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ORIGINAL ARTICLE

Individual attributes and party affect large carnivore attacks on humans

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Abstract Wildlife managers, researchers and the general public have traditionally been demanding information on factors concerning the probability of risky encounters between predators and people, as well as how to react in those situations. This information is crucial to reduce the number of predator attacks, which in absolute terms have increased in the last decades. Here, we focus on the role of carnivore species and sex, as well as victim-related factors (i.e. gender, activities, party composition), as determinants of carnivore attacks on humans. Using a dataset on attacks by grizzlies (*Ursus arctos horribilis*), black bears (*Ursus americanus*), cougars (*Puma concolor*), wolves (*Canis lupus*) and coyotes (*Canis latrans*) in North America during the last five decades, we found that (1) male black bears were involved in attacks more frequently than females; (2) attacks by coyotes, cougars and wolves prevalently caused injuries, whereas cases of death were more frequent during grizzly and black bear attacks; and (3) people in a party were less vulnerable to an attack than a person alone. We identified risky situations and behaviours that should be avoided in areas where people and large carnivore share the landscape.

Keywords Party effects · Predator sex · Victim gender · Attack patterns · Attack outcome · Carnivore-humans conflict · Large carnivore attacks

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The number of large carnivore attacks has increased in the last few decades in North America (Penteriani et al. 2016). As a consequence, wildlife managers, researchers and the general public increasingly demand information on the factors influencing the probability of risky encounters between predators and people, with the expected outcome of a reduction in the number of attacks (Löe and Röskaft 2004). Beyond the influence of predator population sizes on these figures, many of them in fact globally declining (Löe and Röskaft (2004), Ripple et al. (2014), Ferretti et al. (2015), Fukuda et al. (2015), Penteriani et al. (2016), but see Chapron et al. (2015)), several non-mutually exclusive drivers have been suggested to cause the observed trends in the number of attacks.

For instance, after decades of minimal interaction between humans and large carnivores, an increasing number of people involved in outdoor activities may lack appropriate knowledge on how to reduce the probability of a risky encounter with these species. As a consequence, the per capita probability of risky encounters between people and large carnivores might have increased over time (Conover 2008). As an illustrative example, half of the well-documented attacks ($n = 271$) by six carnivores species in North America and Europe during the last few decades were judged due to inappropriate human behaviours (Penteriani et al. 2016).

Beyond such risky human behaviours, several studies (Carbyn 1989; Beier 1991; Herrero et al. 2011; Mattson et al. 2011) also point to predator-specific and other human-related factors as important drivers of carnivore attacks. These include predator species and sex as well as potential victim gender, activity and party composition (i.e. size and age structure of the parties). In general, these studies showed general patterns of attacks: (a) the proportion of humans being attacked by males is higher than by females in cougars (*Puma concolor*) (Mattson et al. (2011); although the opposite can be observed during the breeding season, Teichman et al. (2013)). Similarly, male black bears (*Ursus americanus*) and female grizzlies (*Ursus arctos horribilis*) show a higher probability of being involved in an attack (Herrero and Higgins 1999; Herrero and Higgins 2003; Herrero et al. 2011); (b) attacks can target a specific victim gender. For instance, predatory attacks by coyotes (*Canis latrans*) (i.e. instances in which a coyote directly and aggressively pursued and bit a victim, causing injuries, often to the head and/or neck) were more frequent on women, whereas men were more often involved in non-predatory attacks (White and Gehrt 2009); and (c) the fatality of the attacks may be related to the party composition (Carbyn 1989; Beier 1991; Herrero et al. 2011).

The complexity of factors involved in carnivore attacks demonstrates the need for a comprehensive analysis of those factors and scenarios in which risky encounters are more likely, in order to effectively inform about how to prevent and respond to risky encounters. Among these factors, we consider that identifying key attributes of predators and victims is helpful because of their influence on predator attacks (Herrero and Higgins 1999, 2003; Herrero et al. 2011; Stringham 2013; Penteriani et al. 2016).

Previous studies concerning the patterns of carnivore attacks on humans (e.g. White and Gehrt 2009; Herrero et al. 2011; Teichman et al. 2013) have usually focused on a single species in a narrow geographic range (but see for example Treves and Naughton-Treves 1999 or Mattson et al. 2011). These investigations provided valuable insights into the realized relationships between the predictability of the behaviours of some species and particular conditions during a given encounter. Yet, we need to disentangle the generality of attack triggers by different carnivore species and in multiple contexts. Thus, by comprehensively studying the circumstances in which people were attacked by five species of large carnivores in North America (i.e. grizzlies, black bears, cougars, wolves (*Canis lupus*) and coyotes) during the last five decades, our comparative study highlights general patterns of large carnivore attacks on humans, an approach that has not been explored before. Therefore, using a subset of the dataset analysed by Penteriani et al. (2016), we aim to fill a knowledge gap that is not specifically on factors predicting attacks (which has been previously tested separately for several large carnivores, as previously reported), but we are attempting to replicate previous findings to test for generalizability of attack scenarios. We only considered attacks that ended with injuries (non-fatal) or death (fatal), but did not include attacks without physical harm to people. We firstly focused on effects of sex of large carnivore. Obviously, estimating the probability of large carnivore attack on human is logistically non-viable. Nevertheless, with the data at hand, it is possible to investigate whether, once an attack occurred (i.e. the condition), there are carnivore sex species-specific patterns of attacks on humans on a regional scale. Secondly, we evaluated whether carnivore attack likelihood varies with victim gender. Finally, we also investigated if party characteristics (i.e. size and age structure) and the activity and gender of the victim influenced the conditional probability of attack as well as its outcome (i.e. injuries vs. death).

Methods

Datasets on large carnivore attacks and human activities

We used the largest compiled database to date on attacks on humans by five carnivore species (grizzly, black bear, cougar, wolf and coyote) in North America (Penteriani et al. 2016). Records of attacks were collected from unpublished reports and PhD/MS theses, webpages (last accessed in November 2014, but currently available at the specific addresses listed by species below), books and scientific articles. Furthermore, to complete the data obtained from the above-cited sources, we also collected dozens of 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: "common species name" + "attack" and "common species name" + "attack" + "human". Our dataset contained information from 634 attacks recorded between 1955 and 2014.

Considering our goals, for each attack, we recorded the following information: (*i*) large carnivore species, (*ii*) carnivore sex, (*iii*) victim gender, (*iv*) the activity of the victim before it was attacked simplified into six categories: activities around home, winter outdoor activities (e.g. skiing, snowboarding), outdoor activities, field work, activities with a dog present and hunting, (*v*) party composition, including size and age structure simplified into three categories: victim alone, young people (0 to 16 years old) in an adult (> 16 years) party, and adult in an adult party; and (*vi*) attack outcome (i.e. attack resulting in human injuries [non-fatal] or death [fatal]). Because not all required information was available for all cases, sample size for every analysis was different (see below). As a proxy to evaluate the existence of sex-biased outdoor human activities in

North America (detailed information was available from the Statistical Abstract of the United States: http://www.census.gov/en; last download 02/08/2015), we also collected information on outdoor activities by human gender in the USA between 1989 and 2009 (similar data were not available for Canada): road biking, mountain biking, skiing, skating, jogging, walking, hiking, camping, fishing, hunting and working in the field (Table S1).

Data analysis

We built three sets of generalized linear models (GLMs) with binomial distribution and logit link to explore whether and how, once a large carnivore attack occurred, our response variables (the sex of the predator, the victim gender and the attack outcome) were influenced by the carnivore species (five levels), party composition (three levels), and the activity of victims during the attack (six levels). In particular: (a) the model 1 was built to clarify if, given that an attack has occurred, a particular large carnivore sex was more prone to attack depending on the carnivore species, the party composition, the activity and the gender of victim; and (b) the model 2 was aimed to highlight if there was a preference to attack on a specific victim gender depending on carnivore species that attacked to the victim and the party composition and the activity of victim. For both models sets with sex of predator (codes: male, 0 vs. female, 1) and victim gender (codes: male, 0 vs. female, 1) as binary response variable, we included only cases with known both predator sex and victim gender, in total 87 cases from three species (n = 19 for grizzlies, n = 24 for black bears and n = 44 for cougars). We excluded coyotes and wolves due to small samples (two coyotes and one wolf with known sex). Note that though sex is most often specified as an explicative variable, we used it here as a response variable given that we were particularly interested in the conditional probabilities of sexes for both large predators and human victims given that an attack has occurred. Finally, (c) the model 3 treated attack outcome as a binary response variable (codes: non-fatal, 0 vs. fatal, 1) depending on the carnivore species, the party composition and the gender of victim, and we used 324 cases from five species (n = 81 for grizzlies; n = 56 for black bears, n = 111 for cougars, n = 20 for wolves and n = 56 for coyotes).

We built a set of competing models starting from the null model to one that included all explanatory variables and their interactions. The best candidate model was selected based on Akaike's Information Criterion (AIC), which allows comparing multiple working hypotheses and weighting their level of support in the data (AICc; Burnham and Anderson 2002). A t test compared the percentages of men and women involved in outdoor activities in the USA. All analyses were performed in R 3.0.2 statistical software (R Development Core Team 2013).

Results

Sex of large carnivores involved in the attacks

Sex information of predators was available for 19 grizzly attacks (male = 5, female = 14), 24 black bear attacks (22 and 2, respectively) and 44 cougar attacks (23 and 21, respectively). Thus, we found that the conditional probability of being attacked by a male (coded as 0 in model) or a female (coded as 1) depended on carnivore species (Table 1; Fig. 1a) and on party composition (Table 1; Fig. 1b). When we compared sexes among species, black bear was the only species with significant ($P < 0.0001$) sex-specific conditional probabilities of attack (being 0.92 and 0.08 for male and female, respectively). Grizzlies and cougars showed non-significant effects ($P = 0.101$ and $P = 0.319$, respectively). Regarding party composition, parties including young people showed higher conditional probability of attack by males ($P = 0.83$) than by females ($P = 0.17$), being these differences significant ($P < 0.05$).

The gender of the victim

Gender information of victims was available for 19 grizzly attacks (men = 12, women = 7), 24 black bear attacks (16 and 8, respectively) and 44 cougar attacks (28 and 16, respectively).

Between 1989 and 2009, all outdoor activities except walking were mostly performed by men ($t_{20} = 4.07$, $P = 0.001$; Table S1, available online in Supporting Information). The greatest differences corresponded to hunting (mean ± SD: men = 0.88 ± 0.02, women = 0.12 ± 0.02), field work (men = 0.81 ± 0.02, women = 0.2 ± 0.02) and skating (men = 0.77 ± 0.03, women = 0.23 ± 0.03). The percentage of men (55–60%) practicing the remaining activities (see Table S1) was only slightly higher than that of women (40–45%).

The conditional probability of suffering an attack being a man (coded as 0 in the model) or a woman (coded as 1) seems to prevalently depend on the party composition, although we have to keep in mind that the AIC weight of this model is similar to the null model (Table 1; Fig. 1c). When we compared sexes among parties, we found that parties with significant effects in the probability of suffering an attack were those composed by an alone victim ($P < 0.001$) and by an adult in a party ($P < 0.05$). In the first case, the probability of suffering an attack being a male ($P = 0.75$) was greater than that for a female ($P = 0.25$) whereas in the second one, the probability was very similar among victim gender (male: $P = 0.52$; female: $P = 0.48$).

Table 1 Summary of fitted parameters and models employed to analyse sex-specific patterns of carnivore attacks on predator sex (model 1), victim gender (model 2) and the outcome of an attack (model 3). In particular: (a) the model 1 was built to clarify if one of the large carnivore sexes was more prone to attack depending on the carnivore species, the party composition, the activity and the gender of encountered people; (b) the model 2 was aimed to highlight if there was a preference to attack a given gender depending on the above mentioned variables; and (c) the model 3 was built to explain if the attack outcome depending on the carnivore species, the party composition and the gender of encountered people. We show β, SE, AICc, ΔAICc, and weighted AIC values for selected models only. Asterisks (*) indicate significant variables. Grizzly (species) and alone victim (party) are included in intercept. Competitive models are ranked from the lowest AICc value (best model) to the highest one

Explanatory variable	Competing models		β	SE	AICc	ΔAIC	Weighted AIC
Model 1							
Sex of the carnivore species	Species + party				101.81		0.41
		Intercept	1.11	0.67			
		Black bear*	− 3.23	0.91			
		Cougar	− 0.73	0.73			
		Young person in a party*	− 1.44	0.69			
		Adult in a party	− 0.13	0.72			
	Species				102.65	0.84	0.27
	Species + activity				103.56	1.74	0.17
	Species + party + activity				103.85	2.04	0.15
	Party				117.03	15.22	0.00
	Party + activity				117.98	16.17	0.00
	Null model				120.68	18.87	0.00
	Activity				122.13	20.32	0.00
Deviance = 91.67							
Model 2							
Gender of the victim	Party				115.19		0.35
		Intercept*	− 1.07	0.37			
		Young person in a party	0.45	0.60			
		Adult in a party*	1.07	0.53			
	Null model				115.35	0.16	0.32
	Species + party				116.92	1.73	0.15
	Party + activity				118.58	3.39	0.06
	Activity				119.10	3.91	0.05
	Species				119.32	4.13	0.04
	Species + party + activity				120.11	4.92	0.03
	Species + activity				123.07	7.88	0.01
Deviance = 109.12							
Model 3							
Conflict outcome (non-fatal or fatal)	Party + species				283.74		0.36
		Intercept*	1.45	0.35			
		Young person in a party	− 0.42	0.50			
		Adult in a party*	− 0.75	0.37			
		Black bear	− 0.11	0.41			
		Cougar*	− 3.20	0.43			
		Wolf*	− 3.34	0.81			
		Coyote*	− 4.63	0.80			
	Species				284.24	0.50	0.28
	Party + species + victim sex				284.77	1.03	0.22
	Victim sex + species				285.71	1.97	0.14
	Party				416.79	133.04	0.00
	Victim sex + party				418.22	134.48	0.00
	Null model				426.96	143.22	0.00
	Victim sex				428.70	144.96	0.00
Deviance = 269.7							

Determinants of attack outcome

For the 324 attacks for which outcome information was available, 81 belonged to grizzlies (non-fatal = 22, fatal = 59), 56 to black bears (15 and 41, respectively), 111 to cougars (97 and 14, respectively), 20 to wolves (18 and 2, respectively) and 56 to coyotes (54 and 2, respectively). Analyses of these data showed that the conditional probability of suffering a non-

fatal (coded as 0 in the model) or fatal (coded as 1) attack during an encounter with a carnivore depended on both the species and the party composition (Table 1; Fig. 1d, e, respectively). When we compared attack outcomes among species, we found that black bear was the only species with non-significant differences in the conditional probability of inflicting fatal or non-fatal attacks ($P = 0.793$). Whereas grizzly was the only species with significant ($P < 0.0001$) greater probability of fatal ($P = 0.76$) as compared to non-fatal ($P = 0.24$) attacks, cougar, wolf and coyote showed significantly ($P < 0.0001$) greater probability of non-fatal ($P = 0.88$, $P = 0.89$, $P = 0.97$; respectively) than that of fatal attack ($P = 0.12$, $P = 0.11$, $P = 0.03$, respectively). Regarding party composition, we observed that when the victim was alone ($P < 0.0001$), the conditional probability of non-fatal attack ($P = 0.66$) was significantly higher than that of fatal attack ($P = 0.34$); similarly, when there was an adult within the party, the conditional probability of non-fatal attack ($P = 0.81$) was significantly ($P < 0.05$) higher than that of fatal attack ($P = 0.19$).

Discussion

Our analyses of attacks on humans by five species of large carnivores in North America mainly show that (1) black bear is the only species that shows a significant sex-specific pattern during attacks, being males more likely to attack humans than females. Furthermore, this analysis also highlights that a party that includes a young person is the party more susceptible to suffer an attack by a male carnivore; (2) generally, people in a party seem to be less vulnerable to an attack than while alone, being in both cases more likely that a man suffer an attack; and (3) finally, attacks in which cougars, wolves and coyotes are involved prevalently caused injuries, whereas the death of the victim is more frequent for grizzly attacks. As a general pattern, our results show that although it is more likely to only suffer a non-fatal attack, the probability of being killed (i.e. fatal attack) increases for victims who are alone.

North American male black bears are more likely to attack humans than females (Table 1; Fig. 1a); as previously reported

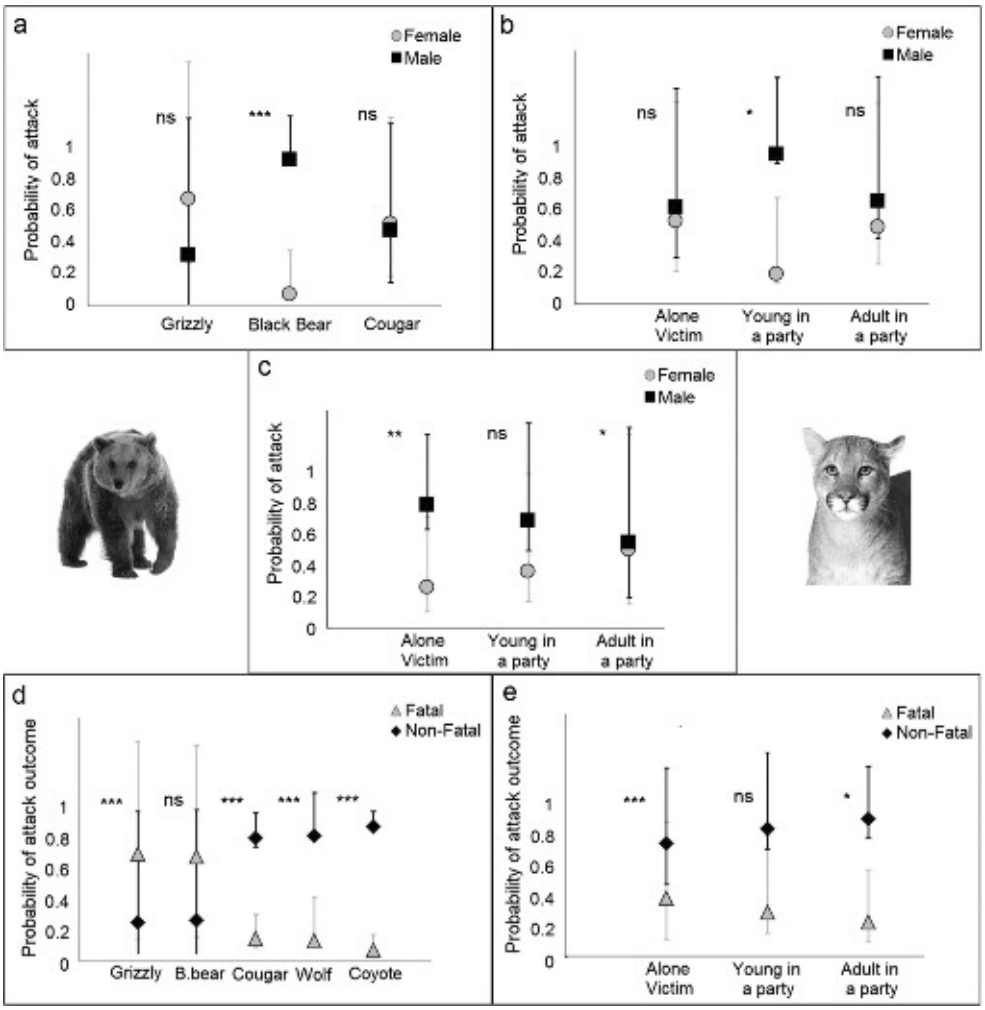

Fig. 1 Effects plots of sex of the large carnivore (**a** and **b**), the gender of the victim (**c**) and the outcome of an attack (**d** and **e**). We show attack probabilities and their intervals of standard errors. Asterisks show the level of significance: * $p = 0.05$, ** $p = 0.001$, *** $p = 0.0001$. (The bear and cougar photos were downloaded from 123RF ROYALTY FREE STOCK PHOTOS, www.123rf.com, Image ID 7980310, Eric Isselee and Image ID 5785754, Megan Lorenz, respectively)

by Herrero and Higgins (1999) and Herrero et al. (2011) for British Columbia and Alberta, male black bears were responsible of ~ 90% of the attacks. The probability of suffering an attack by a male black bear might increase because males have larger home ranges than female and, therefore, are more exposed to potential interactions with people (Herrero et al. 2011). Furthermore, males typically take more risks to feed and fatten for competing with other males during the breeding season (Garneau et al. 2008). Party composition also is an important factor (Fig. 1b), being the party composed by a young person and several adults the most common scenario significantly suffering an attack. However, we have to keep in mind here that this result might be influenced by the dataset composition, i.e. most of the available information was on black bear and cougar. Indeed, as suggested by Herrero et al. (2011) and Mattson et al. (2011), young people are more vulnerable to be attacked by these two large carnivores.

Generally, and independently of party composition, men suffered more attacks than women. However, in 10 out of the 11 human activities that we analysed, there was a greater participation of men than women (and in some of them, like hunting or field work, were represented almost exclusively by men; see Table S1). Thus, the observed pattern of attacks towards men might be mostly related to the fact that men are the sex prevalently involved in outdoor activities and, therefore, more largely exposed to large carnivores than women.

We also observed a clear large-scale pattern in attack outcomes, with bears causing more deadly attacks than cougars, wolves and coyotes (Fig. 1d). This species-specific pattern is in accordance with previous studies that showed similar proportion of low rates of fatal attacks for cougars (Beier 1991; Mattson et al. 2011) and coyotes (Carbyn 1989; Timm and Baker 2007). Although attack outcome was mostly determined by carnivore species, party composition also had an effect. Indeed, alone victims have a greater probability of death than those in a party (Fig. 1e). That is, a party composed by adults is safer than stay alone because an alone victim tends to be quieter and appear less intimidating and less noisy than larger groups (Herrero and Higgins 1999, 2003). Thus, it is recommendable to avoid lone trips when in areas inhabited by large carnivores and, if there are young people within the party, they need to be under a constant vigilance and never left alone, i.e. young people always have to be surrounded by adults and never far from the party.

Although for decades many awareness campaigns have been undertaken in rural areas inhabited by predators, we stress the need of increasing education and information campaigns directed towards urban people, because the number of them enjoying outdoor activities is rapidly increasing. A change in our behaviour when sharing the landscape with these species has also substantial benefits for predator conservation, because by reducing the number of attacks, it is expected that we can avoid peaks of negative attitudes towards these species (Penteriani et al. 2016).

We finally consider that it is fundamental to continue recording well-detailed information on all the parameters associated with predator attacks, including detailed information on both large carnivores and the victims (White and Gehrt 2009) and the ecological context. In several cases, attack reports lack important information (but see, for example, extremely detailed reports on bear attacks as Frey et al. (2012), Cain et al. (2014), Wilmot et al. (2016)). The site of an attack should be analysed with criteria similar to the ones used in the case of a "human crime scene". Lack of detailed information on predator attacks limits research aiming to decrease predator attacks on humans and, in turn, the implementation of effective management interventions to mitigate such disturbing, and frequently tragic, conflicts.

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