Roads threaten Asiatic cheetahs in Iran

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Wildlife–vehicle collisions are an important cause of mortality for many animal species. They also prove extremely detrimental to the critically endangered Asiatic cheetah (*Acinonyx jubatus venaticus*) [1,2]. One to two Asiatic cheetahs are killed by vehicles on Iran's roads annually [3,4]. As such, the Asiatic cheetah could be the next charismatic felid subspecies to go extinct in the near future [5]. We identified one statistically-significant cluster of cheetah-vehicle collisions on the Shahroud-Sabzevar Highway (SSH), in Semnan Province. Because of the extremely small population of cheetahs and the corresponding difficulty of finding statistically-significant clusters, we propose that every single cheetah–vehicle collision should be considered important. We further recommend that wildlife underpasses and associated fencing be constructed in areas of previous cheetah–vehicle collisions.

Fewer than 50 free-roaming Asiatic cheetahs remain in the wild, all of which occur in central Iran in the provinces of Isfahan, Kerman, North Khorasan, Razavi Khorasan, Semnan, South Khorasan and Yazd. The survival in the wild of the Asiatic cheetah is at risk in Iran, due to their extremely small population sizes.

A key element in analyzing road-killed individuals from rare species is understanding the limitations of conventional statistical methods, such as kernel-density analysis and spatial autocorrelation analysis. We therefore used three approaches to triangulate cheetah–vehicle collision hotspots: density analysis, spatial autocorrelation analysis and qualitative consideration of the impacts of each event. Density analysis was carried out using previously described methodology [6,7]. Spatial autocorrelation analysis was carried out using Morans I (Spatial Autocorrelation and Anselin Local Morans I) and Getis-Ord (Getis-Ord General G, clustering and Getis-Ord Gi*) tests in ArcGIS 10.3 (www.esri.com). Qualitative consideration consisted of evaluating the potential significance of each cheetah–vehicle

collision event. A total of 16 Asiatic cheetah road-kills were recorded between 2004 and 2016 in Iran (Figure 1 and Supplemental Information). At the scale of the entire dataset, there was no significant spatial autocorrelation (Morans I: Z = 048, P = 0.65; Getis-Ord: Z = 0.40, P = 0.69). However, for both the Local Morans I and Getis-Ord Hot Spot Analysis tests, a single statistically- significant cluster (P < 0.001 and P < 0.05, respectively) was identified on SSH in Semnan Province (Figure 1B), between the Touran Biosphere Reserve (TBR) and the Khosh Yeilagh and Miandasht Wildlife Refuges (MWR). This cheetah–vehicle collision hotspot was also identified in [7]; however, the statistical significance of the cluster was not assessed. A previous study [7] proposed that one reason Asiatic cheetah and other wildlife–vehicle collisions might be concentrated in this zone of the highway was because it bisects a hypothetical 'wildlife corridor' between TBR and MWR; however, no evidence was provided for the existence of this corridor. Similarly, we do not conclude that the cluster we identify is evidence of a corridor.

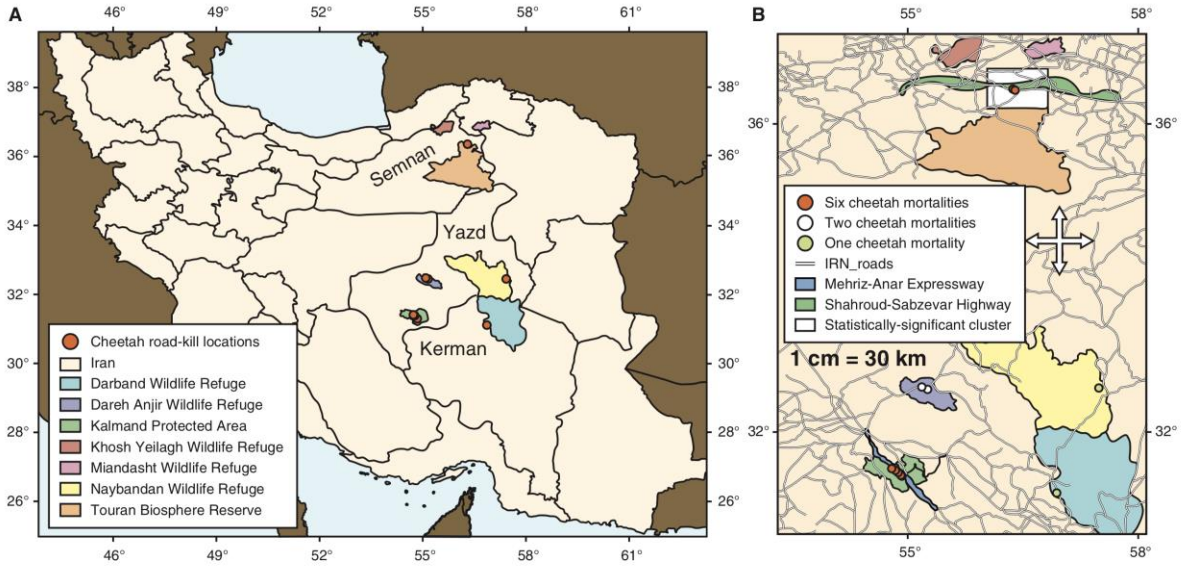

Figure 1. Roads threaten cheetahs in Iran. Map showing the locations of cheetah road-kill across Iran (A), and Semnan, Yazd and Kerman provinces (B) in which the mortalities were recorded. Maps were created using ArcGIS 10.3.

Human population growth and urbanization increase the need for expansion of the road network in Iran. As a result, road construction in ecologically sensitive habitats in Semnan and Yazd Provinces of Iran has increased in recent decades, with subsequent increases in cheetah–vehicle collisions [6,7]. This high level of Asiatic cheetah mortality on Iran's roads may be associated with: first, the subdivision of cheetah home ranges by roads; second, reduced prey availability due to human hunting triggering more long-distance movements; third, greater dispersal distances from natal ranges in protected areas as a result of habitat loss, poaching and persecution by herders; and fourth, higher traffic volumes on both SSH and the Mehriz-Anar Expressway (MAE; passes through the Kalmand Protected Area in Yazd Province) with average traffic volume of 7,447 [7] and 12,948 [8] vehicles per day, respectively, after upgrading to dual carriageways approximately 20 years ago.

To date, the main approach taken to reduce road mortality for the Asiatic cheetah has been centered on the use of standard and enhanced wildlife warning signs, advising motorists to reduce speed and stay alert for cheetahs crossing [9]. However, such signs are not spatially and temporally specific in Iran [6], and therefore cannot be effective at reducing road mortality. On the other hand, wildlife crossing structures can be very effective, especially when used in conjunction with fencing [1]. In Iran, wildlife crossing structures generally take the form of drainage culverts that carry a stream or open drain under roads or railways and are generally dry except in periods of heavy runoff. Although culverts are available under SSH and MAE in the vicinity of the identified cheetah mortality events and clusters, few have appropriate dimensions for large mammals, while the remainder would prevent Asiatic cheetah use due to unsuitable width or height, insufficient light, inappropriate substrate or noise pollution [6,7]. A previous study [7] concluded that two culverts under SSH were used

on two different occasions (i.e., one in summer and one in winter) by two Asiatic cheetahs. This suggests that the Asiatic cheetahs would use wildlife underpasses if available to them. To keep cheetahs off the road, fencing is also required.

In conclusion, we propose an alternative approach to assessing the impact of wildlife–vehicle collisions on exceptionally small populations of rare species. We recommend the very simple approach of regarding every wildlife– vehicle collision event as significant. This assessment does not detract from the importance of clusters of wildlife–vehicle collision of rare species when they occur; rather it suggests the opposite — that clusters of individually significant events are even more important. We advocate this approach because over-reliance on statistical and density analysis could reduce the apparent importance of individual, demographically-critical mortality events for very small populations. This is especially true here for mortality of adult female cheetahs, of which there were six, because of the disproportionate effect they have on population growth and persistence [10]. In addition, the loss of a single Asiatic cheetah from a remaining population with fewer than 50 individuals on Iran's roads can have huge impacts on this critically endangered subspecies, so mitigation efforts are critical. We therefore recommend a strategic shift away from the ineffective warning signage currently used. Instead, we advocate adopting an evidence-based approach focusing at the hotspots and, in conjunction with fencing, constructing wildlife crossing structures or improving existing drainage culverts.

SUPPLEMENTAL INFORMATION

Supplemental Information including experimental procedures and one table can be found with this article online at https://doi.org/10.1016/j.cub.2018.09.005.

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AUTHOR CONTRIBUTIONS

J.P. designed the work, interpreted the data, prepared the figures, and wrote the draft and final versions of the manuscript; F.S. and M.G. analyzed the data; R.B. and S.T.W. reviewed the manuscript; A.T.Q. and M.A.A. provided the data.

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