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The Effect of Settlement Areas on the Distribution of Wild Mammals: Case of Isparta

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Abstract: This study examines the effects of settlement areas related to the distribution of wild mammals. The research was conducted in the central and surrounding settlements of Isparta province, focusing on the reasons why wild animals approach settlement areas and the consequences of these interactions. Using direct and indirect observation techniques, the distribution of wild animals and their interactions with settlement areas were mapped. The Inverse Distance Weighting (IDW) method was used to determine the distribution of the Red Fox (*Vulpes vulpes*), Golden Jackal (*Canis aureus*), European Badger (*Meles meles*), Stone Marten (*Martes foina*), Wild Boar (*Sus scrofa*), and European Hare (*Lepus europaeus*). The species were evaluated using geostatistical methods along with commonly used environmental variables such as Radiation Index, Heat Index, Solar Illumination, Hillshade Index, Slope, Landform Index, Solar Radiation Index, Ruggedness, Altitude, and Distance to Settlements. As a result of the study, it was concluded that there is a need to identify and integrate alternative variables that can better reflect human–wildlife interactions.

Keywords: Geostatistics, Wildlife, Isparta, Habitat, Interaction

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1. INTRODUCTION

Although the challenges of human–wildlife conflict date back to ancient times, it is rapidly growing as an interdisciplinary field of study focused on human–wildlife interactions. In recent years, there has been a noticeable increase in the number of scientific publications addressing this issue. These studies reveal that human–wildlife interactions have increased exponentially (Nyhus, 2016).

Throughout human history, interactions between humans and animals have sometimes been mutually beneficial, while at other times have developed to the detriment of wildlife. Across the globe, forests, agricultural lands, wetlands, seas, lakes, polar regions, and deserts are inhabited by wildlife species with diverse types and populations. Wildlife utilize suitable habitats based on their ecological requirements (Özkazanç & Yiğit, 2023; Özdemir, 2024). A multidisciplinary approach is essential for wildlife management studies aimed at understanding human–wildlife interactions.

With the advent of sedentary human settlements, the habitats of wildlife species located near human communities have gradually diminished, giving rise to increased human–wildlife interactions (Ekinci, 2023; Zenbilci et al., 2024). As a result of such conflicts, environmental, economic, social, public welfare, health, and safety damages have become inevitable (Ünal, 2012; Ünal 2019). Over time, technological advancements and evolving human needs and behaviors have further disrupted the balance between humans and wildlife, mostly to the detriment of the latter (Özkazanç, 2002; Özkazanç, 2012).

As the human population increases, the expansion of settlements and human activities such as agriculture, animal husbandry, and fishing continue to degrade wildlife habitats (Alkan and Ersin, 2018; Süel et al., 2021). The growing integration of human and wildlife habitats increases the likelihood of conflict and brings about additional environmental problems (Lavsund et al., 2003; Şafak, 2008). Wherever wildlife comes into contact with humans, they are subjected to varying degrees and forms of impact. The more densely populated and expansive human settlements become, the greater this impact. Once wildlife enters human-dominated areas, the conditions they face differ significantly from their natural habitats. Humans have reshaped nature to suit their own needs.

Under these conditions, wildlife will either avoid such urbanized areas altogether or, if compelled to remain, must adapt to these altered environments. If humans intend and make efforts to support them, wildlife may have an easier time adapting and potentially become part of the urban ecosystem (Leyla and Oğurlu, 2021). However, regardless of the situation, it is essential to take necessary precautions for the safety and health of both humans and wildlife, as various interactions are inevitable. In order to examine the effects of habitat changes on wildlife populations, one should consider not only the temporal decline of key habitat factors such as food, cover, and water in natural environments, but also the expansion of human settlements that alter the areas where wildlife sustain their natural lives. Changes in land use classifications, habitat loss, degradation and fragmentation, as well as pollution of soil, air, and water have an impact on the reduction of suitable habitats that can retain their natural characteristics. (Beşkardeş, 2016; Mert et., 2024).

Within the scope of this study, mammal species inhabiting the province of Isparta and its surroundings were identified through direct and indirect observation techniques. The spatial distribution of these species was mapped, their likelihood of approaching settlement areas was analyzed, and the species that interact most frequently with human settlements were determined.

2. MATERIALS AND METHODS

2.1. Study Area

The study area covers approximately 17,262 hectares and includes the central district of Isparta Province as well as the surrounding settlements of Sav Town, Yakaören, Deregümü, Kayı Village, Akkent, Küçükhacılar, and Büyükhacılar villages. The area comprises residential zones, highways, agricultural lands, scrublands, and forested areas.

A grid system was created for the study area based on background ; maps. Each cell in the grid corresponds to one pixel from the base maps, with each pixel representing a 100 × 100 m² area. Within this grid system, 2,000 cells were randomly selected for sampling. Each sample unit corresponds to a single pixel.

In these sample areas, field data were collected using direct and indirect observation techniques. Baddeley's (1985) "Presence-Absence" method was employed to evaluate wildlife presence within each sample unit.

2.2. Environmental Layers

This stage includes the data of terrain-related variables and the environmental base maps generated for the study. These base maps consist of slope, aspect, solar angles, hillshade index, solar radiation index, topographic position index, altitude, landform index, ruggedness, and radiation and solar illumination indices.

All environmental variables were generated using the ArcMap software. In this context, a Digital Elevation Model (DEM) of the study area was first created based on contour lines. Using this DEM, raster maps of aspect, slope, and elevation classes were derived.

Subsequently, using the "Topography Tools" extension (developed by Jennes, 2006) available in the same software, the Hillshade Index, Heat Index, and Landform Index maps were created based on the elevation data. In addition, with the help of the Solar Radiation extension, and using the radiation and illumination class maps, both the Solar Illumination Index (SII) and Solar Radiation Index (SRI) were generated (Riley et al., 1999; Mert et al., 2013).

Based on the correlation between Aspect, Bera Aspect, and the Radiation Index, the Radiation Index—which showed the strongest relationship—was selected (R Core Team, 2021; The jamovi Project, 2022). This index was then used in subsequent distribution analyses.

Table 1. Correlation Matrix

		Aspect	Bera Aspect	Radiation Index
Aspect	Pearson's r	—		
	p-value	—		
Bear Aspect	Pearson's r	-0.619	—	
	p-value	< .001	—	
Radiation Index	Pearson's r	0.475	-0.970	—
	p-value	< .001	< .001	

The relationship between the Solar Illumination Index and other variables was evaluated. Due to the very high correlation between the AM8 and PM16 variables, the remaining variables were excluded from subsequent analysis stages (Table 1).

2.3. IDW (Inverse Distance Weighting) Interpolation

IDW (Inverse Distance Weighting) interpolation is a method used to estimate the value of new data points based on known geographic data points. This method calculates the value of an unknown point using the values of nearby known points, assigning weights that are inversely proportional to their distances. In other words, the closer a known point is to the unknown point, the higher the weight it receives. Shepard (1968) noted that using weights inversely proportional to the square of the distance yields more accurate estimations when applying the IDW method. In a study by Watson et al. (1985), it was emphasized that IDW interpolation is widely used for surface modeling in environmental datasets, as it is faster and easier to apply compared to other interpolation techniques. IDW interpolation was performed using Python libraries such as SciPy and PyKrige. Additionally, Hot Spot Analysis was carried out to assess the relationship between wildlife species and their proximity to human settlements (Anselin, 1995; Rey & Anselin, 2010).

3. RESULTS-

3.1. Exploratory Data Analysis

A heatmap is a type of graphical representation that enables two-dimensional visualization of data and is commonly used for analyzing biological patterns observed in natural ecosystems (Wilkinson et al., 2009; Wu et al., 2016). In this study, the relationships between the Solar Illumination Index and Solar Exposure Index were examined, and AM8 and PM16 were selected as representative variables (Figure 1).

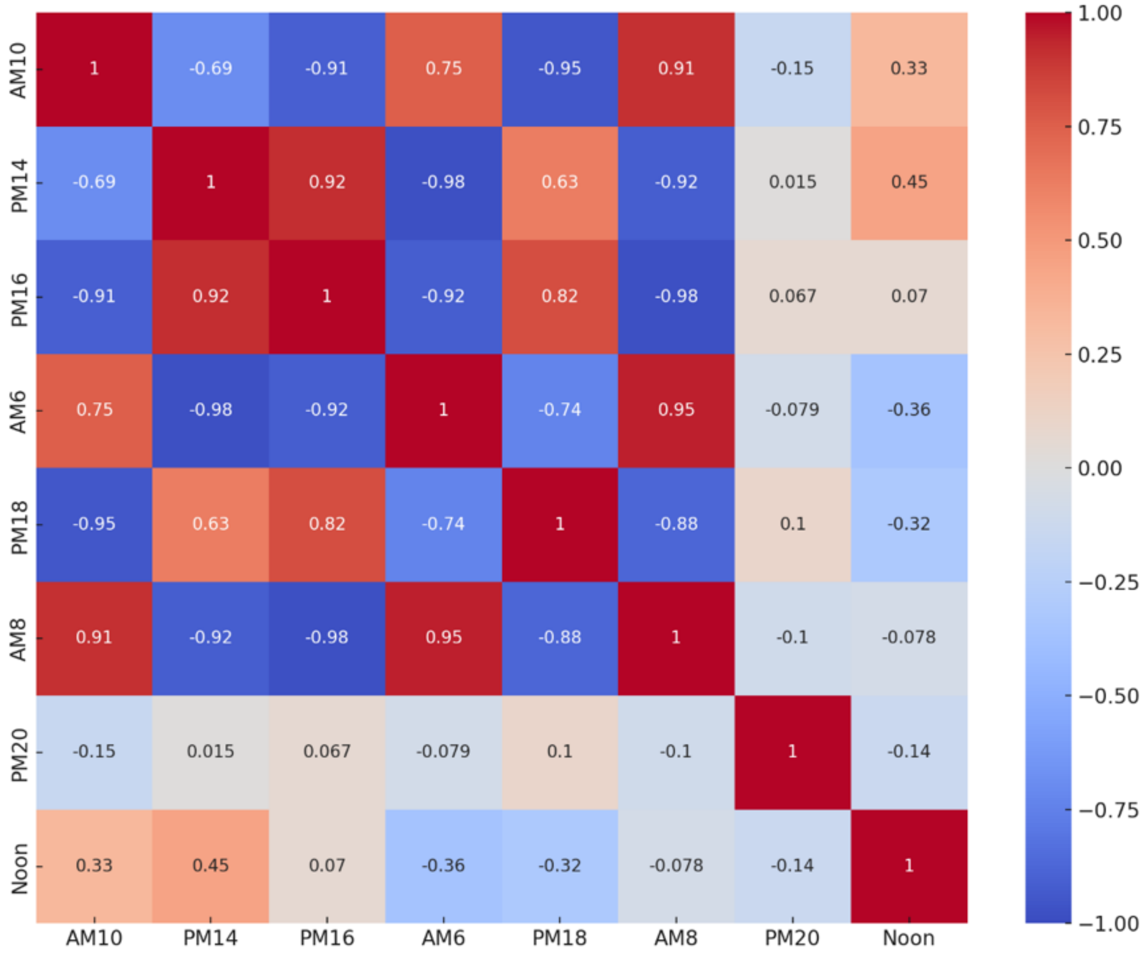

Figure 1. Results of the Correlation Analysis for the Solar Illumination Index

Correlation results among the variables were also obtained using a heatmap, and these variables were used in the subsequent analyses (Figure 2)

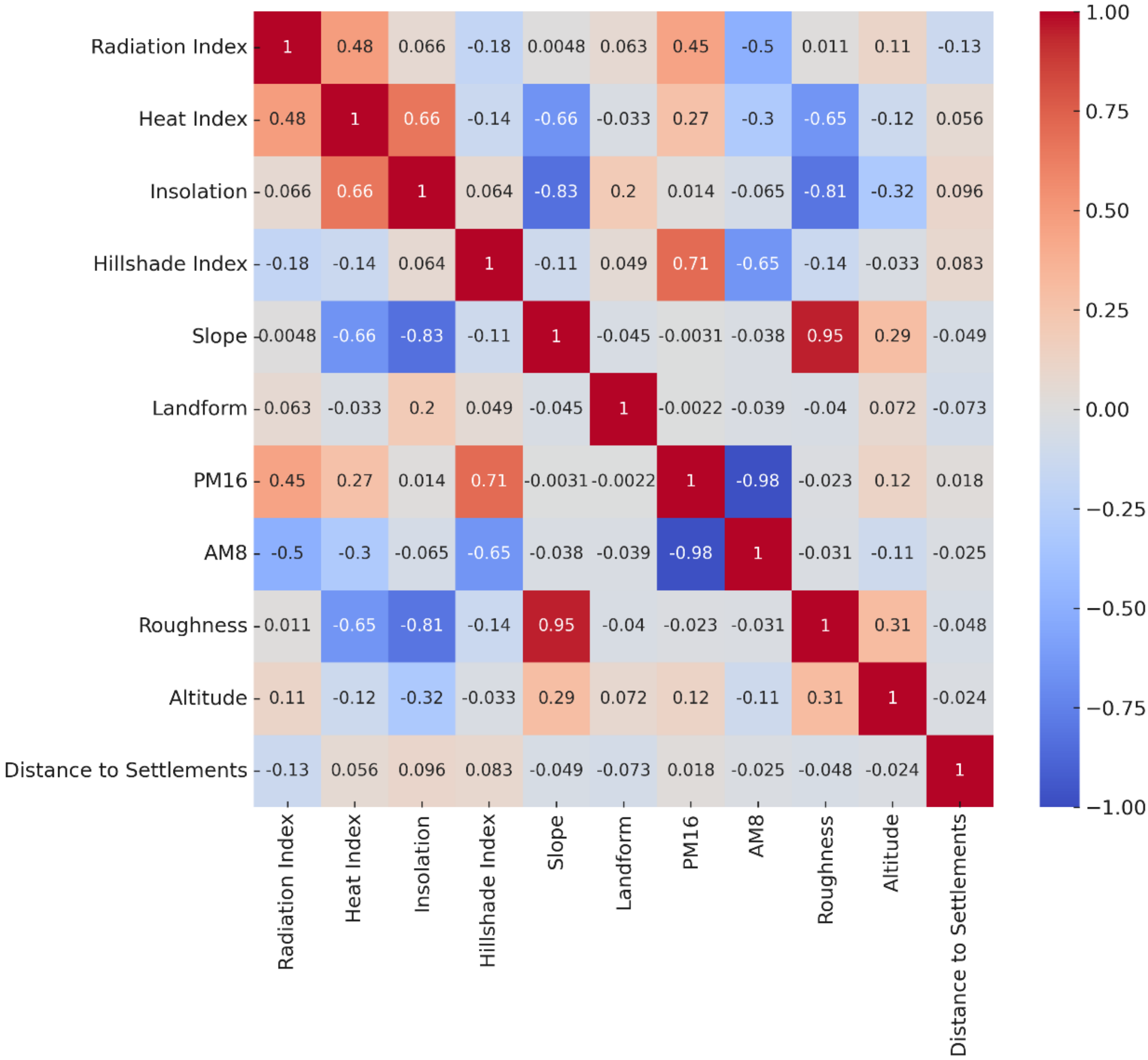

Figure 2. Correlation Results of Selected Environmental Variables

4.2. Relationships Between Animal Species and Environmental Variables

When the correlations between environmental variables and animal species were examined, no significant relationships were found. This suggests that the distribution of these species in urban areas occurs independently from common environmental factors (Figure 3).

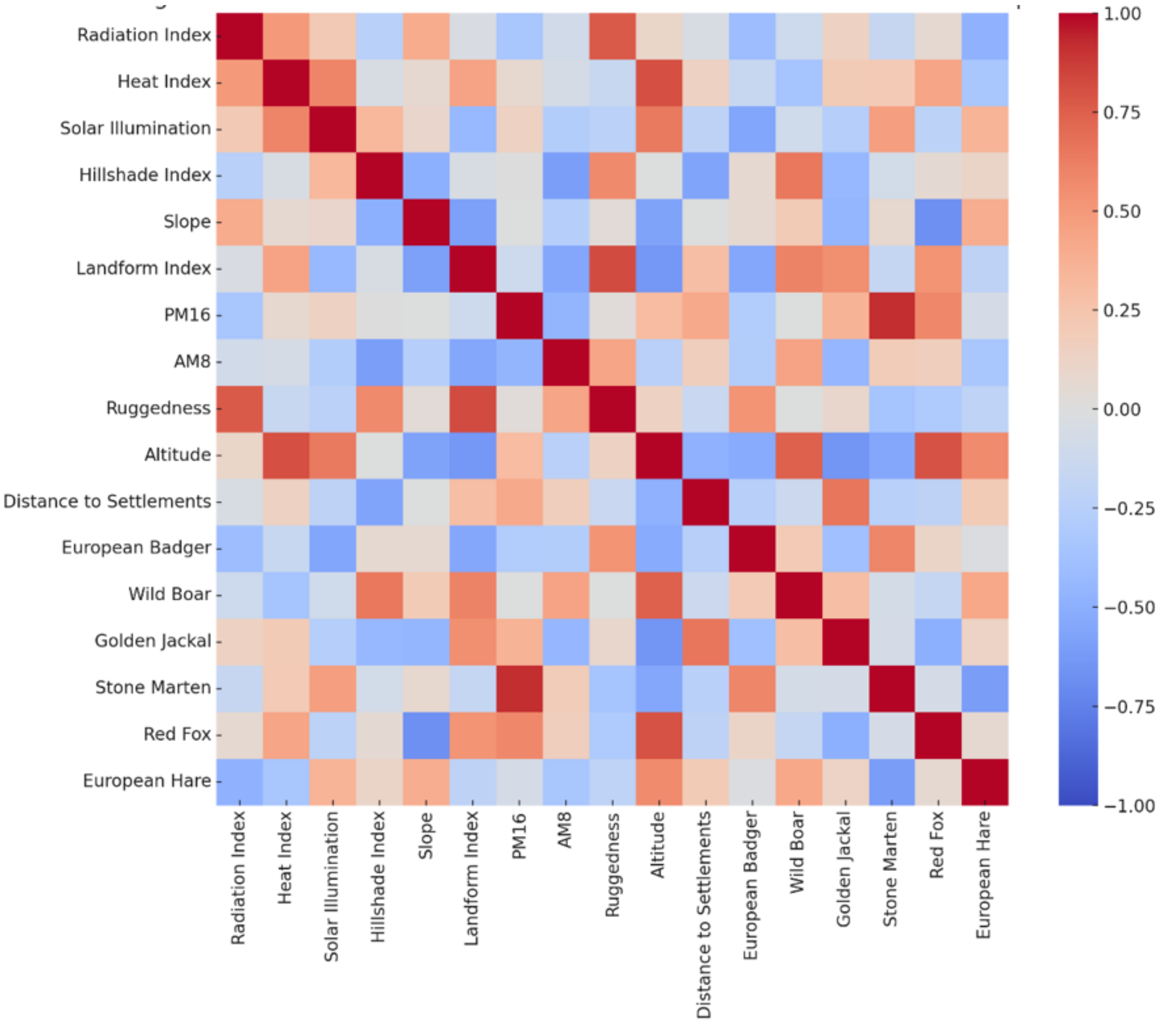

Figure 3. Correlation Results Between Environmental Variables and Animal Species

3.3. Species Distribution Maps

3.3.1. Distribution of the Red Fox

The density of red foxes is observed to be concentrated in certain areas, while it is more sparse in others (Figure 4). Hot spots for red foxes are generally located near settlement areas. The species is frequently observed in areas close to human settlements (Figure 5).

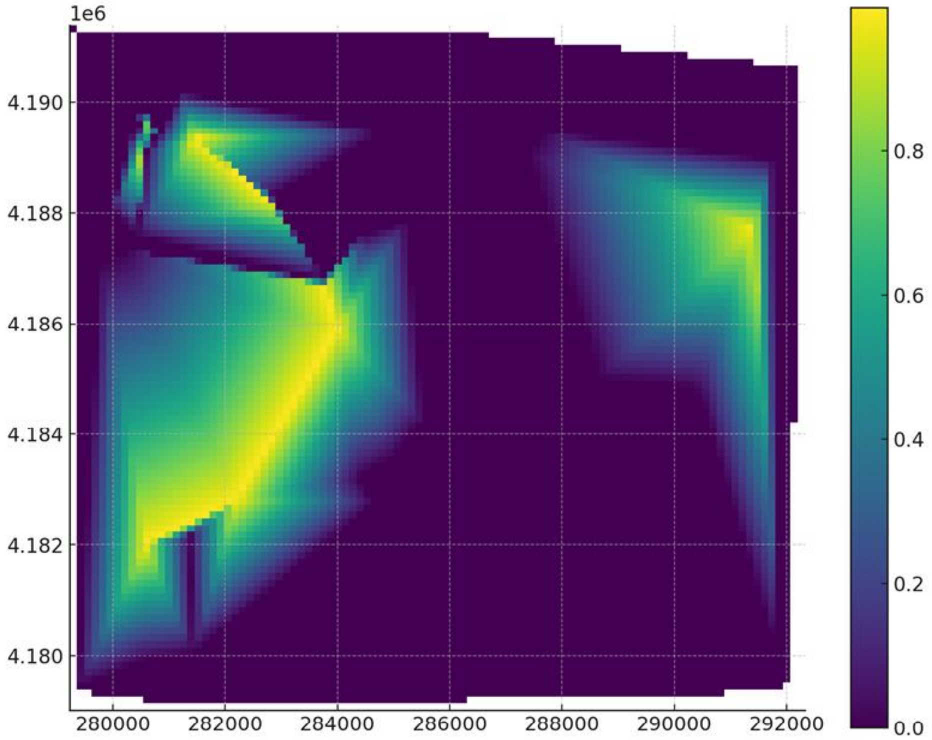

Figure 4. IDW Interpolation of Red Fox

The density of red foxes is observed to be higher in certain areas and lower in others. Red foxes are generally found near settlement areas and are frequently observed in these locations (Figures 4 and Figure 5).

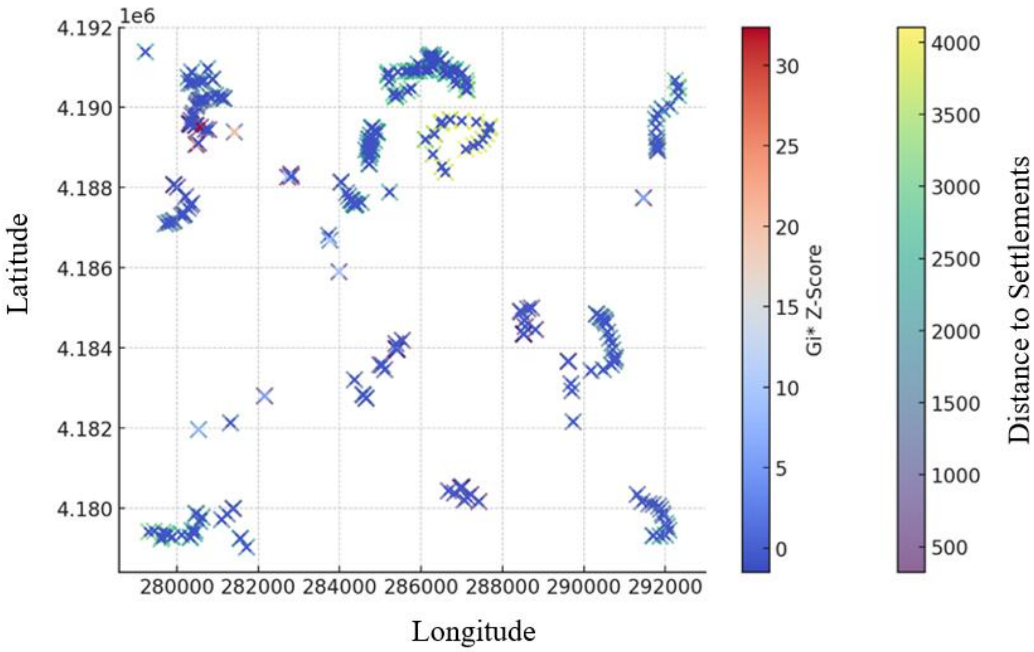

Figure 5. Hot Spot Analysis of Red Fox and Distance to Settlements

3.3.2. Distribution of the Golden Jackal

The golden jackal is observed to be partially concentrated in certain areas and generally occurs at a moderate proximity to settlement areas (Figures 6 and Figure 7).

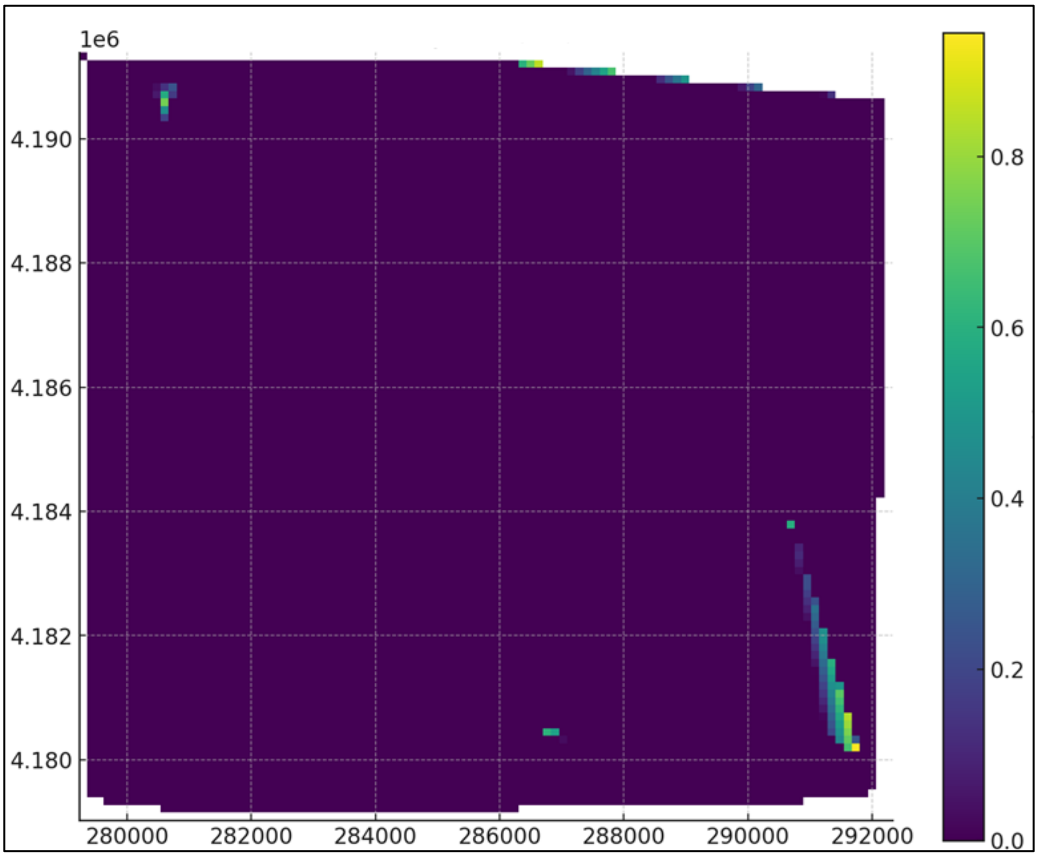

Figure 6. IDW Interpolation of Golden Jackal

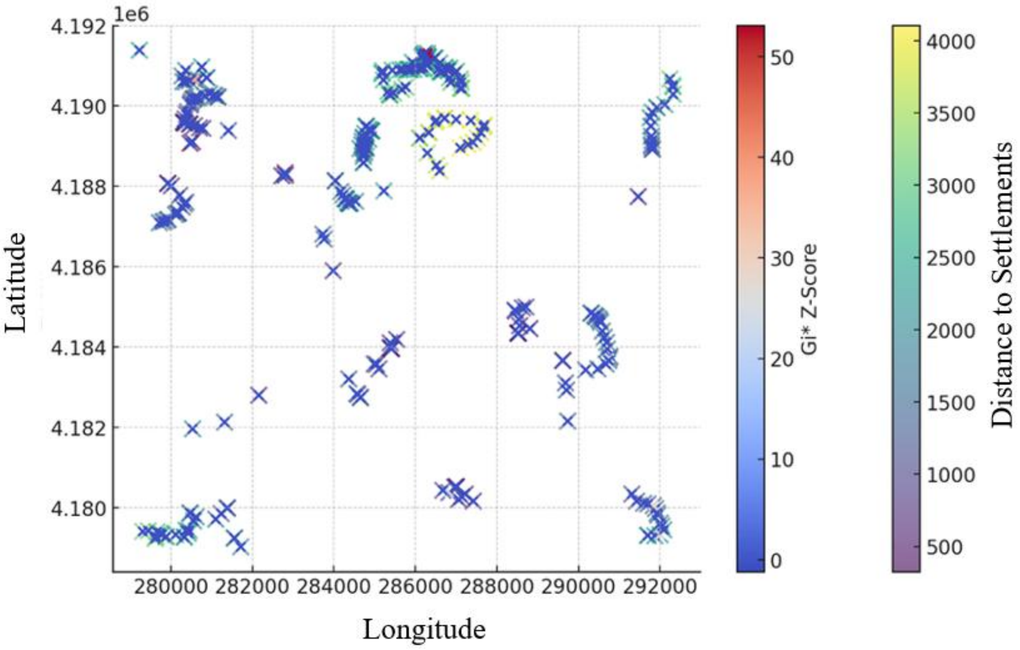

Figure 7. Hot Spot Analysis of Golden Jackal and Distance to Settlements

3.3.3. Distribution of the European Badger

The distribution of the European badger is concentrated in specific areas and is generally located farther from settlement zones. Therefore, it can be inferred that its interaction with urban areas is relatively limited (Figures 8 and Figure 9).

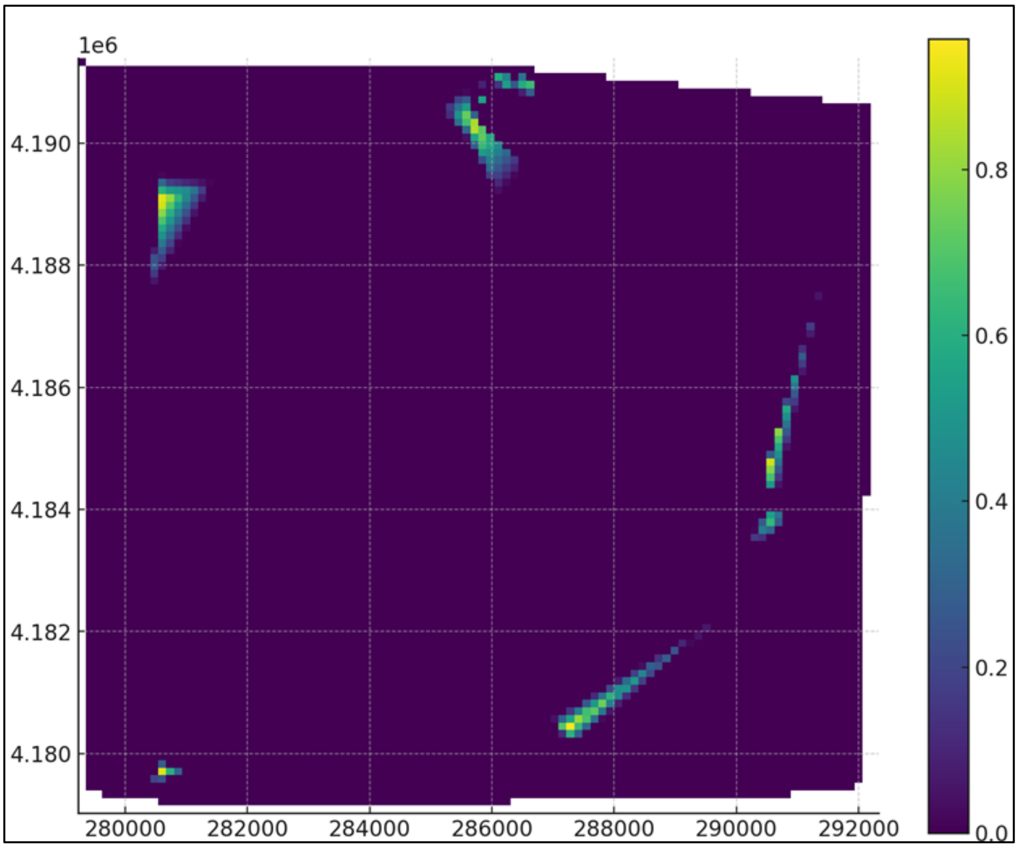

Figure 8. IDW Interpolation of European Badger

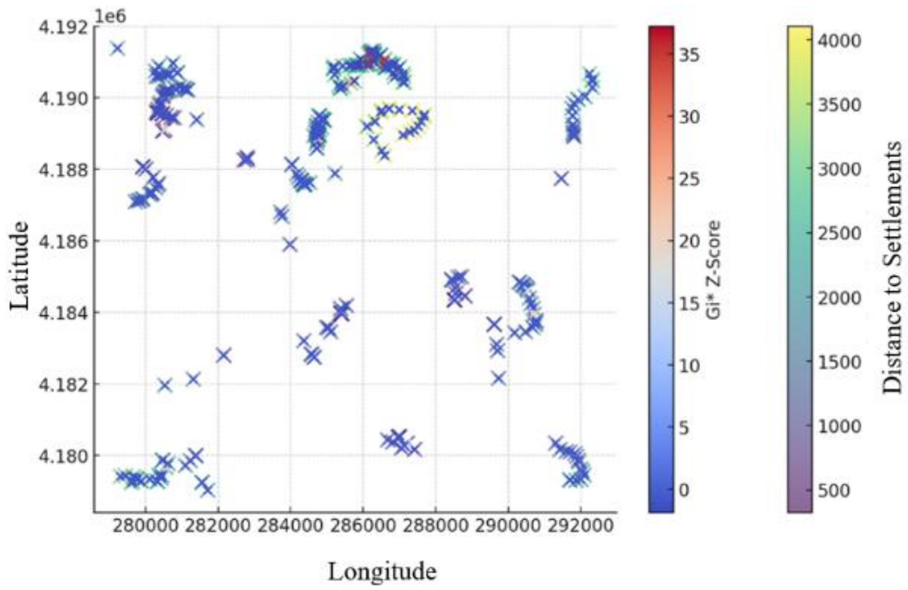

Figure 9. Hot Spot Analysis of European Badger and Distance to Settlements

3.3.4. Distribution of the Stone Marten

The stone marten appears to be concentrated in a very limited area and shows lower density in settlement regions. It is particularly observed to avoid areas with reinforced concrete structures (Figures 10 and 11).

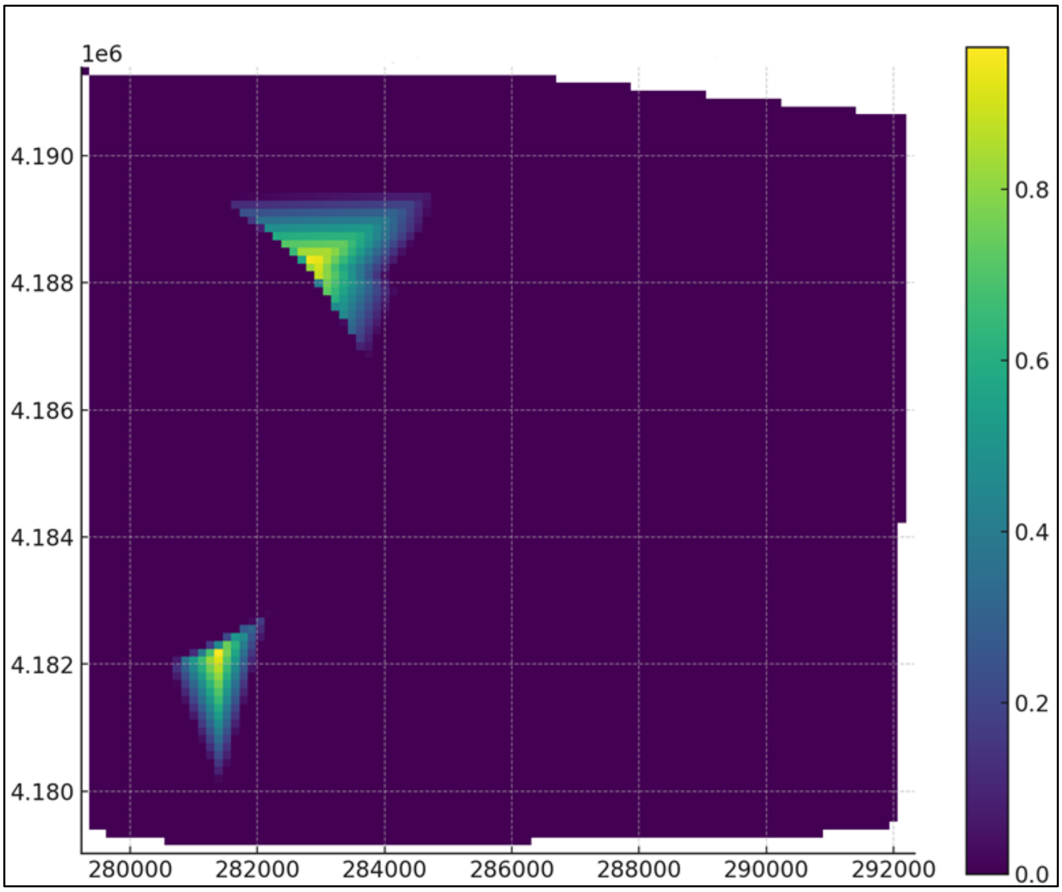

Figure 10. IDW Interpolation of Stone Marten

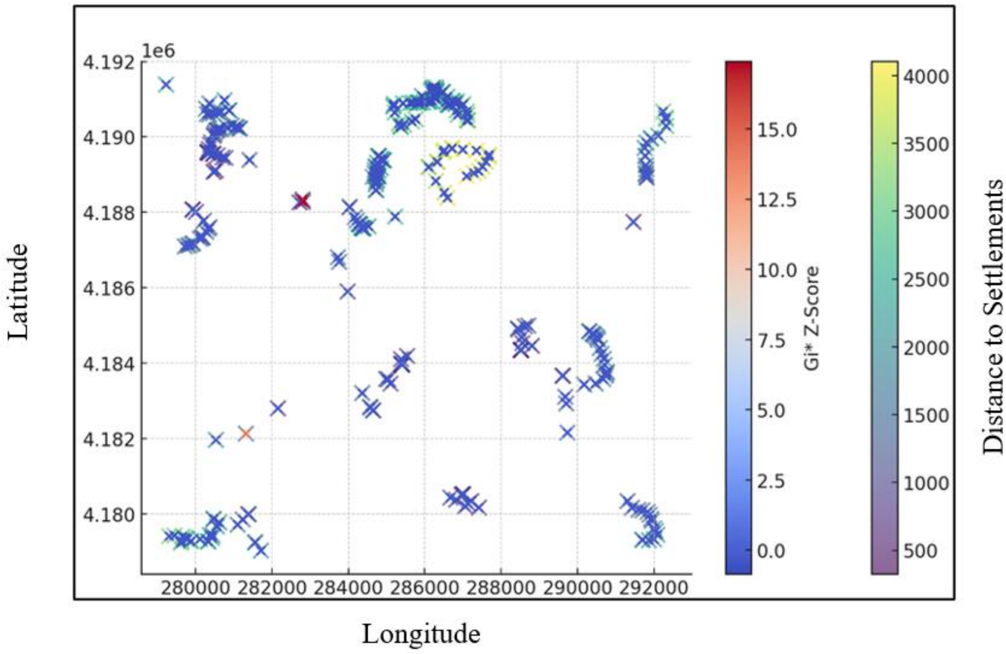

Figure 11. Hot Spot Analysis of Stone Marten and Distance to Settlements

3.3.5. Distribution of the Wild Boar

The density of wild boars is observed in many parts of urban areas, particularly in regions relatively close to human settlements. This indicates a higher level of interaction between wild boars and humans (Figures 12 and 13).

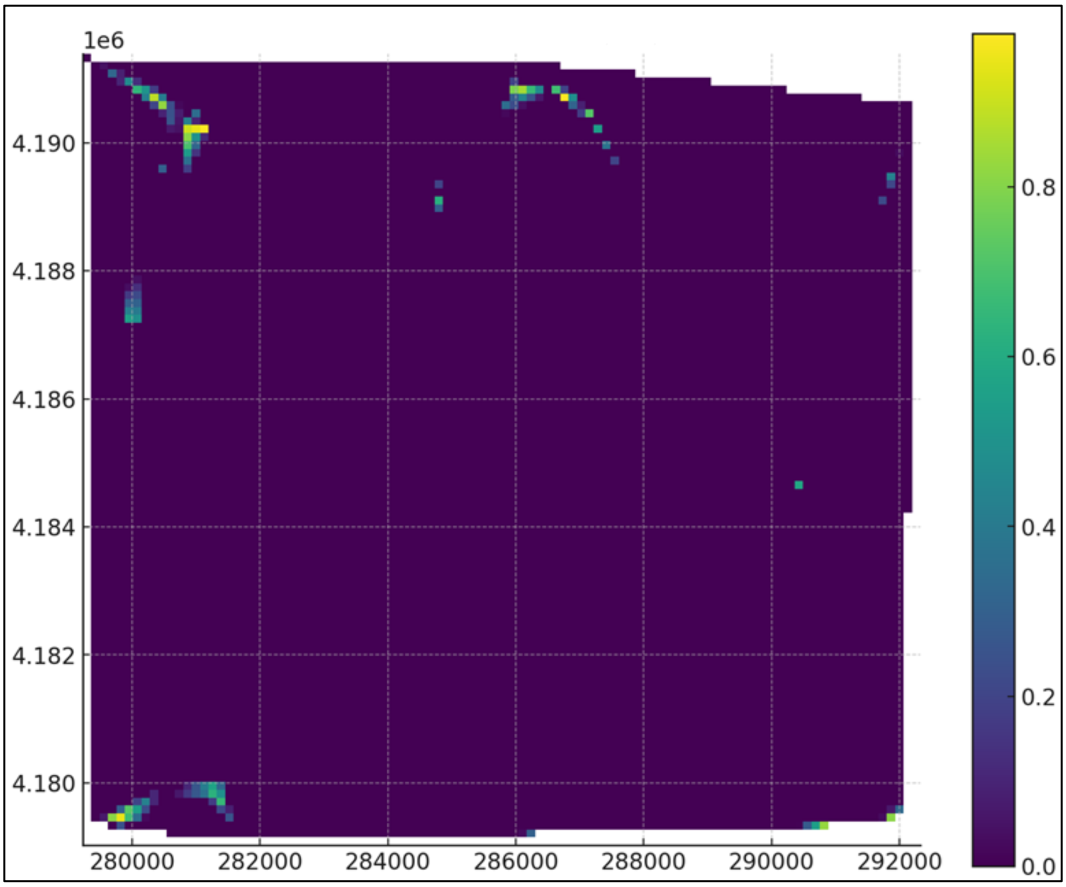

Figure 12. IDW Interpolation of Wild Boar

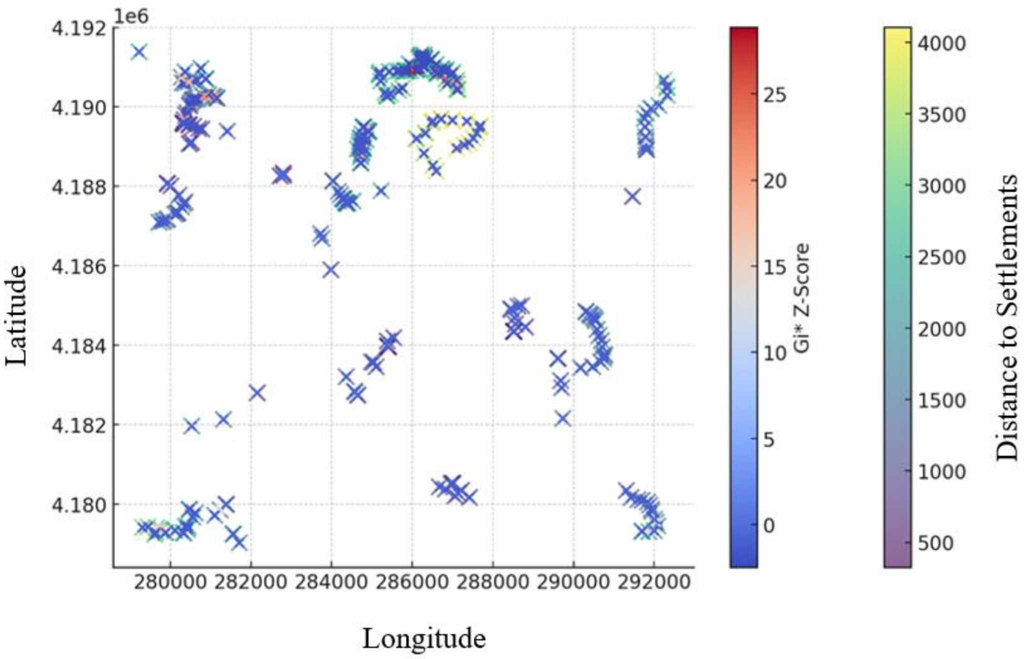

Figure 13. Hot Spot Analysis of Wild Boar and Distance to Settlements

3.3.6. Distribution of the European Hare

The density of the European hare is concentrated in specific regions, while lower densities are observed in other areas. It is also noted that the species does not tend to approach settlement areas closely (Figures 14 and Figure 15).

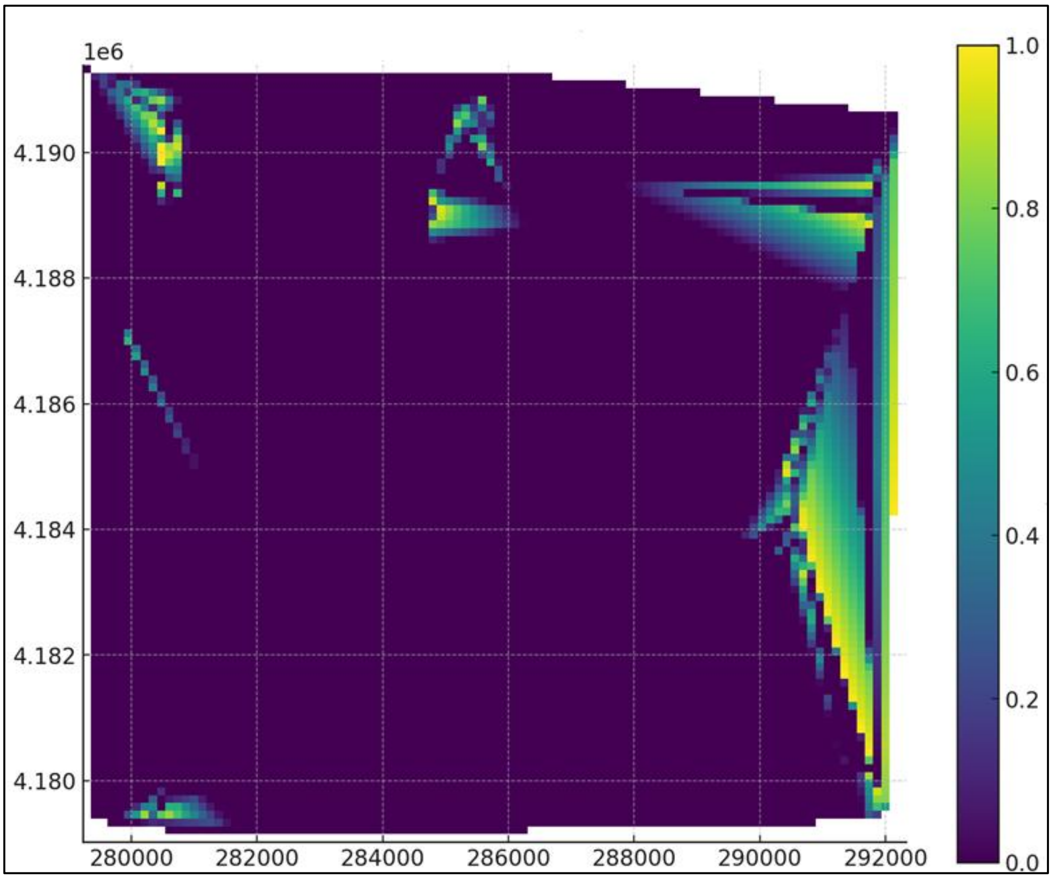

Figure 14. IDW Interpolation of European Hare

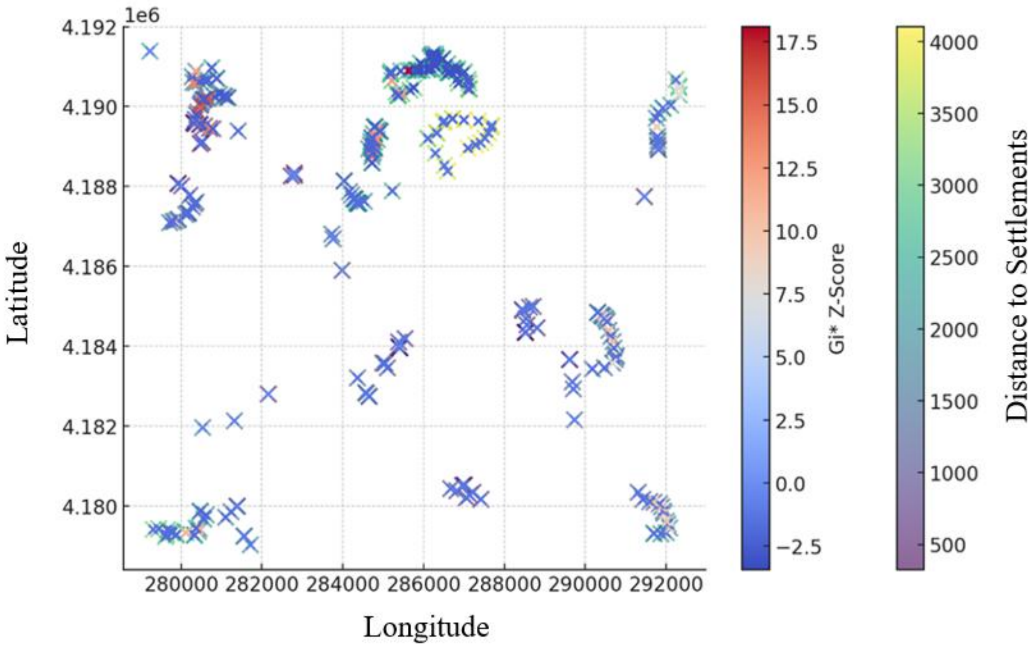

Figure 15. Hot Spot Analysis of European Hare and Distance to Settlements

4. DISCUSSION

The interaction between wild mammals and human settlements is increasingly a subject of ecological concern, particularly in the context of expanding urbanization and anthropogenic land-use change. This study offers insights into species-specific responses of wild mammals to settlement areas in Isparta, revealing varied levels of spatial interaction.

Species such as the Red Fox (*Vulpes vulpes*) and Wild Boar (*Sus scrofa*) were frequently observed near settlements, corroborating global studies that highlight the synanthropic behavior of these mammals. Red foxes are known for their high adaptability to urban environments, often benefiting from food subsidies in anthropogenic areas (Contesse et al., 2004; Bateman & Fleming, 2012). Similarly, wild boars increasingly exploit urban and peri-urban areas across Europe and Asia, driven by reduced predation risk and abundant food waste (Stillfried et al., 2017).

In contrast, species such as the European Badger (*Meles meles*) and Stone Marten (*Martes foina*) exhibited avoidance behavior, maintaining distance from densely populated or developed zones. This aligns with studies that associate badgers with more forested or semi-natural landscapes and indicate their sensitivity to urban encroachment (Davison et al., 2008). While stone martens are occasionally found in urban areas, their avoidance of densely built-up spaces may relate to their need for specific denning habitats and reduced competition (Herr et al., 2010).

Interestingly, the European Hare (*Lepus europaeus*) also showed low interaction with settlements. This species typically favors open fields and steppe environments, and its decline near urban areas is often attributed to habitat fragmentation and disturbance (Smith et al., 2005). In contrast, the Golden Jackal (*Canis aureus*) showed moderate interactions with settlements, indicating a transitional behavioral ecology likely influenced by population dynamics, prey availability, and competition (Šálek et al., 2014).

Another notable outcome is the lack of strong correlation between environmental variables and species distribution, indicating that traditional topographic and climatic layers may not fully capture anthropogenic pressures or resource-driven behaviors. Recent studies advocate for the inclusion of socio-environmental metrics such as human population density, waste availability, road density, and land-use intensity to improve species distribution models (Moll et al., 2019; Gaynor et al., 2018). This study's use of geostatistical approaches, especially IDW interpolation and hotspot analyses, provides a valuable framework but also highlights the need for a more comprehensive variable set for future modeling efforts.

This spatially explicit approach also underscores a critical conservation issue: the duality of urban areas as both threats and opportunities. While urban areas pose risks such as vehicle collisions, disease transmission, and persecution, they also serve as potential refugia for some adaptable species (McKinney, 2006). Consequently, adaptive management strategies, such as urban green infrastructure, wildlife corridors, and public education, must be tailored to species-specific behaviors and ecological thresholds (Soulsbury & White, 2015)..

5. CONCLUSION

This study demonstrates that wild mammal species respond differently to human settlements, depending on their ecological flexibility, behavioral plasticity, and resource use. The findings underscore the complexity of human–wildlife interactions in rapidly changing landscapes and suggest that a one-size-fits-all approach to wildlife management is inadequate.

To improve the reliability of future analyses, integrating anthropogenic variables—such as waste site proximity, traffic intensity, and human activity metrics—into geospatial models is recommended. Additionally, long-term monitoring and community-based conservation programs can help mitigate potential conflicts and foster coexistence between humans and wildlife in peri-urban and rural interfaces.

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Ethics Committee Approval
N/A

Peer-review
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Conflict of Interest
The authors have no conflicts of interest to declare.

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