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Research Article

The Study of Diversity of Mammals in Lal Suhanra National Park Bahawalpur, Punjab, Pakistan

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Abstract: This study assessed mammalian diversity in Lal Suhanra National Park (LSNP), Bahawalpur, Pakistan, through field surveys, camera trapping, and indirect sign analysis. A total of 21 species were recorded, including key carnivores such as the Indian wolf (Canis lupus pallipes) and striped hyena (Hyaena hyaena), herbivores like the nilgai (Boselaphus tragocamelus), and rodents such as the Indian desert jird (Meriones hurrianae). Diversity indices revealed moderate to high species richness (Shannon index: 1.384–2.024; Simpson's index: 0.704–1.708), with apex predators exhibiting lower evenness due to their ecological dominance. Relative abundance analysis highlighted niche partitioning, with desert-adapted species like the desert fox (Vulpes vulpes pusilla) favoring arid zones, while generalists such as the house mouse (Mus musculus) thrived across habitats. The presence of invasive species (e.g., black rat, Rattus rattus) and anthropogenic threats like habitat degradation pose conservation challenges. These findings underscore LSNP's role as a biodiversity hotspot and emphasize the need for targeted strategies, including habitat restoration and community-based conservation, to safeguard its mammalian fauna. This study provides a baseline for future monitoring and informs adaptive management in Pakistan's protected areas.

Keywords: Mammalian diversity, Lal Suhanra National Park, conservation, relative abundance, Pakistan.

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Introduction

Pakistan is a country with a wide range of plants and animals. Pakistan has a wide range of landscapes, from the high mountains in the north to the huge deserts in the south. These different areas are home to many different kinds of plants and animals [1]. Lal Suhanra National Park (LSNP), situated in Bahawalpur, Punjab, Pakistan, represents a significant ecological preserve. Encompassing approximately 153,000 acres [2]. In the South Asian region, LSNP is one of the largest national parks. Designated a UNESCO Biosphere Reserve since its establishment in 1972, the park boasts a remarkably diverse ecosystem. This diverse environment includes significant wetland areas, vast wooded areas, and arid desert landscapes. Consequently, LSNP provides a crucial habitat for a wide array of mammalian species [3]. The park holds significant geographical value due to its position between the Cholistan Desert and the irrigated lowlands of the Indus Basin. This unique location fosters a diverse ecosystem that supports numerous endangered and regionally exclusive species [4]. Mammals play a crucial role in maintaining ecological equilibrium by facilitating plant pollination, aiding in seed dispersal, and regulating prey pop-ulations within their respective habitats [5]. However, in Pakistan, several mammal populations have experienced declines attributed to factors such as habitat fragmentation, the pervasive effects of climate change, and anthropogenic pressures, including unlawful hunting practices and the expansion of agricultural land [5]. Consequently, comprehensive knowledge of mammalian diversity within protected areas such as Lal Suhanra National Park is paramount for the formulation of effective conservation strategies and the implementation of sustainable ecosystem management practices [6]. LSNP boasts diverse terrain that sustains a variety

of mammal species, ranging from large herbivores such as the Indian gazelle (*Gazella bennettii*) and nilgai (*Boselaphus tragocamelus*) to predators like the Indian wolf (*Canis lupus pallipes*) and desert fox (Vulpes vulpes pusilla) [7]. Furthermore, the park serves as a vital refuge for the endangered Punjab urial (*Ovis vignei punjabiensis*), a species facing population decline due to pressures from poaching and habitat degradation [8]. Moreover, Lal Suhanra National Park functions as a migratory corridor, facilitating animal movement between the Thar and Cholistan deserts. This characteristic underscores the park's critical role in safeguarding regional biodiversity [9]. Despite its protected status, LSNP continues to face a multitude of anthropogenic and environmental challenges. Overgrazing by livestock, illegal logging operations, and water scarcity resulting from prolonged drought periods have collectively contributed to ecosystem degradation. These pressures have, in some instances, forced species displacement or placed them at heightened risk of local extinction [2]. Furthermore, instances of human-wildlife conflict, particularly those involving crop-raiding species such as the wild boar (*Sus scrofa*), have resulted in retaliatory killings [10]. These threats are exacerbated by the impacts of climate change, manifested in altered precipitation patterns and rising ambient temperatures, potentially leading to greater resource scarcity regarding both water and food availability [11]. While considerable research attention has been directed towards avian and reptilian diversity within Lal Suhanra National Park, mammalian diversity has received comparatively less scrutiny [12]. Despite the fact that smaller mammalian taxa like bats and rodents make significant contributions to the functioning of ecosystems, existing research has primarily focused on vertebrate diversity at Lal Suhanra National Park [4]. Through a comprehensive assessment of mammalian diversity that includes species identification, estimation of abundance, and characterization of associated habitat preferences, the goal of this study is to fill in the knowledge gaps. In particular, the goal is to provide a thorough analysis of the diverse mammalian fauna that can be found in the Lal Suhanra National Park (LSNP), which is located in Bahawalpur, Punjab, Pakistan. This will be achieved through a combination of field surveys, camera trapping methodologies, and indirect sign analysis, enabling the determination of species richness, distribution patterns, and habitat affiliations. In addition, the research aims to investigate population trends of important species, with a particular emphasis on those that are categorized as endangered or vulnerable, as well as critical habitats that warrant conservation efforts to be prioritized. The study will also look at human-made risks to animal populations, such poaching, habitat loss, and climate change.

Materials and Methods

This study of mammal diversity employed numerous ways to get and look at information on where mammals live and how many there are in different parts of the world. The current study adopted the tools and methods used to count at the variety of mammals, such as field surveys, statistical analysis, and modeling.

Field research

We used traditional ecological methodologies to do field surveys at Lal Suhanra National Park to find out how many different types of mammals live there. The point count method of mammals diversity [13] approach was used, in which observers wrote down all the different types of mammals and the number of each type at set sample locations spaced out in a methodical way (every 100 meters) to make sure that the whole research area was covered. We also did transect walks along set pathways, noting the species we saw within a certain distance to look at how they were distributed in different habitats (such forests vs. grasslands). These surveys yielded data pertaining to species richness, population abundance, and geographical distribution, all of which are crucial for a comprehensive understanding of ecosystem functioning [14].

Data Collection

To obtain data, we used a mix of direct observations, camera traps, and indirect evidence that mammals were there. The survey was place during the dry season, from January to February, when there are less plants, making it easier to see creatures.

Camera traps

Camera traps were strategically deployed across the study area to obtain images and video recordings of mammalian fauna. Placement focused on areas exhibiting high animal activity, such as game trails, proximity to water sources, and locations with detectable signs of mammalian presence. Each unit was equipped with a motion sensor and infrared capabilities, enabling automated image and video capture upon animal detection. The utilization of camera traps in this context offers a non-invasive and demonstrably effective approach to documenting mammalian biodiversity [15].

Live Trap

Live trap was another way to capture mammals for species identification. Live trapping involves setting traps in the field that capture small mammals such as rodents and voles. Trapped mammals were then identified, counted and released back into the wild.

Pit trap

Pit trap was used to catch small mammals like rodents and snails. In this a small hole was dug up in the ground and a crate was placed inside to hold the mammal [16].

Direct observation

Trained field observers conducted direct observations using binoculars and spotting scopes. Transect lines were walked at a consistent pace, and any mammal sightings were recorded. The observers also noted the behavior, group size, and habitat preferences of the observed mammals. Direct observation included observing and recording mammal species. This technique was most commonly used for large mammals such as squirrels, ants, and primates.

Identify the types of mammalian products

Identification of mammal species was an important task to estimate the diversity of mammals in a given area. Identification was done by observing physical characteristics such as coat color, size, head shape and teeth.

Statistical analysis

Collected data were analyzed using a variety of statistical tools, including measures of species richness, diversity indices such as the Shannon-Wiener index, and calculations of relative abundance [17]. Chi-square tests and regression analyses were employed to explore the relationships between various mammalian taxa and environmental variables, including habitat type, vegetation cover, and water availability. These analyses aimed to elucidate the principal factors influencing species distribution patterns and population dynamics over time.

Species Distribution Modeling (SDM)

We used Species Distribution Models (SDMs) to project habitat suitability and species presence, incorporating environmental variables such as temperature, precipitation, and vegetation type [18]. These models facilitated the prediction of range shifts in response to environmental change, thereby informing conservation planning and management decisions.

Data Analysis

Data collected from sampling and identification was analyzed by using various statistical methods to understand the diversity of mammals. Some of the statistical analyses used in thesis writing to assess the diversity of mammals were:

Species richness

Species richness is the number of different species present in a certain area. It is calculated by counting the total number of species present [19].

Formula: species richness = total number of species

It is the number of different species present in a given area. It can be calculated using this formula:

$$S = -\ln (1 - C/N)$$

Where S is the estimated number of species in the study area, C is the number of species observed in the sample, and N is the total number of individuals observed in the sample.

Simpson's diversity index

Simpson's diversity index was the measure of the diversity of species present in a certain area. It considers the number of species present and the abundance of each species [20].

Formula: $D = 1 - (\Sigma (n/N)^2$

Where:

D = Simpson's index of diversity: N = Total number of individuals of all species n = number of individuals of a certain species

Shannon-Wiener Diversity Index

The Shannon-Wiener Diversity Index was another measure of the diversity of species present in a particular area. It considers the number of species present and the abundance of each species [21].

Formula: $H' = -\Sigma (pi * \ln (pi))$

Where:

H = Shannon-Wiener diversity index

Pi = proportion of individuals of a certain species ln = natural logarithm

Evenness

Evenness showed how the abundance of different species was distributed in a given area [22].

Formula: $E = H/H_{max}$

Where:

E = Eq ; H = Shannon-Wiener diversity index

H_{max} = maximum possible value of H

Mapping

Mammal species distribution in a certain area has to be mapped in order to evaluate the variety of mammals. Mapping included putting each species' location on the map and looking at how they were spread out. Finally, a range of procedures and techniques were used to assess mammal diversity, such as sampling, mapping, identifying, and analyzing data. Statistical analysis such as species richness, Simpson diversity index, Shannon-Wiener diversity index, and evenness were used to analyze the data. Mapping the distribution of mammal species is also important for understanding the diversity of mammals in the park.

Informal Meetings with local Citizens

The local people were interviewed to ask about the status of different species of mammals. The local helped us in studying mammals by their observation in different times and their stories about the animals specially the mammals here in LSNP.

Results

As the study was survey based, different methods were used for studying the diversity of mammals as discussed earlier. The zoological survey identified a diverse range of mammals in the study area. A total of 21 species were identified, including both carnivorous and herbivorous mammals. Among the carnivores, the Indian wolf, Asiatic jackal, striped hyena, Indian desert cat, and jungle cat were observed. Additionally, the long-eared hedgehog and desert fox were also observed. In terms of herbivores, the current study identified the Indian wild boar, Nilgai, and Indian hare. The Northern palm squirrel was also observed, along with the small Indian civet and Indian Grey mongoose. Lastly, the study identified several rodent species, including the Indian desert jird, Indian gerbil, Indian field mouse, house mouse, and black rat. The short-tailed mole rat was also observed. Overall, the survey indicates a diverse mammalian population in the study area, with a variety of species occupying different niches in the ecosystem. The identified species are given below in table 1.

Table 1. List of 21 mammalian species recorded in a study in LSNP

Sr.#	Order	Specie Name	Scientific Name
1	Eulipotyphla	Long-eared hedgehog	*Hemiechinus auratus*
2	Chiroptera	Greater asiatic yellow bat	*Scotophilus heathii*
3	Carnivora	Indian wolf	*Canis lupus pallipes*
4	Carnivora	Asiatic jackal	*Canis aureus*
5	Carnivora	Desert fox	*Vulpes vulpes pusilla*
6	Carnivora	Small indian civet	*Viverricula indica*
7	Carnivora	Indian Grey Mongoose	*Herpestes edwardsii*
8	Carnivora	Striped Hyaena	*Hyaena hyaena*
9	Carnivora	Indian desert cat	*Felis chaus affinis*
10	Carnivora	Jungle cat	*Felis chaus*
11	Artiodactyla	Indian wild boar	*Sus scrofa cristatus*
12	Artiodactyla	Nilgai	*Boselaphus tragocamelus*

13	Lagomorpha	Indian hare	*Lepus nigricollis*
14	Rodentia	Northern palm Squirrel	*Funambulus pennantii*
15	Rodentia	Indian Desert jird	*Meriones hurrianae*
16	Rodentia	Indian Gerbil	*Tatera indica*
17	Rodentia	Indian Field mouse	*Mus booduga*
18	Rodentia	House mouse	*Mus musculus*
19	Rodentia	Black rat	*Rattus rattus*
20	Carnivora	Asiatic wolf	*Canis lupus campestris*
21	Eulipotyphla	Short tailed mole rat	*Nesokia indica*

Relative abundance

Relative abundance of each species, which is calculated by dividing the number of individuals of each species by the total number of individuals observed in all species. Then relative abundance can be calculated by different diversity indices. Every species corresponds with a data point; the graph shows the behavior of every series across these species. With a little increase in values for species like Tatera indica and Rattus rattus, Series 1—shown by the blue line—tends to exhibit somewhat low values across most species. Showed in red, Series 2 shows considerable variance for species like Hyaena hyaena, Herpestes edwardsii, and Scotophilus heathii, reaching higher values (up to around 5). Representing Series 3, the green line shows more variation as well, culminating at higher values near species like Mus musculus and Rattus rattus. Though it displays more mild fluctuations, Series 4—shown by the purple line—showcases greater peaks for several species, including Viverricula indica and Hyaena hyaena. With notable peaks for species like Canis lupus pallipes and Hyaena hyaena, Series 5—marked with blue stars—exhibits the highest variation—that is, the most severe values in the data across species (Figure 1). These variations between the series indicate how different measurements or situations might be evaluated across various species; some species show more severe reactions in some series than others. With varied degrees of stability and volatility, the figure shows the variety of measures and how each series possibly catches various traits or behaviors throughout the species examined.

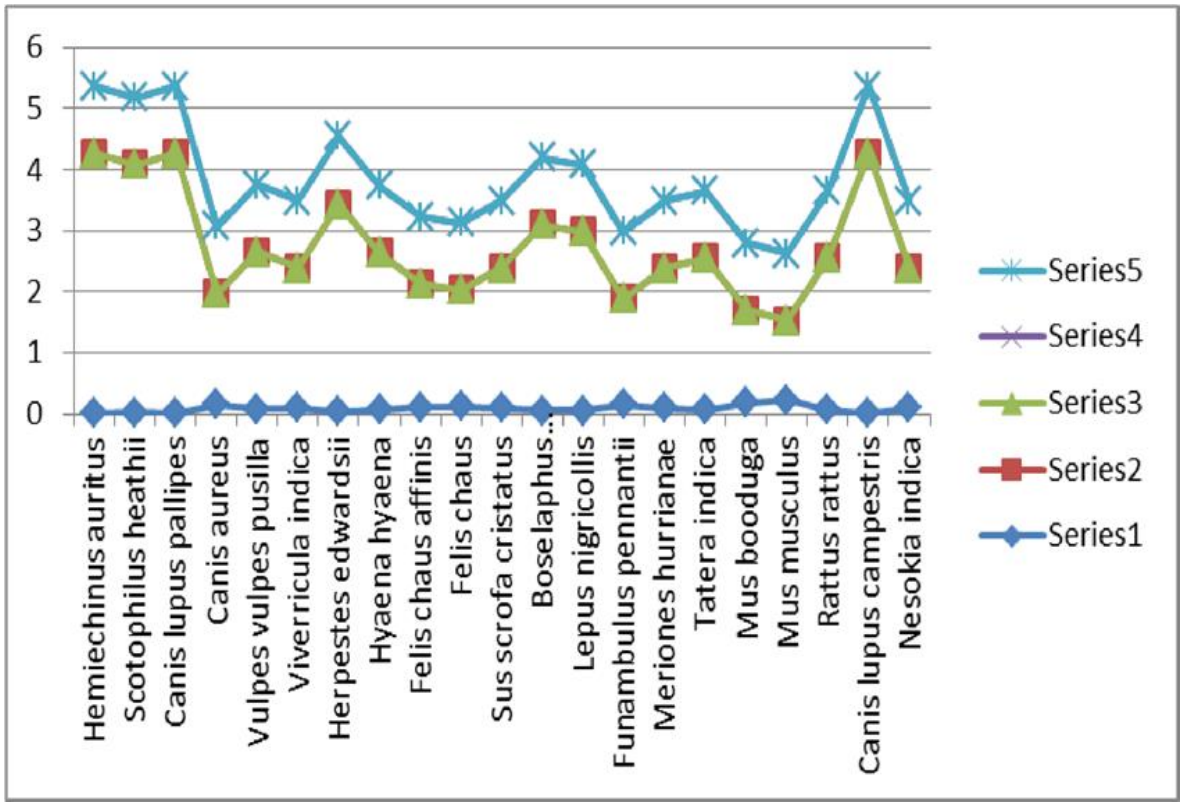

Figure 1. Comparison of five different series (Series 1 to Series 5) across various species.

The line graph illustrates the variability in a specific measured variable for each species, with each series represented by different colors and markers. The x-axis lists the species, and the y-axis represents the measured values. The legend identifies the colors and markers corresponding to each series.

Diversity indices

The findings reveal quite significant differences in diversity among species. Hyaena hyaena, for example, shows a low Shannon index (0.845) and an extremely high Simpson's index (1.708), indicating it could rule its biological niche and hence lower the total diversity in its environment. Conversely, species like Funambulus pennantii (northern palm squirrel) and Mus musculus (house mouse) show lower Simpson's values (0.732 and 0.738, respectively) and higher Shannon values (2.024 and 1.925, respectively), so indicating more balanced species coexistence and greater biodiversity in their related environments. Most species, including Viverricula indica (little Indian civet) and Canis lupus pallipes (Indian wolf), display intermediate values, therefore showing modest dominance and diversity levels. According to the research, some species—especially apex predators like the striped hyena—may have a major impact on community structure by lowering diversity; while, generalist or prey species help to produce more equal distributions (Table 2). The results might come from a habitat-specific research, maybe in a mixed or semi-arid environment where predator-prey interactions shapes biodiversity patterns. Contextual information such the research region, sample techniques, and whether these indices were computed at the species or community level would help to further interpret any results. The findings generally show the ecological functions various species play and their different effects on local biodiversity. The Shannon Diversity Index values range from 1.384 to 2.024, while the Simpson's Diversity Index values range from 0.704 to 0.889. These values indicate a moderate to high level of diversity among the mammals in the National Park. Simpson's Diversity Index ranges from 0 to 1, where 0 indicates no diversity, and 1 represents infinite diversity. The values obtained for the species in the study range from 0.704 to 1.708. The highest value is observed for the Hyaena hyaena species, indicating the highest level of diversity, while the lost value is observed for Hemiechinus auritus. Shannon Diversity Index measures the information content or uncertainty associated with a sample community. The values range from 0 to infinity, with higher values indicating greater diversity. The values obtained for the species in the study range from 0.845 to 2.024 (Figure 2).

Table 2. Diversity indices for 21 mammalian species, recorded in a study in LSNP assessing species distribution and community structure

Sr. #	Scientific Name	Simpson's Diversity Index	Shannon Diversity Index
1	*Hemiechinus auratus*	0.704	1.796
2	*Scotophilus heathii*	0.827	1.663
3	*Canis lupus pallipes*	0.904	1.384
4	*Canis aureus*	0.846	1.700
5	*Vulpes vulpes pusilla*	0.776	1.887
6	*Viverricula indica*	0.816	1.864
7	*Herpestes edwardsii*	0.764	1.686
8	*Hyaena hyaena*	1.708	0.845
9	*Felis chaus affinis*	0.828	1.732
10	*Felis chaus*	0.796	1.758
11	*Sus scrofa cristatus*	0.820	1.697
12	*Boselaphus tragocamelus*	0.864	1.543
13	*Lepus nigricollis*	0.889	1.673
14	*Funambulus pennantii*	0.738	1.925
15	*Meriones hurrianae*	0.812	1.768
16	*Tatera indica*	0.841	1.713
17	*Mus booduga*	0.838	1.734
18	*Mus musculus*	0.732	2.024
19	*Rattus rattus*	0.867	1.570
20	*Canis lupus campestris*	0.867	1.570
21	*Nesokia indica*	0.833	1.741

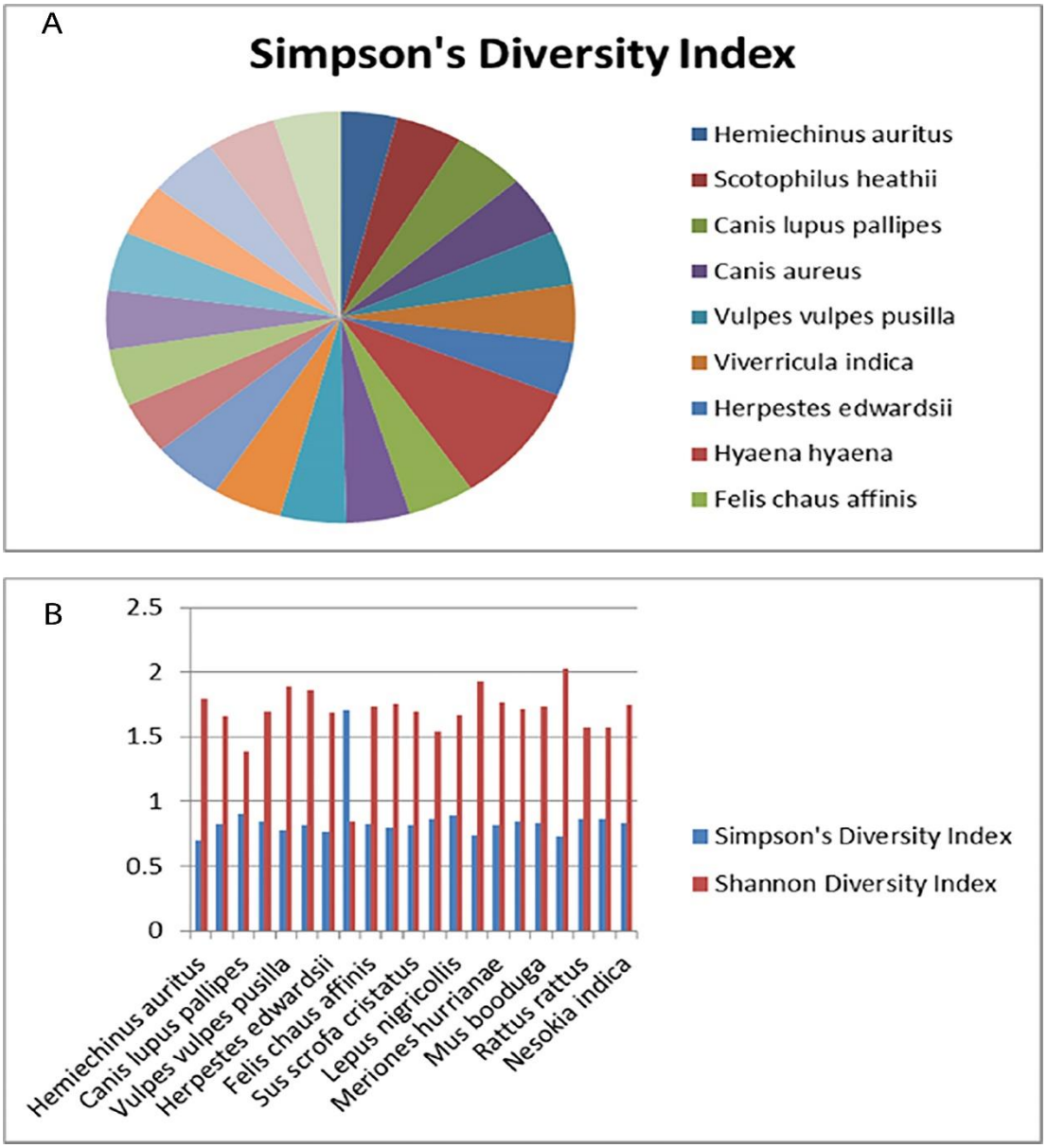

Figure 2. Diversity analysis of mammalian species based on Simpson's and Shannon diversity indices. (A) Pie chart depicting the distribution of species diversity using the Simpson's Diversity Index. Each color represents a different species, with the chart illustrating the evenness of the distribution across species. (B) Bar graph comparing Simpson's Diversity Index (blue bars) and Shannon Diversity Index (red bars) for each species. Error bars represent the standard deviation. Species names are listed along the x-axis.

Comparative analysis of multiple species

The Mean and Standard Deviation are indicated as key statistical measures, suggesting the data represent averaged values with variability across samples or observations. The listed species include a mix of carnivores (Canis lupus pallipes, Vulpes vulpes pusilla), rodents (Meriones hurrianae, Rattus rattus), and other mammals (Sus scrofa cristatus, Herpestes edwardsii), implying a focus on biodiversity or species-specific traits in a shared ecosystem. The coexistence of large carnivores (Canis lupus pallipes) with smaller animals (Mus booduga), for instance, may indicate trophic interactions or the division of habitat. Species like the Indian desert jird (Meriones hurrianae) and the desert fox (Vulpes vulpes pusilla) are examples of those with a restricted taxonomic range, which suggests a focus on mammalian groups in dry or semi-arid environments. It is difficult to interpret the figure's context without axis labels or numerical data, but it seems to back up claims on species distribution, competition, or adaptability in the ecosystem under study. More information about measuring tools and technique would improve interpretation.

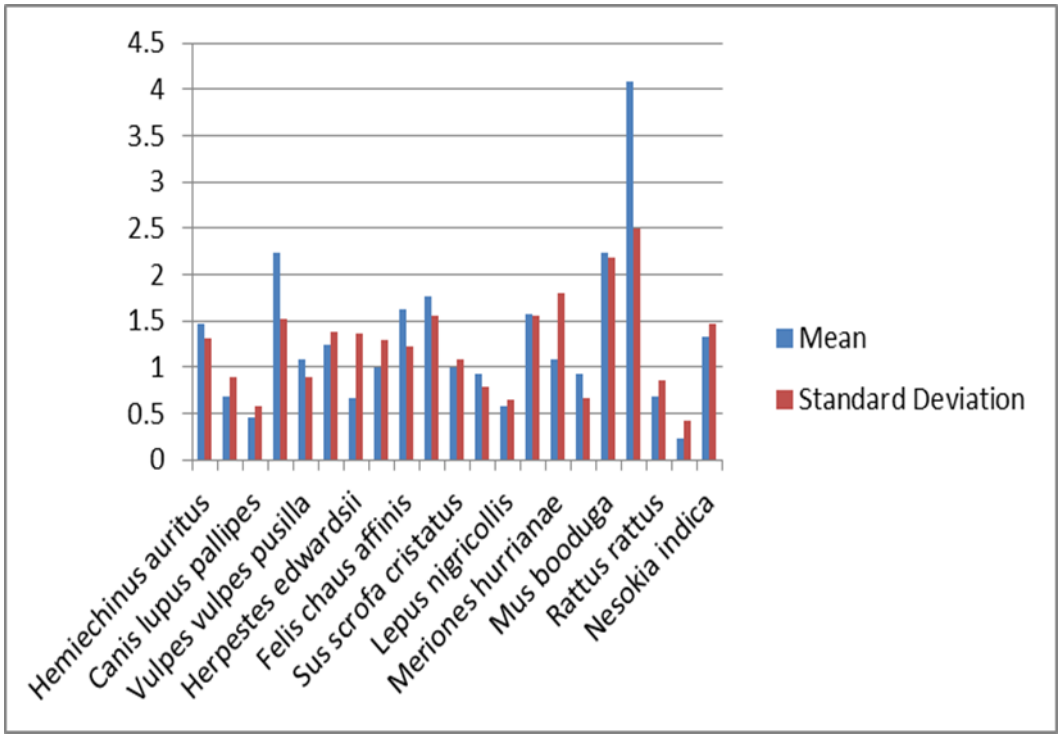

Figure 3. Comparative analysis of multiple mammalian species, displaying measured ecological data in a study in LSNP.

Discussion

The present study documented a rich mammalian diversity in Lal Suhanra National Park (LSNP), with 21 species recorded across various orders, including Carnivora, Rodentia, Artiodactyla, and Lagomorpha. The biological diversity of this area is highlighted by the coexistence of herbivores like the nilgai (*Boselaphus tragocamelus*) and Indian wild boar (*Sus scrofa cristatus*) with apex predators like the Indian wolf (*Canis lupus pallipes*) and striped hyena (*Hyaena hyaena*). This kind of diversity shows that the food chain is still mostly intact, with both predators and prey living together and keeping the environment in balance [5]. The great number of species found here is similar to what has been seen in other protected regions in Pakistan, such Margalla Hills National Park, where different types of ecosystems sustain a wide range of mammals [23]. The examination of relative abundance showed that there were big differences across species. Some were more dominant than others, while others had more even distributions. The striped hyena (*Hyaena hyaena*) has a high Simpson's index (1.708) but a low Shannon index (0.845). This suggests that it is a keystone predator that may keep competing species from becoming too common, which would lower local diversity [24]. On the other hand, generalist species like the house mouse (*Mus musculus*) and the northern palm squirrel (*Funambulus pennantii*) had higher Shannon indices (2.024 and 1.925, respectively), which means they can live in a wide range of ecological niches and help to increase biodiversity [25]. According to ecological theory, apex predators have top-down control over ecosystems, and generalist species perform well because they can use a wider range of resources [26]. The diversity indices made it very clearer what responsibilities various species play in the environment. The Shannon (1.384–2.024) and Simpson's (0.704–1.708) indices show that LSNP has a well-structured mammal community. But the fact that certain species, like the striped hyena, are so common may mean that there are problems, maybe because of human activities like breaking up habitats or making prey less available [12,27]. Other protected regions in South Asia have seen similar tendencies, when human activities interfere with the natural balance between predators and prey [28]. This study shows that large predators and smaller animals may live together, which is a sign of the park's biodiversity hotspot status. However, it also shows that focused conservation efforts are needed to reduce conflicts between people and wildlife [29]. The investigation into species distribution and abundance revealed distinct habitat preferences among the mammalian fauna. The Indian desert jird (*Meriones hurrianae*) and the de-sert fox (*Vulpes vulpes pusilla*) exhibited higher prevalence in arid environments, while the Indian wild boar (*Sus scrofa cristatus*) and the nilgai (*Boselaphus tragocamelus*) were more commonly observed in grassland and forested habitats. This pattern of spatial segregation is typical of diverse landscapes and emphasizes the significance of hab-itat diversity for sustaining viable animal populations [30]. The presence of the black rat (*Rattus rattus*), an invasive species, presents a potential concern regarding competition with native rodent populations, a phenomenon observed in other regions where invasive species have disrupted ecological balance [31]. The findings of this study carry significant implications for conservation strategies. For

vulnerable species such as the Indian wolf and the striped hyena, enhanced anti-poaching measures and habitat restoration initiatives are warranted [32]. Furthermore, community-based conservation approaches may prove effective in mitigating hu-man-wildlife conflict, particularly in areas where livestock depredation by predators has been documented [5]. For species with limited distribution ranges or those that are considered to be rare, such as the short-tailed mole rat (*Nesokia indica*), long-term monitoring programs are also essential for tracking population trends. Combining climate change models with biological data might also assist anticipate how species would move in the future, which would help with proactive conservation planning [11].

Conclusions

A diverse collection of species that occupy a variety of ecological niches is shown by the study's thorough evaluation of mammalian diversity in Lal Suhanra National Park. The park is ecologically important since it has both apex predators and generalist species. The fact that the diversity indices change shows how complicated the relationships are that shape this ecosystem. However, human activity and the existence of invasive species continue to make it hard to protect biodiversity. To protect this one-of-a-kind group of mammals, it is necessary to use specific methods including restoring their habitats, fighting poaching, and getting the community involved. To make sure the park can handle changes in the environment, future study should focus on long-term monitoring and combining ecological data with climate models. LSNP can keep being an important safe place for Pakistan's mammal diversity if it can solve these problems.

Supplementary Materials: Not applicable.

Author Contributions: Conceptualization, GA.; methodology, MSW, GA, MZH and IQ; software, MSW, GA, MZH and IQ; validation, MSW, GA, MZH and IQ; formal analysis, MSW, GA, MZH and IQ.; investigation, IQ; resources, GA.; data curation, MSW, GA, MZH and IQ; writing—original draft preparation, MSW, GA, MZH and IQ.; writing—review and editing, MSW, GA, MZH and IQ; All authors have read and agreed to the published version of the manuscript."

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