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Predation by grey wolf on wild ungulates and livestock in central Iran

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Keywords

Canis lupus; food habit; Ghamishlou; Iran; livestock depredation; scat analysis; sex-selectivity.

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Abstract

The grey wolf *Canis lupus* has the largest geographical range of large mammalian carnivores in west Asia. However, it is one of the least studied species, particularly in Iran. Feeding ecology is a critical aspect of predator ecology and has important implications when formulating species and ecosystem management strategies. Also, predation on livestock is a crucial cause of wolf–human conflicts throughout the wolf's global range. Accordingly, we investigated the diet of the grey wolf in Ghamishlou, an area with high population densities of wild and domestic ungulates in central Iran, between July 2007 and April 2009. Scat analysis indicated that livestock was the single most important prey species for wolves with 47.1% of total biomass consumed, whereas Persian gazelle comprised 27.0% and wild sheep 15.9%. Wild kills were significantly skewed towards males relative to their proportion in the population, and were mainly preyed on during post-rutting months. Based on interview surveys, less than 1% of mean herd size was lost to wolf depredation; however, almost six times more died from non-depredation causes during each winter. We concluded that the high occurrence of livestock in the wolves' diet is mainly because of scavenging rather than depredation; however, owing to high pressure of wolves on local herds during non-winter seasons in other areas with depleted prey populations, local people dislike wolves and try to eradicate them. Finally, management implications are discussed and solutions are recommended.

Introduction

The grey wolf *Canis lupus* has one of the largest geographical distribution ranges of large mammalian carnivores and is found in a wide variety of habitats (Mech & Boitani, 2004), including arid environments in west Asia (Mech & Boitani, 2010). It occurs across most of Iran, but is subject to heavy illegal persecution (Mech & Boitani, 2004; Ziaie, 2008), mainly owing to conflict with local people because of livestock depredation (Ziaie, 2008).

The feeding ecology of the grey wolf has been investigated extensively throughout its global range in North America and Europe (e.g. Ciucci *et al*., 1996; Jedrzejewski *et al*., 2000; Mech & Boitani, 2003; Capitani *et al*., 2004; Nowak, Myslajek & Jedrzejewska, 2005). However, this significant ecological aspect of this predator has rarely been addressed in Asia, particularly in its western range. Although wolves in Asia have been reported to feed on a wide variety of food items, such as trash, carrion and agricultural products in the Negev (Hefner & Geffen, 1999), their main prey in most areas are large and medium-sized ungulates which depend on the composition of the regional ungulate community (Nader, 1996; Jethva & Jhala, 2004; Singh & Kumara, 2006; Wronski & Macasero, 2008; van Duyne *et al*., 2009). Domestic animals are also present in the majority of studied diets of Asian wolves (e.g. Nader, 1996; Liu & Jiang, 2003; Jethva & Jhala, 2004; Singh & Kumara, 2006; Wronski & Macasero, 2008; van Duyne *et al*., 2009). In Iran, a wide range of wild and domestic ungulates have been assumed to comprise the main proportion of the animal's diet (Ziaie, 2008). However, the diet of Iranian wolves has not yet been systematically studied.

Predation on livestock is one of the crucial causes of wolf–human conflicts (Kaczensky, 1996) and leads to wolf persecution (Meriggi & Lovari, 1996). Also, livelihoods can be severely affected by such depredation, generating negative attitudes and persecution of the culprits (Majic & Bath, 2010; Rigg *et al*., 2011). Inadequate understanding of the ecological and social issues of human–carnivore conflicts often hinders the formulation of effective management strategies (Bagchi & Mishra, 2006). However, the subject has rarely been addressed across the range of the wolves in Asia, except India (e.g. Jethva & Jhala, 2004).

In the present study, we investigate wolf feeding ecology in an arid environment in central Iran with high population densities of both wild and domestic ungulates, and wolf–human interaction and wolf depredation. Moreover, describing the

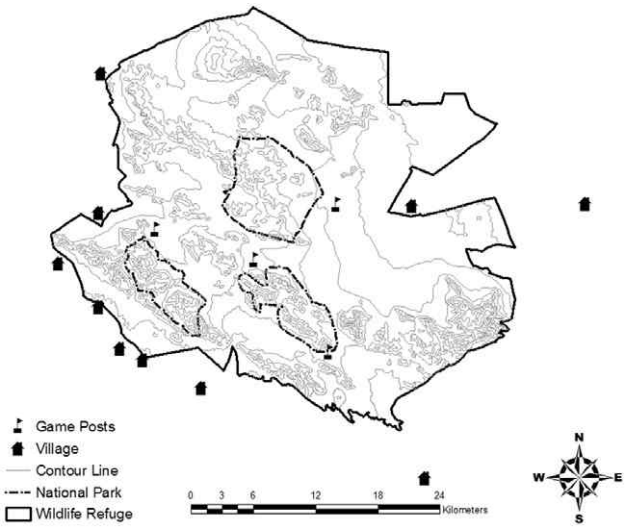

Figure 1 Ghamishlou Wildlife Refuge surrounds three patches of the National Park (NP). Livestock grazing is allowed only within non-NP parts of the Wildlife Refuge.

ecology of predator–prey systems in fragmented habitats is important for understanding the behavior of wolves in human-dominated landscapes. Such information is essential for conservationists interested in managing wolves that range outside protected areas in west-central Asia.

Study area

Located northwest of Isfahan (33°02′ 32°43′N, 50°52′ 51°28′E) in west-central Iran, Ghamishlou has been under official protection since 1964 (Darvishsefat, 2006). With a total area of 300 km^2, the National Park is composed of three isolated patches, which are surrounded by the Wildlife Refuge, resulting in a 1130 km^2 Ghamishlou complex (Farahmand, 2010) (Fig. 1). The altitude ranges from 1700 to 2700 m a.s.l and mean annual precipitation and temperature are 188 mm and 11.5°C respectively, resulting in a temperate arid climate (Darvishsefat, 2006).

The vegetation mainly comprises *Astragalus* spp. and *Artemisia sieberi*, forming a bush-steppe habitat. Ghamishlou is one of the main hotspots for Esfahan wild sheep *Ovis orientalis* and Persian gazelle *Gazella subgutturosa* in Iran and also houses small numbers of Persian wild goats *Capra aegagrus* (Hosseini-Zavarei *et al*., 2010) (Table 1). Other than the grey wolf, striped hyena *Hyaena hyaena*, golden jackal *Canis aureus* and common fox *Vulpes vulpes* occur (Farahmand, 2010).

Ten main human settlements, including towns and villages, surrounded our study area (Fig. 1), each of which has its own garbage disposal sites. Every year, around 13 000 livestock (65% sheep and the rest goat) in 30 herds, mainly from surrounding communities, are allowed to graze within their traditional pastures with distinct established borders in the Wildlife Refuge for a 100-day period in winter (January–March), but they are not allowed to enter the National Park (Fig. 1). They normally spend daytime in the field accompanied by herd dogs (similar in size to an adult wolf), but return to their corrals overnight.

Table 1 Population parameters of bovids in Ghamishlou

	Population size (Esfahan DoE annual census 2008)	Sex ratio (Hosseini-Zavarei *et al*., 2010)
Persian gazelle	2400	31:69
Wild sheep	2400	15:85
Persian wild goat	100	40:60

Methods

Wolf diet assessment

Wolf scats were collected between July 2007 and April 2009 on a monthly basis. Since existing trails in the area penetrate most mountainous terrain, it was not difficult to visit various habitat types using vehicles. The total length of 47 traversed transects was *c*. 259 km, which almost one third of them were traveled each month. However, wherever possible, less-accessible locations were walked to find more wolf signs. Wolf diet was assessed using two methods.

a. Scat analysis

We collected 132 wolf scats along roads and trails and when visiting wolf rendezvous sites ($n = 4$). These sites were identified based on signs of wolf (beds with wolf hairs, scats, wolf tracks) and are reported to be occupied by wolf packs with pups for several weeks (Theuerkauf, Rouys, & Jedrzejewski, 2003).

The scats were identified based on their form, size and presence of footprints in the immediate area. During winter grazing time, we avoided collecting wolf scats outside the National Park, where herds of livestock accompanied by dogs are not allowed to graze and which are not close to human settlements, to decrease the chances of collecting the scats of dogs. On the other hand, except during the grazing season (i.e. winter), we never encountered any dog in Ghamishlou during our field surveys, whereas wolves were encountered 18 times (Hosseini-Zavarei *et al*., 2011). Meanwhile, since herders normally feed their dogs with non-meat foods, such as a mixture of flour and milk, we easily identified these dog scats. Based on these considerations, we believe that the probability of scats belonging to wolves is high.

After washing and drying in the lab, prey items were identified based on at least 20 hairs selected randomly from each sample using a microscope. Features of the cortex and medulla of hairs were compared with a reference collection prepared from museum samples.

The importance of each food item was determined by frequency of occurrence (percentage of total scats in which an item was found), and percentage of occurrence (number of times a specific item was found as a percentage of all items found) (Klare, Kamler & Macdonald, 2011). Frequency of occurrence (FO) is the most commonly used and easily applied method of diet analysis, although this method may overemphasize the frequency of small prey (Ciucci *et al.*, 1996). So, following Klare *et al.* (2011), we selected the methods developed by Floyd, Mech & Jordan (1978) for wolf to convert the frequencies of occurrence (after correcting for scats containing remains of multiple-prey species according to Karanth & Sunquist, 1995) into relative biomass and numbers of individuals based on the following linear regression model:

$$y = 0.38 + 0.02x$$

where y is the weight of that prey represented in one scat and x is the total live prey weight (see Floyd *et al.*, 1978).

b. Kill examination

Kills were normally found along transects or based on flight patterns of raptors (e.g. black vulture *Aegypius monachus* and steppe eagle *Aquila nipalensis*) and/or scavenging birds (e.g. raven *Corvus corax* and magpie *Pica pica*). On a few occasions, hunts on prey were observed directly, so the kills could easily be recorded. We also asked the area's game wardens to report any successful hunts they encountered during their daily anti-poaching patrols across different parts of Ghamishlou. These two sources of data could provide a proper coverage throughout the year; however, since wolf kills are found opportunistically, they were expected to bias towards larger prey species. Seventy-nine kills were located for which species, sex and age class were also determined. In order to evaluate intersexual differences among killed ungulates, we used available data (Hosseini-Zavarei *et al.*, 2010), which were based on total transect counts along existing trails (Table 1) by means of chi-squared test of fitness. Since most of our field efforts were focused on flat, open areas, we probably underestimated species living in more mountainous areas.

Selectivity of wolf predation for prey species and for a particular sex class of a specified prey species was assessed by the Ivlev's electivity index (modified by Jacobs, 1974):

$$D = (r - p)/(r + p - 2rp)$$

where r is the proportion of a given prey species (or a given sex class) in wolf kills, and p is its proportion in the wild ungulate community (Table 1). The index ranges between −1 (negative selection) and +1 (positive selection).

Wolf–human interaction

We assessed livestock owners' perception of wolf–livestock conflict and their general attitude towards conservation through a semi-structured questionnaire with local herders. Pastoralists within the same pastures were interviewed in 2 consecutive years in late March 2008 ($n = 17$) and 2009 ($n = 15$) before the end of the grazing season in the area. However, we asked different ones in the 2 years. One representative from each household was questioned about livestock losses (species, number and year) and the predators that killed the animals. In some cases, we cross-checked the response of the respondents by interviewing multiple persons that herded livestock on the pastures. Two types of non-predation losses for the study period were also collected, including individual animals that did not follow the herd back to the corral but remained in the pasture and died (which were understood when herders regularly count their animals), and animals that died from various causes, including disease.

We also asked our interview partners about the prevailing market value for each type of livestock. Finally, we asked herders to rate their attitude towards wolves on a scale 'strongly like', 'slightly like', 'indifferent', 'slightly dislike' and 'strongly dislike' (Oli, Taylor & Rogers, 1994).

Results

Scat analysis

A total of 235 remains from seven food items were identified in wolf scats (Fig. 2, Table 2), with wild and domestic ungulates being most frequent. We failed to identify rodents, birds or insects to species level. In 25.75% of scats ($n = 34$), multiple-prey species were detected, mostly two items ($n = 31$), followed by three ($n = 2$) and four food items ($n = 1$).

A total of 136 food remains (57.87%) belonged to medium-sized mammals, with no significant difference in the contribution of wild and domestic ungulates to the wolves' diet ($\chi^2 = 1.882$, d.f. = 1, $P = 0.170$) (Table 2). The investigation indicated that the main food of the wolf in Ghamishlou is livestock (FO = 45% and biomass consumption = 47.1%), followed by gazelle (FO = 31%), wild sheep (FO = 17%) and birds (FO = 16%). Meanwhile, in total, wild ungulates make up 52.1% of the biomass consumed (Fig. 3, Table 3). Based on conversion of biomass to number of individuals eaten, the three wild bovid species together are more often killed compared with domestic animals (Table 3). In the meantime, plant materials were found in scat remains on 65 occasions (FO = 49%), of which seeds (e.g. watermelon, grape and sunflower) were identified eight times. Presence of plastic rope, string and paper indicates that wolves are sometimes feeding on waste and garbage (Table 2).

Examination of kill sites

A total of 79 wolf kills was identified belonging to three species of bovids (Table 4). Young animals (i.e. less than 1 year) made up only 3.8% of all killed bovids, whereas males comprised 53.16% ($n = 42$) of kills (excluding lambs), and females accounted for 24.05% ($n = 19$) of investigated kills (Table 4).

Persian gazelles killed by wolves were almost exclusively males, whereas in wild sheep almost equal numbers of males and females were killed. Given that the sex ratio in both wild sheep and Persian gazelles seem highly to moderately skewed

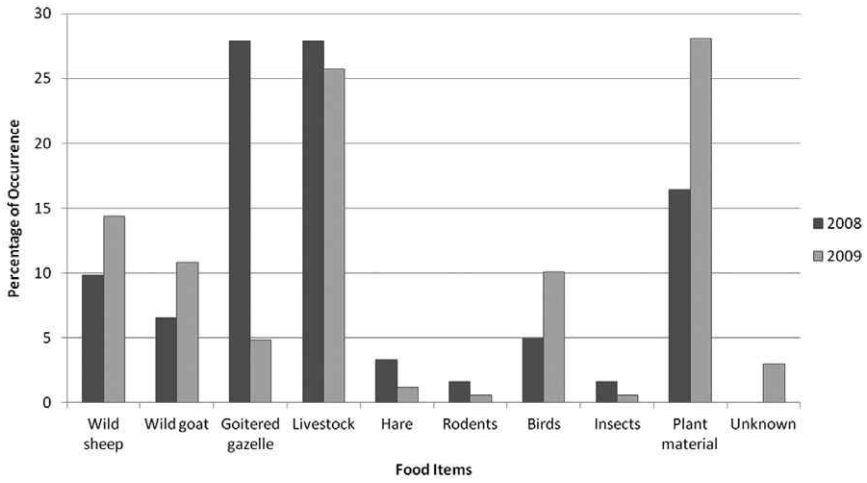

Figure 2 Percentage occurrence of different food items extracted from wolf scats in Ghamishlou, 2008–2009.

Table 2 Frequence of occurrence of food items in scats of grey wolf in Ghamishlou

	2007		2008		Total	
Food item	*n*	FO (%)	*n*	FO (%)	*n*	FO (%)
Medium-sized food items						
Persian gazelle	17	3	24	19	41	31
Wild sheep	6	11	18	14	23	17
Persian wild goat	4	7	8	6	12	1
Domestic sheep and goat	17	3	43	34	60	45
Small food items						
Hare	2	4	2	2	4	3
Rodents	1	2	1	1	2	2
Bird	3	5	18	14	21	16
Insects	1	2	1	1	2	2
Plant material	10	18	47	38	65	49
Unknown	0	0	5	4	5	4
Non-food items						
Garbage	3				3	
Stone	38				38	
No. of food items	235					
No. of scats	132					
No. of food items/scat	1.78					

FO = percentage of total scats in which an item was found.

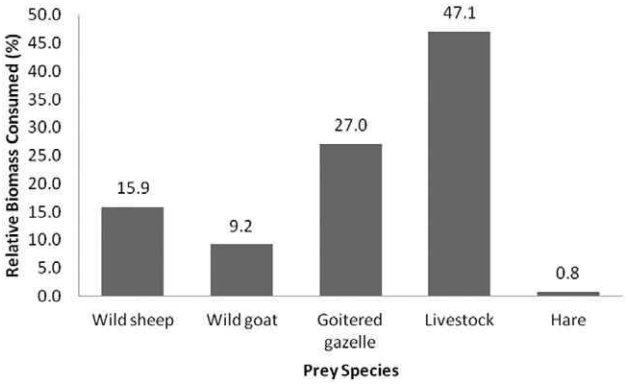

Figure 3 Relative biomass of prey consumed by wolves in Ghamishlou.

towards females (Table 1), the sex ratios of kills strongly suggest that males may be selected for by wolves in both species [Persian gazelle ($\chi^2 = 44.945$, d.f. = 1, $P = 0.000$) and wild sheep ($\chi^2 = 38.347$, d.f. = 1, $P = 0.000$)]. Considering only adult kills, Ivlev's electivity index was positive for males of all bovids whereas, except female gazelles, other species' females scored negative (Fig. 4). This suggests that wolves prey mostly on males and that wild sheep are preferred most, followed by Persian gazelle. Since no female wild goat was recorded, it had the highest score of avoidance among prey (Fig. 4).

In spite of our field efforts, which was distributed over the course of the survey period, 86% of adult male gazelles and 58% of adult wild sheep rams were hunted during a 4-month period of November–February (rutting season to end of winter), both significant (Persian gazelle: $\chi^2 = 27.841$, d.f. = 1, $P = 0.000$ and wild sheep: $\chi^2 = 5.158$, d.f. = 1, $P = 0.023$).

Wolf–human interaction

Mean herd size between years decreased significantly from 391 in 2007 to 257 in 2009 (t = –2.232, d.f. = 30, $P = 0.033$) (Table 5), probably owing to severe drought (Hosseini-Zavarei *et al.*, 2010), which made herders sell their animals due to scarcity of grazing. Herds were accompanied by 8.9 (SE = 0.9) and 5.9 (SE = 0.5) guard dogs during 2 consecutive years, respectively.

Sixty per cent of interviewed herders experienced a wolf attack. We recorded 61 sheep/goat losses in 2007 (accounting for 0.9% of the total stock) and 28 losses in 2008 (0.7%; Table 5).

Except for a few cases of surplus killing (>10 domestic animals killed per attack), 1.7 (SE = 0.2) domestic animals were killed on average in a single wolf attack (Table 5). Almost 10% of wolf depredations took place in night corrals, the rest in the pastures.

Table 3 Estimated biomass consumed by the grey wolf in Ghamishlou

Food item	Estimated mean weight of prey (kg)*	Ingested biomass per scat (kg/scat)	Corrected no. of prey items	Corrected FO (%)	Relative biomass consumed %	No. of individuals eaten
Wild sheep	34	1.1	17	13	15.9	0.1
Persian wild goat	36	1.1	9.5	7	9.2	0.1
Persian gazelle	27.5	0.9	33	25	27.0	0.3
Livestock	35	1.1	49.5	38	47.1	0.4
Hare	2.5	0.4	2	2	0.8	0.1

FO = percentage of total scats in which an item was found.

Table 4 Wolf kills found in Ghamishlou

Species		*n*
Persian gazelle		**40**
Fawn		2
Adult	Female	1
	Male	22
Non-identified		15
Wild sheep		**38**
Lamb		1
Adult	Ewe	18
	Ram	19
Non-identified		0
Persian wild goat		**1**
Lamb		0
Adult	Female	0
	Male	1
Non-identified		0
Total		79

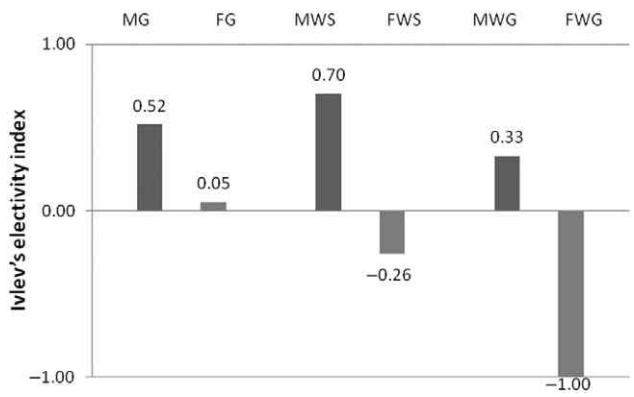

Figure 4 Ivlev's selectivity index for the wolves' wild ungulate preys in Ghamishlou. MG, male gazelle; FG, female gazelle; MWS, male wild sheep; FWS, female wild sheep; MWG, male wild goat; FWG, female wild goat.

Such depredation resulted in economic loss of about 3 407 000 Rial (US$ 340) and 1 323 000 (US$ 132) per herder in winters 2007 and 2008. Concurrently, herders lost a total of 106 animals due to disease and being left behind in the pastures in winter 2007, costing around 10 625 000 Rial (US$ 1062) for a mean loss of 6.2 animals per each herd in winter 2007. For winter 2008, it was calculated as 17 487 000 (US$ 1748) for an average of 9.7 livestock per household. Therefore, these factors caused herders to lose between 1.4% (2007) and 3.8% (2008) of their herds to a combination of wolf attacks and other causes (Table 5).

All respondents believed that the wolf is the most significant enemy to their livestock. More than 85% of herders' attitudes fell into the categories 'dislike' and 'strongly dislike', particularly the latter.

Discussion

Our study revealed that wolves in Ghamishlou primarily prey on wild and domestic ungulates as has been shown in many other areas of their geographical distribution (Jedrzejewski *et al.*, 2000; Mech & Boitani, 2003; Jethva & Jhala, 2004; Gazzola *et al.*, 2005; Barja, 2009). However, although wild ungulates were abundant, livestock was consumed at a much higher rate than we had expected based on previous literature (Capitani *et al.*, 2004; Jethva & Jhala, 2004; Nowak *et al.*, 2005). In the meantime, despite our caution in trying to avoid confusing wolf and dog scats, it is always possible that a proportion of our scat samples belonged to dogs which sometimes feed on carrions, thus leading to an overestimate of the proportion of domestic livestock in the wolf's diet.

Gazelle and wild sheep provide most wild ungulate prey with very few Persian wild goat. This reflects primarily the availability of these prey species to wolves in Ghamishlou, both in terms of abundance and habitat. It has been reported that the wolves rarely go for mountain ungulates when alternative sympatric plains ungulates are easily available (Huggard, 1993; Gazzola *et al.*, 2005).

Where sex could be determined, males were selected over females compared with their proportional availability in the population. For similar-sized prey, such as roe deer *Capreolus capreolus*, females were preferred over males in the Western Carpathian (Nowak *et al.*, 2005). In India, proportionally higher predation on adult male blackbuck *Antelop cervicapra* has been reported (Jethva & Jhala, 2004). Despite our continuous field efforts distributed in all months, most adult males were found to have been predated by wolves between the rutting season (November) and end of winter (February), which suggests that the energy investment for breeding (primarily maintaining territories and harems) predisposes males

Table 5 Details of livestock loss due to various factors in Ghamishlou Wildlife Refuge

		Loss due to wolves				Loss due to disease, etc.				Loss due to left animals in pasture			
Grazing season	Mean herd size (SD)	Total loss	Mean loss/herd	% herd size	Mean economic /herd ($)	Total loss	Mean loss/herd	% Herd size	Mean economic /herd ($)	Total loss	Mean loss/herd	% Herd size	Mean economic /herd ($)
2007–2008	391.2 (47.4)	61	3.6	0.9	340.7	82	4.8	1	436.3	24	1.4	0.4	626.2
2008–2009	257.3 (37.3)	28	1.9	0.7	132.3	114	7.6	3	526.9	31	2.1	0.8	1221.8

with depleted body reserves (Mysterud, Langvatn & Stenseth, 2004), which may lower survival (Forsyth *et al*., 2005) through more susceptibility to predation or post-rut mortality which can enhance scavenging.

Many studies have discussed if, wherever accessible, wild ungulates are preferred by wolves to livestock (e.g. Fritts & Mech, 1981; Jhala, 1993; Gazzola *et al*., 2005; Nowak *et al*., 2005; Barja, 2009). Also, the presence of several species of wild prey appeared to be more effective than a single species, even if abundant, in lowering predation on livestock (Meriggi & Lovari, 1996). However, Ghamishlou possesses one of the highest population existing densities of wild ungulates in Iran, but a considerable proportion of wolves' diet is based on livestock. Where domestic animals and wolves are present in the same area, depredation invariably occurs regardless of the presence or absence of wild prey (Kaczensky, 1996; Boitani, 2000). In the meantime, since only some patches of the area (i.e. National Park) are secure against livestock grazing, most of the area is home to a mixture of high population densities of both wild and domestic ungulates, which has been identified as a contributing factor to livestock depredation by the wolf, as an opportunistic predator (Gula, 2008).

Mean number of livestock predated per each herder during each winter never exceeded 1% of average herd size. Such predation events result in a mean economic loss of about 4 730 000 Rial (US$ 472) for each herder during two grazing seasons in Ghamishlou. In contrast, local people lose almost 28 112 000 Rial (US$ 2810) per capita due to non-predation losses. Therefore, various other factors led to livestock losses almost six times more than those from wolf depredation in Ghamishlou during two winter seasons.

The high proportion of livestock in wolf scats may reflect scavenging as well as predation, especially given that disease was an important mortality factor in local herds. We found more than 60% plant materials and all garbage remains in scats containing livestock, suggesting the foods might have been obtained as carrion at disposal sites (Fritts & Mech, 1981) or around farmlands, which are mainly located in marginal areas. Moreover, a proportion of this non-wolf depredation is accounted for by animals left in pastures, which are expected to be eaten later by the wolves. Interviewed herders never declared this source of mortality when asking about cases of wolf depredation. It is reasonable to consider this phenomenon as indirect wolf depredation contributing an increased proportion of domestic livestock in the wolves' diet in Ghamishlou. However, it never exceeded one per cent of the average herd size in both years.

In Ghamishlou, the average number of livestock killed during a single attack in 2 years (1.7 individuals) was less than that reported from Italy (three individuals per attack; Ciucci & Boitani, 1998; 2.7–6.3 individuals; Gazzola *et al*., 2008), Slovakia (four individuals; Finïo & Hood, 2001) and Poland (five individuals; Nowak *et al*., 2005). Probably, in our study area, wolves had not enough time to kill more animals during the attack because they were usually disturbed by dogs or humans, which are both expected to reduce wolf depredation on livestock (Kaczensky, 1996; Rigg *et al*., 2011), particularly guard dogs, as they play a substantial role in preventing surplus killing, which has a major impact on individual herders (Rigg *et al*., 2011). Also, wolf packs (SD = 2.5) are relatively small in livestock attacks in Ghamishlou (Hosseini-Zavarei *et al*., 2011), which probably also reduces the probability of surplus killing (Iliopoulos *et al*., 2009).

Our investigation indicates that though scat analysis is a reliable technique for understanding the diet, the method usually cannot distinguish between prey that are killed or scavenged (Liu & Jiang, 2003). Consequently, derived predation data may be invalid for predicting human–wolf conflict (Jethva & Jhala, 2004). Therefore, with using local interviews, we can understand the extent of wolf–human interaction and conflict in the area, which is a first step towards the species' conservation and management (Boitani, 2000).

We strongly recommend that the herders avoid abandoning dead domestic animals as carrion near their main pastures, because improper disposal of livestock carcasses also attracts wolves to scavenge, which also helps to increase livestock depredation (Mech, 2000). Also, grazing herds seem to be properly guarded by herders and dogs; however, more care should be taken during patrolling not to leave any domestic animals behind which could also encourage wolves to increase their attacks on livestock. Improving livestock husbandry programs, such as veterinary support, can decrease economic losses due to non-depredation factors, especially diseases. Meanwhile, besides education and raising awareness (Meriggi & Lovari, 1996), a compensation scheme for wolf-predated livestock could also promote a positive attitude and tolerance towards wolves. Finally, parallel to enhancing long-term conservation programs in reserves such as Ghamishlou, which have a high population density of grey wolves, sound scientific surveys should be conducted on the species in order to better inform effective conservation action and population management.

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