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Scientific Report

Evaluation of factors affecting the behaviour of Bengal tiger (*Panthera tigris*) in captivity

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Abstract

The National Zoological Park (NZP), New Delhi is one of the large category zoos of the country housing a number of endangered species of animals. The zoo is visited by a large number of visitors every year. The zoo provides a naturalistic environment and other facilities like feed, healthcare, etc. to the captive animals. However, in captivity the housing conditions, visitation and other factors may jeopardize the natural behaviour, health as well as welfare of animals due to which the animal shows abnormal behaviour i.e. stereotypic behaviour. The study aims to investigate the effect of zoo visitors (visitor noise and density) and different types of enrichment on the behaviour of Bengal tigers (*Panthera tigris*) housed in the NZP. During the study, 10 individual Bengal tigers were studied during two phases: pre-enrichment and post-enrichment. The effect of visitor noise and density were also taken into account during both phases. The results of the study revealed a positive correlation between visitor density and noise with stereotypic behaviours in Bengal tigers (*Panthera tigris*) housed in the NZP. Therefore, there is an urgent need to review the existing visitation pattern at the zoo, and the carrying capacity of the visitor display area for the enclosures housing tigers so that the abnormal or stereotypic behaviour performed by the animals may be reduced and the welfare status of the captive animals can be improved which in turn helps in conserving the animals in captivity. Ultimately, the outcomes of this study can contribute to the development of better management strategies and enriching experiences for both the animals and visitors in zoological parks.

Keywords*:* Zoo visitors, Behaviour, Bengal tiger, Enrichment

Introduction

The zoos are considered at the forefront of conservation efforts and are scientific institutions that are being used for the purpose of education as well as research activities. In recent times, zoos strive to achieve the highest standards of wildlife conservation, animal welfare, and environmental education as per Zoos & Conservation, 2005. According to Tyagi et al. (2015), zoos are visited by around 600 million visitors every year. The main component of a zoo consists of its animals, visitors, its naturalistic surroundings, zoo keepers and other management personnel, etc. In the wild environment, the species enjoys vast areas to explore and manipulate. However, in captivity, the species have a confined, monotonous, and much less complex space for maneuvering as per the case studied by Mallapur, et al. (2002). Furthermore, according to Hediger (1950) species experience an alteration in biological rhythmicity in captive conditions. Behaviours exhibited by the animals in captivity are much less diverse as compared to that in the wild. Stressful factors, such as confined space, substandard enrichment, inadequate management, presence of visitors, and high levels of noise often hamper the goal of maintaining animal welfare in zoos. In zoos, the large felid species such as tigers are the main center of attraction for the visitors. Bengal tigers (*Panthera tigris*) are listed under Schedule I of the Wild Life (Protection) Act, 1972 and therefore, it is necessary for zoos to take essential conservatory measures. On the other hand, White tiger forms a centre of attention for most of the zoo visitors due to its peculiarly pigmented coat.

The evaluation of factors affecting the behaviour of Bengal tigers (*Panthera tigris*) housed at National Zoological Park, New Delhi is a comprehensive and vital study aimed at understanding the different types of behaviour of tigers within a captive environment. According to Garai et al. (2022), the Bengal tiger, being a charismatic and endangered big cats, require a suitable and enriching habitat in captivity to ensure their well-being so that the efforts made towards its conservation becomes successful. By examining and analysing the various factors that may affect the behaviour of Bengal tiger, one can gain valuable insights into how to optimize their captive environments, thereby promoting their physical and psychological health.

Various research have proved the effect of visitors on the behaviour of animals like- influence of large density of human visitors on the behaviour of captive primates.The presence of visitors can have both positive and negative impacts on tiger behaviour also. Tigers may experience stress or anxiety due to increased noise levels, human proximity, and constant observation. It is crucial to study the effects of visitor presence on their behaviour and well-being according to Choudhary & Chisty (2022). By evaluating the impact of visitor numbers, noise levels, and

specific interactions, zoos can develop strategies to minimize stress and provide positive experiences for both visitors and tigers.

Mak et al. (2021) reported that in the wild, animals with the help of behavioural adjustment and changes, survive by adapting to the environment. However, in the captive conditions an animal loses this kind of control over the environment in which it is housed as it is not possible to include the infinite variables that exist in wild environmental conditions. In captivity various factors and conditions which decrease the animal's general reactions and alter their behavioural patterns was observed by Mishra et al. (2013). The design and layout of tiger enclosures play a pivotal role in providing a stimulating and naturalistic environment. Factors such as enclosure size, vegetation, water features, hiding places, and climbing structures influence their physical activity levels, exploration, and natural behaviours as mentioned by Sureshmarimuthu et al. (2021).

There are several benefits of enrichment for the animals housed in the zoo which range from changes in behaviour, such as decrease in aggression, increasing activity and decreasing abnormal behaviour, to improved reproduction and health and increased survival of captive-bred animals released into wild as per Poudel et al. (2021). Environmental enrichment includes the practices of increasing the physical, social and temporal complexity of captive environments. According to Bashir (2020), the animals which are housed in enriched environments utilize areas of the enclosure that are more naturalistic. Studies also shows that animal housed in larger more environmentally complex enclosures exhibit lower levels of stereotypy than animals housed in small barren enclosures. Smith et al. (2022) reported that when four tigers were provided access to three exhibit configurations: one exhibit alone (E, baseline), one exhibit plus about 19 m^2 of trail (ET), and two displays joined by roughly 46 m^2 of trail (E2T). The results showed that providing tigers with voluntary access to wider and more complex habitats encourages natural behaviour while decreasing stereotyped behaviour.

The purpose of this study is to investigate and understand the various factors that affect the behaviour and well-being of selected tigers housed in the National Zoological Park, New Delhi as it is one of the prominent zoos in the country with highest footfall. Specifically, the study aims to examine the impact of zoo visitors, including visitor density and noise, on the behaviour of the tigers during the pre and post enrichment. The extent to which captivity and visitation have an impact on the behaviour of tigers of NZP has not been studied yet. However, such information is pivotal for the welfare of captive species.

Material and methods

A total of 10 numbers of individuallyhoused Bengal tigers were observed during the study. The data regarding the date of birth, sex, and other details of the tigers are shown in table 1. All the tigers housed at National Zoological Park, New Delhi were fed with buffalo meat once a day at around 5 pm in their feeding cubicles or night cells (except Fridays) during the study period. In the first phase, the behaviour assessments of 10 tigers were conducted using scan and focal sampling techniques (Altman, 1974) and ethograms were developed to define and categorize specific behaviours of interest. The behavioural assessments were conducted for 6 hours daily, with sampling periods of 15 minutes. The behaviour recorded was categorize into states and events according to the established ethograms. The effect of visitor presence was taken into account and during that period no enrichment was provided to the tigers i.e. pre enrichment phase.

Thre visitor aspects were considered during the study: visitor density, noise produced, and visitor activities. Visitor density was simply calculated by counting the number of visitors standing at the visitor area. Those passing by or walking were not recorded. Environmental noise was measured using noise meter (Meco Digital Sound Level Meter). The noise level was measured in Decibels. Visitor activities include actions such as standing or sitting on barrier, throwing stones, hooting, or striking the barrier fence etc. was taken into account. All the individual animals were studied when they are in the outdoor enclosure i.e. in the display area. Visitors are allowed in the zoo between 9:00 am and 5:00 pm except on Friday. Accordingly, the various behaviours exhibited by each individual under study were recorded in an activity sheet.

In the second phase, the assessment of 8 tigers was done as one tiger was transferred to other Indian zoo under animal exchange programme and one tiger was died. The focus in the second phase was on the effectiveness of enrichment activities (environmental enrichment provided alongwith social enrichment) and presence of visitors there for which the behaviours of the tigers were recorded for approximately 6 hours daily during the post-enrichment phase. The recorded activity was documented in an activity sheet for analysis as done in case of pre enrichment data.

Data analysis

The data obtained/recorded was compiled in MS Excel sheet on daily basis. The ethogram was constructed by providing the time spent (in percentage) in performing each behavioural activity. For each individual, percentage of stereotypic and non-stereotypic behaviours was calculated. Moreover, percentage of active and inactive behaviours was also calculated,

individual-wise. Additionally, utilization of each segment of the cage by the individuals was also calculated in percentage. The first step in the data analysis process is to calculate the total frequency of each behaviour for each condition. This involves summing up the frequencies of each behaviour observed in the presence of zoo visitors, enrichment, and no enrichment. The frequency count is performed separately for each tiger and behaviour category.

The average visitor density per minute and average noise per minute at the enclosure was then calculated. The independent variables were – visitor density and noise, while the animal activity (behaviour) was taken as the dependent variable. P-value was calculated between a) animal behaviour and visitor density and b) animal behaviour and environmental noise. The statistical tests, such as ANNOVA, aremainly used to analyse the behaviour data and determine the significance of the observed changes.

Table 1. Details on the individual tigers studied

S.No.	House Name	Date of Birth	Sex	Birth type	Local ID	Remarks
1	Karan	June 04, 2013	Male	Captive	260040/DELHI	Normal coloured
2	Rama	May 16, 2011	Male	Captive	260041/DELHI	Normal coloured and died on Sep 20, 2019
3	B-2	June 02, 2005+/- 6 months	Male	Wild	260043/DELHI	Normal coloured
4	Vina Rani	June 20, 2006	Female	Captive	260031/DELHI	Colour mutation
5	Vijay	July 21, 2007	Male	Captive	260032/DELHI	Colour mutation
6	Kalpana	Feb 7, 2007	Female	captive	260038/DELHI	Colour mutation
7	Tipu	March 18, 2015	Male	Captive	260044/DELHI	Colour mutation
8	Gita	March 18, 2015	Female	captive	260045/DELHI	Colour mutation and transfer to Lucknow Zoo
9	Sita	March 18, 2015	Female	Captive	260046/DELHI	Colour mutation
10	Nirbhaya	March 18, 2015	Female	Captive	260047/DELHI	Colour mutation

Results

Active behaviour during pre-enrichment phase

The mean percentage of time spent (standard deviation) for the different active behaviours of ten tigers named Vijay, Kalpana, Rani, Sita, Gita, Nirbhaya, Tipu, B-2, Rama, and Karan during pre-enrichment phasewere calculated which is shown in figure 1 and table 2.

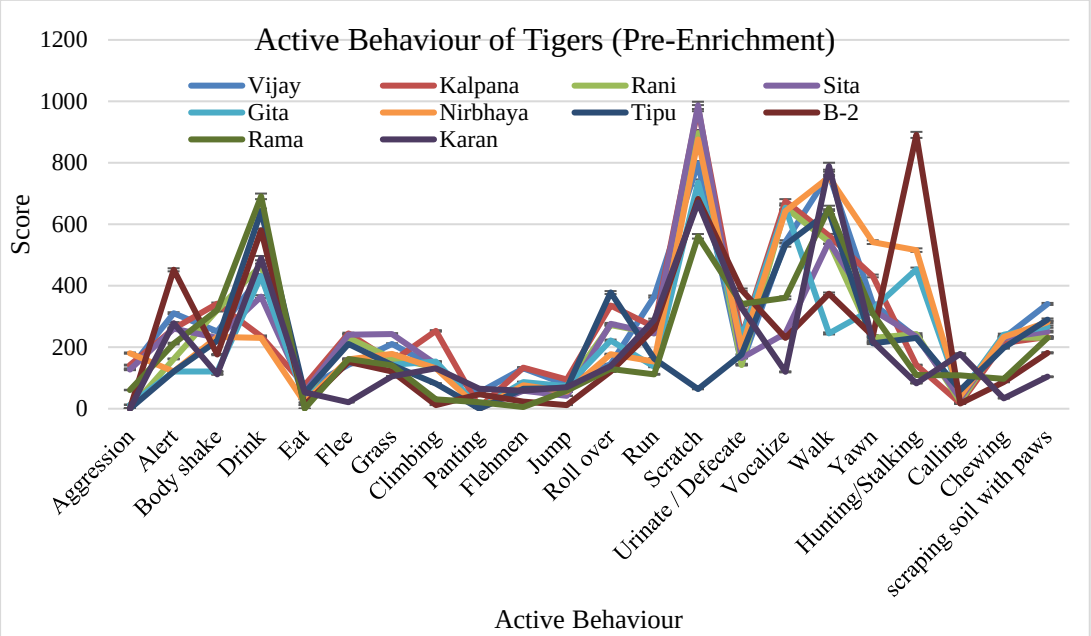

Figure 1. Active behaviour of tigers during pre-enrichment phase

Table 2. Active behaviour of tigers during pre-enrichment phase (Mean and standard deviation)

Tigers	Aggression	Alert	Body shake	Drink	Eat	Flee	Grass	Climbing	Panting	Flehmen
Vijay	130±1.25	311±3	251±2.42	434±4.19	64±0.61	143±1.38	211±2.03	135±1.3	53±0.51	132±1.27
Kalpana	142±1.45	261±2.66	342±3.49	236±2.4	76±0.77	245±2.47	153±1.56	253±2.58	4±0.04	134±1.36
Rani	00	162±1.59	321±3.59	467±5.23	42±0.47	231±2.58	164±1.83	135±1.51	2±0.02	67±0.75
Sita	127±1.52	261±3.12	231±2.76	365±4.37	54±0.64	241±2.88	243±2.91	145±1.73	1±0.01	59±0.7
Gita	13±0.17	121±1.75	121±1.65	431±5.9	31±0.42	152±2.08	143±1.95	153±2.09	2±0.02	87±1.19
Nirbhaya	181±2.02	121±1.35	234±2.61	231±2.58	20±0.22	161±1.8	178±1.99	132±1.47	0	76±0.85
Tipu	0	121±1.54	221±2.82	643±8.2	51±0.65	211±2.69	142±1.81	82±1.04	0	65±0.82
B-2	0	452±4.98	176±1.94	580±6.39	12±0.13	152±1.67	121±1.33	12±0.13	47±0.51	23±0.25
Rama	61±0.79	212±2.77	321±4.2	691±9.05	0	162±2.12	141±1.84	31±0.03	21±0.27	6±0.07
Karan	0	278±3.98	112±1.6	490±7.03	53±0.76	21±0.3	105±1.5	132±1.89	65±0.93	59±0.84

Further, the pearson correlation coefficient was calculated for the active behaviour shown by tigers during the pre-enrichment phase. The pearson correlation coefficient (R), which describes the strength and direction of a linear relationship between dependent and independent variables, was calculated which comes out to be 0.387. The R^2 value is used to measure the

goodness of fit of a model, and it gives the percentage of the total variation in the dependent variable that is explained by the independent variable which comes out to be 0.601. The adjusted R^2 value is 0.597. Further, the ANNOVA test shows the F-statistic value of 10.287 and significance value of 0.024. The coefficient value of noise and density of the visitors are -.194 and -.102 and the calculated t-value for the relationship between noise and active behaviour is -2.341 with a P-value of 0.036 and t-value for the relationship between density and active behaviour is -3.024 with a P-value of 0.32.

Inactive behaviourduring pre-enrichment phase

The mean percentage of time spent (standard deviation) for the different inactive behaviours during pre-enrichment phase by individual tigers are shown in figure 2 and table 3.

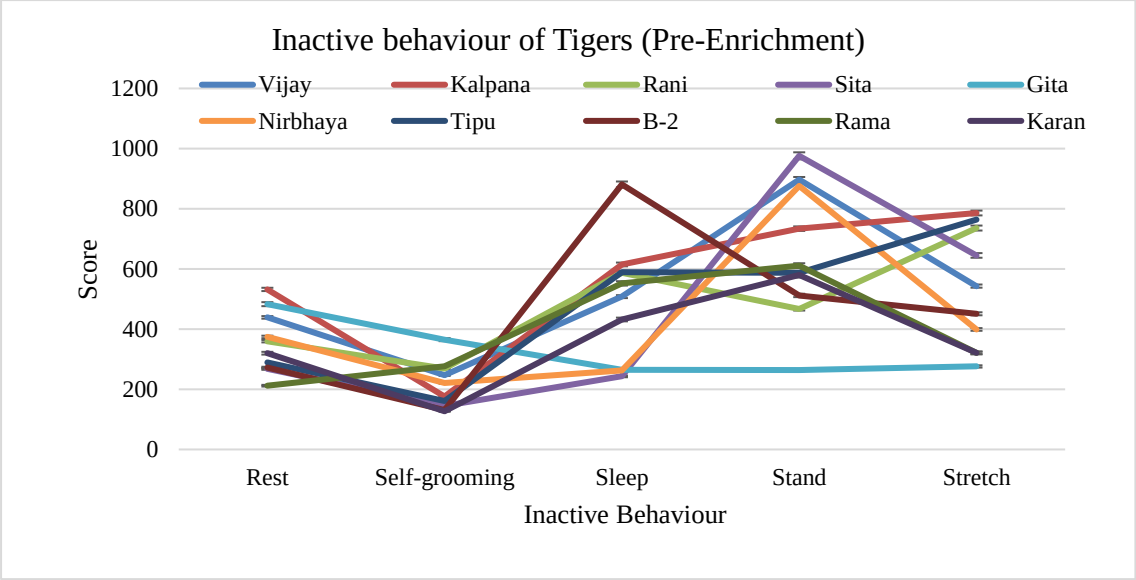

Figure 2. Inactive behaviour of tigers during pre-enrichment phase

Table 3. Inactive behaviour of tiger during pre-enrichment phase (mean and standard deviation)

Tigers	Rest	Self-grooming	Sleep	Stand	Stretch
Vijay	439±4.24	247±2.38	508±4.9	897±8.66	543±5.24
Kalpana	532±5.43	176±1.79	615±6.27	734±7.49	786±8.02
Rani	360±4.03	269±3.01	587±6.57	467±5.23	736±8.24
Sita	268±3.21	145±1.73	243±2.91	976±11.69	645±7.72
Gita	483±6.62	365±5	265±3.63	264±3.61	276±3.78
Nirbhaya	374±4.18	221±2.47	263±2.94	876±9.8	399±4.46

Tipu	289±3.68	161±2.05	589±7.51	587±7.49	764±9.75
B-2	272±2.99	131±1.44	881±9.71	512±5.64	451±4.97
Rama	212±2.77	277±3.62	552±7.22	611±8	321±4.2
Karan	320±4.59	127±1.82	432±6.19	580±8.31	321±4.6

Further, the R-value comes out to be 0.517, R^2 value 0.724, and adjusted R^2 value 0.720. The ANOVA test shows F-statistic value of 9.815 and significance value of 0.047 and the coefficient value of noise and density of the visitors are -.163 and -.147 and the calculated t-value for the relationship between noise and inactive behaviour of tigers during pre-enrichment is -2.432 with a P-value of 0.016 and t-value for the relationship between density and inactive behaviour of tigers during pre-enrichment is -3.274 with a P-value of 0.007.

Stereotypic Behaviour during pre-enrichment phase

The mean percentage of time spent (standard deviation) for the different stereotypic behaviours during pre-enrichment by individual tigers are shown in figure 3 and table 4.

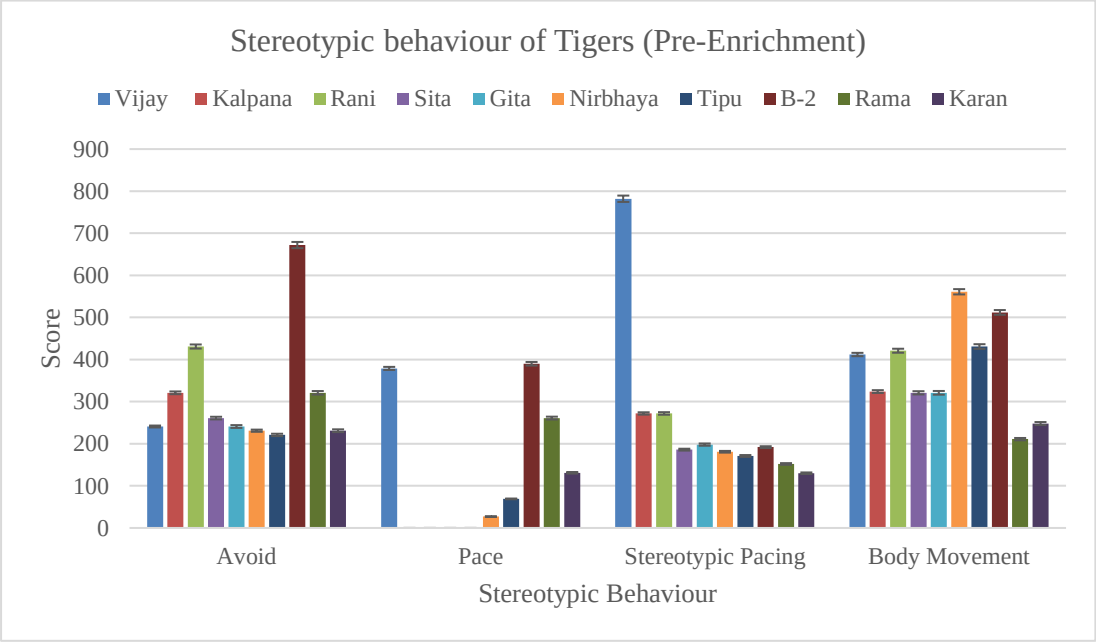

Figure 3. Stereotypic behaviour of tigers during pre-enrichment phase

Table 4. Stereotypic behavior tiger during pre-enrichment phase (Mean and standard deviation)

Tigers	Avoid	Pace	Stereotypic Pacing	Body Movement
Vijay	241±2.31	379±3.66	782±7.55	412±3.98
Kalpana	321±3.27	0	272±2.77	324±3.3

Rani	431±4.83	0	272±3.04	421±4.71
Sita	261±3.12	0	186±2.22	321±3.84
Gita	241±3.3	0	198±2.71	321±4.39
Nirbhaya	231±2.58	27±0.3	181±2.02	561±6.27
Tipu	221±2.82	69±0.88	171±2.18	431±5.5
B-2	672±7.4	390±4.29	192±2.11	512±5.64
Rama	321±4.2	261±3.41	152±1.99	211±2.76
Karan	231±3.31	131±1.87	130±1.86	248±3.55

The R-value comes out to be 0.412, R^2 value is 0.509 and adjusted R^2 value is 0.506. Further, ANOVA test shows F-statistic value of 18.652 and significance value of 0.016. The coefficient value of noise and density of visitors are -.295 and -.638, and calculated t-value for the relationship between noise and stereotypic behaviour of tigers during pre-enrichment is -4.014 with a P-value of 0.012 and t-value for the relationship between density and stereotypic behaviour of tigers duringpre-enrichment is -2.839 with a P-value of 0.41.

Active behaviour during post-enrichment phase

The mean percentage of time spent (standard deviation) for the different active behaviours during post-enrichment by individual tigers are shown in figure 4 and table 5.

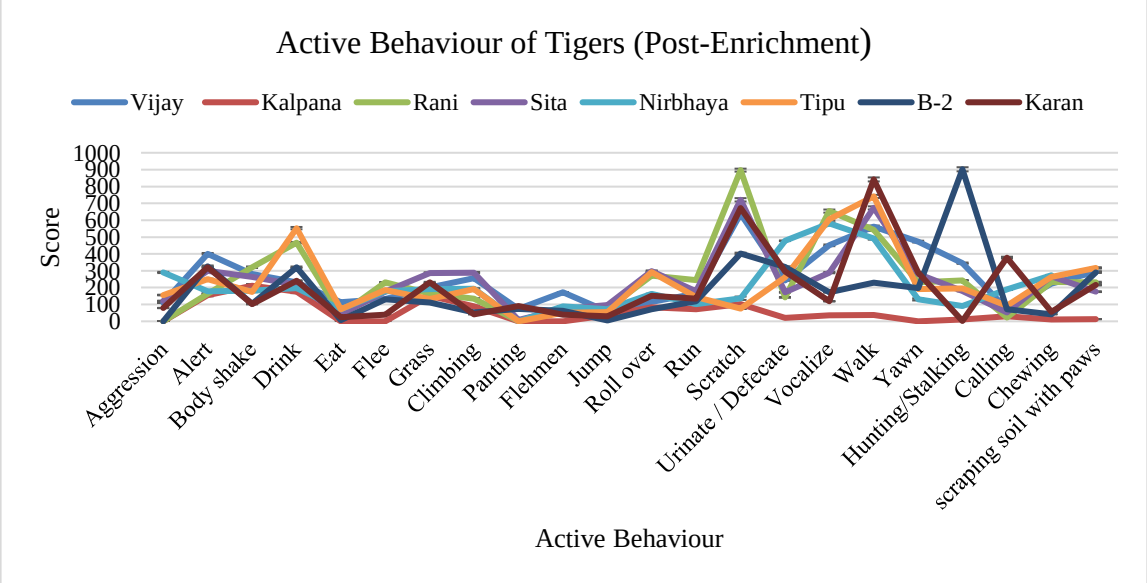

Figure 1. Active behaviour of tigers during post-enrichment phase

Table 5. Active Behaviour of tigers during post-enrichment phase

Tigers	Aggression	Alert	Body shake	Drink	Eat	Flee	Grass	Climbing	Panting	Flehmen
Vijay	110±1.24	401±4.52	281±3.16	231±2.6	114±1.28	133±1.49	201±2.26	255±2.87	73±0.82	172±1.93

Kalpana	00	156±7.7	211±10.42	176±8.69	00	00	151±7.46	89±4.39	00	00
Rani	00	162±2	321±4.48	467±3.85	42±0.34	231±2.19	164±1.36	135±1.67	2±0.2	67±0.85
Sita	121±1.65	299±4.09	264±3.61	216±2.95	41±0.56	176±2.4	287±3.92	289±3.95	8±0.1	73±0.99
Nirbhaya	290±3.68	178±2.26	182±2.31	197±2.5	71±0.9	178±2.26	192±2.44	194±2.46	00	89±1.13
Tipu	156±1.94	250±3.11	175±2.18	553±6.89	72±0.89	185±2.3	132±1.64	191±2.38	00	51±0.63
B-2	00	327±4.41	104±1.4	321±4.33	7±0.09	130±1.75	112±1.51	52±0.7	73±0.98	63±0.85
Karan	79±1.11	321±4.57	102±1.43	240±3.37	24±0.33	39±0.54	231±3.25	42±0.59	91±1.28	40±0.56

The R-value is 0.472, R^2 value is .573, and adjusted R^2 value is .568. The ANOVA test results have an F-statistic value of 12.371 and significance value of 0.37 and coefficient value of noise and density of the visitors are -.297 and -.274. Further, the calculated t-value for the relationship between noise and active behaviour of tigers during post-enrichment is -2.612 with a P-value of 0.031 and t-value for the relationship between density and active behaviour is -2.329 with a P-value of 0.038.

Inactive behaviour during post-enrichment phase

The mean percentage of time spent (standard deviation) for the different inactive behaviours during post-enrichment by individual tigers are shown in figure 5 and table 6.

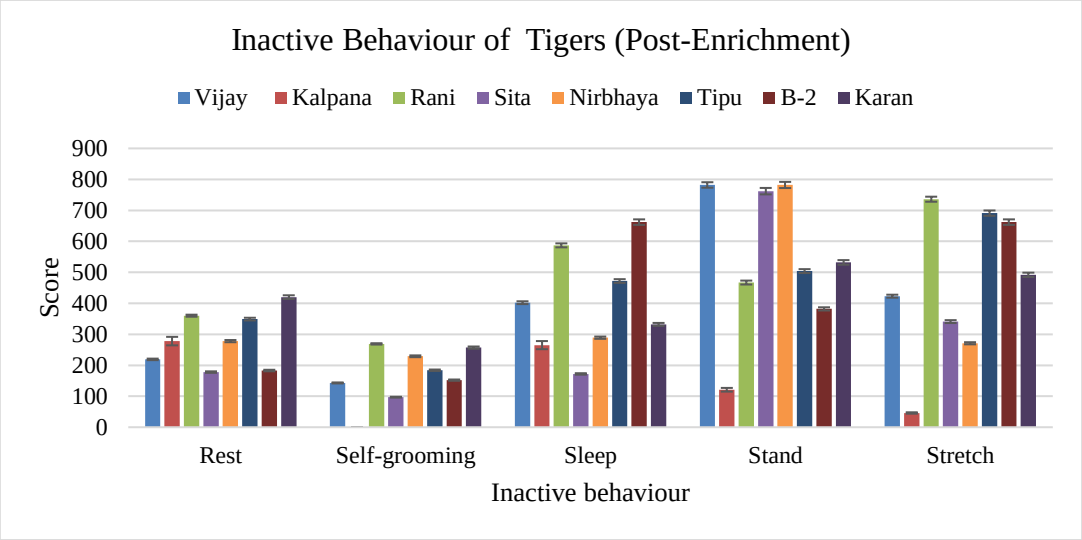

Figure 2. Inactive behaviour of tigers during post-enrichment phase

Table 6. Inactive behaviour of tiger during post-enrichment phase (Mean and standard deviation)

Tigers	Rest	Self-grooming	Sleep	Stand	Stretch
Vijay	219±2.46	143±1.61	402±4.53	782±8.81	423±4.77
Kalpana	278±13.73	0	265±13.09	121±5.97	46±2.27
Rani	360±3.28	269±2.16	587±6.42	467±6.31	736±8.1
Sita	178±2.43	97±1.32	172±2.35	762±10.42	341±4.66
Nirbhaya	278±3.53	229±2.91	289±3.67	782±9.94	271±3.44
Tipu	349±4.35	184±2.29	472±5.88	504±6.28	691±8.61
B-2	183±2.46	152±2.05	662±8.93	382±5.15	662±8.93
Karan	420±5.91	257±3.61	332±4.67	532±7.48	492±6.92

The results shows R-value of 0.651, R^2 value 0.592, and adjusted R^2 value 0.587. Further, the ANOVA test shows the F-statistic value of 8.724 and significance value of 0.031 and coefficient value of noise and density of visitors are -.056 and -.038. Further, the calculated t-value for the relationship between noise and inactive behaviour of tigers is -3.675 with a P-value of 0.043 and t-value for the relationship between density and inactive behaviour of tigers is -3.121 with a P-value of 0.021.

Stereotypic behaviour during post-enrichment phase

The mean percentage of time spent (standard deviation) for the different stereotypic behaviours during post-enrichment by individual tigers are shown in figure 6 and table 7.

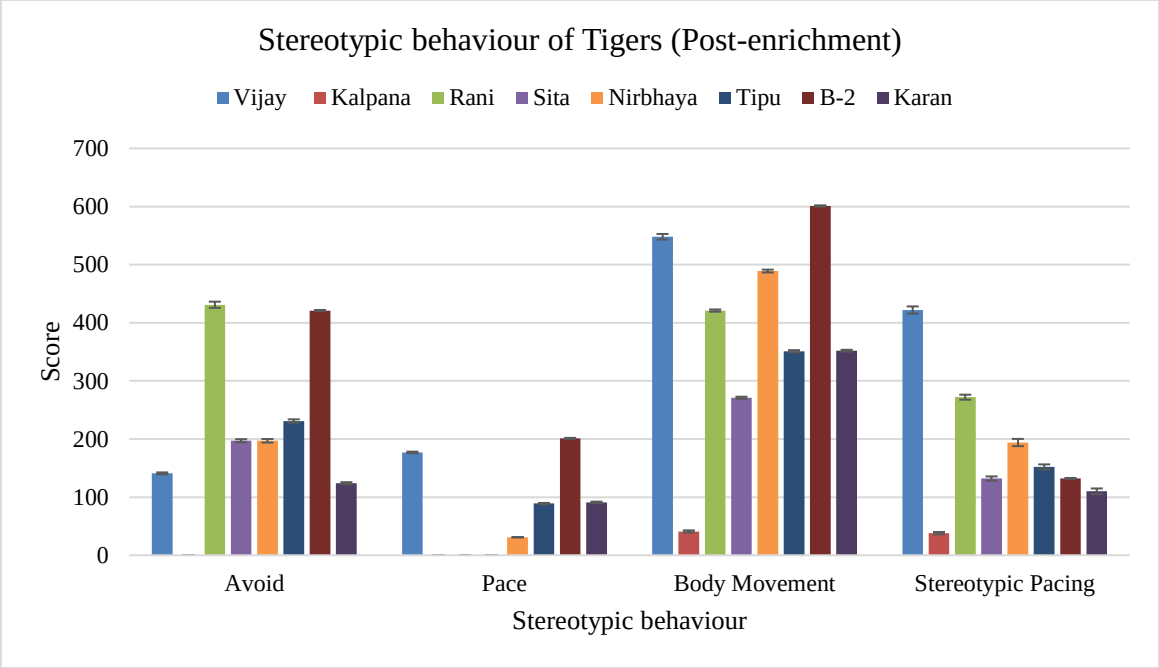

Figure 3. Stereotypic behaviour of tigers during post-enrichment phase

Table 7. Stereotypic behaviour of tiger during post-enrichment phase (Mean and standard deviation)

Tigers	Avoid	Pace	Body Movement	Stereotypic Pacing
Vijay	141±1.59	177±1.31	548±4.75	422±6.18
Kalpana	0	0	41±1.87	38±2.02
Rani	431±5.32	0	421±1.93	272±4.3
Sita	197±2.69	0	271±1.8	132±3.7
Nirbhaya	197±3.07	31±0.39	489±2.46	194±6.21
Tipu	231±2.88	89±1.1	351±1.89	152±4.37
B-2	421±5.68	201±2.71	601±1.78	132±8.11
Karan	124±1.74	91±1.28	352±1.54	110±4.95

The results show R-value of 0.469, R^2 value 0.785, and adjusted R^2 value 0.781. The ANOVA test results shows an F-statistic value of 16.674 and significance value of 0.022 and coefficient value of noise and density of visitors are -.195 and -.106. Further, the calculated t-value for the relationship between noise and stereotypic behaviour of tigers during post-enrichment is -3.578 with a P-value of 0.028 and t-value for the relationship between density and stereotypic behaviour of tigers is -2.692 with a P-value of 0.043.

Discussion

Active behaviour of tigers during pre-enrichment phase

Figure 1 and table 2 presents mean and standard deviation on the behaviours of tiger.The recorded behaviours include aggression, alert, body shake, drink, eat,flee, grass, climbing, panting, flehmen, jump, roll over, run, scratch, urinate/defecate, vocalize, walk, yawn, hunting/stalking, calling, chewing, and scraping soil with paws. The results shows that Kalpana spent the highest active behaviour (6033) with most of the time in scratching behaviour followed by Vijay (5900), Nirbhaya (5804), Rani (5379), Sita (5302), B-2 (5058), Gita (4883), Rama (4717), Tipu (4552), and Karan (4339).

The results show the R-value of 0.387 which depicts a weak and positive correlation between the dependent (active behaviour of tigers) and independent variables (visitors noise and Density). The R^2 value is 0.601, shows that 60.1% changes in active behaviour of tigerspre-enrichment, and is explained by independent variables (noise and density of the visitors). 39.9% is captured by error term, so it can be clearly concluded that the model fitted has good fit. The adjusted R^2 value is 0.597 shows about 59.7% changes in active behaviour of tigers, and is explained by independent variables (noise and density of the visitors). From this adjusted R^2 value also, it can be concluded that the model fitted was good. Besides, the ANOVA test confirms that the overall regression model is significant for data, as F-statistic value is 10.287 and significance value is 0.024 which is less than 0.05.

The coefficient value of noise and density of the visitors are -.194 and -.102, shows that a unit decrease in noise and density, on the average, there is a decrement in active behaviour of tigers by -0.194 units with noise and by -.102 units with density. The calculated t-value for the relationship between noise and active behaviour of tigers during pre enrichment phase is -2.341 with a P-value of 0.036 and t-value for the relationship between density and active behaviour of tigers during pre enrichment phase is -3.024 with a P-value of 0.32. The obtained t-value for noise and density of the visitors is less than -2 and the P-value is less than 0.05, so it is concluded that the noise and density of the visitors have significant negative effect on active behaviour of tigers during pre enrichment phase.

Inactive behaviour of tigers during pre-enrichment phase

Figure 2 and table 3 presents inactive behaviours of ten tigers named- Vijay, Kalpana, Rani, Sita, Gita, Nirbhaya, Tipu, B-2, Rama, and Karan during pre-enrichment phase. The recorded behaviours include rest, self-grooming, sleep, standing, and stretching. It has been observed that Sita shows highest inactive behaviour followed by Vijay, B-2 etc.

The R-value of 0.517 depicts that there is a strong and positive correlation between the dependent (inactive behaviour) and independent variables (noise and density of the visitors). The R^2 value (0.724) shows that 72.4% changes in inactive behaviour of tigers and is explained

by independent variables (noise and density of the visitors). 37.6% is captured by error term, and adjusted R^2 value (0.720) shows about 72.0% changes in inactive behaviour of tigers, and is explained by independent variables (noise and density of the visitors). Therefore, it can be concluded that the model has good fit.

The ANOVA test confirms that the overall regression model is significant for data, as F-statistic value is 9.815 and significance value is 0.047 which is less than 0.05. The coefficient value of noise and density of the visitors are -.163 and -.147, shows that a unit decrease in noise and density of the visitors, on the average, there is a decrement in inactive behaviour of tigers by -.163 units with noise and by -.147 units with density.The calculated t-value for the relationship between noise and inactive behaviour of tigers and t-value for the relationship between density and inactive behaviour of tigers is less than -2 and the P-value is less than 0.05, so it is concluded that there is a significant negative impact of noise and density of the visitors on inactive behaviour of tigers during pre-enrichment.

Stereotypic behaviour of tigers during the pre-enrichment phase

Figure 3 and table 4 present the mean and standard deviation of the behaviours of ten tigers named Vijay, Kalpana, Rani, Sita, Gita, Nirbhaya, Tipu, B-2, Rama, and Karan. The recorded behaviours include avoid, pace, stereotypic pacing and body movement. From the table, it is clear that Vijay spent the highest overall time in stereotypic behaviour which is 1814 followed by B-2 (1766) , Rani (1124), Nirbhaya (1000), Rama (945), Kalpana (917), Tipu (892), Sita (768), Gita (760) and Karan (740).

Further, the R-value of 0.412 depicts that there is a weak and positive correlation between the dependent (stereotypic behaviour of tigers) and independent variables (noise and density of visitors). The R^2 value which is 0.509 shows that 50.9% changes in stereotypic behaviour of tigers during pre-enrichment, and is explained by independent variables (noise and density of visitors). 49.1% is captured by error term, and adjusted R^2 value which is 0.506 shows about 50.6% changes in stereotypic behaviour of tigers during pre-enrichment, and is explained by independent variables (noise and density of visitors) which can be concluded that the model has good fit.

The ANOVA test confirms that the overall regression model is significant for data, as F-statistic value is18.652 and significance value is 0.016 which is less than 0.05. The coefficient value of noise and density of visitors are -.295 and -.638, shows that a unit decrease in noise and density, on the average, there is a decrement in stereotypic behaviour of tigers during pre-enrichment by -0.295 units with noise by -.638 units with density. Besides, the calculated t-value for the

relationship between noise and stereotypic behaviour of tigers during pre-enrichment is -4.014 with a P-value of 0.012 and t-value for the relationship between density and stereotypic behaviour of tigers during pre-enrichment is -2.839 with a P-value of 0.41. The obtained t-value for noise and density of visitor is less than -2 and the P-value is less than 0.05, so it is can be concluded that there is a significant negative effect of noise and density of visitors on the stereotypic behaviour of tigers during the pre-enrichment phase.

Active behaviour during the post-enrichment phase

Figure 4 and table 5 present the mean and standard deviation on the behaviours of eight tigers named Vijay, Kalpana, Rani, Sita, Nirbhaya, Tipu, B-2, and Karanas tiger named Rama died and Gita was transferred to another Indian zoo under an animal exchange programme. The recorded behaviours include aggression, alertness, body shaking, drinking, eating flee, grass, climbing, panting, flehmen, jumping, rolling over, running, scratching, urinating/defecating, vocalising, walking, yawning, hunting/stalking, calling, chewing, and scraping soil with paws. The results depict that the overall highest time spent in active behaviour was 5610 by Vijay followed by Rani (5379), Sita (5158), Tipu (4996), Karan (4393), Nirbhaya (4278), B-2 (4014) and Kalpana (1235).

The results show that the R-value of 0.472 is a weak and positive correlation between the dependent (active behaviour of tigers during post-enrichment) and independent variables (noise and density of the visitors). The R^2 value is .573, which shows that 57.3% changes in active behaviour of tigers during post-enrichment, and is explained by independent variables (noise and density of the visitors). 42.7% is captured by error term, and the adjusted R^2 value is .568 which shows about 56.8% changes in active behaviour of tigers during post-enrichment, and is explained by independent variables (noise and density of the visitors). Therefore, it can clearly be concluded that the model has good fit.

The ANOVA test confirms that the overall regression model is significant for data, as an F-statistic value is 12.371 and significance value is 0.37 which is less than 0.05.The coefficient value of noise and density of the visitors are -.297 and -.274, which shows that a unit decrease in noise and density of the visitors, on the average, there is a decrement in active behaviour of tigers by -0.297 units with noise and by -.274 units with density of the visitors. Besides, the calculated t-value for the relationship between noise and active behaviour of tigers is -2.612 with a P-value of 0.031 and t-value for the relationship between density and active behaviour of tigers is -2.329 with a P-value of 0.038. The obtained t-value for noise and density of the visitors is less than -2 and the P-value is less than 0.05, therefore, it shows that there is a significant negative effect of noise and density of visitors on active behaviour of tigers during post-enrichment.

Inactive behaviour during post-enrichment phase

Figure 5 and table 6 present the mean and standard deviation on the behaviours of eight tigers named Vijay, Kalpana, Rani, Sita, Nirbhaya, Tipu, B-2, and Karanas tiger named Rama died and Gita was transferred to another Indian zoo under an animal exchange programme. The recorded inactive behaviours include rest, self-grooming, sleep, standing, and stretching. The results depict that the highest overall time spent in inactive behaviour was 2419 by Rani followed by Tipu (2200), B-2 (2041), Karan (2033), Vijay (1969), Nirbhaya (1849), Sita (1550), and Kalpana (710).

The R-value of 0.651 depicts that there is a strong and positive correlation between the dependent (inactive behaviour of tigers) and independent variables (noise and density of visitors).The R^2 value is 0.592, which shows that 59.2% changes in inactive behaviour of tigers during post-enrichment phase, and is explained by independent variables (noise and density of visitors). 40.8% is captured by error term, so it can be clearly concluded that the model has good fit. The adjusted R^2 value is 0.587 which shows about 58.7% changes in inactive behaviour of tigers and is explained by independent variables (noise and density of visitors). From this adjusted R^2 value also, it can conclude that the model has good fit.

The ANOVA test further confirms that the overall regression model is significant for data, as an F-statistic value is 8.724 and significance value is 0.031 which is less than 0.05. The coefficient value of noise and density of visitors are -.056 and -.038, which shows that a unit decrease in noise and density, on the average, there is a decrement in inactive behaviour of tigers by -.057 units with noise and by -.038 units with density.The calculated t-value for the relationship between noise and inactive behaviour of tigers during post-enrichment is -3.675 with a P-value of 0.043 and t-value for the relationship between density and inactive behaviour of tigers is -3.121 with a P-value of 0.021. The obtained t-value for noise and density is less than -2 and the P-value is less than 0.05, so it is concluded that there is a significant negative impact of noise and density of visitors on inactive behaviour of tigers during post-enrichment phase.

Stereotypic behaviour during post-enrichment phase

Figure 6 and table 7presents mean and standard deviation on the behaviours of eight tigers named Vijay, Kalpana, Rani, Sita, Nirbhaya, Tipu, B-2, and Karanas tiger named Rama was died and Gita was transferred to other Indian zoo under animal exchange programme. The recorded stereotypic behaviours include avoid, pace, stereotypic pacing and body movement. The results depicthighest overall time spent in stereotypic behaviour was 1355 by B-2 followed

by Vijay (1288), Rani (1124), Nirbhaya (911), Tipu (823),Karan (677), Sita (600) and Kalpana (79).

The R-value of 0.469 depicts that there is a weak and positive correlation between the dependent (stereotypic behaviour of tigers) and independent variables (noise and density of visitors). The R^2 value is 0.785, which shows that 78.5% changes in stereotypic behaviour of tigers during post-enrichment, and is explained by independent variables (noise and density of visitors). 31.5% is captured by error term, and the adjusted R^2 value is 0.781 shows about 78.1% changes in stereotypic behaviour of tigers, and is explained by independent variables (noise and density of visitors). Therefore, from the values it can be concluded that the model has good fit. Further, ANOVA test confirms that the overall regression model is significant for data, as an F-statistic value is 16.674 and significance value is 0.022 which is less than 0.05.The coefficient value of noise and density of visitors are -.195 and -.106, which shows that a unit decrease in noise and density, on the average, there is a decrement in stereotypic behaviour of tigers during post-enrichment by -.195 units with noise and by -0.106 units with density.

The calculated t-value for the relationship between noise and stereotypic behaviour of tigers is -3.578 with a P-value of 0.028 and t-value for the relationship between density and stereotypic behaviour is -2.692 with a P-value of 0.043. The obtained t-value for noise and density is less than -2 and the P-value is less than 0.05, hence it is concluded that there is a significant negative effect of noise and density of visitors on stereotypic behaviour of tigers during post-enrichment.

The study shows visitor presence i.e. noise and density has significant negative effect on behaviour of tigers (active, inactive and stereotypic behaviours) during both pre and post-enrichment phases. It has been observed that tigers incline towards the stereotypic and inactive behaviours more during pre-enrichment phase. The time spent in performing active behaviours is comparatively much less during pre-enrichment phase in comparison to post enrichment phase. The same has been observed by various researchers also. The reason behind this kind of behaviour has been due to lack of enrichment elements that may otherwise keep the animal more active and reduce stereotypy (Mallapur et al., 2002).

Tigers were mostly observed to occupy the rear portions of the enclosure, which may be because of the presence of visitors at the opposite end and it may be to avoid them. Tigers were seen exhibiting high levels of pacing and much less tail/toe sucking. Pacing was performed usually at the rear end of the enclosure, which was closest to the night shelters. Stereotypy is one of the most commonly exhibited behaviours in captivity by tigers. Similar kind of observations have been made during earlier studies at various zoos (Baldwin, 1991; Biolatti et al., 2016; Mohapatra et al., 2014) and a similar trend has been documented by other researchers

as well (Lyons et al., 1997; Sajjad et al., 2011) i.e. the findings of the study is in consistent with the previous studies.

Further, the presence of visitors (density as well as noise) has shown to cause a significant effect on the behaviour of tigers. The two main causes for abnormal behaviours in captive conditions are a) frustration-induced stereotypy and b) malfunction-induced stereotypy (Mason et al., 2007). Locomotory stereotypes may be motivated by various factors (Clubb & Vickery, 2006), Fennec fox exhibit locomotory stereotypy due to high visitor density (Carlstead, 1991), adult orangutans were observed covering their heads with paper sacks and infants were seen holding on to adults in order to avoid humans (Birke, 2002), Lion-tailed macaques exhibit abnormal behaviours such as begging, self-biting, and bouncing (Mallapur et al., 2005), Agonistic behaviours and movement is significantly influenced due to the presence of human visitors in captive Indian Gaur (Sekar et al., 2008), effect on resting, moving, reproductive, social, and aggressive behaviours of Indian blackbuck (Rajagopal et al., 2011) etc. However, there is some evidence that chronic exposure of visitors may lessen this stressful influence in some captive species. In certain circumstances, such as places where public throws food, the human audience has an enriching effect on zoo-housed individuals (Hosey, 2000). Cook and Hosey observed development of interaction sequences between humans and caged chimpanzees. Visitors acted as a source of motivation so as to interact with one another (Cook & Hosey, 1995).

Besides, the results of the present study revealed that the effect of visitor noise and density on the behaviour of tigers are seems to be less during the post enrichment phase (which includes both environment enrichment and social enrichment) which shows that the enrichment plays a pivotal role in decreasing the inactive and stereotypic behaviour and increasing the active behaviour of captive tigers. Further, tigers are known for their agility and love for climbing, so the provision of vertical space and suitable structures can enhance their natural behaviour. Additionally, the introduction of natural elements like trees, rocks, and water bodies can mimic their natural habitat, providing opportunities for hunting, territorial marking, and social interactions.

Therefore, the implementation of enrichment activities is crucial for keeping tigers mentally and physically stimulated. Nguyen et al., 2021 also suggested that enrichment including the introduction of novel objects, scent trails, puzzle feeders, and simulated prey, may encourage natural behaviours such as hunting, exploring, and problem-solving which may help alleviate boredom, promote physical exercise, and provide cognitive stimulation.

The study also suggested having carefully managed pairing of tigers at the National Zoological Park, as during the study the social enrichment has been observed to lessen the effect of visitors on the tiger behaviour. In the wild, tigers are primarily solitary animals, with males and females coming together only for mating. However, in National Zoological Parks, carefully managed social interactions can be beneficial for the well-being of tigers as suggested by Merkebu & Yazezew, 2021. By studying the impact of social grouping, introductions, and compatible pairings, one can understand the effects of social interactions on their behaviour. This knowledge help zoos to amake informed decisions regarding housing arrangements, social dynamics, and breeding programs to ensure the social needs of tigers are met while minimizing stress or aggression (Kumar, 2022).

Conclusion

The study evaluated the behavioural responses of tigers in two phases i.e. during pre and post-enrichment and also investigated the effect of noise and density of visitor on the active, inactive, and stereotypic behaviours of tigers housed in the National Zoological Park, New Delhiduring both the phases. The results of the study show that when two phases- pre and post-enrichment phases are compared, the time spent for stereotypic behaviour in pre-enrichment phase is high which depicts that high noise and density of visitors may result in stress, disturbances, and altered behavioural patterns, including the development of stereotypic behaviours. To know the effect of noise and density of visitors on tiger behaviour (active, inactive and stereotypic behaviours), statistical analysis was carried out using ANNOVA, regression etc. The findings of analysis demonstrated that the noise and density of visitors has significant negative effect on active, inactive and stereotypic behaviours in both pre and post-enrichment phases ($P<0.05$). However, the effect of noise and density of visitors on active behaviour of tigers are high during pre-enrichment phase than in post-enrichment phase and the effect of noise and density of visitors on inactive behaviour of tigers are high duringpost-enrichment phase in comparison topre-enrichment phase, and the effect of noise and density of visitors on stereotypic behaviour of tigers are high duringpost-enrichment phase than in pre-enrichment phase.

The study therefore, depicts that the stress in captivity leads to an alteration in the normal behaviour and such behaviours ultimately affect animals' health, breeding, and survival. The study recommend having a species individual specific enrichment plan and form the basis for reviewing the existing visitation pattern at the zoo, carrying capacity of the visitor display area

etc. so that zoo management will ensure proper animal welfare and may be able to establish a self-sustaining captive population of Bengal tigers.

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