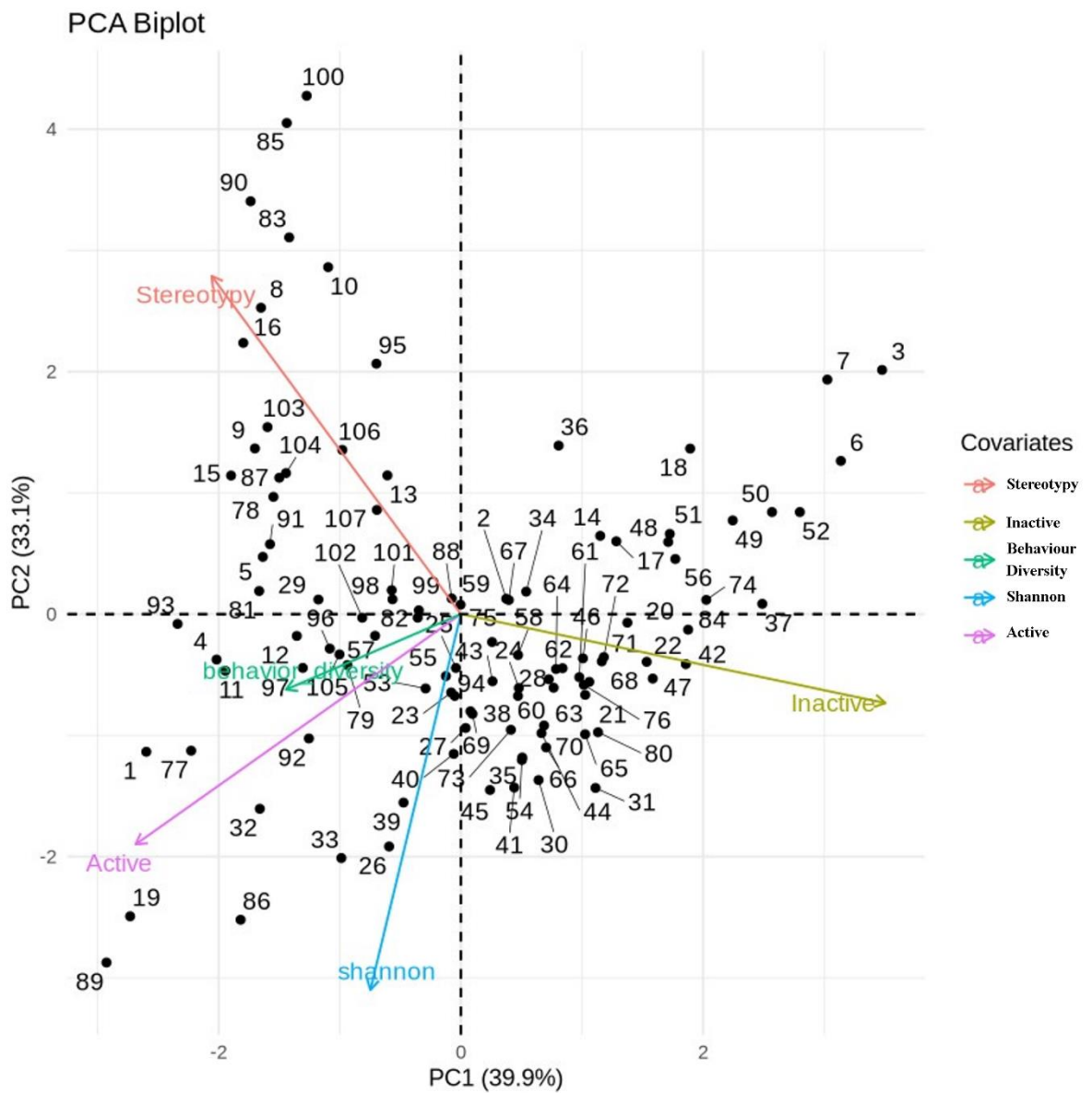


Fig: 12 Biplot, PC1 and PC2 The original variables and principal components are shown in a biplot. The original variables are represented by the arrows, while the observations are represented by the points. The arrows' length and direction show how each variable contributes to the principal components.

	PC1	PC2	PC3
<i>Active</i>	-0.52275	-0.40562	0.316276
<i>Stereotypy</i>	-0.4006	0.595698	-0.06302
<i>Inactive</i>	0.682677	-0.15685	-0.18175
<i>shannon</i>	-0.14544	-0.66207	-0.02092
<i>behavior_diversity</i>	-0.28116	-0.13295	-0.92872

Table:3 This table represents the principal component analysis (PCA) loadings for five behavioral parameters (Active, Stereotypy, Inactive, Shannon, and behavior_diversity) across five principal components (PC1 to PC3).

- PC1 (39.86% of variance explained):

Hence, PC1 not selected for surrogating welfare as both Active and Stereotypy load negatively on PC1.

- PC2 (33.11% of variance explained):

Highest positive loading: Stereotypy (0.5957)

Highest negative loadings: Shannon (-0.6621) and Active (-0.4056)

Activity rate and diverse use of enclosure load negatively and stereotypy load positively on PC2.

Hence, PC2 is a comprehensive welfare index. A lower PC2 indicates better welfare.

A lower PC2 indicates better welfare. PC2 is a comprehensive welfare index. The fact that Mumbai's PC2 is lower than Delhi's suggests that Mumbai bears typically have a higher welfare status. Welfare is not greatly affected by enrichment.

```

Linear mixed model fit by REML ['lmerMod']
Formula: PC2_Score ~ trt + group_id + (1 | individual_sex)
Data: df_welfare

REML criterion at convergence: 338.1

Scaled residuals:
  Min       1Q   Median       3Q      Max
-3.3808 -0.5220 -0.0571  0.4860  2.8654

Random effects:
  Groups             Name             Variance Std.Dev.
individual_sex (Intercept) 0.1259   0.3549
Residual                1.3100   1.1445
Number of obs: 107, groups: individual_sex, 6

Fixed effects:
  Estimate Std. Error t value
(Intercept)    0.62598    0.27812    2.251
trt            -0.02751    0.22537   -0.122
group_idMumbai -1.12820    0.38113   -2.960

Correlation of Fixed Effects:
  (Intr) trt
trt            -0.500
group_idMmb   -0.595  0.095
>

```

Fig: 13 Linear Mixed Model showing the effect of treatment and group (Zoo) on PC2 Scores, with individual sex as a random effect.

PC2 is lower for Mumbai when compared to Delhi, indicating sloth bears in Mumbai bears have generally better welfare status.

There is no significant difference of Enrichment on welfare. It could be understood as the management at Mumbai is comparatively better than Delhi ensuring long term welfare.

Factors influencing behavioural welfare

According to the results of Generalized Linear Mixed Effect models, frequency of inactivity (response) was explained by zoo and enrichment (Akaike wt 0.98), after accounting for random variation between individuals. Frequency of inactivity was greater in delhi zoo and increased after enrichment (Fig 15).

<i>Model</i>	Formula
<i>bmm1</i>	glmer(cbind(obs, scans-obs) ~ 1 + (1 individual_sex), family = 'binomial', data = dat_in)
<i>bmm2</i>	glmer(cbind(obs, scans-obs) ~ trt + (1 individual_sex), family = 'binomial', data = dat_in)
<i>bmm3</i>	glmer(cbind(obs, scans-obs) ~ group_id + (1 individual_sex), family = 'binomial', data = dat_in)
<i>bmm4</i>	glmer(cbind(obs, scans-obs) ~ trt + group_id + (1 individual_sex), family = 'binomial', data = dat_in)
<i>bmm5</i>	glmer(cbind(obs, scans-obs) ~ trt*group_id + (1 individual_sex), family = 'binomial', data = dat_in)

Table:4 Inactivity Models consisting individual traits as a random effect and zoo and Treatment as fixed effects

Model	(Int)	trt	grp_id	grp_id:trt	df	logLik	AICc	delta	weight
bmm5	-0.5138	+	+	+	5	-429.063	868.7	0	0.98
bmm4	-0.6796	+	+		4	-434.453	877.3	8.59	0.013
bmm2	-0.2647	+			3	-436.291	878.8	10.11	0.006
bmm3	-0.9141		+		3	-450.361	906.9	38.25	0
bmm1	-0.4940				2	-452.145	908.4	39.71	0

Table: 5 Inactivity Model Selection – Interactive effect of both enrichment and zoo and individual as a random effect.

This presents the Predicted probabilities of inactivity in both Zoos:

```

> ggpredict(bmm5)
$trt
# Predicted probabilities of cbind(obs, scans - obs)

trt | Predicted |      95% CI
-----|-----|-----
0   |      0.39 | 0.27, 0.51
1   |      0.47 | 0.35, 0.59

Adjusted for:
*      group_id = Delhi
* individual_sex = 0 (population-level)

$group_id
# Predicted probabilities of cbind(obs, scans - obs)

group_id | Predicted |      95% CI
-----|-----|-----
Delhi    |      0.39 | 0.27, 0.51
Mumbai   |      0.34 | 0.20, 0.52

Adjusted for:
*      trt = 0
* individual_sex = 0 (population-level)

attr(,"class")
[1] "ggalleffects" "list"
attr(,"model.name")
[1] "bmm5"
> |

```

Fig:14 Predicted probability of inactivity in both zoo in absence of enrichment and individual = 0

Stereotypy

- Model bmm4: Incorporates treatment, group ID, as fixed effect and individual as random factors.

Model	Formula
bmm1	glmer(cbind(obs, scans-obs) ~ 1 + (1 individual_sex), family = 'binomial', data = dat_st)
bmm2	glmer(cbind(obs, scans-obs) ~ trt + (1 individual_sex), family = 'binomial', data = dat_st)
bmm3	glmer(cbind(obs, scans-obs) ~ group_id + (1 individual_sex), family = 'binomial', data = dat_st)
bmm4	glmer(cbind(obs, scans-obs) ~ trt + group_id + (1 individual_sex), family = 'binomial', data = dat_st)
bmm5	glmer(cbind(obs, scans-obs) ~ trt*group_id + (1 individual_sex), family = 'binomial', data = dat_st)

Table:6 Stereotypy Models consisting individual traits as a random effect and Zoo and Treatment as fixed effects

According to the results of Generalised Linear Mixed Effect models, best-supported model (bmm4) indicates that the frequency of stereotype was explained by treatment and group ID (Akaike wt 0.54), after accounting for individual differences. The results suggest that these factors are significant in understanding variations in stereotype behaviour (Fig 17).

Model	(Int)	trt	grp_id	grp_id:trt	df	logLik	AICc	delta	weight
bmm4	-1.314	+	+		4	-332.09	672.6	0	0.546
bmm5	-1.339	+	+	+	5	-331.867	674.3	1.74	0.228
bmm2	-2.547	+			3	-334.416	675.1	2.5	0.156
bmm3	-1.147		+		3	-335.473	677.2	4.61	0.054
bmm1	-2.385				2	-337.807	679.7	7.17	0.015

Table:7 Stereotypy Model Selection – Additive effect of both enrichment and zoo and individual as a random effect.

```

> ggpredict(bmm4)
$trt
# Predicted probabilities of cbind(obs, scans - obs)

trt | Predicted | 95% CI
-----|-----|-----
0 | 0.21 | 0.06, 0.55
1 | 0.26 | 0.07, 0.61

Adjusted for:
* group_id = Delhi
* individual_sex = 0 (population-level)

$group_id
# Predicted probabilities of cbind(obs, scans - obs)

group_id | Predicted | 95% CI
-----|-----|-----
Delhi | 0.21 | 0.06, 0.55
Mumbai | 0.01 | 0.00, 0.08

Adjusted for:
* trt = 0
* individual_sex = 0 (population-level)

attr(,"class")
[1] "ggalleffects" "list"
attr(,"model.name")
[1] "bmm4"
> |

```

Fig:15 Predicted probability of Stereotypy in both zoo in absence of enrichment and individual = 0

Mumbai exhibits a reduced degree of stereotypy in comparison to Delhi in similar conditions (in the absence of enrichment and controlled for individual = 0).

DISCUSSION

This study on how enrichment intervention affects captive sloth bears' behaviour has similarities and differences compared to prior studies. Earlier studies have shown that introducing enrichment intervention to an enclosure can significantly improve their well-being by reducing stereotypy and unnatural behaviours and promoting natural behaviours. For example, a study by Bashaw et al. (2003) found that novel feeding enrichment reduced repetitive behaviours and increased foraging activities in captive bears. Our study also found from the activity budget that the bear's exploratory and foraging behaviour increased after we introduced enrichment, indicating a positive impact on their welfare.

However, the results were not as consistent as those in Bashaw et al.'s study. While one bear, Mayra, showed a clear decrease in stereotypic behaviours after the enrichment was introduced (Fig:9), other bears, like Krishna and Radha, showed an increase in these behaviours. These differences could be due to each bear's unique personality and past experiences and the type and design of the enrichment we used in the study.

A notable dissimilarity was observed as varied response on stereotypic behaviours across different individuals. While some individuals showed decreased stereotypic behaviours, others did not exhibit significant changes or even showed an increase. This variation could be due to individual differences in response to enrichment, as Mason et al. (2007) suggested, who highlighted the importance of considering individual animal preferences and histories in enrichment studies.

Our results showed that the sloth bears used different zones of the enclosures to carry out various behaviors. For example, in the Mumbai Zoo, Shiva usually used the Tree zone for resting, while Shivani favoured the Left Grill zone for stereotypic behavior in the form of head

bobbing. This difference in zone utilization is similar to previous studies that show animals use specific areas of their enclosures for their associated behavior (Mallapur & Chellam, 2002)

The introduction of enrichment caused a change in the zones utilized by the bears. For example, the heatmaps from our study showed that in the enriched condition, there was a more number of zones being utilized. This suggests that the enrichment encouraged the bears to explore and utilize more of the enclosure, rather than sticking to certain zones as seen in the control condition. Additionally, the enclosure complexity and resources available in different zones might have caused these patterns.

A positive trend in enclosure utilization diversity was seen in the study (Fig:6), suggesting that the enrichment influenced the bears to explore zones of their enclosures, which were previously not being utilized with the introduction of enrichment. (Fig: 8) However, the lack of significant differences could be due to the already high baseline of enclosure use seen in Mumbai or limitations in the enrichment design. Additionally, the effect of management practices at the zoos, such as consistency in feeding and maintenance of the enclosures with accessibility to water resources, likely played a role in the bears' responses as two sloth bears in Delhi were dehydrated at the later part of the study when compared to free-flowing water accessible to the sloth bears housed In Mumbai Zoo.

Hence, to this, we can say that the type and design of the enrichment used can significantly influence its effectiveness. Our study employed a pitfall feeder, which may not have been equally engaging or stimulating for all individuals. Previous studies, such as Ross et al. (2009), used various enrichment devices that provided more complex and stimulating experiences. The pitfall feeder might have provided sufficient novelty and engagement for some bears but not for others, leading to mixed results.

The enrichment intervention was selected from the "Enrichment Manual for Selected Species in India Zoo, 2016". This document talks about testing the efficacy of various enrichment devices, including one of the successful interventions which was selected in this study as the "Pitfall feeder". The study for the document, comprised of two individual inmates from the same zoo and enclosure, lacks variations of individual differences, the environment, management practices, etc. The parameter utilized in determining the efficacy of the enrichment was mainly determined by activity budget by reporting the average time spent on foraging at least 30 minutes at each pit feeder. This method needs a shift as the activity budget is also confounded by the variations discussed in this thesis and may not necessarily indicate the welfare or efficacy of an enrichment intervention, which needs to be customized according to the variations in individual, environmental and management, practices to provide improved and well-studied applications of these enrichment interventions with their efficacies studied further and reflected in management plans of the zoological institutions.

My study emphasizes how changing the activity budget cannot solely incorporate the efficacy of enrichment intervention. There is a need for customized approaches considering individual differences, the environment, and management practices to be applied, studied, and incorporated into the management plan of each zoo to improve animal welfare.

In our results, the Mumbai Zoo showed better welfare outcomes for the sloth bears than the Delhi Zoo. This was indicated by the Principal Component 2 (PC2) scores, which were lower for Mumbai. Lower PC2 scores suggest that Mumbai bears typically have higher overall welfare status. This difference in welfare outcomes could be because of Mumbai Zoo's long-term management practice of changing enrichment interventions every week and following an enrichment plan as opposed to Delhi Zoo, where no enrichment plan was utilized. Other studies also highlight the importance of changing enrichment regularly.

For example, a study by Shepherdson et al. (1993) found that rotating enrichment items on a schedule increased the effectiveness of enrichment programs. They noted that animals exposed to varied and regularly changed enrichment items exhibited more natural behaviours and less boredom than those with static enrichment.

Similarly, Shyne (2006) reviewed various enrichment strategies and concluded that changing enrichment regularly helps maintain the animals' interest and engagement. The study suggested that a predictable schedule for introducing new enrichment items can enhance the overall well-being of captive animals.

The Welfare in Captive Facility could make up from covariates like Behavioural diversity, as measured by indices like the Shannon Diversity Index, is often considered a positive indicator of welfare. Higher behavioural diversity suggests that an animal is engaging in a wide range of natural behaviours, indicating that its environment is stimulating and allowing for the expression of species-typical actions. As we see in the fig:5, most individuals show increased behavioural diversity under enrichment conditions, which is likely associated with improved welfare. From the loadings we can say PC2 is a comprehensive index of welfare – lower values of PC2 indicates greater welfare. Similarly, the proportion of active to inactive time is another important consideration. Animals must rest occasionally, but prolonged inactivity can indicate poor welfare and may be an indication of disease, despair, or a lack of motivation brought on by an uninspiring environment. The PC2 is lower for Mumbai sloth bears than Delhi, indicating that sloth bears at Mumbai site have generally better welfare status. Enrichment doesn't influence significantly. Could be the factor of overall better management practice to ensure long – term management. A similar trend in other covariates can also be in the same way. The proportion of stereotypy as a function of three covariates group_id, treatment and individual also determines negative welfare.

Michael H. Parsons conducted research to validate the Thoroughbred racehorse welfare index, which included thorough behavioral observations, trainer questionnaires, and statistical analysis with PCA. The data revealed strong relationship between various welfare parameters and racehorse behaviors, confirming the index's application for assessing and improving welfare standards in training stables.

In the current study it was observed that the result was a marginal difference between the zoo for inactivity showing Delhi as 0.39 and Mumbai as 0.34. To which we can say that Delhi Zoo inactivity was marginally higher when compared to Mumbai. As the enclosures at the Delhi Zoo have been characterized as smaller and less intricate in comparison to those at the Mumbai Zoo. This simplicity in design may lead to elevated levels of inactivity, as sloth bears in environments with less stimulation tend to display lower welfare and increased periods of inactivity. Conversely, the larger and more complex enclosures at the Mumbai Zoo promoted greater levels of active states, resulting in decreased rates of inactivity.

A study by Débora Boccacino's, 2020 revealed that jaguars were as inactive in the evening/night as they were during the day, indicating that excessive inactivity may be a negative cue on welfare impacted by the confined environment. When examining nocturnal habits in captive wild cats, the study emphasized the necessity of taking individual differences in behavior into account, particularly in terms of age, health, and management conditions.

On the other hand, restlessness or hyperactivity may also be signs of stress or pain. The ideal balance between active and inactive phases should reflect what would be seen in the wild for that species. Kathleen N. Morgan observed in 2007 that hyperactivity in captive animals is highly associated with stress. According to research, animals frequently exhibit hyperactive behaviors in behaviors to environmental stresses, which serves as a coping mechanism. However, persistent stress and the associated hyperactivity can be detrimental to their general

health and well-being. Understanding and managing stress-related behaviors is critical to enhancing the wellbeing and quality of life of captive animals.

REFERENCE

1. Abdul-Mawah, S. S., Chor-Wai, L., Jasnie, F., Norma-Rashid, Y., & Ramli, R. (2022, April). Effects of environmental enrichment on behaviours and faecal glucocorticoid levels in captive sun bear (*Helarctus malayanus*). In IOP Conference Series: Earth and Environmental Science (Vol. 1019, No. 1, p. 012016). IOP Publishing.
2. Altman, J. D. (1999). Effects of inedible, manipulable objects on captive bears. *Journal of Applied Animal Welfare Science*, 2(2), 123-132.
3. Anderson, C., Arun, A. S., & Jensen, P. (2010). Habituation to environmental enrichment in captive sloth bears—Effect on stereotypies. *Zoo biology*, 29(6), 705-714.
4. Anderson, K., Garner, M. M., & Dennis, P. M. (2018). Causes of mortality in sloth bears (*Melursus ursinus*) housed in US zoos. *Journal of Zoo and Aquarium Research*, 6(1), 12-15.
5. Arun, A. S., Sharp, T. R., Pillai, H. C., Swaminathan, S., Satyanarayan, K., & Seshamani, G. (2018). Sloth bear *Melursus ursinus* maternity denning at the Wildlife SOS Bannerghatta Bear Rescue Centre, India. *International Zoo Yearbook*, 52(1), 235-244.
6. Babitz, M., Gibson, A., & Pratte, J. (2023). Improving animal wellbeing using behaviour-based methodologies: A discussion on enrichment and bears under human care. *Journal of Zoological and Botanical Gardens*, 4(1), 256-276.
7. Bargali, H. S., Pigeon, K. E., Akhtar, N., Sharp, T., & Jadav, K. K. (2020). Sloth bear (*Melursus ursinus*).
8. Bauer, E., Babitz, M., Boedeker, N., & Hellmuth, H. (2013). Approaches to understanding and managing pacing in sloth bears in a zoological setting. *International Journal of Comparative Psychology*, 26(1).

9. Byrne, C., Karl, S., Vilker, D., Meller, S., Thompson, B., & Webber, S. (2020, November). Monitoring the welfare of bears in captivity. In Proceedings of the Seventh International Conference on Animal-Computer Interaction (pp. 1-6).
10. Carlstead, K., Seidensticker, J., & Baldwin, R. (1991). Environmental enrichment for zoo bears. *Zoo biology*, 10(1), 3-16.
11. Carlstead, K., & Shepherdson, D. (2000). Alleviating stress in zoo animals with environmental enrichment. In *The biology of animal stress: basic principles and implications for animal welfare*. (pp. 337-354). Wallingford UK: Cabi Publishing.
12. Forthman, D. L., & Bakeman, R. (1992). Environmental and social influences on enclosure use and activity patterns of captive sloth bears (*Ursus ursinus*). *Zoo Biology*, 11(6), 405-415.
13. Ghavamian, Y., Minier, D. E., & Jaffe, K. E. (2023). Effects of complex feeding enrichment on the behaviour of captive Malayan sun bears (*Helarctos malayanus*). *Journal of Applied Animal Welfare Science*, 26(4), 670-684.
14. Goswami, S., Tyagi, P. C., Malik, P. K., Pandit, S. J., Kadivar, R. F., Fitzpatrick, M., & Mondol, S. (2020). Effects of personality and rearing-history on the welfare of captive Asiatic lions (*Panthera leo persica*). *PeerJ*, 8, e8425.
15. Goswami, S., Patel, S. K., Kadivar, R., Tyagi, P. C., Malik, P. K., & Mondol, S. (2021). Effects of a combined enrichment intervention on the behavioural and physiological welfare of captive Asiatic lions (*Panthera leo persica*). *Applied Animal Behaviour Science*, 236, 105222.
16. Hannam, K., & Diekmann, A. (2010). *Tourism and India: A critical introduction*. Routledge.

17. Hill, S. P., & Broom, D. M. (2009). Measuring zoo animal welfare: theory and practice. *Zoo Biology: Published in affiliation with the American Zoo and Aquarium Association*, 28(6), 531-544.
18. Kumar, V., Pradheeps, M., Kokkiligadda, A., Niyogi, R., & Umapathy, G. (2019). Non-invasive assessment of physiological stress in captive Asian elephants. *Animals*, 9(8), 553.
19. Laurie, A., & Seidensticker, J. (1977). Behavioural ecology of the sloth bear (*Melursus ursinus*). *Journal of Zoology*, 182(2), 187-204.
20. Lehner, P. N. (1992). Sampling methods in behaviour research. *Poultry science*, 71(4), 643-649.
21. Mallapur, A., Qureshi, Q., & Chellam, R. (2002). Enclosure design and space utilization by Indian leopards (*Panthera pardus*) in four zoos in southern India. *Journal of Applied Animal Welfare Science*, 5(2), 111-124.
22. Maple, T., Perdue, B. M., Maple, T. L., & Perdue, B. M. (2013). Environmental enrichment. *Zoo animal welfare*, 95-117.
23. Mason, G. J., & Latham, N. (2004). Can't stop, won't stop: is stereotypy a reliable animal welfare indicator?.
24. Park, P. N. H. Z. (2009). Behavioural study for the conservation breeding of Asiatic black bear (*Ursus thibetanus*) in Padmaja Naidu Himalayan Zoological Park, Darjeeling. Darjeeling. pp, 37-44.
25. Pastorino, G. Q., Christodoulides, Y., Curone, G., Pearce-Kelly, P., Faustini, M., Albertini, M., ... & Mazzola, S. M. Behavioural profiles of brown and sloth bears in captivity. *Animals*. 2017a; 7 (5): E39.
26. Plowman, A. B. (2003). A note on a modification of the spread of participation index allowing for unequal zones. *Applied Animal Behaviour Science*, 83(4), 331-336.

27. Queiroz, M. B., & Young, R. J. (2018). The different physical and behavioural characteristics of zoo mammals that influence their response to visitors. *Animals*, 8(8), 139.
28. Shepherdson, D. J., Carlstead, K. C., & Wielebnowski, N. (2004). Cross-institutional assessment of stress responses in zoo animals using longitudinal monitoring of faecal corticoids and behaviour. *Animal Welfare*, 13(S1), S105-S113.
29. Tarou, L. R., & Bashaw, M. J. (2007). Maximizing the effectiveness of environmental enrichment: Suggestions from the experimental analysis of behaviour. *Applied Animal Behaviour Science*, 102(3-4), 189-204.
30. Veeraselvam, M., Sridhar, R., Jayathangaraj, M. G., & Perumal, P. (2013). Behavioural study of captive sloth bears using environmental enrichment tools. *International journal of zoology*, 2013(1), 526905.
31. Vickery, S., & Mason, G. (2004). Stereotypic behaviour in Asiatic black and Malayan sun bears. *Zoo Biology: Published in affiliation with the American Zoo and Aquarium Association*, 23(5), 409-430.
32. Wagman, J. D. (2015). *The Effects of Feeding Enrichment on Behavioural Measures of Animal Welfare in Four Bear Species* (Master's thesis, Case Western Reserve University).
33. Wagman, J. D., Lukas, K. E., Dennis, P. M., Willis, M. A., Carroscia, J., Gindlesperger, C., & Schook, M. W. (2018). A work-for-food enrichment program increases exploration and decreases stereotypies in four species of bears. *Zoo biology*, 37(1), 3-15.
34. Wolfensohn, S., Shotton, J., Bowley, H., Davies, S., Thompson, S., & Justice, W. S. (2018). Assessment of welfare in zoo animals: Towards optimum quality of life. *Animals*, 8(7), 110.

35. Yoganand, K., Rice, C. G., & Johnsingh, A. J. T. (2005). Evaluating Panna National Park with special reference to ecology of sloth bear (*Melursus ursinus*). Final project report. Wildlife Institute of India, Dehradun, India.
36. Choo, Y. S., Kuze, N., Sato, S., Sakamaki, T., & Fujita, S. (2011). Captive management and reproduction of polar bears *Ursus maritimus* in Japanese zoos. *International Zoo Yearbook*, 45(1), 183-192.
37. Clubb, R., & Mason, G. (2003). Captivity effects on wide-ranging carnivores. *Nature*, 425(6957), 473-474.
38. LaFollette, M. R. (2023). Promoting behavioral diversity in captive animals through individual control over enrichment. *Applied Animal Behaviour Science*, 256, 105893.
39. 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(3-4), 341-352.
40. Rabari, A., Patel, B., & Joshi, D. (2024). Behavioral diversity and activity patterns of wild sloth bears in the Gir Forest, India. *Ursus*, 35(1), 1-10.
41. Shepherdson, D. J., Mellen, J. D., & Hutchins, M. (Eds.). (1998). *Second nature: Environmental enrichment for captive animals*. Smithsonian Institution Press.