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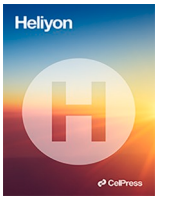

Research article

The effect of ranger patrols on the sighting of large mammals by local herders in Northern Iran

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ABSTRACT

Ranger patrols are essential for biodiversity conservation, particularly in protected areas where they help mitigate poaching of large mammals. Effective patrols reduce poaching and support higher population densities of large mammals. This study investigates the impact of ranger patrols on large mammal sightings in the Central Alborz Protected Area (CAPA), northern Iran, a crucial wildlife corridor with UNESCO-listed Hyrcanian forests and high-altitude grasslands. CAPA also supports livestock grazing in over 200 villages, making it a key area for studying human-wildlife interactions. Data were gathered using semi-structured questionnaires from local herders, whose observations provide valuable insights into wildlife presence and the effectiveness of ranger patrols. The study area was divided into 5 × 5 km grid cells to ensure uniform data collection. Results show that large mammal sightings decrease with increasing distance from active, semi-active, and seasonal ranger stations. This trend is likely due to reduced patrol coverage, which increases poaching risks. Although factors such as habitat preferences and human disturbances may contribute. Inactive ranger stations appear to have lost effectiveness, likely because of the lack of regular patrols, which warrants further investigation. These findings emphasize the critical role of consistent patrol efforts in reducing poaching and maintaining wildlife populations in this ecologically important region.

1. Introduction

Poaching poses a significant threat to the survival of many species in protected areas worldwide [1], often resulting in irreversible damage to endangered species [2]. Illegal hunting significantly contributes to the decline in species richness, particularly in mammal communities, with herbivores being more affected than other mammals [3]. Rangers are regarded as the most effective agents in the legal protection of wildlife, and their effectiveness largely depends on the availability of equipment and the number of personnel [4]. Ranger patrols play a crucial role, with the range and frequency of their activities, as well as the proximity to ranger stations, identified as key predictors of species richness and large mammal sighting rates [5]. However, ranger numbers have significantly declined in Asia over the past two decades, exacerbating challenges to wildlife protection [6].

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The effectiveness of ranger stations is closely tied to the expansion of patrol areas and the increased duration of daily ranger patrols, which, when consistently maintained over the years, leads to a significant reduction in poaching levels [7,8]. However, the protection of threatened species, particularly those classified as Vulnerable (Vu), Endangered (En), or Critically Endangered (Cr), is directly dependent on the extent of patrolling efforts [9]. One of the most effective strategies for reducing human pressures on wildlife is continuous ranger patrols. These patrols focus on fostering cooperation with local communities in protected areas and prioritizing the protection of critical zones, which are essential for the long-term conservation of species [10].

Poaching continues to exert significant pressure on endangered species populations, making it one of the most critical challenges for conservation efforts. Enhancing knowledge and increasing investment in ranger recruitment and equipment are the most effective measures to improve patrol effectiveness and reduce poaching pressure [11]. In Iran, poaching, habitat loss, and climate change are the three primary drivers of species extinction, with large mammals particularly threatened by direct persecution [12]. In some protected areas, populations of certain Artiodactyla species have declined by more than 70 % over the past four decades [13]. Large herbivores, in particular, face intense pressure from poaching, which leads to a significant reduction in natural prey for carnivores and, consequently, increases human-wildlife conflicts with domestic livestock. Retaliatory actions by ranchers, such as setting traps or using poisoned bait, can further endanger carnivore populations [14]. Nevertheless, rangers play a crucial role in protecting wildlife and ensuring species distribution [15]. To effectively combat poaching and address its underlying causes, strategic conservation planning must be centered on ranger patrols [16].

The Central Alborz Protected Area is one of the largest protected regions in Iran, serving as a critical habitat for endangered species and rich biodiversity in the north of the country [17]. Livestock grazing is permitted throughout the Central Alborz Protected Area, with the exception of designated core zones. The presence of villages and pastoral activities, combined with the vast size of the area and the shortage of ranger personnel, has exacerbated the threats to large mammals. This is due to the direct relationship between livestock density and poaching [18].

The deactivation of several ranger stations in recent years, due to a shortage of rangers and equipment in the Central Alborz Protected Area, has raised significant concerns regarding the protection of endangered and protected species in this region. Furthermore, in the absence of regular ranger patrols, we hypothesize that the frequency of large mammal sightings by local herders may provide a similar opportunity for poachers. This study examines the role of ranger stations in the relative frequency of sightings of six large mammal species, as reported by local herders. The objectives of the study are: 1) to assess the impact of active, seasonal, semi-active, and inactive ranger stations on the relative frequency of sightings for each studied species, and 2) to compare the relative frequency of sightings of each species with their distance from ranger stations.

2. Methods and materials

2.1. Study area

This study was conducted on the northern slopes of the Central Alborz Protected Area, located in Mazandaran province, northern Iran. The region encompasses two main ecological zones: coastal and mountainous, featuring Hyrcanian forests, a UNESCO World Heritage site, along with high grasslands and roaring streams (Fig. 1). The area supports indicator species such as the brown bear (*Ursus arctos*), leopard (*Panthera pardus*), gray wolf (*Canis lupus*), Caspian red deer (*Cervus elaphus maral*), roe deer (*Capreolus*), and wild boar (*Sus scrofa*), underscoring its rich biodiversity, [19,20,21]. The Central Alborz Protected Area is home to approximately 40 % of

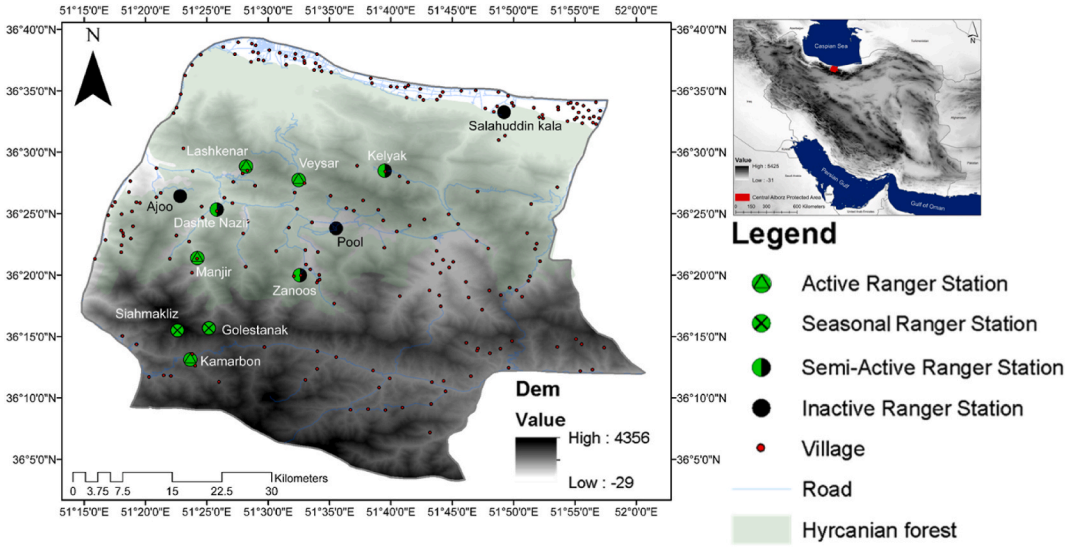

Fig. 1. Central Alborz protected area.

the total wild population of the Caspian red deer in Iran [22] and contains one of the densest brown bear habitats in the country [23]. Additionally, this region is a critical habitat for the Persian leopard, both currently and for future conservation [21,24]. The area is protected by four active, two seasonal, and three semi-active ranger stations. However, three of the 12 ranger stations have been deactivated due to shortages of personnel and equipment. Covering 2980 km^2, the Central Alborz Protected Area is patrolled by only 10–12 rangers per shift, which is nearly 23 times less than the average ranger coverage in Asia Farhadinia et al., 2023.

2.2. Data collection

Data were collected in 2020 through questionnaires administered in villages within the Central Alborz Protected Area. The study involved 110 traditional livestock farmers, whose livelihoods depend on grazing in natural areas, and who had over 10 years of experience in the region. The questionnaire gathered ranchers' observations on the population trends of six large mammal species over the past decade, using three closed responses: "decreased," "constant," or "increased." To ensure consistency in data collection, the study area was divided into 5 × 5 km cells, based on the extent of livestock grazing. Cells were selected based on two criteria: 1) confirmed presence of the target species through field monitoring by rangers, and 2) the presence of traditional herders within the cell [25]. On average, each cell contained 2.4 herders. The study focused on six species: the brown bear, Persian leopard, gray wolf, Caspian red deer and roe deer, all of which are protected species, as well as the non-protected wild boar [26–31].

2.3. Statistical analysis

To quantify the qualitative data collected from the questionnaires, the responses on trends in mammal observations were converted into numerical values. Specifically, the trend of observation was scored as follows:

Increasing = +1, Constant = +0.5, and Decreasing = 0.

This transformation of qualitative responses into quantitative scores allowed for subsequent statistical analysis [32].
These numerical values were used to quantify the relative frequency of observations, calculated as:

Relative frequency of observations = Trend of observation ÷ Distance from Ranger Station (km)

To assess spatial patterns in the observations, we employed the Inverse Distance Weighted (IDW) interpolation method, implemented in ArcGIS 10.8. IDW is a spatial interpolation technique that estimates values at unsampled locations based on the values from surrounding known points, with closer points exerting more influence. The IDW assumes that the influence of each known data point decreases with distance from the prediction location. The formula for IDW interpolation is:

$$Z(x) = \frac{\sum \left(\frac{Z_i}{d_i^p}\right)}{\Sigma \left(\frac{1}{d_i^p}\right)}$$

where:
Z(x) is the estimated value at the location x.
Z_i is the value at known data points
d_i is the distance from the known data point to the location being estimated
p is a power parameter (commonly set to 2)
The IDW technique is particularly useful for generating continuous surface maps that predict mammal observation trends across the

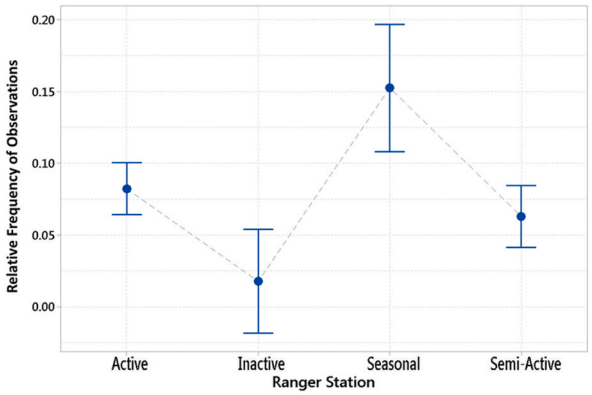

Fig. 2. The effect of distance from Ranger station on species relative frequency of observations.

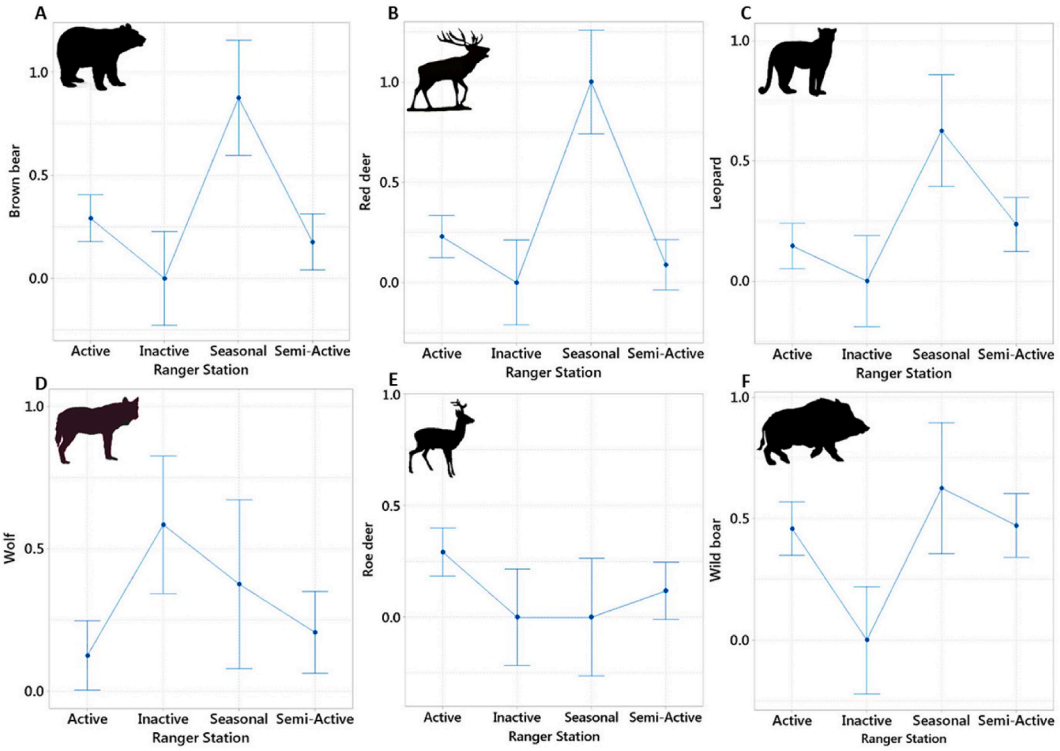

Fig. 3. A–F: The effect of the activity level of the ranger stations on the observation rate of the studied species.

study area, even in locations where field data points are sparse. By using this method, we were able to visualize spatial patterns in observation trends and identify regions with increasing, constant, or decreasing mammal populations.

To evaluate differences in the trends of mammal observations across various ranger stations an Analysis of Variance (ANOVA) was conducted. The ANOVA was used to determine if significant differences existed in the relative frequency of observations between types of ranger stations. This approach helped determine the effect of ranger stations on the trends of mammal observations as reported by the herders.

In addition to spatial interpolation, we explored the correlation between the distance from ranger stations and observed trends in species populations through linear regression. For each farm, the distance from the nearest ranger station and the corresponding trend of observation were used to fit regression models. The relationships between these variables were assessed and visualized using fitted line plots.

By combining IDW spatial interpolation, regression analysis, and ANOVA, we ensured a comprehensive statistical evaluation of the data. This multi-faceted approach allowed us to account for spatial autocorrelation, examine potential spatial patterns, and test the influence of various factors on the observed trends in mammal populations.

3. Results

The results from the questionnaires indicate that the number of observations of the studied species by ranchers has decreased sharply around deactivated ranger stations over the past 10 years. In contrast, observation rates around active ranger stations have remained relatively stable. Notably, around the village of Veysar, where a new ranger station was established in the past six years, there has been a significant increase in sightings of the six species by livestock farmers.

The analysis revealed significant differences in the relative frequency of wildlife observations across ranger station categories (ANOVA, $p = 0.03$). Mean observation frequencies varied significantly, with the highest recorded at seasonal ranger stations (mean $\pm$ SE: 0.17 ± 0.03), followed by active stations (0.10 ± 0.02), semi-active stations (0.08 ± 0.02), and inactive stations (0.05 ± 0.01) (Fig. 2).

The impact of the four types of ranger stations on the observation rates of the studied species varied. Specifically, wolves (Fig. 3D) were observed more frequently around deactivated ranger stations. Conversely, seasonal ranger stations had a direct impact on the number of sightings for bears (Fig. 3A), red deer (Fig. 3B), leopards (Fig. 3C), and wild boars (Fig. 3F).

The descriptive maps illustrate the patterns of species sightings reported by herders (Fig. 4A–F).

The linear regression analysis between the trend of observation and the distance from the ranger stations revealed that the observation rates for brown bears (p-value = 0.000, $R^2 = 34$ %) and red deer (p-value = 0.009, $R^2 = 14.8$ %) decreased significantly as the distance from the ranger stations increased, compared to other species (Fig. 5).

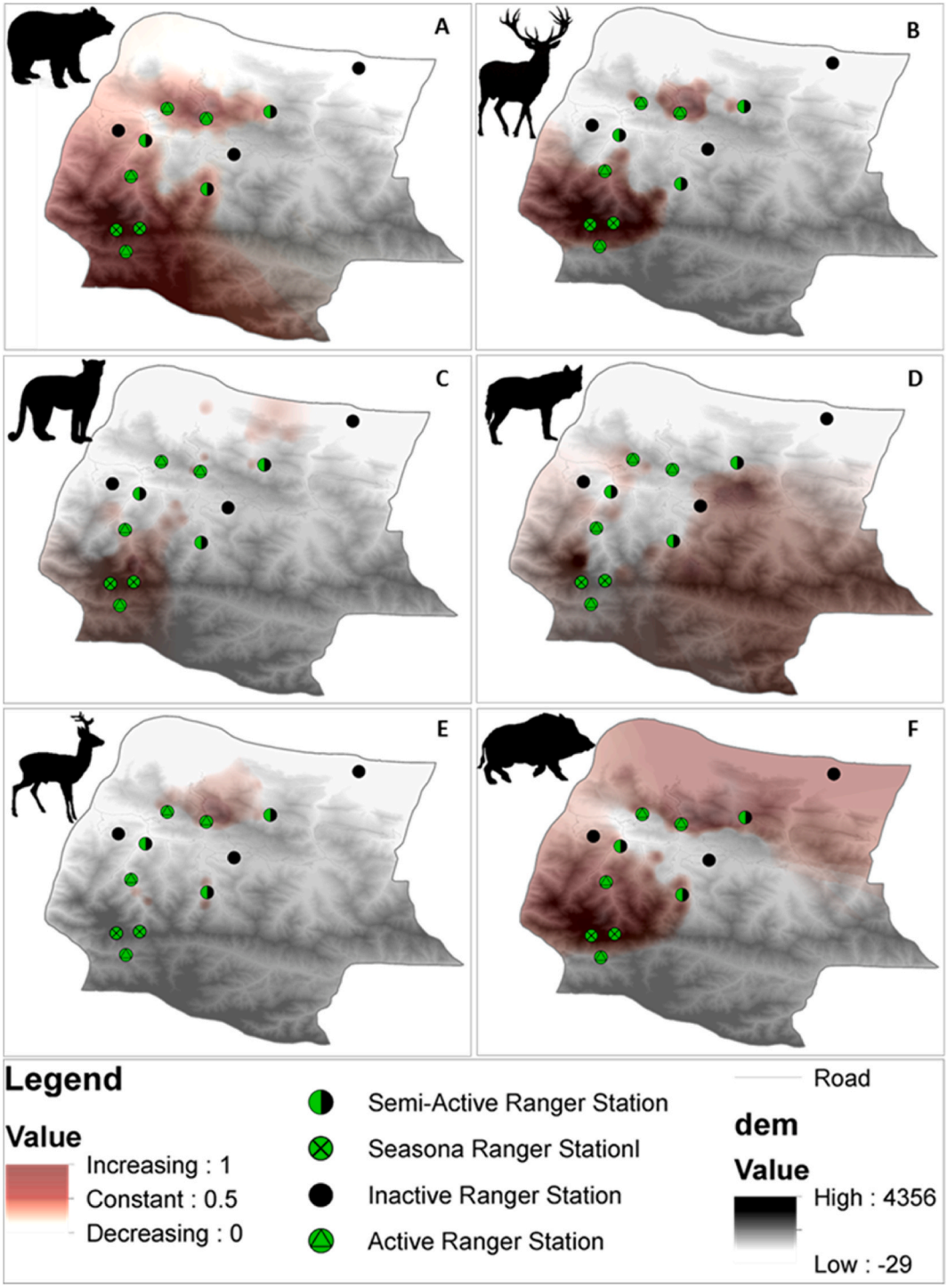

Fig. 4. A–F: Trend of observation of species compared to the ranger stations.

4. Discussion

This study aimed to assess the impact of active, seasonal, semi-active, and inactive ranger stations on the observation rates of six large mammals by local herders. The results indicate that active and seasonal ranger stations had a more pronounced effect on the observation rates of the studied species compared to semi-active ranger stations. Active ranger stations contributed to greater stability, while newly established ranger stations significantly increased the number of sightings reported by livestock farmers. Among the

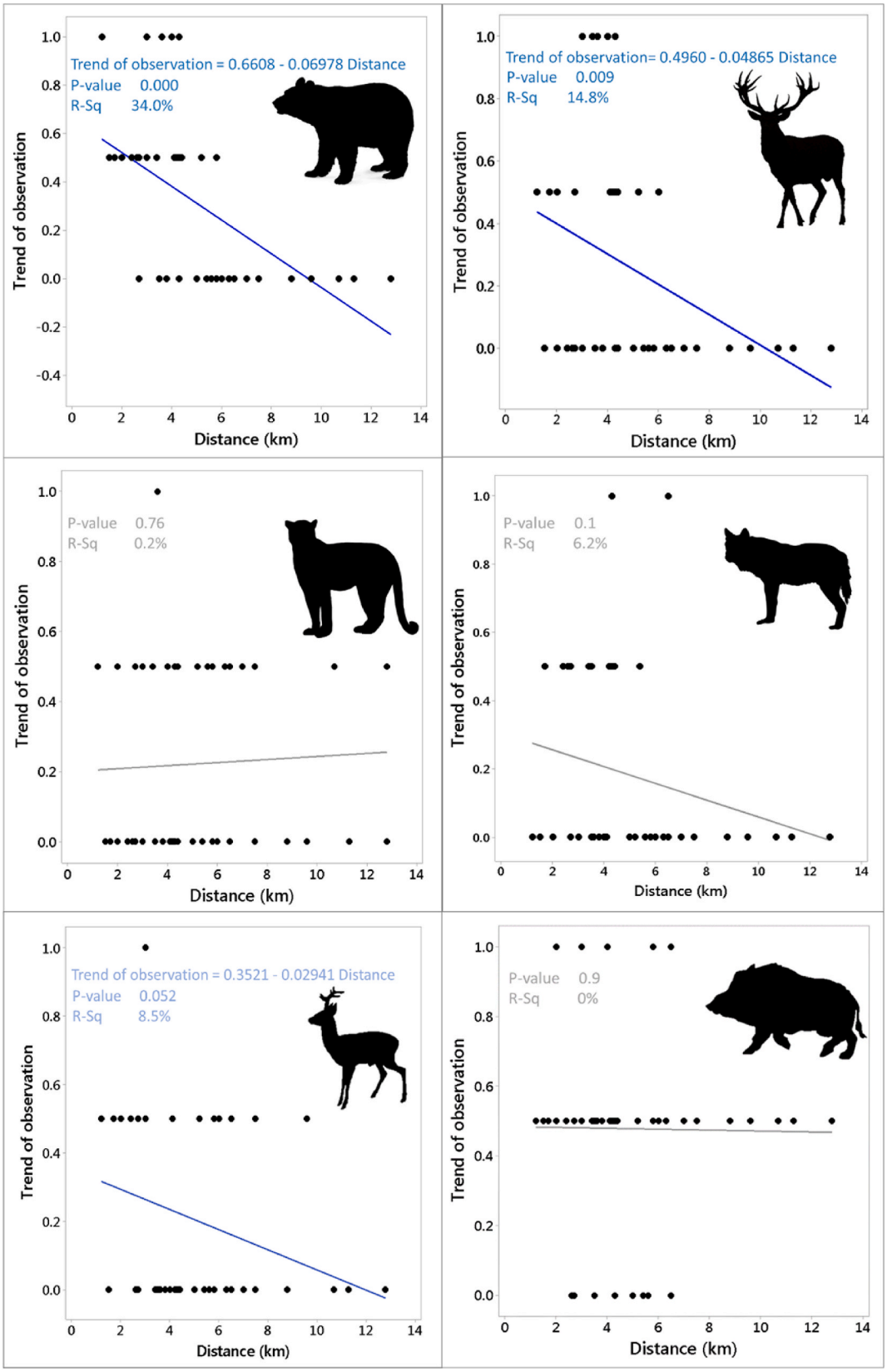

Fig. 5. Regression between species trend of observation and distance from the ranger station.

species studied, brown bears, red deer, and roe deer exhibited a significant response to the distance from active and seasonal ranger stations, whereas leopards, wolves, and wild boars showed less sensitivity to these distances.

The results of this study suggest that active and seasonal ranger stations have the greatest impact on the presence of the six studied species. The seasonal ranger stations in high-altitude pastures, protected by cliffs and dense forests, provide a safe refuge for species like red deer during critical reproductive periods. Strict anti-poaching measures and targeted patrols during these times likely contribute to the higher presence of wildlife in these areas compared to active and semi-active stations. Ranger stations that have been operational for over two decades, such as Lashkenar, Dashte Nazir, Golestanak, Siahmakliz, and Kamarbon, have stabilized mammal populations. This stability is attributed to the ongoing activity of rangers and the longevity of the ranger stations Ghoddousi et al., 2016; [5,8]. Conversely, the deactivation of ranger stations has led to a significant decline in mammal populations, likely due to increased poaching pressure, as large mammals are particularly vulnerable to poaching Yusefi et al., 2022. The Veysar ranger station, activated in the past six years and maintained with 24-h patrols, has notably reduced poaching, resulting in a significant increase in the presence of the studied mammals [4,7,9].

The impact of ranger patrols and their deployment at ranger stations has not been uniform across all six species, as they are differentially affected by poaching [3]. Brown bears, red deer, and roe deer were most frequently observed within a 2 km radius of active and seasonal ranger stations, with their presence decreasing as distance from these stations increased. This pattern suggests that these species are likely more susceptible to poaching pressure than others Ghoddousi et al., 2019. Roe deer exhibited a reduced dependence on proximity to active and seasonal ranger stations compared to red deer. This diminished reliance may be attributed to their smaller size and solitary behavior, which allows them to avoid predators more effectively. When faced with high predation risks, roe deer tend to reduce movement and become more secretive, opportunistically utilizing feeding sites based on seasonal and circadian cycles [33–35]. Additionally, roe deer's ability to inhabit a broader range of habitats, including dense vegetation, may mitigate the need for proximity to ranger stations. Unlike larger mammals, which are more vulnerable to poaching pressure (Yousefi et al., 2022), roe deer's behavioral flexibility likely aids in minimizing human-induced risks, reducing their dependence on areas with active ranger presence.

Overall, red deer and roe deer experience greater poaching pressure and therefore exhibit a more pronounced response to the distance from ranger stations compared to carnivores such as leopards and wolves Ghoddousi et al., 2019; [3]. Brown bears, although primarily herbivorous with a diet consisting largely of plants and insects in lower latitudes [36–38], display a distinct response to ranger station activity. Their presence significantly decreases with increasing distance from active and seasonal ranger stations, likely reflecting the influence of patrolling efforts Ghoddousi et al., 2016.

The manner in which rangers patrol affects the distribution and abundance of large mammals [4,5]. Increased patrolling is likely effective in enhancing species density Ghoddousi et al., 2016; [8]. Consequently, inactive or semi-active ranger stations, due to reduced personnel and equipment, may leave large mammals more vulnerable to poaching due to the density resulting from previous protection. To improve the survival chances of endangered or vulnerable species, it is essential to enhance patrolling through increased human resources and better equipment, guided by effective strategies based on past experiences and local community interactions.

Based on the findings of this study, an effective conservation strategy should emphasize the continuous operation and adequate resourcing of ranger stations to mitigate poaching pressures on large mammals. Ensuring that ranger stations are fully active and well-equipped can significantly enhance the visibility and protection of these species. Additionally, integrating local communities into conservation efforts and improving legal frameworks to support these initiatives can further bolster the effectiveness of ranger patrols and contribute to the long-term survival of endangered species.

5. Conclusion

This study underscores the critical role of ranger patrols in the conservation of large mammals within the Central Alborz Protected Area. Our findings reveal that continuous and well-supported ranger stations significantly enhance the observation and protection of these species, while inactive or semi-active stations lead to decreased sightings and increased poaching risks. The presence of large mammals is notably higher around active and seasonal ranger stations, highlighting the direct correlation between effective patrolling and species conservation. To improve conservation outcomes, it is imperative to maintain and augment the operational capacity of ranger stations, ensuring they are adequately equipped and staffed. Additionally, fostering community involvement and strengthening legal frameworks to support conservation efforts are essential for mitigating poaching pressures and ensuring the persistence of endangered species. By addressing these needs, we can enhance the protection of biodiversity and contribute to the long-term sustainability of natural habitats.

CRediT authorship contribution statement

Farid Salmanpour: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Zahra Shakoori:** Writing – review & editing, Supervision, Software, Methodology, Investigation, Data curation. **Mahan Salmanpour:** Writing – review & editing, Data curation. **Mehdi Tizrouyan:** Writing – review & editing, Data curation. **Mehdi Kia:** Writing – review & editing, Data curation. **Rahman Eshaghi:** Writing – review & editing, Data curation. **Saeid Ghomi:** Writing – review & editing, Data curation. **Abolfazl Rahbarizadeh:** Writing – review & editing, Data curation. **Rahman Naeimaei:** Writing – review & editing, Data curation. **Mehdi Ghaderi:** Writing – review & editing, Data curation.

Data availability statement

Datasets analyzed during the current study are available on Figshare as https://figshare.com/s/7b3092741825208ebc46.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e41452.

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