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Original Article

Finding the best location for installing of wildlife signs using kernel density estimation in Khojir National Park

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ABSTRACT

Aims: The main aim of this study was to investigate the relationship between the amount of wildlife mortality and traffic rates in Khojir National Park, and with regard to that, finding a suitable location for installing signs according to the standard level sign structure.

Materials and Methods: In this study, the current placement of wildlife warning signs was assessed in Khojir National Park, 2010, Tehran, Iran and a method to optimize warning sign placement using kernel density estimations was developed based on existing records for wildlife-vehicle accidents. Kernel density estimation is one of the best methods for finding a suitable location for installing the signs. The most promising of these tools is kernel density estimation, at first with questioner has found nearly point and after that with GPS try to register them in visual page. With kernel density prove to find the best radius, because of installing the sign.

Results: Finally in this project, the best radius was found to be 50 m from one accident point, because of supporting the optimum location for installing signs, and finding the four points for installing the signs, and for designing wildlife signs using the symbol of maximum species that was injured in vehicle collision.

Conclusion: Finding an area for installing wildlife, the designing of warning signs, and other precautions such as wildlife crossings and overpass creation are useful in decreasing wildlife accidents.

Key words: Kernel density, Khojir National Park, sign, wildlife collision

INTRODUCTION

Habitat fragmentation by road is accounted as one of the most critical global threats to biological diversity.[1] This problem led to a decrease in biodiversity, especially in protected areas.[2-4] Roads and buildings separate two sides of a habitat,[5-8] and hence, such roads can be important barriers to the movement of wildlife to other side of their habitat. When animals try to cross the road to obviate their biotic or abiotic requirements, they might kill or injured due to vehicles collisions. During the last decades, wildlife-vehicle collisions have risen in number in many areas with the development of road building, which in turn is associated with damage and injury to animals, and fatalities.[9]

The main effect of road building on wildlife is an increase in mortality caused by motor vehicle collisions.[10] Such mortality

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caused by vehicles is also affected by related factors, including traffic volume, traffic speed, roadway width as well as wildlife behavior.[11] This may have indirect impact on wildlife and human health.[7] Wildlife-vehicle collisions are a significant source of mortality for many species.[1,6,12] It has been estimated that approximately 700,000-1,500,000 collisions between deer and vehicles (*Odocoileus* sp.) are happening annually in the USA.[9] Moreover, as a results of animal-vehicle collisions, more than 200 human fatalities, 29,000 human injuries, and over 1 bn USD of property damage take place in the USA each year.[13] Similarly, in Europe, there are about half a million collisions between animals and vehicles each year.[14]

Kernel estimation is able to quickly and visually identify hotspots from large datasets and therefore provides statistical and esthetically satisfactory outcomes.[15] These methods give better understanding of the geographical changes for point patterns. The most promising of these tools is kernel density estimation. In kernel density estimation, one of the important factors is bandwidth.[16] When multivariate kernel density estimation is considered, it is usually in the forced context with diagonal bandwidth.[17]

Designing of appropriate warning signs and other precautions such as wildlife crossings and overpass creation are useful in decreasing wildlife accidents.[15] The warning signs might help drivers to be aware of crossing of wildlife as well as to prevent some accidents. To increase the effectiveness of the warning signs, they should be used only in known and regular wildlife-crossing points.[16] Regarding that, the relative density of crashes and perception data were analyzed using kernel density analysis as a method to identify the priority locations for signs.[18]

Furthermore, when a location for sign installation is found, the design of the sign is very important as a next step. It is better for the sign designed to include some specific symbol (e.g., logo of an animal) in each area.[11]

To our knowledge, no comprehensive investigation has been reported for decreasing wildlife collisions, or for the designing of special signs for wildlife with relation to vehicle collisions in Iran. The main aim of this project was to find the hot collision spots, or the selection of a dangerous place in order to find suitable locations for installing wildlife signs in Khojir National Park based on spatial statistical analysis with geographic information system (GIS) and kernel density estimation. The "optimized" sign locations have been estimated according to the density analysis method by gathering field recordings of wildlife accidents and their spatial distribution.

MATERIALS AND METHODS

Study location

This study was carried out between summer 2008 and winter 2010 in Khojir National Park, Tehran, Iran. This park, with an area of 11570 ha, was a protected hunting site from 1944 when Tehran had been introduced as the capital city of Iran. This park is under the control of the Department of Environment at the present and its geographic coordinates are 56°97'-56°80' East longitude and 39°38'-39°44' North latitude [Figure 1].

Data collections

For specifying the best location to install warning signs, we have tried to find hotspots for accidents on the road. To achieve this aim, we initially prepared a questionnaire to collect information regarding what kinds of species had accidents, when and exactly where this species had accidents, gender of species, the conditions of the climate, and the date and number of species that were injured or died in a collision. Afterward, every point is registered by GPS set approximately and all data were transferred to GIS software. The road workers, local people, recorded data at the Department of Environment and drivers were asked to complete the data fields mentioned above in the questionnaire.

Data were analyzed for all analyses using SPSS (version 18) software and the kernel density using Wessa software. Kernel density estimation calculates the intensity of a spatial point pattern in a moving function across a two-dimensional area. Kernel estimation is highly sensitive to the bandwidth or smoothing factor because it determines the radius value, or in our case, the length in which events will contribute to the density with relation to each vehicle collision.[19]

Wildlife accident density was applied as an indicator for choosing warning sign locations. Regarding that, for analyzing accident points and wildlife crossings, one map with 5 × 5 m cells was provided. Following that, density has been calculated in every surface unit by using kernel function.[20] For the determination of suitable radii using kernel methods, different radii have been survived. Finally, whenever radiuses are larger, density will be lower, and if the radiuses are smaller, more density points will be found in that area.[16]

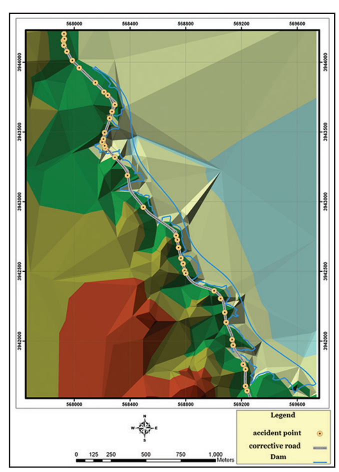

Figure 1: The number of wildlife-vehicle collision in corrective road in Khojir National Park

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Regarding that, in this project, five different radiuses, i.e., 50 m, 100 m, 150 m, 200 m, and 250 m were selected. The reason for the selection of these radiuses is to cover the whole distance of the road with 250 m radiuses. Hence, by decreasing in radiuses, the hotspot of wildlife collision has been calculated according to formula 1. The case study area is the road. X is the number of one species, and a total of *n* observations with each observation point s_n. The density X at each observation point s is estimated by:

$$\lambda(s) = \{Kh(s - si)xi\}, R \in U$$

where (K) represents the kernel and (h) the bandwidth selection of an appropriate bandwidth, which is a critical step in kernel estimation and requires testing.[16] The band width (h) for the accident density in Khojir National Park was set according to distance between accident points, the radii of 50 m to 250 m. The process of optimizing of warning sign locations based on accident densities has been shown in the Figure 1.

The methods of designing suitable wildlife signs and some another facilities are discussed in this manuscript.

In this study, we tried to design different wildlife signs in measurement that might be suitable for especially place. After designing, the authorities have decided which ones are useful and have drivers will have a greater impact.

RESULTS

Of the 51 completed questionnaires, 38 suitable crossing points and wildlife collisions were found in the period between summer 2008 and winter 2010. The maximum number of collisions were with wild sheep (*Ovis orientalis*) and the least was with reptiles [Table 1]. By using GPS set, all wildlife collisions have been registered exactly on the road [Figure 1].

To determine the radius of the kernel, different radii are studied. General consideration was paid to a much larger radius, and in which density values were smaller and smaller the contrary, be considered as more regional variation in density of the resulting map shows.[16]

All figures of collision density have been prepared in Wessa software and corrected in SPSS [Figure 2].

By comparing all five figures, when the radius was increased the peak points in the figure were decreased. Therefore, the radius with 50 m has an important effect on the collision density because the lower radius has been shown more collision density and is thus more dangerous.

Raster maps of density with radii 50 m, 100 m, 150 m, 200 m, and 250 m were prepared [Figure 3].

A radius of 250 m was used all along the road to reform, as the area is considered high-risk for road accidents. Gradually, with decreasing radii the density of collision will be increased and suitable for installation of warning signs appear. Because with

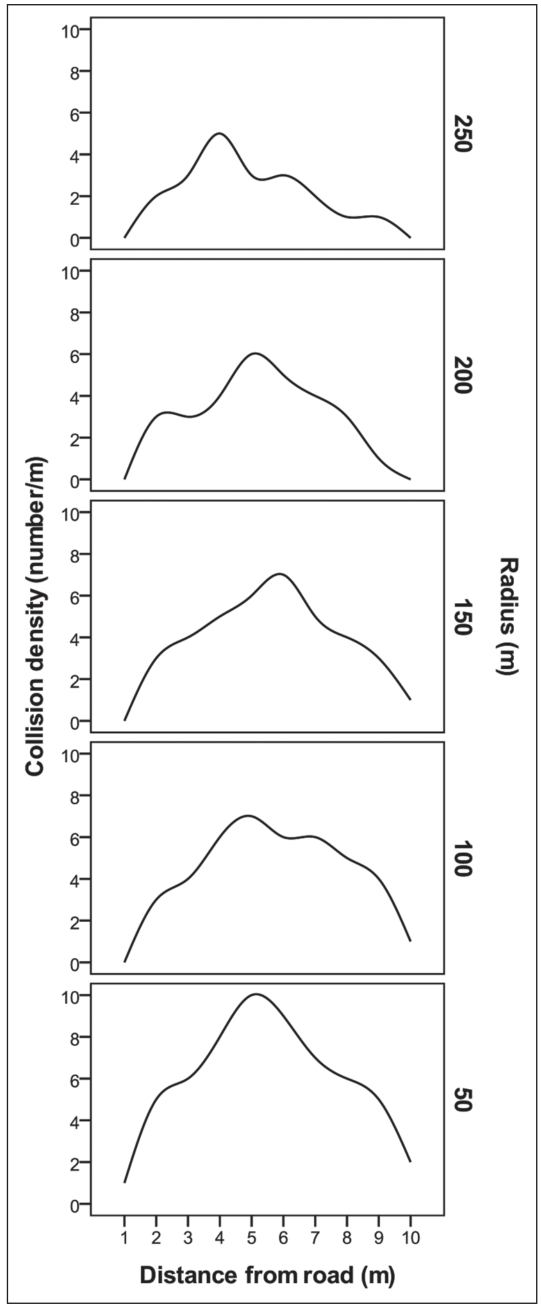

Figure 2: Kernel density estimation for corrective road, Kernel bandwidth increased on road, 50-250 m

Table 1: The number of road accidents and wildlife crossings on the road were shown

Species	Ovis orientalis	Sus scrofa	Vulpes vulpes	Hystrix indica	Alectoris chukar	Reptile	Total
The number of registered points	19	7	2	5	3	2	38

All data gathered from 51 questionnaire forms and summarized separately by different species

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decreasing radius, specially in 50 m, in each circle the crash point was shown. Based on these risk area in four regions A, B, C, and D were determined, and were shown in Figure 4. For the warning signs to reduce collisions with wildlife have influenced the establishment of standards in terms of which they are mentioned.

Given that the most recorded road accidents for wild species are related to wild sheep, wild pig, porcupine, and reptiles, thus the warning signs for motorists were designed with images of these species; also because the people in this place are familiar with each of these species, and these kinds of signs are more effective than signs that are not familiar species to the people. The type of warning signs in each region can vary depending on the circumstances and the facilities.

In Khojir National Park, according to the climate conditions, yellow is an appropriate color for wildlife sign backgrounds. Yellow gives better visibility at night although it later becomes dirty because of dusty weather.

The schematic picture of four species, i.e., *Ovis orientalis*, *Sus scrofa*, *Hystrix indica*, and *Hemorrhois ravergieri* snake for wildlife signs in Khojir National Park have been selected. These pictures belong to species that have the highest vehicle collisions, and these symbols are known by local people.

Finally, the best design has been multishaped signs because this kind of alarm sign has enough efficiency for the driver, wih 180 cm × 90 cm scales, and each picture is designed in each square with 75 cm sides. For installing wildlife signs, it is better

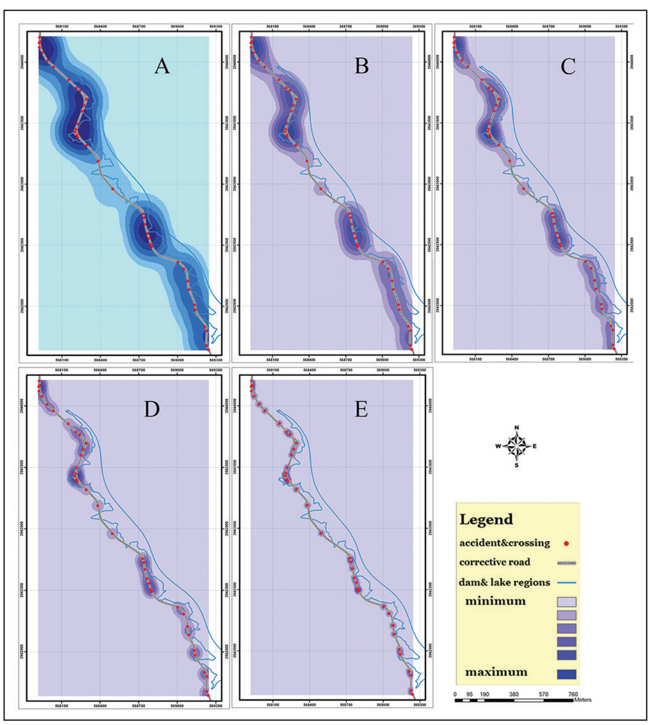

Figure 3: Kernel density estimation for corrective road, Kernel bandwidth increased on road, 50-250 m

to consider four items: Finding the best location, placement of warning signs, height of warning signs of Earth's surface, and the direction of the warning signs over the road and passing vehicles.

The distance of the sign from road depends on the speed limited.

The standard of vehicle speed is 90-80 kph and the minimum distance for clearing observation sign is 90 m. So the standard point on the right for the north-south runway is considered and four point for south-north runway is determined [Table 2, Figure 6].

DISCUSSION

Wildlife-vehicle collisions have increased in many parts of the world in recent decades with associated property damage, injury and fatalities[9] and mostly due to increasing traffic

Table 2: Installation of warning signs on runway of Parchin, Pasdaran road

Sign code	Distance from road outset (m)	Sign code	Distance from road outset (m)
1	0.00	2	500.00
3	814.72	4	1384.00
5	1660.00	6	2470.00
7	2584.39	8	3305.00

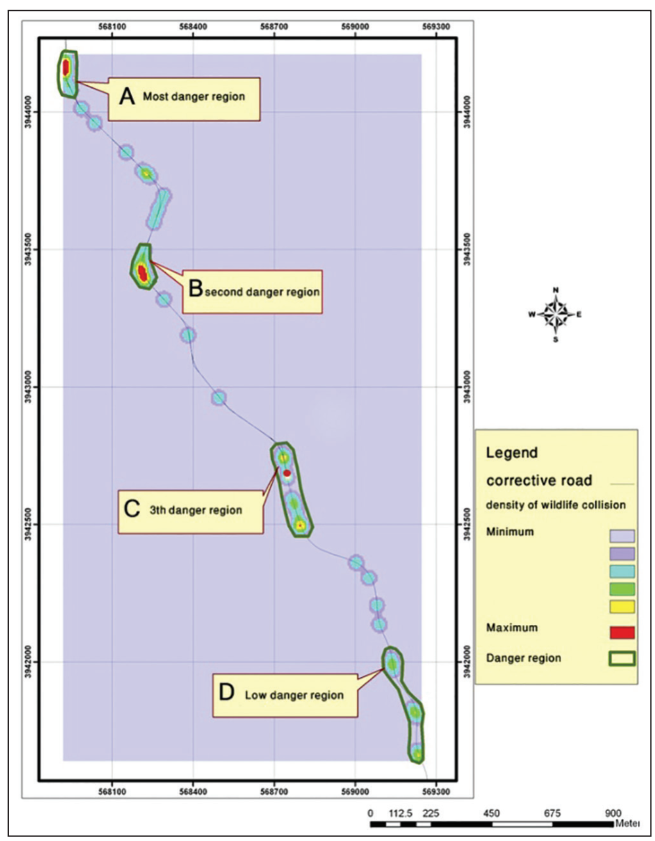

Figure 4: Showing danger points in raster map of density of vehicle collisions in building roads at Khojir National Park

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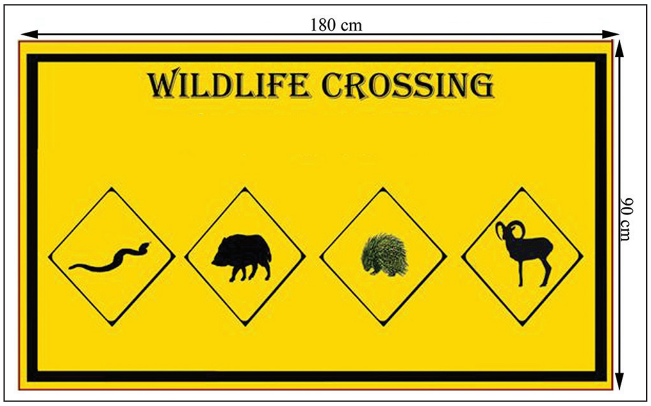

Figure 5: Designing new wildlife signs in Khojir National Park

volumes and decreasing animal population sizes[21] in Europe, most accidents are related to large mammals include wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*) and elk (*Alces alces*)[22] (Bruinderink and Hazebroek 1996). In Khojir National Park, most accidents occur to large mammals such as wild sheep (*Ovis orientalis*) and the least occur to reptiles.

One of the best methods, kernel density, has been widely used in road accident analysis.[23] Kernel density estimations are able to quickly and visually identify accident points from large datasets and so provide a statistical and esthetically satisfactory result. This is because of the nature of kernel density estimation being based on a fixed "cell," whereby supplementary data can be allocated into each cell. The advantages of the surface representations, particularly of road collisions, are that they can provide a more realistic continuous model of collision hotspot patterns reflecting the changes in density, which are often diffcult to represent using geographically constrained boundary-based models, such as the transport network or census tract.[16] In this project with using of questioners, 51 accident points were noted that the most vehicle collisions occur with wild species such as wild sheep, wild boar, porcupine, and reptiles. This research has shown the most species that people can see are big mammals because people were seen them easily, but with reptiles the results are different because of unobvious. The most important part of kernel density estimation is choosing the radius.[20] One of the major challenges associated with using the kernel estimation is the bandwidth selection for the analysis. This is a critical step in any application of kernel estimation, which requires testing and knowledge of the spatial and temporal distribution of the events being described.[16] The best ranges of radius on Khojir roads are 50-250 m because the length of new road that would be building in Khojir National Park is 50-250 m, We chose this range with GIS software and Wessa software.

When the radius is 250 m, all locations of road are included, and if the radius is 50 m, we can show high-density collision, but in the smallest area, so the figure of 50 m radius has

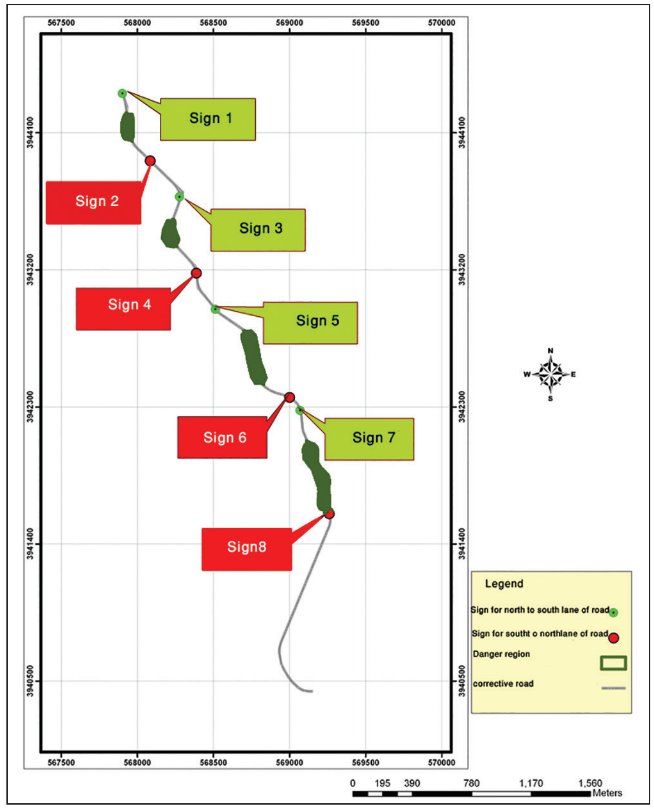

Figure 6: Showing the best location for installing wildlife sign

shown the high peak of danger on the road [Figures 2 and 3]; thus, finding the best location for installing the signs is very important.[24] The best locations are more, focusing on accident hotspot areas [Figure 5]. The optimization of the warning sign location is based on the density of wildlife-vehicle collision. This method assumes that in most cases, the occurrence of accidents marks the location of a potential hotspot and the need for a warning sign. The analysis made for the relation between the warning sign kilometres and the amount of accidents covered by these is specific for the study area of Khojir National Park. Further research needs to consider this relation on a smaller scale, e.g., for the whole of Finland or on a larger scale, such as specific hunting districts.[25] This would help to derive a general relation and perhaps give a more general recommendation on the optimal placements of wildlife warning signs. For example, in Saudi Arabia, due to the reduced rainfall, the weather being foggy, and the extreme heat in this area, white is suitable for the background of the wildlife signs.[12] But in areas where humidity and rainfall is more, yellow is better for wildlife signs.[11]

CONCLUSION

Kernel density estimation lends itself to the integration of supplementary datasets regarding the road environment and the people involved in the road accident(s). The purpose of this comparison was to determine not only the

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different spatial methods associated with defining road accident hotspots but also to evaluate their advantages and disadvantages. It is important to understand the contrasts between the three methods for a more robust understanding of the possibilities within road safety analysis and to provide a unique research strand that has yet to be addressed. The key areas of focus here are accuracy and communication — in short, defining what the most accurate maps may be for the best visual communication methods for decision makers in road safety.

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