Global Ecology and Conservation 27 (2021) e01618

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Human-caused mortality of large carnivores in Iran during 1980–2021

Jamshid Parchizadeh*, Jerrold L. Belant

Global Wildlife Conservation Center, State University of New York College of Environmental Science and Forestry, Syracuse, NY 13210, USA

ARTICLE INFO

Article history:
Received 14 March 2021
Received in revised form 2 May 2021
Accepted 2 May 2021
Available online xxxx

Keywords:
Cause
Human
Iran
Large carnivore
Mortality
Pattern

ABSTRACT

Human-caused mortality is the main cause of death for large carnivores worldwide and has had serious adverse effects on their populations. Detailed quantitative information on potential causes and patterns of mortalities are vital for development of effective conservation strategies. We investigated human-caused large carnivore mortalities across Iran using reports provided by Iran's Department of the Environment (DOE) during January 1980–January 2021, which comprised 399 mortality instances involving 443 carnivore deaths. Brown bears (*Ursus arctos*) had the highest frequency of occurrence (30%), followed by striped hyenas (*Hyaena hyaena*; 24%), and Persian leopards (*Panthera pardus saxicolor*; 17%). Overall, mortalities related to agricultural (i.e. livestock, or crops including plants, fruits, beehives) loss occurred more frequently (31%) than mortality related to illegal trade (21%) and risk to humans (7%). Specifically, brown bears were killed more frequently due to potential threats to human life and crops, whereas leopards and wolves were killed more often because of livestock depredations. Additionally, leopards were killed more frequently for illegal trade of their skins. We recommend the DOE improve local communities' attitudes toward large carnivores by promoting conservation education programs and incentive compensation schemes, as well as implement mitigation measures (e.g. wildlife crossing structures or fencing) at road mortality hotspots to prevent unnecessary deaths of large carnivores in Iran.

1. Introduction

Large carnivores are necessary for the maintenance of biodiversity and ecosystem function (Ripple et al., 2014), and their conservation relies heavily on maintaining their populations within protected areas (Brashares et al., 2001). However, carnivores are wide-ranging and seldom confined within the boundaries of protected areas, often resulting in conflicts with people (Ripple et al., 2014) with considerable socio-economic costs (Treves and Karanth, 2003; Thirgood et al., 2005). Consequently, large carnivore-human conflicts have become one of the greatest threats to carnivore populations worldwide (Fuller, 1989; Noss et al., 1996; Woodroffe and Ginsberg, 1998; McLellan et al., 1999; Woodroffe, 2001).

Carnivores conflict with humans for numerous reasons which often result in intentional or accidental killing (Bischof et al., 2009; Swanepoel et al., 2015). Intentional killing may occur as a result of legal hunting or when people perceive carnivores as a direct threat to human life or property (e.g. livestock and crops including plants, fruits, beehives; Treves and Karanth, 2003;

* Correspondence to: Third Floor Zartoshtian Alley, Hafez Street, City of Tehran, Tehran Province, Iran.
E-mail addresses: Jamshid.Parchizadeh@gmail.com (J. Parchizadeh), jbelant@esf.edu (J.L. Belant).

https://doi.org/10.1016/j.gecco.2021.e01618
2351-9894/

Frank et al., 2005; Miquelle et al., 2005; Rabinowitz, 2005; Penteriani et al., 2016; Garrote et al., 2017). For example, brown bears (*Ursus arctos*) damage crops (Ambarli, 2006; Ohta et al., 2012; Hipolito et al., 2020) more frequently than predation on livestock (Ambarli and Bilgin, 2008; Majić et al., 2011). Additionally, brown bears can injure or kill humans (Garrote et al., 2017; Støen et al., 2018; Kudrenko et al., 2020). In contrast, leopards (*Panthera pardus*) and gray wolves (*Canis lupus*) are more frequently responsible for livestock depredations (Behdarvand et al., 2014; Ghoddousi et al., 2020; Akrim et al., 2021), which may result in their persecution through retaliatory killing (Ghoddousi et al., 2016, 2020).

Illegal trade of carnivores also occurs for medicinal use, clothing, and household decorations (Sillero-Zubiri and Laurenson, 2001; Loveridge et al., 2010; Mondol et al., 2015; Nijman et al., 2019). Due to large profits (about US$20 billion annually), limited enforcement, and judicial disincentives surrounding illegal trade (Loveridge et al., 2010; Mondol et al., 2015), poaching of carnivores has increased, particularly for spotted cats (Sillero-Zubiri and Laurenson, 2001). Consequently, commercial poaching can increase the total mortality in carnivore populations (Creel and Rotella, 2010; Liberg et al., 2011; Creel et al., 2015), limiting their abundance and increasing local extinction risk (Woodroffe and Ginsberg, 1998; Woodroffe et al., 2005; Balme et al., 2010; Murray et al., 2010).

Six large carnivore species occur in Iran: Asiatic black bear (*U. thibetanus*), Asiatic cheetah (*Acinonyx jubatus venaticus*), brown bear, gray wolf, Persian leopard (*P. p. saxicolor*), and striped hyena (*Hyaena hyaena*; Ghadirian et al., 2017; Khorozyan et al., 2017), each of which are subject to human-caused mortality though they are not hunted species (Naderi et al., 2018; Parchizadeh et al., 2018). Detailed information on potential causes and patterns of mortalities are needed for understanding population dynamics of large carnivores (Thapa, 2014), which can facilitate development of effective conservation strategies (Muntifering et al., 2006). We investigated patterns in human-caused large carnivore mortalities in Iran. We predicted that the frequency of killing large carnivores would vary across species based on relative risk to humans and agricultural (i.e. livestock, or crops including plants, fruits, beehives) losses, and that intentional killing of carnivores would occur more frequently than accidental killing. Specifically, we predicted that brown bears would be killed more often due to potential threats to human safety and damage to crops, whereas leopards and wolves would be killed more frequently because of livestock depredation. We further predicted that leopards would be killed more often for illegal trade because of their furs' high value. Finally, we summarized whether mortalities were intentional or accidental and the primary means by which large carnivores were killed.

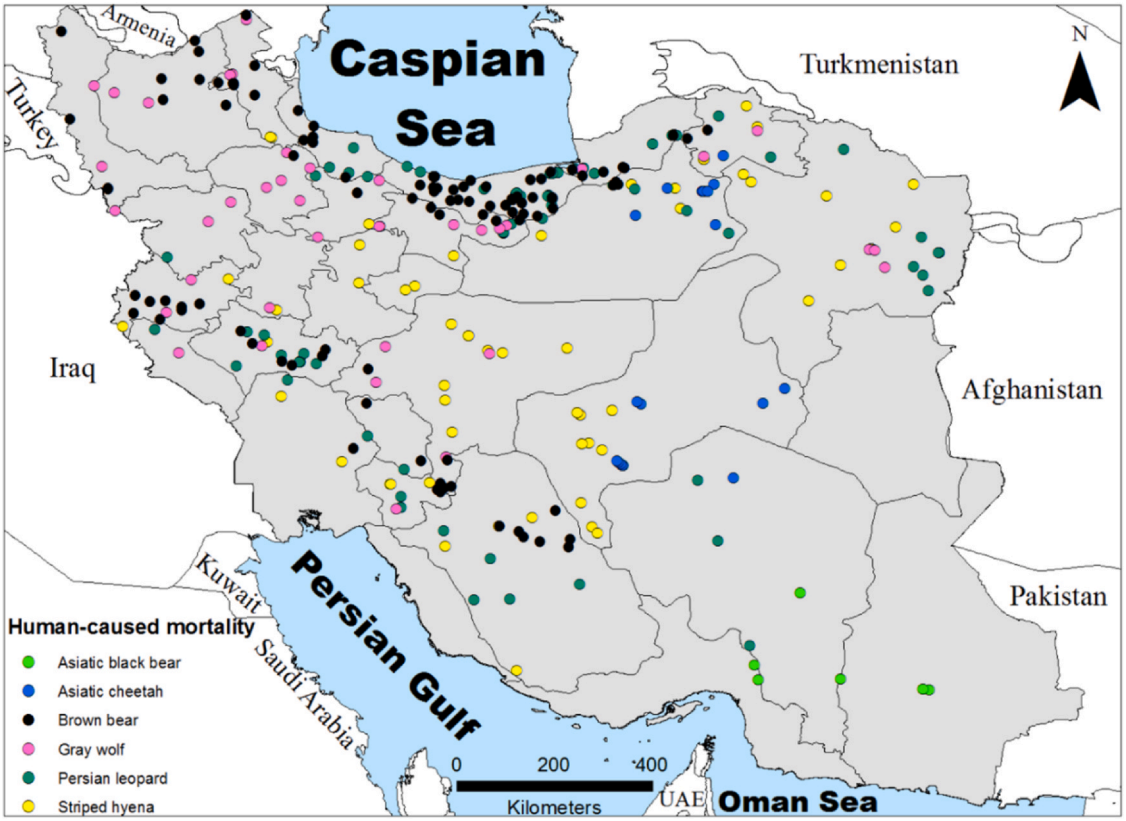

Fig. 1. Locations of human-caused mortality of large carnivores, Iran, January 1980–January 2021.

2. Materials and methods

2.1. Study area

Iran comprises 1,648,195 km^2 in southwestern Asia (25–40°N, 44–64° E), containing 31 provinces (Fig. 1). Major mountain ranges include the Alborz and Zagros which occur across the northern and western parts of Iran, respectively (Raziei et al., 2005). Elevations vary from 28 m below sea level to 5,610 m above sea level (Heshmati, 2007). The climate is continental with hot, dry summers and cold winters. Mean monthly temperatures range from 6.5 °C in January to 31 °C in July (Iran Meteorological Organization, 2021). Annual rainfall decreases from 1800 mm in the north to <100 mm in central arid regions (Modarres and Sarhadi, 2011).

2.2. Data collection

We conducted a Farsi gray literature search for human-caused mortality of large carnivores in Iran using the Google web search engine to access and compile all relevant material confirmed, published, and disseminated by provincial offices of Iran's Department of the Environment (DOE) during January 1980–January 2021. Species included black bear (equivalent Farsi words are خرس سیاه بلوچی, خرس سیاه اسیایی, and خرس سیاه), cheetah (یوزپلنگ ایرانی, یوزپلنگ اسیایی, and یوزپلنگ), brown bear (خرس قهوه ای and خرس), wolf (گرگ خاکستری and گرگ), leopard (پلنگ ایرانی and پلنگ), and hyena (کفتار راه راه and کفتار). We used the search terms: "common species name" + "mortality/fatality/casualty/illegal killing/poaching (شکار غیر قانونی/کشته شدن/تلف شدن/مرگ)" for each species. We did not include mortalities involving rabid carnivores, as their behaviors are likely atypical (Bombieri et al., 2018). When multiple sources for a mortality were identified, we selected up to two sources that contained the greatest amount of information. We reviewed and compared each source to prevent duplicate records in our dataset. We did not have access to DOE's complete large carnivore mortality database.

We defined conflict between humans and large carnivores as when the needs and behavior of carnivores impact negatively on the goals of humans, or when the goals of humans negatively impact the needs of carnivores (Madden, 2004; Krafte Holland et al., 2018).

We compiled several variables for each mortality when available, including species, number of large carnivores killed, and their gender (male, female, or unknown). We categorized age classes of large carnivores as dependent young (dependent animal that is typically with mother; <1 year old), juvenile (independent animal younger than typical reproductive/breeding age; 1–2 years old), adult (independent animal of reproductive/breeding age; >2 years old), or unknown. We classified mortalities as intentional (i.e. illegally shot, poisoned, stoned, trapped, and herding dogs), accidental (i.e. car collision, train collision, and management related), and unknown. We categorized primary cause of mortality as risk to human, agricultural loss, for illegal trade, other, and unknown. We also recorded time of day (day, night, or unknown), month, and year the mortality occurred. Finally, we estimated when possible the geographic location of each mortality (typically within 5 kilometers), plotted them using ArcGIS 10.3 (ESRI, Redlands, CA) and summarized mortalities by province.

We used two-way χ^2 tests to compare differences in the frequency of human-caused large carnivore mortalities by gender and age class, type of mortality (i.e. intentional and accidental killings), primary cause of mortality, time of day, and month. We used α of ≤0.05 to denote statistical significance.

3. Results

We documented 399 reported mortality instances involving 443 large carnivore deaths. Brown bears had the highest frequency of reporting (30%), followed by hyenas (24%), and leopards (17%; Fig. 2a). Overall, mortalities related to agricultural loss occurred more frequently (31%; $\chi^2 = 69.3$, d.f. = 15, $p = 0.01$) than mortality related to illegal trade (21%) and risk to humans (7%; Fig. 2b). Among carnivore species, brown bears were most frequently killed because of potential threat to humans (57%) and damage to crops (96%). In contrast, cheetahs (46%), leopards (33%), and wolves (21%) were killed due to threats to livestock (Table S1). Leopards (42%, $n = 13$) were poached more often because of their furs.

Intentional killing of carnivores occurred more frequently (63%; $\chi^2 = 63.2$, d.f. = 5, $p = 0.01$; Table S1) than accidental killing. Among intentional killing categories, shooting carnivores had the greatest occurrence (75%; $n = 187$), whereas car collision was the most important cause of accidental killing (95%; $n = 139$). Specifically, brown bears and leopards experienced more losses from shooting (42% and 23%, respectively; Fig. 2c), whereas hyenas (47%) and cheetahs (17%) were killed more often due to car collisions (Fig. 2d).

There was no difference between the number of females and males killed (54%; $\chi^2 = 1.5$, d.f. = 5, $p = 0.92$); with females representing 52% of brown bear, 54% of leopard, and 61% of cheetah mortalities (Fig. 3a). Adult large carnivores were killed more frequently (59%; $\chi^2 = 19.6$, d.f. = 10, $p = 0.03$) than were dependent young (25%) or juveniles (16%). Fifty-three percent of brown bears killed were adults, followed by leopards with 63% adults, and cheetahs with 59% adults (Fig. 3b).

Anthropogenic mortalities during the day occurred about 1.5-fold more often than at night (59%; $\chi^2 = 37.9$, d.f. = 5, $p = 0.01$). Among carnivore species, brown bears were killed more frequently during the day with 45%, whereas hyenas were killed more often at night with 27% (Fig. 3c).

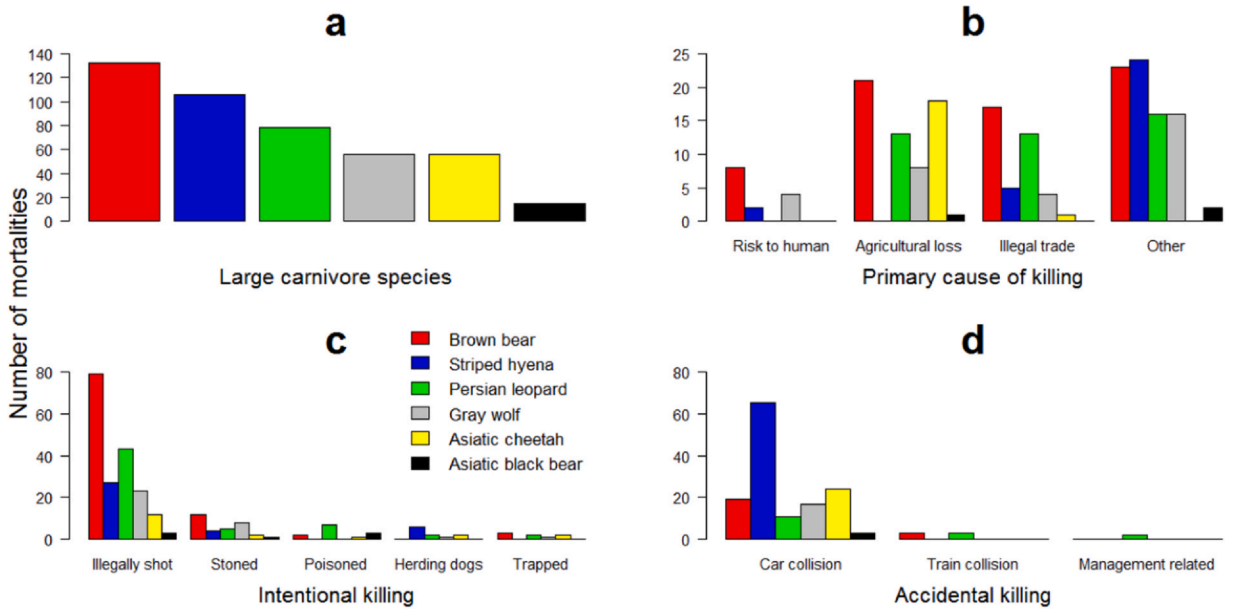

Fig. 2. Number of human-caused mortality of large carnivores by species (a), primary cause of killing (b), intentional killing (c), and accidental killing (d), Iran, January 1980–January 2021.

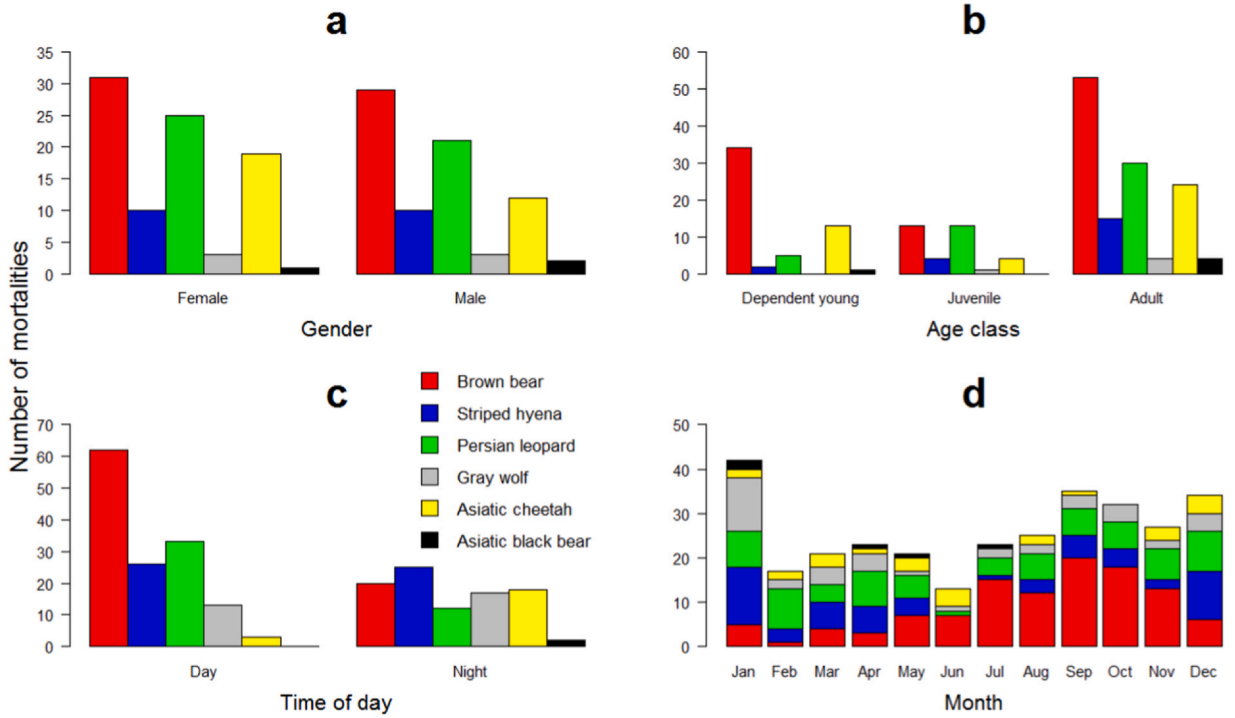

Fig. 3. Number of human-caused mortality of large carnivores by gender (a), age class (b), time of day (c), and month (d), Iran, January 1980–January 2021.

More mortalities occurred during January than during other months (13%, $n = 42$; $\chi^2 = 104.4$, d.f. = 55, $p = 0.01$; Fig. 3d). Reported mortalities were low from 1980 to 2007, then reached a peak to 68 (17%) mortalities in 2018 (Fig. 4). Except for Bushehr province, all other provinces of Iran ($n = 30$) experienced human-caused large carnivore mortalities with Mazandaran having the greatest occurrence (12%, $n = 48$), followed by Yazd (10%, $n = 39$), and Razavi Khorasan (9%, $n = 35$; Table S1).

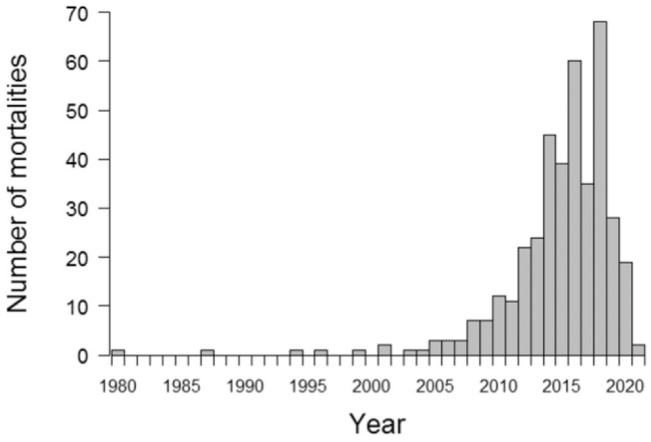

Fig. 4. Number of human-caused mortality of large carnivores by year, Iran, January 1980–January 2021.

4. Discussion

Our predictions of patterns influencing human-caused mortality of large carnivores in Iran were largely supported. Our results indicated that the frequency of killing large carnivores varied across species, based on relative risk to people, livestock, and crops, and that intentional killing of carnivores occurred more often than accidental killing. We further discovered that brown bears were killed more frequently due to potential threats to human safety and damage to crops, whereas leopards and wolves were killed more often because of livestock depredation. We also found that leopards were killed more frequently for illegal trade of their skins.

Brown bears were killed more frequently due to potential threats to human life and damage to crops. This pattern was probably associated with attractants (i.e. anthropogenic food; Wilson et al., 2005, 2006) on agricultural lands resulting in potential ecological traps (Nielsen et al., 2006; Northrup et al., 2012; Steyaert et al., 2016), due to risky encounters with people and increased human-caused mortality. We recommend that the DOE consider working with local residents toward removing or protecting attractants using non-lethal techniques (Wilson et al., 2005). For example, beehive depredation can be reduced substantially through use of electric fencing and solar powered options are available (Wilson et al., 2005). Furthermore, local people could also implement husbandry practices that limit potential interactions with bears, such as proper storage of agricultural attractants. Outdoor recreationists can avoid dense vegetation or make noise to warn bears of their presence when in bear habitats (Støen et al., 2018).

Leopards and wolves were killed more often due to livestock depredations. Leopards and wolves commonly depredate livestock (Farhadiniaa et al., 2017b; Khorozyan et al., 2017) which can include surplus killing that exacerbates human intolerance of these species (Muhly and Musiani, 2009; Khorozyan et al., 2017; Iliopoulos et al., 2019) and likely increased human-caused mortality. Additionally, leopards are a wide-ranging large carnivore that occurs mainly outside protected areas where the potential for conflict with humans is high (Kiabi et al., 2002; Jacobson et al., 2016). For example, agricultural lands on the periphery of core habitats with readily accessible livestock can attract leopards and increase the probability of livestock depredation (Abade et al., 2018). Furthermore, we found that 42% of cheetahs in our study were killed by local herders due to threats to livestock. There are no known records of cheetah depredation on livestock in Iran (Farhadinia et al., 2012, 2016), which suggests that this pattern may have occurred due to the cheetah being perceived by people as a threat to livestock (Farhadinia et al., 2017a) perhaps because cheetahs' appearance resembled that of leopards.

Leopards were killed more frequently for illegal trade of their skins, likely related to economic benefits for poachers. For example, leopard fur is used to manufacture clothing (Loveridge et al., 2010; Nijman et al., 2019), with customers paying up to 270 million Rials (~1000 USD) for a leopard skin in illegal markets inside and outside Iran (Khalaf-von Jaffa, 2017; Parchizadeh and Adibi, 2019). Poaching of wild felid furs including leopards increased with illegal market demand (Payan and Trujillo, 2006; Loveridge et al., 2010), which clearly resulted in increased human-caused mortality of these species. A possible solution to discourage illegal killing of this species is to increase enforcement efforts as well as charge the fine in USD instead of Rials because of the large difference between the value of these currencies (Parchizadeh and Adibi, 2019).

We found that mortalities occurred more often during the day, likely an outcome of the daily activity of humans (Bombieri et al., 2018), which in turn can increase probability of human-carnivore interactions. Furthermore, high frequency of mortalities in winter may suggest that carnivores, particularly leopards and wolves, were attempting to depredate livestock in proximity to humans (e.g. pens inside villages; Dar et al., 2009; Kabir et al., 2014; Iliopoulos et al., 2019; Akrim et al., 2021) and killed as a result. The increasing trend of mortalities across years was probably linked to increased use of internet by DoE for reporting mortalities.

We documented that illegal shooting of carnivores was most often intentional. Firearms are available to the public without serious obstacles from relevant Iranian authorities and also can be acquired illegally for 20–120 USD (Jamaran, 2018).

Additionally, all nomadic people across Iran are permitted to carry firearms to defend themselves and their livestock and crops from potential threats (Iranian Students' News Agency, 2020). Consequently, a large carnivore may be shot whether the human risk is real or perceived, which likely results in increased human-caused mortalities.

An important shortcoming of our dataset was mortalities that were not discovered (e.g. illegal kills) or not reported (e.g. due to the lack of interest by people) which may have introduced biases to our results. Consequently, the actual number of carnivore deaths was likely more than the number reported and documented in this study. We also note that access to DOE's complete large carnivore mortality database, including those not reported online, would have improved the quality of our database. We recommend that the DOE provide access to its large carnivore mortality database for researchers to improve our understanding of human-caused mortality.

Due to the limited accurate location data reported, we were unable to identify high-risk mortality locations which can be critical for species conservation. For example, vehicle collisions with carnivores can contribute substantially to population declines and accurate location data can be used to identify hotspots to mitigate this risk (Shilling and Waetjen, 2015; Sidorovich et al., 2020). Our small sample size ($n = 139$) and limited accurate geographic locations prevented us from identifying potential clusters of vehicle collisions with carnivores. Having accurate location data may have helped us develop models to identify factors increasing risk of large carnivore collisions with vehicles, including identification of hotspots (e.g. Parchizadeh et al., 2018). We recommend identifying high-risk collision locations as a priority to reduce large carnivore mortalities.

Human-caused mortality is the main cause of death for large carnivores outside (and even inside) protected areas which can have negative impacts on their population dynamics (Carter et al., 2017). Consequently, accurate documentation of human-carnivore conflict patterns helps target conflict resolution, and provides a baseline for subsequent management and mitigation measures (Morehouse and Boyce, 2017), which in turn can enhance persistence of large carnivore populations important to the stability and integrity of ecosystems (Murray et al., 1999; Estes et al., 2011). All six large carnivores in our study are protected species according to DOE laws and they are in need of management and conservation action plans (Sanei et al., 2012; Asadi Aghbolaghi et al., 2014; Ashrafzadeh et al., 2016; Fahimi et al., 2018; Farhadinia et al., 2018). We recommend the Iranian DOE consider creating and supporting long-term conservation education programs to improve the limited knowledge local people have about large carnivores (Lagendijk and Gusset, 2008), as well as promote incentive compensation schemes to help local communities with financial losses related to conflicts, which in turn can result in improving attitudes toward carnivores (Ravenelle and Nyhus, 2017). Additionally, implementing mitigation measures such as construction of wildlife crossing structures (i.e. underpasses and overpasses) or installation of fences at road mortality hotspots can further mitigate mortality risk of large carnivores in Iran.

CRediT authorship contribution statement

Jamshid Parchizadeh: designed the work, compiled, analyzed and interpreted the data, prepared the figures, and wrote the draft and final manuscripts. **Jerrold L. Belant**: designed the work, interpreted the data, and wrote final version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the Camp Fire Conservation Fund for support of this research.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2021.e01618.

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