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Factors governing risk of cougar attacks on humans

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Abstract: Since the 1980s wildlife managers in the United States and Canada have expressed increasing concern about the physical threat posed by cougars (*Puma concolor*) to humans. We developed a conceptual framework and analyzed 386 human–cougar encounters (29 fatal attacks, 171 instances of nonfatal contact, and 186 close-threatening encounters) to provide information relevant to public safety. We conceived of human injury and death as the outcome of 4 transitions affected by different suites of factors: (1) a human encountering a cougar: (2) given an encounter, odds that the cougar would be aggressive; (3) given aggression, odds that the cougar would attack; and (4) given an attack, odds that the human would die. We developed multivariable logistic regression models to explain variation in odds at transitions three and four using variables pertaining to characteristics of involved people and cougars. Young (≤2.5 years) or unhealthy (by weight, condition, or disease) cougars were more likely than any others to be involved in close (typically <5 m) encounters that threatened the involved person. Of cougars in close encounters, females were more likely than males to attack, and of attacking animals, adults were more likely than juveniles to kill the victim (32% versus 9% fatality, respectively). During close encounters, victims who used a weapon killed the involved cougar in 82% of cases. Other mitigating behaviors (e.g., yelling, backing away, throwing objects, increasing stature) also substantially lessened odds of attack. People who were moving quickly or erratically when an encounter happened (running, playing, skiing, snowshoeing, biking, ATV-riding) were more likely to be attacked and killed compared to people who were less active (25% versus 8% fatality). Children (≤10 years) were more likely than single adults to be attacked, but intervention by people of any age reduced odds of a child's death by 4.6×. Overall, cougar attacks on people in Canada and the United States were rare (currently 4 to 6/year) compared to attacks by large felids and wolves (*Canis lupus*) in Africa and Asia (hundreds to thousands/year).

Key words: attack, cougar, human–wildlife conflicts, mountain lion, public safety, puma, *Puma concolor*, risk

Since the 1980s, wildlife managers in the United States and Canada have expressed increasing concern about the physical threat posed by cougars (*Puma concolor*) to humans. Reports by states and provinces at regularly convened mountain lion workshops document rising numbers of problematic encounters between cougars and people throughout cougar range, especially during the early 1990s and 2000s (e.g., Wakeling 2003, Barber 2005). Of perhaps greatest relevance to everyone involved, numbers of confirmed attacks by cougars on humans and resulting human fatalities increased by 4- to 5-fold between the 1970s and 1990s (Sweanor and Logan 2010). This has made human safety a priority for most state and federal bureaus that manage cougars (e.g., Arizona Game and Fish Department 2005).

Management of public safety has become complicated for cougar managers since the 1980s, not only because of greater perceived threats from cougars, but also because of stakeholder conflict. Historically, cougars that were judged to be a threat were tracked down and killed. Intensified hunting also was used to reduce numbers of cougars near people (e.g., Treves and Karanth 2003). But, during the last 2 decades, lethal approaches to management of cougars for human safety have precipitated negative public reactions. Not only have public exchanges about cougar management become more common, but cougar mortality and the effectiveness of lethal practices also have been subject to critique by an emerging group of predominantly urban, educated, and female stakeholders (Mattson and Clark 2010). At the same time, traditional stakeholders, who are more often male, hunters, and rural residents, support lethal methods (Mattson and Clark 2010). Cougar managers are, thus, subjected to conflicting demands that, since the 1960s, have arisen from a diversification of stakeholder world views and are linked to urbanization and economic and educational changes (Reading et al. 1994, Rasker and Hansen 2001, Hansen et al. 2002).

Virtually all those who are concerned about cougar management seem to agree that human safety is desirable. They disagree primarily on allocations of responsibility and the role of lethal versus nonlethal methods of control (Mattson and Clark 2010). With stakeholders at odds, better information about factors governing cougar attacks on humans can create a wider range of management options to address conflicting demands. Fitzhugh (1988), Beier (1991), Fitzhugh and Fjelline (1997), and Fitzhugh et al. (2003) pioneered inquiry into factors governing cougar attacks on people to provide managers and the public with improved means of preventing and managing attacks. Beier (1991) and others, including Etling (2001) and Deurbrock and Miller (2001), employed case histories and summary statistics to focus almost exclusively on attacks resulting in physical contact. The body of work unified by E. Lee Fitzhugh and summarized by the Cougar Management Guidelines Working Group ([CMGWG] 2005) focused on judging threat and preventing physical contact during close human encounters with cougars; these studies primarily used deductive reasoning, anecdote, and observations of captive felids to draw conclusions. Fitzhugh et al. (2003) and Coss et al. (2009) provided the most in-depth analyses to date, applying exploratory univariate statistical analyses to 379 and 185 cases, respectively. Their work identified some characteristics of victims that increase risk of attack. These characteristics include the presence of children, being alone, exhibiting prey-like movement, and lacking an aggressive, loud response. For the involved cougars, key factors included being young and in poor condition. Dogs also were identified as a higher risk factor for nearby people because they can trigger cougar aggression.

Our goal for this research was to build on previous investigations in 2 ways: first, by describing a conceptual frame for thinking about risks posed by cougars to humans and potential biases in data used to judge those risks; and, secondly, by adopting a multivariable model-building approach informed by our conceptual frame to analyze a larger sample of close encounters, attacks, and fatalities. Human injury and death are contingent on several transitions in cougar behavior that likely are explained by different human behaviors that are relevant to cougar managers or people involved in close encounters. We structured our analysis according to these transitions and likely explanations. Because data on the total numbers of unproblematic cougar–human encounters are incomplete and attendant details are rarely recorded, the statistical analyses that we report focus on the odds that a close encounter would result in physical contact (an attack), and that an attack would result in human death. Given the uncontrolled nature of field observations used in our analysis, defensible inferences about the effect of a single factor depend on some kind of control for the intervening (e.g., correlated) effects of other factors (Burnham and Anderson 1998). Multivariable statistical models, such as we report here, that were created and evaluated using prior ecological knowledge offer the best prospects for such control and the surest means of judging the relative importance of different factors to human safety.

A conceptual frame

The chain of events leading to human injury or death can be thought of as a series of states and transitions (Figure 1). Transitions are probabilistic (denoted by P), are directly linked to and estimable as log odds ($\ln[P/(1-P)]$), and, according to our conceptualization, consist of the following odds: (1) that a cougar will encounter a person; (2) given an encounter, that the cougar will be aggressive; (3) given aggression, that the cougar will make physical contact with involved people (attack); and, (4) given contact, that the involved person will die. Each transition is followed by an outcome that can be counted and that constitutes data. These data include: (1) number of encounters between cougars and people; (2) number of encounters during which a cougar was aggressive; (3) number of cougar attacks on people (i.e., physical contact); and (4) number of human deaths resulting from cougar attacks. The ratios of subsequent to antecedent counts are a logical basis for estimating probabilities, and factors associated with each transition are a logical basis for explaining outcomes.

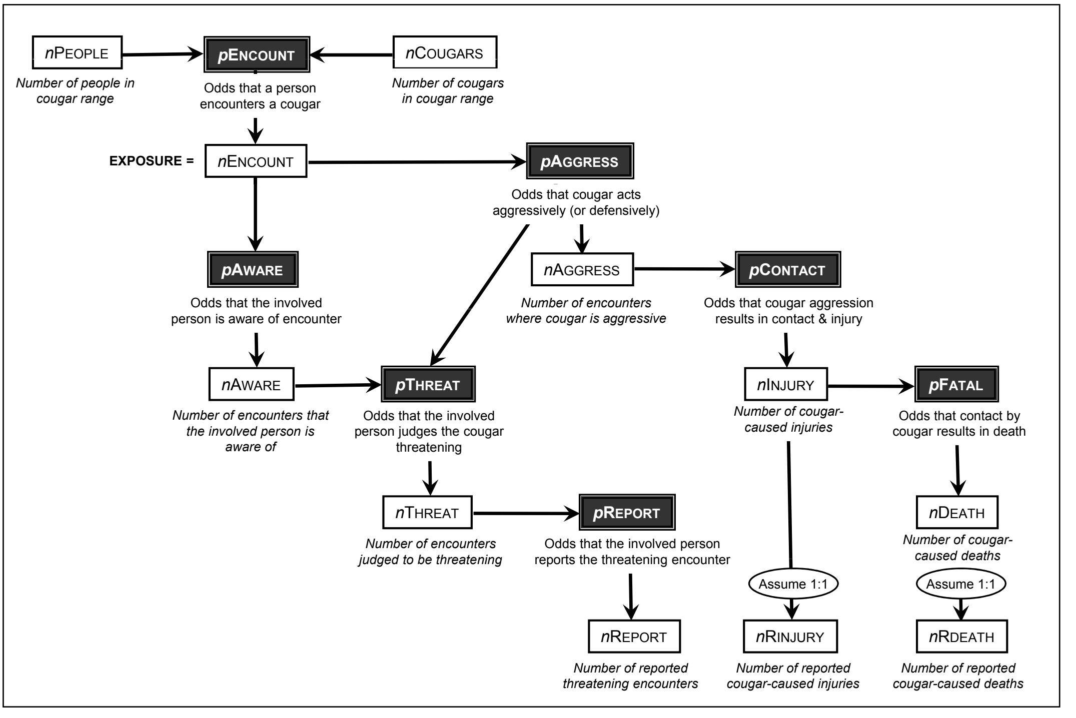

Figure 1. Conceptual frame for analyzing outcomes of cougar–human encounters and for judging prospective data bias. White boxes (with *n* followed by a name) denote outcomes of potential management concern; dark boxes (with *p* followed by a name) denote transitions that are a prospective opportunity for intervention by managers or by people involved in close encounters with cougars.

Each transition and resulting state is associated with different aspects of risk and is likely explained by different factors relevant to human intervention. Numbers of encounters with cougars is analogous to the concept of exposure in risk management (Pritchard 2000), which pertains to the level of contact with a hazard. Per person, exposure is likely governed largely by local cougar densities and the amount of time the person is active in cougar range during times of day when cougars are active (Sweanor et al. 2007). Exposed persons would not include those who are inside a protective vehicle or structure. Exposure is expressed in terms of time and unit area-specific probabilities of a human–cougar encounter. Given exposure, succeeding transitions are likely governed primarily by both the physical characteristics and behaviors of involved cougars and people. Each transition is characterized by diminished prospects of productive intervention by cougar managers as transitions move from aggression, to attack, to death. Wildland managers have the greatest opportunities to affect odds of human injury and death by: (1) managing exposure (e.g., local cougar densities or times and levels of human activity; (2) responding to cougar aggressions that do not result in physical contact; (3) responding to cougar attacks to prevent others; and (4) educating users of cougar range about means of preventing and managing encounters to reduce the odds of physical contact.

Each transition has different definitional and logistical issues that affect conceptual clarity and data bias. With human injury and death as the primary outcomes of concern, an encounter does not happen unless a cougar is aware of a person. Most people are probably not aware of encounters, given the secretive nature of cougars; and official records are probably biased or otherwise unreliable because many encounters go unreported or because people who do report encounters apparently often mistake other species (e.g., bobcats [*Lynx rufus*] and domestic dogs and cats) for cougars (Beier 1991; Figure 1). We do not know of any study where numbers of encounters have been estimated and explained by researchers under controlled circumstances.

Aggression occurs when a cougar, encountering a person, responds in such a way as to increase the odds of physical contact, either as an act of predation or in defense of self, dependent young, or killed prey. Construed in this way, aggression is a continuum along several dimensions of motivation and expression that are difficult to judge even by felid experts, much less by novices (Leyhausen 1979). Some non-contact encounters are very likely reported when the involved people felt threatened but had no reliable knowledge of the aggression actually exhibited by the cougar. Other noncontact encounters might be reported out of curiosity about the animal. In contrast to non-contact encounters, that is, encounters resulting in human injury or death, are typically unambiguous, well-documented, and, at least since the 1960s, comprehensively recorded (Fitzhugh et al. 2003).

Methods

We focused our statistical analysis on explaining transitions from cougar aggression to human injury and from human injury to human death. Because we assumed that almost all injuries and deaths had been documented since at least the 1960s, we interpreted our results regarding odds of death literally and, for the most part, as unbiased (79% of injuries and deaths in our database were post-1959; however, see our discussion of data below). By contrast, we faced considerable conceptual ambiguity and bias affecting data about close but non-contact encounters.

We addressed these problems in several ways. First, we defined cougar behavior as threatening based solely on impressions of the involved people and without passing judgment on levels or types of aggression exhibited by the cougar. We also included only threatening encounters during which a cougar approached to a distance much <50 m (near attack, in the language of Beier [1991]), which increased the likelihood that these encounters did pose a threat to the involved people (Fitzhugh 1988, Halfpenny et al. 1993, Fitzhugh and Fjelline 1997, CMGWG 2005, Sweanor et al. 2005) and that they correctly identified a cougar. Roughly 75% of these close encounters were at estimated distances of ≤5 m (see Results). We further differentiated cases as probable and confirmed, based on considerations that we describe below. We assumed that we documented an unknown but probably only small percentage of all close encounters, which meant that we interpreted our estimated odds as indices biased high. Our emphasis for this transition was on estimating the comparative rather than absolute importance of explanatory factors.

Data

We used data for this analysis only from cases involving wild cougars in the United States and Canada, excluding cases likely attributable to captive or recently captive animals, and going back only to 1890 (as per Beier 1991). Data were obtained from 5 primary sources: (1) official state or provincial records; (2) records compiled by Beier (1991 and personal communication); (3) records compiled by Etling (2001), which encapsulated those of Beier (1991) and Danz (1999); (4) our own searches of newspaper records for all states in cougar range, in part using newspaper archives accessible online through the Access World News, News Bank (<http://infoweb.newsbank.com>), which, depending on the paper, dated back from the mid-1980s to late 1990s); and (5) records compiled by L. Lewis and posted on the Internet (site no longer available). We did not consider the latter to be authoritative, but, nonetheless, we found them informative when subjected to confirmation and critical examination. Records of Etling ended in 2000, and those of Beier in 2003. After 2000, we relied primarily on state and provincial records and our own searches. None of these sources was mutually exclusive.

We judged each record to be either confirmed or probable based on several criteria. A confirmed case was on an official state or provincial list or on the lists of Beier or Etling, without any indication of doubt or equivocation regarding the outcome and involvement of a cougar. Confirmed cases also appeared in original newspaper records, especially those reporting encounters without physical contact and where a state or federal official with appropriate authority (e.g., wildlife manager, police officer) reported that the encounter was authentic. A case was considered probable if it had plausible circumstantial evidence implicating involvement of a cougar, but the authorities registered doubt or equivocation about the authenticity of the encounter.

We built a database that encapsulated all of the information we could glean from written records regarding date, time, location, and circumstances; the nature of involved human victims; victim responses; and the types and numbers of involved cougars. We coded activities of human victims at the time of an encounter according to 11 categories that emerged from our examination of records: playing, running, skiing or snow-shoeing (snow-related), biking, ATV riding, walking, horseback riding, working, hunting, fishing, and at home or camp. We subsequently consolidated these activities into 3 categories that reflected the victim's overall level and nature of movement: active (the first 5 categories); intermediate (the next 5 categories); and sedentary (the final category).

Insofar as victim responses were concerned, we categorized the reaction as aggressive if the victim either made loud noises, tried to appear larger, threw something, or charged or otherwise aggressively approached the involved cougar. We categorized a person as having backed away if they simply backed away or were able to climb a tree or get inside a nearby house or vehicle; we distinguished this from the ran-away category. We also recorded whether an attacked person fought back or not. Finally, we categorized persons as being comparatively passive if all available information suggested that they had not been responsive or did not have a chance to react.

We recorded whether a victim possessed a weapon, fired it, and killed the involved cougar, as 3 different variables. We considered victims to be armed if they possessed a loaded firearm or a bow with an arrow fitted or readily available. We differentiated whether a cougar had been killed during an encounter by the involved people or was killed later by authorities.

We described victims as being children if they were ≤10 years old; teenagers if they were 11 to 19 years old; and adults if they were ≥20 years old. We considered an adult to be present if the adult was the victim or part of a group to which the victim belonged. We considered a group to be ≥2 people who, by all indications, were within distance of ready physical contact of each other. Otherwise, we considered an adult to be nearby if they were within sight or sound of an attack. We also recorded victim age and group size as continuous variables. Considering animals that were part of a group, we recorded whether ≥1 dog was nearby at the time of an encounter or attack.

We also recorded factors related to the involved cougars. Barring instances of missing information, we categorized cougars as young if they had been described as such or were aged as ≤2.5 years old, and adult if otherwise. We categorized cougars as unhealthy if they were underweight (either described as such or by Beier's [1991] criteria) or were described as being either diseased, injured, or healthy. We recorded cougar age, weight, and numbers as continuous variables. Given the incompleteness of written accounts, most records had missing values, especially related to involved cougars and details of victim behavior.

We used information about involved cougars that was from both carcasses and field observations. We included field observations for 3 reasons: (1) only a comparatively small percentage of judgments were based on field observations alone (27% regarding age class, 18% regarding sex, and 9% regarding condition); (2) for the entire sample, judgments about sex and age class based on carcasses did not differ substantially from those based on field judgments (χ_3^2 = 3.4, P = 0.33); and (3) to maximize the otherwise small sample sizes for information about involved cougars (including field judgments on condition [n = 98]; sex [n = 159]; and age class [n = 187]). Because we had comparatively few cases with information about the involved cougar, we specified models, including and excluding cougar-related information. This allowed us to consider cougar-related effects while also taking fuller analytic advantage of cases where little or no information was available about the involved cougars.

Analysis

We analyzed the log odds that a close encounter would result in physical contact (an attack) in 2 ways, using (1) only confirmed cases and (2) both confirmed and probable cases. We reduced odds of mistakenly implicating a cougar (i.e., errors of commission) by using only confirmed cases. In contrast, we implicitly balanced errors of commission and omission, invoking weight of evidence (Smith et al. 2002), when using both confirmed and probable cases.

We always included probable cases in our analysis of odds that physical contact resulted in human death because exclusion of probable cases for this transition likely led to significant bias. Almost all of the probable deaths in our database (6 of 7) involved a lone human victim, which is not surprising. In these instances, there were no witnesses, and human remains were sometimes found only after substantial time elapsed (i.e., weeks to up to 3 years). Overall, the use only of confirmed cases of human injury or death resulted in proportional under-representation of lone victims versus victims in groups (χ_1^2 = 5.3, P = 0.02; 16% of lone victims versus 5% of victims in groups excluded from analysis). To exclude probable cases would have likely led to under-estimating the risks of being alone near cougars.

We used logistic regression and maximum likelihood methods to specify our multivariable models. We selected best models to minimize the sample-size corrected Akaike Information Criterion (AIC_c; Burnham and Anderson 1998) and used the logit transformation ($\ln[P/(1\text{-}P)]$) as our link function. We judged overall model performance by: the score test for the global null hypothesis that $\boldsymbol{\beta}$ = 0; the Hosmer-Lemeshow goodness-of-fit test; the adjusted coefficient of determination (R^2_L); and area under the receiver operating characteristic (ROC) curve (c; Allison 1999, Hosmer and Lemeshow 2000). We used ratios of deviance to degrees of freedom to judge variance inflation. If this ratio was considerably >1, we used the deviance ratio to adjust the covariance matrix, with resulting increases in standard errors and changes to other statistics used for tests (Allison 1999).

We judged the relative importance of explanatory variables in several ways: (1) change in AIC_c (ΔAIC_c) and $-2 \times \ln\mathbf{L}$ (Δ–2lnL) with deletion and replacement of each variable, in turn, from the model that minimized AIC_c; (2) the Akaike weight (w) calculated for models excluding each variable in turn, which can be interpreted as the comparative likelihood of each model given the data (i.e., low values indicate little support for excluding a variable); and (3) probability that β_i (the estimated variable parameter) = 0 by the Wald Chi-square test (Burham and Anderson 1998, Allison 1999, Hosmer and Lemeshow 2000). Because of missing values, each model that we considered tended to be based on different samples and degrees of freedom, and, so, for calculating ΔAIC_c and Δ–2lnL, we fixed the sample at that used to specify the model minimizing AIC_c. Our use of Akaike weights to judge the relative importance of variables was equivalent to considering as many top models as corresponded to the number of variables in our best model, but with each of these additional models missing 1 variable.

We set α = 0.10 rather than 0.05 for rejection of null hypotheses in tests of statistical significance to reduce commission of type II errors, which is conservative relative to management implications. Mistakenly concluding that an effect did not occur, when it did (i.e., committing a type II error), pertaining to some driver of cougar attacks, might cause managers or potential victims to ignore some behavior or management action that could, in fact, reduce risk. It is unlikely that similar risk would arise from committing a type I error.

Given the sparseness of data for human fatalities, we also conducted univariate analyses for each variable that was a candidate for explaining variation in the odds of death given physical contact. Given a globally significant test for rejecting the null hypothesis of homogeneity, we conducted multiple comparisons among proportions of fatalities by variable categories, employing a test based on angular transformations that was analogous to the Tukey test (Zar 1984).

We used simultaneous Bonferroni confidence intervals (Byers et al. 1984) to compare the observed proportional distribution of cougars involved in encounters, by sex-, age-, and condition-class, with a proportional distribution expected by a population of cougars in the San Andres Mountains of New Mexico. This population was unexploited, which may not be representative of cougars throughout the West, but we did have information on the physical condition of trapped animals; such information was important to our comparison. Although we do not know how condition of these animals compared to cougars throughout the West, the San Andres Mountain cougars were more likely to be in poorer condition because this population was naturally regulated for much of the study, and prey abundance was known to be declining (Logan and Sweanor 2001). Logan and

Sweanor (2001) describe methods for capturing and weighing cougars and for estimating their proportions by sex- and age-class.

Results

Our database consisted of 386 cases of which 343 (89%) cases were confirmed. Of these, 29 cases were fatal attacks (of which eight were probable); 171 cases involved non-fatal physical contact attacks (seventeen were probable); and 186 cases involved cougar behavior that was perceived as threatening during a close encounter but did not result in physical contact (eighteen probable). Of the cases involving physical contact by a cougar: 22% were recorded in all three of the first 3 sources given in Methods; 37% were recorded in two of these sources; and 28% were recorded in one. The remaining 14% were based on our primary research. Of the cases not involving physical contact: 4% were recorded in two of the first 3 sources given in Methods; 43% were listed in one of these sources; and 54% were from our primary research, of which 73% dated after 1999. Of the 102 cases without physical contact and where the nearest approach of the cougar was noted, the median nearest distance was 2 m (25th to 75th percentile = 1 to 5 m, rounded to the nearest m).

Annual trends in attacks

Per annum, recorded confirmed, and probable incidents where a wild cougar injured or killed a person were low during the 1900s to the 1940s (0.2 to 0.7/year), reached a minor peak in the 1950s (1.5/year), and trended upward beginning in the 1970s to a major peak in both injuries (5.4/year) and fatalities (0.9/year) in the 1990s (Figure 2A). Viewed as a 3-year running average 1978 to 2008 (Figure 2B), instances of

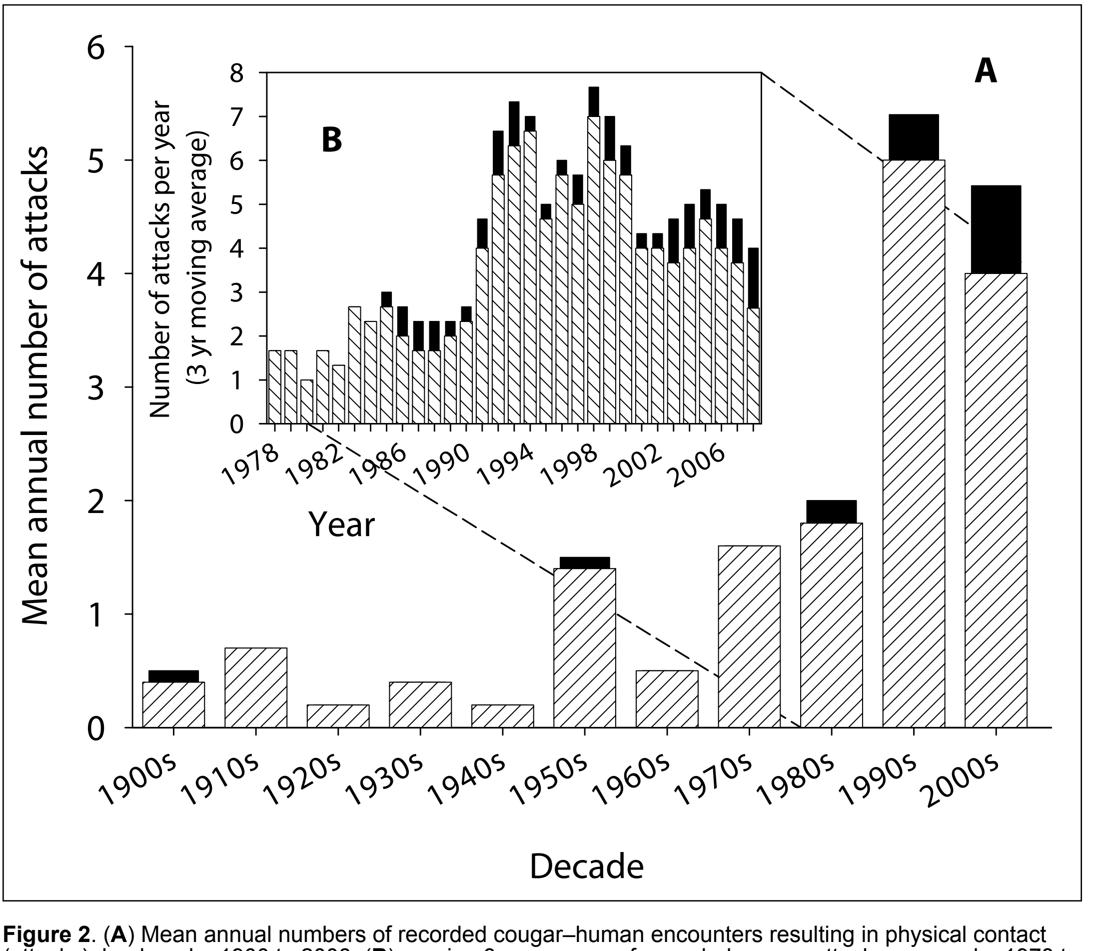

Figure 2. (**A**) Mean annual numbers of recorded cougar–human encounters resulting in physical contact (attacks), by decade, 1900 to 2008; (**B**) running 3-year mean of recorded cougar attacks on people, 1978 to 2008. Hatched bars are for confirmed cases only, whereas narrower black bars include probable cases.

physical contact peaked twice, around 1994 (7.0/year) and 1998 (7.7/year), and dropped, apparently stabilizing at around 4.0 to 5.3 per year since 2000.

Cougars involved in close encounters and attacks

We found 76 cases where the sex, age, and the condition of involved cougars were all recorded. In 70 of these cases, this information was from carcasses, and in the remaining six from field judgments. Of these cougars, young females and young males were proportionately most common (0.37 and 0.34, respectively), whereas healthy adult females and unhealthy adults of both sexes were proportionately least common (0.05 and 0.12, respectively). The proportional distribution of cougars involved in encounters and attacks among 8 sex-, age, and condition-classes was not the same as the proportional distribution observed for an unhunted population of cougars in the San Andres Mountains, New Mexico (n = 294; χ_7^2 = 935.5, P < 0.0001). Proportions differed primarily by (1) more unhealthy young males and females and (2) fewer healthy adults and healthy young females among cougars involved in attacks or close encounters compared to cougars in the San Andres Mountains (Figure 3). The overall sex ratio of involved cougars was 48:52, females to males (n = 161).

Weights estimated for cougars that were involved either in close encounters or attacks (n = 47) were consistent with judgments regarding whether they were healthy or unhealthy and with weights obtained from cougars during the long-term study in the San Andres Mountains, New Mexico. Healthy adult males, young males, adult females, and young females involved in attacks or close encounters were estimated to weigh 62 ± 4 (SE), 45 ± 3, 42 ± 2, and 34 ± 2 kg, respectively, which, with the exception of adult females, were almost identical to weights estimated for these same classes in the San Andres Mountains: 60 ± 0.5, 44 ± 0.6, 33 ± 0.6, and 32 ± 0.6 kg, respectively. Unhealthy adult females, young females, and young males involved in attacks or close encounters were estimated to weigh 27 (n = 1), 24 ± 2, and 27 ± 2 kg, respectively, which (except for young females) were within the parameters for underweight set by Beier (1991): <30, <20, and <30 kg, respectively. We had no weight estimates for unhealthy adult males involved in attacks or close encounters. Controlling for effects of cougar sex-, age-, and condition-class, we found no evidence that weight estimates differed between field judgments and measurments from carcasses (F_1 = 0.2, P = 0.64).

Effects of a weapon

If a person involved in a close encounter with a cougar discharged a weapon and killed the cougar, the encounter self-evidently ended. The cougar did not have options to subsequently exercise in response to the involved person. Of the people involved in a reported close encounter who carried a weapon (n = 71), 78% (± 5 SE) chose to use it. Of those who fired a

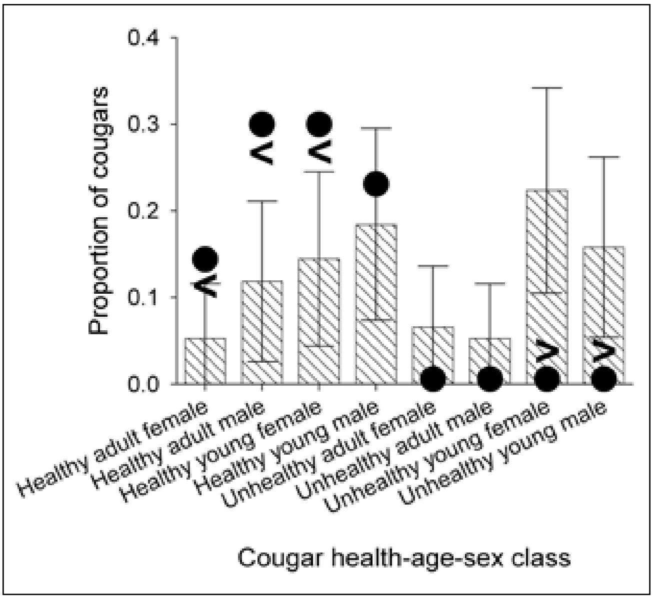

Figure 3. Proportional distribution of cougars involved in attacks or close encounters with people in the United States and Canada, 1890–2008, by sex-, age-, and condition-class, compared to proportions of cougars in each class observed during a long-term study in the San Andres Mountains, New Mexico (Logan and Sweanor 2001). Bars and associated 90% confidence intervals represent proportions of cougars in attacks or close encounters; black dots represent proportions expected by the San Andres population; < represents a class where the observed proportion was less than expected; and > represents a class where the observed proportion was greater than expected.

weapon, 82% ± 5% succeeded in killing the cougar.

Excluding cougars killed after an encounter (typically by some official), the best model for differentiating cougars that were killed during an encounter from those that were not contained a single variable, whether the involved person was sport hunting or not (n = 349; score test χ_1^2 = 62.2, P < 0.0001; R^2_L = 0.220; c = 0.705). The odds index that a cougar was killed during an encounter was 10.8× greater when a hunter was involved versus any other type of person. Hunters were recorded as carrying weapons in 96% ± 3% of cases compared to in 10% ± 2% of cases for all other categories of involved people. Our category of hunters excluded individuals who were hunting cougars for sport; most were hunting other big game.

Juvenile cougars were less commonly among those killed during an encounter (51%) compared to those that were not killed (73%; n = 182, likelihood ratio χ_1^2 = 6, P = 0.02). Of the 147 cougars not killed during an encounter, 66% (n = 97) were killed later, providing reliable information on animals that survived the immediate encounter.

Considering only cases without physical contact, we did not reject the hypothesis that the nearest distance between cougars and people did not vary, depending on whether a weapon was present and used or not ($F_{2,96}$ = 0.24, P = 0.79). In other words, we found no indication that cougars were shot at a distance farther than was recorded for cougars in cases where a weapon was not used, excluding cases where physical contact occurred.

Odds that a close encounter resulted in physical contact

Our best model to explain the indexed log odds that a close encounter resulted in physical contact—excluding cougars killed during the encounter and not considering factors related to the involved cougars—contained 5 explanatory variables (Figure 4):

1. victim reaction (2 classes: was aggressive or backed away or fired a weapon but missed; did not react, either by choice or lack of opportunity);
2. victim group size and composition (3 classes: adult group or lone adult; child with ≥1 adults; child alone or in a group of children);
3. season (2 classes: fall [September to November]; remaining months);
4. whether and where a dog was present (2 classes: dog present on the trail; no dog present or dog present at a camp or residence); and
5. level and nature of victim movement (2 classes: active; intermediate or sedentary).

This result was consistent, regardless of whether probable cases were included or excluded, and statistics for both models indicated excellent performance. Statistics for the model based on all cases were: n = 198; score test χ_7^2 = 65, P < 0.0001; deviance/df = 0.82, df = 26, P = 0.73; Hosmer-Lemeshow test χ_7^2 = 7, P = 0.51; R^2_L = 0.46; c = 0.84. Statistics for the model based on only confirmed cases indicated a somewhat better performing model and were: n = 180; score test χ_6^2 = 67, p < 0.0001; deviance/df = 0.77, df = 21, P = 0.76; Hosmer-Lemeshow test χ_7^2 = 3, P = 0.93; R^2_L = 0.51; c = 0.86.

When we included cougar-related effects, our best model consisted of 5 variables, including variables (1), (3), and (4), whether the involved person was hunting or not, and the sex of the involved cougars (excluding cougars that were killed during the encounter; Figure 4). Classes for variables (1), (3), and (4) differed from above, as follows:

(1) victim reaction (2 classes: was aggressive and retreated or fired a weapon but missed; backed away only or did not react, either by choice or lack of opportunity); (3) season (3 classes: fall; summer [June to August]; remaining months); and (4) whether and where a dog was present (3 classes: dog present on trail; no dog present; dog present at camp or residence).

Statistics for this model also indicated excellent performance: n = 86; score test χ_7^2 = 39, P < 0.0001; deviance/df = 1.089, df = 20, P = 0.35; Hosmer-Lemeshow test χ_8^2 = 6, P = 0.61; R^2_L = 0.67; c = 0.94.

Behavioral reactions, group size and composition, and activity level all provided substantial explanation for variation in indexed odds of an attack, given that the involved cougar survived discharge of a weapon (Table 1). The indexed odds of an attack was 5.4× greater (averaged over all models) for cases where a victim did not have a chance (or did not choose)

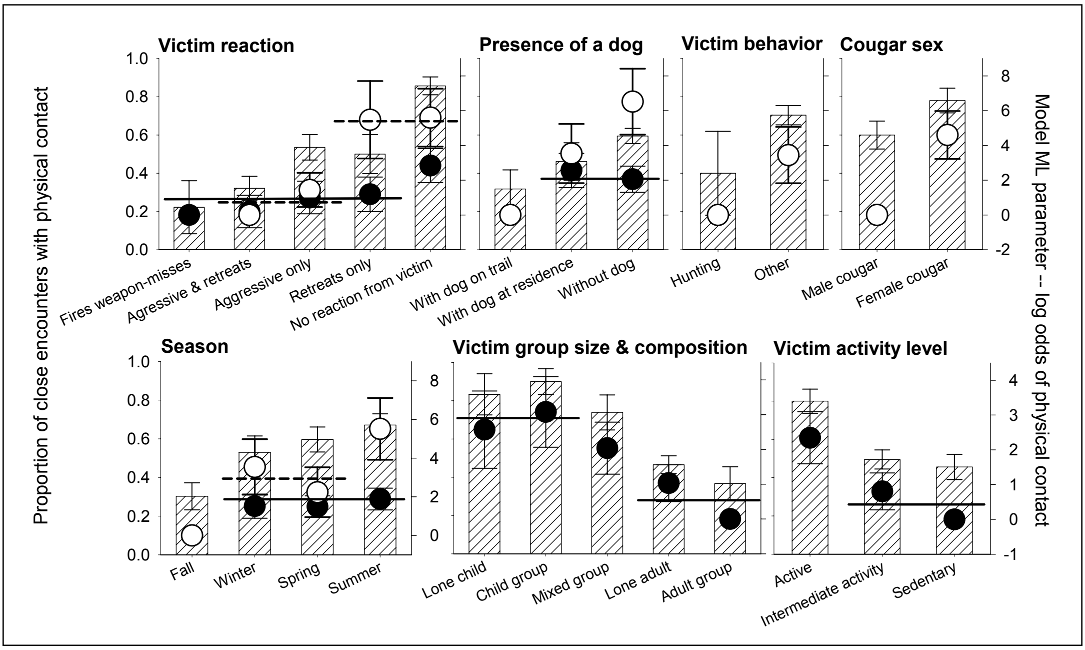

Figure 4. Relations between close cougar–human encounters that resulted in physical contact in the United States and Canada, 1890–2008, and variables included in explanatory models. These results exclude cases where the victim killed a cougar during an encounter. Categories for each variable are shown prior to consolidation on the basis of reductions in AIC_c. Solid horizontal lines indicate variable categories that were subsequently consolidated in the best model when not considering cougar-related effects. Dashed horizontal lines indicate categories that were consolidated in the model including cougar-related effects. Dots and associated SEs indicate modeled parameter estimates for the log odds of physical contact, given a recorded close encounter. Black dots indicate the model including all cases, but excluding cougar effects. White dots indicate the model including cougar effects. Hatched bars and associated SEs are univariate proportions calculated using all cases with information for each respective variable. Relative model parameter and univariate estimates differ because of model control for other modeled effects.

to back away or react aggressively, compared to where the victim engaged in some kind of mitigating behavior. Considering the effect of group size and composition, the indexed odds of attack when a child was present alone or in a group of children was 14.0× greater compared to when the involved people were a group of adults. Even when children were accompanied by an adult, indexed odds of attack were 6.4× greater than that of a group comprised exclusively of adults. Similarly, of 23 cases involving mixed groups of adults and children that were attacked, children were the initial victim in 17 cases (which differed from a 50:50 ratio of children:adults, $\chi_1^2 = 7$, $P = 0.01$); and when there was an adult victim in these cases (whether attacked initially or subsequently), six of seven were female. Finally, of the victim-related effects, people who were engaged in rapid erratic movement or who exhibited intermediate levels of activity at the time of a close encounter experienced 4.8× greater indexed odds of being attacked compared to people involved in more sedentary activity at home or camp.

Of the remaining variables, presence of a dog and season had a consistently strong effect; cougar sex had a strong effect in the model including cougar-related factors; and whether the involved person was hunting or not had a weak effect only in the model that included cougar factors (Table 1). Averaged over models and categories, indexed odds of attack given a close encounter were 2.1× greater for a person either without a dog or in company of a dog around a home or camp compared to a person with a dog on a trail or road. Compared to either when people were unaccompanied by a dog or with a dog on a trail, encounters involving dogs at a residence occurred more often at night (39% versus 8%) and less often during day (11% versus 48%; $\chi_3^2 = 30.0$, $P < 0.0001$). All else being equal, indexed odds of a female cougar attacking during a close encounter were 56.2×

Table 1. Statistical measures of performance for variables in models explaining the indexed log odds that a close encounter between a human and cougar would result in physical contact, for cougar–human encounters in Canada and the United States, 1890–2008. ΔAICc and Δ–2lnL are for changes in model values when the corresponding variable is excluded. Akaike weights indicate relative support for the best model and for models excluding the corresponding variable, considering as many models as there are variables.

	All cases, excluding cougar factors					Confirmed cases, excluding cougar factors					All cases, including cougar factors				
Explanatory variable	ΔAICc	Δ–2lnL	Wald χ^2	*P*	Akaike weight	ΔAICc	Δ–2lnL	Wald χ^2	*P*	Akaike weight	ΔAICc	Δ–2lnL	Wald χ^2	*P*	Akaike weight
(Best model)	0.0	0.0			0.913	0.0	0.0			0.959	0.0	0.0			0.870
Victim reaction	23.9	26.0	19.9	<0.001	<0.001	23.0	23.2	16.8	<0.001	<0.001	17.7	20.0	11.4	0.001	<0.001
Presence and location of a dog	6.3	8.5	6.7	0.009	0.039	10.0	10.2	7.7	0.006	0.006	16.8	21.4	13.1	0.001	<0.001
Season	10.7	12.8	11.3	0.001	0.004	14.5	14.6	12.6	<0.001	0.001	16.3	21.0	12.2	0.002	<0.001
Victim group size and composition	11.1	17.5	14.7	0.002	0.004	15.0	19.3	15.8	<0.001	0.001					
Level and nature of victim activity	6.3	8.4	7.5	0.006	0.040	6.8	6.9	6.5	0.011	0.032					
Victim a hunter versus other											3.8	6.2	5.4	0.020	0.128
Cougar sex											17.3	19.7	11.3	0.001	<0.001

greater than indexed odds of a male attacking. Finally, all else being equal, indexed odds of a cougar attacking during a close encounter were 12.4× less, on average, during fall compared to all other seasons. Fall was associated with a disproportionately large number of close encounters between people and adult female cougars, which comprised 0.36 of cougars in encounters during fall compared to 0.11 during all other seasons (χ_3^2 = 11, P = 0.01). Similarly, adult female cougars comprised 0.41 of cougars involved in close encounters with hunters compared to 0.12 of cougars involved in encounters of all other types (χ_3^2 = 13.4, P = 0.004).

Odds that physical contact resulted in death

Considering all attacks, 14.6% were fatal to the involved person, although death rate varied from 10.9% for adults, to 15.8% for teenagers, to 19.2% for children. Adults, teenagers, and children comprised 51.0%, 9.6%, and 39.4%, respectively, of all people physically contacted by a cougar (i.e., attacked) and 37.9%, 10.3%, and 39.4% of all fatalities. Of the children, 75% were attacked while in a group (≥2 people) of any kind (wholly children or mixed children and adults), which increased to 92% if cases were included where an adult was near enough to intervene.

The best model for the log odds that a cougar attack would result in a human death included the effects of victim group size and composition, as well as the level and nature of victim movement. Reductions in AIC_c supported collapsing variable categories to (1) lone child versus all others and (2) active versus all others. This model performed moderately well: n = 164; score test χ_2^2 = 21, P < 0.0001; deviance/df = 0.18, df = 1, P = 0.67; Hosmer-Lemeshow test χ_1^2 = 0.03, P = 0.87; R^2_L = 0.18; c = 0.71 (Figure 5). The multivariable models that included cougar-related variables tended to be unstable and poorly specified, primarily because of sparse data for certain categories. The best of these models included cougar age class (young versus adult) and level and nature of victim movement (Figure 5) and exhibited modest performance: n = 104; score test χ_2^2 = 15, P = 0.0007; deviance/df = 0.001, df = 1, P = 0.99; Hosmer-Lemeshow test χ_2^2 = 0.0, P = 1; R^2_L = 0.22; c = 0.76.

Considering the single cougar-related effect, victims were 6.4× more likely to die if attacked by an adult than by a young cougar. Adult cougars killed 32% of their victims, whereas young cougars killed only 9% of theirs. This effect was the strongest of any that we considered for explaining odds of human death (Table 2).

Considering victim-related factors, the nature and level of activity at the time of the attack offered a better explanation for variation in odds of death compared to victim group size and composition (Table 2). Victims who were active at the time of attack were more likely to die compared to victims who were sedentary or involved in intermediate levels of activity (28% died compared to 8% for the other activity classes pooled; Figure 5); modeled odds that an active victim would die, given an attack, was 4.0× greater. Considering the characteristics of victim groups, lone children were more likely to die, compared to any other type of victim (50% lone children died, compared to 11% for all other cases). The modeled odds that a lone child would die was 4.6× greater than for victims under any other circumstances. This result included instances where an adult was within sight or sound of the attack. In instances where the victim was a lone child and no adult was nearby four of five died, compared to four of eleven when an adult was nearby. No adult victim who was part of a group of adults or within sight or sound of another adult died from an attack.

Discussion

We interpreted our models of a cougar attack resulting in death of the victim and a close encounter resulting in an attack, differently. The data on cougar-caused injuries and deaths supported strong inference. These phenomena were comparatively unambiguous, and data were likely comprehensive since the 1960s (Fitzhugh et al. 2003). The modeled odds warranted being interpreted literally. By contrast, the odds of physical contact during a close encounter were probably biased high (perhaps very high) and also were affected by bias in coverage of encounters that did not result in injury. This bias arose because our sample of close encounters very likely constituted only a small percentage of the total, whereas our observations of physical contact likely

Table 2. Statistical measures of performance for variables in models explaining the log odds that physical contact between a human and cougar would result in human death, for cougar–human encounters in Canada and the United States, 1890–2008. ΔAICc and Δ–2lnL are for changes in model values when the corresponding variable is excluded. Akaike weights indicate relative support for the best model and for models excluding the corresponding variable, considering as many models as there are variables.

Explanatory variable	All cases, excluding cougar factors					All cases, including cougar factors				
	ΔAICc	Δ–2lnL	Wald χ^2	P	Akaike weight	ΔAICc	Δ–2lnL	Wald χ^2	P	Akaike weight
(Best model)	0.0	0.0			0.825	0.0	0.0			0.859
Victim group size and composition	3.9	6.0	6.3	0.012	0.117					
Level and nature of victim activity	5.3	7.4	7.3	0.007	0.058	3.9	6.0	5.5	0.018	0.120
Cougar age class						7.5	9.5	9.1	0.003	0.021

comprised all of those that occurred during the last 40 years. Without physical contact, a close encounter also suffered from definitional and conceptual ambiguity. We, thus, treated the modeled odds as a biased index of true odds in need of careful interpretation.

However, we were primar-ily interested in determining comparative, rather than absolute, effects of variables in our models. This objective linked closely to management concerns, which focus on key drivers and potential points of intervention. We were most concerned about bias that affected comparative evaluations of explanatory variables that was to some extent contingent on the conceptual and statistical adequacy of our models. We used models to isolate the effects of individual variables through conditioning on the effects of all other variables (i.e., conditional independence; Dawid 1979). As Kyburg (1969) remarked, modeling often is a simple matter of finding the appropriate reference class, i.e., the class that a certain subject is a random member of, relative to our body of knowledge. Residual variation contains the remaining bias, and when residuals are small, the potential effects of bias are lessened (Rosenbaum 1984). We avoided over-fitting, or spurious explanation, by selecting models on the basis of parsimony and conceptual plausibility (Burnham and Anderson 1998). All of the relevant metrics indicate that our models explaining odds of physical contact during a close encounter performed very well and thereby provide a basis for judicious inferences about the relative importance of variables.

Cougar characteristics

Relative to other large carnivores with a history of attacking humans, cougars are among the least lethal. In the recent past, fatality rates for tiger (*Panthera tigris*) and lion (*Panther leo*) attacks have been 78% (Nyhus and Tilson 2004, Chowdery et al. 2008) and 62% (Treves and Naughton-Treves 1999, Packer et al. 2005, Begg et al. 2007), respectively, compared to 15% for our sample of cougar attacks. Even leopard (*Panthera pardus*) and hyena (*Crocuta crocuta*) attacks have had higher recorded fatality rates (32% and 31%, respectively; Treves and Naughton-Treves 1999, Begg et al. 2007). These differences among species may be partly a function of body mass. Maximum sizes for tigers and lions are in the range of 200 to 300 kg, whereas leopards, cougars, and hyenas are typically no larger than 70 to 100 kg (Nowak 1999). This possible effect of predator body mass on human fatality rates is consistent with the greater lethality of adult compared to young cougars (32% versus 8%); however, age-related increases in hunting proficiency undoubtedly explain part of this difference. More to the point, the ratio of predator size to size of human prey is likely a factor in fatality rates. For example, wolves (*Canis lupus*) killed roughly 62% of the children they attacked in India (n = 3 episodes; Rajpurohit 1999) and lions and leopards killed roughly 88% and 74%, respectively, of the women and children they attacked in Africa (Treves and Naughton-Treves 1999). These high rates are consistent with the much higher fatality rate among lone children attacked by cougars (50%) compared to lone adults (13%).

Even though older cougars were more lethal to the humans they attacked, young and unhealthy cougars were much more likely than any other age- or condition-class to be involved in close encounters that threatened the involved people (i.e., close-threatening encounters; Figure 6). This result is consistent with the results and speculations of previous investigators (Beier 1991, CMGWG 2005), but it is based on a larger sample size and on an explicit comparison with conditions expected from the well-studied San Andres, New Mexico, population. Hypothetically, close-threatening encounters would be more common in areas with comparatively high densities of young cougars in poor condition (Løe 2002). This could happen under at least 2 scenarios. (1) There is evidence that densities of young, dispersing cougars are likely to be comparatively high where local densities of resident adults have been depressed by hunting, as long as other nearby and less-heavily exploited areas serve as sources of dispersers (Robinson et al. 2008). Under such a scenario, heavy localized hunting of older cougars could increase rather than reduce exposure of people to close-threatening encounters with cougars. (2) Alternatively, comparatively high densities of nutritionally stressed young cougars could be caused by local shortages of prey. As our results show, however, human injury or death resulting from close encounters with young cougars is

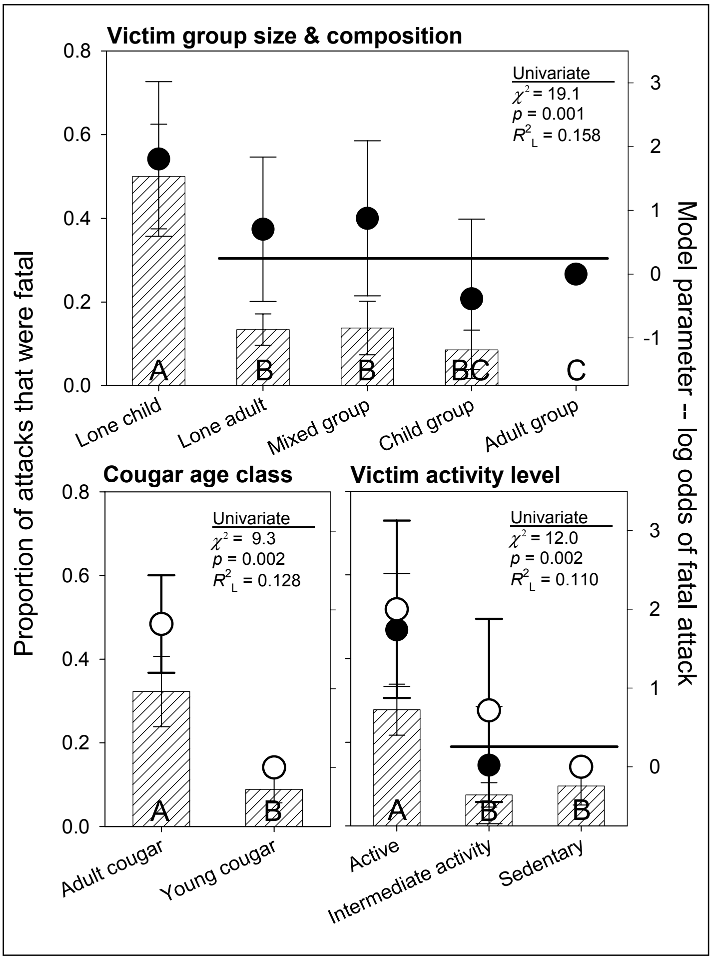

Figure 5. Relations between fatal cougar attacks on humans in the United States and Canada, 1900 to 2008, and variables included in explanatory models. Categories for each variable are shown prior to consolidation on the basis of reductions in AIC_c; horizontal lines indicate variable categories that were subsequently consolidated in the best model. Dots and associated SEs represent modeled parameter estimates for the log odds of death given physical contact (attack). Black dots indicate the model that includes all cases, but excludes cougar effects. White dots indicate the model including cougar effects. Hatched bars and associated SEs are univariate proportions calculated using all cases with information for each respective variable. Univariate denotes results of univariate tests of homogeneity of proportions by categories within variables. Proportions with the same capital letters, within variables, are not different based on multiple comparisons.

likely governed by a number of other factors, including the nature and behaviors of involved people.

Cougars that were young and in poor condition increased the odds that they would be involved in a close-threatening encounter, but of the involved animals, females seemed more likely to attack. We did not expect, nor could we readily explain, this pattern. We posit 3 explanations: (1) female cougars experienced a greater energetic incentive to attack; (2) reproductive females were defending their (often undetected) young; and (3) prey recognition by and prey images of females were broader and more flexible. The first explanation might hold for females with dependent young (Ackerman et al. 1986), which then holds for the second explanation, and is also consistent with the greater tendency of females with cubs to exhibit threat behaviors during close approaches (Sweanor et al. 2005). However, adult (as opposed to young) females were uncommon overall among cougars involved in close encounters. The third explanation is consistent with the more diverse prey of more varied sizes killed by females compared to males in areas such as northern Arizona (Mattson et al. 2007). Moreover, we speculate that competition for food has its greatest impact on females (Logan and Sweanor 2010), which might cause comparatively more females to include humans as prey. This result clearly warrants reexamination in light of more evidence.

Effects of weapons

People with weapons who are involved in close encounters with cougars had a definitive effect on the odds of an attack. Most people who had a weapon used it, and they typically killed the involved cougar, effectively ending an encounter. These results run counter to speculations that people carrying weapons might not have time to use them or, if they did, would not use them effectively. Even so, possession and use of a weapon had no apparent effect on odds of death, given an attack, which is consistent with previous analyses of large carnivore attacks (Løe 2002). The strong

Figure 6. Young cougars, like this one, were more likely to attack, but not kill, people than were cougars of any other age. (*Photo courtesy Brandon Holton, National Park Service, Grand Canyon National Park*)

effect of weapons on odds of an attack begs the question: how many times were weapons used when an attack would not have occurred in any case? Almost all people with weapons involved in close encounters were adults who were less likely to be attacked in the first place.

We have no information that definitively addresses this question of potential overreaction by people with weapons. However, the nearest distance of the cougar to the involved person is relevant. Weapons were used at distances much closer than those of Sweanor et al. (2005) when these researchers deliberately approached cougars and elicited a response from them. People in the cases we examined also did not use weapons at distances appreciably greater than those at which cougars decided whether to attack or not. This critical distance of 1 to 5 m—at which cougars apparently exercised choice—was evident in cases where victims did not have or use weapons. All of this evidence suggests that most people who used weapons were not overreacting to the near approach of a cougar. In any case, having and using a weapon was precautionary from the perspective of human safety, although we do not consider here the intrinsic risks of carrying a loaded weapon.

Given the tendency of people with weapons to use them, it is noteworthy that adult female cougars were disproportionately involved in close encounters with hunters. The greater incidence of close encounters with adult female cougars could have arisen from the unique extent to which hunters were dispersed. Although hunters exhibit an attraction to roads, trails, and camping areas, they, nonetheless, spend more time away from these linear features compared to people under most other circumstances (e.g., Thomas et al. 1976, Millspaugh et al. 2000, Diefenbach et al. 2005). Unlike young and dispersing cougars, adult females tended to be more uniformly distributed and are expected to comprise a greater proportion of independent animals in a cougar population (Logan and Sweanor 2001), which would mean a proportionately greater encounter rate with hunters compared to people distributed exclusively in point or linear concentrations. This speculative explanation is consistent with the increase in proportions of female cougars among hunter kills in Washington, from 42 to 59%, after a shift in hunting methods from dogs to spot-and-stalk, predator calling, and incidental encounters by deer (*Odocoileus heminous*) and elk (*Cervus elaphus*) hunters (Marotello and Beausoliel 2003). Use of hounds probably allowed hunters to exercise greater selectivity by sexing and releasing treed female cougars (Zornes et al. 2006).

Effects of other human behaviors

People involved in even moderate levels of rapid or erratic movement at the time of an encounter not only were more likely to be attacked, but also to die as the result of a cougar attack. This finding is consistent with previous speculations based on case studies and generalized knowledge of feline behavior (e.g., Leyhausen 1979) that rapid transverse movement by a human can trigger instantaneous predatory responses from nearby cougars (Fitzhugh 1988, Beier 1991, Rollins and Spencer 1995, Fitzhugh and Fjelline 1997). By contrast, Coss et al. (2009) suggested that rapid movement decreased odds of severe injury given that an attack was occurring. We do not have any ready explanation for this difference in results.

People who were sedentary seemed to more often interact with cougars whose intent seemed uncertain or exhibited intense curiosity

(Etling 2001, Deurbrock and Miller 2001)—a likely mix of defensive and predatory impulses (Leyhausen 1979). People who reacted to an encounter aggressively or in a deliberate manner were more successful at staving off an attack compared to those who did not. Given the gaps in our data, our definition of human aggression included a number of specific behaviors, including yelling, throwing objects, charging, looming large, and the nonlethal firing of a weapon. But this result is consistent with previous recommendations (Fitzhugh 1988, Beier 1991, Fitzhugh and Fjelline 1997, CMGWG 2005) and with the results of Fitzhugh et al. (2003) and Coss et al. (2009), suggesting that sustained loud noise and other signs of aggression could deter cougar attacks.

There was a predictable effect of activity at the time of a close encounter on subsequent victim responses, with effects, in turn, on odds that a cougar would attack. Active people not only were more likely to deal with an overtly predatory cougar at the onset, but also they were less likely able to respond in a mitigating manner. Among those who did not kill the involved cougar outright, sedentary people more often had a chance to successfully respond by backing away compared to people who were active (in 27% versus 7% of cases, respectively). Similarly, compared to people involved in sedentary activities, unarmed and active people less often had a chance to deter an attack through any kind of reaction (52% versus 16% of cases, for those who were active versus those who were sedentary). Consistent with this interpretation, the only cases where an unarmed and active person was able to stave off a cougar attack were those where they responded quite aggressively (Etling 2001), suggesting that extreme measures were required to countervail against strong predatory responses to prey-like movements.

Effects of age and group size

Given a close encounter, cougars were more likely to attack if children were present and, given the presence of both children and adults, more likely to select children. Attacked children were also more likely to die compared to attacked adults. These results are consistent with those of previous investigators who concluded that, compared to adults, children were at greater risk around cougars (Fitzhugh 1988, Beier 1991, Fitzhugh et al. 2003). This result also was consistent with a broader pattern of relations between predator body mass and selection for children (Løe 2002). Large predators, such as lions and tigers, kill proportionately fewer children, historically—in the range of 5 to 35%—compared to medium-sized predators, such as wolves and leopards, which have historically killed 51 to 52% children—nearly identical to the fraction of children among cougar victims in our sample (52%). Not only might children more often move in ways that excite a predatory response from cougars, but also, compared to human adults, children might be closer to the right size for cougars. We speculate that stature rather than mass is the critical variable. Patterns of predation observed in regions such as northern Arizona, where cougars have access to prey of diverse sizes, suggest that preferred prey are 50 to 130 kg in mass (Mattson et al. 2007), which is closer to the mass of adults than children. By contrast, children 8 to 10 years of age are, on average, closer in height (130 to 140 cm; Centers for Disease Control 2010) to that of adult mule deer (Anderson 1981) and elk calves (Bubenik 1982), which are the preferred prey of cougars throughout much of their North American range (Iriarte et al. 1990).

Children did not gain much protection by being in groups, even when adults were present or nearby. The odds of an attack given a close encounter were not much different when children were alone, in groups, or in the company of adults. This result is consistent with previous observations by Fitzhugh (1988), Kadesky et al. (1998), Fitzhugh et al. (2003), and Coss et al. (2009). Predatory cougars might not be deterred by the presence of adults or by group size because cougars routinely prey on social animals, often selecting among groups for smaller individuals, such as calves. Nonetheless, the presence of other people reduced odds of death for children who were attacked. Interventions, especially by nearby adults, clearly saved a number of people (Etling 2001) and, in the case of children, apparently halved the fatality rate. No adult in the company of other adults died from an attack.

Effects of a dog

Our results suggested that the presence of a dog did not increase the odds of a cougar attacking a nearby person, at least during daylight when dogs and people were out walking. Given a close encounter, odds of an attack were less when a dog was present compared to when it was not. The exception to this general pattern pertained to dogs at night near a residence or camp. Under these circumstances, the odds of an attack were nearly as great as for people unaccompanied by a dog. An explanation for the discrepancy between results for dogs on trails and dogs at residences plausibly relates to the motivation of involved cougars. Evidence from individual cases suggests that a residence scenario involved a person intervening to defend a dog from overt predation, which is consistent with a peak in predatory activity by cougars during dusk and night (Beier et al. 1995, Anderson and Lindzey 2003, Mattson et al. 2007, Sweanor et al. 2007). These results support recommendations to secure dogs at night, but do not support recommendations to exclude dogs from trails as a means of increasing human safety.

Effects of season

The effect of season on modeled odds of a cougar attack during a close encounter is probably the most likely of any effect to have resulted from sampling bias. The effect of season persisted even when controlling for other factors that might be correlated with season, including size and composition of the involved human groups, whether the involved people were hunting or not, and characteristics of the involved cougars. It may be that people were more likely to report close-threatening encounters that did not result in an attack during the fall, especially compared to during the summer. The small effect of whether a victim was hunting or not, which was evident when controlling for cougar-related factors, could also have been an artifact of hunters more often reporting encounters, compared to people engaged in other types of activities. This is another effect that warrants reexamination with more evidence.

Numbers of attacks and deaths

Probably the most important result of our investigations was the comparative rareness of deadly cougar attacks. In recent decades cougars accounted for around one, on average, of the roughly 150 animal-caused deaths in the United States every year, most of which were caused by domesticated animals (Langley and Morrow 1997). Even though attacks increased from 1 to 3/year during the 1970s and 1980s to 4 to 8/year during the 1990s, attacks have since dropped. The major increase in recorded attacks between 1990 and 1994 was probably real given that data collection was relatively consistent and comprehensive during this period. However, the greater number of attacks recorded during the 1970s and 1980s compared to earlier decades, especially pre-1950, could have been largely an artifact of less-intensive record keeping and fewer accessible records for 1890 to 1950.

Large carnivores, especially in Asia and Africa, have killed, and continue to kill, many more people than cougars have killed. Tigers in India killed a minimum of 150 to 1,300 people per year between 1930 and 1960 (Løe 2002), and lions in Tanzania killed >870 people during 1990 to 2005 (Packer et al. 2005). At the scale of regions, leopards killed 158 people during 1987 to 2000 in Pauri Garwhal, India (Goyal 2001); in the Sundarbans, tigers attacked 249 people during 1999 to 2001 in India, and in Bangladesh tigers killed 401 people during 1977 to 2001 (Reza at al. 2002, Azad et al. 2005). Similarly, a population of roughly 250 lions in the Gir Forest of India attacked >14 people and killed >2 people per year during 1978 to 1991 (Saberwal et al. 1994). Wolves from roughly 5 packs in Hazaribagh, India, attacked 122 children during 1980 to 1986 and 80 children during 1993 to 1995 (Rajpurohit 1999). By comparison, wild cougars have killed only 21 to 29 people during the nearly last 120 years in the United States and Canada, despite an extensive range that overlaps with millions of people (Halfpenny et al. 1993, George and Crooks 2006, Arundel et al. 2007, Sweanor et al. 2007).

We find it difficult to explain why cougars attacked so few people despite almost certainly having many opportunities (Halfpenny et al. 1993, Sweanor et al. 2007). As we noted above, people are optimal size for cougar prey, whether adults, by mass, or children, by stature. Some explanation for lack of attacks may stem from the daytime partitioning of human (day) and cougar (night) activity (Sweanor et al. 2007). Yet, night-active predators, such as leopards, have killed many people in Africa and Asia (Treves and Naughton-Treves 1999, Goyal 2001). As others have speculated (Fitzhugh 1988, Kruuk 2002), learning among cougars likely plays a substantial role in determining whether humans are considered prey. Seidensticker and McDougal (1993) observed that bipedal humans do not exhibit the transverse posture of most ungulate prey, which also means that the nape of the neck—the natural point of attack for most felids (Leyhausen 1979)—is not in the right place.

Studies of other large predators show that man-eating is often attributable to individuals, prides, or packs that have learned to consider people prey, with resulting localized outbreaks of attacks (McDougal 1987, Daniel 1996, Rajpurohit 1999, Yamazaki and Bwalya 1999, Peterhans and Gnoske 2001, Kruuk 2002, Begg et al. 2007). However, traditions of felids attacking people can persist for decades, such as in the Sundarbans of India and Bangladesh (Sanyal 1987, Reza et al. 2002), and in coastal regions of Tanzania (Packer et al. 2005). Persistence of learned behaviors could also explain differences between widespread attacks on humans by wolves in Asia and eastern Europe (Kruuk 2002, Graves 2007) and rare wolf attacks on people in North America (McNay 2002). These behaviors of other species elsewhere in the world serve as a cautionary tale and may partly explain the high concentration of cougar attacks on Vancouver Island, British Columbia (Kruuk 2002), where 27% of confirmed attacks and 24% of confirmed human deaths have occurred in <1% of cougar range.

Other potential explanations invoke genetics. Compared to large felids of Africa and Asia, those of the Western Hemisphere are perhaps not as likely to treat humans as prey because of shorter evolutionary exposure to our species. Alternatively, cougars that prey on people could have been subject to negative directional selection, especially since European settlement, but also perhaps for the entire 13 to 14 millennia that relatively well-armed humans have been in the Americas (Kelly and Todd 1988, Kay 1994, Frison 1998).

Management implications

Based on the weight of the evidence, our analysis supports the following management implications.

- Young cougars in poor condition are more likely than other cougars to threaten people. However, the resulting close threatening encounters do not often result in human injury and death. By contrast, adult cougars are less likely to threaten people, but are more likely to cause death when they do attack.
- Repeat encounters involving young cougars in poor condition can allow for management intervention. The much rarer attacks by adult cougars are a classic low-frequency, high-consequence event that is difficult to anticipate and prevent.
- Possession and use of firearms by people involved in close (<5m) encounters with cougars is precautionary and effective at preventing physical contact.
- Cougar attacks and resulting human deaths are more likely if a child is present during a close encounter or if the victim is moving rapidly or erratically.
- The presence of adults does not appreciably lessen the odds of a cougar attacking a child, but adult intervention reduces the odds that an attacked child will die.
- Aggressive behavior (yelling, throwing objects, charging, looming large, discharging a weapon) by people involved in close encounters lessens the odds that the involved cougars will attack.
- The presence of dogs during daylight hours reduces the odds of a cougar attacking a person. On the other hand, the presence of a dog outside of a residence at night increases odds of human injury, largely as a result of the involved people intervening to deter cougars attacking dogs.

Acknowledgments

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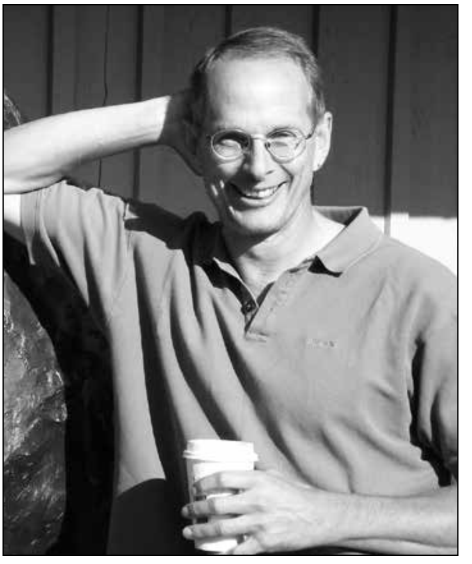

David Mattson received advanced degrees in plant and wildlife ecology from the University of Idaho in 1985 and 2000. For the last 32 years, he has studied large carnivores, including grizzly bears in the Yellowstone region and cougars in 6 different study areas in southern Utah, northern Arizona, and southeastern Nevada. His research interests include not only all facets of the ecology of these large carnivores, but also the social, psychological, and organizational aspects of their management. His interest in and teaching about natural resources policy has led to appointments with the Yale School of Forestry and Environmental Studies (continuing) and the MIT Environmental Policy and Planning Group (2007-2008). He is currently station leader and research wildlife biologist with the U.S. Geological Survey, Southwest Biological Science Center.

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