



# Analysis of wolf–human conflicts: implications for damage mitigation measures

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## Abstract

The wolf (*Canis lupus*) is a keystone and damage-causing carnivore species around the world. Although the species is widespread in Asia, there is limited information on its ecology and interactions with the humans in this continent. This paper presents the conditions and consequences of wolf–human conflicts in Turkey between 2002 and 2017, based on data from 234 incidents compiled from the archive of national media and ISI Web of Science. Most conflicts (90.6%) were portrayed in a negative light in the news. Most incidents (64.1%) were related to domestic animals and attacks on humans (24.8%). Mostly sheep and goats were killed by wolves (79.3% attacks on domestic animals). The wolf depredation rates were significantly higher in open lands and relatively protected corrals. Attacks on livestock were likely to happen at night and those on people during the day. The presence of livestock guarding dogs did not significantly change the wolf depredation rate. There was no significant difference among years and preventive measures against the wolf damage on livestock. A total of 58 human–wolf encounters resulted in attacks on humans and caused 12 deaths and 107 injured people. Those incidents were significantly related to rabid wolves (63.8%). To prevent rabies transmission in canids and thus rabid wolf attacks, we recommend enclosing dump sites in rural areas and vaccination of canid species especially in eastern Turkey, where wild canids and feral dogs encounter more frequently. To develop effective mitigation measures, a database which will provide conflict data should be established, and further researches for effective precautions should be supported.

**Keywords** Rabies · Large carnivores · Canids · Depredation · Damage compensation · Livestock guard dogs

## Introduction

The grey wolf (*Canis lupus* Linnaeus, 1758) is one of the most widespread and damage-causing carnivore species in the northern hemisphere (Mech and Boitani 2010). Wolf-caused damage have been increasing in frequency (Fernández-Gil et al. 2016) as well as their coverage in the media. This has been because of increasing protection status (EU countries) or delisting from the protected species list (USA), while large carnivore populations have been recovering globally (Chapron et al. 2014). Although a range of preventive measures with varying sophistication were used in the world

against wolf attacks on livestock, only a few of them are effective for mitigating the damage (Stone et al. 2017; van Eeden et al. 2018).

The literature on human–wildlife conflicts and its management mostly lacks views from the Asian continent, where large carnivores are still extant in most of potential habitats. As an Old-World species, wolves have a long history of conflict with humans due to common food such as wild preys and livestock. The most detrimental conflict for wolves is probably due to depredation of livestock as even in areas with high wild ungulate abundance, wolves can prefer livestock (Imbert et al. 2016; Iliopoulos et al. 2009). This has caused extirpation of many wolf populations by humans mostly in the economically developed countries during the last century (Mech and Boitani 2010). However, there is no information about the conditions and consequences of historical or current conflicts in Asia except few recent studies in Pakistan (Hamid et al. 2019), Georgia (Kikvidze and Tevadze 2015), and Iran (Hosseini-Zavarei et al. 2013). The fertile crescent at the southwest Asia, extending from central and south-eastern Turkey to Jordan and Mesopotamia, is where the domestication of wild cattle (Arbuckle et al. 2016), sheep, and

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goats (Naderi et al. 2008) co-occurred with wolf or dog domestication in the fertile crescent (Koler-Matznick 2002). Therefore, Turkey is probably among the first places where the first conflicts occurred between wolves and herders (Ambarlı 2013).

The overall wolf population in Turkey is about 6000 individuals in the mainland, distributed across the steppes, forests, mountain habitats, and locally some Mediterranean habitats, but excluding the coastal areas (Ambarlı et al. 2016). Although there is limited law enforcement and personnel in the Department of Wildlife, fines for poaching of large carnivores (from 1500 to 26,000 Turkish Lira) (Official Gazette of Turkish Republic 2018) seem high for locals (Ambarlı and Bilgin 2008) and prevent some local people from killing (Milliyet 2014). Additionally, there is no national wildlife damage compensation scheme in Turkey contrary to Europe (Iliopoulos et al. 2009) and some other countries (Naughton-Treves et al. 2003; Karanth et al. 2013). However, recently, damage caused by wild animals on livestock has begun to be covered by an insurance mechanism, TARSIM (TARSIM 2017), in which half of the insurance costs to farmers are subsidized by the Ministry of Agriculture and Forestry.

In addition to the depredations, wolf attacks on humans play an essential role in human attitude for wolf conservation and management (Røskaft et al. 2003). Attacks on humans were classified mostly into three categories: rabid wolf attacks, and defensive and predatory attacks (Linnell et al. 2002). Probably, the most detrimental and widespread ones in Asia are the rabid and livestock (or pet)-related wolf attacks on people, causing fierce retaliation from people (Linnell et al. 2002). Rabies is not uncommon in Turkey: more than 180,000 people on average get rabies vaccination every year due to attacks by domestic and wild animals (TÜİK 2017; Aidoros 2015). The probability of rabies transmission among canid species (wolves; red foxes, *Vulpes vulpes*; golden jackals, *Canis aureus*; feral dogs, *Canis lupus familiaris*) probably increase with gathering at dump deposition areas with high number of feral dogs (Ambarlı et al. 2016) that are protected by law (Turkish Law No. 5199, Official Gazette of Turkish Republic 2004). Some of the rabid wolf attacks result in death of locals (Türkmen et al. 2012), but it is not known what is the percentage of attack to humans caused by rabid wolves in Turkey.

People, wolves, and domestic animals in Turkey have been interacting since the first domestications of sheep and goats. For an effective legislation, enforcement, and mitigation, it is necessary to know the causes, conditions, and consequences of human–wildlife conflicts. However, there is limited research about the ecology of wolves (Ertürk 2010; Tokmak and Ambarlı 2018), wolf–human conflicts (Tuğ 2005), and the human dimension of large carnivore conservation in Turkey (Ambarlı et al. 2016). Therefore, the aim of this study was to document and explore the reasons and consequences of recent wolf–human conflicts by systematically analyzing data obtained from online sources. My specific research questions

were (1) what are the spatial and temporal trends of wolf–human conflicts in Turkey reported in media and attitude in media reporting? (2) What are the common types and consequences of conflicts and whether rabies is an important driver of attacks on humans? (3) Under which conditions wolf–human conflict took place (e.g., the timing)? (4) What are the preventive measures and mitigation activities taken by involved humans, and are they effective? Finally, I suggested management solutions to decrease the wolf depredation and rabies-induced wolf attacks on humans.

## Materials and methods

### Study area

Turkey has a wide range of habitats from Mediterranean coasts in the south and west, continental plateaus to humid forests in the north. There is a high variation in elevation, from sea level to above 3000 m. The mean elevation of inner Anatolia (the Asian part of Turkey) is about 900 m whereas Eastern Anatolian plateau is about 2000 m. The land is mostly covered by croplands, steppes, and steppe forests with oaks, Black Pine, and Scots Pine (Kaya and Raynal 2001). Livestock husbandry is the most important economic activity for the rural people at high altitudes in Anatolia (Redman and Hemmami 2008). The average number of sheep per flock varies from 75 to 200 (Kaymakçı and Cengiz 2010), while the goat numbers per flock are 125 to 75 from western to eastern Turkey, respectively (Ayvazoğlu Demir et al. 2015).

### Documenting wolf–human conflicts

I collected data from online resources as there is no Turkish national database keeping wildlife damage data. I used common search engines ([google.com](http://google.com)) and literature databases ([scholar.google.com](http://scholar.google.com) and ISI Web of Science, [webofknowledge.com](http://webofknowledge.com)) including national newspapers and scientific journals between 2000 and 2017. I searched for the following keywords in Turkish: “*Canis lupus*”; “wolf”; “wolf attack”; “wolves attacked livestock”; “wolf has been seen”; “rabid wolf”. I checked every link found by the search engine and databases unless it was clearly irrelevant to wolf–human conflicts in general. I accepted the incident as wolf–human conflict if there is either a wolf attack on humans, human attack on wolves, or wolf depredation on domestic animals. I recorded each incident in a database with date, time, place, perception of the news, preventive measures, number of attacking wolves, damage types, damage on the body, presence of dogs, and results of confrontations for wolves and people (Supplementary Material 1). I confirmed each incident by verifying the news from at least one local and one national news agency (Anadolu Agency or Dogan News Agency) and

by checking the photographs from the conflict sites. I excluded two incidents from 2002 and 2000 from further analysis because internet usage was not very widespread during that time and the incidents from those years may have been under-recorded. Furthermore, I did not find any incidents in 2003 and so the analysis on conflict data cover the period of 2004–2016. The final dataset included 241 wolf-related news items from 57 provinces (out of 81) of Turkey. In addition, I found two wolf-caused rabies-related deaths, not reported in the news, in scientific journals and included in the dataset (Emsen 2007; Türkmen et al. 2012). News that included only speculative reports but no photos of damage, depredation, or a dead wolf were excluded from further analysis ( $n = 7$ ).

I used a Likert scale to categorize the title of news in terms of perception toward wolves in a five-point scale from very negative ( $-2$ ) to very positive ( $+2$ ) including neutral ( $0$ ). I used three-point scales for preventive measures as “none,” “yes, but partial or primitive,” and “yes.” I categorized the incidents as attacks on livestock, humans, and/or dogs. Incidents occurring on the same day and by the same wolf were counted as a single incident to prevent spatial bias in analyses (e.g., in one case, a wolf in one day killed two cows, wounded five people, and was then killed by hunters and this was counted as one incident), but the damage were recorded in different categories. The outcome of wolf attacks on humans or livestock were categorized as 0—none, 1—head, 2—neck, 3—arms/forelegs, 4—chest, 5—back, 6—lower body or hind feet, and 7—unknown. The categorization was made based on photographs and videos associated with the news. I also recorded the outcome of the incident for wolves (wolf wounded or killed). When a video content of the news with local people was produced by journalists, I watched to analyze the news and their contents for discourses of people. I recorded the month, season, and time of the human wolf incidents. If there was no exact time and only a time period was indicated, such as darkness ( $n = 25$ ) or twilight ( $n = 15$ ), I recorded them as night time for calculating the time of attacks (Supplementary Material 1). I used the data from annual reports of Turkish Statistical Institute about the numbers of livestock (TÜİK 2017) to calculate the average percentage for the killed and wounded sheep and goats per year by the wolves.

## Analysis

I used  $\chi^2$  goodness of fit to test whether incidents were equally distributed among times of day, months, and seasons by using the SPSS 18 for Windows (Chicago, IL, USA), and the significance level was set at  $p < 0.05$  (Field 2005). Besides,  $t$  test was used to compare depredation rates according to presence of livestock guarding dogs (LGDs). To compare the damage types and preventive measures, I also used cross-tabulations to find out the effectiveness of preventive measures by applying  $\chi^2$  statistics (Field 2005). To analyze the wolf–human

incidents spatially and show the hotspots of wolf–human incidents, I used “Optimized Hotspot Analysis” with 90%, 95%, and 99% confidence intervals in ArcGIS 10.3 (ESRI Spatial Analyst© 2018). This analysis aggregate the points by using the Getis–Ord  $G_i^*$  statistic and creates a map of statistically significant hot and cold spots regarding equally weighted incident points (Ord and Getis 1995).

## Results

In total, 234 wolf–human conflicts were documented in the last 15 years (Fig. 1), and 90.6% of the news headline regarding perception of the wolf–human conflicts were reported negatively by media (e.g., “*hungry wolf scattered horror*,” mean =  $-0.905$ , ranging  $-2$  to  $+2$ ,  $n = 212$ ).

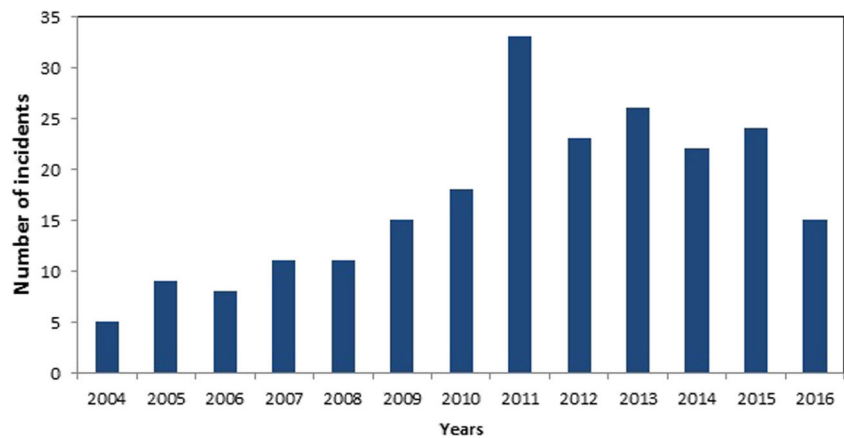
## Types of conflicts

Wolf–human conflicts in Turkey ( $n = 234$ ) has a stable trend in the last decade ( $y = 0.009x$ ,  $r^2 = 0.0028$ ) and were composed of wolf attacks on domestic animals (64.1%,  $n = 150$ ), wolf attacks on humans (24.8%,  $n = 58$ ), and human attacks on wolves (9.4%,  $n = 22$ ) (Fig. 2), and there was no damage to any party in 1.7% of the interactions ( $n = 4$ ). Most of the incidents (69%) occurred in Eastern (52%) and Central (17%) Anatolia, representing the main distribution ranges for wolves (Fig. 3). The number of incidents was the minimum in Thrace (3%), European part of Turkey, and Mediterranean (3%) regions in the south (Fig. 3). The hotspots of conflicts are significantly (99% CI) present on the eastern Turkey and throughout the borders with the neighboring countries whereas the wolf–human conflicts are significantly less likely to occur in the north western Anatolia and around the biggest city of Turkey, Istanbul (Fig. 3).

## Attacks on domestic animals

Most of the total wolf incidents (64.1%) involving domestic animals were related to sheep and goats (79.3%,  $n = 119$ ) whereas attacks on cattle and dogs were very limited (19.3%,  $n = 29$ ). Depredation on sheep and goats in the last 15 years resulted in at least 4702 dead and 840 wounded individuals between 2004 and 2017 (Table 1). Wolf attacks to livestock occurred mostly in open lands at high plateaus (51.4%), followed by attacks in sheepfolds used to keep the flock together without any protection measure (35.5%), and barns or stables (13.1%, closed buildings with proper doors, cameras, CCTVs, or LGDs) with a significant difference among places of wolf attack (Table 2,  $\chi^2 = 23.79$ ,  $p < 0.001$ ). Sheep and goats on high plateaus without any protection or in the partially protected corrals (e.g., low number of dogs, corrals in low height or without proper door) were more likely to be attacked

**Fig. 1** Number of wolf–human conflicts between 2004 and 2016



by wolves ( $\chi^2 = 62.72$ ,  $p < 0.001$ ,  $df = 4$ ). Sheep and goats attacked by wolves mostly exhibit wounds to the throat and head (44%), whereas wounds on front legs (21%), chest and lower back (24%), and hind legs (11%) were also common.

Number of wolf incidents with cattle ( $n = 12$ ), donkeys ( $n = 3$ ), and horses ( $n = 1$ ) were very limited ( $n$  total = 16), and the total damage (only 46 animal killed by wolves) was very scarce. Local farmers in their discourses sometimes (7%) perceive damage as wolf sustenance (i.e., part of nature), but most of them (84%) were angry when wolves kill more sheep and goats than they can eat. There were 13 wolf attacks (8.6%) directly targeted and killed dogs ( $n = 25$ ) mostly in front of their houses or barns during the wintertime.

### Attacks on humans and the effect of rabies

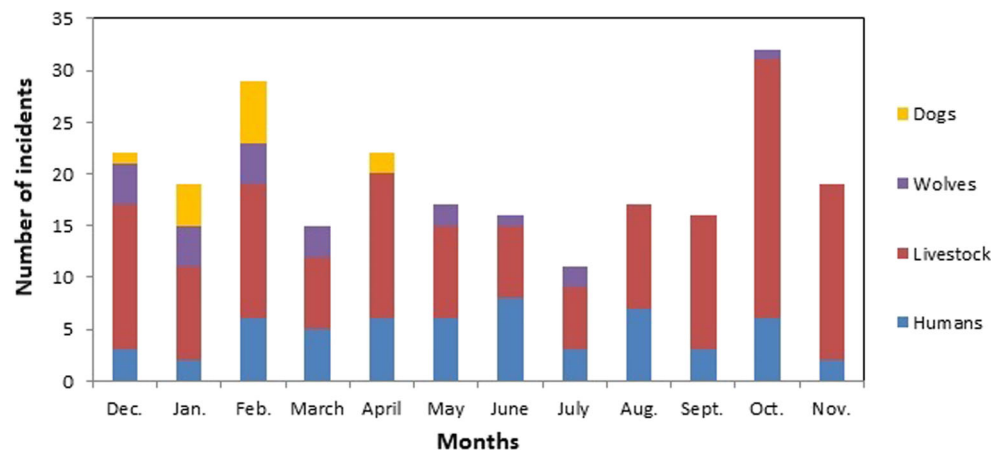
The wolf attacks on people ( $n = 58$ ) were mostly related to rabies (63.8%, 29 confirmed and 8 highly probable incidents), domestic animals (17.2%), and winter food shortage (6.9%). Other wolf attacks on people were composed of two sudden encounters (3.4%), two wolf–dog hybrid (3.4%), and three defensive attacks (5.1%). Wolves wounded 107 people (87.6% caused by rabid wolves) and killed 12 people (only one was reported by Emsen 2007, but not by news) (75%

caused by rabid wolves) during human–wolf encounters. The mean age of victims was  $38.24 \pm 2.3$  years, but there were 33 people younger than 18 years old (ranging from 5 to 18) (28.2%). Most of the victims were male (65%). Wolves killed five people instantly during the attacks on humans, whereas others died due to heavy trauma ( $n = 5$ , e.g., Emsen 2007—a woman died because of sepsis) or post rabies infection ( $n = 2$ ) (e.g., Türkmen et al. 2012—a man died after vaccination). Wounded people were mostly harmed on their hands (45.9%) and heads (36.5%). In one case, a rabid wolf attacked more than 13 people in a day at agricultural fields in Eastern Anatolia and seriously wounded three of them. There was no confirmed unprovoked attack as predatory on humans except the rabid wolf incidents. Locals killed 90 wolves in 82% of the wolf attacks on people ( $n = 58$ ).

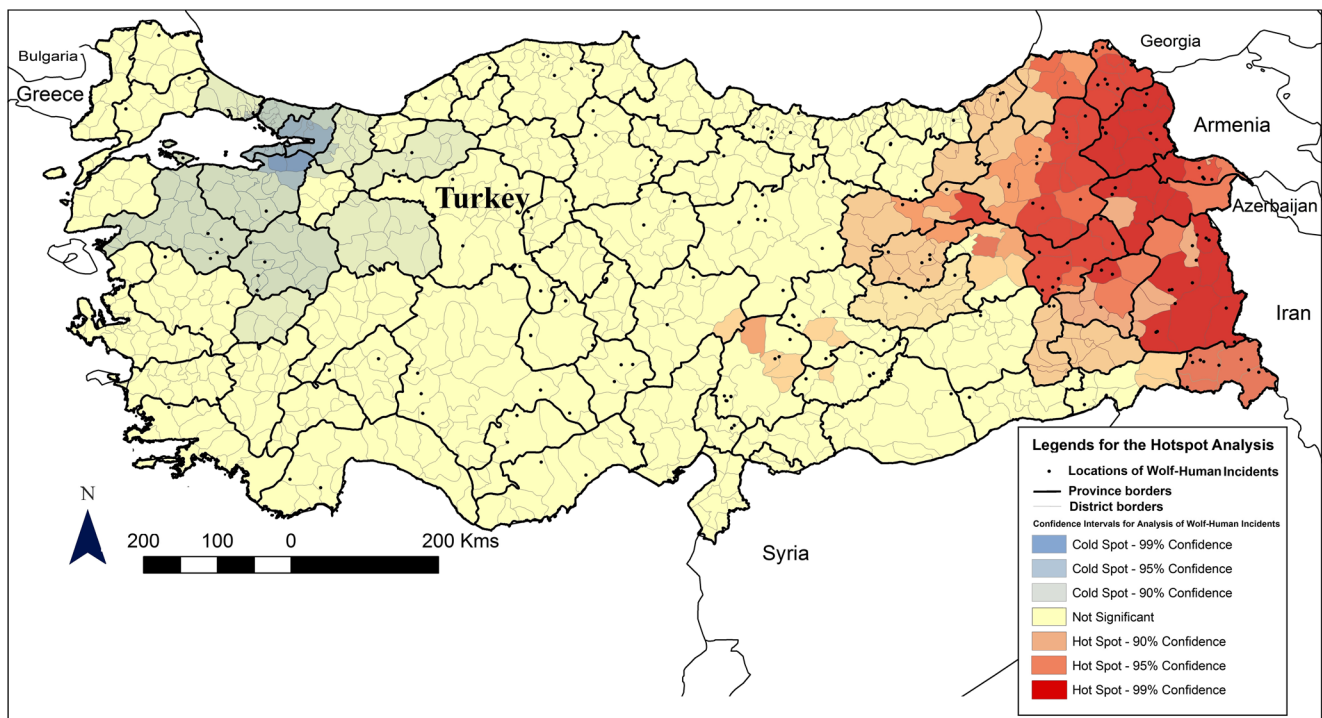
### Time of conflicts

Most of attacks were more likely to occur during night (Fig. 4) ( $\chi^2 = 4.69$ ,  $p = 0.03$ ), though the timing of incidents differed between wolf attacks on humans and on livestock. Attacks on livestock were most likely to happen during the night ( $\chi^2 = 15.61$ ,  $p < 0.001$ ). Attacks on people were most likely to happen during day (64%,  $n = 35$ ) ( $\chi^2 = 9.58$ ,  $p = 0.002$ ). Almost

**Fig. 2** Data series represent the conflict types (not the total damage given by wolves or humans) separated into attacked parties and months of incidents ( $n = 234$ )







**Fig. 3** Spatial distribution of wolf–human conflicts between 2004 and 2016, and spatial demonstration of hot and cold spots of conflicts in Turkey with the confidence intervals (90% to 99%)

all attacks on dogs happened during the night. There was no monthly temporal difference in terms of total number of incidents ( $\chi^2 = 18.7$ ,  $p = 0.066$ ,  $df = 11$ ), but there was a seasonal difference among types of the conflict. For example, damage to livestock mostly occurs during mostly autumn (38%) and winter (24%) ( $\chi^2 = 15.72$ ,  $p = 0.0012$ ,  $df = 3$ ), peaking during October (Fig. 2).

### Preventive measures

Most attacks on sheep and goats occurred in open lands, sheepfolds, and corrals near to temporary settlements on high plateaus (86.9%, Table 2). There were only 11 wolf attacks in properly protected barns with dogs and fences (10% of total attacks). The lowest wolf depredation rates ( $d$  = sheep and goat loss per wolf attack) occurred in properly protected barns ( $d = 29.5$ ) and partially protected open lands ( $d = 25.6$ ) compared to highest depredation rates in open lands without protection ( $d = 59.8$ ) and in protected corrals or sheepfolds ( $d = 70$ ) (Table 2).

Livestock guarding dogs were not present in 78.2% of domestic animal incidents and 91.4% of the wolf attacks on human incidents. While the average depredation rate on sheep and goats was 46.6, the depredation rates with the presence of LGDs ( $n = 26$  incidents) and without LGDs ( $n = 87$  incidents) were 20.8 and 52.1, respectively. However, the presence of LGDs did not change the damage rate significantly at  $p < 0.05$  ( $t$  value = 1.75,  $p = 0.083$ ). Of the 136 wolf attacks to livestock

reported, 79 attacks (58%) were done by single wolf, and 59 attacks (42%) involved two or more wolves. Wolf packs attacking dogs, sheep, and goats consisted of 4.77 wolves on average (ranging from 2 to 11).

### Discussion

Wolf–human conflicts ( $n = 234$ ) reported by the media in the last decade were generally in a negative tone, but they did not demonize the wolf as seen in Nordic countries (Linnell et al. 2002), probably because of the positive attitude toward wolves in shamanic culture in the Turkish past (Ambarlı 2013) and myths telling that wolves led Turkish people out of central Asia (Worringer 2016). Besides, media tend to report speculations, negative events, and exaggerations. The wolf depredation rates on domestic animals and the number of conflicts were higher in eastern Turkey compared to the western half. The most prominent reasons are sheep and goat numbers in flocks are almost double in size (200) in the east, and they mostly graze on open lands (Kaymakçı and Cengiz 2010), and they stay outside during night hours while wolf densities are also higher in that region (Ambarlı et al. 2016). Besides, rabid wolf attacks were much more common in eastern Turkey because there was no vaccination against the wild canids and feral dogs that can aggregate at dump deposition areas and transmit the rabies. Eastern Turkey, which has borders with five countries, is the hotspot of wolf–human

**Table 1** Total number of sheep and goats (a), total number of killed animals (b), total number of wolf attacks on sheep and goats (c), wolf depredation rates (average number of killed animals per wolf attack, d) according to total number of sheep and goats and years between 2004 and 2016, and percentages (%) of killed animals every year to the total number sheep and goats every year

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Averages
(a) Total number of sheep and goats (million)	31.8	31.8	32.3	31.7	29.6	26.8	29.3	32.3	35.8	38.5	41.5	41.9	41.3	34.2
(b) Total number of killed animals	70	219	194	245	139	306	367	486	546	683	570	795	519	395.3
(c) Total number of wolf attacks	1	3	3	8	5	7	10	10	11	13	10	18	13	8.6
(d) Depredation rate % of “b” to “a”	70	73	64.7	30.6	27.8	43.7	36.7	48.6	49.6	52.5	57	44.17	39.9	49.17
	2.2E-04	6.9E-04	6.0E-04	7.7E-04	4.7E-4	1.1E-03	1.2E-03	1.5E-03	1.5E-03	1.8E-03	1.4E-03	1.9E-03	1.3E-03	1.1E-03

**Table 2** The average number of sheep and goat individuals predated per wolf attack (d) according to place and types preventive measures implemented

	Unprotected	Partially protected	Protected
Open land	59.8 ( <i>n</i> = 42)	25.6 ( <i>n</i> = 9)	31.8 ( <i>n</i> = 4)
Corral or sheepfold	45.4 ( <i>n</i> = 5)	38.8 ( <i>n</i> = 22)	70.0 ( <i>n</i> = 11)
Barn or stable	16.5 ( <i>n</i> = 2)	0 ( <i>n</i> = 1)	29.5 ( <i>n</i> = 11)

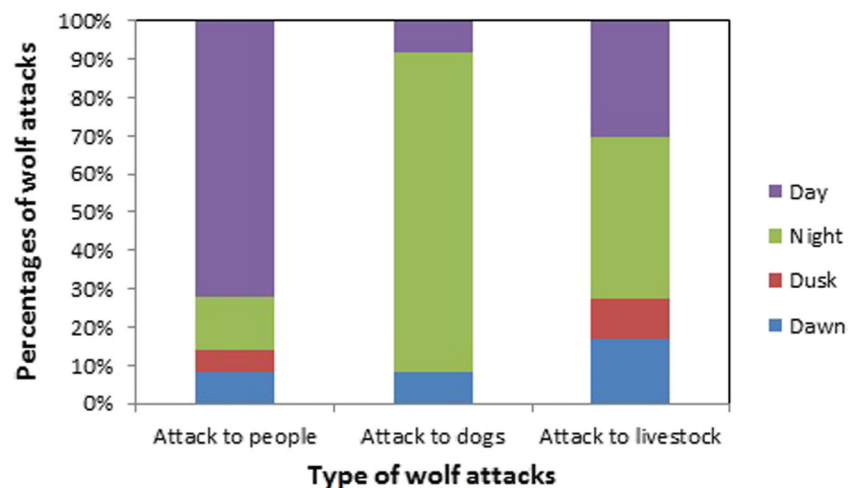
The numbers in parentheses represent the number of wolf attacks for nine different scenarios. Partially protected option represents improper preventive measures or missing ones (e.g., low number of dogs, and corrals in low height or without a proper door)

conflicts (Fig. 3). This is why transboundary management actions should be implemented to decrease livestock losses (e.g., in Georgia and Iran) and rabid wolf-related human casualties also in neighboring countries. Even if rabid wolf attacks were very scarce compared to more than 100,000 dog bites per year in Turkey (Aidoros 2015), and feral dogs caused rabies much more than wolves (Buzgan et al. 2009), the negative perception of people is generally dominated by wild animal attacks (Roskaft et al. 2003).

### Attacks on domestic animals and wolves

More than 5000 sheep and goats killed by wolves in the last decade, causing economic losses for farmers (who lost ca. 395 sheep and goats per year), but still, this average number of losses remains a low proportion (0.0012%) of the total yearly average number of sheep and goats in Turkey in the last decade (34.7 million) (TÜİK 2017) (Table 1). Although the total number of livestock has been increasing since 2009, the number of attacks on livestock had a stable trend (Table 1). The domestic animals killed by wolves were mainly calves of cattle in North America (Treves et al. 2002), Italy (Dondina et al. 2015), Spain (Llaneza and Lopez-Bao 2015), and Portugal (Pimenta et al. 2017) whereas it is mainly sheep and goats (79.3%) in Turkey as similar to Pakistan (88.2%; Hamid et al. 2019) and Iran (92%; Meinecke et al. 2018).

Livestock are most vulnerable during the night in Turkey, similar to Slovenia (van Liere et al. 2013), and the number of wolf-caused injuries and deaths were higher in autumn and winter than other seasons. Attacks on wolves by humans and attacks on dogs by wolves mostly occurred during winter when wolves cannot find wild prey and come down to city centers, especially in eastern Turkey to feed on anthropogenic foods and livestock carrion at dump deposition areas (Capitani et al. 2016). The highest number of human–wolf conflicts happened in 2011 (14.1%, *n* = 33; Fig. 1). The reason was probably related to extreme snow depth in winter and many cold days in summer of that year mainly in eastern Turkey (Sensoy et al. 2012).

**Fig. 4** Time of the wolf–human conflicts

### Rabies and wolf attacks on humans

Rabies in Turkey is more common and widespread than Europe (Johnson et al. 2013) mainly because there are a high number of feral dogs as potential vectors of rabies with foxes. Furthermore, feral dogs and foxes were not vaccinated against rabies in Eastern and Central Anatolia contrary to Aegean Region (Johnson et al. 2013). The number of human casualties and wounded people caused by rabid wolves was higher in Turkey compared to neighboring Iran (Behdarvand and Kaboli 2015). Attacks on humans by wolves without rabies occurred mostly after provocation by either LGDs or humans in an attempt to kill or frighten the wolves. There was no evidence for predatory wolf attacks on humans in Turkey contrary to neighboring Iran (Behdarvand and Kaboli 2015) and North America (Linnell et al. 2002). Although Western Iran and Eastern Turkey share similar environmental conditions, most wolf attacks on humans in Iran were on children (12 years old or lower, 62%) and predatory (67%) (Behdarvand and Kaboli 2015) contrary to Turkey where wolf attacks were mostly on adults (older than 18 years, 71.8%) and related to rabies (63.8%). Wounded people were mostly harmed on their hands and heads (Kuvat et al. 2011).

Ongoing rabid wolf incidents are concerning and mitigations are hard to be taken because of (1) lack of educated personnel in rural areas, (2) no control on feral dog populations, and (3) no control over on accessibility to waste food resources of feral dogs and wolves. Animal welfare organizations in Turkey are strongly defending feral dogs' rights by organizing big meetings and rallies, and do effective lobbying against the culling of feral dogs by using media, public relations, and close political relationships in the parliament (Ambarlı et al. 2016). Moreover, in Eastern Anatolia, there are no integrated waste disposal systems which can prevent access of wolves and other canids to anthropogenic food at dumps, and their interactions (Ambarlı et al. 2016), and decrease the habituation to humans (Linnell et al. 2002; Behdarvand and Kaboli 2015).

### Preventive and damage mitigation measures

People in Turkey suffer much higher rates of wolf damage to humans and livestock than neighboring countries (e.g., Iran, Hosseini-Zavarei et al. 2013; Meinecke et al. 2018) and some EU countries with sustainable wolf populations (Gula 2008; Kaartinen et al. 2009; Dondina et al. 2015) and North American countries (McNay 2002; Stone et al. 2017) probably due to recovery of wolf populations, ineffective preventive measures against wolf damage, and protection status of the species (Ambarlı et al. 2016). Use of corrals, shotguns, and LGDs were the preventive measures reported from the incidents. These measures are aged and not evidence based as it was revealed in other parts of the world (Stone et al. 2017; van Eeden et al. 2018). Villagers and shepherds do not have enough knowledge about effective preventive measures such as number of LGDs needed and avoidance of grazing in risky periods. Not using such crucial knowledge by the new generation of farmers such as in Georgia led to a higher percentage of wolf damage (Kikvidze and Tevzadze 2015). The number of LGD guarding the flock did not change the number of killed livestock significantly, probably due to presence of untrained LGDs and/or insufficient LGDs for big flocks as was shown in Greece by Iliopoulos et al. (2009). Besides, untrained LGDs can also lead to more sheep losses because they can be responsible for some depredation on livestock (20%) as revealed in Estonia (Plumer et al. 2018).

The sheep and goat loss per wolf attack was much higher (46.6 per attack) compared to other studies in Eurasia:  $3.3 \pm 2.8$  individuals per attack in Iran (Meinecke et al. 2018), 3.1 individuals per attack in the Pamirs of northwestern China (Wang et al. 2018), and less than four individuals per attack in Greece (Iliopoulos et al. 2009) and Slovakia (Rigg et al. 2011). However, this can be also related to the depredation news not reporting incidents when a few livestock kills, lack of effective protection, and higher numbers of flock sizes in

Turkey (Kaymakçı and Cengiz 2010). Therefore, our database was conservative in estimating the number of livestock kills. Thus, the total damage given by wolves in Turkey may be underestimated whereas the depredation rates on sheep and goats may be overestimated.

Damage to livestock can be decreased effectively by using high fences, electric fences (> 1.5 m), and fladry barriers, according to a recent study at the global scale (van Eeden et al. 2018). I found no evidence of the use of these measures in practice to prevent from wolf damage in Turkey. Although some local studies report opposing results (Rigg et al. 2011; van Liere et al. 2013) and wolf attacks to livestock cannot be prevented completely in open lands, still, using such fences can be promoted around corrals and barns in addition to trained LGDs active during the night time to reduce wolves' depredation rates. Besides, further research on effective preventive and mitigation measures should be supported by the Department of Wildlife. As higher damage was experienced in open lands during crepuscular hours, shepherds should graze livestock only during the daytime with the help of effective LGDs to avoid high depredation rates. Finally, more knowledge and a better understanding of human–wolf conflict are necessary to take effective measures. Therefore, a national or internationally coordinated human–wildlife conflict database should be established to assess the real dimension of conflicts and damage especially at the transboundary regions similar to Eastern Turkey.

## Conclusion

Human–wolf conflicts had high rates in Turkey compared to neighboring countries in the East or European countries in the West due to high population size of wolves, large flock size of livestock, usage of aged methods to protect livestock, and higher incidences related to rabid wolves. News reports had negative tone about the conflicts but no demonization, owing to cultural significance of the species. Wolves without rabies had predatory attacks to sheep or goats but not to humans or cattle. Several actions need to be taken to decrease the incidents, such as avoiding grazing during night when most of the attacks took place, keeping sufficient number of trained LGDs, promoting insurance to compensate losses. Additionally, rabid canid attacks and potential vector of rabies can be prevented by implementing a vaccination program for feral dogs and wild canids in the Eastern Anatolia to eradicate rabies and reduce the disease transmissions including neighboring countries. Finally, collecting conflict data in a database and on-site research on effective preventive measures are necessary to fully understand the attacks and develop mitigation. Along with the current insurance system for wolves and other carnivores, a damage compensation system similar to the EU countries can be offered to remedy the conflict.

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