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Comparative Analysis of Herbivore Population Structure and Distribution in Protected Areas and Adjacent Non-Protected Forests

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Key Words

Herbivore population, Protected areas, Non-protected forests, Biodiversity, Population structure, Habitat fragmentation, Spatial distribution.

Abstract

This research work aims to offer a comparative analysis of the herbivore population structure and its spatial distribution in protected and non-protected areas. In the course of field observations and by use of camera traps at 40 locations per site over a 12-month period, population density, the proportion between age groups, sex ratio, and diversity of animal species were examined. It is shown that the level of population density, balanced structure, and equalized sex ratios were characteristic of herbivores in protected zones; meanwhile, populations in non-protected forests were more fragmented with a biased population structure. The results suggest that diversity indices (Shannon H′ and Simpson D) were higher in the former zones. Analysis of spatial distribution patterns proved that the animals' mobility was considerably reduced in non-protected forest areas due to the fragmentation of their habitats.

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Introduction

Herbivores are arguably significant in the establishment of ecosystems structure and dynamics through recommended influence of vegetation, nutrient cycling and predator prey relationships (Kiffner et al., 2024). Habitat quality, the presence of resources, and human pressures contribute significantly to their population structure, distribution and abundance (Almudhafar et al., 2024). Over the past decades, rising anthropogenic processes, including deforestation, the spread of agricultural land, and the building of infrastructure can result in the severe fragmentation of the habitat that may drastically disturb the population of herbivores and their ecological functions (Ziwei & Han, 2023). It is necessary to understand the effects of protection measures on the population of herbivores in terms of effective wildlife management and biodiversity conservation (Mesariya et al., 2026).

Protected areas (PA) are essential as critical wildlife habitats via restricting human disturbances and maintaining natural habitats (Negi et al., 2025). They offer comparatively safe space or areas where the population of herbivores would have consistently stable densities, age structures, and reproductive success. On the other hand, neighboring non-preservation forests usually experience increased anthropogenic stresses, such as poaching, logging, and encroachment, leading to decreased populations of forests, as well as sex ratios and reproductive associations affected by juvenile breeders. Although the role of PAs is acknowledged, there has been a lack of comparison in the studies to determine the population structure and distribution of herbivores in both the protected and non-protected areas especially in fragmented forests (Mialhe et al., 2026).

This research seeks to fill this knowledge gap by undertaking a systematic comparison of the herbivore population in the safeguarded zones and other neighboring forests, which are non-protected. Some of the key goals are the quantification of population densities, the distributions of age-classes and sex ratios, the species diversity, and the spatial distributions patterns of study sites. The study aims to inform conservation avenues, inform habitat management and support policies that improve the connectivity and resilience of herbivores populations by emphasizing the differences between population structure and distribution between landscape with and without protection. Also, the study covers the larger ecological implications of habitat fragmentation and human disturbances, which will give essential insights on the maintenance of biodiversity amidst landscapes that become more and more dominated by humans.

In this paper, there are five sections. Section I presents the study, its purpose and the significance of herbivores and conservation zones. In Section II, the study area, the species, data collection and data analysis methods were described. Section III provides the population densities, age and sex structures, diversity indices, as well as, patterns of spatial distribution. In section IV, the outcomes in conservation and

ecological contexts are addressed. Section V ends with crucial findings, recommendations, and future research directions.

Materials and Methods

Study Area

The area studied is central India, to which three types of protected areas, namely Kanha National Park, Bandhavgarh National Park, and Pench Tiger Reserve plus a buffers area of 10-20 km were studied. The nature of the protected areas is well managed with low human activities, thick mixed forests of broadleaf as well as occasional perennial waters. Opposite non-protected forests are characterized by high levels of anthropogenic stress factors such as selective logging, grazing and small-scale agriculture. The altitude varies between 350 to 850 meters above the sea level with the vegetation being Sal forests, mixed forests of deciduary and scrublands. The GPS position of every survey plot was noted, and the quality of the habitat was characterized according to the canopy cover, density of the understorey, and human activity traces.

Target Species

The monitored species of Herbivores were Chital (Axis axis), Sambar (Rusa unicolor), Nilgai (Boselaphus tragocamelus) and Wild Boar (Sus scrofa). The age classes were grouped into juveniles (under one year), sub-adults (1-3 years) and adults (over three years) and the sex was identified using the secondary sex-characterist that is observable in the field and also through the camera trap photographs.

Data Collection

The documentation was made in a 12-month period between January and December 2025 that was used to gather population data. In the protected and non-protected regions, 5 km transects which were laid in a systematic manner were used to carry out line transect surveys. The transects were walked twice a month, and species, group size, age group and sex were recorded by the observers. There were as well 40 camera traps at each location, which were positioned along waterholes, trails and grazing fields and they worked round the clock, 60 days at a time during each season. The transect walks were conducted, with a view to recording opportunistic observations to supplement line transect data, and camera trap data.

Table 1 compares the herbivore population density, sex and age ratios, and the species diversity index of the protected and the non-protected forest nearby. In the protected areas, the densities are higher, the sex ratios are even and the variety of species is greater compared to forests that are not under protective measures, which display lower densities, skews, and differences.

Table 1: Comparative Population and Diversity Metrics of Herbivores in Protected and Non-Protected Forests

Species	Population Density (individuals/km²)	Age Ratio (Juvenile:Adult)	Sex Ratio (Male:Female)	Shannon H′	Simpson D
Protected Areas					
Chital	12.5	0.42	0.95	2.13	0.85
Sambar	5.8	0.42	0.95	2.13	0.85
Nilgai	2.4	0.42	0.95	2.13	0.85
Wild Boar	4.6	0.42	0.95	2.13	0.85
Non-Protected Areas					
Chital	6.7	0.28	1.20	1.48	0.62
Sambar	3.1	0.28	1.20	1.48	0.62
Nilgai	1.2	0.28	1.20	1.48	0.62
Wild Boar	2.3	0.28	1.20	1.48	0.62

Spatial Analysis

GIS-based kernel density mapping was used to perform analysis of spatial distribution. The condition of the protected areas was characterized by high-density areas with overlapping home ranges and non-protected areas were characterized by fragmented populations confined to the remaining areas of habitat and corridor-like areas.

Statistical Analysis

T-tests and one way ANOVA were used to make comparisons between the sites which were being guarded and the ones which were not. All data analyses were done using R version 4.2.2, p significant value of less than 0.05.

Results

Population Density

The population density was also greatly different in both the forested and unforested areas. There were also greater herbivore proportions in the protected areas with Chital 12.5 individuals/km², Sambar 5.8 individuals/km², Wild Boar 4.6 individuals/km 2 and Nilgai 2.4 individuals/km 2. Conversely, non-protected forests had lower densities: Chital 6.7 individuals/km 2, Sambar 3.1 individuals/km 2, Wild Boar 2.3 individuals/km 2 and Nilgai 1.2 individuals/km 2. These differences were proven statistically as significant (t-test, $p < 0.05$).

Age-Class and Sex Structure

Protected areas demonstrated equal population structures where juvenile-to-adult ratios were at 0.42; male-to-female ratios were at 0.95. Skilled demographics were observed in

non-protected forests, showing a ratio between young people and adults of 0.28 and male-female 1.2. This evidence suggests less recruitment and even demographic instability in unprotected habitats.

Species Diversity

The diversity of species was always greater in the protected (Shannon H 4, = 2.13, Simpson D, = 0.85) than the non-protected forests (H 4, = 1.48, D 4, = 0.62). This goes to show that the benefit of protection status is that it increases evenness and species richness which leads to a stability of the ecosystem.

Spatial Distribution

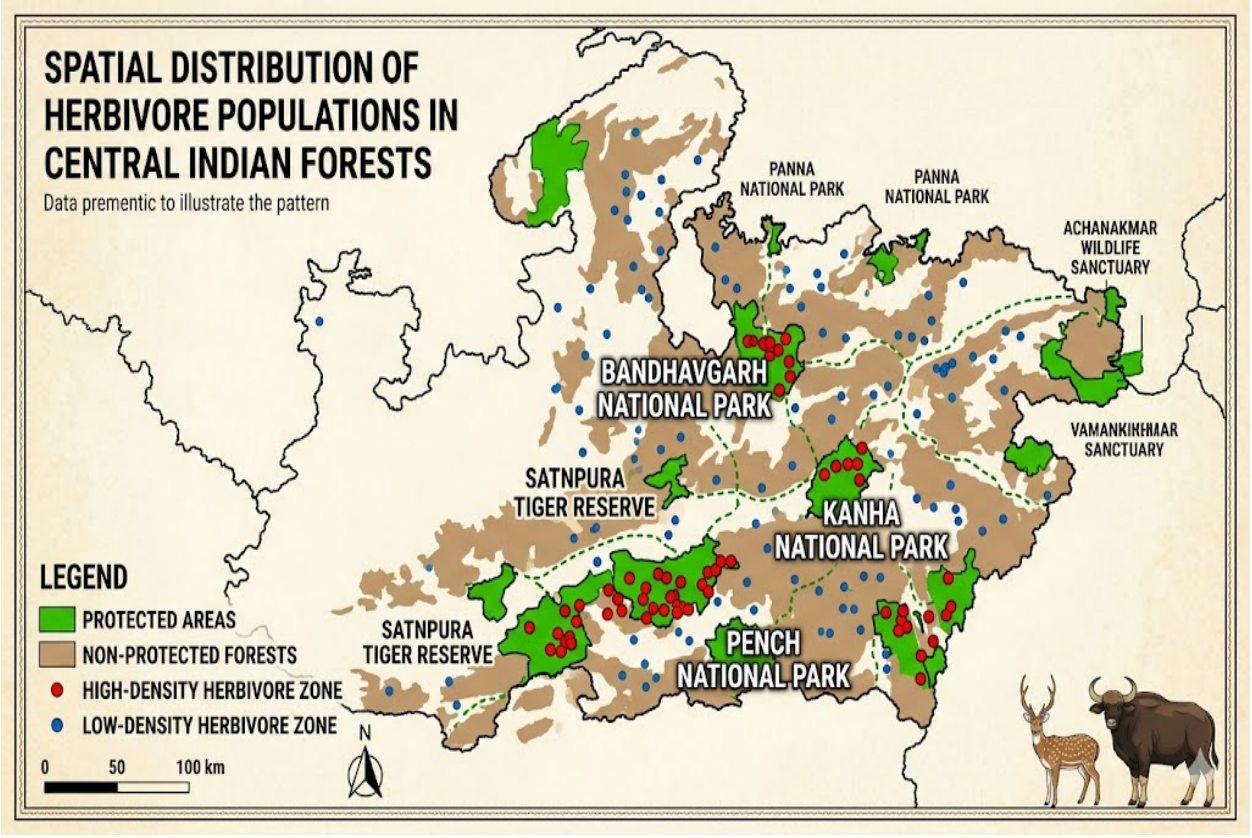

Figure 1: Spatial Distribution of Herbivore Populations

The distribution of populations of herbivores in space is depicted in figure 1. High-density areas (red) were found within the core habitats in the protected areas (green), whereas the non-protected forests (brown) had fragmented populations, with low density areas (blue). Key conserved areas, such as Kanha, Bandhavgarh, Pench and Satpura, are hotspots in terms of population thus forecasting the importance of their conservation.

Discussion

These findings indicate that sanctuaries have more herbivores, equal age composition, and species diversity than non-sacred forests. These trends are likely caused by reduced human disturbance, discontinuous habitat, a consistent

food and water supply, and fragmentation in unprotected zones, which leads to low densities and biased demographics (Kurian & Sultana, 2024; Paul et al., 2024; Chen et al., 2025).

These results highlight the ecological significance of natural and man-made reserves as havens for wild animals. Population fragmentation and decreased recruitment of non-protected forests can be minimized by targeting conservation efforts, including habitat restoration, buffer zones, and community-based interventions to minimize human-wildlife conflict (Paramasivam & Venkataraman, 2022; Scramoncin et al., 2024; Nematollahi et al., 2022).

The management interventions must aim at improving connectivity of the divided habitats by ecological corridors and reforestation, and the incorporation of local people in conservation. Frequent review of the population structure and spatial distribution may inform adaptive management as well as sustainability over the long term of the herbivores in the protected and non-protected landscapes (Ziwei & Han, 2023; Coletta et al., 2023; Jakhir, 2024).

Conclusion

This paper shows that wildlife reserves are an important consideration in the maintenance of healthy herbivores. Population densities, sex and age structures, and species diversity were found to be higher in the protected areas as compared to non-protected forests which were found to be fragmented and had a lower biodiversity. The results point to the ecological significance of having a well-conserved area and the necessity to provide conservation measures into the nearby non-conserved forest areas. Setting ecological corridors, rehabilitating deteriorated habitats and engaging local communities in conservation programs are critical measures towards enhancing the integrity of habitats and population dynamics. The following research questions should be considered in future studies: how demographic changes can be tracked over time, how seasonal changes in resources may influence herbivores and their survival, and how human activities affect their movement patterns. A combination of spatial mapping and population surveys can be very helpful in guiding adaptive management and conserving herbivore populations in both protected and unprotected landscapes over the long term.

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