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Spatial risk model and mitigation implications for wolf–human conflict in a highly modified agroecosystem in western Iran

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ABSTRACT

Human–carnivore conflict is hampering carnivore conservation worldwide. Conflicts between humans and wolves (*Canis lupus*) in western Iran, especially Hamedan province (HP), occur in the form of livestock depredation and predatory attacks on people. These conflicts have become a major concern for the lives and livelihoods of the local people as well as an obstacle for conservation of the wolf. To determine the most important predictors of such conflicts and to identify the distribution of areas with potential risk of wolf attack on humans and livestock in HP, we employed Maximum Entropy (Maxent) algorithm to build predictive models with reported conflict data from 2001 to 2010. The resulting models correctly assigned subsequent attack sites from 2011 and 2012 to high-risk areas. We found that variables related to land use/cover types affected by anthropogenic influences on the landscape, such as irrigated farms and human settlements, were the most important in predicting wolf attack risk levels. The risk maps developed in this study are useful tools for identifying conflict hotspots and facilitate policymaking and action planning for conflict mitigation in western Iran.

1. Introduction

The rapid growth of human population and consequently the increase in resource use and habitat destruction have exacerbated the problem of human–wildlife conflicts throughout the world (Graham et al., 2005; Holmern et al., 2007; Treves et al., 2004). In particular, large predators are subject to such conflicts due to their large home ranges that overlap with human distributions and their dietary requirements that attract them to human settlements and food sources (Iftikhar Dar et al., 2009; Linnell et al., 2001; Treves and Karanth, 2003). This can threaten human lives and livelihoods (Gurung et al., 2008; Iftikhar Dar et al., 2009; Michalski et al., 2006; Sidorovich et al., 2003; Vos, 2000) and build negative attitudes toward carnivores, leading to extermination of carnivore populations by local people (Sacks et al., 1999; Sillero-Zubiri and Switzer, 2004).

Understanding carnivore–human conflict has become an important concern in the scientific community. The majority of carnivore–human conflicts in the world is attributed to livestock depredation (Graham et al., 2005). This is a common problem especially in range countries of the wolf (*Canis lupus*) and is usually mitigated by compensation programs (Bostedt and Grahn, 2008; Breck et al., 2011; Muhly and Musiani, 2009) and improvements in husbandry techniques (Ciucci and Boitani, 1998; Mishra, 1997). However, wolf attacks on humans, which are relatively rare worldwide (Linnell et al., 2002, 2003), cannot be compensated for and prevention remains the best approach for their mitigation.

Globally, wolf attacks on humans are classified into three types (Linnell et al., 2002). The majority of attacks are attributed to rabid wolves. The second type involves animals provoked by human interventions (traps, persecution of pups, and destruction of dens). These attack types are unpredictable and incidental in nature (Linnell et al., 2002). The rarest of all wolf attacks are non-rabid predatory attacks, with animals involved mostly identified as wolf-dog hybrids. Hybrids generally have less fear of humans than wild wolves (Linnell et al., 2002; McNay and Hicks, 2002), and are more likely to live in the vicinity of human settlements. This type of attack has been reported from countries including Spain, India, Lithuania, and Italy (Mech and Boitani, 2010).

The wolf in Iran was once widely distributed through the country, except in the deserts, but has been heavily persecuted as a response to the increasing level of conflict with rural communities (Ziaie, 2008). The problem has escalated in recent years mainly due

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to the expansion of agriculture and other anthropogenic activities, creating a human-dominated landscape that is particularly evident in western Iran (Imani Harsini, 2012). Although wolf attacks on humans were historically quite rare and death incidents were even less frequent, an increase in fatal attacks on humans in recent years reveals a high level of wolf–human conflict in Hamedan province (HP), reaching a peak of 10 attacks in summer 2010 (DOE Hamedan Provincial Office, unpublished reports). Tests for rabies (DOE Hamedan Provincial Office, unpublished reports) and hybridization (Khosravi et al., 2013) have been negative, and thus attacks in HP can generally be categorized as predatory attacks made by hungry wolves (Behdarvand and Kaboli, in press). With increased wolf–human conflicts in the province, local peoples' tendency to exterminate wolves and wolf pups has increased (DOE Hamedan Provincial Office, unpublished data), making conflict mitigation a high priority for the local government.

An important criterion for the success of wolf–human conflict management, and consequently the conservation of wolves, is maintaining such conflicts at a low level (Iftikhar Dar et al., 2009). Achieving this goal can be challenging in multi-use landscapes inhabited by people and wolves (Edge et al., 2011; Löe and Röskaft, 2004; Northrup et al., 2012). However, because such conflicts are distributed in non-random patterns (Treves et al., 2011; Wydeven et al., 2004), predictive spatial models, or risk maps, can be used for determining possible conflict locations. Risk maps provide a chance for early warning and targeted prevention of predator damage to humans and livestock (Iftikhar Dar et al., 2009; Jones et al., 2008; Kaartinen et al., 2009; Löe and Röskaft, 2004; Treves et al., 2004; Venette et al., 2010; Wydeven et al., 2004).

We developed risk maps for wolf attacks to livestock and humans in HP to (i) identify environmental parameters associated with wolf attacks on humans and livestock in the province and (ii) provide mitigation recommendations for such conflicts. We were especially concerned with detecting the influence of land use types in the highly modified human-dominated landscapes.

2. Material and methods

2.1. Study area

The present study was conducted in HP, western Iran (47°34′–49°36′E, 33°59′–35°48′N; Fig. A1). Mean annual temperature ranges between −4 °C (January–February) to 35° C (July–August). Mean annual rainfall is about 300 mm distributed unevenly in different months of the year. The province encompasses approximately 19,493 km^2 and supports a population of over two million people. Hamedan province is characterized by a human-dominated landscape with a mean human population density of about 88 inhabitants per km^2, twice the mean population density in the country. The landscape is dominated by rangelands (33%) and croplands (32%), whereas mixed deciduous forest covered by Persian oak (*Quercus brantii*), hawthorn (*Crataegus* spp.) and cherry plum (*Prunus divaricata*) make up only 2% of the province. These patches of natural forest are distributed within an agricultural matrix of orchards, intensive irrigated farms of potato and corn and scattered dry farms of cereal crops. There are six protected areas in the province (62 km^2), comprising a combination of mountainous habitats, undulating hills, and plains. The vegetation cover and low levels of human disturbance in these areas provide suitable habitat for the major ungulate prey for wolves in the study area, including wild goat (*Capra aegagrus*), wild sheep (*Ovis orientalis*) and wild boar (*Sus scrofa*). Economic activities in the region consist mainly of livestock rearing and agriculture (Reyahi Khoram and Fotros, 2011). Livestock husbandry is an important source of income for local people in the province and consists of herds of sheep and goat freely grazing in fields and rangelands, watched over by a couple of shepherds (including children) and native guard dogs. Livestock are gathered at night and kept in covered pens either in villages or on rangelands.

2.2. Conflict locations

Between 2001 and 2010, 47 incidents of wolf attack on people, mostly children (70%), and 57 incidents of wolf attack on livestock were documented (DOE Hamedan Provincial Office, unpublished data). A large number of attacks on humans and livestock were fatal while in others, the offending wolf was scared off or killed after injuring the victim (Behdarvand and Kaboli, in press). Documentation of wolf depredation on livestock is commonly done in Iran for compensation purposes. Insurance companies compensate for livestock injuries and loss due to various causes, including depredation by wolves. In cases of attacks on humans that lead to lives lost, the Department of Environment pays a refund to families to prevent negative and vengeful attitudes toward wildlife in general and wolves in particular. Governors of rural districts immediately report all such attacks to DOE, which is responsible for determining the cause of the attack. Other than the wolf, hyenas are the only large wild carnivores in the area and DOE rangers and officials differentiate the attacks by examining animal signs at the attack site and types of wound and damage on the victim or prey, as well as through interviewing eyewitnesses and, in case of attack to humans, the survivors. In some cases, the offending wolf is killed by local people on site and DOE confirms the wolf attack by identifying the carcass as belonging to a wolf. However, in some instances, especially when victims or prey are assumed to be taken by the wolf but no sign of them can be found, there is not enough evidence for the DOE to confirm the attack.

We recorded the locations of confirmed wolf attack sites in the field by compiling a list of attack sites based on previous work by Behdarvand and Kaboli (in press) as well as data provided by the DOE. We visited the villages mentioned in the list and subsequently located and recorded 88 of the 105 documented attack sites (31 locations of attack on people and 57 locations of livestock depredation; Fig. 1) through interviews with local people and DOE rangers.

To determine whether attacks to livestock and humans are spatially correlated, we divided the study area into 14 km × 14 km grids and the number of cells that contained wolf attack records was arranged into a contingency table. Cell size was selected based on empirical values of the nearest neighbor distance for breeding wolves as a value of the extent of wolf pack activity and calculated based on Jędrzejewski et al. (2004). Next, using the contingency table and Chi-square test, the probability of the independence of wolf attacks on humans from attacks on livestock was determined.

2.3. Environmental predictor variables

A set of variables known to be important predictors of wolf–human conflict was selected by reviewing relevant literature (Eggermann et al., 2011; Mladenoff et al., 1999; Norris et al., 2002). Although the distribution range of wolf packs is an important affecting variable in predicting wolf–human conflicts (Treves et al., 2011; Wydeven et al., 2004), the lack of long-term studies on wolf ecology that would provide direct or indirect measures of wolf territory in the study area confined us to omit biological aspects of wolf packs from our modeling. However, we included a data layer of areas of high probability of wolf denning (Ahmadi et al., 2013). Because these areas are of special interest to wolves throughout the year, they are identified as centers of wolf aggrega-