Large carnivore attacks on humans: a worldwide study to investigate triggering factors, scenarios, spatial-temporal patterns and species attributes

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"Los ataques de grandes carnívoros a humanos: un estudio a escala mundial sobre escenarios, factores desencadenantes, patrones espacio-temporales y atributos de las especies."

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RESUMEN DEL CONTENIDO DE TESIS DOCTORAL

1.- Título de la Tesis	
Español/Otro Idioma: **Los ataques de grandes carnívoros a humanos: un estudio a escala mundial sobre escenarios, factores desencadenantes, patrones espacio-temporales y atributos de las especies.**	Inglés: **Large carnivore attacks on humans: a worldwide study to investigate triggering factors, scenarios, spatial-temporal patterns and species attributes.**

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RESUMEN (en español)

Los ataques de grandes carnívoros a personas han estado aumentando a escala global y representan la forma más extrema de conflicto entre los humanos y la fauna silvestre. Debido a sus efectos negativos tanto sobre el bienestar humano como la conservación de estas especies, adquirir un conocimiento exhaustivo de los escenarios y los factores que determinan la ocurrencia de estos eventos tiene un doble efecto positivo. A pesar de la existencia de algunos estudios previos sobre el tema, el enfoque de los mismos ha sido casi exclusivamente local y centrado en un número reducido de especies. Sin embargo, el aumento en los ataques por parte de muchas especies y en muchas regiones del mundo remarca la necesidad de un enfoque más amplio.

El objetivo de esta tesis doctoral es analizar y comparar los escenarios de ataques de grandes carnívoros a personas ocurridos en todo el mundo con el fin de ampliar los conocimientos sobre este fenómeno y tratar de identificar potenciales factores y soluciones para reducir la ocurrencia de estos conflictos tanto a escala global como local. Con este propósito, recopilamos y analizamos informaciones sobre ataques ocurridos en todo el mundo. El objetivo principal de esta tesis se ha abordado a través de cuatro objetivos específicos, que están enmarcados en los siguientes capítulos:

En el Capítulo 1, analizamos los patrones y los factores relacionados a los ataques ocurridos en áreas urbanas de Norteamérica. En particular, nos centramos en analizar las características del paisaje alrededor del lugar donde ocurrió cada ataque. Los resultados principales de estos análisis sugieren que la mayoría de los ataques ocurrían en presencia de perros o en lugares donde había comida de origen humano. Además, las especies involucradas, en particular el coyote y el oso negro, presentan patrones diferentes en términos de las características del paisaje. Mientras que los ataques de coyote ocurren en cualquier tipo de hábitat, los ocasionados por el oso negro se concentraron en aquellos entornos urbanos donde la vegetación es más abundante y hay una menor presencia de infraestructuras humanas.

En el Capítulo 2 estudiamos los patrones generales de ataques de todas las especies de osos a escala mundial. Encontramos tanto diferencias como similitudes entre especies y entre diferentes regiones del mundo. Por un lado, en los llamados países en vías de desarrollo o emergentes, los encuentros negativos ocurren principalmente cuando los habitantes locales llevan a cabo sus actividades diarias de trabajo y subsistencia (e.g. la recogida de productos alimenticios o el cuidado de cultivos o ganado) en hábitats de osos. Por otro lado, en los países desarrollados, los ataques tienen principalmente lugar cuando las personas desarrollan actividades recreativas en áreas de presencia de osos. En general, estos resultados sugieren la necesidad de evitar generalizaciones a la hora de plantear soluciones para reducir este tipo de conflictos.

En el Capítulo 3, analizamos los patrones de ataques de oso pardo a escala global. El escenario más común a nivel mundial es la reacción defensiva de una osa con crías. Además, la mayoría de las personas implicadas en los ataques se encontraban realizando actividades recreativas.

En el Capítulo 4, examinamos un aspecto distinto de estos conflictos, relacionado con la percepción humana. Concretamente, estudiamos cómo los periódicos internacionales presentan y describen los ataques de todas las especies de grandes depredadores, enfocándonos en particular en el uso de sus contenidos "gráficos" y sensacionalistas. Encontramos que casi la mitad (41.5%) de las noticias utilizan este tipo de contenidos para presentar casos de ataques. Esta cifra supone una proporción muy elevada y preocupante, sobre todo dado el poder que los medios de comunicación tienen de influir en la opinión y percepción del público sobre los grandes carnívoros.

En general, esta tesis aporta nuevos conocimientos e informaciones de gran relevancia para lograr reducir encuentros peligrosos con los grandes carnívoros. En particular, las diferencias entre áreas geográficas y entre especies encontradas sugieren que estrategias que busquen reducir el riesgo de ataques tienen que ser desarrolladas basándose tanto en las características particulares de las especies como en el contexto socio-económico local.

RESUMEN (en Inglés)

Large carnivore attacks on humans are increasing globally and represent the most extreme form of human-wildlife conflict. Because they have negative effects on both human welfare and large carnivore conservation, gaining a deep knowledge of the scenarios and factors behind such events has a double positive effect. Although some studies have addressed the issue by focusing on single large carnivore species or local scales, the increase in attacks by many species of large carnivores in many areas of the world highlights the need for a comprehensive approach. The aim of this thesis is to broaden the knowledge on this phenomenon by analyzing and comparing scenarios of large carnivore attacks on a worldwide scale to try identifying potential factors and provide solutions to this issue both at a global and local scale. To this goal, we collected and analyzed available reports on attacks occurred all around the world. The main objectives of the thesis have been developed into four chapters:

In Chapter 1, we aimed at analyzing patterns and correlates of attacks occurred in North American urban areas. In particular, we focus on the landscape characteristic of the site of the attack. Main findings of these analyses suggest that most of the attacks involved the presence of dogs or anthropogenic food. Moreover, the species involved, i.e. coyote and black bear, showed different patterns related to the landscape structure. Specifically, whereas coyotes attacked in all kinds of environments, black bear attacks were concentrated in those areas where vegetation cover was more, and human infrastructures were less abundant.

In Chapter 2, we describe general patterns of attacks by all species of bears around the world. We found both differences and similarities among species, as well as among different geographical areas. On one hand, in developing countries dangerous encounters mainly involved local people who entered bear habitats for their daily work and subsistence–related activities, such as collecting food items or taking care of crops or livestock. On the other hand, in developed countries attacks mainly occurred to people that were involved in recreational activities in bear areas. These results imply that generalizations should be avoided when trying to find solutions to reduce this kind of conflicts.

In Chapter 3, we analyze patterns of attacks by brown bears on a worldwide scale. We found that the most common attack scenario on a global level was the defensive reaction by a female with cubs and attacks mainly involved people engaged in recreational activities.

In Chapter 4, we explore a different aspect of this kind of conflicts, which is more related to human perception. Specifically, we investigate how international newspapers cover and describe attacks by all species of large predators, focusing in particular on the use of graphic contents in presenting the events. We found that nearly half (41.5%) of the news reports

collected used graphic and sensationalist contents when describing cases of attacks. This represents a high proportion, given the power that the media has in influencing public opinion and perception on large carnivores.

In general, our work provides new insights on the issue and useful information that could help reducing dangerous encounters with large carnivores. In particular, the differences among geographical regions and among species highlighted in this thesis suggest that strategies aimed at reducing attack risk need to be developed based on both species–specific characteristics and the local socio-economic context.

SR. PRESIDENTE DE LA COMISIÓN ACADÉMICA DEL PROGRAMA DE DOCTORADO EN BIOGEOCIENCIAS

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General introduction

Although rare compared to attacks by other wildlife and domestic species (https://www.statista.com/chart/2203/the-worlds-deadliest-animals/ n.d., Beier 1991), attacks on humans by large carnivores have increased during the last decades in many areas of the world (Packer et al. 2005, Conover 2008, Acharya et al. 2016, Penteriani et al. 2016). Increasing overlap between human and carnivore habitats may be behind this trend. On the one hand, some populations of large carnivores have expanded in numbers and range due to improved human attitudes and stricter protection in recent years (Chapron et al. 2014). On the other hand, the rapid expansion of human population and, consequently, of urban areas into landscapes inhabited by these species is causing large areas of natural habitat to surround or be incorporated into highly human-modified landscapes (Adams 2005, Kabisch and Haase 2013, Soulsbury and White 2015). The positive trend in the occurrence of negative encounters with large carnivores is leading to increased people's apprehension and reduced willingness to share the landscape with these species. Together with other types of conflicts such as damages to properties and livestock, these events represent one of the main causes that have led to carnivore persecution in the past and, in more recent times, to public resistance towards conservation objectives (Chapron et al. 2014, Ripple et al. 2014). Certainly, attacks on people represent the most extreme form of human-carnivore conflict (Støen et al. 2018). Besides raising human safety concerns, such events undermine large carnivore conservation efforts, as well as the recovery of several of these species around the world (Löe and Röskaft 2004). Indeed, sometimes, the carnivore involved in the attack must be lethally removed; however, because it is not always easy to know which individual was involved in the attack, one or more individuals of the species are killed. Such events also harden public attitudes and may encourage retaliatory killing by local communities (Mathur et al. 2015). On top of this, when an attack occurs, it elicits considerable and lasting attention by both local and international mass media, which often emphasize the events by using sensationalist texts and graphic pictures (Siemer et al. 2014, Knopff et al. 2016). Because it especially targets

the audience's emotions rather than its logic, such amplified media coverage can lead people to overestimate the risk of an attack and, eventually, cause negative public reactions and resistance towards conservation actions (Treves and Karanth 2003*a*, Hathaway et al. 2017). Moreover, when using graphic contents and negative framing to describe an attack, the media does not help to correctly inform people on how to avoid dangerous encounters with large carnivores and how to behave in case of an encounter, but it rather unnecessary alarms the public about a phenomenon that is actually very rare (Myers 2001, Zillmann et al. 2004, Crown and Doubleday 2017). If carnivore and human populations and consequent habitat overlap continue to increase, we could expect an increasing number of negative interactions, followed by decreased public tolerance. Because of this, now more than ever, there is a need for objective and accurate information regarding not only the current trends and mechanisms behind large carnivore attacks on humans, but also potentially risky situations and risk-enhancing human behaviours. Reducing the occurrence of these events, indeed, would benefit both human wellbeing and large carnivore conservation efforts.

Development and objectives of the thesis

This thesis is part of a larger project aimed at investigating the main factors and circumstances of large carnivore attacks on humans occurred all around the world to provide important information that can improve our understanding of this phenomenon and reduce the occurrence of attacks. Although several studies have addressed this issue by focusing on single or few carnivore species and/or local scales, a comprehensive approach including many species and a wide geographical scale was lacking. Whereas a narrow scale analysis can provide useful insights and highlight specific management recommendations to deal with this problem in the local context or with a specific carnivore species, an analysis on a wider level can provide a new perspective of the issue to both conservationists and managers, and allow examining differences and similarities among species and among regions.

What are the main situations that could lead to an encounter with these animals in the first place and, if the encounter happens, what are the main factors and circumstances that can trigger an aggressive behaviour? How often is the animal's "fault" and how often is it ours? Is there something we could do to avoid creating dangerous situations? And how do all these things vary depending on the species and the location under study? Can we make generalizations when talking about attacks of different species and in different regions of the world to help reducing the number of large carnivore attacks?

These are some of the questions we were interested in finding an answer to. With these ideas in mind, we collected and analysed available reports on attacks on humans by different species of large carnivores on a worldwide scale and such data has allowed us to explore several aspects related to these events. Because information on attacks occurred in North America and other developed countries is easier to access and more reliable than in other parts of the world, we started by analysing cases occurred in this region, which my working group already started to collect before my arrival. Several are the ideas developed and the information obtained from this first dataset, some of which have not been included as chapters in this

thesis. A first overview on attacks occurred in developed countries has been provided in Penteriani et al. (2016) and Garrote et al. (2017). Main findings of these works suggest that risk-enhancing human behaviours (e.g., leaving children unattended and walking with an unleashed dog) are among the main causes determining the occurrence of dangerous encounters. Moreover, bear attacks have been found to be more often fatal than attacks by other large carnivore species (e.g., cougar, wolf and coyote) and alone victims were more likely to be killed than people in groups. Among the various attack types recorded, patterns and correlates of predatory attacks have been explored in detail by Penteriani et al. (2017*b*). Despite their rarity, such encounters represent probably the most dangerous and the ones that depend the least from human behaviour and, because of this, they deserve particular attention. By analysing this kind of attacks, we found that categories that were most frequently targeted by carnivores with predatory intentions were the most vulnerable, that is children and people moving alone in carnivore areas.

The ideas addressed in the above-mentioned studies have made space to new questions, which have been developed in this thesis. Specifically, the main objectives are elaborated into four chapters:

Chapter 1. Urban areas represent the most extreme form of human-modified landscapes, the centre of human societies and culture, where human power and laws rule and interactions with "the wild nature" are supposed to be totally or almost absent. But what happens when large carnivores adapt to live in proximity or even inside urban areas? Although tolerance towards these species is generally higher in urban contexts, and lethal management less supported, negative interactions do occur. In North American towns and villages, coyotes and black bears have especially adapted to thrive in highly humanized areas, and have sometimes become a threat not only to human properties, but also to pets and people's safety. Because of this, the aim of this chapter is to describe main patterns and circumstances of the attacks occurred in these contexts and provide information that could help managers to better tackle this issue.

Chapter 2. With Chapters 2 and 3, we expanded the view on the issue from North America to the whole world. On one hand, because different geographical areas are characterized by different socio-economical situations and cultures, we would expect to find different kinds of relations and interactions with large carnivores as well. Similarly, because different areas of the world are inhabited by different large carnivore species, such differences would probably influence attack patterns and circumstances. On the other hand, we also expected to find similarities in attack patterns across countries and species, depending on various factors. Specifically, in Chapter 2, we aim at giving a general and descriptive overview on attacks on humans by all species of bears of the world that are known to be involved in such conflicts with humans (i.e., American black bear, polar bear, Asiatic black bear, sloth bear and sun bear), highlighting differences and similarities across countries and species.

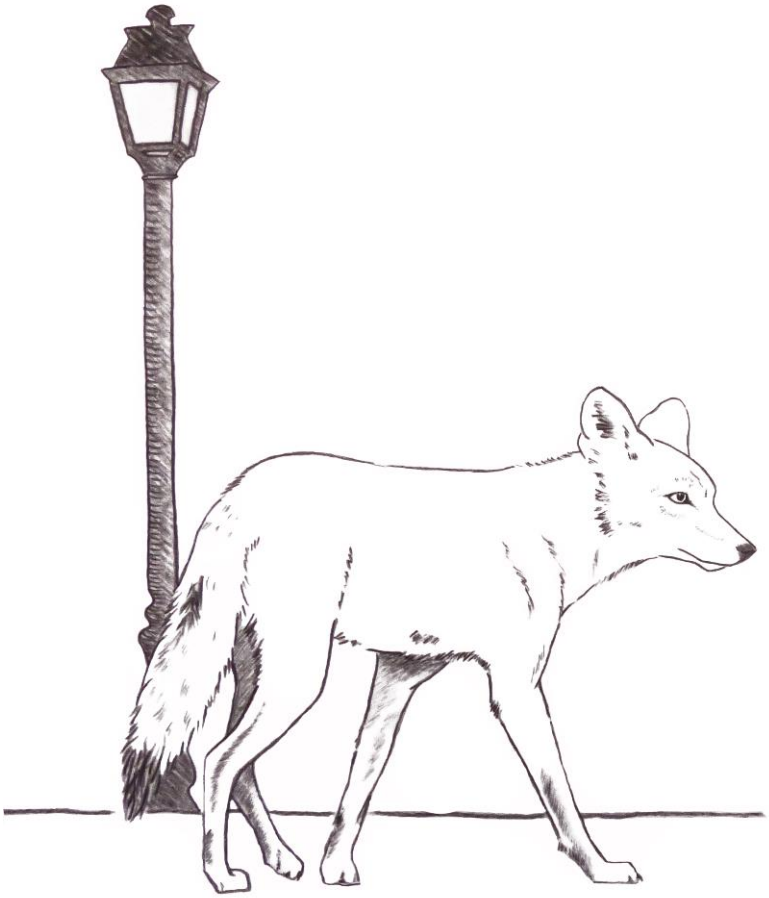
Chapter 3. After the general introduction on attacks by all species of bears provided in Chapter 2, we decided to focus on one bear species in particular, the brown bear, which is the most common and widely distributed bear species. Because of this, it represents a good example that shows how the same species can present similarities as well as differences in patterns and frequencies of attacks across countries, suggesting that different local contexts and histories of coexistence play an important role in determining human-bear relations and the occurrence of negative encounters.

Chapter 4. In the last chapter, we have examined a slightly different aspect of attacks, by providing an overview on how international newspapers frame and describe cases of attacks on humans. Specifically, we explored if and to what extent newspaper use graphic contents to describe attacks. Because mass media is one of the main sources of information on large carnivores for the general public, and has the power to drive public perception and opinion on many issues, understanding how media decide to cover these events, for instance through the use of graphic and sensationalistic contents, can provide insights into the power of this communication tool in delivering information on large carnivores and, as a

consequence, driving the opinion of the large public and its acceptance towards these species.

Chapter 1

Patterns of wild carnivore attacks on humans in urban areas.



Bombieri G., Delgado MM., Russo LF., Garrote PJ., López-Bao JV., Fedriani JM. and Penteriani V.

Scientific Reports 8, 17728 (2018)

ABSTRACT

Attacks by wild carnivores on humans represent an increasing problem in urban areas across North America and their frequency is expected to rise following urban expansion towards carnivore habitats. Here, we analyzed records of carnivore attacks on humans in urban areas of the U.S. and Canada between 1980 and 2016 to analyze the general patterns of the attacks, as well as describe the landscape structure and, for those attacks occurring at night, the light conditions at the site of the attacks. We found that several behavioral and landscape-related factors were recurrent elements in the attacks recorded. The species for which the attack locations were available (coyote and black bear) attacked in areas with different conditions of landscape structure and artificial light. Specifically, black bears attacked more frequently in areas with abundant and aggregated vegetation cover and scarce buildings and roads, while coyotes attacked in a broader range of landscape conditions. At night, black bears attacked in generally darker areas than coyotes. By providing a comprehensive perspective of the phenomenon, this study will improve our understanding of how effective strategies aimed at reducing the frequency of risky encounters in urban areas should be developed.

INTRODUCTION

Recent years have witnessed an increase in conflicts between humans and wild carnivores in North American urban areas (i.e., populated places, defined by the U.S. Geological Survey (https://www.usgs.gov/) as "*a place or area with clustered or scattered buildings and a permanent human population (city, settlement, town, village)*") (Evans et al. 2014, Baker and Timm 2017). These conflicts include property damage, anthropogenic food consumption, livestock and pet attacks and, more rarely, attacks on people (Don Carlos et al. 2009, Merkle et al. 2011, Baker and Timm 2017, Poessel et al. 2017*a*). Increasing overlap between human and carnivore habitats may be behind this trend (Baruch-Mordo et al. 2008, Soulsbury and White 2015). On the one hand, some populations of carnivores have expanded their range due to the improved human attitudes and stricter protection in recent years. On the other hand, the rapid expansion of urban areas into landscapes inhabited by these

species is causing large areas of natural patches to surround or be incorporated into urban areas (Adams 2005, Kabisch and Haase 2013, Soulsbury and White 2015). These natural patches provide carnivores with suitable habitats (e.g., abundance of prey and shelter) in close proximity to, or even inside, human developments. This, together with the ability of some carnivores to use anthropogenic resources (e.g., non-seasonal and high-caloric anthropogenic food) and thrive in highly human-modified landscapes may lead to increased conflictual interactions (Kretser et al. 2008, Lewis et al. 2015, Blecha et al. 2018).

Even though attacks on humans in urban areas are rare and mainly result in minor injuries, they often elicit lethal responses towards the animals considered responsible for the attack and decrease public tolerance towards these species, subsequently influencing management and conservation actions (Löe and Röskaft 2004, Poessel et al. 2013, Soulsbury and White 2015). Therefore, both humans and carnivores lose when such incidents happen and, because of this, reducing the occurrence of such attacks in urban areas should be considered a priority for authorities. For this reason, rigorous analysis of attack scenarios aimed at identifying the factors which may drive risky human-carnivore encounters can provide decision-makers with useful information (Löe and Röskaft 2004, Poessel et al. 2013).

Only a handful of studies have focused on wild carnivore attacks on humans in urban areas (Timm et al. 2004, Timm and Baker 2007, Baker and Timm 2017). These studies have analyzed coyote *Canis latrans* attacks only and have highlighted that changes in human behaviors (e.g., management of attractants and pet supervision) can play a crucial role in reducing the number of attacks. However, several other factors need to be taken into consideration when analyzing attack triggers and scenarios. For example, information regarding the characteristics of the natural and human environment at the site of the attack, as well as the conditions of artificial illumination for those incidents that occurred at night, might turn out to be crucial for understanding the dynamics of the attacks and for the development of management actions aimed at reducing the risk of dangerous encounters. Moreover, although until recent years coyotes have been almost the only species responsible for attacks on humans in urban areas, the current increase in the number

of attacks by other wild carnivores (Penteriani et al. 2016) highlights the need for a more comprehensive approach encompassing all carnivore species occurring in urban landscapes.

Here, we analyzed the scenarios of carnivore attacks on humans that occurred in urban areas across the U.S. and Canada during the last 36 years (from 1980 to 2016). We first studied temporal patterns of the attacks at different scales (i.e., circadian, seasonal and annual) and general patterns related to various factors such as age and sex of the victims, party composition, location and scenario of the attacks. Further, we examined the structure of the landscape (i.e., abundance and structure of vegetation, abundance of buildings and roads) at the attack sites and assessed whether differences in attack patterns between species exist. Specifically, following what found in previous studies on other kinds of conflicts (Lukasik and Alexander 2011, Merkle et al. 2011, Poessel et al. 2017*a*), we hypothesized that species which are mostly forest-obligate and generally avoid humans will mainly attack under landscape conditions characterized by high vegetation cover and the fewest human infrastructures, whereas we expected landscape structure to not be relevant for those species which are known to reside in urban environments and tolerate human presence. Finally, for those attacks occurring at night, we explored whether (and how) light conditions might influence the occurrence of an attack. Specifically, we hypothesized that a higher number of attacks will occur in dark areas.

METHODS

Collection of records of carnivore attacks on humans in urban areas

We collected reports of wild carnivore attacks on humans resulting in physical injury or death that occurred in urban areas in the United States and Canada from 1980 to 2016. We used attack reports included in the database used in Penteriani *et al.* (Penteriani et al. 2016) by only selecting the attacks which occurred in urban areas within the above-mentioned study area and time period. We included attack reports starting in 1980 because attacks were poorly documented before that year. We then updated the database by adding reports from the years 2014 to 2016.

Our search included the following species: brown bear/grizzly *Ursus arctos*, black bear *Ursus americanus*, polar bear *Ursus maritimus*, cougar *Puma concolor*, grey wolf *Canis lupus* and coyote *Canis latrans*. We attempted to exclude attacks by rabid animals from this work because their behavior is likely atypical. Records of attacks were collected from unpublished reports and PhD/MS theses, webpages, books and scientific articles. To complete the dataset, we also collected news reports from online newspapers. To do this, for each species and area, we searched on an annual basis for news articles on Google using the combination of the following terms: 'species name' + 'attack', 'species name' + 'attack' + 'human' and 'species name' + 'attack' + 'State/province name' + 'year'. Because we used several sources, some of the attacks recurred repeatedly during the search, but we used information such as date, location and sex/age of the victims to prevent duplicate records in the dataset. Furthermore, we were able to obtain additional information concerning attacks from the Florida Fish and Wildlife Conservation Commission, Washington Department of Fish and Wildlife, New Mexico Department of Game and Fish and New York Department of Environmental Conservation. This information allowed us to (1) verify if the information we had recorded about the attacks was correct, (2) obtain the exact location of the attacks recorded and (3) obtain new attack reports (if any).

We collected a total of 177 attacks, of which 63% were by coyotes (n = 101), 27% by black bears (n = 44), 7% by cougars *Puma concolor* (n = 12), 2% by polar bears *Ursus maritimus* (n = 4) and 1% by grizzlies *Ursus arctos* (n = 2) (Supplemental Figure S1b).

For each attack, we recorded the following information: (1) carnivore species; (2) year; (3) month; (4) exact location of the attack; (5) time of the day, which we classified into three categories: twilight, day, night; (6) location of the attack within the urban area: inside home, near home, playground/park, school, others (examples of other locations include: outside a hotel, parking lot, golf course, university campus, on the street); (7) sex and age of the carnivore; (8) sex and age of the victim; (9) party composition, simplified into three categories: (a) victim alone, (b) child –from 0 to 13 years old– in a party of adults, and (c) party of adults, i.e., people > 13 years old; (10) end of the attack, i.e., injuries or death; and (11) scenario, i.e.,

the main factor that could have triggered the attack. We defined four scenarios: (a) predatory, i.e. when the carnivore deliberately attacked and/or killed a human with the presumed purpose of consuming it. Specifically, we considered predatory only those cases where: 1) the human was treated as food (i.e., the person is dragged by the carnivore far from the attack site to a more hidden location such as a forest patch or bushes); 2) the body (of both live and dead victims) is covered with leaves and soil; 3) after its death, the victim is partially consumed; and/or 4) a carnivore has been found near the body. (Penteriani et al. 2017*a*); (b) dog-related, i.e., one or more dogs present; (c) anthropogenic food-related, e.g., a carnivore reported feeding on anthropogenic food at the time of the attack or an individual known to be food-conditioned or intentionally fed by humans; and (d) other scenarios, i.e., female with young, aggressive reaction after a sudden encounter, food/territory defense or a wounded animal.

Characterization of the landscape structure at the site of the attacks

To describe the landscape structure of the attack site, we selected only those attacks for which the exact location was available (39% of the total attacks recorded; an estimated maximum error of ca. 100 m was accepted). The exact locations of the attacks were obtained from the U.S. departmental agencies mentioned above and other sources reporting the precise site of the attack (i.e., providing the address, coordinates or the name of the park/school where the attack took place).

We uploaded the coordinates of each attack into the Google Earth Pro application and selected a plot of 1 km^2 centered at the point of the attack. We considered 1 km^2 to be a good trade-off between the accuracy of the location points recorded and the aim of our work, which was to analyze landscape structure in the immediate vicinity of the attack site. Because of the dynamic structure of both natural and human landscapes, for each attack we searched for the map of the year when the attack took place. When the map of the year was not available, we used a map from within 3 years preceding or following the attack. Once the satellite images for each attack location were extracted, we analyzed them by using the image processing software Photoshop CS6 and calculated 5 landscape parameters to both quantify vegetation structure and describe the degree of aggregation of the vegetation in our

plots: the area (in m^2) occupied by (1) vegetation (trees and shrubs), (2) buildings and (3) roads; (4) the vegetation patch density (PD), defined as the number of vegetation patches (i.e. homogeneous areas occupied by vegetation) per unit area, where high values of PD mean a high number of patches per area unit (i.e., highly fragmented vegetation); and (5) the mean patch size in the form of area-weighted mean patch size (AREA_AM), which equals the sum, across all patches, of the patch area multiplied by the proportional abundance of the patch (i.e., patch area divided by the sum of all patch areas). The area-weighted mean patch size (AREA_AM) is less sensitive to small patches than simple mean size and provides a better overall measure of subdivision (Mcgarigal et al. 2002). PD and AREA_AM were calculated using the area of vegetation and the number of vegetation patches in each plot following Mcgarigal *et al.* (Mcgarigal et al. 2002). Both metrics were calculated at the class level (i.e., vegetation level), as our landscape area was constant throughout all 1 km^2 plots.

Collection of information related to artificial light during night attacks

For those attacks that occurred at night and for which we had the exact location ($n_{black\ bear}$ = 7, n_{coyote} = 8), we analyzed the amount of artificial light available near the attack site. Specifically, we extracted a map of artificial light at the attack site (as with the landscape parameters, we considered an area of 1 km^2 centered at the point of the attack) from the website https://www.lightpollutionmap.info/. This website provides a world atlas of artificial night sky radiance (in $W/cm^2 * sr$, where W = watt and sr = steradian or square radian, i.e. the International System of Units of solid angles that quantifies planar angles, which is used to measure the luminous intensity of a light source) (Falchi et al. 2016), where different ranges of radiance are represented by different colors. Specifically, low values of radiance correspond to lower amounts of artificial light, with radiance values < 0.25 considered as a typical moonless night sky background far from the Milky Way, zodiacal and artificial light (artificial sky brightness <1% of the natural background) (Falchi et al. 2016). The atlas includes maps from 2010 to 2017 and, as with the landscape metrics, when the map of the year was not available we used a map from within 3 years preceding or following the attack. Once the images were extracted, we calculated

the area occupied by each color (i.e. range of radiance) using Photoshop CS6 and calculated the mean radiance of each map.

Data analysis

Landscape structure and artificial light at the site of the attacks

Since the landscape parameters estimated were correlated (Spearman rank correlation r_s always > 0.70, P < 0.001), after log-transforming PD and AREA_AM, we ran a Principal Component Analysis (PCA) including the 5 variables. We then built a set of competing models which included the number of attacks per species as the response variable and principal component 1 (PC1) and principal component 2 (PC2) obtained from the PCA as explanatory variables. We finally built a second set of models, again with the number of attacks per species as the response variable, but now including radiance (i.e., our proxy of the artificial light conditions) as the explanatory variable. In both sets of models, as our response variable was categorical and had 2 levels (i.e., either attacks by coyotes or attacks by black bears), we built Generalized Linear Models (GLMs) with a binomial distribution. We performed model selection based on the Akaike's Information Criterion corrected for small sample sizes (AICc; Burnham & Anderson, 2002), and calculated two additional statistics for each model: ΔAICc and AICc weights, which indicate the probability that the model selected was the best among the competing candidates (Gelman and Hill 2006). We considered models with ΔAICc values lower than 2 as competitive. All statistical analyses were performed using R 3.2.5 statistical software (R Foundation for Statistical Computing 2018).

RESULTS and DISCUSSION

General patterns of the attacks

Most of the attacks occurred in California (n = 66, 37%), followed by Colorado (n = 16, 9%), British Columbia (n = 13, 7%) and the other jurisdictions (47%) (Fig. 1 and Supplemental Figure S1a). The number of attacks recorded in urban areas has

increased over time, with similar trends for the different species (Supplemental Figure S2a). Spring and summer were the seasons showing the highest rates of attack (Supplemental Figure S2b). Coyotes attacked uniformly throughout the year, with a slight peak during the spring, bear attacks were rare during winter and cougars attacked more often during spring and summer. This seasonal pattern conforms to the species' biology and confirms what was previously shown in other studies (Herrero and Higgins 2003, White and Gehrt 2009, Baruch-Mordo et al. 2014, Penteriani et al. 2016). Indeed: (a) bears are generally hibernating during winter; and (b) coyotes are rearing their pups during spring, when we observed a slight increase in attacks, and thus they might be in search of additional food and defending their dens during this period (Baker and Timm 2017), which makes them more likely to be involved in aggressive encounters with humans and pets (Morey et al. 2007).

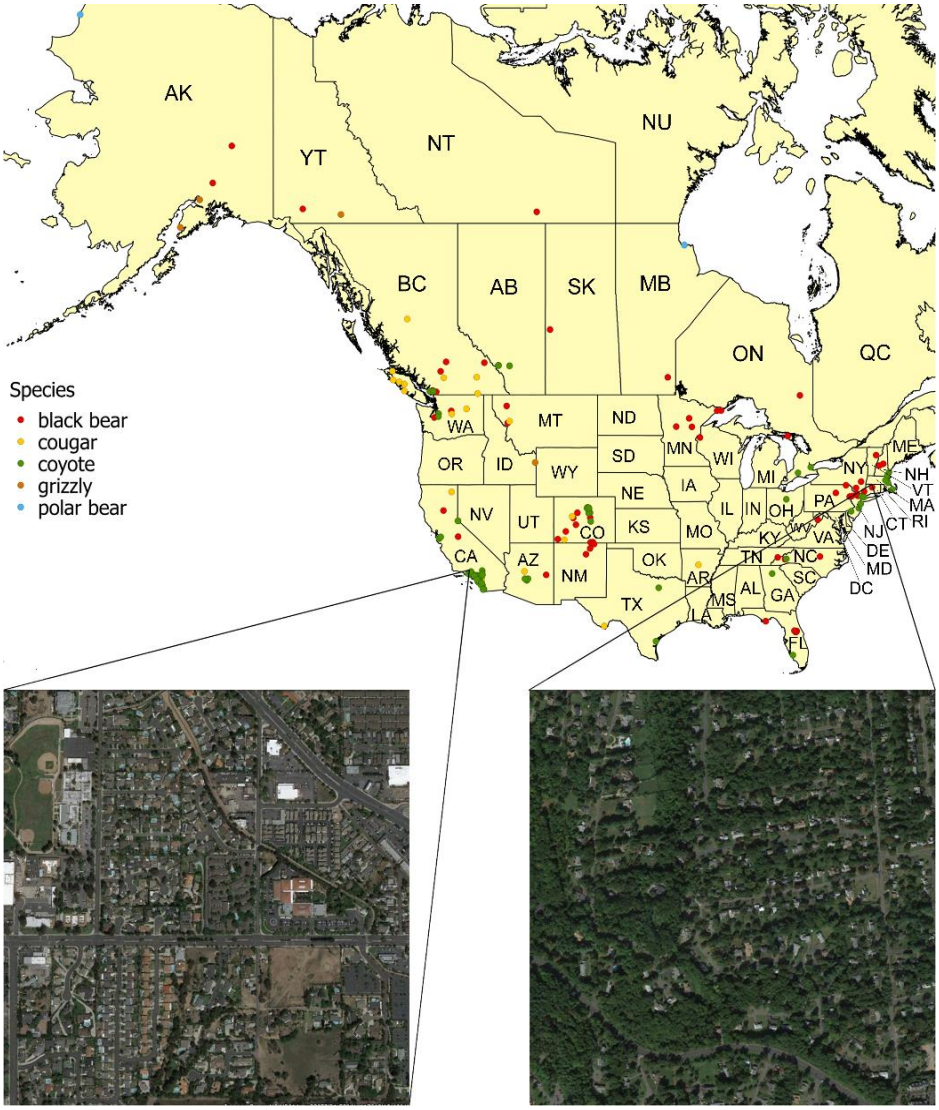


Figure 1. Map of the spatial distribution of wild carnivore attacks on humans recorded in North American urban areas between 1980 and 2016. As an example of the landscape structure analyzed in this study, two 1 km² maps centered at the point of the attack are also shown. The two satellite images were obtained from the Google Earth Pro application (Google Earth Pro 2017). Left image: Google Earth 7.3.1. (Imagery Date: April 24, 2014). California, U.S. 33°53'16.00'' N, 117°48'40.04'' W. Landsat/Copernicus. https://www.google.com/earth/ [September 20, 2017]. Right image: Google Earth 7.3.1. (Imagery Date: September 20, 2013). Connecticut, U.S. 41°47'24.87'' N, 72°45'32.29'' W. Landsat/Copernicus. https://www.google.com/earth/ [September 20, 2017].

Most of the attacks occurred during the day, especially those involving coyotes and cougars (Supplemental Figure S3a). This outcome is likely the result of the daily activity of humans in urban areas. Moreover, although coyotes in urban environments have been shown to change their activity patterns to crepuscular and nocturnal to avoid humans (Timm et al. 2004), in many cities they have become habituated to people and, consequently, they might have lost their avoidance behavior and returned to being active during the day (Timm et al. 2004). On the other hand, black bears tend to be mostly active at night to avoid humans (Beckmann and Berger 2003, Merkle et al. 2013).

In general, children (< 13 y. o.) were attacked less often than adults (Supplemental Figure S2c), with a trend towards younger individuals (n = 34 attacks between 0 and 3 years old, n = 16 between 4 and 7 years old and n = 14 between 8 and 11 years old; no attacks were recorded on 9-, 10- and 12-year-old children). Coyotes and cougars attacked children and adults almost equally, while bears attacked considerably more adults than children (Supplemental Figure S2c). This difference is probably related to the reasons triggering an attack. Indeed, brown and black bears were mainly involved in attacks related to dog presence and anthropogenic food (related to food and trash handling), two scenarios that primarily involve adults, whereas most of the predatory attacks in which victims were prevalently children (Penteriani et al. 2017*a*) were carried out by cougars and coyotes. Additionally, bears attacked more frequently at night, when children are less likely to be found outside than adults.". These patterns also reflect differences in the species' ecology. While bears are omnivores, cougars are strictly carnivore and coyotes, although they are known to forage on other resources as well (Fedriani et al. 2001, Poessel et al. 2017*b*), are also mainly carnivore. Consequently, we can expect cougars and coyotes to be involved in predatory attacks (and, therefore, attack children) more likely than bears.

The presence of dogs at the moment of the attack was the most prevalent scenario, followed by attacks related to anthropogenic food, predatory motivation and other kinds of scenarios (Supplemental Figure S2d). Cougar and polar bear attacks were all predatory. Victims of predatory attacks were mainly children (84%), and coyotes were responsible for the majority (63%) of these attacks. People involved in attacks

related to dog presence were all adults, which represented the majority of the victims of food-related attacks as well. The high incidence of night attacks when the presence of a dog is involved is probably linked to the late walks that dog owners take in urban areas due to their work schedules and locally hot temperatures during the day (Cutt et al. 2007, Lee et al. 2009).
There was only a slight difference between the number of male and female victims (Supplemental Figure S3b). Most of the victims of black bear attacks were alone, while coyotes attacked unaccompanied people and children in a party nearly equally (Supplemental Figure S3c).

Landscape structure and artificial light at the site of the attacks

The exact location of the attacks was available for coyotes and black bears only ($n_{black\ bear}$ = 22, n_{coyote} = 47) and, of these attacks, 15 occurred at night ($n_{black\ bear}$ = 7, n_{coyote} = 8). Our results were consistent with our initial hypothesis. Indeed, the PCA (Supplemental Table S1A, Supplemental Table S1B) showed a clear difference between attacks by coyotes and black bears in terms of landscape structure (Fig. 2). On one hand, black bear attacks occurred in areas with specific landscape conditions, i.e. (a) few buildings and roads, and (b) dense vegetation cover, which is in line with the ecology of the species both in wildlands and urban areas (Johnson et al. 2015, Lewis et al. 2015, Tri et al. 2016), as well as with previous studies which have analyzed the spatial distribution of other types of human-black bear conflicts (Baruch-Mordo et al. 2008, Merkle et al. 2011, Evans et al. 2014, McFadden-Hiller et al. 2016). These studies suggested that the probability of conflicts with this species was correlated with proximity to large forest patches and intermediate housing densities. This is probably related to the fact that black bears are predominately a forest obligate species (McFadden-Hiller et al. 2016, Tri et al. 2016), although they have been shown to increase selection for human developments during poor food years and the hyperphagia period (summer-fall) (Baruch-Mordo et al. 2014, Johnson et al. 2015). On the other hand, coyotes, a species known to be able to adapt well to urban areas and to tolerate high levels of human disturbance (Bateman and Fleming 2012), attacked in a wider range of landscape types than black bears, from areas with high and aggregated cover and few human structures, to extremely

urbanized areas with little and fragmented vegetation. Specifically, most of the attacks by this species (~70%) occurred in areas where the vegetation cover was less abundant and more fragmented (i.e., divided into more and smaller patches), and with relatively more buildings and roads, while fewer attacks (~30%) occurred in areas with characteristics similar to those of black bears (i.e., more abundant and aggregated vegetation cover, fewer buildings and roads). Our results are in line with observed patterns related to other types of human-coyote conflicts, which have been shown to be more frequent in developed areas with intermediate housing densities and low vegetation cover than in areas with higher percentages of forest (Poessel et al. 2013, 2017*a*). Additionally, Lukasik and Alexander (Lukasik and Alexander 2011) found that more conflicts occurred where small parks, greenspaces and riparian habitats were present in areas with high human densities.

We found that those attacks that occurred at night took place in areas with a relatively low amount of artificial light (radiance always < 6.00 $W/cm^2 * sr$), with black bear attacks occurring in particularly dark areas (radiance values lower than 1.00 $W/cm^2 * sr$; Supplemental Table 1C, Fig. 3). This outcome might be related to the recorded abundance of vegetation cover at the locations of black bear attacks. Indeed, we can expect that areas with high vegetation cover are also characterized by lower artificial light than intensely urbanized sectors.

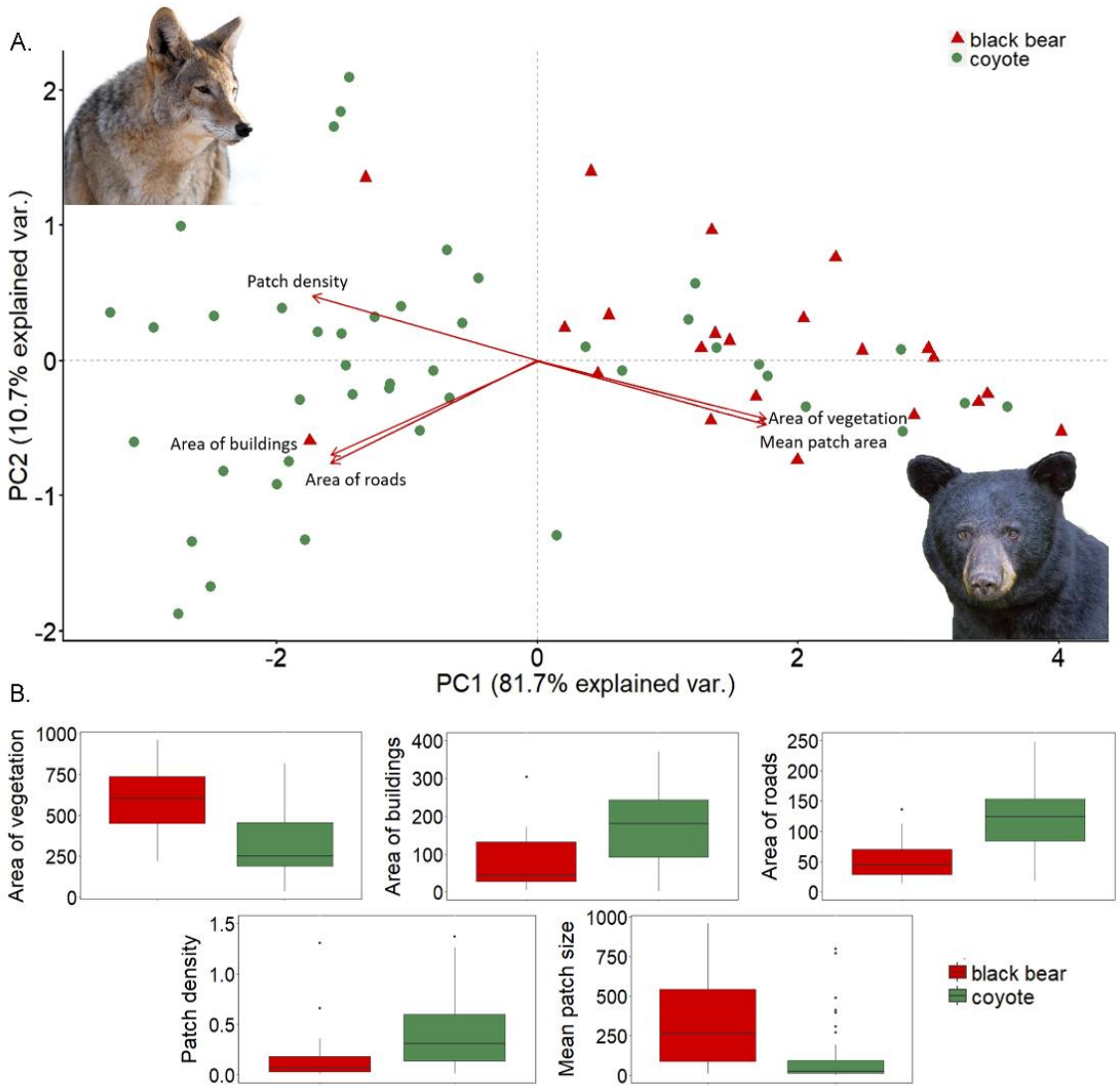


Figure 2. A. Outcome of the PCA run on the 5 landscape variables for black bears (n = 22) and coyotes (n = 47), the species for which the exact location of the attacks was available. Each point represents one attack and arrows show the direction of the variables considered, with variable values increasing according to the direction of the arrow. PC1 and PC2 explained 81.7% and 10.7% of the variance, respectively. **B**. Boxplots depicting how values of each landscape parameter differ between the two species considered (the coyote photo was downloaded from www.123rf.com, Image ID 52238509, copyright Koji Hirano; the black bear photo was downloaded from www.123rf.com, Image ID 69859949, copyright cuttsnaturephotography.

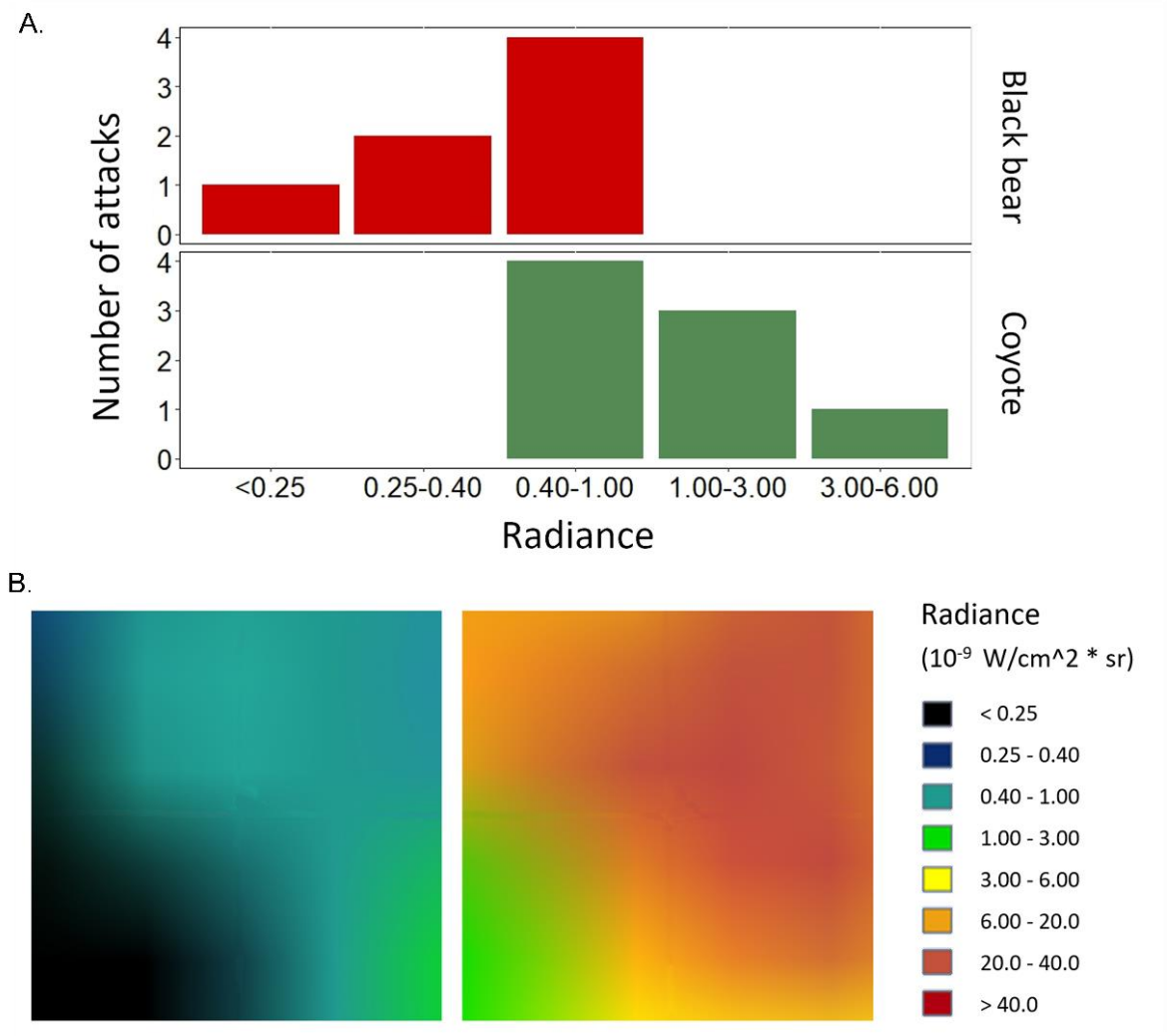


Figure 3. Artificial light conditions for those sites where the attack occurred at night. **A.** Frequencies of the different ranges of radiance for the two species for which exact locations were available, i.e., coyotes (n = 8) and black bears (n = 7). **B.** Two 1 km² plots centered at the point of the attack are presented as an example of the artificial light conditions analyzed. Each range of radiance is assigned a different color, from black (radiance < 0.25, i.e., no artificial light) to dark-red (radiance >40, i.e., highest amount of artificial light) (Falchi et al. 2016) (see the main text for more details). The two images were obtained from the website https://www.lightpollutionmap.info.

Are there solutions for this increasing conflict?

The role of human behavior in the attacks

1. Dog presence

It is noteworthy that in at least 20 (66%) of the 33 attacks related to the presence of dogs, humans were not the first target. In these incidents, either the carnivore targeted the dog first and the owner intervened in its defense (most of the cases, 80%, n = 16) or the dog confronted the carnivore, with the owner being subsequently involved in the encounter. Improved public education by local authorities on how to behave with dogs in areas frequented by wild carnivores would certainly help increase public awareness and thus reduce the occurrence of these incidents. As also previously suggested (Timm and Baker 2007, Poessel et al. 2013, Penteriani et al. 2016), keeping dogs on-leash while out walking in areas with carnivores would reduce the number of risky encounters. In the case of coyotes, scaring off the animal with the help of objects has been recommended by wildlife services (U.S. Department of Agriculture 2002, Timm and Baker 2007, White and Gehrt 2009). Similarly, keeping dogs inside or in a well-fenced shelter in the yard might help to avoid predatory attempts when the owner is not directly taking care of their dog (Timm and Baker 2007). Our results suggest that, while for coyotes these precautions should always be taken, i.e. independent of the landscape structure and light conditions, in areas where black bears are present they might be particularly important when the vegetation cover is high and the density of human buildings is low. Additionally, particular attention should be taken at night, especially in areas where artificial illumination is scarce.

2. Attractants management

The insufficient management of anthropogenic food such as pet food, bird feeders and garbage, both in private properties and public parks, together with the practice of wildlife feeding, are already known to be among the most common causes of human-carnivore conflicts (Herrero and Higgins 2003, Timm et al. 2004, White and Gehrt 2009, Young and Malpeli 2015). The proper management of attractants is

even more important within urban areas, due to the high number of people potentially exposed to a risky encounter with a wild carnivore. Although significant effort has been made to inform and educate the public on how to reduce attractants, and wildlife feeding has been forbidden in many cities (Gore et al. 2006, White and Gehrt 2009), the increasing trend of attacks indicates that current efforts might not be sufficient and more resources should be invested in preventive actions. Additionally, while education and regulations alone might have little effect on changing human behaviour (Gore et al. 2008, Baruch-Mordo et al. 2011), combining these actions with proactive enforcement (e.g. increased patrolling and application of warnings) might prove to be more efficient in altering human behaviour (Baruch-Mordo et al. 2011, Lewis et al. 2015).

3. Predatory attacks on children

Lone children are the preferred target of coyote, cougar and black bear predatory attacks. This kind of attack is the most dangerous and has already been documented in previous studies (Timm et al. 2004, White and Gehrt 2009, Penteriani et al. 2017*a*). When outside, both in yards and green spaces, children should be continuously supervised by an adult, at a minimum, and never left alone. The presence of an adult may help to reduce the chances of a child being attacked. Additionally, fencing yards and playgrounds in areas where carnivores are present may be an effective precaution to increase child safety.

4. The role of landscape planning

Assuming that both human and carnivore populations will continue to rise in the future, we should expect an increasing overlap between urban areas and carnivore ranges and, therefore, an increase in the number of attacks. The sprawl of human developments towards natural habitats is rapidly rising and residential housing is expected to increase across the landscape, due to homebuyers' preferences for single-family detached homes (Vogt and Marans 2004, Kretser et al. 2008). Moreover, the recent trend towards "greener" and wildlife-friendly urban landscape design is leading urban planners to promote the inclusion of natural patches and wildlife habitat requirements into the urban matrix (Adams 2005, Pataki 2015,

Aronson et al. 2017), which may create optimal habitats for some carnivore species. The presence of green spaces and the recent spread of the practice of "wildlife gardening" (i.e., employment of a series of practices aimed at increasing wildlife in gardens) have been shown to provide important benefits to both human health and wildlife biodiversity (Gaston et al. 2005, Soulsbury and White 2015, Aronson et al. 2017). However, practices such as keeping dense vegetation and fruit-trees in yards and green areas, as well as leaving bird feeders outside, are likely to attract wild carnivores and, consequently, may increase the probability of a risky encounter (Lewis et al. 2015, McFadden-Hiller et al. 2016, Poessel et al. 2017*a*). These practices should then be avoided in urban areas with resident carnivore populations and/or located near carnivore habitats. Instead, reducing thick vegetation (e.g., dense forests or bushes) to increase visibility and prevent carnivores from using it as shelter, as well as the implementation of fences and improved artificial illumination systems in green areas and yards, can effectively result in increasing both human and pet safety (see also (U.S. Department of Agriculture 2002, Timm et al. 2004, Poessel et al. 2017*a*)).

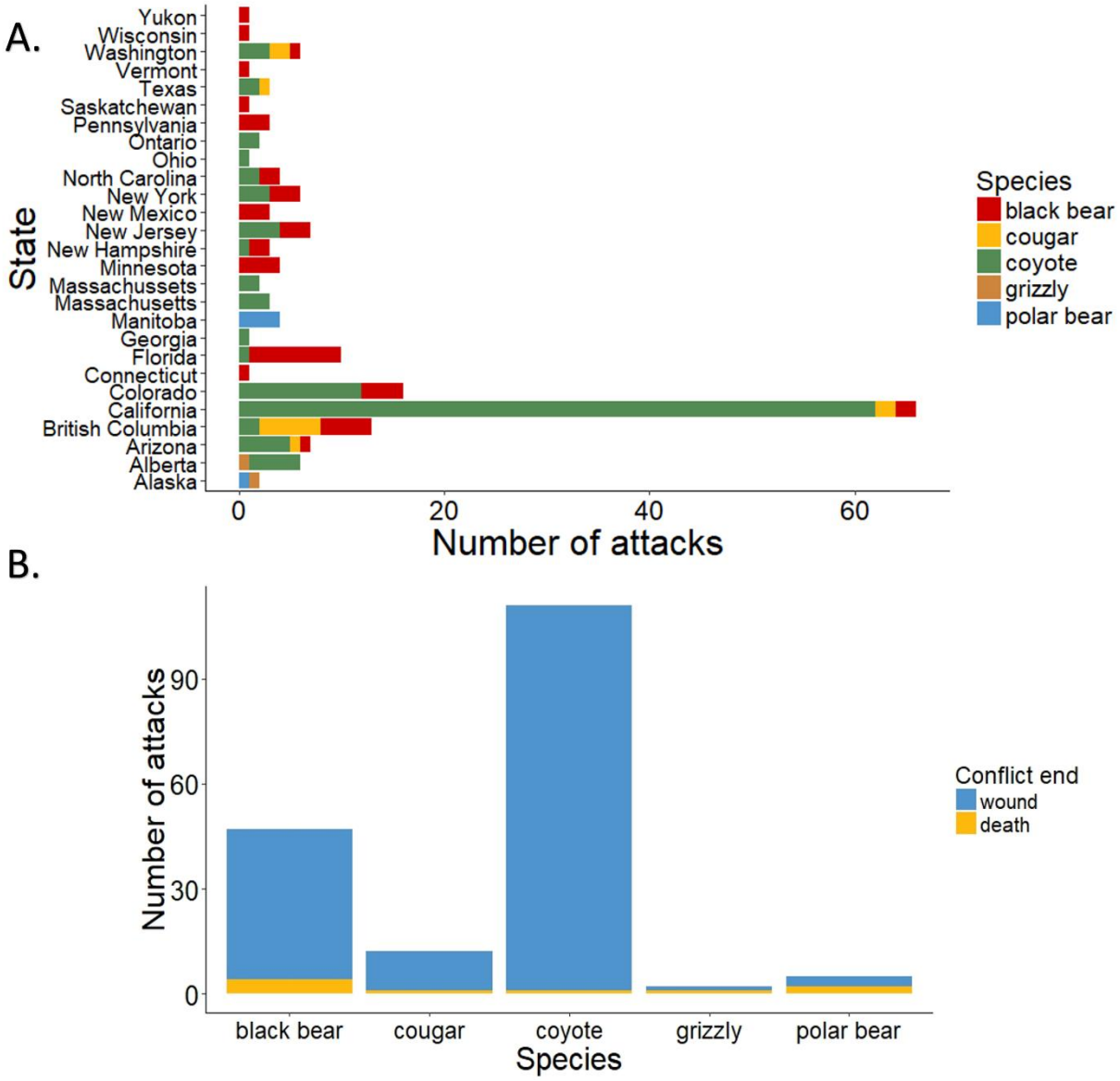
Similarly, in areas scheduled for development, urban planners and homebuyers should be informed of the risk that low-density developments (i.e., sparse housing developments which incorporate large wildland areas) might involve (Kretser et al. 2008). These kinds of developments, which also include ex-urban and suburban areas, have already been shown to favor the colonization of urban areas by wild carnivores (Bateman and Fleming 2012, Poessel et al. 2017*a*) and present a higher concentration of human-wildlife conflicts, especially when situated in proximity to natural areas (Kretser et al. 2008, Merkle et al. 2011, Poessel et al. 2013, Soulsbury and White 2015). In this sense, in terms of land use, our findings support the "land sparing" model, which favors high-density developments in order to preserve wildland (Phalan et al. 2011, Lin and Fuller 2013). This kind of development might be an effective way not only to minimize habitat fragmentation in general, but also to exclude carnivores from urban areas by separating human developments from wildlife habitats and, thus, reduce the occurrence of negative interactions with these species. Finally, we suggest that further studies should investigate whether the

attacks are more likely to occur in specific areas within the areas used by the species. This fine-scale analysis would require radiotagging of urban carnivores, which will allow comparing the characteristics of the urban sites where attacks may occur (our results) *vs.* the areas selected by these species.

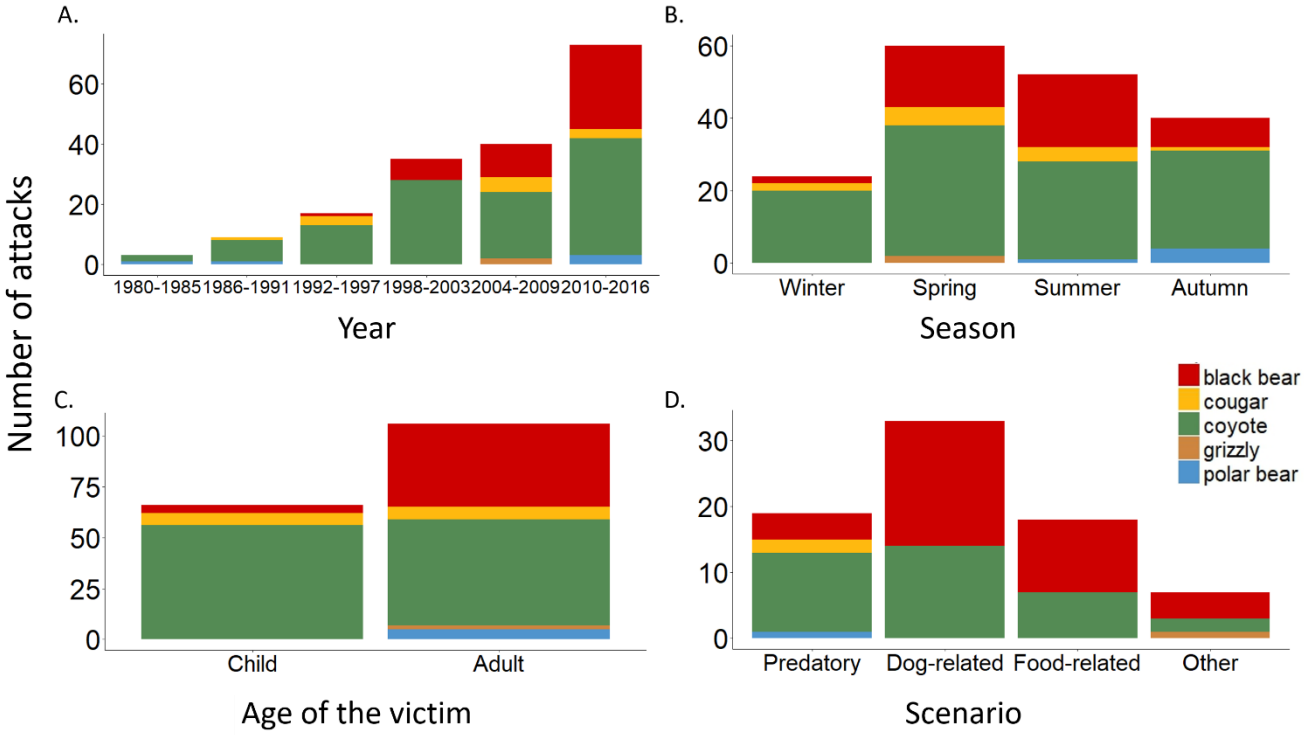
CONCLUSIONS

Several behavioural and landscape-related factors were recurrent elements in the attacks recorded in North American urban areas. Therefore, effective strategies aimed at benefitting both humans and carnivores will need to combine carnivore knowledge, citizen education and landscape planning. Specifically: (1) because different species attack under different conditions, management plans should be developed according to the species occurring in a given area and generalizations should be avoided; (2) education actions should provide the public with practical information on how to avoid conflicts and how to behave in case of an encounter with a wild carnivore; and (3) landscape planners should work to develop plans able to balance human health, wildlife conservation and conflict risk. Specific landscape modifications and design should thus be employed both in already existing urban green areas and when planning new urban areas.

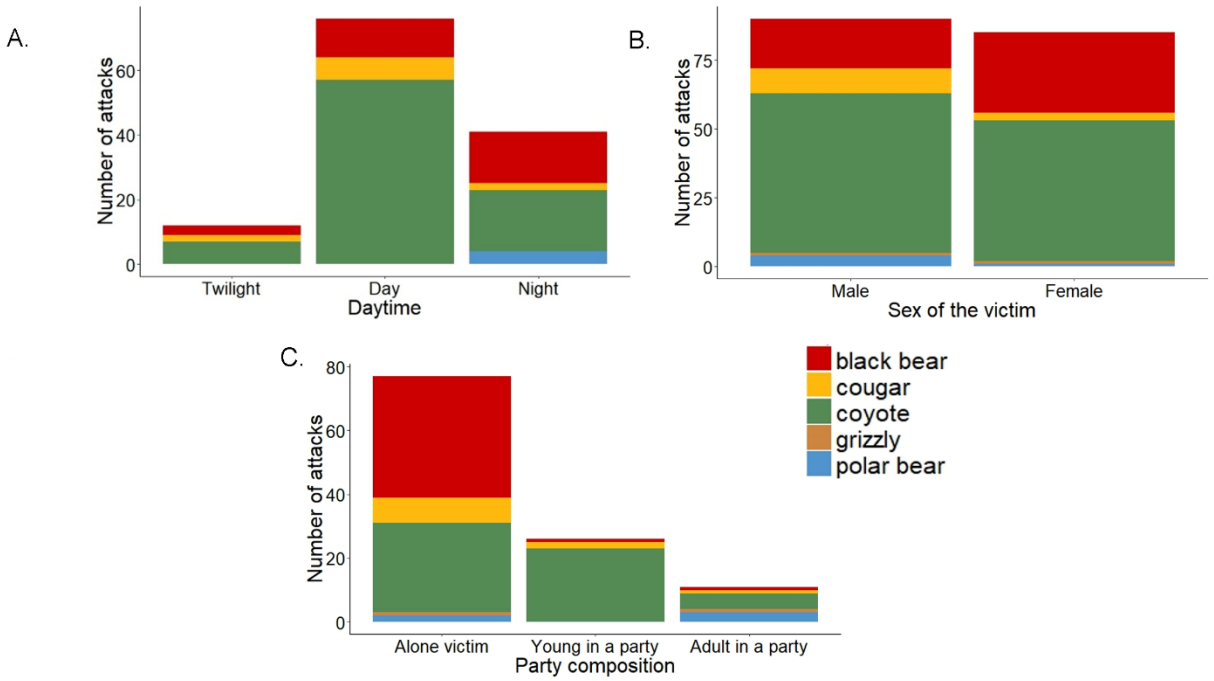
Supplemental Figure S1. a. Urban areas of the U.S. and Canada where large carnivore attacks occurred between 1980 and 2016; **b**. Species of large carnivores involved in attacks on humans in urban areas of the U.S. and Canada between 1980 and 2016. The conflict end (i.e., injury or death) is also shown.



Supplemental Figure S2. Features of large carnivore attacks on humans in North American urban areas from 1980 to 2016. **a**. Temporal trends, showing an increase in recent times; **b**. Seasonal patterns; **c.** Age of the victims; and **d**. Scenario of the attacks, i.e., factors triggering the attacks.



Supplemental Figure S3. a. Dial patterns of large carnivore attacks on humans recorded in North American urban areas between 1980 and 2016; **b**. Sex of the victims; **c**. Composition of parties involved in the attacks.



Supplementary Table S1. A. Comparison of the competing models built to analyse the landscape structure at the site of the attacks based on values of AICc, ΔAICc and AICc weights (n = 69). Competitive models are ranked from the lowest (best model) to the highest AICc value. Summary of fitted parameters is shown for models with ΔAICc < 2.

Response variable: number of attacks per large carnivore species (2 levels: attacks by coyotes and attacks by black bears) – binomial distribution error. Deviance = 0.288.

COMPETING MODELS		*β*	*SE*	*p*	*AICc*	*ΔAICc*	*AICc weights*
PC1					*67.84*	*0.00*	*0.50*
	Intercept	*1.079*	*0.343*	*0.00164*			
	PC1	*-0.722*	*0.182*	*7.08e-05*			
PC1+PC2					*67.84*	*0.00*	*0.50*
	Intercept	*1.228*	*0.391*	*0.001672*			
	PC1	*-0.798*	*0.205*	*0.000101*			
	PC2	*-0.762*	*0.527*	*0.148228*			
NULL					*88.45*	*20.60*	*0.00*
PC2					*89.91*	*22.07*	*0.00*

B. Summary of the output of the PCA run on the landscape variables. Importance of each component and loadings are reported.

IMPORTANCE OF COMPONENTS	PC1	PC2	PC3	PC4	PC5
Standard deviation	2.02	0.73	0.46	0.32	0.26
Proportion of Variance	0.82	0.11	0.04	0.02	0.01
Cumulative Proportion	0.82	0.93	0.97	0.99	1.00
LOADINGS					
Area of vegetation	0.466	-0.328	-0.196	0.427	0.675
Area of buildings	-0.422	-0.573	-0.657	-0.247	
Area of roads	-0.424	-0.560	0.659	0.265	
Mean patch size	0.465	-0.356		0.335	-0.732
Patch density	-0.458	0.351	-0.295	0.758	

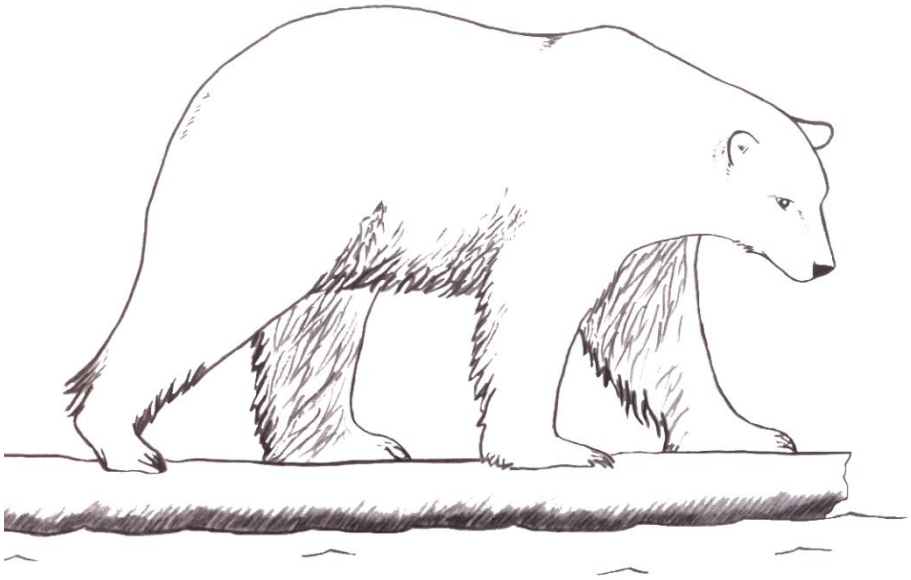
C. Comparison of the competing models built to analyse conditions of artificial light at the site of the attacks based on values of AICc, ΔAICc and AICc weights (n = 15). Competitive models are ranked from the lowest (best model) to the highest AICc value. Summary of fitted parameters is shown for models with ΔAICc < 2.

COMPETING MODELS		*β*	*SE*	*p*	*AICc*	*ΔAICc*	*AICc weights*
RADIANCE	*Intercept*	*-4.372*	*2.754*	*0.1124*	*15.92*	*0.00*	*0.97*
	Radiance	*0.328*	*0.197*	*0.0951*			
NULL					*23.04*	*7.11*	*0.03*

Response variable: number of attacks per large carnivore species (2 levels: attacks by coyotes and attacks by black bears) – binomial distribution error. Deviance = 0.473.

Chapter 2

Patterns of bear attacks on humans, factors triggering risky scenarios and how to reduce them.



Penteriani V.*, Bombieri G.*, Delgado MM., Sharp T., Yamazaki K., Bargali HS., Dharaiya N., Kumar Jangid A., Kumar Sharma R., Lamichhane BR., Ratnayeke S., Seryodkin I., Shekhar Palei H., Subedi A., Ambarli H., Fedriani JM., Garrote PJ., Jerina K., Kojola I., Krofel M., Mardaray P., Melletti M., Ordiz A., Pedrini P., Revilla E., Russo LF., Sahlén V., Servheen C., Støen OG., Swenson JE., Smith T.

* These authors equally contributed to this work

Chapter within the book *"Bears of the World: Ecology, Conservation and Management"*. Cambridge University Press. Vincenzo Penteriani & Mario Melletti (Editors). In press.

INTRODUCTION

Of the eight bear species inhabiting the world, two (i.e., Andean bear and giant panda) have never been reported to attack humans, whereas the other six species did: sun bears *Helarctos malayanus*, sloth bears *Melursus ursinus*, Asiatic black bears *Ursus thibetanus*, American black bears *Ursus americanus*, brown bears *Ursus arctos*, and polar bears *Ursus maritimus*. These species occur across four continents (Asia, Europe, North and South America) characterised by a huge range of social and cultural practices, e.g., from increasing leisure activities in bear areas in developed countries to daily forest works in developing countries. Such differences in the use of bear habitats by people may determine that different scenarios trigger bear attacks on humans around the world. However, even if the motivations that determine human presence in bear countries and risky encounters with bears are diverse, some triggering factors might be common in activating bears' dangerous reactions towards people, e.g., inappropriate human behaviours when sharing the landscape with bears or when encountering them at a close range.

This chapter provides insights into the causes, and as a result the prevention, of bear attacks on people. Prevention and information that can encourage appropriate human behaviour when sharing the landscape with bears are of paramount importance to reduce both potentially fatal human-bear encounters and their consequences to bear conservation.

METHODS

We reviewed scientific/grey literature and analysed personal databases on bear attacks on humans available from 1980 to 2018. Moreover, we also searched for PhD/MS theses and webpages on bear attacks on humans. In addition, we collected news reports from online newspapers to complete the dataset obtained from the above-mentioned sources. To this aim, for each bear species and area, we searched for news articles on Google on an annual basis using the following combination of words: 'species name' + 'attack' and 'species name' + 'attack' + 'human'. To prevent duplicate records in the data, we cross-checked information such as date, locality, and human characteristics. When possible, for each attack, we recorded the

following information: (1) period of the attack, i.e. year, month, and time of the day; (2) location; (3) outcome, i.e. human injury or death; (4) characteristics of the person/party and bear involved in the attack, e.g. age and sex of both the person and the bear; (5) human activity at the time of the attack; and (6) the attack scenario, i.e. the factor(s) that could have triggered the attack.

An Overview of Bear Attacks in the World

Sun Bear

The sun bear, the smallest ursid in the world, is found in Southeast Asia, where few (n = 11) attacks on humans have been reported. Although the available information is extremely scarce and incomplete (Sethy and Chauhan 2013), attacks seem to be extremely rare and mainly the consequence of sudden encounters (i.e. with the bear being inadvertently surprised at a close distance). Such encounters mainly occur when people venture inside the forest for different purposes (Sethy and Chauhan 2016). For example, in Indonesia most attacks happen to people working in the forest on a daily basis, such as rubber harvesters (55%), whereas fewer cases occurred to people who work in crop fields and collect non-timber forest products (Windler 2014). In general, encounters with these bears are mainly non-fatal.

Sloth Bear

Sloth bears are known for their aggressive behaviour toward humans (Burton 1856, Anderson 1957). Although the total number of people seriously injured or killed by sloth bears during a given year is not known, within one Indian state (Madhya Pradesh, central India), 48 sloth bear-inflicted fatalities and 687 maulings were documented between 1989 and 1994 (Rajpurohit and Krausman 2000). This accounts for an average of six deaths and 115 maulings per year in this Indian state. Because sloth bears occupy 19 Indian states, as well as Nepal, Sri Lanka, and possibly Bhutan, this species might be responsible for more attacks on humans than all other seven species of bears combined.

The sloth bear's motivation to attack is mainly defensive. There has never been a documented predatorial attack (Sharp et al. 2017), although there have been

several documented cases of sloth bears consuming portions of their victims (Bargali et al. 2005, Akhtar 2006). This appears to be the result of opportunistic behaviour after the attack, rather than the motivation for the attack. The sloth bear's aggressively defensive nature may be the result of having coevolved with large predators, namely tigers *Panthera tigris*, and leopards, *Panthera pardus*, which are known to occasionally prey upon sloth bears (Littledale 1889, Fenton 1909, Kurt and Jayasuriya 1968, Laurie and Seidensticker 1977). Sloth bears are not adept climbers and are often in scrub jungle or grasslands, where climbing is not an option. They are not particularly fast runners, either. However, they are exceptionally strong animals that possess large canines and claws. Although no match for a tiger in an extended encounter, sloth bears can make themselves a particularly difficult prey (Figure 1). In addition to their physical attributes, sloth bears make use of intimidation tactics, such as charges coupled with vocalizations and making themselves appear larger with a bipedal stance (Bargali et al. 2005, Ratnayeke et al. 2014, Sharp et al. 2017). This aggressive-defensive nature may serve to deter predators, but impedes conservation efforts whenever they attack humans (Akhtar 2006, Dharaiya et al. 2016).

To better understand this type of human–sloth bear conflicts, we compiled information on 1169 attacks that took place in the three countries with extant sloth bear populations: India, Nepal, and Sri Lanka. We also considered the reported results from individual studies conducted throughout the sloth bear's distribution.

Figure 1. It has been suggested that the defensive nature of sloth bears is the result of having coevolved with large predators such as tigers (photo by Ayan Sadhu).

We found that the spatio-temporal patterns of these attacks varied across studies. Whereas some studies reported a spike in attacks during the monsoon season, others reported more attacks during the dry season (Rajpurohit and Krausman 2000, Bargali et al. 2005, Ratnayeke et al. 2014, Garcia et al. 2016, Dhamorikar et al. 2017, Sharp et al. 2017). These differences may be related to seasonal and daily patterns of human use of forests, or to proximity between bears and people in highly fragmented bear populations. For example, in Bilaspur (India), attacks mainly occur in villages and agricultural fields (Bargali et al. 2005), whereas, in other study areas, the majority of attacks occur in forests (e.g., Ratnayeke *et al.* 2014; Dhamorikar *et al.* 2017). The high number of attacks during monsoon may be because people start agricultural practices in crop fields, collect mushroom from forest, and use forests for livestock grazing at the onset of this season. In monsoon, it also becomes easy for sloth bears to dig termite mounds and there is increased

vegetation cover as well. Such a combination of different factors and the increased disturbance in and around sloth bear habitats considerably augment the probability of risky encounters with a sloth bear. The time of day that attacks occurred also varied a great deal. Although some studies suggested that dawn and dusk were the most dangerous times to be moving through sloth bear country (Bargali et al. 2005, Mardaraj and Dutta 2011, Mardaraj 2015, Debata et al. 2017, Dhamorikar et al. 2017, Sharp et al. 2017), others reported that most attacks occurred during midday (Ratnayeke et al. 2014, Garcia et al. 2016).

There is little doubt that local factors, including human activity patterns, play a large role in the spatio-temporal patterns of sloth bear attacks. For example, although sloth bears are generally known to be more active at dusk and during the night, in many places several attacks occurred during the day. This may be partly due to resting bears being disturbed, or surprised, rather than the presence of active bears; yet, very few attacks happen during daylight hours in areas that are known to have many naturally occurring caves and hollows.

A large portion of attacks (42%) took place when humans were active in the forest (e.g. collecting forest products, walking, etc.). For example, in central India, people collect tendu leaves (*Diospyros melanoxylon*) and mahua flowers and seeds (*Madhuca indica*) for commercial use, as well as sal leaves (*Shorea robusta*), bamboo (*Dendrocalamus strictus*), chironji (*Buchanania lanzan*), and wild mushrooms, which increases the probability of sudden encounters between people and sloth bears. The second highest category (25%) involved persons who were farming or caring for orchards. These types of activities are more often performed by men than by women or children, which likely explains why adult males were found to be involved in the majority of attacks (87%).

Perhaps surprisingly, the third highest number of attacks (15%) took place when humans were defecating in the forest. This tends to occur in areas which are often frequented for this purpose. The reason for this type of attack is unclear. It is possible that faecal odours attract sloth bears to areas often used for defecation. However, this is purely speculative at this point, though it is interesting to note that

the smell of human faeces is known to attract both brown *Ursus arctos* and American black bears *Ursus americanus*. (T. Smith, unpubl. data).

Sudden encounters triggering defensive-aggressive attacks accounted for 47% of the attacks. Often the victim was unaware of the sloth bear's presence until they saw the bear charging from just meters away (Figure 2).

Figure 2. The main scenario of sloth bear's attacks on humans is sudden encounters in dense forests, where the victim is often unaware of the bear presence (photo by Luxshmanan Nadaraja, Wildlight Pvt. Ltd).

Like most mammals, sloth bears are protective of their young and, of the 1169 attacks complied for this chapter, 22% (n = 109) involved females with cubs, although several studies reported this number to be higher (Ratnayeke et al. 2014, Sharp et al. 2017).

Most studies on sloth bear attacks report that human group size plays a role in the likelihood of attack (Ratnayeke et al. 2014, Sharp et al. 2017). We found that nearly half of all attacks involved a single person (46%). However, reported group size can be misleading, because if people are spread out, the bear may perceive each

individual as a single person, rather than as part of a group. Ratnayeke et al. (2014) found that a human companion < 50m away significantly reduced the likelihood of severe injury during a sloth bear attack. Human groups are likely to be noisier, thus less likely to surprise a bear, and more intimidating to an attacking bear than a solitary person. Additionally, in some cases the person attacked by a sloth bear has been saved by other nearby people or even by animals accompanying the victims (Bargali et al. 2005, Dhamorikar et al. 2017, Silwal et al. 2017), although dogs may sometimes precipitate an attack. Indeed, Ratnayeke et al. (2014) reported 3 attacks that resulted from dogs running back to their owners with a bear in pursuit, putting the human directly in the path of an angry bear.

Of the 1169 sloth bear attacks we reviewed, 5% (n = 58) resulted in the death of the victim. Based on other studies (Sharp et al. 2017), moderate to severe injuries make up another 35% to 50% of the attacks.

Asiatic black bear

Although not scientifically documented, the Asiatic black bear seems to be more nervous than its American relative, the American black bear. This might be due to the relatively small body size compared to humans or to long-term persecution by humans (Japan Bear Network 2006, Yamazaki 2010). Because Asiatic black bears are generally shy and nervous, most of their attacks on humans are defensive attacks, especially when a female bear is with cubs or in the event of sudden or unexpected encounters (Rasool et al. 2010, Japan Bear Network 2011).

Our search resulted in a total of 747 attacks by Asiatic black bears in Pakistan, India (Kashmir, northern India), Bhutan, Nepal, Russia (Far East Region), and Japan (Honshu Island, the largest and most populous island of Japan). Although we do not know whether bears hibernate throughout these areas, most attacks occurred between May and November, with the highest frequency of attacks occurring in October (18%). Ninety-five percent of the attacks occurred between April and November and 5% from December to March. During late autumn and early winter, when bears enter their hyperphagic period, they predominantly rely on acorns (Kozakai et al. 2011) and, when the autumn acorn production is low, bears become

bolder and search for alternative, high-energy food resources (Kozakai et al. 2011, Ali et al. 2018), resulting in drastically increased human-bear conflicts, including bear attacks.

Most attacks occurred during daylight (94%), compared to twilight (4%) and night (2%). Even though Asiatic black bears are diurnal and their activity peaks are during dawn and dusk (Hwang and Garshelis 2007, Yamazaki et al. 2008), they can modify their behaviour to become more nocturnal when they approach human habitation (Arimoto et al. 2014).

Most people involved in attacks were males (78%). Attacks mainly occurred while people were farming or participating in various activities in the forest (45% and 32%, respectively), and it is possible that more males are generally involved in these activities than females. The age of victims was biased to adults (>13 yr. old; 94%), which is likely explained by the same phenomena as the sex bias. Most of the attacks recorded were the result of sudden encounters (86%), with bears reacting aggressively when surprised at close distances. Notably, we found that at least 30% of such kind of encounters occurred while bears were feeding on crops or other products in people's fields or orchards. Such scenario has been found to be the main attack circumstance in several studies, with people encountering bears at close range and consequently being attacked when visiting or working in their crop fields or orchards (Nabi et al. 2009*a*, Tak et al. 2009, Rasool et al. 2010, Charoo et al. 2011). Other reported scenarios involve people entering dense forest to collect wood or other forest products or to graze livestock (Tak et al. 2009, Lal Moten et al. 2017, Ali et al. 2018).

The number of bear attacks has been increasing recently in Nepal (Acharya et al. 2016), India (Kashmir) (Nabi et al. 2009*b*), and Japan (Yamazaki 2010). This is mostly due to human population expansion, deforestation, and destruction and fragmentation of bear habitat in most Asian countries (Japan Bear Network 2006). In contrast, the reason for increasing bear attacks in Japan is quite different, because the population and range of bears have been expanding in recent decades, due to habitat recovery as a result of aging human population and depopulation (Yamazaki 2004, Yamazaki and Sato 2014). From statistics by the Ministry of Environment in

Japan, 851 people were attacked (including 13 deaths) by bears in the last 10 years (2008–2017). Although the frequency of attacks by Asiatic black bears is relatively high, these attacks rarely result in fatalities (8%). Similar or lower fatality rates are reported in Nepal (Acharya et al. 2016), India-Kashmir (Nabi et al. 2009*b*, Rasool et al. 2010, Shah et al. 2010), and Japan (Akiyama et al. 2017). Although fatalities are rare, injuries are frequently serious, as bears often stand upright and first attack the person's neck and face using their claws, causing devastating damages such as bone fractures and deep tissue lacerations (Nabi et al. 2009*b*, Rasool et al. 2010, Oshima et al. 2018). Many victims must undergo multiple and complex facial reconstructive surgeries (Rasool et al. 2010, Shah et al. 2010).

In the northern part of Honshu Island, Akita Prefecture, Japan (Yamazaki 2017, Oshima et al. 2018), four local residents who were gathering bamboo shoots were killed and partially eaten by bears in 2016, and another local resident was attacked and partially eaten by a bear(s) in 2018. As a result, local attitudes towards bears have drastically changed within this prefecture and have become more negative, resulting in a total of 1676 bears being killed as nuisance animals between 2016 and 2018. These attacks have had a bad influence even in other prefectures, and bear management is facing serious difficulties in many areas.

The American Black Bear and Humans: A Tolerant Predator

Outnumbering the other two species of North American bears by ten-fold, the American black bear is the most ubiquitous ursid on the continent (Herrero 2018). Not surprisingly, black bears account for the majority of human-bear incidents in North America, though most resolve without injury (Penteriani et al. 2016). In a recent study of human-bear conflict in Alaska, Smith and Herrero (2018) reported that black bears, which outnumber brown bears three-to-one in the state, were responsible for only 14% (89 of 638) of bear attacks reported from 1880 to 2016. This suggests a tolerance for humans not shared by brown bears. A similar pattern has been found on a continental scale by Penteriani et al. (2016). In that study, which collected and analysed attack cases by all large carnivore species in North America, 85 attacks by black bears (12.2% of the total cases recorded, less than

coyotes, cougars, and brown bears) were reported between 1955 and 2014. Herrero (1972) suggested that this reluctance to engage with people is the result of their unique evolutionary past. Black bear evolved in the densely forested regions of North America and could often resolve conflict by either climbing a tree or disappearing into the dense understory (Herrero 1972). Therefore, when suddenly confronted by people, they flee. Indeed, Smith and Herrero (2018) found in Alaska that brown bears accounted for nearly 6 times more attacks than black bears (508 vs 89), resulting in 47 brown-bear inflicted fatalities compared to just 5 due to black-bears (9.4 times higher rate for brown bears).

Nonetheless, on rare occasion, when black bears attack and kill people, 90% of them were deemed predatory (Herrero et al. 2011). From 1900-2009, Herrero et al. (2011) documented 63 fatal black attacks in the United States and Canada. They also found that black bear-inflicted fatalities were highly correlated with human population growth in those countries, suggesting that the more people enter black bear habitat, the more likely it is that a conflict will arise. Although the vast majority of black bears clearly avoids conflict with humans, a few bears apparently perceive people as prey and attempt to take them.

Herrero and Higgins (2003) identified the behaviour of predatory black bears by a series of behaviours: searching, following and testing, attacking (capturing), killing, sometimes dragging a person, sometimes burying, and often feeding upon a person. By analysing patterns of predatory attacks by all large carnivore species in North America, Penteriani et al. (2017) found that the black bear was the third most frequent species involved in this kind of encounters (16%), after cougars and coyotes, and, as expected, the target of predatory attacks were the most vulnerable individuals, namely children and lone people.

Black bears are powerful predators quite capable of inflicting severe injury and death on humans. Herrero et al. (2011) speculated that black bears likely do not prey on people more often than they do, because bears with those genes have been consistently culled from the gene pool. Importantly, fatal attacks by black bears are fundamentally different than those of brown bears because browns are rarely predatory, whereas black bear-inflicted fatalities are almost always the result of

predation. Unlike brown bears, black bears have been often reported to cause conflicts and, more rarely, injure people in urban areas across North America (Bombieri *et al.* 2018b). In such environments, risky encounters with this species are mainly due to the presence of dogs or anthropogenic food (e.g. a bear is surprised by a person while feeding on pet food or trash in the yard and react aggressively). Probably due to the forest-obligate nature of the species, attacks in urban areas are more likely to occur where the vegetation cover is more abundant and less fragmented and far from buildings and roads. Half of such encounters have been found to occur at night, especially in areas where the artificial illumination is scarce (Bombieri *et al.* 2018b).

Human- Polar Bear Conflict: The Past, Present and Future

Human-polar bear conflict has existed for as long as both species have shared the Arctic. Without a written language, these conflicts went unrecorded by Indigenous peoples, but undoubtedly occurred with some regularity. The earliest written accounts of human–polar bear conflict are sporadic and were recorded by European mariners who kept journals. Among the earliest of these is an account of Dutch mariner William Barents (1594), who attempted to capture a polar bear to bring back alive to Holland (Wikipedia 2019). Unfortunately, the bear broke loose aboard ship, rampaged the vessel and was killed in the process. Additionally, Barents wrote a year later that two men in his expedition were attacked and killed by a polar bear, the earliest polar bear–inflicted fatalities we know of on record. More recently, Charlie Brower of Barrow (Alaska) witnessed a polar bear casually crush the skull and ribs of a Native guide in 1883 (Brower 1942). Such graphic accounts have unquestionably fuelled the widely held belief that it is fundamental to a polar bear's nature to 'stalk and kill humans' (Ramachandran 2009). Even though brutal accounts of polar bears ravaging humans dot the pages of history books, one must ask if they truly deserve the moniker "stalker and killer of humans". Human–polar bear attack research does not support that claim.

In recent years, a number of studies of have documented the nature of human–polar bear conflicts (Fleck and Herrero 1988, Clark 2003, Wilder et al. 2017).

Both Clark (2003) and Fleck and Herrero (1988) reported that most human–polar bear interactions do not result in injury, and when persons were injured, rates of interactions resulting in injury were low (2% and 5%, respectively). Specifically, Clark (2003) reported that only one bear–inflicted injury occurred in 53 polar bear-human interactions. Fleck and Herrero (1988) documented 373 aggressive polar bear interactions, of which only 10 bear–inflicted injuries occurred. Because Wilder et al. (2017), reported only on polar bear attacks, their data are not comparable to the previous studies that included non–injurious interactions. However, over a 144–year period, Wilder et al. (2017) documented only 73 attacks on humans by polar bears across their entire range, and in those attacks 20 persons were killed and another 63 injured. By contrast, Smith and Herrero (2018) reported nearly the same number of attacks for brown bears in Alaska in a single decade (2000–2009). The record is clear that polar bears injure and kill far fewer humans that do black and grizzly bears (Fleck and Herrero 1988). Although some may point out that the interaction rates between polar bears and humans are far lower than that of black and grizzlies, injuries are low and deaths extremely rare where polar bears and people commingle considerably (e.g., Churchill, Manitoba; Kaktovik, Alaska). In all of these human–polar bear interactions, predation was rare, but when people were killed, predation was considered the primary motivation (Wilder et al. 2017).

The 'take in the bear home' message: How to Avoid and Survive to Bear Attacks and Specific Measures of Risk Reduction

Sloth bears

Information on sloth bear attacks suggest that being in a group and making noise while moving through sloth bear habitat helps reduce the likelihood of startling a bear at close quarters, giving it the opportunity to leave the area without incident. Bear spray and guns are not available for protection to most who live in sloth bear country and many attacks occur too quickly for weapons to be used effectively. However, villagers carrying a heavy club or walking stick have been able to drive off an attacking bear, and this might prove to be especially effective when more than one person acts in concert (Ratnayeke et al. 2014, Sharp et al. 2017).

If a sloth bear is observed, but is not aware of the observer, people should slowly back away, giving the bear as much space as possible. Running has been reported to trigger a chase response, and several runners have been pursued and killed by sloth bears (Sharp and Sonone 2011, Ratnayeke et al. 2014, Sharp et al. 2017). Yelling or throwing stones at a non-aggressive sloth bear may also elicit an attack.

Although some have reported that the sloth bear retreated when fought, Sharp et al. (2017) reported that those who fought were more likely to be killed than people that played dead. The safest response to an attack might highly depend on factors such as the bear motivation to attack and the human characteristics as well as group size. A person that is attacked may decrease the risk of injury or death by using the protective position recommended by Herrero (2018) for grizzly bear attacks: lying face down on the ground with hands locked behind the neck and arms protecting the face. The effectiveness of this defensive position for sloth bear attacks is yet untested, however, most sloth bear attacks are defensive, cause injuries to the face and head, and limited data suggest that the attack does not persist when the bear perceives that the threat has faded.

Temporal patterns of sloth bear attacks across different geographic areas suggest that peaks in specific types of human activities increase the potential for human-sloth bear encounters and attacks. These activities may vary by location and managers should work with local people to seek solutions. For example, at locations where bears frequent village compounds and agricultural fields, villagers could be encouraged and financially supported to construct toilets and to use extreme caution moving around when bears are active (Jangid and Sharma 2018). Similarly, avoiding the collection of 'non-timber forest products' during twilight hours may reduce the risk of encountering active sloth bears. Moving in groups and advertising one's presence via sound and loud conversation will give resting bears an opportunity to leave the area. In areas where bears reside within or on the periphery of human settlements, cultivating crops (e.g., maize, ground nuts) that attract bears will increase the likelihood of attacks, let alone crop losses. Training programmes aimed at sustainable livelihoods, including support for alternative forms of agriculture and

income to reduce the dependency of local communities on forest resources could help to keep sloth bears and people well-separated. Proper garbage/waste management practices should be promoted in those areas where sloth bears are attracted and approach garbage sites to feed on remnants of fruits and edible materials (A. Jangid unpubl. data). In addition, provisioning of edible materials in remote temples should be stopped, so the encounters can be reduced near temple sites. Indeed, a few cases have been reported of bears breaking in and raiding houses and small temples located inside forests to feed on edible products such as oils left by pilgrims as offer (A. Jangid unpubl. data; Singh *et al.* 2017; Jangid & Sharma 2018), alarming the villagers. Finally, for bears that have little alternative but to survive in forest fragments surrounded by agriculture and human settlements, guidelines and policies for safely trapping and relocating them may be the most feasible option (Figure 3).

Figure 3. Trapping and relocating conflictual sloth bears might represent an alternative to retaliatory killing (photo by Ashish Jangid).

Asiatic black bear

There are no easy solutions to reduce Asiatic black bear attacks on humans. However, public education about bears (i.e. bear habitat, behaviour, and ecology) to local residents and people engaging in various activities in the forest can be one major effective approach (Japan Bear Network 2006, Jamtsho and Wangchuk 2016). Because attacks often occur to farmers working on crop fields or orchards, suggesting that bears are attracted by agriculture products, preventive measures aimed at protecting such areas might prove effective to avoid both crop raiding and potentially dangerous encounters between farmers and bears (Jamtsho and Wangchuk 2016). Moreover, people should be cautioned about the possibility of encountering bears when working in their crop fields or moving in the forest and should be provided information on how to avoid being attacked. Moving in group and making noise while moving in areas with poor visibility might help the bear

notice human presence and leave the area to avoid the encounter (Rasool et al. 2010). Given the evident defensive strategy of attacking the head and face region commonly adopted by Asiatic black bears, if a bear reacts aggressively when encountered, people should not fight back, but protect these sensitive regions and adopt a passive position. It has been shown, indeed, that the attack terminated spontaneously in most of the cases, with the bear leaving immediately once the victim was overpowered (Rasool et al. 2010, Shah et al. 2010). Also, increasing the distribution/availability of bear avoidance equipment, such as pepper spray, at affordable prices could also be effective. Once a bear attack has occurred, comprehensive on–site verification and sharing of the obtained information among related organizations is also very important to prevent similar future types of incidents.

American black bears

Smith and Herrero (2018) and Herrero and Higgins (2003) identified a number of insights regarding safety in black bear country. These findings fall into four broad categories of bear safety messaging: (1) general information; (2) how to avoid bear encounters; (3) how to defuse encounters; and (4) how to survive attacks. Firstly, food and garbage should be secured to avoid attracting bears. People should move in bear area in groups of more than two and try to group together if a bear is encountered. Carrying bear spray is highly recommended. Additional specific precautions should be taken in urban areas and their proximities (Bombieri et al. 2018*a*). In such environments, increased attention to dogs and improved attractants management (i.e., avoid leaving garbage, pet food, and bird feeders outside houses) would likely reduce the probability of risky encounters with this species. Moreover, to reduce the occurrence of predatory attacks, particular attention should be taken with children, who need to be constantly and strictly supervised by adults (Garrote et al. 2017, Penteriani et al. 2017*b*). Finally, in case of an attack, being able to recognize the motivation behind it may be crucial in determining the attack outcome. That is, in case of a predatory attack, one should try to aggressively deter the bear and fight back in any possible way. Instead, if the attack is defensive, one

should be passive and adopt a defensive posture by lying face down and protecting neck with hands.

Polar bears

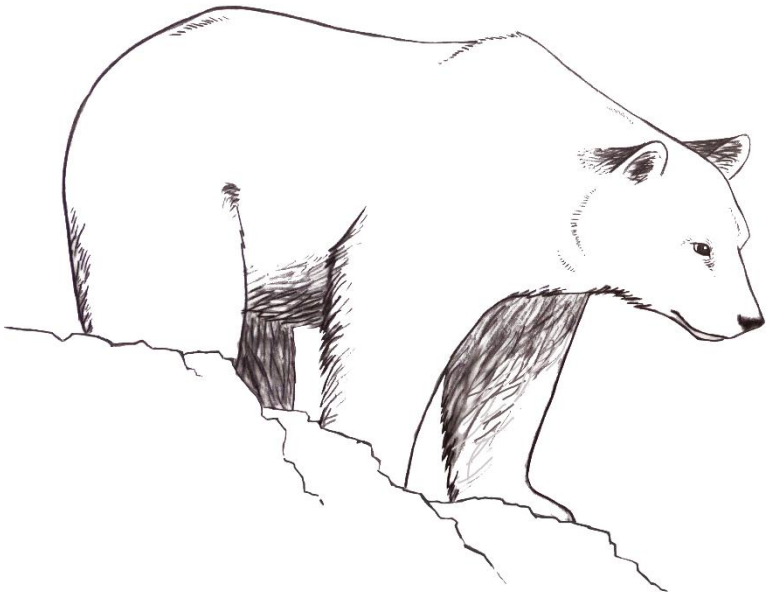
Wilder et al. (2017) cautioned that, as sea ice continues to shrink, human–polar bear conflict can be expected to rise. Importantly, Fleck and Herrero (1988) observed that the outcome of human–polar bear conflict was most often a dead bear and much more rarely an injured or dead human. Therefore, improved conflict investigation is needed to collect accurate and relevant data and communicate accurate bear safety messages and mitigation strategies to the public. With better information, people can take proactive measures in polar bear habitat to ensure their safety and prevent conflicts with polar bears.

To conclude, although rare, bear attacks on humans do occur within the whole range of bear species and undermine bear conservation efforts (Røskaft et al. 2007). Different bear species showed differing attack patterns and, although some bear species, such as the Andean bear, the sun bear, and the giant panda have never or rarely been reported to be involved in such incidents, the other five species of bears may locally represent a more serious threat to human safety. Therefore, it is of the utmost importance for bear conservation worldwide to reduce such conflicts by developing and implementing effective strategies based on both species–specific characteristics and the local socio–economic context. In developed countries, where most attacks occur to people involved in recreational activities in bear areas, conflicts can be decreased through education and outreach (i.e. providing accurate bear safety messaging to the public). For instance, recent efforts in Yosemite National Park have demonstrated that with effective education, outreach and appropriate penalties for the uncompliant, bear conflicts can be dramatically decreased (down 99% since 1998), benefitting both people and bears (National Park Service 2019). A different approach should be employed in developing countries, where people involved in attacks are mostly local people who must enter bear areas for their daily work and subsistence–related activities. Here, education on how to avoid bear encounters and attacks might not be sufficient alone and must be

combined with improved facilities and financial support for local communities living in bear areas.

Chapter 3

Brown bear attacks on humans: a worldwide perspective.



Bombieri G.*, Naves J.*, Penteriani V., Selva N., Fernández-Gil A., Lopez-Bao JV., Ambarli H., Bautista C., Bespalova T., Bobrov V., Bolshakov V., Bondarchuk S., Camarra J-J., Chiriac S., Ciucci P., Dutsov A., Dykyy I., Fedriani JM., García-Rodríguez A., Garrote PJ., Gashev S., Groff C., Gutleb B., Haring M., Härkönen S., Huber D., Kaboli M., Kalinkin Y., Karamanlidis AA., Karpin V., Kastrikin V., Khlyap L., Khoetsky P., Kojola I., Kozlow Y., Korolev A., Korytin N., Kozsheechkin V., Krofel M., Kurhinen J., Kuznetsova I., Larin E., Levykh A., Mamontov V., Männil P., Melovski D., Mertzanis Y., Meydus A., Mohammadi A., Norberg H., Palazón S., Pătraşcu LM., Pavlova K., Pedrini P., Quenette PY., Revilla E., Rigg R., Rozhkov Y., Russo LF., Rykov A., Saburova L., Sahlén V., Saveljev AP., Seryodkin IV., Shelekhov A., Shishikin A., Shkvyria M., Sidorovich V., Sopin V., Stöen OG., Stofik J., Swenson JE., Tirski D., Vasin A., Wabakken P., Yarushina L., Zwijacz-Kozica T. and Delgado MM.

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ABSTRACT

The increasing trend of large carnivore attacks on humans not only raises human safety concerns but may also undermine large carnivore conservation efforts. Although rare, attacks by brown bears *Ursus arctos* are also on the rise and, although several studies have addressed this issue at local scales, information is lacking on a worldwide scale. Here, we investigated brown bear attacks (n = 664) on humans between 2000 and 2015 across most of the range inhabited by the species: North America (n = 183), Europe (n = 291), and East (n = 190). When the attacks occurred, half of the people were engaged in leisure activities and the main scenario was an encounter with a female with cubs. Attacks have increased significantly over time and were more frequent at high bear and low human population densities. There was no significant difference in the number of attacks between continents or between countries with different hunting practices. Understanding global patterns of bear attacks can help reduce dangerous encounters and, consequently, is crucial for informing wildlife managers and the public about appropriate measures to reduce this kind of conflicts in bear country.

INTRODUCTION

The end of legal and widespread persecution, strict protection measures, and reintroductions have allowed brown bear *Ursus arctos* populations to recover and expand in many areas of North America and Europe (Clark et al. 2002, Kasworm et al. 2007, Chapron et al. 2014, Bautista et al. 2017, McLellan et al. 2017). Currently, brown bears are estimated to exceed 200,000 individuals worldwide, most of which live in Russia (~100,000), whereas North America and Europe are home to around 58,000 and 15,400 brown bears, respectively (McLellan et al. 2017). Although the number of bears is growing globally, several small subpopulations are still endangered and, in several cases, their location in close proximity to highly humanized areas leads to increased negative interactions with humans (McLellan et al. 2017).

Although brown bears are known to adjust their behaviour in order to avoid humans (Ordiz et al. 2011), complete avoidance is not always possible. Brown bears, indeed,

are known to be involved in various types of conflicts with humans, which typically include property damage (Bautista et al. 2017) and, more rarely, direct attacks on people (Penteriani et al. 2016). These conflicts might be even more severe in areas of recent expansion and reintroduction, where bears had previously been extirpated. Here, traditional prevention practices have been lost and people are no longer used to sharing the landscape with this large carnivore (Stahl et al. 2001, Bautista et al. 2017). At the same time, human population is growing all around the world, leading to an expansion of urban areas towards natural habitats (Bombieri et al. 2018*a*). In addition, in developed countries, people living in cities are increasingly engaged in recreational outdoor activities in natural parks (Penteriani et al. 2016), and owning a second house in natural areas outside the city has become a common trend (Vogt and Marans 2004). Such intensified use of wilderness area by humans, especially people that are not used to cohabit with wildlife, increases the probabilities of potentially dangerous encounters with these species, urging wildlife managers and conservationists to take action.

Among all large terrestrial and aquatic predators, attacks by brown bears are the most highly covered by the international media (Bombieri et al. 2018*b*). This suggests that, even if attacks by brown bears are less frequent than those by other predators, at least among North American large carnivores (Penteriani et al. 2016), this species has the power to attract amplified attention of mass media, which has the potential to negatively impact public attitude.

Several studies have investigated attacks on humans by brown bears at local scales, suggesting a general increase in the number of incidents over the years in different regions of the world (e.g., [1,14,21,22]). However, most of the published literature on the topic is concentrated in North America and Scandinavia, and large-scale studies are lacking.

Here, we investigated patterns of brown bear attacks on humans occurring between 2000 and 2015 on a worldwide scale, with the main aim of improving our knowledge on this type of conflict and, consequently, providing useful information that could help reduce the occurrence of negative human-bear encounters. In particular, we: (*i*) provide a first global-scale perspective of the phenomenon; (*ii*)

describe temporal and spatial patterns of these incidents; (*iii*) describe main attack circumstances, highlighting common features and local peculiarities in attack scenarios between geographical areas with different histories of human coexistence with this species (e.g. North America *vs.* Europe); and (*iv*) explore the effect of various factors, such as bear and human densities, as well as differences in geographic location and management practices, on the number of attacks. In this regard, we hypothesised that:

(*a*) higher numbers of attacks occurred in those countries/jurisdictions where both bear and human densities are higher, due to the consequent higher encounter probability; and (*b*) fewer attacks occurred in those countries where bears are legally hunted, due to potential removal of bold individuals.

METHODS

Collection of information on brown bear attacks

Brown bear attack data

We collected reports of brown bear attacks on humans that resulted in physical injury (i.e., the person required medical attention) or death from 2000 to 2015 all around the world. We limited our search to attack cases occurred starting from 2000 as, before that year, information on attacks was scarce. Attack records were collected from personal datasets of the co-authors, published literature (Shkvyria et al. 2015), unpublished reports, PhD/MS theses, webpages, and news reports. We searched for the above-mentioned sources using the search engines Google (google.com n.d.) and Google Scholar (google.scholar.com n.d.). In particular, to collect cases in North America, in addition to these sources, we also carried out a systematic search of news articles on Google for each jurisdiction on an annual basis, using the combination of the following terms: 'brown bear' or 'grizzly' + 'attack' or 'attack' + 'human'. Because some attacks recurred repeatedly during the search, due to the use of multiple sources, we cross-checked attack location, date, and sex/age of the people involved to avoid duplicate records in the dataset (additional information on the data collection method is available in (Penteriani et al. 2016)).

For each attack, we recorded the following information: (1) year; (2) month; (3) location of the attack; (4) time of day, classified into three categories, i.e. twilight, day and night; (5) sex and age (subadult, < 4 years old; adult, > 4 years old) of the bear; (6) sex and age (child, < 13 years old; adult, > 13 years old) of the victim (Bombieri et al. 2018*a*), where age was classified into two categories; (7) human party composition, simplified into four categories (Garrote et al. 2017): (a) adult alone, (b) child alone, (c) adult in a group, and (d) child in a group; (8) result of the attack, i.e., injury or death; (9) human activity at the time of the attack, three categories: (a) leisure activities, e.g., hiking, camping, fishing, berry/mushroom/antler picking, (b) hunting and (c) outdoor work, e.g., guarding livestock, farming, logging, wildlife-related fieldworks; and (10) attack scenario, i.e., the main reason that could have triggered the attack. We defined five different scenarios: (a) attack by a female with cubs; (b) sudden encounter with a solitary bear, i.e., when a bear (except females with cubs) was surprised at a close distance; (c) predatory, i.e., when the bear deliberately attacked and/or killed a human with the presumed purpose of consuming it (Penteriani et al. 2017*a*); (d) dog-related scenario, i.e., one or more dogs were present at the moment of the attack; (e) wounded bear (i.e. a bear that was shot or trapped during hunting).

Information related to the countries of the attacks

For each country/jurisdiction where an attack occurred (excluding Russia, for which we lacked information), we recorded: (a) bear density, i.e., bears per 1000 km^2; (b) human population density, i.e., inhabitants per km^2, within the range occupied by brown bears; and (c) brown bear management practices. Specifically, we were interested in exploring possible differences in attack patterns between countries where the brown bear is legally hunted or harvested and countries where bear hunting is forbidden. We therefore classified each country/jurisdiction as either a 'hunting country' (i.e., where the brown bear is legally hunted or where the species is protected, but legally and regularly harvested) or a 'non-hunting country' (i.e., where brown bear is protected and killing them is generally forbidden).

Estimates of bear and human population densities and bear ranges for Europe and Turkey were obtained from (Penteriani et al. 2018), (Bautista et al. 2017) and

(Ambarli et al. 2016). The numbers of bears for North American jurisdictions were obtained from published literature and reports (Government of Yukon n.d., Festa-Bianchet 2010, Ministry of Forests Lands and Natural Resource Operations 2012, Alaska Department of Fish and Game 2015, Wyoming Game and Fish Commission et al. 2016, Species at Risk Committee 2017). Bear ranges and human population densities for these jurisdictions were calculated in QGIS (QGIS Development Team 2016). Specifically, we derived bear ranges and human population densities using the North American border layer (Government of Canada Natural Resources Canada et al. 2010), the IUCN layer of bear distribution (IUCN SSC Bear Specialist Group 2017) and the gridded world population data set (Center for International Earth Science Information Network (CIESIN) 2017). Bear ranges included areas of both permanent and occasional brown bear presence. All the above-mentioned values for each country/jurisdiction are reported in Table 1.

Data analysis

Spatio-temporal patterns of the attacks

To explore general spatio-temporal patterns of bear attacks, we built a set of a priori competing models that included the number of attacks as the response variable. As explanatory variables, we included: (1) year of the attack; (2) 'hunting' or 'non-hunting' country; and (3) continent, i.e., North America and Europe. We did not include the Eastern part of bear distribution in these analyses, given the spatial heterogeneity of the data, as we were able to only collect attack data from Iran, Turkey and some Russian areas. Fixed factors also included (4) bear density and (5) human population density. To test for potential interactions between variables, we additionally included: (6) the interaction between bear density and human density; (7) the interaction between continent and bear density; and (8) the interaction between continent and human density. Correlation between explanatory variables was calculated before building the models and was always lower than 0.6. Moreover, because we had repeated measures throughout the dataset, we included country as a random factor. Following preliminary data exploration and model diagnostics, we excluded two years of data for Romania (i.e., 21 attacks in 2014 and 17 attacks in

2015) and all observations from Croatia (i.e., 3 attacks in total), which were found to be highly influential observations. Consequently, our model was run on a sample size of 431 attacks. All models were fitted using GLMMs with a Poisson distribution.

We selected the best model(s) based on AICc values and we considered models with ΔAICc < 2 as equally competitive. Once we obtained the best set of models, we selected the most parsimonious (i.e., the model that included the lowest number of explanatory variables) and, for this model, we estimated fitted parameters, confidence intervals (CI), as well as the variance explained by each explanatory variable. All statistical analyses were performed in R v. 3.5.1 statistical software (R Foundation for Statistical Computing 2018). Models were fitted using the "glmer" function from the "lme4" package (Bates et al. 2015). Model generation and AICc calculation were done using the "dredge" function from the "MuMIn" package (Bartoń 2013). Calculation of R-squared for the model and each explanatory variable was done using the "r2glmm" package (Jaeger et al. 2017).

RESULTS

Spatio-temporal patterns of the attacks

Our search resulted in a total of 664 attacks between 2000 and 2015 from the three main geographical blocks of the brown bear distribution: West (i.e. and hereafter North America, n = 183), Centre (i.e. and hereafter Europe, n = 291), and East (i.e. Russia, Iran and Turkey, hereafter East, n = 190), for which at least information regarding the year was available (Fig. 1 and Table 1). We also recorded an additional 61 cases of attacks from the published literature (4 cases in Albania, 11 in Bosnia and Herzegovina, 9 in Macedonia, 2 in Nepal and 35 in Japan), which we did not include in the analyses due to the lack of sufficient information. We recorded an attack rate of 39.6 attacks/year globally: 11.4 attacks/year in North America and 18.2 attacks/year in Europe (10 attacks/year, if we exclude Romania). The recorded value of 19 attacks/year in the East probably represents an underestimation, due to the lack of information for several regions of the continent. Most attacks, 85.7% (n = 568), resulted in human injury and 14.3% (n = 95) ended with the death of the person involved. Specifically, 19 deaths occurred in Europe (6.6% of the attacks

recorded in Europe), 24 in North America (13.1% of the total attacks in North America) and 52 in the East (32.0% of the total attacks in the East).

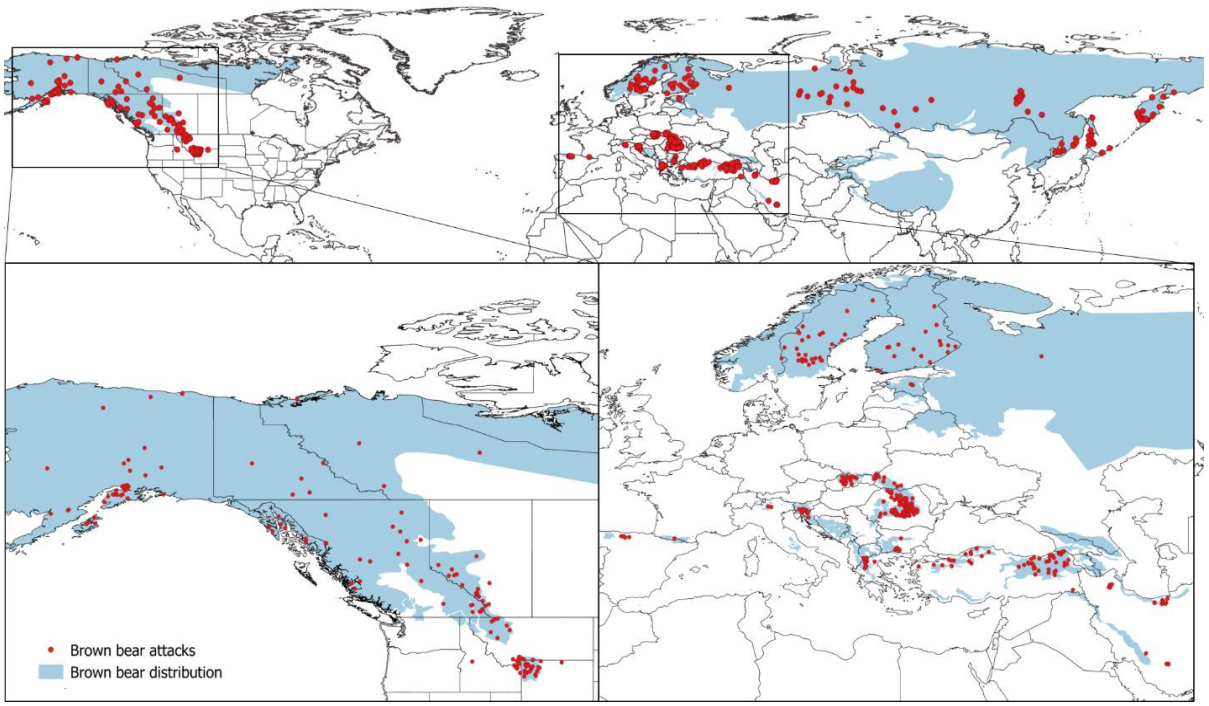


Figure 1. Spatial distribution of brown bear attacks on humans recorded between 2000 and 2015. Only attacks for which at least approximate coordinates were available are shown in the map (95% of all the attacks recorded, n = 664). In some cases, one point corresponds to more than one attack. The map was created in QGIS software, using the world borders layer (Sandvik 2008) and the IUCN layer of brown bear distribution, including both permanent and occasional presence (IUCN SSC Bear Specialist Group 2017).

Within Europe, most attacks occurred in Romania (n = 131), followed by Slovakia (n = 54), Sweden (n = 28), and Finland (n = 17). In North America, most of the attacks occurred in Alaska (n = 51), British Columbia (n = 42), Wyoming (n = 29), Montana (n = 25), and Alberta (n = 18). In the East, we recorded 111 attacks in Russia, 25 in Iran and 54 in Turkey (Fig. 1 and Table 1).

COUNTRY/ STATE	NUMBER OF ATTACKS (2000-2015)	NUMBER OF FATALITIES (2000-2015)	NUMBER OF BROWN BEARS	BROWN BEAR RANGE (km^2)	HUMAN DENSITY (inhabitants/ km^2)	BROWN BEAR DENSITY (bears/1000 km^2)
Romania	131	11	6000	89900	62.3	66.741
Slovakia	54	0	1000	12855	89.0	77.790
Turkey	54	11	4000	190552	29.7	20.992
Alaska	51	7	32000	1455855	0.3	21.980
British Columbia	42	2	15000	768801	0.4	19.511
Wyoming	29	5	511	27896	1.2	18.318
Sweden	28	2	2900	316300	5.0	9.169
Iran	25	0	unknown	241327	12.7	unknown
Montana	25	2	1105	64713	2.9	17.075
Alberta	18	4	691	148114	0.8	4.665
Finland	17	0	1700	357900	13.7	4.750
Greece	12	1	350	19500	26.8	17.949
Slovenia	12	0	455	13700	73.3	33.212
Poland	8	1	115	10400	75.7	11.058
Ukraine	8	2	350	28000	101.0	12.500
Idaho	8	0	34	6663	3.5	5.103
Bulgaria	7	1	560	32800	35.2	17.073
NW Territories	6	1	4000	772227	0.01	5.180
Spain	5	0	247	12800	7.2	19.297
Yukon	4	3	6000	480406	0.03	12.489
Croatia	3	0	1000	12372	21.5	80.828
Norway	2	0	105	149550	6.9	0.702
Italy (Alps)	2	0	51	2000	92.4	25.500
Estonia	2	0	700	34000	19.2	20.600

Table 1. Number of brown bear attacks on humans recorded during the period 2000-2015 and characteristics of the country/jurisdiction where the attacks occurred. Values are calculated within the brown bear population of each country where the attacks took place. When attacks occurred in more than one bear population within one country, values were calculated for the total area occupied by the populations involved.

The number of attacks increased worldwide over the years (Fig. 2; Supplementary Table S1 and S2; Supplementary Figure S1), with most of the attacks occurring in summer (48%; Supplementary Figure S2a) and during daytime (73%; Supplementary Figure S2b).

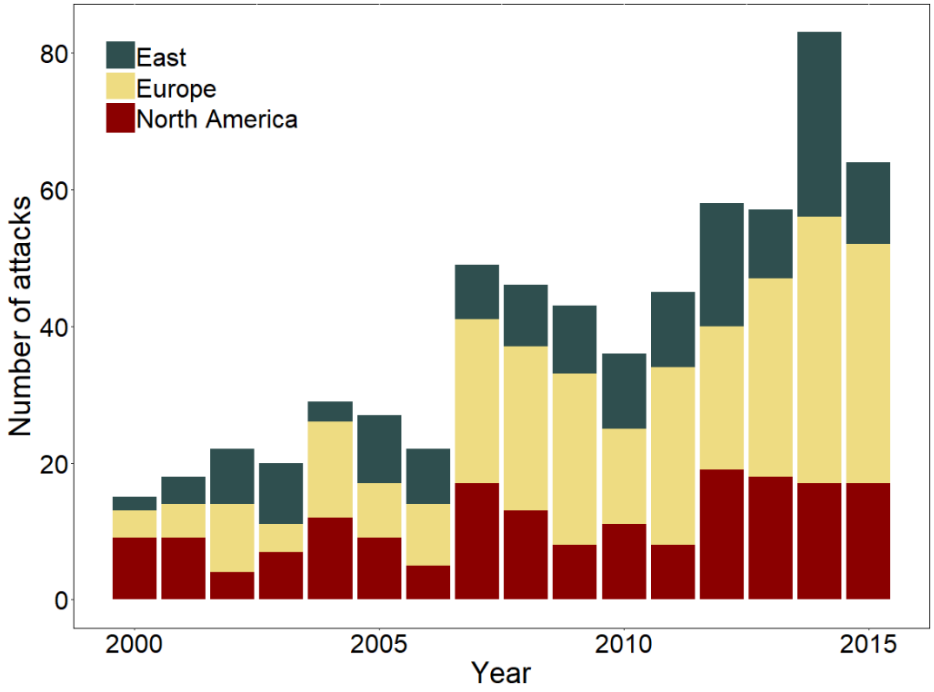


Figure 2. Temporal trends of brown bears attacks on humans throughout the species' range during 2000-2015, n = 664.

Main circumstances of the attacks

Attacked people were almost exclusively adults (99%; Supplementary Figure S3a) and males (88%; Supplementary Figure S3b). In 63% of the cases, the person was alone at the moment of the attack (Supplementary Figure S3c). When the attack occurred, 50% (n = 279) of the people were engaged in leisure activities, such as hiking (n = 88), picking berries, mushrooms, or antlers (n = 64), camping (n = 31), fishing (n = 18), or jogging (n = 17). As for the other activities, 28% (n = 158) of the attacked people were working outside, i.e. farming, guarding livestock, or logging (n = 104), or doing wildlife-related fieldwork (n = 12), and 22% (n = 123) were hunting (Fig. 3a). Attacks that occurred during bear hunts (n = 27) were

concentrated in a few countries/states (Sweden, Finland, Alaska and Russia). In Europe, this kind of attack was only present in Fennoscandia (n = 16), where bears are often hunted with chasing dogs. No attacks occurred in European countries where bears are hunted using bait from a stand. The attacks that occurred while working outside were more frequent in Europe (n = 94, of which 64 occurred in Romania) than in the rest of the brown bear range included in our study.

The most prevalent scenario of a brown bear attack was an encounter with a female bear with cubs (47%, n = 137; Fig. 3a), followed by sudden encounters (20%, n = 59), dog presence (17%, n = 48; Fig. 3b), bear attacking after being shot or trapped (10%, n = 30), and predatory attacks (5%; n = 9 in Russia and n = 6 in North America) (Fig. 3b). However, sometimes the scenario was more complex, because an attack could have been triggered by more than one factor. For example, in seven cases, the attack was caused by the interaction of a female with cubs and a dog.

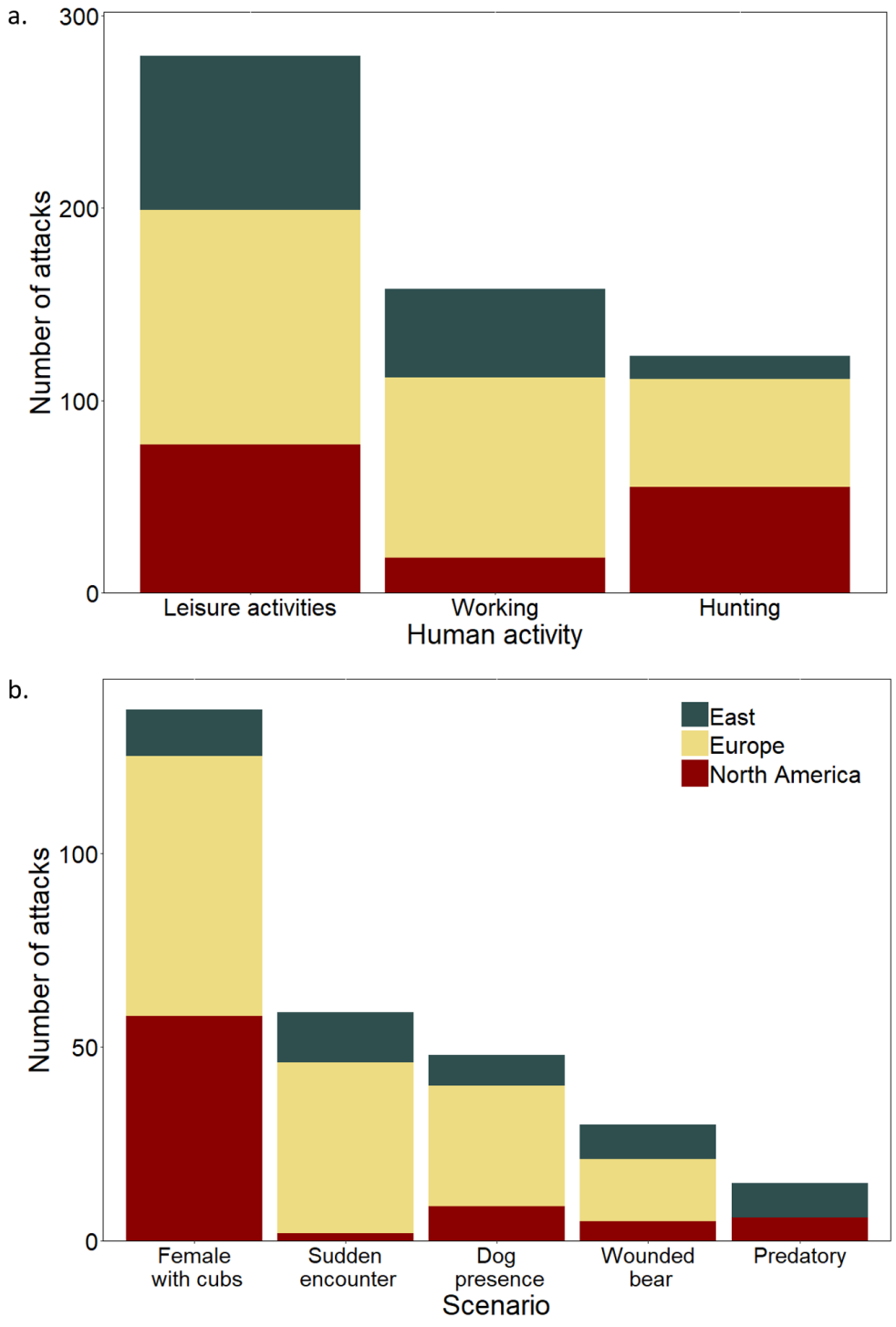


Figure 3. a. Main activities carried out by people at the moment of an attack (n = 560); **b.** Main scenarios of the attacks (n = 289).

Correlates of the attacks

We explored general spatio-temporal patterns of bear attacks and found that the following four factors were the most important in explaining the number of attacks: (a) year of the attack, (b) bear density, and (c) human population density (Supplementary Tables S1 and S2). In such analysis, the Eastern part of bear distribution was excluded, given the spatial heterogeneity of the data, as we were able to only collect attack data from Iran, Turkey and some Russian areas. The importance of these three variables was also confirmed by their P-values (P always $\leq$ 0.01) and confidence intervals (Supplementary Table S2). Specifically, we observed: (1) a significant increase in the number of attacks over the years; (2) higher bear density was associated with higher number of recorded attacks; whereas (3) attacks were negatively correlated with human population density. Bear density explained the largest proportion of variance (Supplementary Table S2). We found no significant difference in the number of attacks between continents or between countries with different management practices.

DISCUSSION

This first large-scale overview of brown bear attacks on humans has highlighted several elements that may serve as a general framework to this worldwide issue. Our results show a global increase in the number of attacks over the last decades, which is likely the result of several factors, such as the growth of both bear and human populations worldwide, that has led to increased habitat overlap. Additionally, a growing number of people is engaged in recreational activities in bear areas, which likely enhances the probability of encounters (Penteriani et al. 2016). Seasonal and circadian patterns were similar between continents. Europe had a slightly higher number of attacks during winter than North America and the East, which might be because hibernation is usually shorter in Europe (Krofel et al. 2017) and, thus, brown bears are more active in Europe during this season than on the other continents. The peak of attacks during the summer and during daylight is likely due to the fact that humans mainly engage in recreational activities or outdoor work in bear habitats during this season and are generally most active during the day. These

patterns are in line with previous studies on attacks by brown bears both in North America (Penteriani et al. 2016, Smith and Herrero 2018) and Scandinavia (Støen et al. 2018). Most people were engaged in leisure activities at the moment of the attack. This suggests that attacks mainly occur when people visit bear areas for recreational purposes, which is especially true in North America, where only a few attacks occurred to people working outside.

The fact that attacked people were almost exclusively adults is in line with the main human activities and attack scenarios. Indeed, when attacked by large carnivores, children are usually involved in predatory attacks, which are generally very rare for brown bears (Penteriani et al. 2017*a*). The fact that the most prevalent scenario, both in North America and Europe, was an encounter with a female with cubs agrees with that found in previous studies at smaller scales (Smith and Herrero 2018, Støen et al. 2018) and suggests that this class of bear is more likely to respond aggressively to encounters with humans and, therefore, requires additional attention and public information campaigns. Additionally, females with cubs, together with subadults, are most likely to use areas close to human activities in order to avoid male bears and predators or search for anthropogenic food (Zarzo-Arias et al. n.d., Herrero et al. 2005, Elfström et al. 2014, Steyaert et al. 2016), and this might make them more susceptible to accidental encounters with people. In this sense, where possible, temporal restrictions on public access to areas where females with cubs are commonly present might be crucial for avoiding human disturbance to brown bear females and resulting dangerous encounters.

Figure 4. Two of the main brown bear attack scenarios: (a) defensive reaction of a female with cubs and (b) unleashed dogs harassing bears. Photos by Ivan Seryodkin.

Other frequent scenarios (sudden encounters, presence of dogs, wounded bear) are mainly the result of inappropriate and risk-enhancing human behaviours (e.g. moving alone and being silent in bear country, walking an unleashed dog, or chasing a wounded bear while hunting), and could be reduced by improving public education and awareness of the issue (Penteriani et al. 2016). For example, when in bear country, announcing one's presence can help to avoid sudden encounters and unleashed dogs should be strongly avoided. In Alaska, dogs have been found to help terminate attacks in nearly half of the cases (Smith and Herrero 2018); however, in other cases both during leisure activities and hunting, dogs are known to have initiated the attack (Penteriani et al. 2016, Smith and Herrero 2018, Støen et al. 2018). Therefore, keeping them leashed when engaging in recreational activities might reduce the occurrence of such incidents, while it might still help to deter the attack, when it happens. Additional preventive measures such as proper garbage management, securing trash and food containers both in developed and natural areas frequented by tourists can help prevent bears from approaching people and cause conflicts (Herrero and Higgins 2003, Smith et al. 2005).

The main profile of the involved humans and the main scenarios agree with what has been highlighted in previous studies. In Alaska, for instance, Smith and Herrero (Smith and Herrero 2018) found that the majority of people involved in attacks by bears were adult males (83%), who were primarily engaged in hiking and hunting. The authors also found that interactions were usually initiated by humans (59%), such as people surprising bears, wounding them in hunts, or disturbing them while defending a carcass (Smith and Herrero 2018). In the same study, unaccompanied individuals were also observed to be more vulnerable to attacks than people in groups, which is in line with our findings, as well as findings for other bear species in North America (Herrero et al. 2011, Garrote et al. 2017). The reason for this is likely related to the fact that larger groups are more easily detectable and, consequently, avoided by bears, because groups tend to make more noise than a lone person. Additionally, when an encounter actually occurs, bears are more likely to flee than attack when confronted with a group of people (Smith and Herrero 2018). The above-mentioned, as well as other, basic precautions are key to

reducing the occurrence of dangerous encounters and should be constantly made available to people entering bear areas. For instance, in some regions of North America, warning panels are placed at trails' entrance, on which basic safety measures are provided. Additionally, visitors of National Parks receive a mandatory presentation and safety instructions on how to behave in bear country. In Russia, which hosts the largest number of brown bears and has the highest recorded number of attacks on humans, specialized manuals were developed, published, and distributed in large quantities to minimize conflicts with bears (e.g.,(Puchkovsky 2009, Korytin 2010)). Bear spray is also commonly used in North America as a personal safety measure by people who engage in recreation and work in bear areas, and its effectiveness in deterring attacking bears has been demonstrated (Smith et al. 2008, Smith and Herrero 2018). This non-lethal deterrent has also been successfully used in Slovakia (R. Rigg, unpublished data), however, it is currently illegal in many other European countries. Such evidence highlights the need for further investigation on its effectiveness and potential implementation in other countries with growing number of bears.

Although we did not find any difference in the number of attacks between continents, there was a remarkable difference in the number of attacks among European countries. Indeed, Romania accounted for nearly half (45%) of all attacks registered in Europe. Romania is home to the largest number of bears in Europe and traditional semi-subsistence agriculture and livestock husbandry are still common in the Carpathian Mountains (Dorresteijn et al. 2014). In particular, sheep and goats, which are the most vulnerable livestock to bear depredation (Dorresteijn et al. 2014), are the most common and are increasing year to year (Union and States 2018). This might explain the fact that 50% of bear attacks in Romania for which detailed information was available (n = 109) involved shepherds, farmers, or cattle herders. Interestingly, in at least 8 cases, the person was attacked while chasing or directly harassing the bear after it had attacked livestock or crops. We therefore suggest that education campaigns on how to avoid or react to close encounters with brown bears and improved livestock protection measures should particularly target Romanian shepherds, farmers, and cattle herders. This scenario differs vastly from

the general patterns observed in other brown bear countries, where attacks mainly occurred during leisure activities. These differences in attack patterns suggest that the occurrence of attacks might also greatly depend on local socio-cultural contexts and human behaviours (Penteriani et al. 2016). Russia,

Previous studies analysing brown bear attacks at a local scale have shown a correlation between the number of attacks and the growth of the human population at a national or continental scale (Herrero et al. 2011, Smith and Herrero 2018). These studies suggest that the more people live and work in bear areas, the greater the probability of an encounter with this species (Smith and Herrero 2018). Another study found a relationship between the number of attacks on hunters and the brown bear harvest in Scandinavia (Støen et al. 2018), but there was no clear relationship with the number of attacks on people involved in non-hunting outdoor activities and the brown bear population size. However, at a global scale, attacks were more frequent in those countries/jurisdictions where human density is lower and bear density higher. Because human density is a measure of the degree of human encroachment into bear range, our results suggest that attacks are less frequent where human developments and activities extend more into bear areas, and more frequent in countries where recreational activities in bear areas are more common. This result might also suggest that bears and people have learnt to coexist better in highly humanized regions, whereas those people who are more at risk of attack are visitors of high bear-density areas, where bears are less accustomed to encountering people, because of lower human density and, consequently, bears and people might be less used to avoiding each other. Additionally, there was no significant difference in the number of attacks between 'hunting' and 'non-hunting' countries, which does not support our initial hypothesis that fewer attacks occurred in countries where bears are legally hunted.

To conclude, negative encounters with brown bears are extremely rare and mainly non-fatal. However, to increase both human and bear safety, and promote coexistence, it is crucial to gain a deeper understanding, and promote public knowledge of the riskiest circumstances that may trigger an aggressive response by brown bears. To this aim, strong connection and collaboration between researchers,

managers and education tools such as mass media and schools should be established to promote correct and scientific-based information about bears among the large public. This first worldwide approach showed that, although similar patterns in attacks exist across the distribution range of brown bears, specific local contexts might prove to be crucial in explaining particularly high or low attack numbers. We therefore believe that, although it is important to have a global picture, additional studies at a local scale, especially in those countries where information is still scarce, will help identify additional factors related to local situations which will provide wildlife managers with specific information on how to effectively deal with this issue.

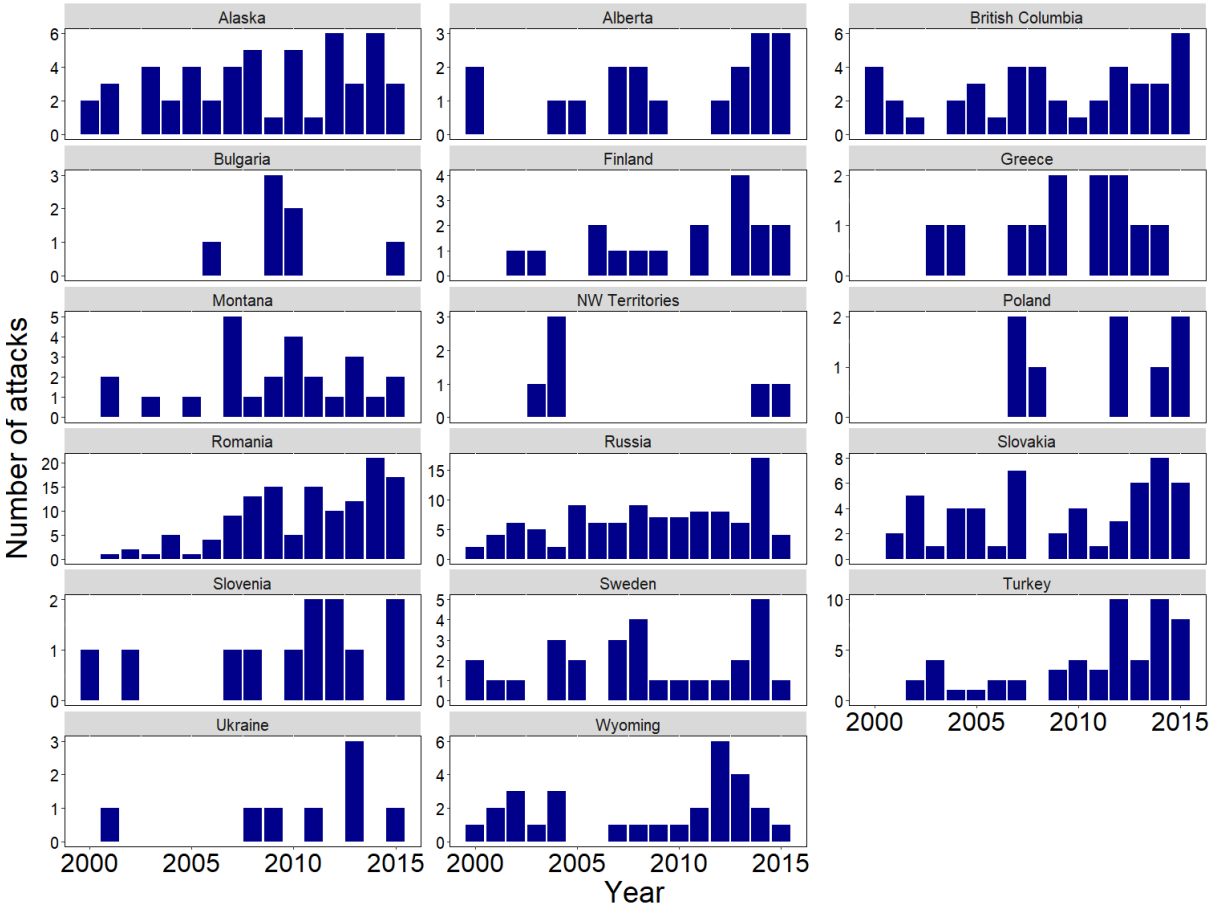
Supplementary Table S1. Comparison of the competing models built to analyse the spatial-temporal patterns of brown bear attacks on humans between 2000 and 2015 based on values of AICc, ΔAICc and AICc weights. Only the models with ΔAICc < 2 are shown. Competitive models are ranked from the lowest to the highest AICc value. Response variable: number of attacks – Poisson distribution error. R^2 = 0.427.

COMPETING MODELS	*AICc*	*ΔAICc*	*AICc weights*
HUNTING COUNTRY+BEAR DENSITY+HUMAN DENSITY+YEAR	*600.3*		*0.21*
HUNTING COUNTRY +BEAR DENSITY+HUMAN DENSITY+YEAR+BEAR DENSITY:HUMAN DENSITY	*601.2*	*0.98*	*0.13*
BEAR DENSITY+HUMAN DENSITY+ YEAR	*601.3*	*1.06*	*0.12*
CONTINENT+HUNTING COUNTRY+BEAR DENSITY+HUMAN DENSITY+YEAR	*602.2*	*1.91*	*0.08*

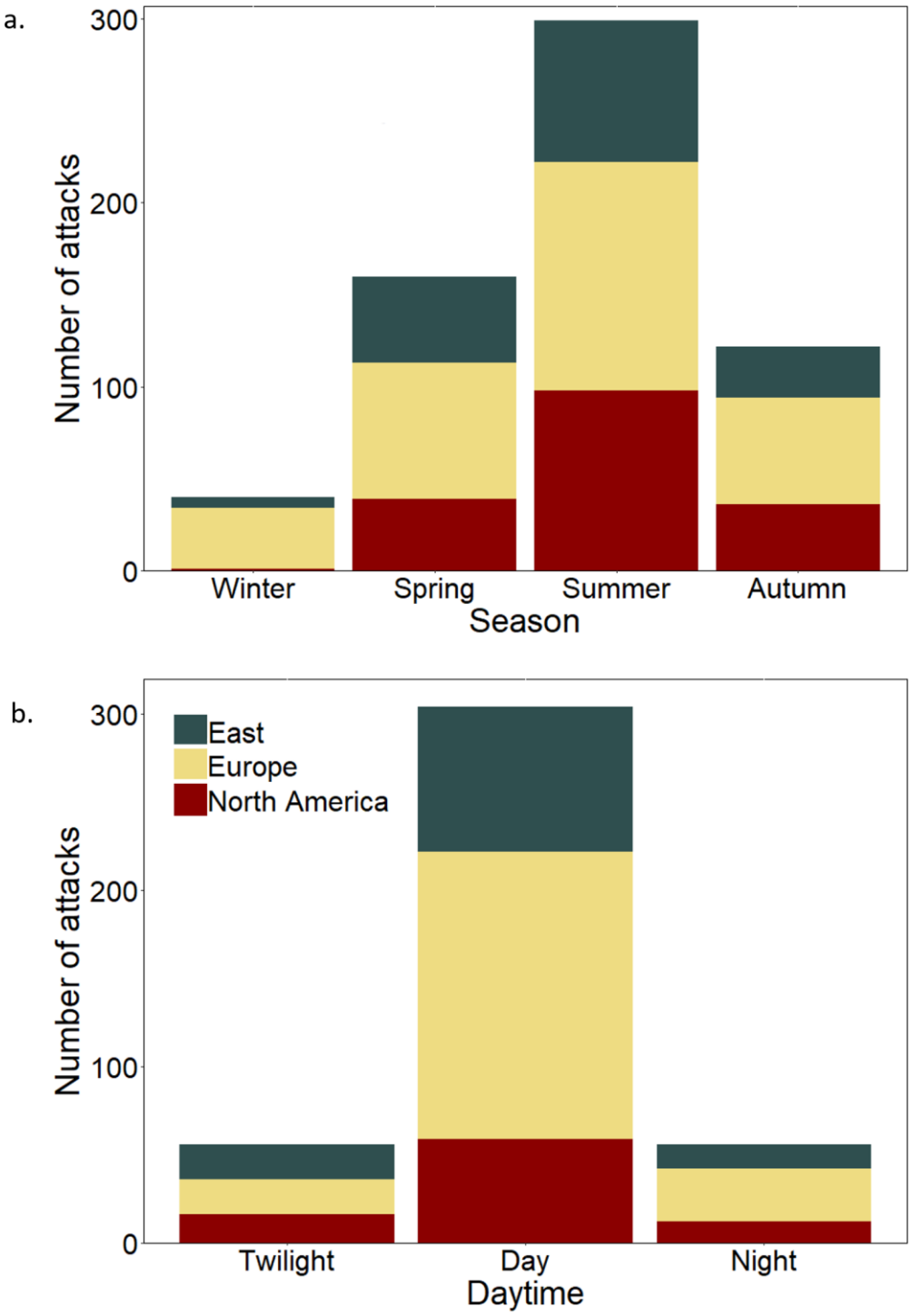
Supplementary Table S2. Summary of fitted parameters for the most parsimonious model within the best set of models (models with ΔAICc < 2 shown in Supplementary Table S1) built to analyse the spatial-temporal patterns of the attacks by brown bears on humans between 2000 and 2015. Estimate (β), standard error (SE), p-value (p), confidence interval (CI) and the variance explained are shown for each explanatory variable. $R^2 = 0.468$.

EXPLANATORY VARIABLE	*β*	*SE*	*p*	*CI*	*VARIANCE EXPLAINED*
INTERCEPT	*0.758*	*0.055*	*< 0.0001*	*(0.616; 0.863)*	
BEAR DENSITY	*0.663*	*0.066*	*< 0.0001*	*(0.474; 0.793)*	*0.389*
HUMAN DENSITY	*-0.352*	*0.078*	*< 0.0001*	*(-0.510; -0.139)*	*0.118*
YEAR	*0.222*	*0.052*	*< 0.0001*	*(0.122; 0.325)*	*0.133*

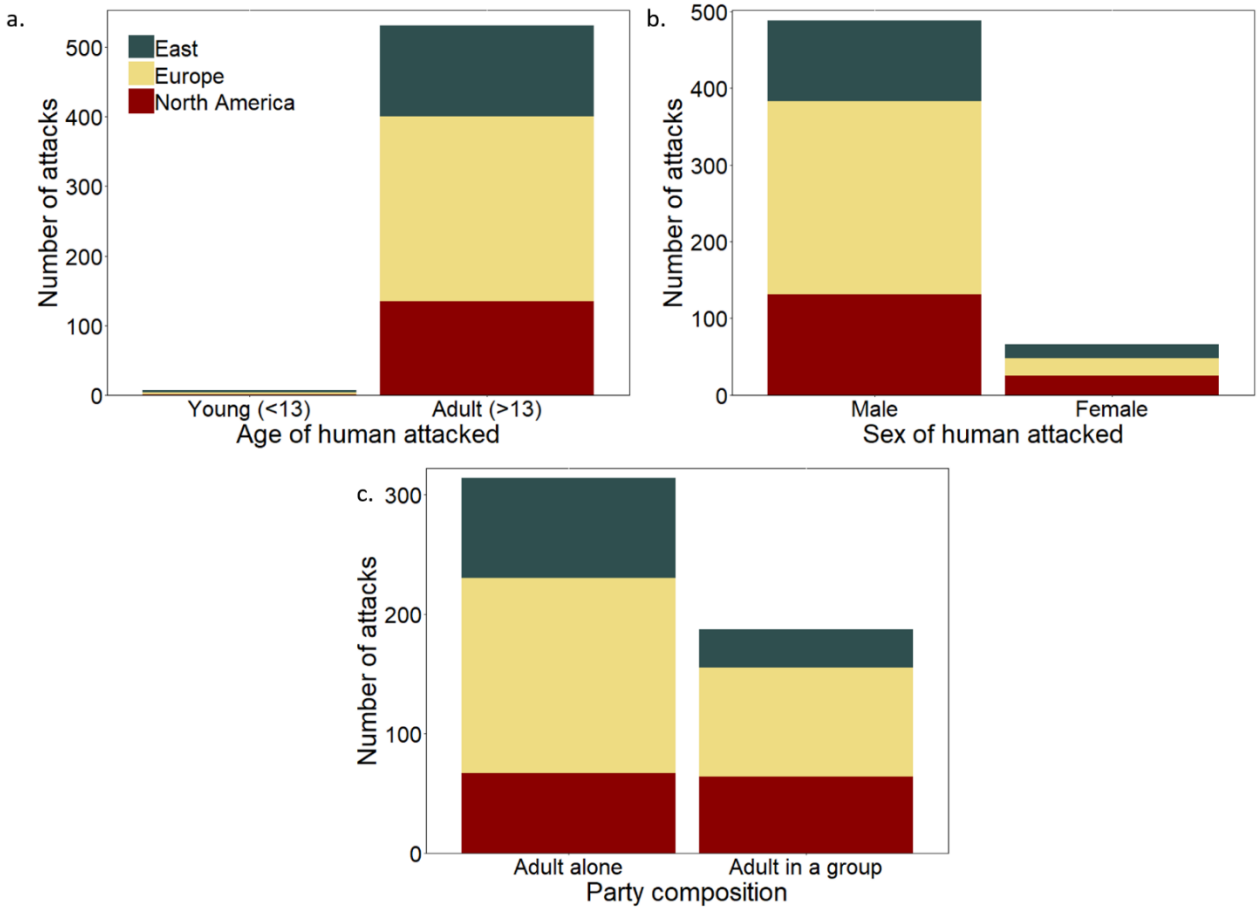
Supplementary Figure S1. Temporal trends of brown bears attacks on humans presented for each country/jurisdiction under study between 2000 and 2015. Only countries/jurisdictions with more than five attacks are reported.



Supplementary Figure S2. Seasonal (**a**; n = 621) and circadian (**b**; n = 416) patterns of the attacks by brown bears on humans between 2000 and 2015.

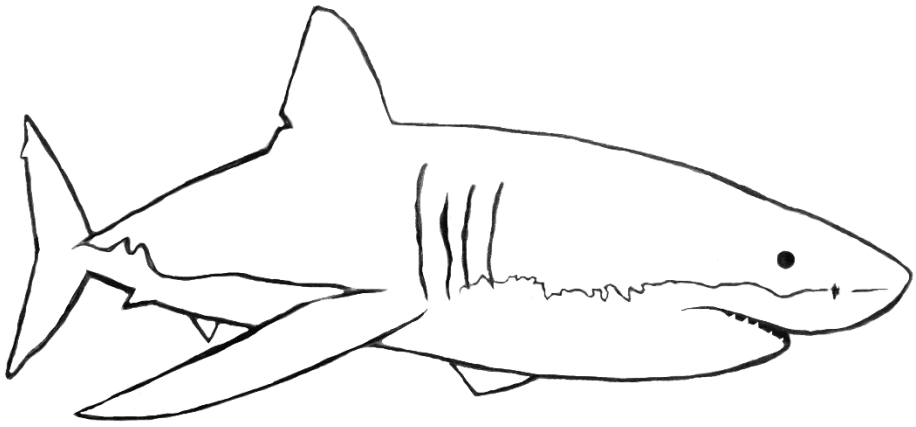

a.
300
200
100
0
Number of attacks
Winter
Spring
Summer
Autumn
Season
b.
East
Europe
North America
300
200
100
0
Number of attacks
Twilight
Day
Night
Daytime

Supplementary Figure S3. Characteristics of humans attacked by brown bears between 2000 and 2015: age (**a**; n = 538), sex (**b**; n = 554), group size and composition (**c**; n = 501).



Chapter 4

Content Analysis of Media Reports on Predator Attacks on Humans: Toward an Understanding of Human Risk Perception and Predator Acceptance.



Bombieri G., Nanni V., Delgado MM., Fedriani JM., López-Bao JV., Pedrini P. and Penteriani V.

Bioscience 68, 577–584 (2018).

ABSTRACT

Public tolerance towards predators is fundamental in their conservation and is highly driven by people's perception of the risk they may pose. Although predator attacks on humans are rare, they create lasting media attention and the way the media covers them might affect people's risk perception. Understanding how mass media presents attacks and how this can affect perception will provide insights into potential strategies to improve coexistence with these species. We collected media reports of predator attacks on humans and examined their content. Almost half (41.5%) of the reports analysed contained graphic elements. Differences in framing between species groups/species were found, with sharks and leopards having the highest proportion of graphic reports, while canids and bears had the highest number of neutral reports. This bias in coverage, instead of providing insights into the causes of these incidents and possible remedies, may provoke fear and decrease support for predator conservation.

"*The man who reads nothing at all is better educated than the man who reads nothing, but newspapers*" Thomas Jefferson (third president of the United States).

INTRODUCTION

In the last few decades, the number of attacks on humans by predators has been increasing in several regions around the world. Regardless of the variation in individual attack risk (Ferretti et al. 2015), this trend is true not only for large terrestrial carnivores (Packer et al. 2005, Conover 2008, Acharya et al. 2016, Penteriani et al. 2016), but also for other predators, such as sharks and crocodilians (Caldicott et al. 2005, McPhee 2014).

The increase in reported attacks may likely be attributed to several factors, such as the growth of both human and predator populations worldwide, which has led to increasing habitat overlap (Baruch-Mordo et al. 2008, Glikman et al. 2012, Bruskotter and Wilson 2014). In addition, the use of wilderness areas by humans for economic and recreational purposes has risen in recent years, which is likely to increase the probability of encounters with these species (Bruskotter et al. 2007, Conover 2008, Neff 2014, Penteriani et al. 2016).

Traditionally, threats by predators to humans have caused people to persecute them, resulting in the local extirpation of many species (Woodroffe 2000, Treves and Karanth 2003*b*, Ripple et al. 2014), and these threats still have the potential to decrease human acceptance of predators and consequently undermine the conservation of these species (Knopff et al. 2016). Indeed, because public opinion has become fundamental in political decisions, and governments are more likely to protect what the public cares about rather than what is feared, management of human-wildlife conflict has become a political challenge (Crossley et al. 2014, Neff 2014, Frank et al. 2015).

Human tolerance is a crucial aspect of predator conservation and calls for greater understanding of the factors that enhance or inhibit such tolerance (Ripple et al. 2014). Generally, tolerance is lower when people associate large carnivores with high levels of risk (Treves and Karanth 2003, Eriksson et al. 2015, Knopff et al. 2016), and antipredator feelings can hamper conservation efforts and be deeply entrenched in human culture, sometimes lasting centuries after predators have been extirpated (Kellert et al. 1996).

Antipredator sentiments can be exacerbated by an exaggerated perception of the risk associated with predator attacks on humans (Gore and Knuth 2009, Hathaway et al. 2017). Several models and theories have been developed to try explaining risk perception (e.g., psychometric model (Fischhoff et al. 1978), cultural theory (Douglas and Wildavsky 1982). Studies have shown that people are more likely to make judgements about risks based on their feelings and instinct rather than on analytic evaluation (Slovic and Peters 2006). This leads them to often overestimate events associated with dramatic and sensational items and to underestimate events that are unspectacular. Indeed, people significantly overestimate highly publicised causes of death, which are likely to lead people to be exceedingly fearful of statistically small risks (Sunstein 2002), as is the case for injury and death from predator attacks. The overestimation of risks associated with human safety is the result of a 'cognitive bias' (or 'cognitive illusion'), i.e., a systematic error in judgment common to all human beings that can be due to cognitive limitations and motivational factors (Wilke and Mata 2012). This occurs when rare but striking events are so impressed in our memory that we tend to overestimate their frequency (Kahneman and Tversky 1996). For example, people's risk judgments of low probability events are often inflated due to biased media coverage of natural catastrophes and accidents (Kasperson et al. 1988, Wilke and Mata 2012). In the specific case of attacks by predators on humans, this cognitive bias is likely to occur because, even if attacks are rare, they create lasting media attention, which increases our perception of risk (Knopff et al. 2016). Indeed, fear of predators is easily provoked in humans because we have a long evolutionary history of conflictual coexistence with predators that produces a natural fear (Kruuk 2002). This cognitive illusion has obvious relevance when resource managers are asked to make probability judgments about outcomes for which they are responsible (Anderson 1998), as in the specific case of the management of human-predator conflicts. Risk perception and amplification, which involves intuitive judgments made by citizens, may then influence support for predator management and conservation, as well as public receptivity to educational messages (Gore et al. 2007, Bhatia et al. 2013).

Reading news on the web has become a regular habit for many people, offering unlimited coverage of breaking news worldwide. The impact of the media on our perception of an event is well known and recognised, and different models exist which illustrate how mass media drive public perception (e.g., framing, priming and agenda-setting (McCombs and Shaw 1972, Kasperson et al. 1988, Scheufele and Tewksbury 2007). Additionally, the possible role of graphic information in risk perception and the acquisition of fear is now widely accepted (e.g. Burns and Crawford 1999, Harrell 2000, Field et al. 2001, Zillmann et al. 2004, Quillian and Pager 2010, Schafer 2011, Visser et al. 2013, Altheide 1997, Ruigrok et al. 2016). Indeed, we fear what is most readily available in our minds, and graphic texts and/or images of media reports may form indelible memories that help construct our intuitive rule-of-thumb for judging risks (Myers 2001). Some studies have found that media coverage increased after a predator attack, suggesting that extensive coverage and the negative attitude of the media may lead to a decrease in public tolerance for predators (Gullo et al. 1997, Siemer et al. 2009, 2014, McCagh et al. 2015, Sabatier and Huveneers 2018). For example, Røskaft et al. (2003) reported that the increased negative attitude towards large carnivores in the Norwegian media may explain the increased fear of brown bears *Ursus arctos* in that country. This phenomenon reveals the important role played by mass media in emphasising or not attack events, ultimately influencing perceived risks and amplifying our fear of predators (Armfield 2007, Knopff et al. 2016).

Analysis of media reports of predator attacks on humans can provide insight into potential strategies for the coexistence of predators and humans: most people will never encounter a predator in the wild making depiction by the media a crucial factor in public perceptions about the risks (Jacobson et al. 2012). Because viewing negative media reports is associated with the greatest increases in anxiety and fear (e.g. Visser et al. 2013, Harrell 2000, Field et al. 2001), the main aim of this work is to analyse media reports of predator attacks on humans to: (1) highlight how the media conveys information on predator attack events; and, consequently, (2) understand how these media reports may affect human perception of risk and, as an end consequence, predator acceptance by the public.

METHODS

We reviewed media reports of predator attacks on humans from January 2005 to July 2016 by using the name of 13 species of predator or groups of predators combined with the word 'attack'. Specifically, we searched for media reports on attacks related to 10 large carnivores, i.e., both Eurasian and North American brown bears/grizzlies *Ursus arctos* (+ *Ursus arctos horribilis*), black bear *Ursus americanus*, sloth bear *Melursus ursinus*, polar bear *Ursus maritimus*, grey wolf *Canis lupus*, coyote *Canis latrans*, cougar *Puma concolor*, leopard *Panthera pardus*, lion *Panthera leo,* and tiger *Panthera tigris*, as well as the generic words 'alligator', 'crocodile' and 'shark'. In fact, in most of the reported attacks by these latter three groups of predators the exact species is unknown or rarely mentioned. We also tried to search for media reports using the words 'maul' and 'kill', but we got nearly the same news articles, and thus we only used the word 'attack' followed by one of the years between 2005 and 2016; for example, 'crocodile attack 2006' or 'cougar attack 2014'. These parameters determined a total of 156 search words combinations, i.e., 12 years x (10 species + 3 species groups). By simulating web searches of people looking at news on the internet, we collected attack news on the first five pages of Google (when no more articles on attacks by a particular species were shown) or up to the 10th Google page if news about attacks on humans were still present on the fifth page.

For every media report, we scored the: (a) title and (b) sub-heading (if any), as well as (if any), picture(s) and/or drawing(s) of (c) predators and (d) people (or elements like canoes, paddles and surf boards that were related with the attack scenario). These elements of a media report are the means through which news frames are made relevant (Zillmann et al. 2004). Scores were recorded as 0 for neutral content, 1 for graphic content and 2 for positive/safe content. Examples of neutral *vs.* graphic titles or sub-headings include, respectively: (a) "*Bear attacks leave at least three people dead in Siberia and far-east Russia*" vs. "*Siberia: Bear buries woman alive so it can come back and eat her later*"; (b) "*Elderly Montana woman dies from rare black bear attack*" vs. "*Human flesh found in stomach of bear shot after fatal attacks*"; (c) "*Wild leopard enters school and attacks six people*" vs.

"*Bloody brutal leopard attack in India*"; (d) "*Leopard attacks and kills girl in Mumbai suburb*" vs. "*Man 'scalped' in deadly leopard attack in India*"; (e) "*Woman dies in WA shark attack*" vs. "*Shark kills diver while daughter watches in horror*"; (f) "*Teen killed in shark attack*" vs. "*Shark spotted with the body of a man in its jaws as witnesses look on in horror* "; (g) "*Wolves kill teacher in Alaska*" vs. "*Wolf pack attacks Chinese villagers, tearing off victim's ear*"; and (h) "*Woman killed by crocodile near Bhitarkanika National Park in Odisha*" vs. "*Human remains discovered inside crocodile during search for woman killed in attack* ".

Additionally, we considered as graphic text those that included words like 'blood', 'bloody', 'badly', 'gruesome', 'eaten', 'horror', 'horrific', 'man-eating', 'nightmare', 'scary', 'terrifying', 'terrorizes' and 'jaws' (e.g., "*…alligator snatched child in its jaws*"), as well as explicit mention of the injured part of the body (e.g. "*A great white shark ate my leg*"). However, just specific mention of bodily injuries, e.g. "*Boy sustains leg injuries in croc attack*", was not considered as graphic.

We considered drawings and pictures as being graphic if images: (a) explicitly showed predator 'weapons', i.e. teeth and claws; (b) showed the attack; and/or (c) included details of injured parts of the body or victims clearly displaying their injuries, as well as dead people. Images of the animal in normal postures, e.g. a mother bear with cubs, a resting lion, a swimming shark or a sleeping crocodile were considered as neutral. As for pictures, the entire media report was considered to have graphic images even if only one image had explicit content having the potential to stimulate a feeling of fear in readers. Safe pictures or texts were those considered to convey the message that the predator has been trapped and/or killed, as well as pictures of fences, nets and warning panels, which should reassure people that the situation is under control.

To verify if the criteria we used to score the different elements of media reports were generalizable, we prepared and distributed an online survey with the aim of estimating the rate of agreement between respondents and our score for the same elements. In the survey we presented a total of 40 elements of media reports (i.e., 10 titles, 10 sub-headings, 10 pictures of the predator and 10 pictures of the victim —or elements related to the attack scenario—) randomly chosen from the

media reports we had previously collected and scored for the study, and we asked people to assign a score to each element based on their personal opinion. The possible scores were the same as those which we used (i.e., 0 for neutral, 1 for graphic and 2 for positive), and we received 47 responses (Supplemental File 3). The age range of the respondents was 23-49 year old. 21 of the people surveyed were students or hold a degree in biology-related fields, while 26 people have other kinds of background. 27 of the respondents were females and 20 were males. For each element presented, we calculated the percentages of people who agreed with our score: on average, 78.9% of surveyed people agreed with our scores for graphic contents, whereas 57.7% and 33.1% agreed with our evaluation of neutral and safe contents, respectively. The low agreement for neutral and safe contents is mainly due to people who classified these two categories as graphic (51.6%). This means that the perception of surveyed people of media reports was even more negative than our perception when we classified the attack reports. That is, our results might underestimate the negative impact of the contents of media reports on predator attacks on humans.

As additional parameter of the way in which the media conveys information on attacks on humans, we calculated an 'overall score' for each media report. The 'overall score' defined in a global manner the content of each media report, based on the rule that the presence of even only one graphic element in a media report (i.e., minimum one element of the report with score equal to 1) classified the report as graphic (i.e., overall score equal 1), even if elements with score 0 or 2 were also present in the report. Once we assigned the overall scores equal to 1, the remaining media reports were classified as safe/positive (i.e., overall score equal to 2) if they contained at least one safe/positive element (even if a 0 score was present), while the rest were classified as neutral (i.e., overall score equal to 0). Results are presented per group of species, i.e., bears –black, brown, polar and sloth bears–, canids –coyotes and grey wolves–, reptiles –crocs and alligators–, felids –cougars, leopards, lions and tigers– and sharks, as well as for each of the above-mentioned species, except for sharks and reptiles which are only presented as groups of species (Supplemental Files 1 and 2).

RESULTS

Overall view

From January 2005 to July 2016, the web search resulted in a total of 1584 media reports for all species and group of species pooled (Supplemental File 4). Media reports principally focused on bears (30.1%, n = 477), reptiles (24.6%, n = 389) and felids (23.4%, n = 371), followed by sharks (11.7%, n = 185) and canids (10.2%, n = 162). In particular: (a) 14.0% (n = 221) of media reports concerned attacks by brown bear, 10.4% (n = 164) by black bears, 4.3% (n = 68) by polar bears and 1.5% (n = 24) by sloth bears; (b) 11.2% (n = 177) reported attacks by leopards, 5.7% (n = 90) by cougars, 4.6% (n = 73) by lions and 2.0% (n = 31) by tigers; and (c) there were 6.4% (n = 101) media reports for coyotes and 3.9% (n = 61) for wolves.

Half of the media reports showed graphic content

Pictures of predators and victims displayed graphic content (38.5% and 36.8%, respectively) more frequently than titles and sub-headings, which were prevalently neutral (Figure 1). Based on the overall score, almost half (41.5%, n = 657) of the examined media reports were classified as having graphic content, whereas 53% (n = 840) of the media reports were classified as neutral (only 5.5% of the media reports showed positive/safe elements; n = 87).

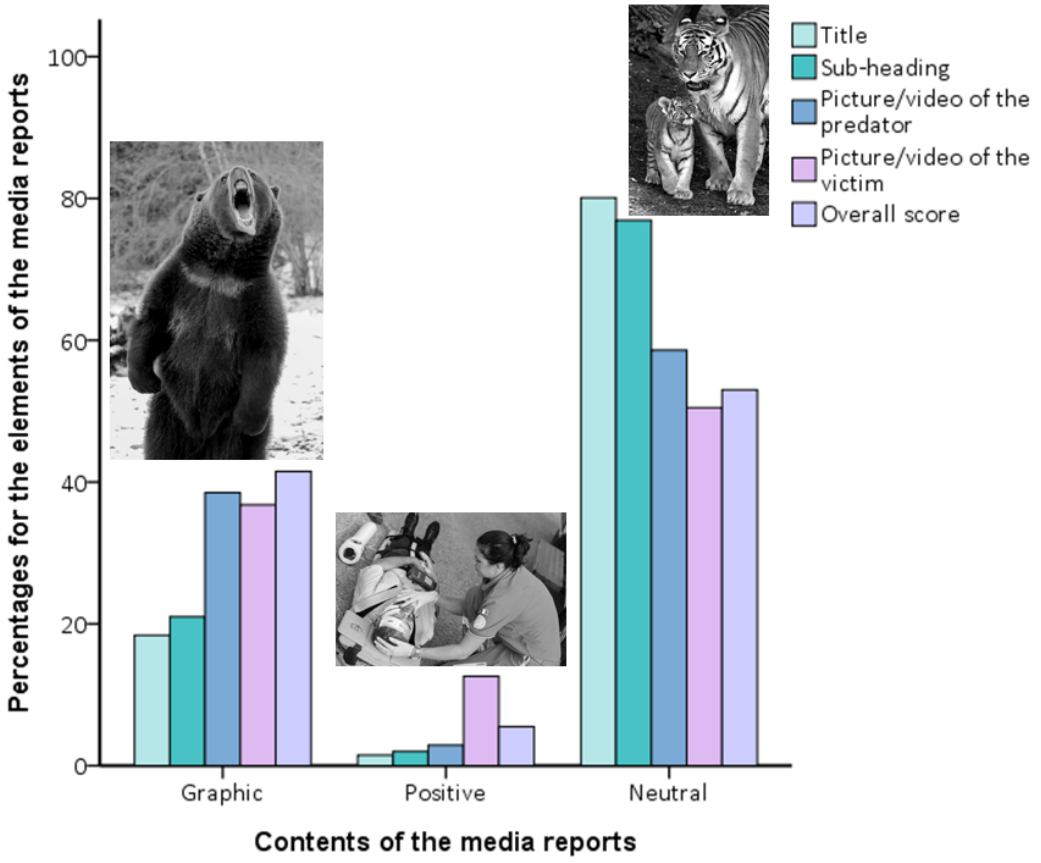


Figure 1. Percentages, for each score category (graphic, positive/safe and neutral), of the different elements of media reports (n = 1584; from January 2005 to July 2016) on attacks on humans by 10 large carnivore species, reptiles and sharks. The following elements were taken into account within each media report: (a) title (n = 1584), (b) sub-heading (n = 642), (c) picture/video of the predator (n = 780), (d) picture/video of the victim (n = 657) and (e) the overall score (see Methods for more details; n = 1584). (Picture credits: all the pictures were downloaded from http://www.123rf.com; Image ID: 49214234, action sports (brown bear); 22164614, William Perugini (rescue team); 31900112, Dennis Jacobsen (tiger).

Patterns of media reports for species groups

When comparing the different groups of species, graphic titles were found more frequently in those news articles reporting attacks by reptiles, bears and felids, whereas graphic sub-headings were primarily used for sharks, followed by reptiles and bears (Supplemental File 1). Graphic images of the predator were most frequent in cases of felid and reptile attacks, whereas graphic victim pictures and videos were more common in those media reports related to attacks by felids, bears and sharks (Supplemental File 1). Consequently, when comparing the overall score between species groups, reptiles, felids and bears had the highest percentage of graphic reports (Figure 2).

When comparing the overall score within groups (Supplemental File 1), we found that sharks, canids and bears showed the highest difference in the overall score. Indeed, reports on shark attacks were mostly graphic (60%), whereas reports on canids and bears were mainly neutral (62% and 59%, respectively).

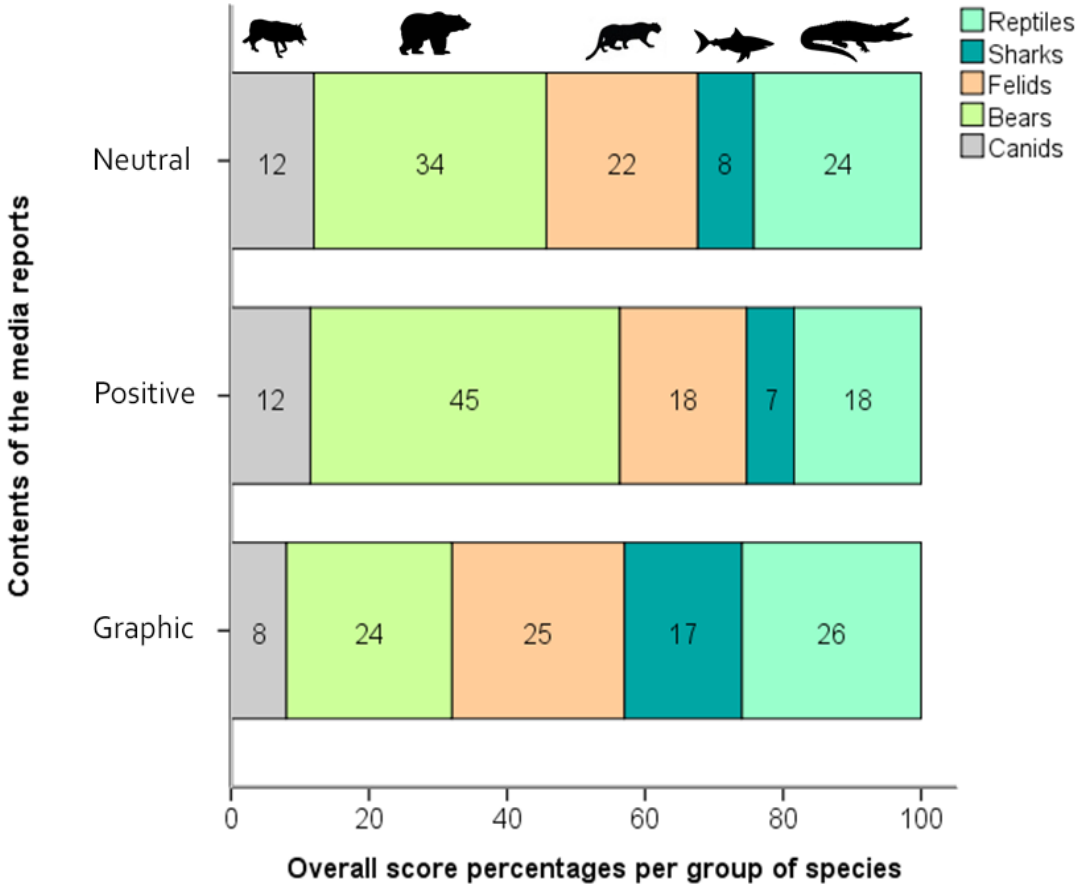


Figure 2. Percentages of the different categories (graphic, positive/safe and neutral) obtained from the overall scores for the different groups of predators. The 'overall score' defined in a global manner the content of each media report, based on the rule that the presence of even only one graphic element in a media report (i.e., minimum one element of the report with score equal to 1) classified the report as graphic (i.e., overall score equal 1), even if elements with score 0 or 2 were also present in the report. Once we assigned the overall scores equal to 1, the remaining media reports were classified as safe/positive (i.e., overall score equal to 2) if they contained at least one safe/positive element (even if a 0 score was present), while the rest were classified as neutral (i.e., overall score equal to 0).

Patterns of media reports for species

When comparing patterns between species (Supplemental File 2), graphic titles were found more frequently in those news articles reporting attacks by leopards, brown bears and polar bears. Graphic sub-headings were primarily used for polar bears and leopards. Graphic images of the predator were most frequent for leopards and brown bears, whereas graphic victim pictures and videos were more common in those media reports related to attacks by leopards and brown bears.

Patterns within species show that leopards, wolves and black bears present the highest difference in the overall score. Specifically, reports on leopard attacks were mostly graphic (63%), while reports on wolves and black bears were mainly neutral (72% and 67%, respectively).

DISCUSSION

Even if in most of the reports and for several groups of species neutral elements were dominant, we found that nearly half (41.5%) of the media reports analyzed, dating from 2005 to 2016, contained graphic contents. Moreover, we found differences in framing between groups/species, which could be due to distinct cultural and social factors associated with the different species. Specifically, sharks and leopards were the group/species with the highest proportion of graphic reports (respectively 60% and 63% of graphic reports calculated on the total of reports for the group/species considered). On the other hand, canids and bears were the groups with the highest proportion of neutral reports (respectively 62% and 59% of neutral reports calculated on the total of reports for the group). Given the large number of reports and species considered, as well as the power that graphic content has on viewers' perception, 41.5% represents a relatively high proportion of graphic reports. Memory for graphic elements in media reports, indeed, has been shown to be stronger than memory for nongraphic ones, especially when supported by visual images (Harrell 2000). Indeed, viewers who watch negative news reports tend to remember a higher percentage of the stories they watched than do positive news viewers.

In addition, most people can live their entire lives without seeing a predator outside of a zoo or an aquarium and, therefore, rely on the media to form their opinion about them. By carefully framing the graphic images of the stories of personal injury and death, media reports may persuade the audience that a predator is a threat (Schafer 2011) and elicit a cognitive illusion on a phenomenon that, in reality, is extremely rare (Penteriani et al. 2016). This may generate fear which can lead not only to significant public resistance towards predator conservation efforts (Jacobson et al. 2012) but also to increased support for lethal management actions towards predators (Thompson et al. 2003, Meeuwig and Ferreira 2014, Shiffman 2014). By provoking unnecessary fears through graphic contents, reports on predator attacks do not help to accurately inform people on how to correctly behave when in a landscape inhabited by predators, although it has been shown that appropriate behaviours may help significantly reduce the number of attacks (Penteriani et al. 2016). Instead, by providing accurate information about the attacks and how to avoid them, the media has the potential to promote both carnivore conservation and human safety. To this aim, constant engagement of carnivore experts with the media, aimed at providing correct knowledge about carnivores, might lead to a positive change in how human-carnivore conflicts are covered. For instance, a recent study by Hathaway et al. (2017) showed that sensitisation workshops held for local reporters in India had a positive effect on the quality of media reports regarding human-leopard interactions.

Today, the media landscape is characterised by an increasing number of media outlets that compete for the attention of readers, leading to a form of journalism that is heavily market-oriented (Ruigrok et al. 2016). The human-impact angle is commonly used in media reports and the saying that "if it bleeds, it leads" has been professed as the motto under which much American journalism operates (Zillmann et al. 2004). This commercialization and fierce competition dictate that editors and journalists focus on more attractive news stories with impressive titles and images that are likely to attract large audiences and advertisers (Zillmann et al. 2004). For example: (a) after each shooting incident in the US, various media outlets flood the public with shocking accounts, e.g., through sensationalistic media reports

of select horrific incidents (Burns and Crawford 1999); and (b) in online news media the coverage of youth crime is exaggerated compared to the facts (Ruigrok et al. 2016). Similar to what happens for youth crime: (1) a frequently biased coverage of predator attacks on humans may reinforce the existing feeling of insecurity rather than provide insights into the causes of these incidents and possible remedies; and (2) this way of covering attacks on humans may contribute to the feeling that a fear of predators reigns in human communities and that repressive measures are needed. A considerable amount of research has been conducted on the effects of the framing of news reports (Zillmann et al. 2004). In the case of predator attacks and conflicts, studies have analysed media coverage and suggested how changes in public perception and tolerance towards predators might be driven by the media (Thompson et al. 2003, Muter et al. 2013, Siemer et al. 2014, Crown and Doubleday 2017).

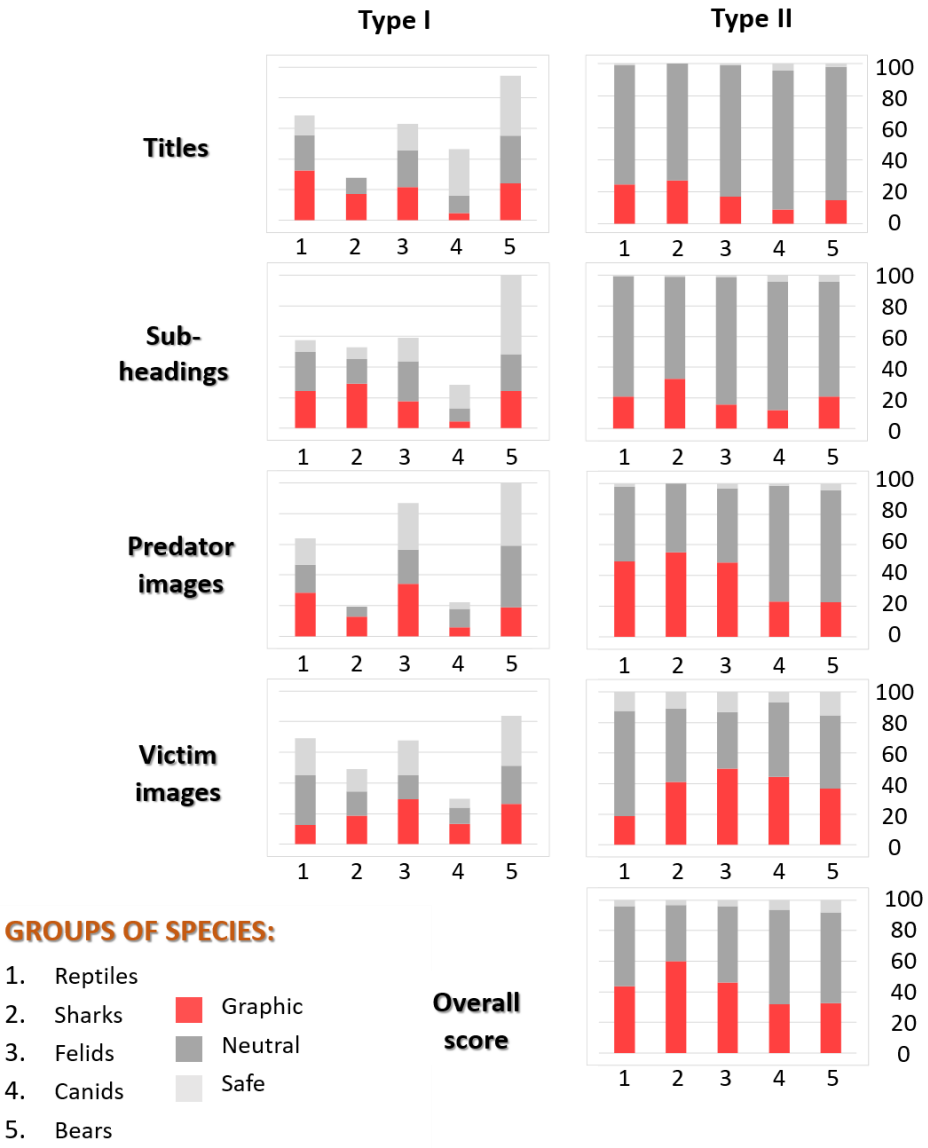
Fear of potential dangers during outdoor activities in areas inhabited by predators may encourage people to stay indoors, where they watch more media reports that tell them things which in turn reinforce their fears (Altheide 2018). Current trends in graphic media reports might contribute to shaping attitudes towards predators, leading to an increase in negative perceptions, mainly in those areas where predator populations are recovering. Therefore, predator-human conflicts are expected to increase (Penteriani et al. 2016) and, consequently, to generate an increasing number of graphic media reports. Moreover, the magnitude of negative perceptions and phobias towards predators can also spread relatively fast. Indeed, a number of studies have shown that there is a familial aggregation of animal phobias, suggesting that there may be a familial transmission process involving either genetic or learning mechanisms (Torgersen 1979, Wing et al. 1982). Further, human attitudes, which can seem to be resistant to change, may also change rapidly when human attitudes and feelings are challenged by new information or experiences (Zaller 1992, Olson and Zanna 1993, Eriksson et al. 2015). Schafer (2011) posed the following question: are we fearful of predators because of our ancestors, our direct experience or the media telling us that we should be scared? The question as to

whether media reports are the cause or the effect of public fears remains unresolved (Altheide 2018).

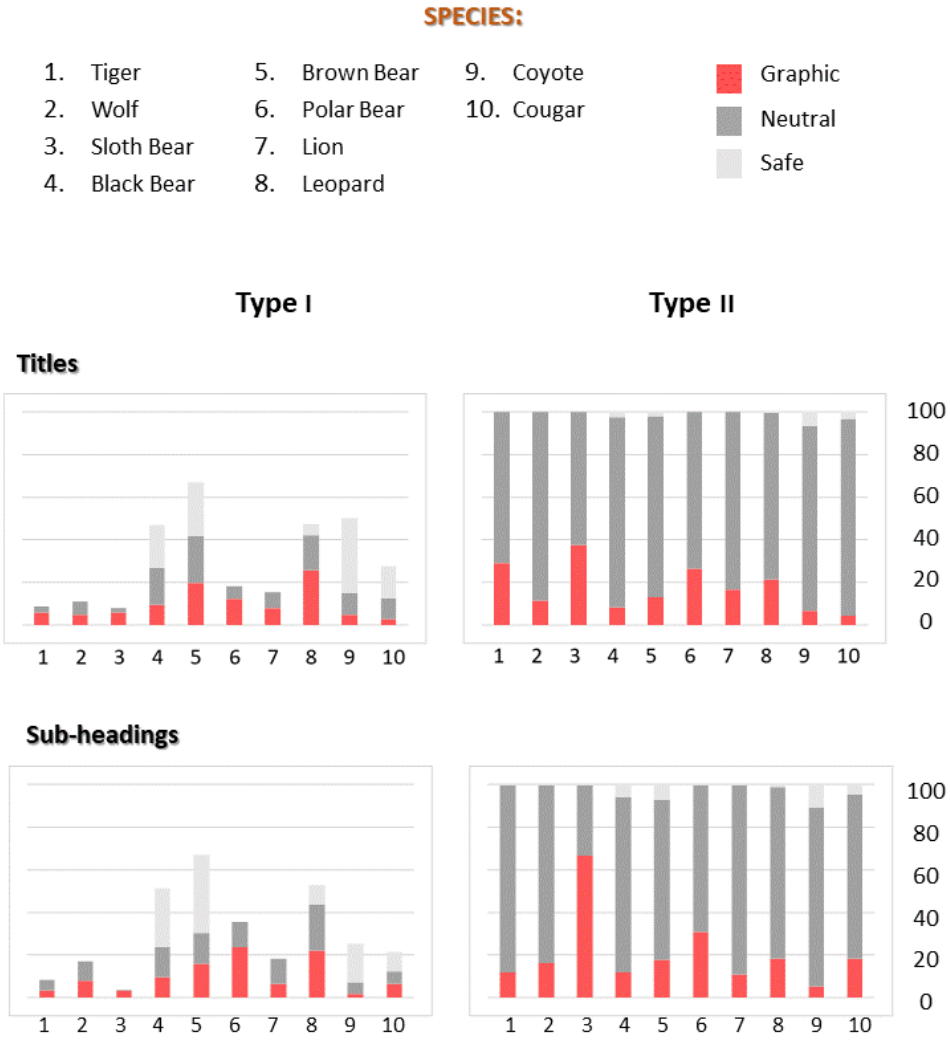
CONCLUSIONS

Human tolerance represents a fundamental component of predator conservation, since the most important limitation to tolerance is the threat (real and perceived) predators pose to people and goods, more than a lack of wilderness or protected areas (Knopff et al. 2016, López-Bao et al. 2017). With our work, we have highlighted that a relatively highly proportion of graphic contents is present in media reports concerning predator attacks on humans, with different groups/species being differently framed by the media. Since mass media are likely to have an important impact on such tolerance, reducing the still high number of graphic elements in media reports concerning predator attacks on humans may help avoid creating unnecessary fears. Further research could analyse media reports at local scales or/and explore potential differences in media framing of one or more groups/species between different geographical areas of the world. In addition to decreased graphic contents, the inclusion of scientific-based knowledge on large carnivore habits and useful information on how to avoid conflicts may prove to enhance human safety and facilitate coexistence with predators.

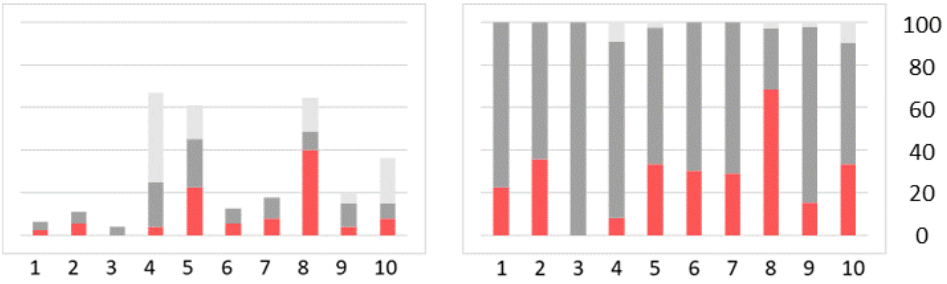
Supplemental File 1. Results of the analyses of media reports on carnivore attacks on humans. The elements of media reports that we have taken into account in this study, i.e. title (n = 1584), sub-heading (n = 642), picture/video of the predator (n = 780), picture/video of the victim (n = 657) and the overall score (n = 1584), are presented as percentages of the different scores (0 = neutral, 1 = graphic, 2 = positive/safe) for groups of species. In the column "Type I", percentages are calculated on the total articles for each score category (i.e., graphic, positive/safe and neutral). In the column "Type II", percentages are calculated on the total articles for each species group.



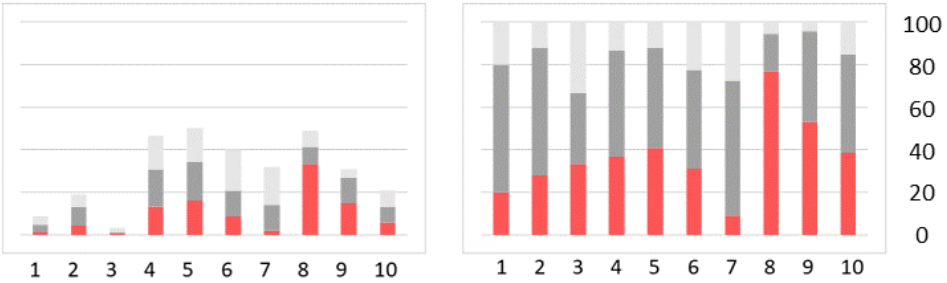
Supplemental File 2. Results of the analyses of media reports on carnivore attacks on humans. The elements of media reports that we have taken into account in this study, i.e. title (n = 1584), sub-heading (n = 642), picture/video of the predator (n = 780), picture/video of the victim (n = 657) and the overall score (n = 1584), are presented as percentages of the different scores (0 = neutral, 1 = graphic, 2 = positive/safe) for the different species. In the column "Type I", percentages are calculated on the total articles for each score category (i.e., graphic, positive/safe and neutral). In the column "Type II", percentages are calculated on the total articles for each species.



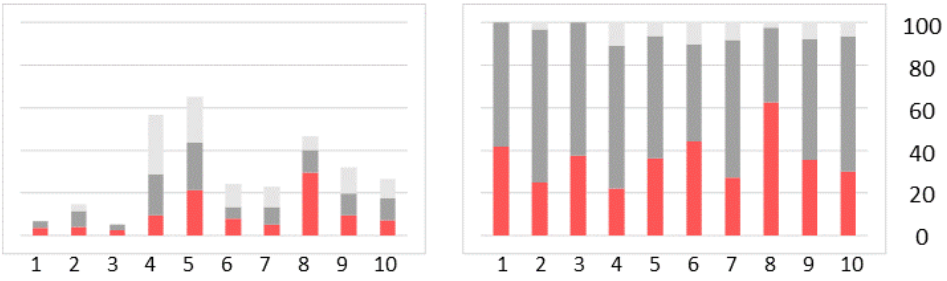
Predator images



Victim images



Overall score



General discussion

Our large-scale analysis has provided a new and wider perspective on the issue and allowed to explore factors related to different species and regions with different socio-economic situations. We were also able to make comparisons among species and within species in different areas of their distribution range, and found that both similarities and differences exist and need to be taken into account to develop effective preventive solutions. In general, the results of this thesis suggest that attacks are very complex interactions and the result of many factors. We need to keep in mind that human behaviour is very often the primary cause that triggers such events, and this is especially true when considering developed countries and, as highlighted in Chapter 2, bear species on a global scale. Deliberate attacks by large carnivores (e.g. with predation purposes) are generally rare, and mainly involve felid species in developing countries (Packer et al. 2019; Bombieri et al. in preparation). Because of this, human behaviour should be the first and main target of any management action aimed at reducing attack occurrence. With respect to the role of mass media in conveying information on large carnivores, our results suggest that great efforts and resources need to be invested to improve the quality of the information spread by the media to the large public, and highlight the need for an active and constant collaboration between large carnivore experts and the media with the aim of promoting education based on correct and objective information.

Looking for solutions in developed vs. developing countries

One of the most interesting findings in terms of conservation and management is the fact that developed and developing countries presented very different patterns and causes behind the occurrence of conflicts with large carnivores. On the one hand, we have developed countries, where attacks mainly occur to 1) people that enter carnivore areas mainly by choice and for recreational purposes or 2) in those urban areas with resident large carnivore populations. In these contexts, reduction of attacks and enhanced acceptance of these species are not hard to reach. In the first case, for example, we can expect that people decide to go to recreate in

wilderness areas because they appreciate its values and are aware of the species that inhabit these areas. Therefore, an improved communication about carnivore behaviour and how to avoid encounters while recreating outside can effectively reduce such conflicts and improve human tolerance of these species. Successfully reaching the kind of audience that we have identified as the most vulnerable in developed countries can be achieved by concentrating information campaigns and warning panels in national parks or in urban areas where carnivores are known to be present, as it has already been done in many regions of North America. Additionally, because economic resources and technologies are usually available in these regions, different types of information channels can be employed to reach the maximum audience possible.

On the other hand, reducing this kind of conflicts and improving attitudes towards large carnivores is not as straightforward in developing countries. Here, conflicts with carnivores are much more serious because attacks happen to people that are carrying out their daily subsistence activities, in and outside natural parks and, in most cases, local people cannot afford to avoid visiting these areas. In addition, if we consider felid species such as lions in Africa or tigers and leopards in Asia, which attacks have predatory purposes most of the times (Bombieri et al. in preparation), the issue becomes even more serious and management solutions to deal with the carnivore involved must be applied straight away to avoid further predations. In these regions, because the direct threat that carnivores pose to people safety is more impellent than their value, reasons for persecution are more obvious to local communities than the reasons to conserve them. On top of this, in regions where technologies and economic resources are limited, reaching local communities that have to deal with carnivores in their daily lives to provide information that could help avoid dangerous encounters with these species is a challenging or even impossible task. Thus, even if information on main attack patterns and factors that could explain their occurrence is made available by researchers, the real problems here are the lack of resources that could allow people to avoid having to face large carnivores in their daily activities and the lack of a communication system that could reach those people that are more vulnerable to encounters with large carnivores.

Because in these regions conflicts with large carnivores, and wildlife in general, are clearly the result of a general socio-economic issue in the first place, the first step to improve coexistence would imply improving economic and social conditions of the local communities, for example by reducing their dependence on forest resources and giving them alternative livelihood options.

Limitations and further research

Because official and standardized protocols for reporting cases of attacks and their details are often lacking, the data collected was sometimes incomplete and many useful details were missing from the reports. Similarly, we know that there were probably more attacks than the ones we were able to collect. Because of this, our main recommendation is that standard reports including all possible details about an attack should be developed and used by wildlife managers. Objective knowledge about previous cases is indeed the first step towards finding solutions to avoid the occurrence of future ones. Moreover, such information should be made available to the public, at least after official request. Further research could certainly benefit from an easier access to information collected by wildlife managers and access to more detailed information would allow a deeper examination of these incidents, and to investigate the effectiveness of some specific human behaviours or deterrents to avoid attacks.

We hope that this work, together with our oncoming analysis of attacks by all species of large carnivores in the world will provide an even wider perspective on this issue, and stimulate improved efforts to collect information on these cases and, consequently, further analyses and ideas to help finding solutions aimed at reducing these conflicts and improve coexistence. Most importantly, we hope that the information provided by our work will have real application and will help managers in developing strategies to prevent the occurrence of attacks.

Conclusions

1. In those urban areas where large carnivores are known to reside, several factors are involved in the occurrence of an attack. Because we found that the three main attack scenarios were a) predatory, b) related to dog presence and c) related to anthropogenic food, special efforts should target proper management and removal of anthropogenic related food (e.g., garbage, pet and bird food, fruit trees) and special attention and protection should be given to children and dogs, both outside and inside people's properties.
2. As for bear species, attack patterns on a global scale presented both differences and similarities across countries and species. In the specific case of brown bears, most of the attacks involved defensive reactions of females with cubs (almost half of all attacks recorded) and people engaged in recreational activities in bear area. These results suggest that more efforts should be put into education campaigns targeting visitors of natural areas and special monitoring and protection measures should be taken to prevent encounters with female bears with cubs.
3. In general, and considering all large carnivore species, we must keep in mind that attacks are very complex interactions and the result of many factors. As highlighted throughout this thesis, human behaviour is often the primary cause of such events and should thus be the first and main target of any management action aimed at reducing their occurrence.
4. In developed countries, because attacks mainly involve people that enter carnivore areas for recreational purposes and many of them are the result of irresponsible behaviours, their occurrence can be reduced by promoting awareness and correct information in the large public.
5. In developing countries, the first step towards a better coexistence implies better living conditions for the local communities that share the landscape with large carnivores on a daily basis.
6. Accurate knowledge of attack cases occurred in the past is the first and fundamental step to find effective solutions to avoid future cases. Because of this, 1) collecting detailed information when an attack takes place and 2) share this

information among regions with similar contexts as well as the general public is key to find effective solutions and spread correct information to the public.

7. To avoid false information on the attacks to spread, active and constant collaboration between wildlife managers and the local media (included social media) is crucial.

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Resumen y conclusiones

Introducción

A pesar de que los ataques de grandes carnívoros a humanos son eventos raros, este fenómeno, junto a otros daños económicos como la depredación sobre el ganado y otros tipos de daños a propriedades humanas, representa una de las formas más extremas de conflicto entre humanos y la fauna silvestre y es una de las principales causas que ha llevado a la persecución de estas especies a lo largo de la historia. A escala mundial, los ataques de grandes carnívoros a humanos han incrementado en los últimos años. El aumento de la población humana y la expansión de sus actividades en áreas frecuentadas por grandes carnívoros, unido a la recuperación que vienen experimentando muchas de las poblaciones de estas especies, aumenta la probabilidad de encuentros desafortunados, muchos de los cuales acaban con la muerte de personas y/o del predador.

Debido a los fuertes efectos negativos tanto sobre el bienestar humano como para la conservación de estas especies, adquirir un conocimiento exhaustivo de los escenarios y los factores que determinan la ocurrencia de estos eventos tiene un doble efecto positivo. Por un lado, desde el punto de vista humano, se puede llegar a reducir el número de personas heridas o muertas por encuentros desafortunados con grandes carnívoros. Por otro lado, la reducción de este conflicto tiene una repercusión inmediata sobre la conservación de estas especies y en la recuperación de muchas de sus poblaciones. En numerosas ocasiones, tras un ataque de un carnívoro a un humano, se organizan batidas para localizar y abatir al predador. Desgraciadamente, en muchos casos, estas batidas conllevan la muerte de varios individuos de la especie que ha atacado al humano. Además, generalmente estos eventos atraen a los medios de comunicación (e.g. periódicos, redes sociales, etc.), que en muchos casos exageran y/o dan una versión equivocada de estos eventos, utilizando imágenes y lenguajes sensacionalistas y "gráficos". Esta dramatización genera una percepción negativa hacia los grandes carnívoros y puede llevar a situaciones de graves conflictos entre humanos y predadores, como oposiciones a

medidas de conservación y furtivismo. Así mismo, cuando los medios de comunicación describen los ataques de esta forma, no solo alimentan la percepción negativa hacia las especies de carnívoros, sino que tampoco se preocupan de difundir informaciones correctas y útiles sobre cómo evitar encuentros con los grandes carnívoros y de cómo comportarse en el caso de que un encuentro ocurra.

A pesar de la existencia de algunos estudios previos sobre el tema, el enfoque de los mismos ha sido casi exclusivamente local y/o centrado en un número reducido de especies. Sin embargo, el aumento en los ataques por parte de muchas especies y en muchas regiones del mundo remarca la necesidad de un enfoque más amplio.

Objetivos y métodos generales

El objetivo principal de esta tesis doctoral es analizar y comparar los escenarios de ataques de grandes carnívoros a humanos ocurridos en todo el mundo con el fin de ampliar los conocimientos sobre este fenómeno para tratar de identificar potenciales factores que los causan, con el fin de buscar soluciones efectivas que reduzcan la ocurrencia de estos eventos, tanto a escala local como global. Con este propósito, se recopilaron informaciones sobre ataques ocurridos en todo el mundo durante las últimas décadas y se creó una base de datos mundial que incluye todas las informaciones disponibles sobre ataques, como por ejemplo la fecha, el lugar, las características de la/s persona/s (por ejemplo, el sexo, la edad y el número de personas involucradas, la actividad desarrollada por la persona cuando el ataque ocurrió), así como del carnívoro (por ejemplo, la potencial motivación del ataque por parte del mismo) implicado en el encuentro. Otro objetivo de este trabajo es llegar a entender como los medios de comunicación presentan y describen estos eventos. Con este propósito, recopilamos noticias sobre ataques de todas las especies de predadores terrestres y acuáticos publicadas en periódicos internacionales y analizamos la presencia de contenidos “gráficos” en sus principales componentes (es decir, en las imágenes, título y subtítulo).

Objetivos y resultados por capítulo

El objetivo principal de esta tesis se ha abordado a través de cuatro objetivos específicos, que están enmarcados en los siguientes capítulos:

En el Capítulo 1, analizamos los patrones y los factores relacionados con los ataques ocurridos en áreas urbanas de Norteamérica. Las áreas urbanas representan la forma más extrema de paisaje humanizado, donde las interacciones entre personas y naturaleza son casi o totalmente ausentes. En Norteamérica, algunas especies de grandes carnívoros, como son el coyote y el oso negro, se han adaptado a vivir en entornos urbanos y a utilizar sus recursos. En estos contextos, las probabilidades de encuentros entre humanos y estas especies de carnívoros son elevadas, y son muchos los casos de ataques que se han documentado en las últimas décadas. Frente a estas circunstancias, estudiamos cuales son las condiciones más frecuentes que pueden generar una situación de riesgo en estos entornos urbanos. En particular, nos centramos en analizar las características del paisaje (es decir, abundancia y densidad de vegetación, presencia de edificios y carreteras) y el grado de iluminación artificial alrededor del lugar donde ocurrieron los ataques. Los resultados principales de estos análisis sugieren que los tres escenarios principales implican una intención de depredación por parte del carnívoro, la presencia de perros acompañando a los humanos y la presencia de comida de origen humano. Además, las especies involucradas, en particular el coyote y el oso negro, presentan patrones diferentes en términos de las características del paisaje. Mientras que los ataques de coyote ocurren en cualquier tipo de hábitat, los ocasionados por el oso negro se concentran en aquellos entornos urbanos donde la vegetación es más abundante y hay una menor presencia de infraestructuras humanas. En cuanto a la iluminación artificial, observamos que la mayoría de los ataques de las dos especies ocurrieron en áreas escasamente iluminadas. En particular, los ataques de oso negro ocurrieron en áreas con menor iluminación comparados con los de coyote.

En el Capítulo 2, estudiamos los patrones generales de ataques de todas las especies de osos a escala mundial. Encontramos que, salvo dos especies de osos (i.e. el panda Ailuropoda melanoleuca y el oso andino Tremarctos ornatus), las demás especies han estado involucradas en ataques a humanos. Observamos tanto diferencias como

similitudes entre especies y entre regiones del mundo con diferentes contextos socio-económicos. Las especies que son más frecuentemente protagonistas de este tipo de conflictos son: oso pardo Ursus arctos, oso negro americano Ursus americanus, oso polar Ursus maritimus, oso negro asiático Ursus thibetanus y oso bezudo Melursus ursinus. Muy pocos casos han implicado el oso malayo Helarctos malayanus. Por un lado, en los llamados países en vías de desarrollo o emergentes, los encuentros negativos ocurren principalmente cuando los habitantes locales llevan a cabo sus actividades diarias de trabajo y subsistencia (por ejemplo, la recolección de alimentos, el cuidado de cultivos o ganado) en hábitats de osos. Los ataques son muchas veces el resultado de encuentros repentinos debido a que la visibilidad es escasa por la presencia de vegetación y las personas se mueven en silencio. Por otro lado, en los países desarrollados, los ataques ocurren principalmente cuando las personas desarrollan actividades recreativas en áreas de presencia de osos (ejemplos, excursionistas, cazadores) y son sobre todo el resultado de encuentros repentinos o de reacciones defensivas por parte de osas con cría(s). Estos resultados sugieren la necesidad de evitar generalizaciones a la hora de plantear soluciones para reducir este tipo de conflictos a nivel local.

En el Capítulo 3, analizamos los patrones de ataques de oso pardo a escala global. El oso pardo es la especie de osos más común y con mayor rango de distribución en el mundo, y por tanto representa un buen ejemplo de cómo una misma especie pueda presentar similitudes, así como diferencias, en los escenarios y patrones de ataques entre regiones con distintos contextos locales y distintas historias de coexistencia con esta especie. En general, la frecuencia de ataques por oso pardo ha aumentado a nivel mundial en las últimas décadas, ocurriendo la mitad de los denunciados en Europa en Rumania. El escenario más común a nivel mundial (47% de los ataques recopilados) es la reacción defensiva de una osa con cría(s), lo cual significa que esta clase de osos en particular es más susceptible de responder de manera agresiva frente a un encuentro con humanos. Otros escenarios plausibles son el resultado de encuentros repentinos y de la presencia de perros acompañando a humanos. En general, la mayoría de las personas implicadas en los ataques se encontraban realizando actividades recreativas. Aun así, observamos importantes

diferencias en los patrones en función del área geográfica. Por ejemplo, ataques a personas que realizaban actividades de trabajo ocurrieron principalmente en Europa, sobre todo en Rumania, donde el 50% de los ataques fueron hacia ganaderos o agricultores, mientras que en Norteamérica la mayoría de los ataques ocurrieron a personas que estaban realizando actividades recreativas (por ejemplo, excursionistas o cazadores).

En el Capítulo 4, examinamos un aspecto distinto de estos conflictos, relacionado con la percepción humana. Concretamente, estudiamos cómo los periódicos internacionales presentan y describen los ataques de todas las especies de grandes depredadores a humanos. Dado que los medios de comunicación, como es el caso de los periódicos y de las redes sociales, representan casi exclusivamente la única fuente a través de la que la sociedad en general recibe informaciones acerca de los grandes carnívoros, y tienen un gran poder para condicionar la percepción y opinión general, conocer como los mismos presentan y describen los ataques de grandes carnívoros es esencial para poder mejorar la calidad de las informaciones que vienen publicadas sobre los grandes carnívoros. En este capítulo, nos enfocamos en particular en el uso de contenidos "gráficos" y sensacionalistas en las noticias publicadas en los periódicos. Encontramos que casi la mitad (41.5%) de las noticias utilizan contenidos "gráficos" para anunciar los casos de ataques. Estos resultados son muy preocupantes, sobre todo dada la capacidad que los medios de comunicación y, en tiempos más recientes, las redes sociales, tienen para influenciar en la opinión y percepción del público hacia los grandes carnívoros. Por esta razón, y porque la opinión de la sociedad es la que más influye en las decisiones políticas y de manejo de estas especies, actuar para mejorar las informaciones difundidas por los medios de comunicación a través de una constante colaboración entre expertos y periodistas es fundamental.

Discusión

En general, esta tesis doctoral aporta nuevos conocimientos e informaciones de gran relevancia para lograr reducir encuentros peligrosos con los grandes carnívoros, así como intentar mejorar la calidad de las informaciones sobre estos eventos. En particular, nuestros resultados sugieren la existencia de importantes diferencias en los escenarios entre distintas especies, así como dentro de la misma especie, dependiendo de los contextos locales y del comportamiento humano. Las diferencias debidas a las áreas geográficas y entre especies encontradas sugieren que estrategias que busquen reducir el riesgo de ataques tienen que ser desarrolladas basándose tanto en las características particulares de las especies como en el contexto socio-económico local en el que los ataques ocurren. Por un lado, en los países desarrollados, donde los ataques principalmente ocurren cuando las personas desarrollan actividades recreativas en áreas de presencia de carnívoros, estrategias destinadas a la disminución de estos encuentros desafortunados deben concentrarse sobre todo en áreas naturales visitadas por turistas, y tendrían que informar a los visitantes sobre el comportamiento de los grandes carnívoros y sobre los comportamientos que hay que adoptar para evitar encuentros con ellos. Por otro lado, en los países en vías de desarrollo, los ataques ocurren principalmente cuando los habitantes locales llevan a cabo sus actividades diarias de trabajo y subsistencia (por ejemplo, la recolección de alimentos, el cuidado de cultivos o ganado) en hábitats de carnívoros. Por tanto, estos conflictos son el resultado de un problema socioeconómico generalizado. En este caso, campañas de educación e información no son suficientes, y el primer paso para reducir la ocurrencia de encuentros negativos implica mejorar las condiciones de vida de las comunidades locales que viven en contacto con los grandes carnívoros.

Los resultados de este estudio sugieren que los ataques de grandes carnívoros a humanos son interacciones muy complejas y el resultado de distintos factores. En muchos casos, el comportamiento humano es la primera causa responsable de la ocurrencia de estos eventos y, por eso, difundir una correcta información a la sociedad y, en particular, a aquellas personas que pueden ser más propensas a vivir encuentros con grandes carnívoros, es un elemento fundamental y debería ser el

primer paso para favorecer una mejor coexistencia. Es cierto que más informaciones acerca de cada ataque serían necesarias y permitirían profundizar con más detalle cada uno de estos eventos, así como analizar la efectividad de algunas medidas comportamentales preventivas en particular. El primer paso para obtener estas informaciones detalladas sobre los casos de ataques es el desarrollo de protocolos estandardizados para la recogida de informaciones, que deberían ser utilizados por los gestores cada vez que un nuevo caso ocurriese. En la actualidad, la implementación de estos protocolos existe en muy pocas regiones del mundo y, aun así, también cuando están disponibles, las informaciones que se recogen siguen siendo escasas. Respecto a los medios de comunicación, este estudio sugiere la necesidad de un gran trabajo y esfuerzo para poder mejorar las informaciones que son proporcionadas acerca de los grandes carnívoros, y remarca la necesidad de una constante colaboración entre expertos de grandes carnívoros y los medios de comunicación con el fin de promover una educación basada en una información correcta y objetiva.

Conclusiones

1. En aquellas áreas urbanas frecuentadas por grandes carnívoros, varios factores son responsables de la ocurrencia de un ataque. Dado que los tres escenarios más frecuentes en estas áreas son: a) ataques predatorios, b) ataques relacionados con la presencia de perros y c) ataques relacionados con la presencia de comida de origen humana, esfuerzos para mitigar estos encuentros deberían dirigirse a un mejor manejo de la comida de origen humana (e.g., basura, comida para mascotas y pájaros) y especial atención y protección debería ser dirigida a niños y perros, tanto en espacios públicos como privados.

2. Los patrones de ataques de osos a escala global presentan tanto diferencias como similitudes entre países y especies. En el caso específico del oso pardo, la mayoría de los ataques implican una reacción defensiva de una hembra con cría. Estos resultados sugieren que más esfuerzos tienen que ser invertidos en campañas de educación dirigidas a los visitantes de áreas recreativas. Además, especial vigilancia y protección tendrían que adoptarse para evitar encuentros con hembras con crías.

3. En general, y considerando todas las especies de grandes carnívoros, hay que tener en cuenta que los ataques son interacciones muy complejas y el resultado de muchos factores. El comportamiento humano es muchas veces la primera causa responsable de la ocurrencia de estos eventos y, por tanto, cualquier estrategia que busque reducir estos eventos debería centrase principalmente en mejorar la educación de los humanos cuando coexisten con especies de grandes carnívoros.

4. En países desarrollados, ya que los ataques tienen principalmente lugar cuando las personas desarrollan actividades recreativas en áreas de presencia de carnívoros y muchas interacciones son el resultado de comportamientos humanos irresponsables, su ocurrencia puede ser reducida promoviendo una correcta sensibilización/ conciencia e información dirigida en particular a este tipo de público.

5. En países en vías de desarrollos, el primer paso para una mejor coexistencia implica en primer lugar una mejora de las condiciones de vida para las comunidades locales que tienen que convivir con los grandes carnívoros en su día a día.

6. Un conocimiento exhaustivo sobre los ataques que ocurrieron en el pasado es un paso fundamental para poder encontrar soluciones para evitar casos de ataques en el futuro. Por eso, 1) recopilar informaciones detalladas cuando ocurra un ataque y 2) compartir estas informaciones con otras regiones con contextos parecidos, y con el público, es fundamental a la hora de encontrar soluciones y difundir informaciones correctas.

7. Para evitar que informaciones falsas acerca de los ataques se difundan, una colaboración activa y constante entre gestores y medios de comunicación locales es esencial.

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During these years I had the luck – in some cases unluck, actually – to collaborate with many researchers from all over the world and this has definitely opened my mind and taught me to deal with many different kinds of people and opinions. I think this was the hardest, most stressful and frustrating part of my PhD, both for me and my supervisors. I would like to thank all the co-authors that have participated in our papers, especially the ones that have really cared about the project and contributed to the papers' preparation and improvement. From some of you in positive, from some of you in negative, but from all of you I have learnt a lot about what I want and what I do not want to be in the future.

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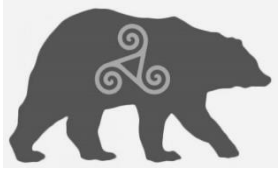

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