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Conflicts Between Humans and Terrestrial Vertebrates: A Global Review

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Abstract

Conflicts between human beings and wild animals have been recorded in many parts of the world and mainly involve damage to crops, predation of domestic animals, and attacks on humans. This study presents, by means of a literature review, a worldview of such conflicts and their implications. The results found 262 species of terrestrial vertebrates recorded in conflicts with humans, of which 53 are included in the list of threatened species. The results indicated that damage to agricultural crops and attacks on domestic animals are the most common factors of conflicts and that socioeconomic factors seem to be correlated with their incidence. Studies aimed at finding more efficient ways to reduce conflicts and lessen the impact on animal populations are relevant to the search for a more peaceful coexistence between humans and wild animals.

Keywords

human–animal conflict, ethnozoology, animal predation, crop damage, human death, conservation

Introduction

Conflicts between humans and wild animals occur when the needs and behaviors of wildlife impact negatively the objectives of humans, or when the objectives of humans impact negatively the needs of wildlife (Dickman & Hazzah, 2016). As a response to such conflicts, affected people tend to persecute the species of wild animal involved. Persecution in the context of human–wild animal conflict is different from hunting itself because in hunting the hunter sees a product (meat, trophy, and sport), while in conflict, the aim is to threaten or eradicate the individual animal involved or even the species (Zimmermann et al., 2010). Hunting as means of defense against predators is generally carried out in response to conflicts caused by damage to domestic animals or crops, or in response to the danger that animals pose to people (Alves, Gonçalves, & Vieira, 2012; Alves et al., 2016). These conflicts have been recorded in various parts of the world, including terrestrial, aquatic, and aerial environments, and have involved a wide variety of animals (Torres, Oliveira, & Alves, 2018). In terrestrial environments, actions in response to conflicts occur when there is crop degradation, predation on livestock, competition between hunters and carnivores for game species, or even fear of attacks on humans (Conover, 2002). Retaliation may also occur in response to attacks on humans (Dunham, Ghiurghi, Cumbi, & Urbano, 2010; Fukuda, Manolis, & Appel, 2014; Fukuda, Manolis, Saalfeld, & Zuur, 2015), destruction of property (Dickman & Hazzah, 2016), and the transmission of diseases between wild animals and domestic animals, and even to humans (Craft et al., 2016; Dunham et al., 2010; Lavelle et al., 2011).

Hunting and deforestation are recognized as the main causes that lead predators to attack domestic animals (Leite-Pitman & Oliveita, 2002). Large terrestrial carnivores are more predisposed to conflict because they require space and resources often compromised by increased human dominance in landscapes (Zimmermann et al., 2010). Similarly, crop attacks by herbivores have mainly been due to the scarcity of natural food and habitat fragmentation (Freitas, Setz, Araújo, & Gobbi, 2008). Another relevant cause of conflict is

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competition for wild prey (Donázar et al., 2016; Thorn, Green, Scott, & Marnewick, 2013) and competition between wild animals and domestic animals for food in natural environments. Millions of wild ungulates, such as the Tibetan antelope, gaur, gunacos, bison, antelope, moose, and zebra share plant resources with cattle, camels, yaks, sheep, and goats (Wrobel & Redford, 2010). For these reasons, conflicts are considered an important threat to both biodiversity conservation and economic development worldwide (Lewis, Baird, & Sorice, 2016). However, on the one hand, the conflicts generate economic losses and severe damage for the people involved; on the other hand, rural producers, in an attempt to keep the number of wild animals low (Bennett, 2000), end up generating negative impacts to wild fauna through the hunting of species in retaliation for the damage caused, which may even result in drastic reductions to their populations. For example, due to their diversity and abundance, canids generate many conflicts with humans resulting in intense persecution, especially of large species whose populations have been drastically reduced in number and distribution (Boitani, Asa, & Moehrenschlager, 2004). The impacts of conflicts can be even more severe when they involve species that are threatened with extinction or that are already suffering from hunting pressure. Although some species of canids exhibit marked resilience to widespread and prolonged hunting, other species, such as *Dusicyon australis*—Falkland Island wolf, have been brought to extinction (Sillero-Zubiri, Reynolds, & Novaro, 2004). This fact evidences the importance of investigating the species involved in conflicts, the level of tolerance exhibited by the people affected by the conflicts, and the degree of predation of domestic animals and degradation to crops by wild species. Studies have shown that in many cases conflicts may be overestimated (Donázar et al., 2016; Macdonald, Loveridge, & Rabinowitz, 2010); thus, the first step in reducing negative perceptions is to discern and disclose the true extent of the threat to livestock (Zimmermann et al., 2010) as well as to crops and human life. In addition, it is necessary to understand the context that leads people to have a negative perception about a particular animal because, according to Naughton-Treves and Treves (2005), people's perception of conflicts can be affected by past events and by reports of conflicts by other people or communities.

Concerning attempts to mitigate conflicts, people tend to carry out translocations or lethal control of problem individuals, perform lethal or fertility control to reduce the population size of species, and change animal behavior through the use of provocative stimuli of fear and chemical repellents (Conover, 2002), among others. Financial compensation measures, as well as the use of nonlethal methods for mitigating conflicts, appear to be ecologically more interesting than the application of lethal methods, although studies are needed to prove their effectiveness in maintaining economic activities and conserving species.

Thus, studies that investigate the conflicts that exist between human populations and wild animals become relevant because they allow the assessment of whether there is a pattern in the occurrence of conflicts in regional and global contexts and identify those aspects that can increase people's tolerances in the face of such conflicts. In addition, the assessment of the influence of socioeconomic and environmental factors on the occurrence or intensification of conflicts can contribute substantially to efforts of species conservation by providing relevant data for decision-making, especially with regard to the implementation of action plans aimed at mitigating these conflicts and maintaining species.

In this way, this study sought to inventory the species of wild animals involved in terrestrial conflicts with people and that are caused by predation of domestic animals, damage to crops, or attacks on humans on a worldwide scale, and to analyze how the incidence of these conflicts are distributed across countries and continents. Therefore, we sought to answer the following questions: (a) Is the greater incidence of conflicts between people and wild animals in the world linked to the losses with the domestic animals predation? It is expected that the number of records of conflicts arising from the loss of domestic animals is greater than the number of records of crop damage and the number of records of attacks on people. (b) Are the socioeconomic indicators of countries predictive of the incidence of conflicts? It is expected that countries with lower Human Development Indexes (HDIs) and lower per capita incomes would be those where conflict records are concentrated. In addition, we sought to evaluate the distribution of publications on the theme over the years, the main species and taxonomic groups involved in the conflicts, and the similarity in richness of these species among continents.

Methods

Data Collection

Data were obtained from publications that recorded conflicts between humans and wild animals. The information was collected through the analysis of scientific articles published and available in the international online databases of *Scopus* and *Web of Science*, using the following word combinations: *human wildlife conflict* AND *crop damage*, *human wildlife conflict* AND *livestock predation*, *human wildlife conflict* AND *livestock depredation*, *human wildlife conflict* AND *human death* and *human wildlife conflict* AND *human dead*. The review involved consulting all scientific articles published on the subject until May 2017.

Criteria for Data Selection

Certain exclusion criteria were used in the selection of articles. Only articles that presented the scientific name of the wild species involved in the conflicts were included in the database. Thus, articles that only identified taxa to the generic level or reported only their popular name were excluded from the analysis. In addition, only articles that allowed the identification of the type of conflict, according to the following categories, were considered: (a) damage to crops, (b) predation of domestic animals, and (c) attack, injury, or death of human beings. Articles that did not provide the conflicting factor were also excluded from the analysis. The database generated from the collected articles contained information, such as the name of the conflicting species and type of conflict, and included whether the same species incited different conflicts simultaneously. The database also included information on the types of crops damaged, the domestic animals targeted for predation, and the number of attacks on people, as well as the number of deaths and injuries, when the information was provided by the articles. Data on the country of the conflict and the year of publication were also included.

Data Analysis

The scientific names of the species and their respective families are in accordance with the *Integrated Taxonomic Information System* (2017). The threat *Status* of the species was evaluated through the *Red List of Threatened Species* of the *International Union for Conservation of Nature* (IUCN, 2017). In order to identify the existence of a pattern in the distribution of the conflicts in the world relative to conflicting species richness per family, Non-Metric Multidimensional Scaling (nMDS) was performed through the Jaccard Similarity Coefficient. In addition, the *software ArcGis* 10.3 was used to map the distribution of conflicts throughout the world according to the number of conflicts registered by country and continent and by the three types of conflicts considered. In order to record the incidence of conflicts, the richness of species recorded as conflicting in the articles and the number of articles that recorded species in each country were considered. Normality of the data was assessed with the Shapiro–Wilk test (S–W). After confirming normality of the data, and with the objective of evaluating if there is a significant difference in the number of citations among the three types of conflicts investigated, an analysis of variance (*one-way* analysis of variance) was performed with the Tukey *post hoc* test. The Pearson correlation coefficient was used to evaluate whether socioeconomic indicators, such as the HDI and per capita income of the countries, are correlated with the incidence of conflicts. Statistical analyses were performed using the *software* PAST *Version* 2.17 (Hammer, Harper, & Ryan, 2001), Statistica 13.3 (StatSoft, 2017), and SPSS Versão 22 (IBM, 2013).

Results

In all, 473 scientific articles were compiled that dealt with the subject of conflicts between humans and wild animals and which fit the preestablished selection criteria. Analysis of the distribution of publications over the years revealed a considerable growth in the number of publications on the subject over the last 10 years because 87.31% of the publications were concentrated in this period (Figure 1).

The occurrence of conflicts was registered for 99 countries (Figure 2), of which 33 were on the Asiatic continent and 19 on the African continent, being the first and second continents, respectively, in the number of countries with published records of conflicts. Among the countries that had the greatest richness of wild species involved in the conflicts, countries from the continents of Africa and Asia were predominant. The 10 countries with the highest recorded species richness were Uganda ($n = 37$), Tanzania ($n = 35$), India ($n = 31$), United States ($n = 29$), Cameroon ($n = 20$), Nepal ($n = 20$), Australia ($n = 19$), Zimbabwe ($n = 18$), Ethiopia ($n = 17$), and Indonesia ($n = 17$). Antarctica was the only continent that had no studies indicating the occurrence of conflicts.

Regarding the incidence of recorded conflicts, the most noteworthy continents were Africa and Asia (Figure 3), and the 10 countries with the greatest incidence of recorded conflicts were, respectively, India ($n = 100$), Tanzania ($n = 88$), United States ($n = 86$), Uganda ($n = 85$), Kenya ($n = 50$), Nepal ($n = 47$), South Africa ($n = 39$), Japan ($n = 37$), Botswana ($n = 36$), and Indonesia ($n = 35$) (Figure 2). Analysis of the types of conflicts revealed that for crop damage, Uganda ($n = 82$), United States ($n = 53$), and Japan ($n = 37$) were most prominent (Figure 4). For predation on domestic animals, India ($n = 70$), Tanzania ($n = 55$), and Kenya ($n = 39$) had the greatest number of records (Figure 5), while the number of attacks on people was greatest for Nepal ($n = 26$), India ($n = 24$), and Tanzania ($n = 17$) (Figure 6).

A total of 262 species of terrestrial vertebrates (online Appendix 1) distributed among 56 families were recorded as wild species targets of conflicts in the world. Of the taxonomic groups involved in conflictual interactions, mammals and birds stood out in species richness. Among mammals were those of the order Carnivora, specifically the families Felidae, Canidae, and Ursidae, as well as herbivores of the families, Elephantidae and Cercopithecidae. The 10 families with the largest number of conflictual species were Cercopithecidae ($n = 35$), Felidae ($n = 27$), Bovidae ($n = 25$), Psittacidae ($n = 19$), Canidae ($n = 16$), Cervidae ($n = 12$), Anatidae

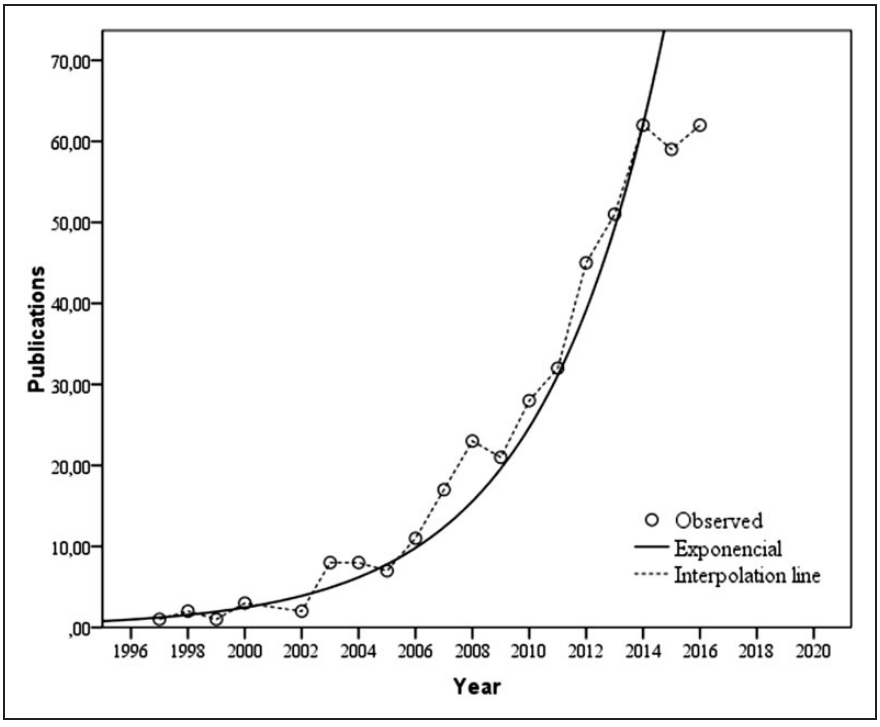

Figure 1. Temporal distribution of studies (until December 2016) on human–wildlife conflicts in the world.

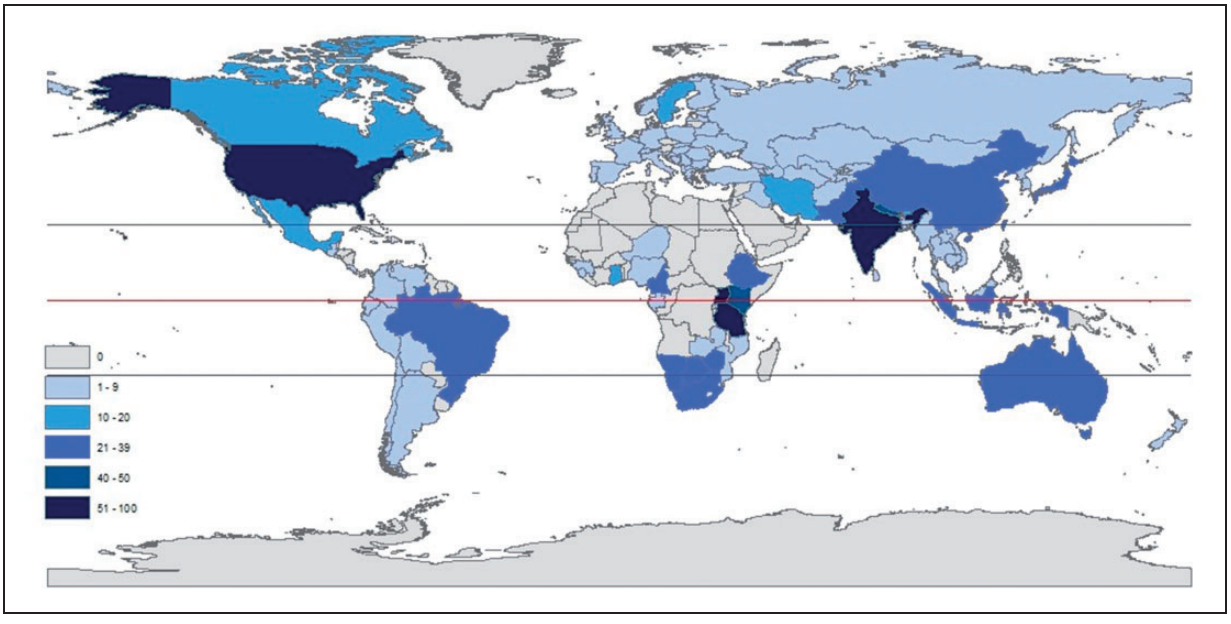

Figure 2. Distribution of human–wildlife conflicts incidence for countries in the world, considering the occurrence of the three types of conflicts investigated (predation of domestic animals, crop damage, and attacks on humans). The color scale indicates the incidence of conflicts, which considers the number of publications and species richness recorded for country.

($n = 10$), Ursidae ($n = 9$), Icteridae ($n = 8$), and Mustelidae ($n = 7$). The species recorded were distributed among three taxonomic groups: mammals ($n = 192$), birds ($n = 67$), and reptiles ($n = 3$), with mammals representing 73% of the species recorded. Of the mammals, 136 species were cited for damage to crops and 69 for predation of domestic animals (Figure 7). The species most frequently reported in the articles were leopard (*Panthera pardus*, 70

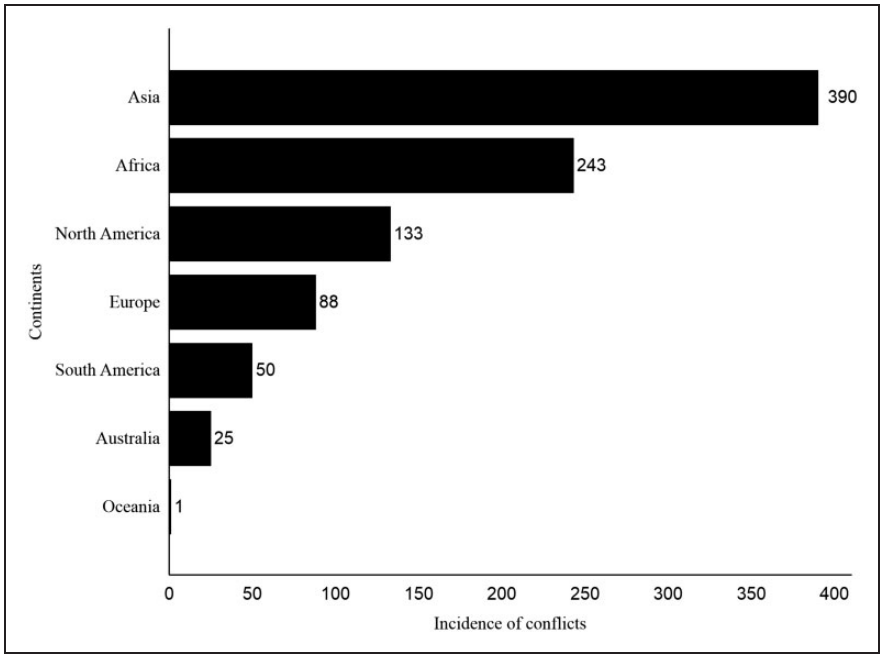

Figure 3. Distribution of human–wildlife conflicts incidence for continent, considering the occurrence of the three types of conflicts investigated (predation of domestic creations, crop damage, and attacks on humans). The incidence of conflicts considers the number of publications and species richness recorded for continent.

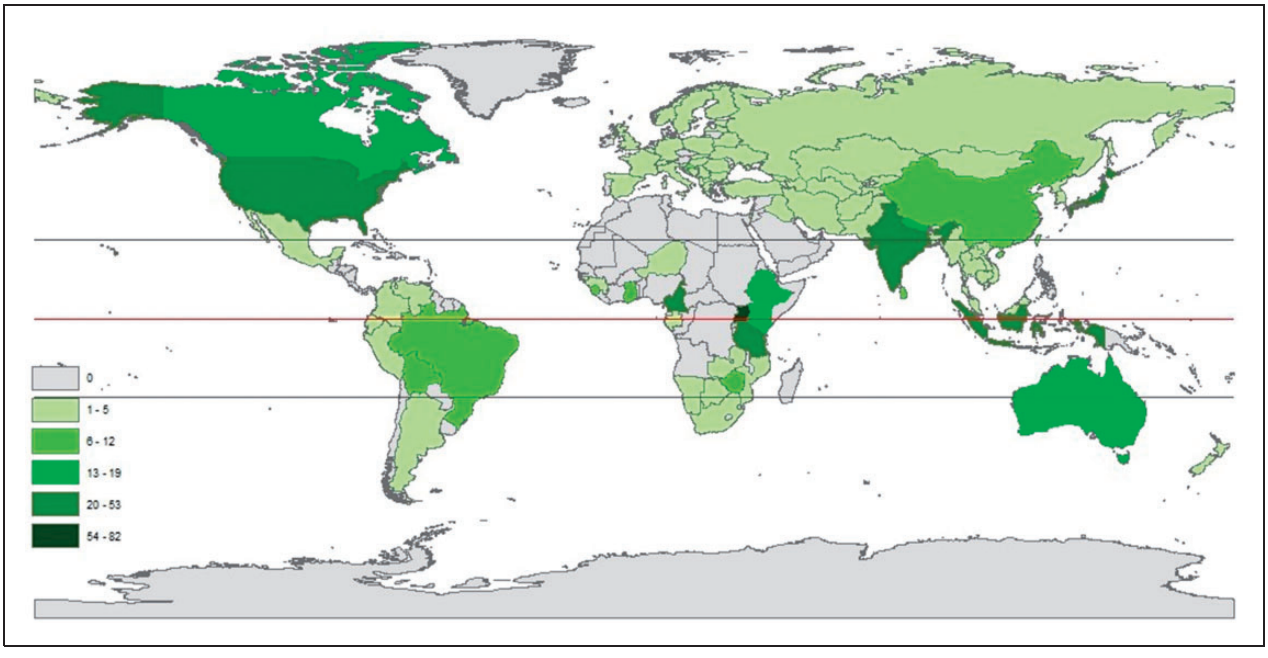

Figure 4. Distribution of human–wildlife conflicts incidence for country, caused by crop damages. The color scale indicates the incidence of conflicts, which considers the number of publications and species richness recorded for country.

studies), brown bear (*Ursus arctos*, 61 studies), wolf (*Canis lupus*, 54 studies), African lion (*Panthera leo*, 43 studies), wild boar (*Sus scrofa*, 43 studies), African elephant (*Loxodonta africana*, 40 studies), spotted hyena (*Crocuta crocuta*, 39 studies), tiger (*Panthera tigres*, 38 studies), Asian black bear (*Ursus thibetanus*, 33 studies), and cheetah (*Acinonyx jubatus*, 26 studies). It should be noted that the number of conflictual species is probably much greater than the richness obtained in this study due to the fact that some articles used popular names or the

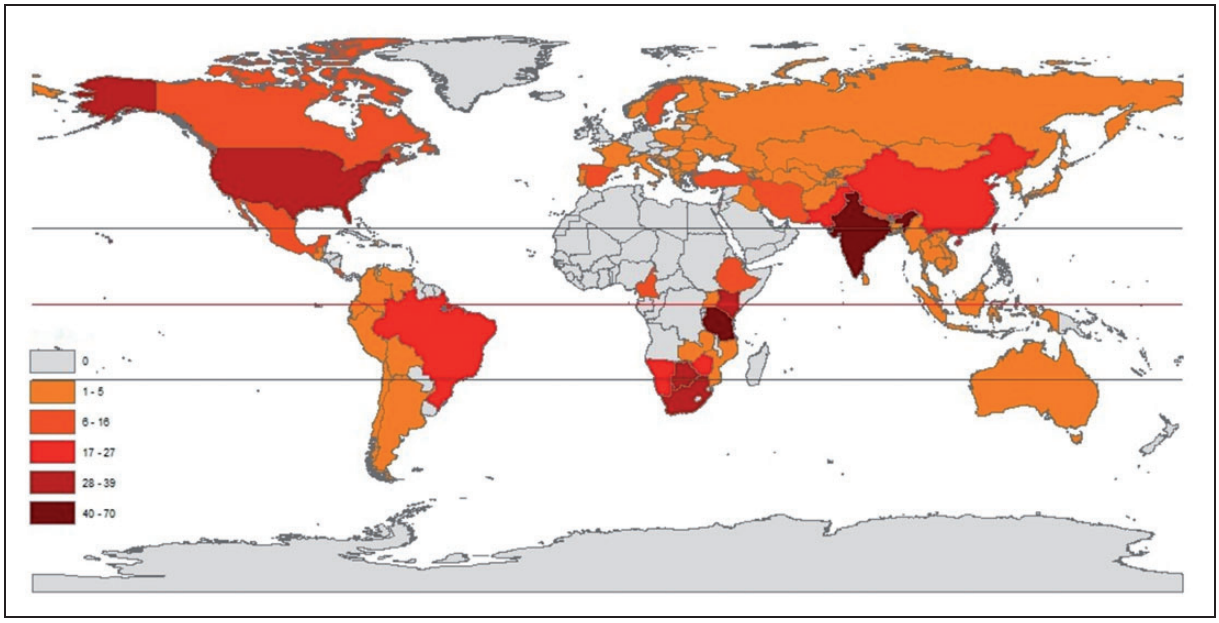

Figure 5. Distribution of human–wildlife conflicts incidence for country, caused by domestic animals predation. The color scale indicates the incidence of conflicts, which considers the number of publications and the wealth of species registered for country.

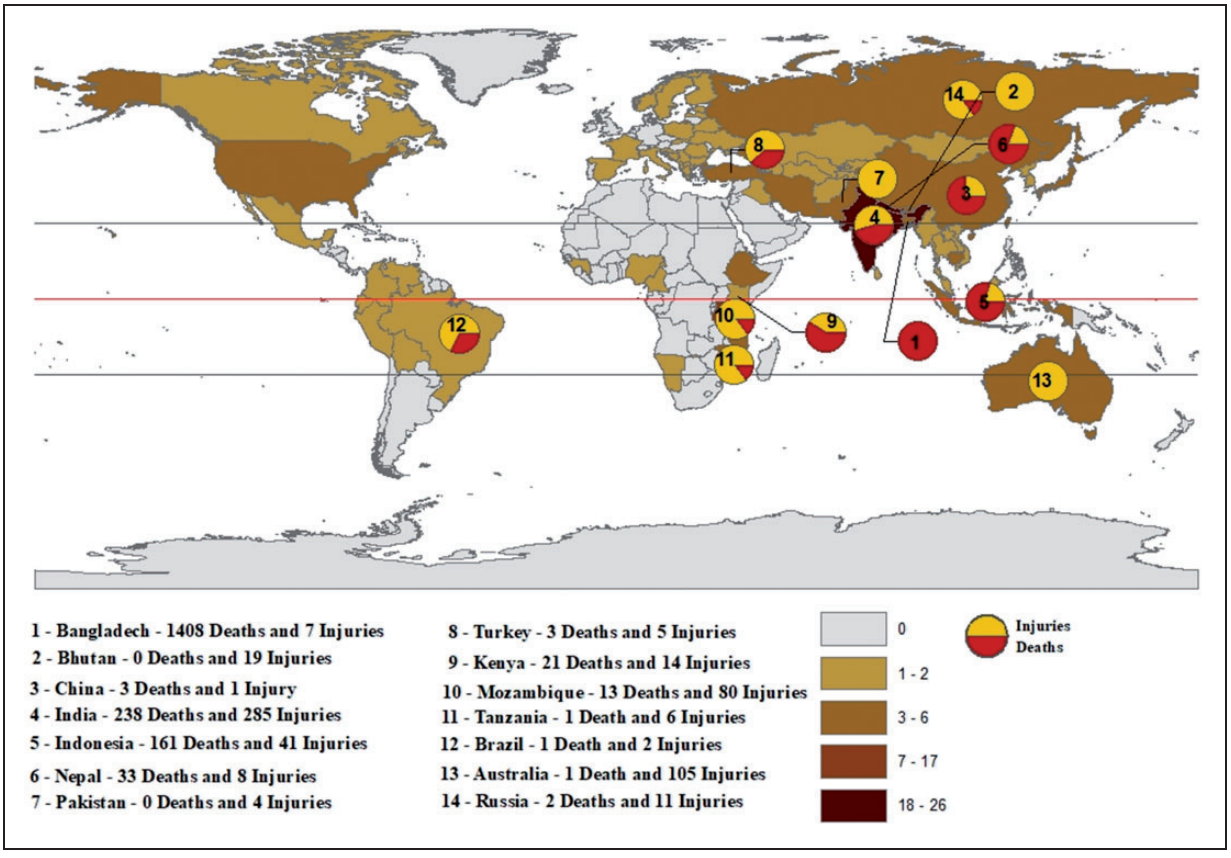

Figure 6. Distribution of human–wildlife conflicts incidence for country, caused by attacks on humans. The color scale indicates the incidence of conflicts, which considers the number of publications and the wealth of species registered for country. The countries that had the quantified attacks were numbered from 1 to 14. The circles represent, proportionally, the number of injuries (yellow) and the number of deaths (red) recorded.

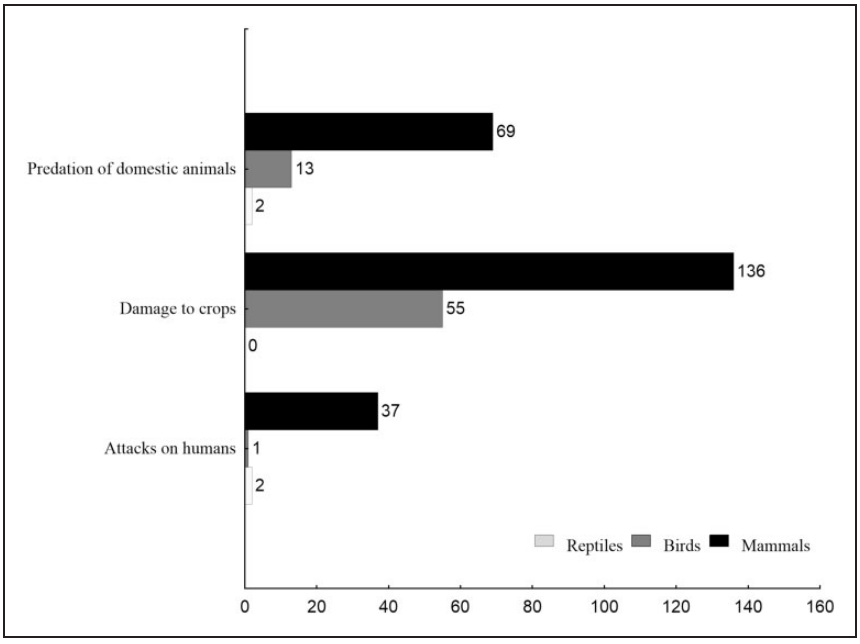

Figure 7. Number of terrestrial vertebrate species involved in human–wildlife conflicts, according to taxonomic category.

animals were cited only to the level of genus, thereby precluding their inclusion in this study. In this context, a group that deserves prominence is snakes, which in many cases are not even mentioned by their vernacular names and are only reported in a generalized way as "snakes." The African rock python (*Python sebae*) was the only snake specifically reported in conflicts with humans in the studies analyzed.

Of the three types of conflicts investigated in this study, 49 species were found to be exclusively involved in conflicts with the predation of domestic animals, 168 species were linked only to crop damage, and 4 were recorded exclusively for human attack. However, a considerable proportion of the animals were recorded for more than one type of conflict. Five species were recorded for conflicts with both domestic animals and crop damage, 18 for causing conflicts with both domestic animals and human attacks, 6 for crop damage and human attacks, and 12 species were recorded for inciting, simultaneously, all three types of conflicts.

Of the total of 262 species recorded in this review, 56 are listed in the IUCN Red List of Threatened Species. Of these, one species is listed as Data Deficient, two as Least Concern, 14 as Near Threatened, 23 as Vulnerable, 15 as Endangered, and one as Critically Endangered (*Pongo abelii*—orangutans/Sumatran orangutan). Of the species that are on the red list, those that presented at least five citations of conflicts are listed in Table 1.

Considering the number of species counted in this review, there was a low degree of similarity between the taxonomic composition of the species involved in conflicts and the continents on which the conflicts occurred. The analysis showed the formation of two groups: the first composed of Asia and Europe and the second formed by Oceana and Australia. Africa, North America, and South America appeared more isolated compared to the other continents (Figure 8(a)). When the analysis was carried out considering the families of the recorded terrestrial vertebrates and the continents, the similarity was also low, with the formation of a main grouping composed of Europe, Asia, Africa, and North America (Figure 8(b)). Regarding the number of conflict incidence records, which considers the number of publications and the number of species cited by country, the results showed that there was a significant difference between the types of conflicts ($F_2 = 6.09$, $p = .002$), with domestic animals predation and crop damage being recorded significantly more frequently than attacks on humans. When comparing the number of conflict incidence records for the three types of conflicts investigated with the socioeconomic indicators of HDI and per capita income of the countries, the results revealed that the sum of citations of the three types of conflicts showed a significant negative correlated with country HDI ($r = -.21$, $p = .03$). Despite being a weak correlation, this finding suggests that the countries with the highest incidence of conflicts have the lowest socioeconomic indicators among the countries analyzed.

Discussion

The information obtained through this review reveals that a high number of wild animal species are involved in interactions with humans throughout the world.

Table 1. Wild species listed in IUCN. Only species that were recorded in at least five articles were included in the table.

Species	Types of conflicts			*Status* IUCN	Number of papers that recorded the species
	Crop	Livestock	Human		
Canidae					
Cuon alpinus (Pallas, 1811)—dholes or wild dogs		X		Threatened	10
Lycaon pictus (Temminck, 1820)—African wild dog/wild dog		X	X	Threatened	17
Elephantidae					
Elephas maximus (Linnaeus, 1758)—Asiatic elephant/Asian elephant	X		X	Threatened	24
Loxodonta africana (Blumenbach, 1797)—elephant/African elephant/African savana elephant	X	X	X	Vulnerable	40
Felidae					
Acinonyx jubatus (Schreber, 1775)—cheetah		X	X	Vulnerable	26
Panthera leo (Linnaeus, 1758)—lion/African lion		X	X	Vulnerable	44
Panthera onca (Linnaeus, 1758)—jaguar		X	X	Near Threatened	24
Panthera pardus (Linnaeus, 1758)—leopard/common leopard		X	X	Vulnerable	71
Panthera tigris (Linnaeus, 1758)—tiger		X	X	Threatened	38
Panthera uncia (Schreber, 1775)—leopard/snow leopard		X		Threatened	17
Hominidae					
Pan troglodytes (Blumenbach, 1775)—chimpanzee	X			Threatened	11
Pongo abelii (Lesson, 1827)—orangutans/sumatran orangutan	X			Critically Endangered	5
Hyaenidae					
Hyaena brunnea (Thunberg, 1820)—brown hyena		X		Near Threatened	9
Hyaena hyaena (Linnaeus, 1758)—hyena/striped hyena		X	X	Near Threatened	7
Hippopotamidae					
Hippopotamus amphibius (Linnaeus, 1758)—hippopotamus	X		X	Vulnerable	11
Ursidae					
Helarctos malayanus (Raffles, 1821)—sun bear	X	X	X	Vulnerable	13
Melursus ursinus (Shaw, 1791)—sloth bear	X	X	X	Vulnerable	8
Tremarctos ornatus (F. G. Cuvier, 1825)—Andean bear	X	X	X	Vulnerable	7
Ursus thibetanus G.[Baron] (Cuvier, 1823)—Himalayan black bear/Asiatic black bear	X	X	X	Vulnerable	33

Note. IUCN = International Union for Conservation of Nature.

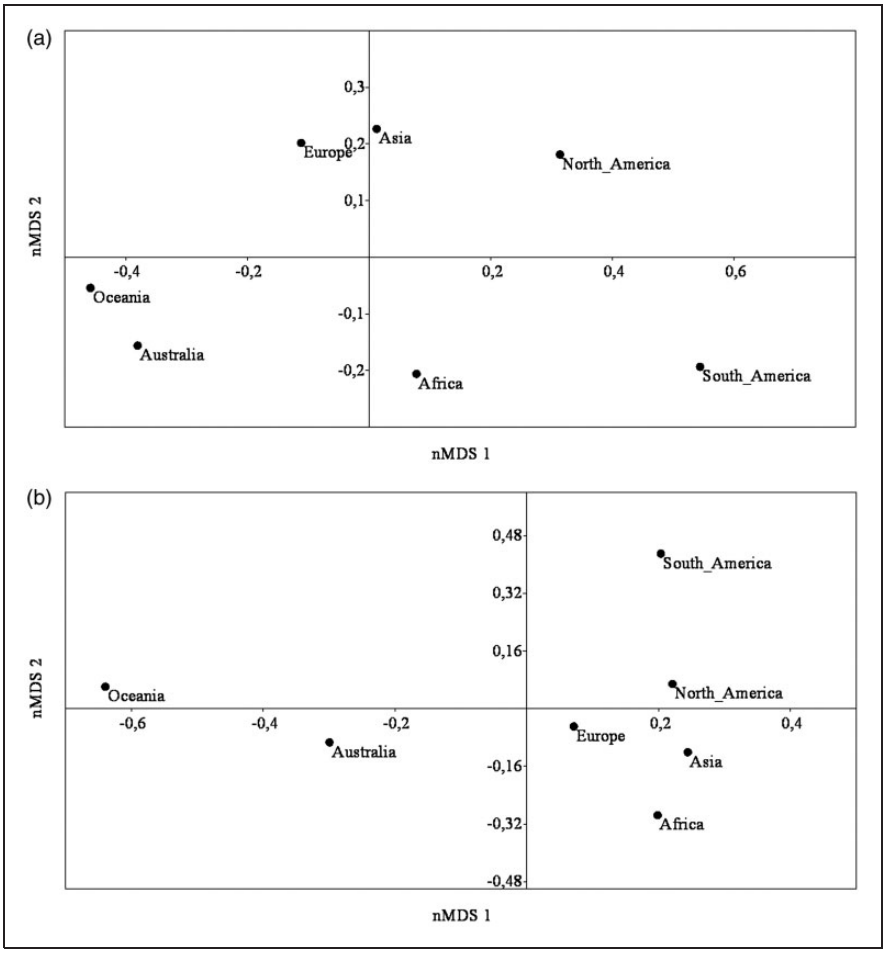

Figure 8. Similarity analysis across continents using nMDS according to the richness of species involved in conflicts (a) and according to families of recorded terrestrial vertebrates (b). nMDS = nonmetric multidimensional scaling.

On the one hand, the species richness of mammals and birds recorded were high. On the other hand, the results also expose how the reptile group may be being neglected in this type of investigation as a result of the concentration of studies on groups with higher appeal for conservation, such as mammals. This situation is corroborated by the large number of publications that investigated conflicts involving carnivorous mammals, which was also evidenced by the fact that of the 10 species most frequently reported in articles, eight belonged to this group (Bhattarai & Fischer, 2014; Dickman, Hazzah, Carbone, & Durant, 2014; Kabir, Ghoddousi, Awan, & Awan, 2013; Miller, Jhala, & Schmitz, 2016; Thorn et al., 2013; Treves et al., 2004). In Brazil, for example, studies have already indicated a predominance of human conflicts with carnivorous mammals and venomous snakes because they predate or represent risks to domestic animals and human health (Alves, Mendonca, Confessor, Vieira, & Lopez, 2009; Barbosa, Nobrega, & Alves, 2011; Mendonça et al., 2011). However, the role that reptiles, and especially snakes, play in this type of interaction seems not to be reflected in the focus of scientific papers on the subject. In the present review, only one species of snake was recorded. In addition, it should be considered that, in general, the richness of animals involved in conflicts is likely considerably higher than that obtained in this review because some animals cited in the articles as a target of conflicts were not identified, so they were not included in the list. Therefore, it is recommended that more studies be carried out on the subject that seek greater taxonomic rigor because a more accurate listing of the animals involved in conflicts would contribute data relevant for the establishment of strategies for the management and conservation of species.

The impact of conflicting interactions may also vary according to the type of conflict and the degree of tolerance displayed by the human populations involved. In general, people tend to be intolerant of target animals of conflicts, both those that kill humans and livestock as well as those that cause crop losses (Treves & Naughton-Treves, 2005). However, according to these authors, it is believed that people tend to be more tolerant

of herbivores than carnivores because of fear or the higher financial cost of losing livestock to the latter. A study carried out in China (Xu, Yang, & Dou, 2015) found that all people who presented negative attitudes toward wolves mentioned that the loss of livestock caused by these animals was the main reason for their conflicting attitudes. The impact of conflict can also be aggravated by the size of the livestock that are the target of wild predators. This fact was verified by Carter et al. (2017), who, when investigating conflicts with lions, found that when a conflict was caused by the death of cattle, it had a greater emotional impact on people that when lions killed smaller animals. In the context of intolerance, the importance of confirming the real seriousness of the reported conflicts is also highlighted. There are many situations in which people report very negative views on some species, claiming that they have caused substantial damage; however, when the damage is assessed, it is found to be minimal or even nonexistent (Dickman & Hazzah, 2016).

Another important point to consider is when the occurrence of conflicts reduces tolerance to animal species that are already threatened with extinction (Gandiwa, Heitkönig, Lokhorst, Prins, & Leeuwis, 2013). The high number of species compiled in this review that are included in the IUCN's list of threatened species highlights the importance of investigating this issue and identifying species that urgently need action to minimize conflicts as well as actions that can ensure their persistence in nature. In addition, it is also important to consider the importance of evaluating with caution those animals that, besides being threatened, are identified as species with the highest citations of conflicts as well as those involved in multiple types of conflicts (Table 1).

Some studies have also indicated that socioeconomic factors can be predictors of conflicts between people and wildlife. Level of schooling has been indicated as a factor that improves tolerance (Holmern, Nyahongo, & Røskaft, 2007). In Norway, for example, Røskaft, Händel, Bjerke, and Kaltenborn (2007) found that older, poorer, less educated men who experienced financial loss from conflict had more negative attitudes toward wolves than, respectively, people who are younger, female, with higher levels of schooling and who did not have financial losses generated by conflicts with wild fauna. In this study, the socioeconomic factors evaluated were HDI and per capita income of the compiled countries. Although only HDI showed a correlation with the incidence of conflicts, the results seem to indicate that the highest incidence of conflicts is related to the main economic activities developed by the countries as well as the presence of natural habitats near productive areas. Some studies have reported that local and subsistence communities are potentially the most common targets for damage from wild animals compared to, for example, commercial farms (Hill, 2000; Seoraj-Pillai & Pillay, 2016). In a study carried out in India, it was found that most of the victims of attacks by tigers and leopards were surprised when they were collecting forest products or when they grazed their livestock near or even within forests (Dhanwatey et al., 2013), because, according to these authors, outdoor activities increase the likelihood of encountering, for example, carnivores, and thus consequently increase the vulnerability of people to attacks. Other studies have also pointed out that the enclosure of properties (Honda & Iijima, 2016) and the management of livestock are factors that decrease the incidence of attacks (Breck et al., 2011). Comparative studies in France, Switzerland, and Eastern Europe have indicated that the maintenance of sheep in enclosed fields or pastures outside forested areas has drastically reduced losses caused by lynx predation and that when predation occurs it is more associated with specific individuals (Zimmermann et al., 2010). Some species of livestock, such as cattle, for example, may present greater vulnerability to attacks than other types of livestock because they are not easy animals to control and can move to places where they are most vulnerable to carnivores (Kgathi, Mmopelwa, Mashabe, & Mosepele, 2012). In the case of crops, some local characteristics should be considered to reduce conflicts, such as distance of the farm to forest edges and choice of crops being cultivated (Hill, 1997).

Several studies have focused on surveying or analyzing the efficiency of appropriate methods and techniques for conflict reduction (Ahmad, Khan, Javed, & Ur-Rehman, 2012; Breck et al., 2011; Constant, Bell, & Hill, 2015; Tshering & Thinley, 2017). Such methods can be divided into two groups: lethal and nonlethal. Lethal methods are used to reduce the predation of livestock (McManus, Dickman, Gaynor, Smuts, & Macdonald, 2014) and to reduce crop damage (Månsson, 2017) but have also been used, for example, in attempt to protect people and domestic animals from canine borne zoonoses (Woodroffe, Cleaveland, Courtenay, Laurenson, & Artois, 2004). The use of lethal methods may also occur when other methods are employed, but are not efficient, or when the animal clearly demonstrates a risk to human life (Sechele & Nzehengwa, 2002). Lethal methods are also well accepted because they are readily available and are even considered to be cheaper, and more practical and efficient than nonlethal methods (McManus et al., 2014). However, lethal methods are often used indiscriminately, applied even in the absence of conflict, or even involve illegal techniques such as poisoning. A study carried out in Spain showed that the perceived risk of predation of domestic animals by wolves was the main reason for the use of poisoning (Mateo-Tomás, Olea, Sánchez-Barbudo, & Mateo, 2012). The results of this

study also showed that illegal poisoning affected seven endangered species. Among the most commonly used nonlethal methods are fencing, electrified (Garrotea et al., 2015; Honda, Miyagawa, Ueda, & Inoue, 2009) or not (Honda & Iijima, 2016), lighting systems (Stone et al., 2017), human accompaniment of grazing animals (A. L. Hoogesteijn, Tortato, et al., 2016; Kgathi et al., 2012; Ohrens, Treves, & Bonacic, 2016), guard animals (Potgieter, Kerley, & Marker, 2015; Tumenta, Iongh, Funston, & Haes, 2013), sound mechanisms for scaring (Simonsen, Madsen, Tombre, Nabe-Nielsen, & Thompson, 2016; Stone et al., 2017), confinement of domestic animals (Kgathi et al., 2012; Silva-Rodríguez, Soto-gamboa, Ortega-solís, & Jiménez, 2009; Tumenta et al., 2013), and the translocation of wild animals (Weise, Stratford, & van Vuuren, 2014; Weise, Wiesel, Lemeris, & van Vuuren, 2015). Translocations are routine for North American pumas that invade urban areas or that kill livestock and have occasionally been applied to gray wolves and African wild dogs (Sillero-Zubiri et al., 2004).

The present compilation of studies also revealed the importance of considering the species involved as an effective way of minimizing existing conflicts. In a study conducted in northern Botswana, respondents pointed out that most attacks on livestock occurred both during the day and at night, and for this reason, the use of methods such as daytime grazing and confinement at night were identified as potentially the most appropriate ways to prevent attacks (Kgathi et al., 2012). Another method indicated in the studies to minimize conflicts concerns the compatibility of the livestock with the conflicting animals of a certain region. It has already been pointed out that animals, such as donkeys, are rarely attacked by wild animals, and for this reason, in some countries, they are used as guard animals of other livestock (Kgathi et al., 2012). Another way to reduce conflict would be through the joint livestocking of animals that are less vulnerable to attacks with other, more vulnerable animals, or even the substitution of traditional livestock with animals less vulnerable to predation. In India, cattle livestock have been replace by buffalo (*Bubalus bubalis*) because they have a defensive behavior that has been shown to be efficient in reducing the incidence of predation by felines (R. Hoogesteijn & Hoogesteijn, 2014). Similar results were obtained in the province of Colon in Panama, where for 20 years attacks on cattle livestock by wild felines were recorded, but after the cattle were livestocked in the presence of buffalo (*Bubalus bubalis*), the situation reverted and no predation events by felines were recorded despite evidence of the presence of jaguars and pumas at the site (Moreno et al., 2016). Positive results were also observed by cattle farmers in Colombia and Brazil using creole cattle, an animal that exhibits a gregarious behavior similar to the buffalo, and which also has a capacity for defense against predators such as jaguars and pumas (R. Hoogesteijn, Payán, Valderrama-Vásquez, Tortato, & Hoogesteijn, 2016). Another important factor is the way animals are handled with regard to lowering their exposure at more vulnerable stages of life. Calves, for example, would be more susceptible to predators than adult animals because they are characterized by extreme curiosity and limited defensive behavior, which would expose them to predation (Michalski, Boulhosa, Faria, & Peres, 2006). In addition, small-sized domestic animals or young animals are more defenseless and vulnerable in comparison to adult cows, bulls, and horses because it is more risky for a puma or jaguar to attack an adult animal because of their larger size (Sarmiento-Giraldo, Sánchez-Palomino, & Monroy-Vilchis, 2016).

Another relevant way of minimizing the impact of hunting wildlife in retaliation to conflicts is through the payment of financial compensation for the damage caused (Bauer, Müller, Van Der Goes, & Sillero-Zubiri, 2017). Compensation measures seek to share the burden of damage by predator tolerance and, to be effective, require strong institutional support and clear guidelines (Sillero-Zubiri et al., 2004). However, financial compensation is not always considered the best way to reduce conflicts. Previous knowledge of compensation for conflict damage can lead people to reduce the care for crops and livestock that they normally would practice (Bulte & Rondeau, 2005). According to these authors, people can even facilitate the occurrence of conflicts in order to receive compensation. Another example is the death of small animals such as hens, which are predated by foxes but also by domestic dogs. In this case, producers will overestimate the damage caused by foxes by not identifying predation by dogs (Silva-Rodríguez et al., 2009). In addition, in some cases, producers are still likely to defraud the conflict in order to receive compensation. There were cases in which the producers complained about the damage caused by wolves, but after analysis by means of necropsy, it was verified that the death of the animal occurred by another cause, plus there was evidence that the carcass was altered in order to simulate the attack (Dalmasso, Vescoa, Orlandoa, Tropinib, & Passalacquab, 2012). According to these authors, cases such as these show the importance of having a qualified professional determine the cause of death of an animal to avoid the waste of public resources as well as the distortion of the real impact of conflicts. Additional negative points related to compensatory measures are that they do not alleviate the problem, rarely deal with total costs, are open to corruption, and may involve expensive bureaucracy (Sillero-Zubiri et al., 2004).

The results of this study revealed that several species around the world are involved in conflicts with humans,

and that publications on the subject have given special attention to important groups such as mammals, especially large carnivores, certainly due to the intensity of occurrence of conflicts with these animals and the strong conservation appeal associated with wild mammals. However, the results also indicate that more attention needs to be paid to reptiles, which, although they have been addressed in a less expressive way in studies dealing with conflicts between people and wild animals, have already been identified as one of the groups most impacted by conflicts (Mendonça et al., 2011). The results demonstrate that conflicts involving attacks on people were less significant than damage to crops or the predation of domestic animals; however, no differences were observed between the incidence of crop damage and predation of domestic animals, evidencing that these two types of conflicts seem to have similar impacts on a global scale.

The compilation of studies presented in this review corroborates Dickman and Hazzah (2016) who point out that conflicts do not present a simple linear relationship between damage, attitudes, and actions, and that these are in fact influenced by multiple factors. To better manage conflicts, it is necessary to understand the spatial and ecological dynamics of human–wild animal interfaces, to emphasize the importance of the human dimension in conflicts, to compare conflict mitigation results, and to adapt forms of mitigation according to the characteristics of each case (Zimmermann et al., 2010).

Implications for Conservation

It is recommended that further studies on the subject be carried out, mainly in countries where there is the combination of concentrated rural practices along with well-conserved habitats, in order to increase knowledge about the species involved in conflicts. Further studies are expected to be conducted on the efficiency of nonlethal methods so that, where lethal methods can be dispensed with, more people will use methods that allow biodiversity conservation. At the same time, it is recommended that population studies on the species involved in conflicts, especially those with a degree of threat, be carried out in order to quantify the real impact of conflicts on their populations, thus favoring the maintenance of economic activities while seeking the conservation of species, thus achieving a more harmonious relationship between humans and nature.

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