https://doi.org/10.37939/jhcc.v3i1.6

Visitors Mediated Spatio-Temporal Variation in Noise Pollution of Lahore Zoo and Possible Effects on Animal Behavior

*Hafiza Salma [1], Ghulam Hassan Abbasi [1], Kiran Saleem [2], Noman Ahmad [3], Muhammad Nadeem [1], Muhammad Ali [1], Muhammad Irfan [1], Muhammad Ashar Ayub [1]**

Abstract

Lahore Zoo is an ex-situ conservation facility housing various indigenous and exotic species of captive wild animals and is a source of gratification for visitors, especially children. The location of Lahore Zoo is very prominent in this regard, making it a most active and accessible tourist/visitor destination. On average working days, around 3000-4000 visitors are recorded in Lahore Zoo, which can shoot up to 20,000 on peak weekends and public holidays. The present investigation was carried out to measure spatial and temporal variation in sound levels (dB (A)) at selected sites, along with on-site behavioral recording of selected animals throughout the week. Spatial analysis (Inverse Distance Weighted -IDW) of recorded sound data was done with ArcGIS 10.5 software. A comprehensive questionnaire was also designed to determine visitors' attitudes toward this issue. Results for sound level reveal that the average sound level was under the WHO limits mostly during weekdays, where the average visitor number ranges from 3838 to 4148. On weekends, it goes from 8950 to 19154 visitors with loud noise recorded at most sites. Results from the general ethogram revealed that socially interactive species like monkeys, deer, and bears were more responsive towards visitors, unlike felines (leopard, tiger and lion) which increased their resting period with increased visitor density. Highlighted noisy areas by surveyed visitors were Tiger, Lion, Deer, Monkey, Aquarium, Rhino, Wolf, Cafeteria, Bird section, Ostrich, Camel, Snake House, Zebra, Giraffe, and Bear. To combat this issue, an awareness campaign has been done in the zoo to educate visitors.

Keywords: Noise; Anthropogenic Noise; Zoo: Captivity; Animal Behavior; Animal welfare.

[1]Institute of Agro-Industry and Environment, The Islamia University of Bahawalpur, Pakistan, Lahore
[2] Zoological Gardens, Lahore, Punjab 54000, Pakistan
[3]Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad-38040, Pakistan
***Correspondence:** ashar.ayub@iub.edu.pk
Received March 25, 2024; accepted May 28, 2024

1. Introduction

Sound can be defined as an auditory stimulus produced as a result of alteration of sound waves that travels through an elastic medium.[1] It is a wide-ranging term that encompasses both significant and irrelevant sounds,[2] whereas noise is an auditory expression that is annoying, harms hearing capacity, or hinders the recognition of desired sound.[3] According to a WHO report published in 2011, noise pollution is one of the most perilous and pervasive pollutants on the planet.[4]

Ecological alterations stemming from anthropogenic sources within an ecosystem can significantly and adversely impact the survival of living species within that biome.[5, 6] Major sources of noise in urban areas include road traffic, trains, airplanes, and loud sounds emanating from industrial and construction sites. Animal physiology and behavior depend on the duration of exposure to a specific range of noise. Reproductive stress and declines in feeding and activity patterns in animals can be triggered by loud noise. However, stress resulting in the form of behavioural changes can be more easily assessed compared to physiological modifications due to loud noise.[7]

The range of impact resulted from loud noise may extend from minor inconvenience i.e., avoiding the noisy area to major changes i.e., demonstrating stereotypic behaviours, injury, hearing loss or in some cases, death.[8, 9] According to research conducted by de Queiroz et al., the fundamental mechanism for hearing impairment is the same in auditory system of all mammals.[10] Therefore, we can assume that all mammals respond the same way to auditory damage as humans.[11, 12] Zoos now a days plays a vital role in conserving endangered species, promoting public education and awareness about animal welfare and facilitating zoo visitors for recreational purposes. Urban zoos are most likely to receive a variety of soundscape from the surrounding areas, routinely managerial practices and operation at zoos and most importantly, zoo visitor.[13]

A documented study revealed an increase in cortisol levels among wolves on days with high visitor density.[14] Researchers also observed the behaviour of lions in response to construction noise, revealing their preference for resting and spending most of their time in off-exhibit areas.[15] Larson and coworkers noted an elevated response in Koalas towards high-density visitors.[16] However, Quadros et al., did not find any specific behavioural modifications in response to loud noises among captive mammals.[17] Wark provided evidence for the positive influence of offering off-exhibit areas to captive animals.[18] Another study conducted by Suárez et al., found no significant correspondence between animal behaviour and visitor rush.[19] On the other hand, Dancer and Burn reported an increase in active behaviour with an escalating number of visitors.[20] Jakob-Hoff and fellow workers observed a negative impact of construction noise on mammals and ratites, with no discernible effect on reptiles.[21] Pelletier and colleagues (2020) established an association between elevated noise levels and the presence of zoo visitors, underscoring its relevance.[22] Similarly, Williams and their team (2021) demonstrated a connection between increased animal pacing and ground vibrations originating from nearby construction sites, emphasizing the multifaceted impact of environmental factors.[13] The diverse range of responses to noise observed across species was corroborated by Harley and associates (2022).[23] In contrast, Waterman's research (2017) yielded inconclusive findings, indicating no significant alterations in macaques' behaviour during peak visiting hours.[24] Therefore, our study aims to delve into noise levels during both visitor-heavy and quieter periods, as well as assess their influence on animal behaviour within Lahore Zoo.

2. Materials & Methods

The study was conducted at Lahore Zoo during October 2022. Lahore Zoo covers an area of approximately 10 hectares housing 1200 birds, mammals, and reptiles belonging to 102 species with more than half of the total count being exotic. We chose this zoo primarily due to its popularity among the public and its location, which makes it easier for people to visit here. Eighty-eight (88) locations were marked within the zoo which includes animal houses, enclosures, and public amusement amenities to measure different soundscapes and their impact on animal behavior. The sites were individually marked, as illustrated in (Fig. 1), with the help of Garmin's GPS64s, a high-quality GPS meter, which obtained accurate coordinates data in degree decimal along with the altitude for selected sites.

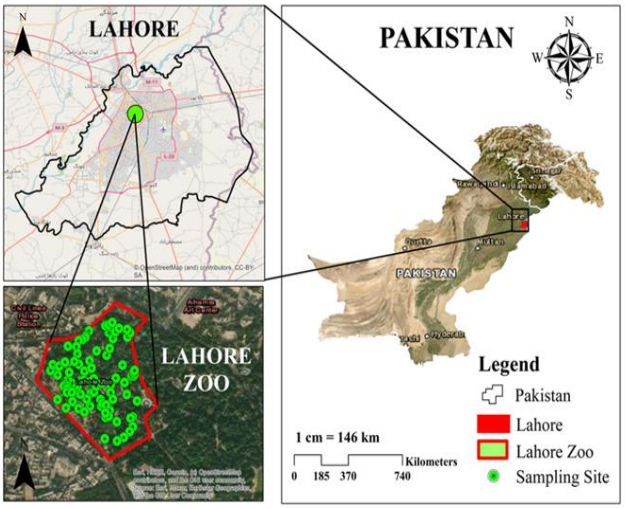

Figure 1: Study area map with sampling sites (developed using ArcGIS 10.5)

Measurement of Sound Level

The sound level was recorded with the help of calibrated noise measuring meter (UT-352). The sound level (dB (A)) was recorded once a day at each site consecutively for a week, i.e., Monday to Sunday. To ensure the accuracy of sound data, each sound level was recorded thrice at each site with a ten (10) second interval. Visitor density varies at the marked situates throughout the week depending on the animal activity and time of the day. For visiting hours, the sound level recording time was from 09:00 am till the Adhan-e-Maghrib, i.e., the zoo's closing time for the visitors. Whereas the sound level data for non-visiting hours were collected once before the zoo's opening and right after the zoo's closing, i.e., after sunset.

Statistical Analysis

The final value of measured sound levels was attained by calculating the mean of three recorded values from each site. Then the Standard Error (SE) formula was applied to the average values of sound level data

Table 1: Acoustic Data measured for Visiting and Non-Visiting Hours

Name of Site	Non-Visiting Hours		Visiting Hours						
	Morning	Evening	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Vervet Monkey	56.4± 0.3	62.3±0.2	61.7±0.8	61.3±4.2	68.2±0.033	58.1±1.3	61.6±4.2	68.7±1.2	***79.3±5.9**
Capuchin Monkey	58.5±1.6	57.8±0.1	62.8±4.1	59.7±3.2	69.2±0.3	63.1±5.4	63.8±4.4	65.3±1.3	***72.5±1.2**
Olive Baboon	54.5±0.7	57.4±0.1	62.1±3	68.7±3.2	***72.5±1.9**	58.8±0.9	***71.9±4.3**	***72.8±0.2**	***79.8±2.4**
Gray Langur	56.2±1.3	60.6±0.1	67.5±0.6	67.5±3.5	69.7±0.2	64.8±4.2	68.2±2.1	***70.2±1.2**	***76.1±1.7**
Otter	56.9±0.6	57.4±0.1	69.3±2.6	***77±2.3**	69.2±0.7	59.2±0.9	***76.6±2.5**	***71.4±2.8**	***81±1**
Tortoise	56.6±0.7	57.6±0.6	60.8±2.5	67.4±2.2	69.7±0.6	67.7±4.1	69.8±2.5	65.3±2.1	***74.3±1.9**
Mechanical Elephant	56±1	57.1±0.1	***74±1.9**	***77.8±2.3**	***78.9±0.7**	62.9±0.4	***77.3±1.9**	***76.7±2.4**	***82.6±1.5**
Leopard (Male)	57.9± 0.6	59.1±0.5	63.9±4.4	55.3±0.2	***72±0.3**	54.5±0.9	67±1.1	***72.6±1**	***73.1±2.1**
Hill S2	54.9± 0.7	60.7±0.1	62.4±1.1	59.3±1.9	61.5±0.7	60.8±3.8	65.6±3.1	60.4±1.2	***71.3±1**
Leopard (Pair)	56.9±0.5	58.7±0.3	62.3±1.5	63.1±2.6	***70.7±0.3**	60.8±1	55.9±0.5	62.6±0.4	***74±2.0**
Hill S1	57.9 ± 0.5	58.9±0.3	59.9±0.5	61±0.9	57.9±2.4	65.4±0.7	64.4±1.3	64.6±1.2	67.6±2.2
Lion House Enc. 1	59.5±0.3	60.5±0	64.4±2.9	69.5±0.4	***71.3±0.7**	64.2±0.9	***72.5±1.6**	65.1±0.3	68.1±2.7
Lion House Enc. 2	62±0	59.4±1.3	64±1	***73.6±3.6**	***74.3±1.4**	***70.2±2**	69.4±4.7	***70.2±3.2**	***75± 4.2**
Lion House Enc. 3	62.8±0.7	56.3±0.2	69.2±1.9	67.3±2.8	***78.6±6.6**	63.9±1.2	69±2.5	***74.1±5.4**	***73.6±0.5**
Lion House Enc. 4	68.7±4.9	58.5±0.1	69.7±1.2	***72.3±1.1**	***72.3±3**	65.8±2.3	***70.9±3.9**	***86.7±5.8**	***73.4±1.4**
Lion House Enc. 5	66.4±0.7	58.1±0.3	***79.4±6.5**	61.7±0.9	68.9±0.3	66.9±1.8	***73.3±2.8**	68.1±2.7	***84.1±7.4**
Lion Outdoor	57.1±0.2	54.8±0.1	62.2±0.4	61.9±4.9	68.4±0.1	60.6±1.2	62.1±2.8	***76.2±4.1**	***75.1±2.4**
Tiger Enc. 1	60.7±0.3	58.5±1.6	68.1±2.6	59.5±0.8	***77.8±3.5**	59.7±0.5	64.6±4.4	***70.3±0.7**	***76.1±2.2**
Tiger Enc. 2	60.2±0.7	57.9±0.5	***72.1±0.3**	66.1±0.7	***77.9±3.3**	66.4±3	69±2.4	***77.1±3.7**	***86.9±3.1**
Tiger Enc. 3	60.2±0.5	59.2±0.2	***72.5±1**	64.7±0.7	***76.5±1.7**	65.4±1.5	***70.4±4.7**	***82.6±3.7**	***80.1±2**
Tiger Outdoor (Rosha)	67.9±5.9	54.3±0.3	69.2±0.8	65.6±3.3	69.5±0.1	64.5±1.6	***73±4.7**	64.9±1	***77.4±3.7**
Tubewell	***77.4±0.6**	55.2±0.1	63±2.3	***72.8±0.9**	69.3±0.2	57.3±1.1	65.7±0.5	61.1±1.1	***72.4±0.8**
Tiger Outdoor 1	62.9±0.5	55.6±0	67.6±1.5	65.8±0.4	***81.3±3.7**	67.7±3.9	***71.4±1.2**	69.7±2.3	***74.4±1.3**
Tiger Outdoor 2	56±0.2	58.4±0.2	67.1±1.4	67.3±4.6	68.3±0.1	61.2±0.7	***70.5±1.9**	***71.1±0.4**	***75.5±3.6**
Aviary Opp. Dolphin	59.8±0.8	56±0.1	***76.3±2.2**	65.3±1.4	68.4±2.8	59.7±0.1	66.7±0.1	***72.2± 0.3**	***71±0.5**
Aviary Opp. Ration	64.9±1.2	57.6±0.2	66.1±3.3	***72.2±0.7**	***74.1±0.7**	63.6±0.6	49.2±23.9	***79.5±3.3**	***74.6±0.8**
Camel Ride	63.8±1.4	55±0.4	***72±3**	***72±1.2**	***72.6±1.6**	63.5±1.2	***75.9±3.1**	***80.7±2.8**	***80.3±2.2**
Kiddy Ride	55.9±0.5	55.8±0.3	***75.8±0.6**	***80.7±0.8**	***72±0.5**	***79.2±0.4**	***74.6±2.3**	***80.7±0.9**	***83.8±1.1**
White Lions	65.8±7.8	55±0.2	64.9±2.7	68.7±1.6	63.7±1.2	62.5±0.1	***70.4±2.7**	69.5±1.8	***78.3±1.6**
Waterfall	62.2±1.1	60.8±0.3	67.2±0.4	61.6± 2.3	***79.8 ± 0.2**	59.7 ± 4.1	65.7±1.2	***71.2±0.5**	***72.3±1.2**

Waterfowl Lake S1	58.4±0.4	61.1±0.3	***70.2±3.4**	***70.2±1.9**	62 ± 1.2	62.4 ± 0.8	63.7±2.5	***70.2±0.2**	***72±0.5**
Waterfowl Lakes S2	59.4±0.2	59.1±0.1	***70.2±1.8**	62.1±2.6	***71±1.1**	59.2±0.6	69.1±3	***72.7±0.6**	***71.6±1**
Water Fowl Lake S3	59.1±0.8	60.5±0.1	68.7±0.7	61.3±0.8	***72.8±1.4**	65.1±0.4	65±0.8	69.2±0.7	***70.6±0.4**
Pet Photography	58.2±0.2	58.8±1.1	***73±0.9**	67.5±4.1	69.8±0.7	61.9±1	***80.2±0.6**	***79±2.7**	***82.9±1.6**
Aquarium Entrance	62.8±2.9	58.5±0.7	***72.3±0.6**	65.4±5.1	59.9±0.1	66.3±4.5	65.5±2.6	***70.2±0.5**	***72.3±0.9**
Aquarium S1	61.6±0.7	63.4±0.5	***75.1±1.9**	***72.3±5.8**	***75.7±0.7**	***72.1±1.1**	***70.1±0.8**	***89.8± 7.3**	***83±2.3**
Aquarium S2	60.7±0.7	62±0.4	***76.9±0.6**	65.3±0.4	***75.2±0.9**	***71.6±2.8**	***78.4±1.5**	***83±0.9**	***90.7±3.8**
Aquarium Exit	62.4±1.4	56.2±0.3	64.9±1	63.8±3.2	65.9±1.3	***70.7±5.3**	63±1.9	67.1±1.2	***75.4±0.3**
Wild Boar	57.2±2.4	67.4±1.1	68±1.7	***73.2±0.6**	69.4±0.3	62.1±1.3	57.3±1.5	59.3±0.3	***74.3±0.8**
Jungle Café	60.7±3.1	60.1±0.7	***74.4±1.8**	65.4±1.6	***72.5±0.9**	67.3±1.3	***73.1±3.1**	***73.8± 2.3**	***79.7±3.2**
Jumping Castle	57.4±0.4	56.6±0.2	***76.6±2.9**	***72.7±3.5**	***72.7±1.5**	58.9±1.4	67.6±0.5	***74.7±1**	***80.4±1.5**
Sambar Enc. 1	58.5±0.4	56.3±0.3	66.2±3	65.7±2.9	69.3±0.2	65.6±0.3	61.3±1.3	66.8±1.3	***72.7±1**
Sambar Encl. 2	60.5±0.7	56.9±0.5	64.1±0.4	59±1.3	69±0.2	58.7±1.1	66.2±1.5	65.3±1.3	***74±1.5**
Zebra Encl. 1	59.2±0.2	55.3±0.1	63.1±1.7	61.7±1.3	***70.2±0.6**	59.5±1.7	59.7±0.3	68.4±2.7	***75.6±1.8**
Zebra Encl. 2	59.5±0.8	55.2±0.2	61±0.7	69.9±5.6	68.5±0.3	61.1±2.7	62±2.4	68.6±1.5	***73.9±0.5**
Ostrich	59.6±0.8	57.3±1	63.6±0.1	66.2±4	69.9±0.8	68±2	66.1±3.1	***73±1.4**	***79±4**
Emu	60.9±0.3	58.7±0.3	63.9±1.2	62.4±0.2	68.6±0	67.9±2	***71±1.1**	***70.7± 1.8**	***77.4±4.1**
Giraffe (Backside)	57.9±0.2	62.4±1	63.7±1.4	63.6±1.9	68.3±0.1	69±3.4	61.9±0.7	66.4±1.7	***74.9±1.9**
Giraffe	61±1.9	55.8±0.2	67.2±3.3	***78.9±3.2**	***70.9±0.8**	***72.6±0.6**	68.2±2.7	***75.2±2.9**	***72.5±0.8**
Prayer Area	60.7±0.7	57.2±0.8	***74±3.5**	63.7±0.6	69.1±0.4	**73.6±0.2 ***	69.1±0.1	***75.8±2.2**	***78.7±1.1**
Jungle Hut	59.2±0.6	56.2±0.2	***70.4±0.3**	***70.1±1.1**	***76.3±0.2**	***80±0**	***71.3±1.7**	***75.9±1.2**	***78.8±0.6**
Snake House Entrance	60.7±0.1	55.6±0.1	***73.2±2**	***77.2±1.4**	***70.3±0.2**	66±2.8	***70.9±0.6**	***73.1±0.6**	***75.8±0.3**
Snake House S1	67.5±0.2	53.5±0.3	***74.8±0.4**	***74.4±0.3**	***76.7±2.5**	***71.9±0.9**	69.3±0.7	***77.9±0.9**	***81.5±1**
Snake House S2	69.5±0.2	53.3±0.2	***71.7±2.3**	***75±0**	***79.8±0.5**	***73.4±1.5**	***70.3±0**	***79.6±0.2**	***81.5±1.3**
Snake House Exit	59.1±0.8	56.5±0	***71.4±2.2**	***72.5±0.4**	***71.3±0.8**	***71.7±0.4**	64±0.5	***78.2±0.8**	***84.5±0.6**
Brown Bears	56±0.8	54.8±0.3	***71.1±4.9**	***81.7±4.6**	61.1±1	60±2	***72.3±1.6**	***73.6±1.8**	***77.7±1.8**
Black Bear	55.4±0.4	58.9±1	67.3±1.4	64±1.4	60.2±2.3	64.6±4.7	63.4±1.6	***74.2±1.6**	***75.4±2.3**
Fox	55.9±0.4	54.7±0.6	68.8±3	59.1±1.5	68.7±0	66.4±1.1	59.6±2.2	63±1.2	***78.7±1.7**

White Lion Cub (Omega)	58.6±2.3	53.8±0	62.6±1.8	60.4±1.4	69.2±0.4	62.1±1.7	***78.1±1.5**	***75.4±3.1**	***78.7±0.9**
African Lioness (Mynico)	55.1±0.2	55.8±0	60±1.3	64.3±2.3	69.9±0.3	***72.7±3.4**	69.8±1.4	***75.9±1.7**	***73.5±0.9**
African Lion Cub	57.8±0.3	56.4±0.1	61.5±1.1	***80.1±6.3**	***73.3±3.4**	***77±8.9**	62.7±0.9	***71±0.4**	***74.4±1**
Jackals	56.5±0.3	56.5±0.1	***71.3±2.1**	65.8±2.6	68.9±0.1	58.7±1.2	60±2.9	***70.6±1.6**	***73.5±1.8**
Hyena	56±0.4	55.7±0.2	60.8±2	59.9±0.1	69.3±0.2	67.9±4.1	66.9±0.4	***73.1±1.6**	***76.4±3**
Wolf	58.6±0.9	57±0.3	59.7±0.8	68.7±1.8	69.7±0.6	***71.5±1.5**	64.2±1.8	***73.2±0.7**	***77.1±2.8**
Rhinoceros	53.2±0.6	55.4±0.6	64.3±0.6	61±1.6	68.8±0.1	65.3±4.4	67.1±1	***75.6±2.6**	***79.5±1.2**
Big Mammal House	51.9 ± 0.4	53.7±0.5	***70.6±1.6**	***77.3±2.7**	68.8±0.7	56.2±0.1	58.4±2.3	67.6±2.7	***77.3±1.2**
Hippopotamus	60.6 ± 0.4	62.1±0.1	58.7±1.1	62.2±2.3	***70.6±0.3**	66.6±4.1	58.8±1.2	64.3±1.7	***74.9±2.3**
Llama	56.5±3	56±0.9	60.3±1.4	***75.1±1.7**	64.2±3.2	63.5±2.3	64.7±2.1	***70.5±1.3**	***79.1±3.2**
Urial	58.5±1.3	57.6±0.3	58.4±1.6	61.1±2.6	64±1.1	69.3±3.8	63.5±0.7	69.2±1.7	***75.4±1.6**
Mouflon Sheep	55.4±0.8	54.7±0.2	***72.1±1.8**	***74.4±3**	69.8±0.8	62.2 ± 0.1	***71.9±1**	***74.8±2.3**	***75.8±2.2**
Blue Bull	63.2±5.2	56±0.2	58.1±0.6	***77.1±2.7**	60.5±0.9	63.7±0.9	62.3±1	***70.4±0.2**	***80.7±3.9**
Red Deer	65.2±1.3	67±3.4	69.7±1.7	***75.7±2.3**	***71.8±4.5**	66.4±1.5	***73.4±1.1**	***80.4±7.4**	***80±1.3**
Fallow Deer	64.9±2.6	63.5±5.5	***71.1±0.8**	***76±1.7**	67±1.6	67.3±1.4	***71.3±0.9**	***74.5±1.6**	***77.9±3.4**
Black Buck	62.7±0.6	58 ± 1.4	***71.4±0.5**	64.8±1.5	***74.8±3.3**	62.4±0.7	***70.4±2**	*71.4±1.5	*78.5±2.4
Red Deer (Backside)	***70.5±2.2**	69.4±2.8	***70.8±2.3**	64.3±0.8	***71.2±0.7**	***70.6±1.2**	69.2±1.2	68.5±2.9	***72.6±0.4**
Chinkara	67.1±1.6	68.2±0.8	66±1	68.7±0.5	69.4±0.3	66.9±1	61.6±1.5	67.2±2.1	65.3±1
Hog Deer	56.9±1.7	55.6±0.3	60.5±1.5	***75.5±5.4**	***73.5±1.8**	68.3±1.4	64.3±0.3	***72.9±0.9**	***73.9±0.8**
Spotted Deer	58.9±0.4	56.4±0.1	60.6±1.8	***70.3±1.9**	69.8±1.2	***76.5±3.2**	65±0.8	***71.7±1.5**	***76.7±2.6**
Wallaby	57.7±2.7	54.1±0.1	64.6±1.3	59±0.4	***70.5±0.9**	***74.4±1.5**	***72.8±1.3**	***70.8±2.1**	***74.7±2.4**
Water Turtle	61.2±1.4	60.6±0	62.4±2.4	64.4±1	***72.8±3.3**	66.6±6.8	***76.8±6.1**	***71.7±1.5**	***74.4±1.2**
Crocodile	61.6±0.6	62.6±0.5	69.4±3.3	64.4±2.1	***70.8±0.8**	60.6±0.8	65.6±3.6	***71±0.7**	***76.6±2.5**
Bird Section S1	60.1±0.6	62.9±0.2	57.7±2.4	59.3±0.8	***75.1±2**	65.1±2.7	63.9±1.7	***72.2±2.1**	***74.5±2.8**
Bird Section S2	58.9±1.6	57.3±0.1	***70.3±3.1**	64.9±1.8	69.2±0.5	56.6±1.3	61.2±0.5	***77.1±8**	***74.6±2.4**
Bird Section S3	54.6±1.6	56.9±0.2	58.8±1.8	62.4±1.3	***71.6±0.9**	62.1±1.2	67.3±3	***74.9 ± 2.5**	***71.3±0.4**
Poultry Section S1	69.3±5.7	59±0.1	57.4±0.5	64.2±0.7	69.6±0.3	66.1±2.1	59.7±0.4	***73.6±1.6**	***74.6±0.6**
Poultry Section S2	64.7±0.4	58.2±0.2	62.9±0.9	60.1±0.7	69.1±0.2	62.4±1.3	58.9±0.6	***71.6±0.3**	***72.6±1.3**
Poultry Section S3	***70.4±3.7**	59.3±1	61.1±0.7	63.2±0.5	69.4±0.2	59.1±0.2	61.5±0.7	***72.6±1.5**	***71.9±0.6**
Poultry Section S4	61.2±0.5	60.9±0.3	61.5±1.5	61.5±0.9	68.2±0	59±0.6	64.8±3.6	***70.7±0.2**	***71±0.2**

collected for both visiting and non-visiting hours (Table 1).

Spatial Analysis

A mapping software ArcGIS 10.5 was used to create the thematic maps from the numerical data, showing the spatial variation in sound levels in order to comprehend and detect the areas with high sound levels at different localities within the zoo by comparing the average value data for sound with the standardize permitted sound value, i.e., <70 dB (A), specified by WHO.

Animal Behavior Sampling during Visiting Hours

Approximately 50 enclosures housing carnivores, herbivores, and omnivores were carefully selected. The behaviors of the animals were documented alongside measurements of sound levels. The onset behavior of the animals was observed for sixty seconds by using an instantaneous sampling technique during visiting hours for seven days. To record specific behaviors such as activity, rest, aggression, feeding, out of site, visitor interaction, and intra-species interaction, a comprehensive ethogram (refer to Table 2) was employed. This ethogram was coupled with the collection of acoustic data, aiming to investigate animals' diverse responses to the anthropogenic soundscape. Behavioral data were recorded during visiting hours only, as most animals shifted to their indoor spaces at night.

Table 2: Sample ethogram for animal behavior observation

Sr. No.	Animal Behavior	Description
1	Active	Walking/running, hooping around within the enclosure
2	Resting	Sitting with eyes open or closed or laying down
3	Aggression	Vocalization, Roaring, sprinting urine
4	Feeding	Eating the feedstuff within the enclosure
5	Out of site	Animal moving away from visitors/went to off exhibit area
6	Visitor Interaction	Animal come closer to the fence and respond to or interact with the visitors
7	Intra-species interaction	Animal socializing or interacting with its species members i.e., grooming, mating, fighting, playing

Survey-based Questionnaire from Visiting Public

A quantitative survey was conducted at the zoo to acquire the visitor response regarding noise pollution and animal welfare. The questionnaire was designed in the simplest way possible. It was comprised of a total of eighteen (18) questions, sixteen dichotomous questions just to know the level of understanding and awareness about the issue of noise pollution among the general public and two free response questions in which the visitors were asked to mention any site in the zoo where they encounter most of the noise and one site free of any disrupting human noise.

Noise Pollution Awareness Campaign for Public Awareness and Education

An active campaign was planned out in collaboration with the Zoo Education Office with the support of the zoo administration. Apart from zoo officials, employees, visitors, and media members, The Trust School also participated in the awareness movement. The students dressed up in animal costumes, holding charts, and placards with awareness messages written on the topic of animal welfare and noise pollution.

3. Results

Acoustic Results

Non-visiting hours. During non-visiting hours, i.e., before opening and after the closing of the zoo, the average sound level recorded falls below the permissible limits prescribed by the WHO at all locations except for three areas in the morning. One of these areas with high sound levels was in the deer park, which is near the boundary wall facing Lawrence Road (backside enclosure of red deer, i.e., 70.5 ± 2.2). The second area with a high sound level was in the poultry section (Site 3: 70.4 ± 3.7), which is close to the mall road. Lastly, the tube well area had the highest recorded value (77.4 ± 0.6) among all areas because the tube well was running at the time (see Figure 3 A and B).

Visiting Hours. Sound level data for visiting hours during the week vary widely. The sound level chronicled on Monday was higher than the permitted WHO standards <70 dB (A) on 29 areas, out of which eight (8) were public amusement and facilitation sites i.e., Jungle Hut, Jungle Café, Prayer Area, Mechanical Elephant, Camel Ride, Kiddy Ride, Pet Photography, Jumping Castle and resting twenty-one were animal enclosures i.e., Black Buck, Fallow deer, backside enclosure of the Red deer, Mouflon Sheep, Jackals, Brown bear, Lion House enclosure 5, enclosure 1, 2 and 3 at tiger house,

Snake House, Aquarium Entrance, S1 and S2, waterfowl lake Site 1 and Site 2, Big mammal House indoor, Bird Section site 2 and Aviary opposite to Dolphin. Red zones in (Fig. 3 C) indicates the areas with noise above the permissible values.

On Tuesday 28 sites were observed with higher levels of sound including the areas including few animal enclosures from Deer Park, i.e., Fallow deer, Hog deer, Red deer, Spotted deer, Blue Bull, African Lion Cub, Llama, Giraffe, Lion House Enclosure 2 and 4, Otter, Brown Bear, Wild Boars and Big Mammal indoor, all sites within Snake House, Aquarium Site 1, Waterfowl lake Site 1, Aviary in front of Ration Area and all the amusement sites. Red zones in (Fig. 3 D) indicate the spatial distribution of sound.

Approximately 45% of total nominated areas recorded with high sound level on Wednesday including Baboon enclosure, Hippopotamus, Wallaby, Leopard House, Tiger House enclosure 1, 2 and 3, Zebra enclosure 1, Giraffe, Tiger outdoor 1, African lion cub, Aquarium Site 1 and Site 2, Waterfowl lake Site 2 and Site 3, Snake house, Red deer (Front), Red deer (backside), Black buck, Hog deer, in Bird Section Site 1 and Site 3, Aviary in front of ration area, Crocodile pond, Water Turtles, Waterfall, Jungle hut, Jungle café, Kiddy ride, Camel ride, Jumping castle and Mechanical elephant. As indicated with red zone in (Fig. 3 E).

On Thursday, fewer areas were recorded with high sound levels compared to previous working days. These include three points of Aquarium i.e., Site 1, Site 2 and Exit, all sites except for entrance at Snake House, 2 enclosures of deer, i.e., Red deer (Backside) and Spotted deer, Giraffe, Wallaby, 3 animal enclosures from Felican section, i.e., African Lioness, African Lion cub and Wolf, enclosure 2 from Lion House, Kiddy ride, Jungle Hut and Prayer Area among amusement and facilitation sites all appeared in red zones in (Fig. 3 F).

On Friday, Baboons, Otter, Wallaby, Water Turtles, Riger outdoor (Rosha), enclosure 1, 4 and 5 from Lion house, Tiger enclosure 3, tiger outdoors, Aquarium S1 and S2, Entrance and Site 2 in Snake house, Emu, Mouflon sheep, Brown bears, White lion cub (Omega), White lions, Red deer, Fallow deer, Black buck, Camel ride, Kiddy ride, Mechanical Elephant, Pet Photography, Jungle café and Jungle hut were areas among all site where sound level recorded beyond the permissible limit of WHO (<70 dB) appeared as red zone in (Fig. 3 G).

On weekends (Saturday and Sunday), the noise level was quite high at most of the sites due to the large number of visitors at the zoo. Only areas with sound levels recorded within the permissible limit on Saturday were Hill Site 1 and Site 2, Leopard pair, Lion house enclosure 1 and 5, Tiger outdoor 1, Tiger outdoor (Rosha), Fox, white lion enclosure, Big Mammal House indoor, Hippopotamus, wild boar, Sambar Deer enclosures, both of Zebras' enclosures, Urial, Red deer backside (68.5±2.9), Chinkara, Vervet and Capuchin Monkey, Tortoise, Waterfowl lake Site 3 and Tube well (Fig. 3 H).

On Sunday, noise levels were recorded above the permissible limits on each site except for three sites, i.e., Lion house enclosure 1, Chinkara, Hill Site 1 (Fig. 3 I).

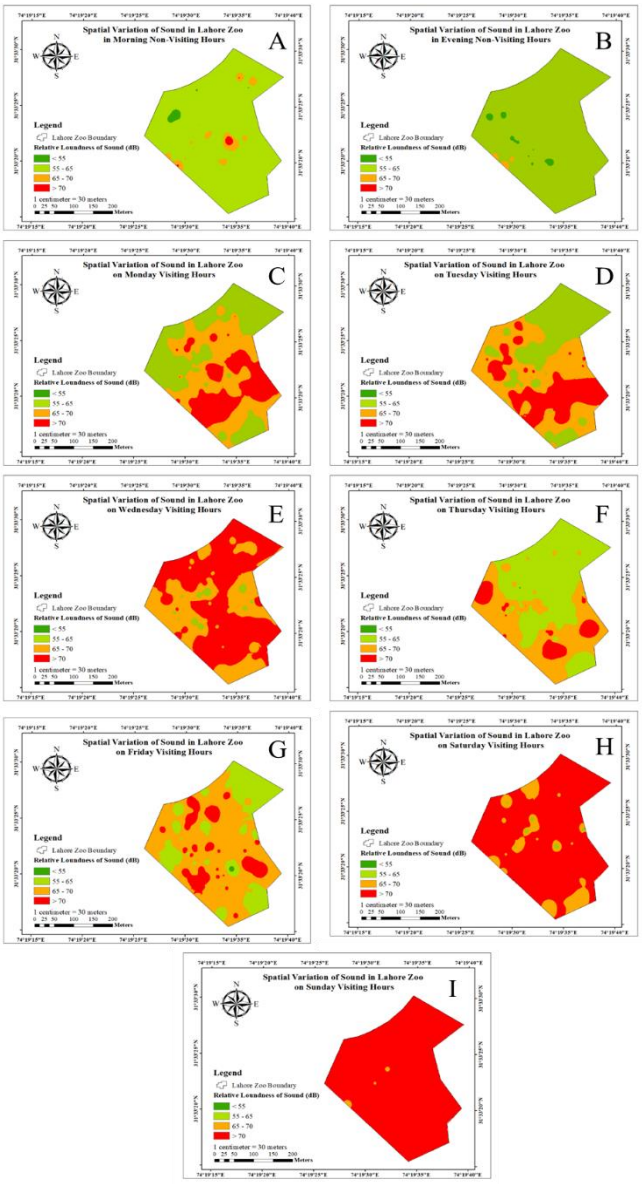

Figure 2: Spatial distribution of sound level (dB (A)) in Lahore Zoo during visiting and non-visiting hours in a week

Animal Behavioral Responses. The animal behaviors were observed only during visiting hours, as most of the animals were resting at night or mostly preferred to be in indoor spaces where no loud sounds were recorded in the non-visiting hours, especially in the evening. Vervet monkeys spent most of their time (57.14%) walking or running around their enclosure, (28.57%) by interacting with visitors and resting (14.28%) by socializing within their group. Capuchin monkeys can be seen engaged with visitors most of the time (57.14%), once eating their food (14.28%), and the rest of the time (28.57%), they were out of sight. Olive Baboons were observed spending the same amount of time with visiting audience (42.85%) and (42.85%) interacting with the members of their own species and once noted consuming the food provided to them (14.28%). Grey Langur spent most of his time (71.42%) in the off-exhibit area (remaining out of sight) and, for the remaining time (28.57%), was seen resting in the enclosure. Brown bears demonstrate active behavior (14.28%), responding towards visitors (14.28%), interacting with their species members (28.57%), laying down in the enclosure (14.28%), and were out of site (28.57%). Black bears can be seen walking, running, swimming in the enclosure (57.14%), and out of site (42.85%). During behavioral observation, Hippopotamus remained submerged in water all the time (100%). Rhinoceros were active most of the time (57.14%), once seen sitting in the enclosure (14.28%), and busy eating their food (28.57%). Male Leopard demonstrated pacing behavior around the enclosure most of the time (85.71%) and once can be seen enjoying his food (14.28%). On the other hand, the leopard pair can be seen sitting all the time (100%) in the enclosure, away from the visitor's range. Red deer were observed to spend most of their time (71.42%) interacting with the visiting public, socializing within their group (14.28%), and occasionally being out of sight (14.28%). The red deer in the backside enclosure always engage with visitors (100%). Fallow deer spent their time resting (14.28%), eating (28.57%), interacting with visitors (42.85%), and recorded out-of-site (14.28%). Sambar deer in enclosure one spent all their time (100%) sitting with open eyes in the enclosure. Whereas sambar deer in enclosure 2 can be seen eating their fodder (14.28%) and spending the remaining time (85.71%) resting in the enclosure. Blackbucks were observed actively walking and running (71.42%) in the enclosure as well as remaining out of site (28.57%). The observed activities recorded for mouflon sheep were as follows: active (28.57%), resting (14.28%), visitor interaction (42.85%), and interaction with members of the same species (14.28%). White lion cub named Omega was much respondent towards visitors by jumping and running towards the visitors (71.42%), the rest of the time (28.57%) she was observed resting. Recorded behaviors for African lion cub in the felican section were resting (42.85%), resting (42.85%) and visitor interaction (14.28%). African lioness named Mynico spent (42.85%) of the time resting, can be seen eating (28.57%) and interacting with visiting public (28.57%) of the time. Fox spent most of the time (71.42%) in resting position in the enclosure with eyes closed and can be observed walking (28.57%). Hyena spent (85.71%) their time resting in the enclosure and noted out of site once (14.28%). Wolf was observed running in the enclosure for most of time (57.14%), spent (14.28%) time resting and (28.57%) feeding. Jackals were kept running in the enclosure (100%) during the time observed. The recorded behaviors for the lion in enclosure 1 was predominantly resting (85.71%) and walking (14.28%). Lions in enclosure 2 were once observed vocalizing (14.28%), walking in the enclosure (28.57%) and resting (57.14%). Lion pair in enclosure 3 demonstrate aggressiveness by roaring (28.57%) and observed sleeping rest of the time (57.14%). Lion enclosure 4 recorded with feeding (14.28%) and resting (85.71%). Enclosure 5 in the Lion house observed with feeding (28.57%), walking in the enclosure (28.57%) and mainly resting (42.85%). Pair in lions' outdoor area witnessed walking in the enclosure (42.85%), mating (14.28%) and resting (42.85%). Tiger from Tiger House enclosure 1 actively engaged in feeding (14.28%), walking (42.85%), voicing (14.28%) and resting (28.57%). Tiger in enclosure 2 spent most of his time (85.71%) walking near the fence in the enclosure and was observed resting (14.28%) of the time. whereas in enclosure 3 the animal spends most of the time (71.42%) resting than being active (28.57%). Tiger in the outdoor area named Rosha exhibit active 14.28%), resting (57.14%), vocalizing (14.28%), and feeding (14.28%) behaviors. Tiger in outdoor 1 was observed walking (42.85%), sitting in water (28.57%), vocalizing (14.28%) and interacting with other tigers (14.28%) via see-through fence. Tiger in outdoor enclosure 2 spotted walking near the fence wall (42.85%), vocalizing (14.28%), feeding (14.28%) and interacting with the tiger in adjoining enclosure (28.57%). The giraffe was engaged in actively walking (57.14%) around the

housing and feeding the rest of the time (42.85%). Ostriches were predominantly engaged with visitors most of the time (71.42%) and can also be observed walking (14.28%) and walking (14.28%). Emu was observed walking (71.42%) and engaged in feeding together (28.57%). Water turtles can be seen swimming (85.71%) in the water bodies and resting (14.28%). Mugger crocodiles can be spotted resting outside the water (42.85%) and cannot be seen the rest of the time (57.14%). Wallabies can be seen hooping around the enclosure (14.28%), resting (14.28%), eating food (28.57%) and hiding themselves indoors or in the bushes (42.85%). White lions rested i.e., sleeping predominantly (71.42%), actively roaming around their space (14.28%) and mate (14.28%). Wild boars were observed sleepy in muddy puddles (57.14%), walking around (28.57%) and eating (14.28%). Otters demonstrate active behavior most of the time by swimming in their pool (71.42%), ingesting food (14.28%) and once was out of site (14.28%). Behaviors recorded for tortoises were resting (42.85%), walking (14.28%), eating (14.28%), interacting within their species members i.e., fighting and mating (28.57%). Llamas were spotted eating (28.57%), walking (28.57%) and sitting peacefully in their open space (42.85%). Zebras in enclosure 1 can be seen running in the enclosure (57.14%) and the rest of the time eating their fodder (42.85%). Zebras in enclosure 2 were also active (57.14%), spotted eating (28.57%) and showing attentiveness towards visitors (14.28%) (Fig. 3).

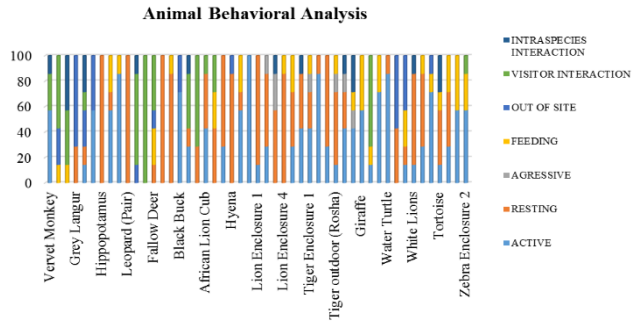

Figure 3: Activity Chart (%age) based on Animal Behavioral Analysis

Noise Pollution Survey. According to the survey results, as shown in Fig. 4, obtained from visitors, including individuals ranging from small children aged 7 to adults of 45 years and older, 56.6% were males and the remaining 43.5% were females. Most respondents (76.5%) said they enjoyed observing animals. More than half of the respondents (56%) were aware of wildlife in Pakistan. More than half (52.5%) of visitors agreed that they realize the importance of wildlife in our ecosystem. Less than half (45.5%) showed interest in learning about environmental issues. About 51.5% of all the respondents were cognizant of noise pollution. Among all the surveyed visitors 62.5% admitted that noise is a part of environmental pollution. Many respondents (62%) agreed that we should care about animals just like we do for humans. About (58.5%) approved that noise can be a disrupting factor for the animals. More than half of respondents (57%) agreed that visitor education would be helpful in minimizing this issue, but many the population/ respondents (60.5%) don't think that this issue can be resolved only by educating the visitors. In response to the suggestion of limiting the audience near the enclosure, more than half of respondents (51.5%) replied that they don't think that this would prove beneficial in cracking the issue. Half of the surveyed audience (50%) approved that the distribution of awareness material will be effective in eradicating the issue. However, (61.5%) agreed to the point that visually displayed symbolic signs and awareness messages will be an effective strategy to imply. Less than half (35%) of the total respondents didn't participate in any social awareness campaign regarding animal welfare but upon asking about their willingness to participate in the campaign organized by the zoo, more than half (58%) showed their interest in participation to spread the awareness regarding the issue of noise pollution. More than half (63%) assured that they will play their part in abating the issue by not making loud noises in front of the animal enclosures (Fig. 5 A). When asked from visitors to mention the noisy areas within the zoo, (89%) of respondents mentioned the area they encountered with a loud noise. Those enclosures were Tiger 11.5%, Lion 20%, Deer 9%, Monkey 23.5%, Aquarium 8%, Rhino 2.5%, Wolf 0.5%, Cafeteria 3.5%, Bird section 4%, Ostrich 0.5%, Camel 4.5%, Snake House 0.5%, Zebra 0.5%, Giraffe 0.5%, Bear 4 %. Upon asking if they found any peaceful or noise-free zone during their visit, more than three fourth (¾) of the respondents (78.5%) mentioned these areas (Llama 2.5%, Bird Section 11.5%, Snake House 3%, Aviary 3.5%, Waterfowl Lake 12.5%, Crocodile 3.5%, Monkey 1%, Tiger 1.5%, Lion 2%, Sambar 1.5%, Aquarium 2%, Giraffe 1.5%, Deer 3.5%, Camel 3%, Rhinoceros 1%, Hippopotamus 7.5%, Ostrich 3.5%, Tortoise 1%, Wallaby 0.5%, Bear 1%, Poultry section 5.5%, Zebra 6%) (Fig. 5 B).

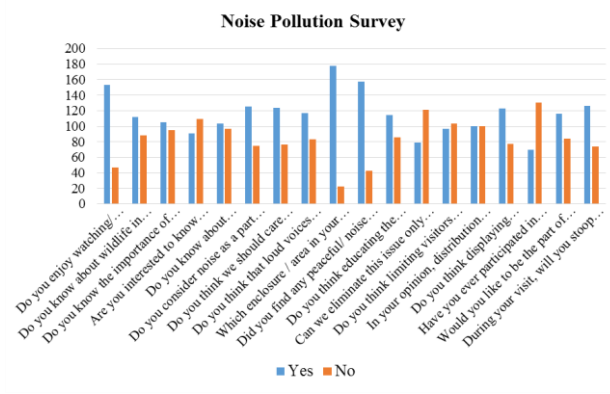

Figure 4: Survey Responses from Zoo visitors

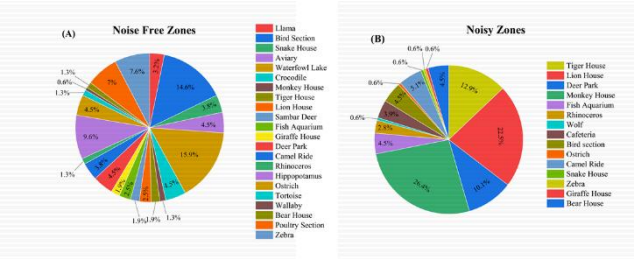

Figure 5: Noise Free (A) and Noisy Zones (B) nominated by Zoo visitors

4. Discussion

Sound Level Pressure

With an average footfall of about three million annual visitors, Lahore Zoo is considered among the most popular and prime visiting sites within Lahore for people of all age groups. Researchers have associated high visitor density with an elevated level of noise.[25, 22] The study was conducted during October, where the average temperature recorded was 31.77 °C. A gradual increase in visitor density was observed from the first working day towards the weekend, with a minimum of 3000 visitors and a maximum of 19,000 visitors according to the visitor records. Throughout the week, a high level of sound is primarily recorded at visitors' facilitation and amusement sites, coinciding with the substantial presence of visitors. In the context of animal enclosures, high sound levels are recorded in areas where animals are more responsive to humans or engage in active behaviors such as walking, running, eating, swimming, and socializing within their groups.

Density-Responsive Behavior

Many captive animals habituate to the noise of visitors and consequently adapt their behavioral patterns accordingly.[23] The soundscape near the animal enclosures was mainly anthropogenic. Monkeys capture the attention of visitors through their interactions among species members, involving activities such as fighting, grooming, and chasing each other. They engage in various actions like using monkey bars and climbing ropes. Additionally, monkeys respond enthusiastically to visitors who offer them food. Previous literature revealed that primates are more inclined to respond to visitors who provide them with food.[20] Vigilant behavior was also recorded among primates in response to visitors' noise.[26, 27] Furthermore, Waterman analyzed an escalation in active behavior triggered by visitors.[24]

According to findings deer species responded affable towards visiting audience near the enclosure especially those who offered them something to eat. Ostrich activity wasn't affected by varying visitor numbers. Some species, such as white rhinoceros, wallabies, giraffes, emu, otter and hippopotamus, are popular because of their rarity and exotic status. Individuals often tend to irritate felines, such as lions, tigers, and leopards, by loudly shouting in front of their enclosures, compelling them to roar. In response, the animals displayed behaviors indicative of agitation, including frequent resting, occasional vocalization, and sporadic urination in the presence of visitors. Studies has shown minimal behavioral changes,[28] heightened resting behavior,[19] and increased pacing activity in felines in relation to loud noises. [13]

Enclosures' Design

Enclosures comprised of spacious and well-ventilated indoor or off-exhibit areas, as well as ecologically enriched outdoor displays designed to meet the needs of the animals. Circular and rectangular style enclosures are provided for felines, primates, zebra and giraffe to keep the animal away from anthropogenic noise along with ecological enrichments to maximize their activity period. Additionally, glass-enclosed structures, such as the snake house and fish aquarium, contribute to the reduction of surrounding noise.

Access to off-exhibit Area

Studies have supported the idea that offering free access to the off-exhibit area, or a quiet space reduces stress responses in captive species both behaviorally and physiologically, thereby promoting animals' wellbeing.[29, 18, 30] Open access to indoors can be provided to big mammals, monkeys, deer, ratites, zebras, giraffes and bears at Lahore Zoo.

Conclusion

The study demonstrates that the sound level increased with the increased visiting audience near the enclosures

of mammals that are popular among visitors. The species response vary from animal to animal. Some animals respond positively towards visitors and others ignored the visitors' shout and stayed in resting position. Noise sensitivity also varies among different group of animals. Multiple opportunities should be provided to the animals which helps them minimizing visitors' stress. The suggested recommendations would be helpful in combating visitors' stress in captive animals.

Recommendations

Increased Plantation: Plantation within or outside the enclosures will not only be aesthetically pleasing but will be helpful too in canceling the effect of noise. Trees aid in reducing noise pollution since they act as environmental buffers by absorbing proximate anthropogenic noise.

Visitors' Education: Deliver animal welfare messages in the simple, creative, and best way possible. Provide reading brochures, pamphlets, and booklets to those who are willing to take them. Otherwise, display messages symbolically in visual arts or signs or written in the local language to make it easy for the people to learn and educate themselves and others.

Monitoring for the Implication of Rules and Regulation: Frame out strict rules that must be monitored for implication, and heavy fines should be imposed on violations of these rules and regulations.

Safety Precautions: Safety and precautionary measures must be taken to minimize the human-animal interaction as they have in Lahore Zoo in some houses where there are double railings and additional fine iron mesh to keep the visitors at a fair distance from the animal enclosure to ensure the visitors' safety and animal wellbeing.

References

1. Berg, R. E. Sound. Encyclopedia Britannica. 2022 Dec 08. https://www.britannica.com/science/sound-physics
2. Clark FE, Fitzpatrick M, Hartley A, King AJ, Lee T, Routh A, Walker SL, George K. Relationship between behavior, adrenal activity, and environment in zoo-housed western lowland gorillas (Gorilla gorilla gorilla). Zoo Biology. 2012 May;31(3):306-21. DOI: 10.1002/zoo.20396
3. Popper AN, Hawkins AD. An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. Journal of fish biology. 2019 May;94(5):692-713. DOI: 10.1111/jfb.13948
4. World Health Organization. Burden of disease from environmental noise: Quantification of healthy life years lost in Europe. World Health Organization. Regional Office for Europe; 2011.
5. Walther GR, Post E, Convey P, Menzel A, Parmesan C, Beebee TJ, Fromentin JM, Hoegh-Guldberg O, Bairlein F. Ecological responses to recent climate change. Nature. 2002 Mar 28;416(6879):389-95. DOI: 10.1038/416389a
6. Cardoso P, Barton PS, Birkhofer K, Chichorro F, Deacon C, Fartmann T, Fukushima CS, Gaigher R, Habel JC, Hallmann CA, Hill MJ. Scientists' warning to humanity on insect extinctions. Biological conservation. 2020 Feb 1;242:108426.
7. Erbe C, Thomas JA. Exploring animal behavior through sound: Volume 1: Methods. Springer Nature; 2022. DOI: 10.1016/j.biocon.2020.108426
8. Kight CR, Swaddle JP. How and why environmental noise impacts animals: an integrative, mechanistic review. Ecology letters. 2011 Oct;14(10):1052-61. DOI: 10.1111/j.1461-0248.2011.01664.x
9. Duarte CM, Chapuis L, Collin SP, Costa DP, Devassy RP, Eguiluz VM, Erbe C, Gordon TA, Halpern BS, Harding HR, Havlik MN. The soundscape of the Anthropocene ocean. Science. 2021 Feb 5;371(6529):eaba4658. DOI: /10.1126/science.aba4658
10. de Queiroz MB. How does the zoo soundscape affect the zoo experience for animals and visitors?. University of Salford (United Kingdom); 2018.
11. Anthony A. Criteria for acoustics in animal housing. Laboratory animal care. 1963 Jun;2:340-50. PMID: 14013315.
12. National Institute of Health Consensus Report. Consensus conference. Noise and hearing loss. JAMA. 1990 June 20;263(23):3185–3190.
13. Williams LJ, Finch K, Agnew R, Holmes L. Effects of nearby construction work on the behavior of asiatic lions (Panthera leo persica). Journal of Zoological and Botanical Gardens. 2021 Feb 27;2(1):66-74. DOI: 10.3390/jzbg2010005
14. Pifarré M, Valdez R, González-Rebeles C, Vázquez C, Romano M, Galindo F. The effect of zoo visitors on the behaviour and faecal cortisol of the Mexican wolf (Canis lupus baileyi). Applied Animal Behaviour Science. 2012 Jan 15;136(1):57-62. DOI: 10.1016/j.applanim.2011.11.015
15. Chosy J, Wilson M, Santymire R. Behavioral and physiological responses in felids to exhibit construction. Zoo biology. 2014 Jul;33(4):267-74. DOI: 10.1002/zoo.21142
16. Larsen MJ, Sherwen SL, Rault JL. Number of nearby visitors and noise level affect vigilance in captive koalas. Applied Animal Behaviour Science. 2014 May 1;154:76-82. DOI: 10.1016/j.applanim.2014.02.005
17. Quadros S, Goulart VD, Passos L, Vecci MA, Young RJ. Zoo visitor effect on mammal behaviour: Does noise matter?. Applied Animal Behaviour Science. 2014 Jul 1;156:78-84. DOI: 10.1016/j.applanim.2014.04.002
18. Wark JD. The influence of the sound environment on the welfare of zoo-housed callitrichine monkeys. Case Western Reserve University; 2015.
19. Suárez P, Recuerda P, Arias-de-Reyna L. Behaviour and welfare: The visitor effect in captive felids. Animal Welfare. 2017 Feb;26(1):25-34. DOI:10.7120/09627286.26.1.025
20. Dancer AM, Burn CC. Visitor effects on zoo-housed Sulawesi crested macaque (Macaca nigra) behaviour: Can signs with ‘watching eyes’ requesting quietness help?. Applied animal behaviour science. 2019 Feb 1;211:88-94. DOI: 10.1016/j.applanim.2018.12.005
21. Jakob-Hoff R, Kingan M, Fenemore C, Schmid G, Cockrem JF, Crackle A, Van Bemmel E, Connor R, Descovich K. Potential

impact of construction noise on selected zoo animals. Animals. 2019 Jul 31;9(8):504. DOI: 10.3390/ani9080504
22. Pelletier C, Weladji RB, Lazure L, Paré P. Zoo soundscape: Daily variation of low-to-high-frequency sounds. Zoo Biology. 2020 Nov;39(6):374-81. DOI: 10.1002/zoo.21560
23. Harley JJ, Rowden LJ, Clifforde LM, Power A, Stanley CR. Preliminary investigation of the effects of a concert on the behavior of zoo animals. Zoo Biology. 2022 Jul;41(4):308-27. DOI: 10.1002/zoo.21676
24. Waterman JO. Human-macaque encounters in Ifrane National Park, Morocco: behavioural, spatial, and temporal coping strategies of the Barbary macaque (Macaca sylvanus) (Doctoral dissertation, University of Lincoln).
25. Hosey GR. Zoo animals and their human audiences: What is the visitor effect?. Animal Welfare. 2000 Nov;9(4):343-57. DOI: 10.1017/S0962728600022946
26. Birke L. Effects of browse, human visitors and noise on the behaviour of captive orang utans. Animal Welfare. 2002 May;11(2):189-202. DOI: 10.1017/S0962728600028141
27. Choo Y, Todd PA, Li D. Visitor effects on zoo orangutans in two novel, naturalistic enclosures. Applied Animal Behaviour Science. 2011 Aug 1;133(1-2):78-86. DOI: 10.1016/j.applanim.2011.05.007
28. O'DONOVAN DE, HINDLE JE, McKEOWN SE, O'DONOVAN SE. Effect of visitors on the behaviour of female Cheetahs acinonyx jubutus and cubs. International Zoo Yearbook. 1993 Jan;32(1):238-44.
29. Owen MA, Hall S, Bryant L, Swaisgood RR. The influence of ambient noise on maternal behavior in a Bornean sun bear (Helarctos malayanus euryspilus). Zoo biology. 2014 Jan;33(1):49-53. DOI: 10.1002/zoo.21105
30. Wells DL, Coleman D, Challis MG. A note on the effect of auditory stimulation on the behaviour and welfare of zoo-housed gorillas. Applied Animal Behaviour Science. 2006 Nov 1;100(3-4):327-32. DOI: 10.1016/j.applanim.2005.12.003