March 13, 2025

Senator Alvarado-Gil
4364 Town Center Blvd, Suite 313
El Dorado Hills, CA 95762

RE: Opposition to SB 818 enabling the hazing of lions with hounds in El Dorado County

SB 818 is based on the false assumptions that lion population and behavior has changed in El Dorado County and that hazing lions with hounds is a solution. This letter explains my opposition to SB 818.

There is no conclusive evidence that lion behavior has changed because of an overpopulation of lions, California Department of Fish and Wildlife (CDFW) policies, or because lions are less fearful of humans. There are other reasons that explain lion behavior in El Dorado County:

1. An increase in the number of domestic and small herd animals, attracting lions.
2. The 2011 Caldor fire displaced lions.
3. Lions have been killed through depredation permits, upsetting their social order.
4. Deer reside closer to human habitations, attracting lions.
5. The proliferation of security cameras has increased the sightings of lions.
6. Media coverage and social media has fanned a local hysteria regarding lions.
7. Deer population numbers and migration patterns have changed, affecting lions.

SB 818 may have significant unintended consequences because there is no scientific basis justifying hound hazing in El Dorado County. A lion chased or killed in an area will be replaced by a young lion looking for territory. Young lions are more likely to prey on domestic animals and potentially encounter humans. The unintended consequence of SB 818 is to jeopardize public safety rather than protect it.

SB 818 has a number of flaws, including that it is an attempt to get a “foot in the door” to manage (hunt) lions and not a legitimate public safety effort. There are other scientifically proven methods to deter lions that do not threaten public safety or the lions.

Further details are on the following pages and attachments.

Thank you for your time,

Roger Trout, Retired
El Dorado County Planning Director (2008 – 2018)
El Dorado County Planner (1990 – 2008)
UC Davis BS Environmental Planning and Management (1986)

Reasons that explain lion behavior in El Dorado County:

(1) Increase in small herd animals: The increase in number of animals is validated by the El Dorado County Agricultural Commission annual crop report. The crop report shows a significant increase in small herd animal valuations from $1.88 million in 2012 to $4 million in 2023. The Agricultural Commissioner stated at the October 8, 2024 County Board of Supervisors meeting that the valuation change was due to a change in valuation methodology. However, the response did not clarify whether there was an increase in animals.

The increase in domestic animals is validated by the fact that they are commonly raised as 4H projects, used for vegetation management, and simply raised as pets by many residents of the foothills. Small herd animals are very useful to create and maintain defensible space in El Dorado County foothill terrain. However, the animals are often left out at night or do not have adequate nighttime enclosures. Small herd animals that are not protected at night are subject to lion predation. The increase in domestic animals combined with poor husbandry practices results in increased predation by lions.

Rarely are non-lethal lion deterrents used. Members of the public, including local officials, have stated that the non-lethal deterrents do not work. However, scientific research has proven otherwise. See Attachment 1: "Summary Report of Mountain Lion Hazing/Deterrent Devices Testing aimed at Reducing Livestock Predation and Associate Mountain Lion Depredation Permits." UC Davis, 2023, Winters, VanVuren and Vickers.

Although that study was conducted in Southern California, there is a study currently underway to test non-lethal deterrents in the foothills: Sierra Nevada Foothills Mountain Lion Study, Julie K. Young, Utah State University.

(2) Caldor fire: Lion behavior has changed because they were displaced by the 2021 Caldor fire that burned over 220,000 acres in El Dorado County. A study of lions tracked after the 2018 Woolsey fire found that lions avoided the burn scarred area even though their primary prey, deer, had returned. It was concluded that the lions lacked the vegetation cover they use to stalk and ambush prey. See Attachment 2: "Lions and Wildfire," Current Biology, Volume 32, Issue 21, 7 November 2022, Pages 4762-4768.e5: Rachel V. Blakey, Jeff A. Sikich, Daniel T. Blumstein, Seth P.D. Riley.

Lions have moved to the lower elevations of El Dorado County because of the Caldor fire. Although it has been years since the fire and deer have returned to the burn area, lions have not. Lions displaced by the fire have not returned to their old habitats because there is not vegetative cover for them to stalk prey. El Dorado County has had two additional fires: the

Crozier fire, August 6, 2024, 1,960 acres; and the Mosquito fire, September 6, 2024, 76,788 acres. These fires cause more lions to lower, more populated, elevations of El Dorado County.

(3) Lions killed: The issuance of depredation permits by CDFW and resultant lion kills upset the natural social order of lions. Young lions avoid areas occupied by adult male lions and are more likely to approach rural communities. The young lions are usually the ones that prey upon domestic animals and are then subject to depredation permits. Lions that are killed with depredation permits are replaced by other lions. El Dorado County has one of the highest numbers of reported lions killed by depredation permit in the State. Over time, this has resulted in an unnatural population dynamic of lions, with unknown consequences to public safety. See Attachment 3: "Factors Governing Risk of Cougar Attacks on Humans." Mattson, Logan, Sweaner, 2011.

(4) Deer living near homes: Lions have been moving closer to human residences because of the vegetation planted by humans for landscaping and gardens. Deer fencing is a necessity in rural areas of El Dorado County. Even the commercial vineyards require deer fencing because of the presence of deer. Regrettably, there are many residents who routinely feed deer, regardless of the legality. The rural development pattern of El Dorado County is conducive to deer because of the large acreage of many rural homesteads that provide deer both forage and cover. Lions follow their prey into these same areas. Lions are getting accustomed to human activity because they are in close proximity.

Residents that have dogs, cats, sheep, and/or goats often allow them to roam free. These animals are potential prey for lions. The El Dorado County Agricultural Commissioner has tracked an increase in reported predation and concluded that lion behavior and/or high lion population was to blame. That conclusion is not substantiated. Predation of small animals is unlikely the result of one factor, but more likely a combination of causes: 1) the dislocation of lions due to the Caldor Fire; 2) increased population of small herd animals without protection; 3) increased reporting of depredations due to media coverage; 4) proximity of deer near human residences; and 5) the land use pattern in El Dorado County.

(5) Cameras: The perception that lion population has increased and lion behavior has changed is compounded by the common use of security cameras. Lions that were previously unseen are now captured on cameras. These cameras were not very availble in the past. Sightings of lions are almost exclusively at night and in fairly remote or otherwise quiet areas. The fact that a lion can travel miles each night results in many people reporting sightings of the same lion. Most lion sightings are on these cameras and not a result of face-to-face contact.

(6) Media coverage: The tragic death of one man in El Dorado County on March 23, 2024 received significant attention and created a heightened awareness of lion activity. El Dorado County responded with an informational report presented at their July 16, 2024 Board of Supervisors meeting. A subsequent meeting on October 8, 2024 concluded with a letter of concerns addressed to CDFW. Community interest and social media discussions persist and result in increased lion sighting being reported. By comparison, the 1994 death of Barbara Barsalou Shoener on a running trail in Auburn Lake Trails did not generate the same community and media response.

(7) Deer Population: The status of the deer population in El Dorado County is not known. CDFW states that the population is stable, but they provided no supporting data. Anecdotal information indicates that some areas of the County have many deer, while others do not. Long time residents state that the migratory deer are decreasing, although resident deer may be increasing. Lion behavior would change if the deer population numbers, location, and migratory patterns change.

Unintended consequences of SB 818:

The unintended consequence of SB 818 is to change lion behavior in an unnatural way resulting in lions relocating to more populated areas of El Dorado County and increasing the risk to humans.

Young lions are most likely to venture into human territory because of lion social dynamics. The larger, older male lions claim a large territory and they defend it from younger lions. Young lions are forced to avoid older male lions and, as a result, are more likely to prey on domestic animals and encounter humans than older lions. Hazing of lions would upset the social dynamic and further cause younger lions to approach populated areas. Young lions are then more likely to prey on domestic animals and potentially meet humans.

SB 818 is flawed and not a legitimate public safety effort:

The justification for a pilot program using hounds to haze lions is nebulous at best. Hazing lions with hounds will not change their behavior. A recent study has firmly concluded that hazing with hounds is not effective**.** See Attachment 4: "Response of Mountain Lions to Hazing: Does Exposure to Dogs Result in Displacement?" (UC Davis, 2024)**.**

Hazing will also clearly not be effective if a lion has already learned to prey on small herd animals or has become accustomed to human activity.

Non-lethal deterrents are available and used in other areas of the State, such as Mendocino County, where there is similar lion populations and behaviors. CDFW officials have consistently recommended non-lethal deterrents as a first step at protecting domestic animals before issuance of a depredation permit.

SB 818 uses flawed logic to justify hazing lions with hounds. SB 818 states that during five years following the 1990 Wildlife Protection Act (Prop. 117), conflicts with lions "dramatically escalated, including two human fatalities." The two human fatalities were in 1994: Barbara Shoener in Auburn Lake Trails and Iris Kenna in Cuyamaca State Park, near San Diego. If the purpose of SB 818 is to protect humans, then the solution would not be to haze lions with hounds, but to avoid traveling alone in lion country and/or be prepared for the rare situation of meeting a lion.

Finally, the issue of lions is not new or unique to El Dorado County. Similar stories abound throughout California. One such case is documented in a UC Davis Online Magazine article describing the fatality in Cuyamaca and the subsequent steps taken to study the situation and provide scientific information to managers for the welfare of both humans and lions. See Attachment 5: UC Davis Magazine, "In Lion Country" by Sylvia Wright.

Attachments:

1. "Summary Report of Mountain Lion Hazing/Deterrent Devices Testing aimed at Reducing Livestock Predation and Associate Mountain Lion Depredation Permits." UC Davis, 2023, Winters, VanVuren and Vickers.
2. "Lions and Wildfire," Current Biology, Volume 32, Issue 21, 7 November 2022, Pages 4762-4768.e5: Rachel V. Blakey, Jeff A. Sikich, Daniel T. Blumstein, Seth P.D. Riley.
3. "Factors Governing Risk of Cougar Attacks on Humans." Mattson, Logan, Sweaner, 2011.
4. "Response of Mountain Lions to Hazing: Does Exposure to Dogs Result in Displacement?" Sierra Y. Winter and Dirk H. Van Vuren Department of Wildlife, Fish, and Conservation, University of California, Davis, California T. Winston Vickers Wildlife Health Center, University of California, Davis, California Justin A. Dellinger Large Carnivore Section, Wyoming Game and Fish Department, Lander, Wyoming 2024.
5. "In Lion Country." UC Davis Magazine. Sylvia Wright.

ATTACHMENT 1

Current Biology

Report

Mountain lions avoid burned areas and increase risky behavior after wildfire in a fragmented urban landscape

Highlights

- After the wildfire, mountain lions avoided burned areas and increased risky behavior
- Post-fire risky behavior included increased road crossings and daytime activity
- Altered movement and space use post-fire increased risk of intraspecific conflict
- Risky behavior may increase mortality risk for animals in urban fire-prone regions

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In brief

When wildfires and urbanization coincide, animals trade off risks of burned landscapes with those of anthropogenic environments. Blakey et al. find that after an exceptionally large wildfire in an urbanized region, mountain lions avoided burned areas and increased activities that elevated their risk of negative interactions with humans and conspecifics.

Blakey et al., 2022, Current Biology *32*, 4762–4768

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Current Biology

Report

Mountain lions avoid burned areas and increase risky behavior after wildfire in a fragmented urban landscape

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SUMMARY

Urban environments are high risk areas for large carnivores, where anthropogenic disturbances can reduce fitness and increase mortality risk.[1] When catastrophic events like large wildfires occur, trade-offs between acquiring resources and avoiding risks of the urban environment are intensified. This landscape context could lead to an increase in risk-taking behavior by carnivores if burned areas do not allow them to meet their energetic needs, potentially leading to human-wildlife conflict.[2,3] We studied mountain lion behavior using GPS location and accelerometer data from 17 individuals tracked before and after a large wildfire (the 2018 Woolsey Fire) within a highly urbanized area (Los Angeles, California, USA). After the wildfire, mountain lions avoided burned areas and increased behaviors associated with anthropogenic risk, including more frequent road and freeway crossings (mean crossings increased from 3 to 5 per month) and greater activity during the daytime (means from increased 10% to 16% of daytime active), a time when they are most likely to encounter humans. Mountain lions also increased their amount of space used, distance traveled (mean distances increased from 250 to 390 km per month), and intrasexual overlap, potentially putting them at risk of intraspecific conflict. Joint pressures from urbanization and severe wildfire, alongside resulting risk-taking, could thus increase mortality and extinction risk for populations already suffering from low genetic diversity, necessitating increased connectivity in fire-prone areas.

RESULTS

Direct effects of wildfire on mountain lions

Direct and immediate effects of wildfire on mountain lions can include injury and mortality. Of the 11 individual mountain lions being tracked at the time of the Woolsey Fire that had the potential to be affected by it, two died or were presumed to have died during or soon after the fire.

Do mountain lions avoid burned areas after a large wildfire?

At the population level, mountain lions avoided burned areas after the wildfire (Figures 1 and 2) and no individual animal showed significant selection for them. Males avoided burned areas more than females, as indicated by their generally larger and more negative effect sizes (Figure 1). Proportions of locations within burned areas compared before and after the fire showed the same trend as selection analyses (Table S1), specifically, much lower proportions of locations in burned areas post-fire. Excluding the two males that had less than 10% of their pre-fire locations within the burn perimeter (P56 and P61, Table S1), all 3 males showed strong and significant avoidance (effect size −0.63 to −1.45). The response of females to the fire was more variable (Figure 1). The post-fire burned area use that did occur was concentrated (61%) in the patchily burned region in the southeast corner of the outer burn perimeter, and within the Simi Hills (north of the US-101 freeway) where the majority of the landscape (66%) burned (Figure 2).

Do mountain lions increase behaviors that put them at anthropogenic risk after a large wildfire?

While there was support for mountain lions increasing use of urban areas after the wildfire, the magnitude of this increase was negligible (Figure 3A). The probability of urban use was low before the fire (∼4.3%), and while this increased after the fire, it remained low (∼5.4%); this 1% change was much lower than

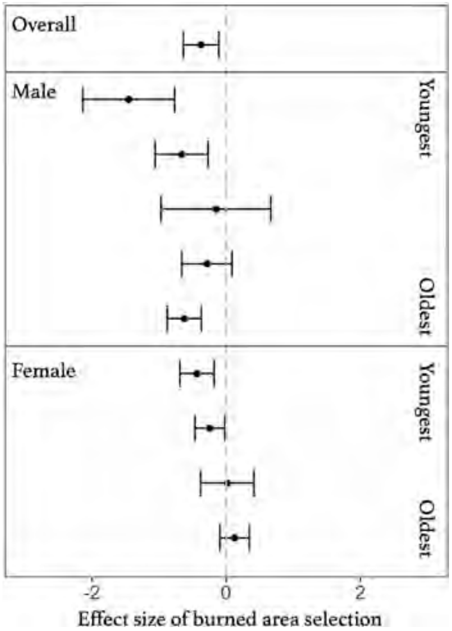

Figure 1. Results of resource selection analysis for burned areas after the fire by the 9 individual mountain lions who were tracked both before and after the fire

The two individuals assumed to have perished during or soon after the fire were excluded. Each point shows the effect size comparing selection for burned areas before and after the fire using step selection functions, for each individual mountain lion. The overall effect size was calculated using a meta-analytic approach and all error bars show 95% confidence intervals. Negative effect sizes indicate selection against burned areas while positive effect sizes indicate selection for burned areas following fire.
See also Table S1.

the range of variability in proportion of urban use by mountain lions across the population (0%–15%) (Table S2). Regardless of fire, mountain lions used urban areas rarely (mean for study animals was 5% of the time, including time periods before and after the fire) and use of urban areas was variable among individuals ranging from one female who used urban areas less than 1% of the time to two females who used urban areas > 10% of the time. All sex and age classes were variable in urban area use.

Consistent with our predictions, mountain lions tended to increase road crossings after the wildfire, with the fitted relationship indicating an increase from ~3 crossings per month before the fire to ~5 crossings per month 15 months after the fire (Figure 3B). Mountain lions also increased their daytime activity after the fire from 10% of the day to 16% of the day, although the continuous response model indicated a potential slight increase prior to the wildfire event (Figure 3C). Our analysis pooled all major road crossings (major roads shown in Figure 4), though mortality risk (both perceived and actual) is likely to vary with the size and traffic volume of roads. California has the busiest roads in the USA and the busiest interstate in any USA city runs through our study area (I-405).[4] The first successful crossing of the I-405 freeway over the 16 years of the broader study was recorded in the months after the fire; comparing crossing frequencies of the busy US-101 freeway, we observed roughly one crossing every 2 years before the fire, compared to one crossing every 4 months after the fire.

Do mountain lions increase behaviors that could increase the risk of conflict with conspecifics after a large wildfire?

Mountain lions increased both their distance traveled and the amount of space used after the fire (Figures 3D and 3E). Distance travelled increased from ~250 ± 48 (predicted 95 % confidence interval [CI]) km per month to ~ 390 ± 48 km per month, a more than 50% increase from pre-fire distances. Although adult males either decreased or retained similar amount of space used after the fire, subadult males and all females, the groups most at risk in intraspecific encounters, increased their amount of space used by ~15%–24%. Results of the age-sex class analyses should be interpreted cautiously due to the low number of individuals per class and wide confidence intervals (Figure 3E and Table S3).

Where analyzed, trends towards increases in spatial overlap in mountain lion landscape use after the fire did not perform better than the null model (Table S4), potentially due to the relatively low sample size and the confounding factor of two males perishing in the fire and an additional three males perishing of anticoagulant rodenticide poisoning and vehicular collision during the 15 months post-fire. However, we saw a trend towards an increase in spatial overlap after the fire between the dominant male and other males in the study area after the fire (Figure 4). Additionally, mean observed overlap was greater for all age-sex classes after the fire across all iterations of the model validation expressed as a proportion of male and female home ranges, though this difference was negligible for male-female overlap (Figure S1). Specifically, important components of intrasexual overlap in this territorial species more than doubled: overlap of the dominant male on other males increased from 10% to 23% post-fire (Figure 4C) and overlap between females increased from 7% to 18% post-fire (Figure S1).

DISCUSSION

In an urban landscape after the wildfire, we found support for the prediction that mountain lions avoided burned areas post-fire, and increased behavior that could expose them to risk. Changes in behavior by mountain lions post-fire are likely due to a complex trade-off balancing the necessity to acquire food and breed, while avoiding conspecific conflict and encounters with humans in a transformed and fragmented landscape. These kinds of trade-offs between anthropogenic disturbances and other major disturbance events are an increasing reality for carnivores persisting in human-dominated landscapes worldwide.[5–7]

Carnivores have varying responses to fire, and this is likely to be strongly influenced by how fire changes the structure of vegetation, and with it, the ability to capture prey.[8,9] In the case of cursorial carnivores, such as wolves and coyotes, fire may increase their abilities to capture prey.[10,11] Whereas ambush predators such as mountain lions, lynx, and African lions may require more heterogeneity, including retained vegetation cover, in post-fire landscapes in order to successfully stalk prey.[12–15] The mountain lions in our study mostly avoided burned areas in the 15 months after the fire. This contrasted with studies that indicate opportunistic use of burned landscapes by carnivores,[7,16,17] but was consistent with Eby et al., [13] who found that despite abundant prey in burned areas, African lions (*Panthera leo*) avoided the burned landscape, likely due to reduced

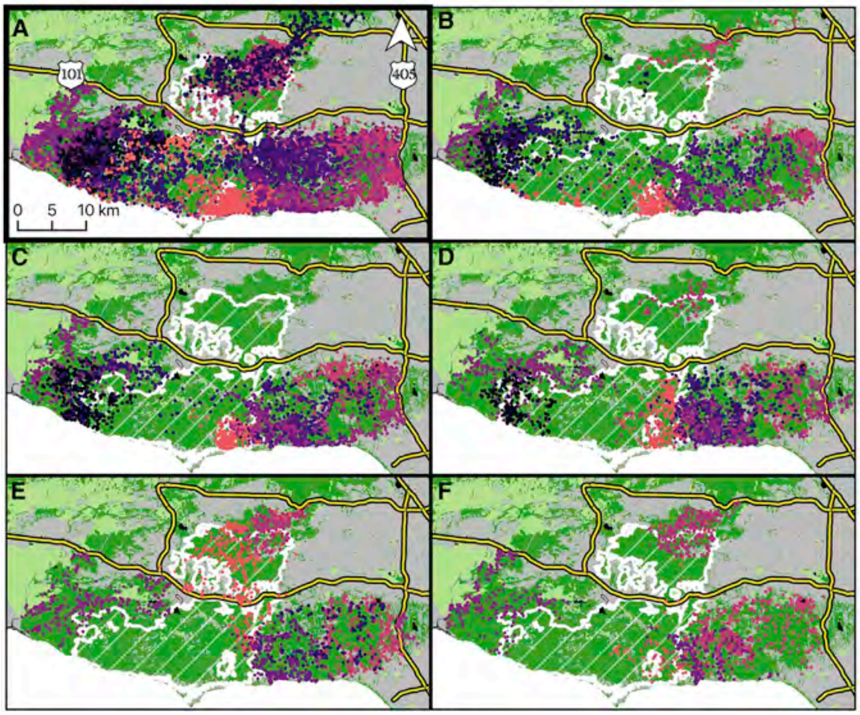

Figure 2. Study area within the Los Angeles and Ventura County areas of California, USA, showing locations of 17 individual mountain lions in periods before and after the 2018 Woolsey Fire

The study area includes the Santa Monica Mountains (south of the 101 freeway) and Simi Hills (north of the 101 freeway).

(A–F) Locations of 17 individual mountain lions studied within the periods from 15 months prior the fire (A) and 15 months after the fire (B)–(F) (in 3-month intervals) are shown in different colors for each individual. Time periods shown include 15 months pre-fire to time of fire (A); time of fire to 3 months post-fire (B); 3–6 months post-fire (C); 6–9 months post-fire (D); 9–12 months post-fire (E); and 12–15 months post-fire (F). Of the 17 individuals, 12 were tracked both pre- and post-fire (though of these, 1 individual was suspected to have perished in the fire and 1 individual died soon after) and 5 individuals were tracked only after the fire (Figure S3). Land use is shown by dark green (natural areas), light green (altered open areas) and gray (urban areas). The area burned by the Woolsey Fire (2018) is shown in white outline with white hatching. Freeways are shown in yellow.
See also Table S1.

cover decreasing ambush hunting success. In the Santa Monica Mountains, the most intensive use of burned areas in our study occurred in areas surrounding a patchily burned area in the southeastern part of the outer burn perimeter of the Woolsey Fire (Figure 3), an area that was more heterogeneously burned and that included some sizable unburned patches. Use of these areas could be due to hunting advantages and prey availability in landscapes where burned areas are patchy, and near the edges of burns.[14,18] We did not account for differences in burn severity across the landscape, which can be an important predictor of wildlife post-fire habitat use, because fires within Southern Californian shrubby vegetation tend to burn with uniformly high-intensity, stand-replacing fire.[19] Our findings are overall consistent with the reduction in predator-prey interactions for ambush predators after the fire proposed by Doherty et al. [9], and the need to find suitable habitat to capture prey is likely one of the drivers of the risk-taking behaviors we observed.[2]

There is extensive evidence globally that large carnivores avoid areas of high human footprint (areas of relatively greater human population and infrastructural development) in space and time.[20,21] Our study indicated that even after a considerable disturbance that transformed the structure of over half the landscape used by the resident population, urban areas remained a strong deterrent. However, mountain lions did increase their exposure to anthropogenic risk by increasing road and freeway crossings and by increasing activity during the day when human activity is greatest. Human killings of mountain lions (in response to depredation of livestock) may be more likely in areas of intermediate housing density than in more urban areas,[22] and vehicle strikes are also a very high cause of mountain lion mortality[23] in this population. Therefore, mountain lions in our study area may be experiencing an assessment risk-response mismatch, whereby the animals' assessment of risk does not accurately reflect mortality risk.[24]

Reduction of suitable habitat after fire has the potential to result in greater risk of intraspecific conflict in carnivore populations within urban environments, where dispersal is constrained by multiple barriers. Though carnivore home ranges tend to be smaller and population densities higher in urban areas,[25] during the study period, the population we studied presented a relatively extreme example, given that the Santa Monica Mountains, south of the 101 freeway, were being used by at least eight males (most being subadults), though its size is the equivalent of 1 to 2 home ranges for adult males.[26,27] In this context, multiple behavioral changes by the mountain lions in our study, including a 50% increase in distance traveled, use of 15%–24% larger areas by females and subadults, and a trend towards greater intrasexual overlap, have the potential to increase the risk of intraspecific conflict, especially between males. In our study area, intraspecific conflict, specifically being killed by an adult male, is the biggest cause of mortality for subadult mountain lions, and adult males have also been recorded to kill adult females and kittens, including their own offspring and past mates.[23,26] Intraspecific conflict (fatal or otherwise) is likely to be exacerbated in urban areas where barriers prevent subadults from dispersing into new territories.[23,26,28] Therefore, after a severe wildfire, when space available for hunting and moving within cover is reduced, animals must trade-off energetic demand with perceived risk of encountering adult males, weighing behaviors that put them at greater risk of conflict against greater flexibility in space use and, potentially, diet.[29]

The increases in amount of space used and distance traveled that we observed could be influenced by multiple factors. A severe wildfire like the Woolsey Fire could allow mountain lions to move more efficiently by removing dense cover in the landscape and

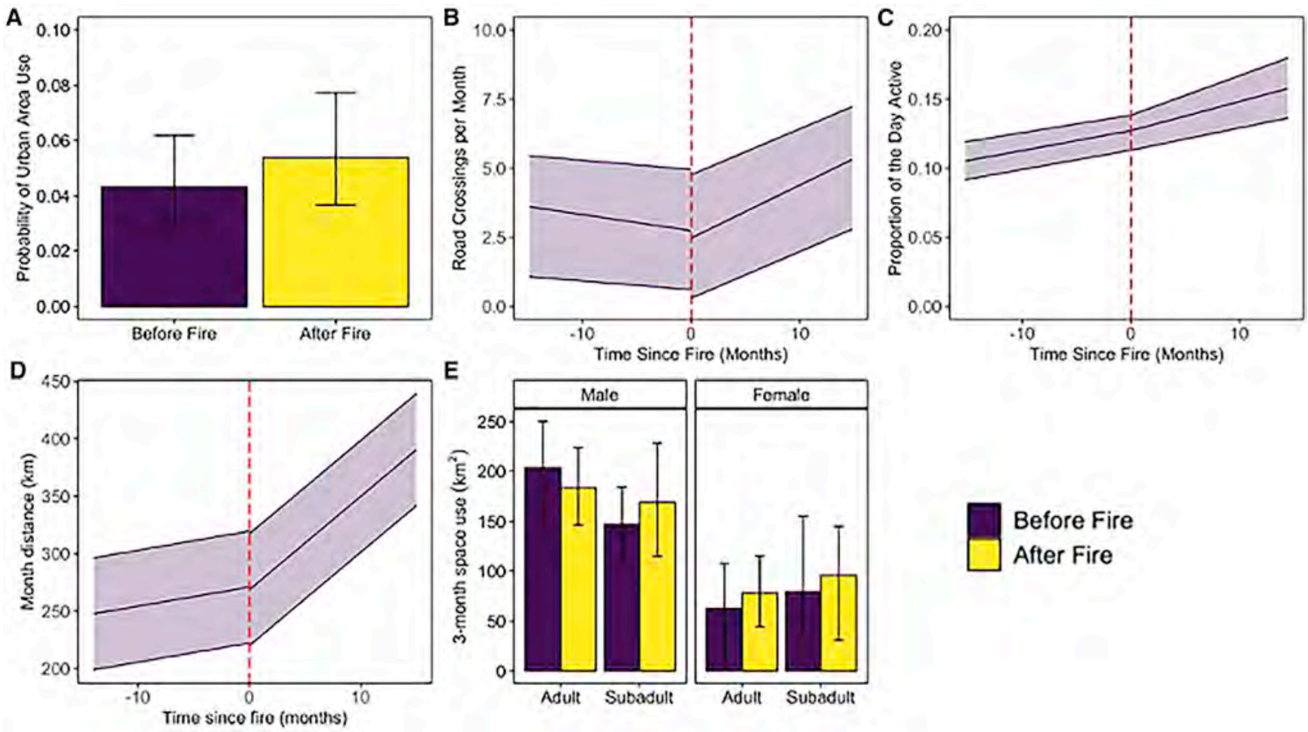

Figure 3. Predicted changes in risky behaviors by mountain lions after the 2018 Woolsey Fire, based on mixed effects models comparing probability of mountain lion use of urban areas

(A–D) Comparing probability of mountain lion use of urban areas (A), frequency of road crossings per month (B), proportion of day spent active (C), monthly distance traveled (D), and mean area of amount of space used over 3-month periods separated by sex and age class before and after the 2018 Woolsey Fire (E). The periods before and after fire were defined by the 15 months prior to and following the Woolsey Fire.

Models used to predict relationships included a mixed effects logistic regression model (A), segmented linear mixed effects models (B) and (C), segmented mixed effects meta-regression (D), and a linear mixed effects model (E).

Error bars and bands show 95% confidence intervals around fitted relationships.

See also Table S2.

due to the reduction in human recreational use in the short-term after fire.[30,31] Alternatively, increased space use could indicate an increase in avoidance of either humans or adult males, in the more sparse landscape where concealment is more challenging, given that mountain lions generally avoid open areas.[27] Alternatively, or perhaps concurrently, hunting could be more difficult for mountain lions due to the lack of cover on the landscape to ambush deer, as observed for African lions in savanna habitats.[13] All of these scenarios are likely to influence energy expenditure, indicating that a major disturbance, such as the wildfire in this study, could lead to energy deficits in carnivore populations.[32]

Our study was an opportunistic study of a population of mountain lions who were tracked before, during, and after a wildfire. The limited number of individuals who were not impacted by the wildfire precluded a natural experiment (such as a BACI design), therefore we must consider the possibility of other factors that could have influenced the behavior of mountain lions in our system over the 30 months of the study. Variability in human activity is unlikely to have contributed to changes in mountain lion behavior because our study ended (March 2, 2020) prior to local and statewide restrictions on public movement due to COVID-19 in the state and county (beginning March 19, 2020). Over the study period, rainfall varied, with greater rainfall after the fire than before, and two and a half mule deer (*Odocoileus hemionus*) calving seasons (important periods for mountain lion hunting) occurred, with one and a half prior to the fire and one after the fire (Figure S2). We cannot rule out the possibility that fluctuations in, and interactions between, weather and mule deer abundance influenced mountain lion behavior during our study. However, it is unlikely that these variables resulted in the findings we report here. The greater rainfall after the fire would be expected to increase deer forage and subsequently decrease, rather than increase, mountain lion space use and therefore reduce road crossings.[33,34] Further, given that mule deer tend to be crepuscular, the increase in daytime activity is unlikely to be explained by variability in environmental conditions changing deer abundance.[35,36]

Conservation implications

Our findings have important implications for the conservation of large carnivore populations living near urban areas, showing that wildfire can not only result in direct mortality, but could also influence carnivore behavior in ways that increase anthropogenic risks, like vehicular collisions and encounters with humans, as well as increase the risk of intraspecific conflict. These risks can interact. For example, one subadult male in this study was hit and killed by a vehicle on a freeway immediately after an altercation with an uncollared adult male. Behavioral changes observed in this study (e.g., variable usage of burned areas, increased activity

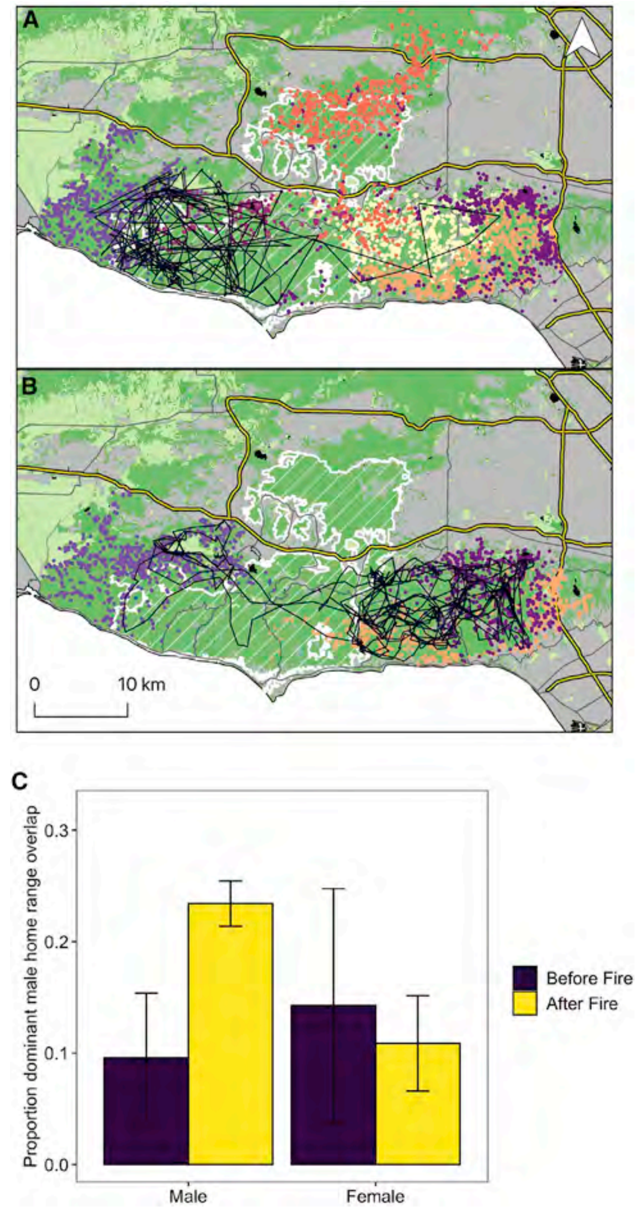

Figure 4. Observed overlap between the dominant adult male and subadult males before and after the 2018 Woolsey Fire

The dominant male (P30) is shown by a black line and subadult males are shown in colored points, different colors signify different individuals. Time periods include two ~6-month periods before (8th May 2018–8th November 2018) and after (21st March 2019–10th September 2019) the 2018 Woolsey Fire.

(A–C) (A) indicates the period before the fire until the Woolsey fire, when P30 was dominant (8th May 2018–8th November 2018), and (B) shows a similar period of time ending with P30's death (21st March 2019–10th September 2019). Before the fire, P30 regularly used the area within the fire perimeter and was rarely in the eastern half of the Santa Monica Mountains (A), whereas post-fire, he occasionally moved through the burned area and largely relocated to the eastern end, overlapping extensively with multiple subadult males. (C) shows the mean (± SE) proportion of P30's space use that overlaps with six other individual mountain lions (3 males and 3 females), tracked concurrently with him, before and after the fire. We defined P30 as the dominant male since he showed behaviors including territorial marking through scraping, breeding, and regular use of core natural areas.

Land use is shown by dark green (natural areas), light green (altered open areas), and gray (urban areas) and the extent of the Woolsey Fire (2018) is shown in white outline with white hatching. Primary and secondary roads are shown with gray lines with freeways in yellow (both were used in the road crossing analysis).
See also Figure S1.

during the day, and increased distance traveled) could be indicative of increased hunting challenges or hunting flexibility. If the fire-transformed landscape reduces the ability of mountain lions to ambush deer, they might rely on other prey items, including smaller carnivores, which in turn put them at greater risk of poisoning from toxicants such as anticoagulant rodenticides.[37]

Greater risk-taking behaviors by carnivores living near urban areas could lead to increased mortality in populations already suffering from low genetic diversity, leading to increased extinction risk.[38–40] As the world continues to urbanize and as we see increasing frequency of high severity fires in many of the world's fire-prone landscapes,[41] we are likely to see similar challenges for carnivore conservation in a broader range of global regions and taxa. Increasing the connectivity among urban habitat patches through a system of wildlife overpasses or underpasses,[42] already known to be important for increasing genetic exchange, could be particularly critical in fire-prone areas when the quantity of already limited suitable habitat can be greatly reduced post-fire.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

- KEY RESOURCES TABLE
- RESOURCE AVAILABILITY
  - Lead contact
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SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.cub.2022.08.082.

A video abstract is available at https://doi.org/10.1016/j.cub.2022.08.082#mmc3.

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AUTHOR CONTRIBUTIONS

R.V.B., S.P.D.R, D.T.B, and J.A.S. conceived the ideas, J.A.S. and S.P.D.R collected the data, R.V.B. conducted the analysis, wrote the paper and made graphs. J.A.S, S.P.D.R., and D.T.B. edited and provided feedback on the manuscript throughout development.

DECLARATION OF INTERESTS

The authors declare no competing interests.

INCLUSION AND DIVERSITY

We worked to ensure sex balance in the selection of non-human subjects. One or more of the authors of this paper self-identifies as a member of the LGBTQ+ community. While citing references scientifically relevant for this work, we also actively worked to promote gender balance in our reference list.

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STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Deposited data		
Data and code	Dryad data repository	Data and code are available at Dryad: https://doi.org/10.5068/D1M97D
Software and algorithms		
R v 3.6.1	R Development Core Team	https://www.r-project.org/
Rstudio v. 1.3.1093	Rstudio Team	https://www.rstudio.com/
adehabitatHR v. 0.4.16	The Comprehensive R Archive Network (CRAN)	https://cran.r-project.org/web/packages/adehabitatHR
adehabitatLT v 0.3.25	CRAN	https://cran.r-project.org/web/packages/adehabitatLT
amt v. 0.1.4	CRAN	https://cran.r-project.org/web/packages/amt
ctmm v. 0.5.11	CRAN	https://cran.r-project.org/web/packages/ctmm
ggplot2 v. 3.3.0	CRAN	https://cran.r-project.org/web/packages/ggplot2
lme4 v 1.1-23	CRAN	https://cran.r-project.org/web/packages/lme4
metafor v. 2.4-0	CRAN	https://cran.r-project.org/web/packages/metafor
momentuHMM v. 1.5.1	CRAN	https://cran.r-project.org/web/packages/momentuHMM
QGIS v. 3.4	QGIS Development Team	https://qgis.org

RESOURCE AVAILABILITY

Lead contact

Further information and requests for resources or reagents should be directed to and will be fulfilled by the lead contact, Rachel Blakey (rvblakey@cpp.edu).

Materials availability

The study did not generate new unique reagents.

Data and code availability

The data and code generated during this study are available at Dryad: https://doi.org/10.5068/D1M97D.

EXPERIMENTAL MODEL AND SUBJECT DETAILS

We captured and tracked mountain lions using global positioning system (GPS) collars (*Puma concolor*) as part of a long-term study conducted by the National Park Service (2002–present).[26,27,43] Mountain lions were captured using foot cable-restraints, baited cage-traps, or by treeing them with trained hounds; and immobilized with ketamine hydrochloride combined with medetomidine hydrochloride, administered intramuscularly. All animals were monitored throughout the time they were immobilized, during which time we estimated age, based on body size and tooth wear measurements. Age classes were: kittens (dependent offspring with their mother, 0-14 months), subadults (independent animals prior to reproduction: females 14-25 months, males 14-42 months), and adults (breeding animals: females >25 months, males >42 months).[44] We fitted adult and subadult animals with Vectronic Aerospace GPS collars (Berlin, Germany; Vertex Plus and Vertex Lite models) equipped with VHF beacons. Animal capture and handling procedures were permitted through a scientific collecting permit with the California Department of Fish and Wildlife (SCP # 05636) and the National Park Service Institutional Animal Care and Use Committee (Protocol PWR_SAMO_Riley_Mt.Lion_2014.A3). For this study, we used locational and accelerometer data for 17 individual mountain lions, collected over a 2.5-year period between 2017 and 2020, encompassing a large wildfire event, the 2018 Woolsey Fire. Individuals tracked for the study included 9 females (5 adult, 2 subadults, and 2 subadults that became adults during the study period) and 8 males (2 adult, 1 subadult, 1 kitten, and 4 subadults that became adults during the study period). Age was calculated for each three-month period, and the male kitten was treated as a subadult for the purposes of the study, given that he was estimated to be close to subadult age ($\sim$ 1 year old) and his mother was not observed during his capture.

We programmed collars to collect 8 locations per 24-hour period (7 at night, 1 during the day). The seven fixes at night were at 2 h intervals beginning at 5:00pm Pacific Standard Time (PST), while the day location was collected at 1:00pm PST. On average, 90% of programmed fixes for periods used in this study were successful, with individual mountain lion fix rates ranging from 69% to 98%. Collars also collected activity data on two axes (X: anterior-posterior/surge, Y: lateral/sway), averaged across every 5 minute period. A third axis (Z: dorso-ventral/heave) was only available for two of the seventeen individuals, so these data were not used in the analysis. Accelerometer measurements were 99% successful on average, with all individuals recording > 96% of expected measurements.

METHOD DETAILS

Study area

We studied an urban population of mountain lions within Los Angeles and Ventura counties, California, in the Santa Monica Mountains and Simi Hills (34°05’N, 118°46’W) (Figure 2). All patches of natural habitat were bordered by major freeways, urbanization, agricultural development, or the Pacific Ocean. The study population in the Santa Monica Mountains, in particular, has been genetically isolated from nearby populations by roads and urbanization,[26,38] leading to high extinction risk.[44] Land-use was variable across the study area, and included federal, state, and local parklands, as well as urban areas consisting of high-density residential, commercial, and industrial areas, low-density rural or suburban residential areas, and agricultural areas. Natural vegetation in the study area consisted of mixed chaparral, coastal sage scrub, oak woodlands and savannas, riparian woodlands, and non-native annual grasslands. The only wild, large ungulates were mule deer, which are the predominant prey for mountain lions in the region,[43] and two-and-a-half mule deer (*Odocoileus hemionus*) calving seasons occurred during the study period (Figure S2). The climate of the study area was Mediterranean, with cool, wet winters and hot, dry summers. Rainfall varied over the study period, with greater rainfall after the fire than before.,. The area is prone to drought and wildfire,[45] with two major wildfires occurring within less than a decade prior to this study, the Springs Fire in 2013, 9,814 ha, and the Woolsey Fire in 2018, 39,234 ha. The Woolsey Fire was the largest fire on record to have affected the Santa Monica Mountains and burned > 40% of the natural area in the Santa Monica Mountains and > 66% of the natural area in the Simi Hills (Figure 3).

QUANTIFICATION AND STATISTICAL ANALYSIS

Study design

We included locational data for 17 individual lions during 15 months leading up to and 15 months following the Woolsey Fire (2018). Mountain lion tracking periods varied (Figure S3), and more individuals were tracked after the fire (F: 9; M: 6) compared to before the fire (F: 5; M: 7). We therefore used resampling methods that balanced numbers of individuals among age classes to validate our findings (Table S3).

Do mountain lions avoid burned areas after a large wildfire?

To evaluate whether mountain lions decreased use of areas after they were burned in the Woolsey Fire, we compared selection coefficients for individual mountain lions derived from step selection functions before and after the fire using a meta-analytic approach.[46] Individual mountain lions were excluded from this analysis if an adaptive Local Convex Hull (LoCoH), calculated from every location recorded during the study period (the period spanning 15 months before and after the focal fire), overlapped with the burned area from the focal fire by less than 10%, or if they were not tracked during both periods (both before and after fire). We used the *adehabitatHR v0.4.16* package[47] within the *R v3.6.1* environment[48] to fit LoCoH home ranges and used the maximum number of nearest neighbors as all those points which were within the maximum distance between any 2 points recorded for animals in this analysis.

We first fitted a separate step selection function to each individual mountain lion during the periods before and after the fire separately using the *amt v 0.1.4* package.[49] These functions compared observed “steps” (movements connecting successive locations) with random possible steps generated from distributions of turning angles and step lengths from the broader population. We used only night locations for the step selection analysis, defined as locations collected between one hour after sunset and one hour before sunrise. The observed and random (i.e., "available") steps were compared to estimate selection coefficients using a conditional logistic regression to match observed to related randomly selected steps as strata. We used a sample rate of 2 h with a tolerance of 1 h and generated 1000 random steps for each observed step. The high tolerance level was not necessary and unlikely to have influenced the analysis, given > 99.96 of steps were within ± 5 minutes of the 2 h interval. Steps were separated into “bursts” for each night, to ensure sample intervals were regular (2 h intervals between each step). We then calculated effect sizes (yi) representing the change in selection of areas within the fire perimeter before and after they were burned by subtracting the “before fire” coefficient ($coef_{before}$) from the “after fire” coefficient ($coef_{after}$) for each individual. This meant that positive coefficients indicated selection for burned areas was higher after the fire, and negative values indicated that selection for burned areas was lower after the fire. We calculated the sampling standard error (sei) using the following approach recommended by Senn, Gavini, Magrez, & Scheen, [50] where se_{before} and se_{after} are the standard errors of the selection coefficients before and after the fire for each individual and ri is the correlation between the coefficients before and after the fire.

$$yi = coef_{after} - coef_{before}$$

$$sei = \sqrt{se_{after}^2 + se_{before}^2 - (2 \times ri \times se_{after} \times se_{before})}$$

Our sample size was small (5 males and 4 females tracked both before and after the fire), so we were chiefly interested in population-level selection for or against burned areas. We therefore estimated a population-level effect size using random effects meta-analysis[46] using the *metafor v. 2.4-0* package.[46] Along with the step-selection analyses and for comparison with them, we calculated mountain lion use of areas within the burn perimeter before and after the fire as the number of point locations whose 10 m radius intersected with the burned area (to allow for some variability in GPS location and fire layer accuracy).

Do mountain lions increase behaviors that put them at anthropogenic risk after a large wildfire?

We calculated three metrics associated with behaviors that may place mountain lions at additional risk from humans and anthropogenic threats: use of urban areas; number of road crossings; and proportion of daytime period active. We defined urban areas as commercial, and industrial areas and residential areas with $\geq$ 2.5 houses/hectare identified within the Southern California Association of Governments land use map.[51] This map was the most accurate available land-use data for the region, because later versions classified land uses at the parcel scale, rather than based on observed boundaries between different land uses. The dataset we used was reflective of the landscape throughout the study period from 2017–2020 for the broad development and altered-open classifications that we used in these analyses. The geographic information system (GIS) program for the park monitors land use in and around SMMNRA as part of the National Park Service Inventory and Monitoring Program. We defined mountain lion use of urban areas before and after the fire as a binary variable where point locations whose 10 m radius intersected urban areas were recorded as used (1), and those locations whose buffer did not intersect with urban areas were unused (0). We compared use of urban areas before and after the fire using a mixed effects logistic regression with period (before and after fire) as a fixed effect and individual mountain lion as a random intercept using *lme4 v 1.1-23*[52] (see Tables S3 and S5 for details of all analyses). We compared 3 models to investigate how the probability of mountain lion use of urban areas changed after the fire including: null (no effect of fire); step response (an abrupt change in urban use after the fire compared to before the fire); continuous response (a change in the relationship between urban use and time after the fire) (Table S5). We compared models using Akaike's Information Criterion adjusted for small sample size (AICc) and identified the most parsimonious model as the model with the lowest AICc, that was separated from a less complex nested model by ΔAIC > 2. Modelled coefficients and fitted relationships are presented with 95% confidence intervals, and confidence intervals around the fixed effects were calculated for fitted relationships using parametric bootstrapping.

To quantify road crossing behavior, we first exported each month of locations for each mountain lion into a movement trajectory using the *adehabitatLT v0.3.25* package.[47] We classified a major road as all freeways and secondary roads using road data from the U.S. Census Bureau, ([53]), adding roads that had similar amount and speed of traffic based on observations by National Park Service biologists. Specific roads included are shown in Figure 4. We added a 50 m buffer (50 m either side) to each road, to allow for road width and spatial uncertainty in road and mountain lion datasets. Road crossings were identified manually as "minimum road crossings", using lines between two consecutive points that traversed any buffered road, using QGIS v. 3.4.[54] When the line drawn between two consecutive point locations traversed a single road more than once, and the starting point was on one side of the road, whereas the ending point was on the other side, this was counted as one crossing. When the line drawn between two consecutive point locations traversed a road any number of times, but both starting and ending points were on the same side of the road, this was counted conservatively as zero crossings. As point locations were separated by a minimum of 2 h, we cannot discount the possibility of the animal taking an alternative (rather than the shortest) route to traverse between the two points. However, in all cases where we have recorded a crossing, the alternative route would have resulted in at least one road crossing, so our measure of "minimum road crossings" remains consistent with these possibilities.

We analyzed the relationship between road crossings and fire in a similar way to the urban use analyses (Tables S3 and S5). We used linear mixed effects models with the number of road crossings per individual per month as the response variable and individual mountain lion as a random intercept, and we used model selection to assess support for either an abrupt (step) response or a gradual (continuous) response to fire (Table S5). To account for unequal fix rates among months and individuals, we included fix rate (the number of locations recorded for an individual mountain lion during the month when road crossings were counted) as a fixed effect in all road crossings models.

To estimate the proportion of the daytime period spent active, we analyzed accelerometer data for lions where it was available (Figure S3 & Table S3). Given that we did not have field observations to inform our estimations of behavioral state, we used unsupervised Hidden Markov Models (HMMs) to estimate two states approximating "resting" and "active" behavior.[55] The HMM method explicitly models temporal dependence which is inherent in accelerometer data and assumes that the observed acceleration data time series is driven by an unobserved (hidden) behavioral state process.[55] We split the data into separate individuals.[55] We fitted a 2-state HMM using two data streams (activity of the X and Y axes), for which we assumed Gaussian distributions. We estimated starting values for our two states by examining distributions of the two data streams. We also fitted HMMs considering time of day as a covariate (cosine(2*pi*(hour of day/24)) using starting values extracted from the simpler models. These models did not improve fit compared to the simpler models based on AICc, so we retained the simpler models. Prior to analysis we standardized activity measurements by dividing all values for separate individuals and collars by the maximum recorded value during the period the collar was worn by the animal, given collar tightness can affect acceleration values measured by the sensor.[56] We fitted HMMs using the *momentuHMM v1.5.1* package.[57]

Next, we separated daytime activity data, including all data collected from one hour after sunrise to one hour before sunset to avoid crepuscular periods.[27] We removed 24 h periods from the dataset if they had < 95% of expected recordings. We then calculated the proportion of daytime active as the proportion of time that was classified as "active" using the HMM method. We used logit-transformed proportion of daytime active as the response variable in linear mixed effects models (LMM) with individual as a random intercept to account for variability in activity levels among individuals (Tables S3 and S5). Consistent with the urban use and road crossings analyses, we used model selection to assess support for either an abrupt (step) response or a gradual (continuous) response to fire (Table S5).

Do mountain lions increase behaviors that could increase risk of conflict with conspecifics after a large wildfire?

We calculated three metrics to quantify behaviors that could place mountain lions at additional risk due to increased chance of conspecific interactions: distance travelled, amount of space used, and spatial overlap with other mountain lions.

We quantified distance travelled using a continuous time movement modelling (CTMM) approach.[58] The continuous time approach aims to separate the sampling processes from the animal's underlying movement processes by fitting a model accounting for the positional and velocity autocorrelation properties inherent in movement data, and then simulating multiple possible trajectories based on this model.[59] We used model selection to fit a movement model to each monthly period for each individual mountain lion that best described the positional and velocity autocorrelation of the animal's movement for that period. For 38 out of 257 individual-months analyzed, the movement showed no statistically significant evidence for velocity autocorrelation, so we were unable to estimate distance for these months. We estimated monthly distance travelled and variance of these estimates for the remaining 219 months. Given that the CTMM approach allows for estimation of uncertainty, we used a mixed effects meta-regression approach, fitted via restricted maximum likelihood, using estimated distance as the effect sizes and variance of distance as the sampling variances, with individual mountain lion as a random effect (Tables S3 and S5). Our estimated values of distance travelled were normally distributed around a mean of 330 ± 120 km (SD) per month. Moderators (covariates) were defined in the same way as fixed effects for the models of urban use, road crossings, and daytime activity (Table S5). We compared 3 models to investigate whether mountain lions changed their distance travelled after the fire including: null (no effect of fire on distance travelled); step response to fire (abrupt change in distance travelled after the fire); and continuous response (a change in the relationship between distance travelled and time after the fire) (Table S5). We fitted continuous time movement models and estimated distance travelled using the *ctmm v 0.5.11* package.[58]

We quantified the amount of space used and estimated home range overlap using adaptive local convex hulls (LoCoH),[60] implemented within *the adehabitatHR v0.4.18*. While we recognize that this method can underestimate the amount of space used and is sensitive to sampling rates,[61] it performs well when animal movement is constrained by barriers like roads and urban areas,[60] and our sampling rate was generally consistent among individuals. Since we were more interested in comparative space use (before and after fire), rather than absolute measurements of area, we believe this approach is robust.

We quantified the amount of space used by calculating the adaptive LoCoH for every individual mountain lion and every 3-month period which contained a $\geq$ 75% fix rate (Table S3). We analyzed the relationship between amount of space used and fire using linear mixed effects models with individual mountain lion as a random intercept (Table S5). We used model selection to assess support for an abrupt (step) response to fire and did not investigate a gradual response to fire as space use was calculated for 3-month periods (Table S5). We also fitted models including the interaction between period (before and after fire) and age-sex class, given the known disparities between amount of space used across age-sex classes,[27] though we interpret these results cautiously due to the low number of individuals in each group (Table S3).

We took two approaches to investigating changes in home range overlap before and after the fire. For the first approach, we focused on an adult male who held the largest territory within the Santa Monica mountains prior to the Woolsey Fire, P30, which we refer to as the "dominant male". We examined all animals that had the potential to overlap with P30 (individuals that used the Santa Monica Mountains area as part or all of their home range) and that were tracked at the same time as P30 for at least 3 months both before and after the fire. This resulted in a dataset of 6 mountain lions (3 males and 3 females), who were tracked for periods ranging from 5 to 11 months (both before and after fire) concurrently with P30. For space use calculations, we limited tracking periods to the same period of time before and after the fire for each individual. For each individual we calculated amount of space used over the period they were tracked concurrently with P30 using adaptive LoCoHs. We then calculated areal overlap of the LoCoH with the corresponding LoCoH for P30 during the same period. Given the small sample size (6 individuals with one measure of overlap per period for a total of 12 measures of overlap), we interpreted the results graphically rather than conducting a formal analysis. Our second approach to quantifying overlap involved calculating the overlap between every pair of mountain lions that were tracked during concurrent 3-month periods (Table S3). We restricted this to animals that used the same region (e.g., animals that exclusively used the Simi Hills portion of the study area were only compared to other animals that used this part of the study area). We analyzed the overlap data in the same way as the first overlap analysis, but separated into two datasets, one expressing overlap as proportions of female home ranges overlapped and the other expressing overlap as proportions of male home ranges overlapped. We fitted linear mixed effects models to each of those two datasets using pair category (male-male, male-female, female-female) as a fixed effect and overlap pair (pair of individual mountain lions for which overlap was calculated) as a random intercept (Table S5). Similar to the space use analysis, we used model selection to assess support for an abrupt (step) response to fire (Table S5).

All analyses were conducted within *R v3.6.1*[48] using *Rstudio v. 1.3.1093*,[62] all plots were made using *ggplot2 v. 3.3.0*[63] and all map figures were made using QGIS v. 3.4.[54]

Resampling for model validation

In order to account for the variability in sampling across individuals and age-sex classes, we resampled observations in each dataset 100 times to provide equal numbers of locations across sex and age classes and re-ran the model selection analysis. The specific approaches for each analysis are listed in Table S3. We recorded the percentage of iterations for which the most parsimonious models from the full dataset were selected as well as the proportion of models that resulted in fitted relationships in the same direction (e.g. greater or lower magnitude after compared to before fire) as the full-data model for all analyses. Where the majority of the relationships were in the same direction as the full dataset and the majority of iterations showed the same direction in relationships, we classified the relationships as robust. An additional validation step was performed for the urban use analysis. Given the female who used urban areas the most frequently (P75 — 15% of use was urban) was only sampled after the wildfire, we performed an additional check and removed her from the dataset and re-fit the models. We found that the strength and direction of the relationships were similar and that the same model type was found to be the most parsimonious, so we retained the full dataset.

Most of our analyses showed that the most parsimonious model and the direction of relationships were consistent across 100% of iterations, and we report only the exceptions below. In the analysis of urban use, models predicting abrupt changes were selected as the most parsimonious 76% of the time, with continuous responses to fire 24% of the time. In the road crossings analysis, 78% of model iterations showed an increase in road crossings after fire with 25% of models showing an abrupt change and 62% showing a continuous response. For the space-use analysis, direction of the relationships (increase in space use after fire) was consistent across 83 % of iterations. When space use was separated into sex and age classes, model selection was consistent across all iterations, but the consistency of relationship directions (increase or decrease after fire) varied among sex and age classes (adult male: 63 %, subadult male: 100 %, adult female: 81 %, subadult female: 92 %).

ATTACHMENT 2

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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.

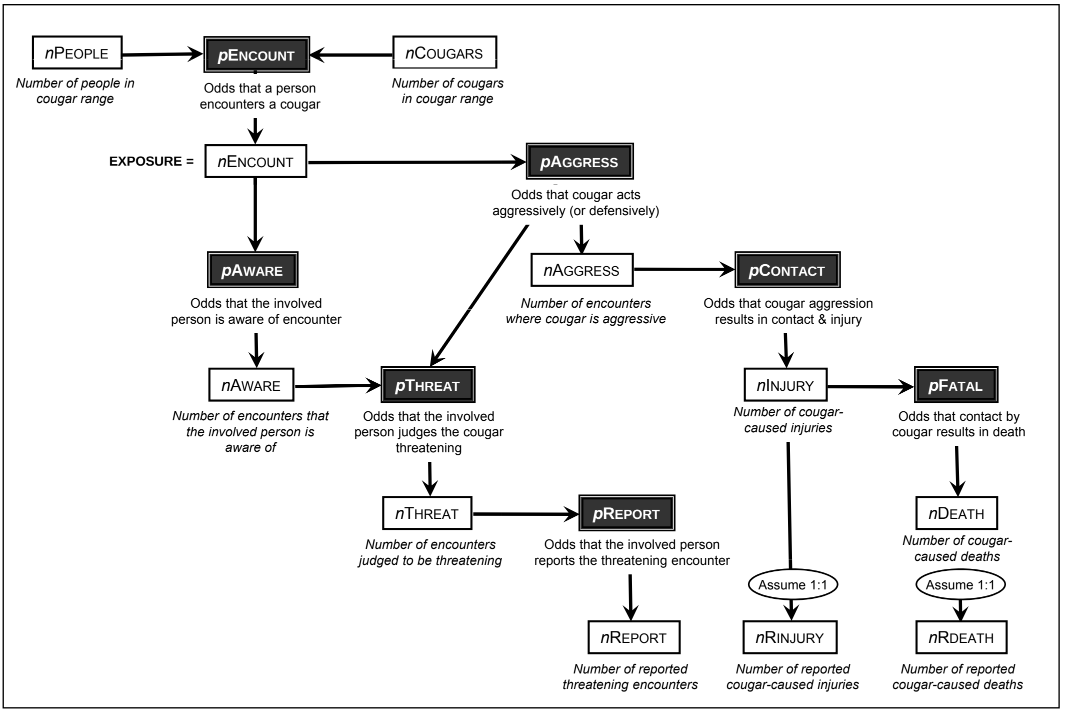

Figure 1. Conceptual frame for analyzing outcomes of cougar–human encounters and for judging prospective data bias. White boxes (with *n* followed by a name) denote outcomes of potential management concern; dark boxes (with *p* followed by a name) denote transitions that are a prospective opportunity 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 ($\chi_1^2 = 5.3$, $P = 0.02$; 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 ($\ln[P/(1-P)]$) 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 $\alpha = 0.10$ 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 (25^{th} to 75^{th} 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

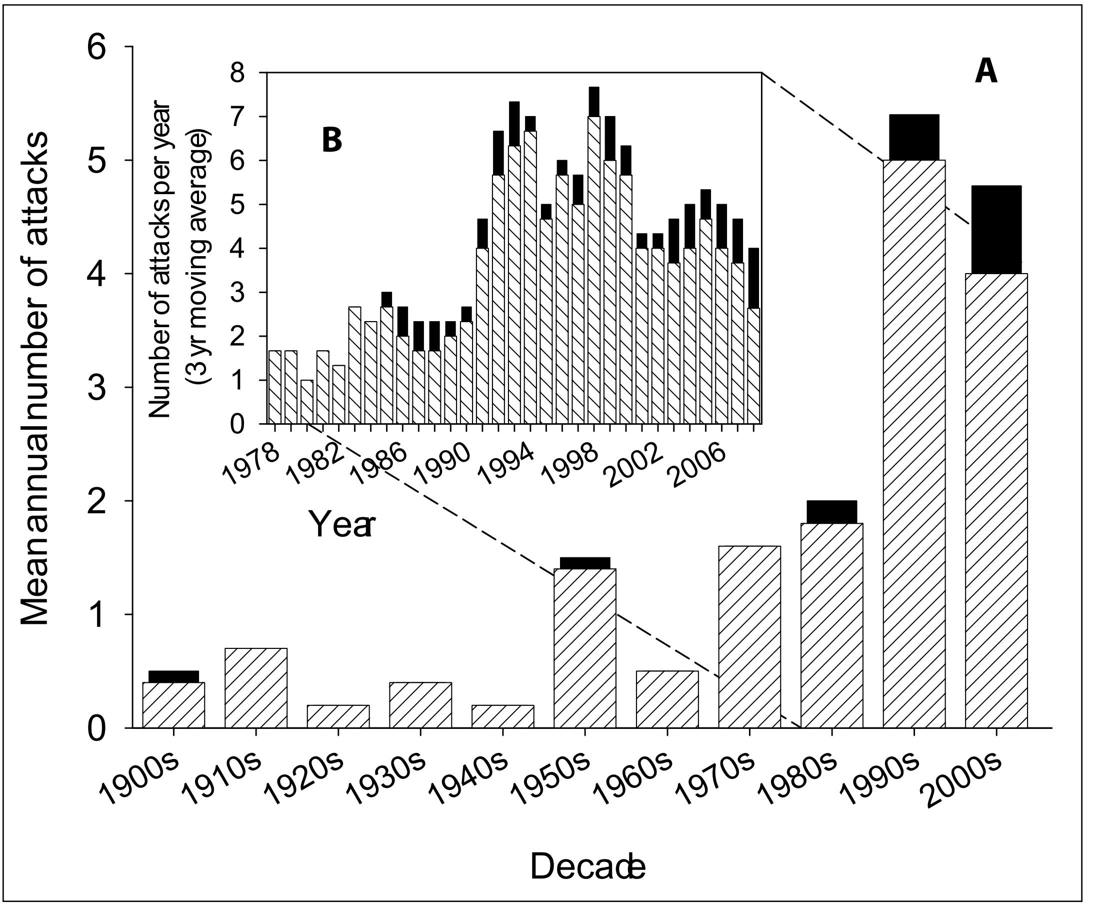

Figure 2. (**A**) Mean annual numbers of recorded cougar–human encounters resulting in physical contact (attacks), by decade, 1900 to 2008; (**B**) running 3-year mean of recorded cougar attacks on people, 1978 to 2008. Hatched bars are for confirmed cases only, whereas narrower black bars include probable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

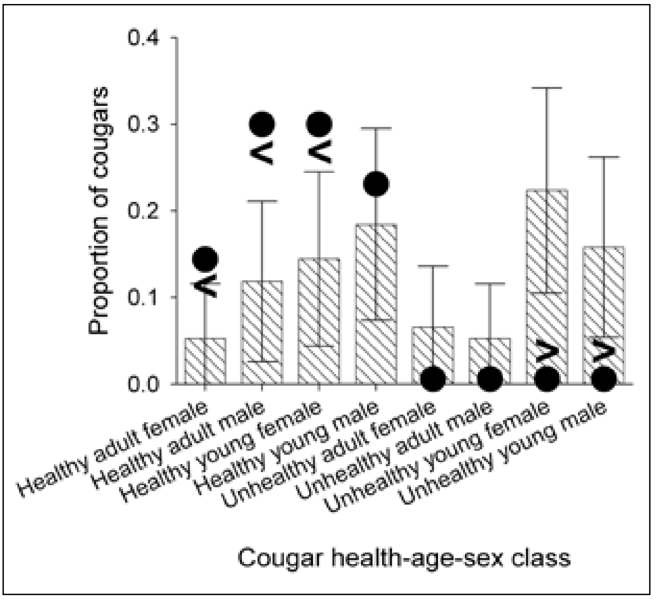

Figure 3. Proportional distribution of cougars involved in attacks or close encounters with people in the United States and Canada, 1890–2008, by sex-, age-, and condition-class, compared to proportions of cougars in each class observed during a long-term study in the San Andres Mountains, New Mexico (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)

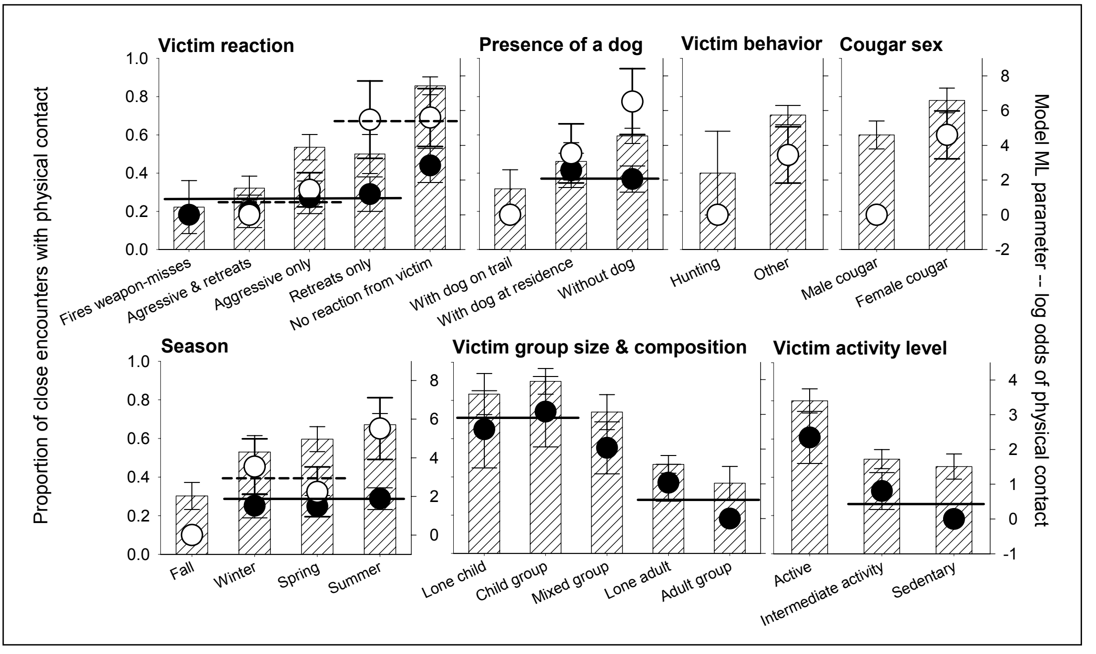

Figure 4. Relations between close cougar–human encounters that resulted in physical contact in the United States and Canada, 1890–2008, and variables included in explanatory models. These results exclude cases where the victim killed a cougar during an encounter. Categories for each variable are shown 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

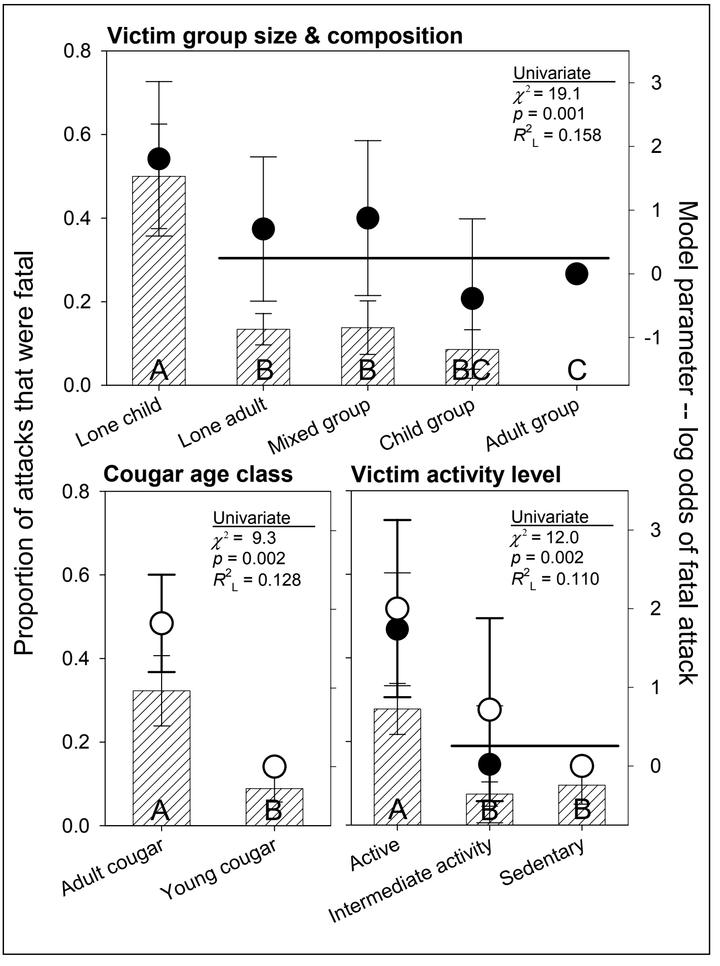

Figure 5. Relations between fatal cougar attacks on humans in the United States and Canada, 1900 to 2008, and variables included in explanatory models. Categories for each variable are shown prior to consolidation on the basis of reductions in AIC_c; horizontal lines indicate variable categories that 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.

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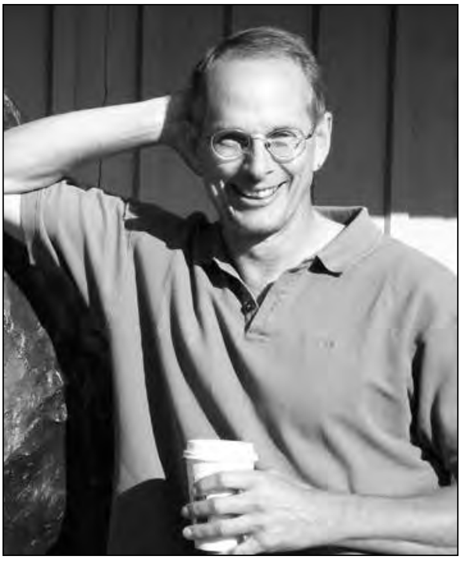

David Mattson received advanced degrees in plant and wildlife ecology from the University of Idaho in 1985 and 2000. For the last 32 years, he has studied large carnivores, including grizzly bears in the Yellowstone region and cougars in 6 different study areas in southern Utah, northern Arizona, and 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.

Kenneth Logan (left) has a Ph.D. degree in wildlife sciences from the University of Idaho. He has been studying wild cougars since 1981, including populations in Wyoming, New Mexico, California, and Colorado. Currently, he is a mammals researcher for the Colorado Division of Wildlife and is studying cougar ecology on the Uncompahgre Plateau. His previous research has dealt with cougar evolutionary ecology, population biology, behavior, social structure, cougar−prey relationships, habitat use, and behavior of cougars in relation to people. He has authored and co-authored numerous peer-reviewed scientific writings on cougars including, *Desert Puma: Evolutionary Ecology and Conservation of an Enduring Carnivore*, which was awarded Outstanding Publication in Wildlife Ecology and Management by The Wildlife Society in 2002. He is also an original member of the Cougar Management Guidelines Working Group, which produced the first *Cougar Management Guidelines,* published in 2005.

Linda Sweanor (right) obtained her M.S. degree in wildlife sciences at the University of Idaho in 1990; her thesis was on cougar social organization. She has been involved in cougar research, including population ecology, cougar–prey relationships, cougar social organization, and cougar–human interactions. She studied cougars in New Mexico for the Hornocker Wildlife Institute and in California for the University of California at Davis. She has co-authored several scientific papers and co-authored with her husband Ken Logan, *Desert Puma: Evolutionary Ecology and Conservation of an Enduring Carnivore* (2001). She recently assisted with a felid (cougar, bobcat, domestic cat) disease transmission study for Colorado State University and has volunteered on a cougar population study in western Colorado. She was a co-founder the Wild Felid Research and Management Association in 2007 and currently serves as the association's president.

ATTACHMENT 3

Summary Report of Mountain Lion Hazing/Deterrent Devices Testing aimed at Reducing Livestock Predation and Associate Mountain Lion Depredation Permits

University of California – Davis Agreement A37682 Amendment #2 SANDAG Contract #5005298 Amendment #2 (S890571)

Task 2

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F307

Executive Summary

This document seeks to provide the San Diego Association of Governments (SANDAG) a summary of the activities on Task 2 (Agreement #A37682/MOU #5005298/ AMENDMENT NO. 2 (S890571)) related to the educational efforts, and testing and use of deterrent devices and strategies, undertaken by the UC Davis Wildlife Health Center mountain lion project team with the goal of reducing domestic animal and mountain lion mortalities in the County. Being killed after depredating domestic animals, usually small livestock or pets, is the number one source of mortality for mountain lions in San Diego County and California as a whole (Benson et al. 2023, Vickers et al. 2015). Low overall survival rates are a concern in the San Diego County mountain lion population, and reducing livestock predation and associated mountain lion mortalities is a high priority. Our UC Davis mountain lion study team has worked to reduce losses of domestic animals and mountain lions for many years. This report details the work conducted under this contract, as well as other funding, to advance animal owner education regarding proper husbandry of their domestic animals, and to explore strategies and tools that can assist owners in that effort. This is one of the goals of our study team not only in San Diego County but throughout California.

Deterrents to mountain lion depredation can take the form of securing animals in predator-proof structures at night, livestock guardian dogs, and various other strategies and devices that can diminish the likelihood of predation. The vast majority of mountain lion mortalities secondary to depredation in southern California, as well as the rest of the state, involve small groups of sheep or goats kept in rural or semi-rural settings. Obviously, putting animals into secure housing at risky times of day (before dusk to after dawn) is the gold standard of protection for domestic animals, and trained livestock guardian dogs are also generally effective. However, because of the expense of guardian dogs, they are primarily used with large commercial flocks or herds of livestock. Thus our primary focus in San Diego County has been on education of owners of small livestock in regards to proper securing of those animals, or in the event that is not possible, on trying to provide them with alternative deterrents that can reduce risk to their animals (and the possible loss of mountain lions).

The San Diego County mountain lion population is primarily a part of the genetically distinct eastern Peninsular Range mountain lion population east of I-15, but some San Diego County mountain lions are part of the separate genetically distinct Santa Ana Mountains population in west of I-15 (Gustafson et al. 2018, 2022; Ernest et al. 2013). Both populations have been petitioned for listing as threatened under the California Endangered Species Act, increasing the urgency of the need to reduce mortality threats in the San Diego County population.

Our team's efforts under this contract have fallen into two main categories during this contract period, as well as previous to this study period:

1. Education
2. Deterrent testing

1. Education:

   Our efforts in the education realm during this study period have centered on a) giving general community presentations, especially in areas where depredations are more common; b) working with groups such as the UC Extension Service, 4-H Clubs that they oversee, the Mountain Lion Foundation, the California Department of Fish and Wildlife (CDFW), and other animal owning groups to help them understand the threat posed to both domestic animals and mountain lions by inadequate husbandry practices and to educate others themselves; c) developing specific curricula for 4-H Clubs to use to teach proper livestock protection practices to reduce risk from predators; d) working with CDFW conflict specialists to be certain that messages that they, and we, are putting out are the same, as well as seeking opportunities to work with people who have suffered depredations to help them reduce future risk; e) communicating to all interested parties the results of deterrent testing and other experimental methods that can reduce risk to domestic animals from predation.

2. Deterrent testing

   Uses of deterrent devices to reduce depredation of domestic animals is an area of research that other researchers and groups have pursued but that is difficult to accomplish with wild mountain lions due to their wide-ranging nature. Choice of devices and strategies for our team to test was based on previous work done by the UCD team in this area, on the large body of knowledge Dr. Vickers has helped accumulate through his work as the hazing and deterrence director for oil spill response with the UC Davis Oiled Wildlife Care Network, collaborations with UC Extension Services, CDFW, USDA Wildlife Services, and other researchers. More recently, the team's thinking has been influenced by participation in a hazing and deterrent summit held at UC Davis in 2023 where Dr. Vickers was the keynote speaker (Figure 1). That two-day summit featured national and international speakers on the subject of hazing and deterrence covering many different species and techniques, leading to the emergence of a wider array of ideas for application to mountain lion depredation prevention that the UCD team will be incorporating into their testing and education efforts going forward.

Figure 1. Wildlife Hazing and Deterrence Summit logo.

The UCD team's participation in the newly formed Hazing and Deterrence Working Group (Figure 2) will also help expand the team's research-based knowledge of best measures for prevention of depredation. Besides the devices and strategies detailed below, others are emerging that can contribute to livestock protection from predators and reduction in secondary losses of mountain lions.

Figure 2. Hazing and Deterrence group logo.

During the Agreement time-period (2021-2023), UC Davis WHC personnel and collaborators were able to assess the responses of mountain lions to many types of deterrent devices (n=16 different devices and tools alone or in combination; Figure 3). These have included:

1. Mr Beams Solar Wedge Security Lights® – motion-triggered light
2. Building mounted security lights – motion-triggered light
3. Continuous outdoor lighting
4. Foxlights® – random lights different colors in different directions to mimic flashlight moving around
5. Predator Guard ® solar powered predator deterrent LED light units – constant light to mimic eyes of a predator
6. Wasatch Wildlife Product® FurFinderR® predator calls - Programmable speakers with human voice or other sounds that play for 15 seconds approximately every 5 minutes from dusk to dawn

7. Margo Supplies Squawk Boxes® – loud outdoor programmable speakers – random or continuous human voice or other sounds
8. "Ora" – Programmable units from student Vedant Srinivas – random and motion-triggered human voice or other sounds and light
9. Programmable sound and light units from Cal State Northridge electronics engineer Aaron Nanas – random and motion-triggered human voice or other sounds
10. Solar sound and light security alarm units - siren type sounds and light - motion-triggered
11. Hulpre Outdoor motion sensor alarms – siren type sound and light – motion-triggered
12. Margo Supplies Gadflys®– siren type sound and light – motion-triggered
13. Campark TC17 Cellular Trail Camera®: cellular camera capable of transmitting pictures and videos remotely. It has built-in a high-sensitivity sound-collecting microphone and speakers allowing one to listen and speak using an app.
14. Vectronic street tags® – UHF transmitters that trigger GPS collars in vicinity to increase frequency of GPS point acquisitions
15. Vectronic electronic fence – programming in some Vectronic collars that notifies the researcher when a mountain lion collar takes a data point within a programmed geographic area – pairing of street tags and electronic fences allows rapid detection of collared mountain lions within preprogrammed boundaries.
16. Opaque plastic or fabric shielding around pens to block the mountain lion's view of the interior and reduce the likelihood of jumping the fence.

Figure 3. Various devices and strategies tested by the UC Davis team.

Based on our preliminary results outlined below of greater than 50% success at altering mountain lion behavior and directing them away from the device or livestock pen, we recommend using deterrent devices as a part of depredation prevention in those instances where securing livestock at night in predator-proof enclosures or use of trained livestock guardian dogs is not possible.

No electronic device or other strategy can replace secure housing at night, the gold standard of livestock protection from predators, and we urge all livestock owners to use that strategy if at all possible. We feel that though definitely not foolproof, deterrent devices and strategies, especially when combined and changed over time, can affect mountain lion behavior and reduce the likelihood of livestock losses. We feel that the use of devices and strategies such as those we tested, and others, can promote mountain lion-human coexistence in fragmented/urbanizing landscapes such as southern California.

Introduction.

Large carnivores are key components of ecosystems providing a suite of direct and indirect stabilizing effects on them (Ripple et al. 2014). However, humans have disrupted ecosystems through habitat destruction and extirpation of large carnivores, resulting in constriction of their geographical range and a decline in the number of these taxa. That is the case of mountain lions (*Puma concolor*), an apex carnivore that although has historically occurred throughout the Americas, has been extirpated or decimated in much of their former range in the past 200 years (Cougar Management Guidelines Working Group, 2005).

In California, mountain lions are considered a “specially protected mammal” (Cal. Fish & Game Code § 4800(a)). As a result, hunting of mountain lions is generally prohibited, and there are restrictions on taking, injuring, possessing, transporting, importing, or selling mountain lions (Cal. Fish & Game Code § 4800(b)). However, some exceptions allow for the removal or killing of mountain lions if they are perceived to be an imminent threat to public health or safety or pose a threat to the survival of threatened, endangered, candidate, or fully protected sheep species (Cal. Fish & Game Code § 4801). Furthermore, if a mountain lion damages or destroys livestock or other property, a person may request a permit to “take” the mountain lion (Cal. Fish & Game Code § 4802). The California Department of Fish and Wildlife (CDFW) is responsible for issuing depredation permits, which authorize the removal of mountain lions in such cases.

In southern California, mountain lions live in a human-dominated fragmented, and urbanizing landscape which may result in more cases of human-mountain lion conflicts. Mountain lion mortality due to depredation permits issued after mountain lions killed domestic animals is considered their leading cause of death in San Diego County as well as across the rest of the state (Benson et al. 2023; Vickers et al., 2015).

This highlights the need to find mitigation tools to reduce livestock depredation by mountain lions. Currently, there is no consensus as to which tools and techniques are most useful and under what circumstances, or on the associated tradeoffs between time of duration and effectiveness levels (Miller et al., 2016).

Table 1 summarizes contemporary conflict mitigation techniques for predator / livestock conflict that are most applicable to mountain lions. Modified from Miller et al. (2016).

Non-lethal	**Predator Removal/Lethal**
Deterrents	Lethal population reduction Retaliatory killing of offending animal Problem animal removal Problem animal relocation Population control
Aversive stimuli Disruptive stimuli Visual restriction Behavior conditioning Behavior modification	
Preventive Husbandry	
Fencing Guard-dog/guard animal Herder/sheperd/guards Secure Penning Livestock breeding Separation from predator habitat Deterrents Visual restriction between predator and prey	
Indirect management of land/prey	
Buffer zone Core zone Grazing management Land use modification	

Within the non-lethal conflict mitigation techniques, preventive husbandry and deterrents have demonstrated the greatest potential but also the widest variability in effectiveness in reducing livestock losses (Miller et al., 2016).

We hypothesized that our deterrent device suite employed would be effective on more than 50% of the occasions based on current literature on the use of deterrents in mountain lion-livestock conflicts (see Ohrens et al., 2019; Guerisoli et al., 2021; Kertson et al., 2022).

Material and Methods.

Education:

For the first focus of this task (Task 2 in associated SANDAG agreement noted above), we utilized education and collaborations to enhance awareness of depredation impacts on livestock and mountain lions and encouraged preventive husbandry practices such as nighttime confinement in secure pens or guard dogs, as well as potentially using deterrent devices. The emphasis on the education side has been focused on kids in 4-H programs as well as the general public who may own domestic animals in rural areas. Partnering with CDFW, UC Extension, and the Mountain Lion Foundation has extended the reach of those efforts. In the case of 4-H clubs we worked with the UC Davis Extension office at the School of Veterinary Medicine and the Mountain Lion Foundation to develop a peer reviewed curriculum for 4-H leaders around the country to use to teach 4-H kids proper husbandry for protecting their animals from predators (Figure 4). That curriculum has also been accessed for use by other educational organizations such as CDFW, UC Extension, and the San Diego Zoo that outreach to the general public and those groups specifically that own livestock, especially small livestock. In addition, on several occasions UCD veterinarians or staff have been in contact with livestock owners after depredations and have provided consultation on measures they could take to prevent further losses, and assistance in some cases improving their livestock enclosures.

Figure 4. Upper left-Cover of 4-H curriculum book; Upper right – Logo for educational event organized by the Mountain Lion Foundation and 4-H in San Diego County; Lower right- parade float created by Julian, CA 4-H Club highlighting the value of securing animals in pens.

Testing deterrents and other strategies:

For the second focus of this task, we employed multiple strategies to gain insight into the responses of mountain lions to protective measures that might be employed in the absence of secure housing at night. When opportunities arose at livestock depredation sites and owners wished to take advantage of our assistance we placed deterrent devices to deter the animal from returning to livestock enclosures and assessed the mountain lion's response.

Testing was also done in experimentally contrived (bait stations set up for mountain lion captures) and opportunistic situations (along travel corridors) with both GPS-collared and un-collared mountain lions in the wild. Testing was done primarily in our southern California study area but we also took advantage of opportunities to test deterrents and strategies in our study areas in the Tehachapi and Gabilan mountain ranges.

We evaluated the effectiveness of several types of non-lethal deterrents and strategies on mountain lions, primarily, and other carnivores opportunistically when they were feeding at our mountain lion bait sites (Figure 3; Addendum 1). Most devices tested were commercially available devices but we also worked with a graduate electrical engineering student at Cal State Northridge, and a national science award-winning high school student from the Seattle area who both developed devices with the capability to play custom sounds and light both randomly and when triggered by motion. The purpose of working with these students was to try to develop devices with more total capabilities than those currently on the market.

Historically, most of our deterrent work that was not conducted at depredation sites has focused on our collared male mountain lions that found bait placed for capture of other mountain lions. Because those bait sites represented artificial feeding supplementation for those animals, and the sites were intended for trapping of un-collared mountain lions, we utilized those opportunities to test behavioral responses of those already-collared males to the devices. We felt that situation most closely approximated a depredation situation where a mountain lion that has depredated would likely return to a livestock pen and potentially take additional animals.

Additionally, we tested mountain lion behavior when both male and female mountain lions (collared and uncollared) encountered deterrent or other devices along travel corridors. Although we were able to conduct testing regularly during 2021 and 2022 in our southern California study area, most of the previously collared males had dropped their collars in 2023 and the one remaining did not operate in areas where we were baiting. However, we were able to do some testing of devices and education strategy in our other study areas during that year.

We considered the use of the device to be effective if the target species involved in the event would leave the area. We considered partial success or failure if the individual left but it came back within 24 hours or did not leave respectively.

Results (including some testing prior to the current contract period).

Mountain lion events.

Testing in association with depredation events.

When informed of depredation events by California Department of Fish and Wildlife personnel where livestock owners were interested in cooperation with the research, our team or collaborators placed deterrent devices in strategic locations where a returning mountain lion would be expected to encounter them. The devices tested included Foxlights combined with Predator Guard devices in two tests prior to the current period, and during the current period Gadfly devices alone in three tests, Gadfly devices combined with blinding material placed on fencing in one test, blinding material alone in another test, motion triggered house lights combined with Mr. Beams solar wedge security lights in another case. These were all short-term efforts to assess behaviors when the mountain lion returned over one to three days post-depredation. Cameras were placed at all sites to try to capture the behavioral responses of the mountain lions when encountering the devices.

Education alone was also tested in concert with CDFW personnel on two occasions and in both cases, the animal owner made no husbandry/confinement changes and subsequently suffered additional losses the following night.

In five depredation cases, the offending mountain lion was captured, and GPS collared then released.

M294:
One of those collared individuals (M294) was collared after depredating goats on two occasions at one site. The owner of the goats was given advice on strengthening his pen after the first occasion but did not do so, and M294 returned. On both occasions he was still in the pen when CDFW arrived. On the first occasion he was darted and transported to a nearby wild area and released. On the second occasion he was darted and our UCD team placed a GPS collar on him before he was released in a wild area. After the second depredation the owner made changes to his pen structure and did not have more depredations though M294 later came by the site again. After being collared M294 depredated at two other locations where the UCD team was notified and was able to place Gadfly devices the next day. At one site M294 returned the following night and did not try to enter the pen or depredate again, though human presence was also increased in the area of the pen. However, the cameras did not capture the direct response to the Gadflys if they were triggered.

At the second site M294 was able to enter a barn and was still inside when CDFW wardens arrived. He was again darted and transported a distance away. Gadflys were placed around the barn where a lion might approach, and the barn strengthened. M294 did return the following night and did not reenter the barn, but we did not observe triggering of the Gadflys on our cameras. We were unable to classify either of the two tests as successful or unsuccessful in regards to the Gadflys, but successful in terms of the strengthening of the pens and increased human presence in one case. Unfortunately, M294 was later killed in response to approaching unsecured livestock at another location, though no depredation occurred before he was shot. As a side note, this owner was cited by CDFW for an unjustified killing.

F307:
In a case where recurring mountain lion visitation and several depredations had been documented, capture of one offending mountain lion was accomplished (F307). In the case of F307, her return visits to the area allowed us to test her responses to devices in a number of ways. Testing of deterrents to restrict her entry over a fence into a conserved area seemed to cause her to alter the locations where she crossed the fencing, but because of long expanses of fencing the entire length could not be completely outfitted with deterrents (Figure 5). A long-term effort was instituted where an array of devices were utilized both on fencing and in the habitat and trails where F307 commonly traveled. This array included at different times and in different combinations Gadfly units, two Squawk boxes, two Ora units, Wasatch calls, solar and Hulpre motion sensor alarms, and blinding material on fencing. Testing along travel routes did demonstrate that alteration of F307's route was accomplished most of the time by

an array of devices playing human voices (Figure 6). However, in other instances she did not appear to change behavior when encountering areas in the general habitat where devices were deployed that were playing voices and other sounds randomly or when triggered by motion.

Figure 5. F307 with GPS collar

Because the collar on F307 was programmed to respond to UHF signals from Vectronic street tags (Figure 6) with an increase in GPS point acquisition, and the collar had an electronic fence programmed in that surrounded the site, UCD personnel were notified when she crossed the electronic fence. That allowed the team to notify personnel in key locations to respond with human presence. This measure was effective at preventing further depredations. However, a subsequent visit by an uncollared mountain lion resulted in a depredation after it entered pens in an area where no deterrent devices were deployed.

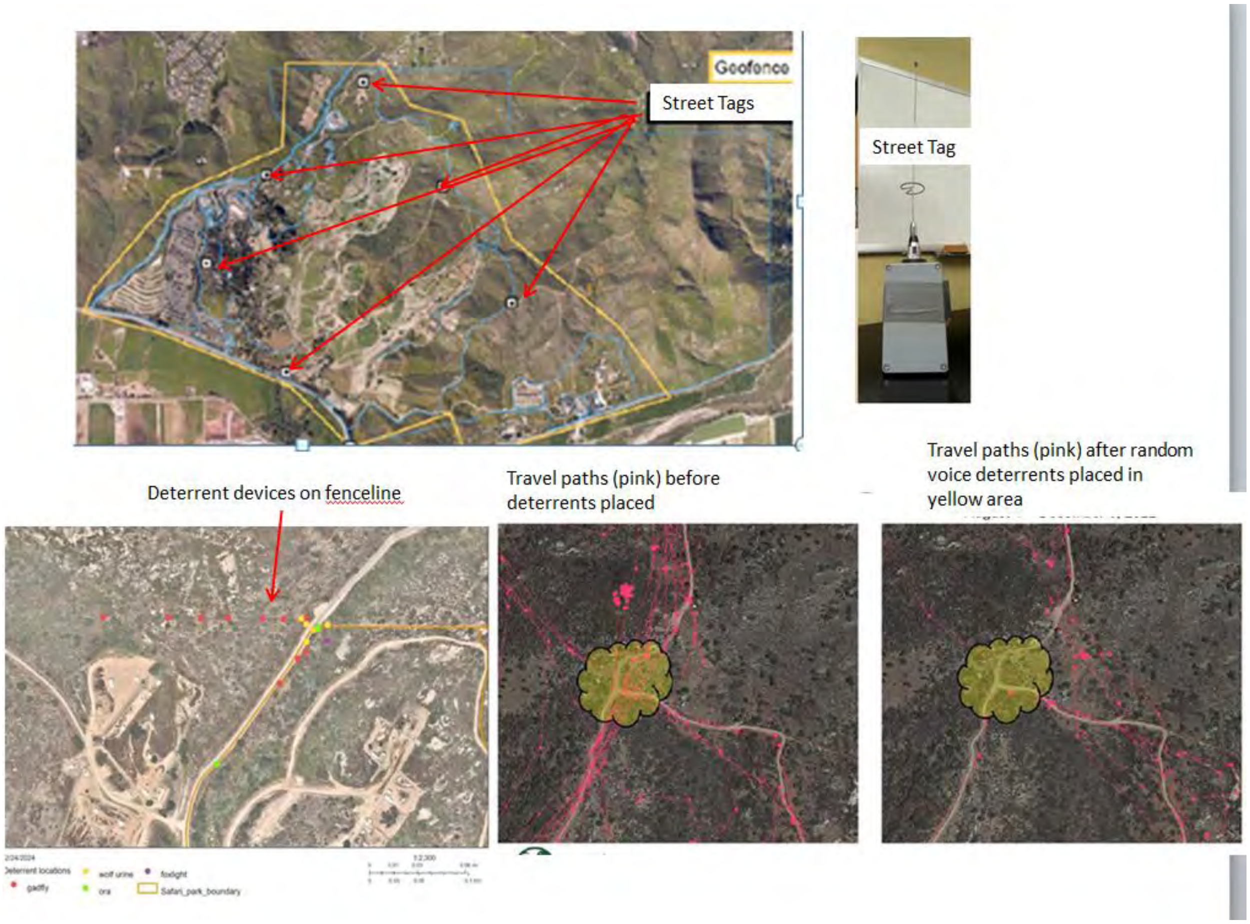

Figure 6. Locations where Street tags and geofence were utilized, deterrent devices placed on fenceline, and deterrent random voice devices placed in travel paths.

M338:

In the case of another site, the depredating individual (M338) was captured and collared and the owner counseled by CDFW and the UCD team to securely house their animals at night. M338 returned to the site the following night and because the owner had not instituted secure housing or deterrents another depredation occurred. After that, another site visit by CDFW resulted in the owner securing the animals at night which prevented further depredation at that site. A presentation to the local community also raised awareness and likely increased protections at other farms. No other depredations have occurred by M338 or other mountain lions in that immediate area since then to our knowledge.

M32:

In a case where an emu in an open corral was killed, the mountain lion (M32, a mountain lion collared approximately 10 years earlier as a juvenile but whose collar had dropped earlier as scheduled) was re-collared and released. The owner instituted additional lighting where he had smaller birds in covered pens. M32 did return to the site 3 days later and did not depredate any smaller birds, so the increased lighting could not be judged as successful or unsuccessful with certainty – we judged this to be partial success for lighting. Unfortunately a month later he depredated at a nearby location where no devices or adequate husbandry were in place and was killed.

M108:
In this case, the mountain lion (M108) had killed a sheep in an open pen and was captured and collared the following night when he returned. The owner was counseled by CDFW and UCD personnel but was unable or unwilling to alter his husbandry except to add a large longhorn bull to the pen with his sheep. Though M108 remained in the general area he did not return to the site and depredate again until the bull was taken out of the sheep pen to be allowed to graze in another area. At that point M108 depredated again and was recaptured and euthanized by the CDFW team. This was deemed a success for use of a guard animal, but a failure of education alone since the owner did not otherwise improve his housing,

In device testing at additional depredation sites where the offending mountain lions were not collared:

One mountain lion had depredated goats in an open pen and the UCD team visited and the remaining goats were confined in secure housing. The UCD team placed multiple Foxlights around the pen where the depredation had occurred to assess the animal's response. When the mountain lion returned it hesitated for a period and then left when it encountered the Foxlights, but subsequently overcame hesitation and walked past a Foxlight to re-enter the pen where the depredation had occurred (Figure 7). Nevertheless the education provided and the improved housing of the remaining animals did prevent further depredations. Education was deemed successful but Foxlights unsuccessful in this case.

Mountain lion sees Foxlight on approach to pen

Mountain lion retreats

Mountain lion returns the following night and walks past Foxlight on fence to enter pen

Figure 7. Test of multiple Foxlights at depredation site.

In another case, a mountain lion had depredated house cats left outside at night and the UCD team visited and provided education. This prompted the owner to start bringing the remaining cats in at night. The owner did not want any sound emitting devices placed near his house so a motion triggered security light was installed on the house and several Mr. Beams motion-triggered security lights on flashing mode were deployed in the yard and near a game trail next to the house. A mountain lion subsequently used the game trail near the house despite the extra lighting. Education was deemed successful in this case but motion-triggered lights unsuccessful.

At another site where a goat was depredated in an open pen, an un-collared mountain lion did not reenter the pen with the remaining goat after encountering two Gadfly units twice in relatively short succession. Blinding material had also been placed on the fencing of the pen so that the animal could not see where it would land if it jumped the fence (Figure 8). The mountain lion did not return that night. This was deemed a successful test. However, the owners did not institute bringing the goats into more secure housing or fully deploy shielding and Gadflys and lost another goat to depredation 1-2 weeks later. So education was deemed unsuccessful in this case.

Mountain lion approaching pen with 2 Gadflys and plastic sheeting on fence to block lion's view of where it would land if it jumped the fence

Gadfly going off

Mountain lion fleeing

Figure 8. Test of Gadflys combined with blinding material on fence.

At another site where blinding material alone was deployed around a pen where a goat depredation had occurred, and other goats were still present but in a secure cage inside the pen the following night. No re-entry by the mountain lion occurred based on tracks. However, it was not clear from the cameras deployed whether the animal had returned to the outside of the pen or not, and no tracks were found. This test was not classified as successful or unsuccessful.

At another site, our Gadfly units were deployed by a UC Extension collaborator on a depredated calf that was left in the field where it had been killed and fed on by a female mountain lion and two large kittens. When the family group returned the following night, the Gadfly frightened away the kittens but the female fed on the calf again despite the Gadflys going off. This was deemed a partial success.

At another site a depredation had occurred due to a mountain lion gaining entry to a barn under a small opening at the bottom of a gate. After a site visit by the UCD team the gate was repaired. A Foxlight was placed near the barn, and Predator Guard units placed on each of the gates into the barn pens. The mountain lion did return and did not approach the gates but did jump onto the low roof of the barn at the end away from the Foxlight. It walked near the gates with the Predator Guards but did attempt to get in any of them. After failing to enter from the roof the mountain lion left and did not return.

Testing at artificial bait sites, trap sites, and travel paths in wild habitat.

This mode of testing occurred on 8 individual mountain lions on 17 occasions. Devices tested included Wasatch calls playing human voices or other sounds randomly, Gadfly units, Wasatch units and Gadfly units combined, and Campark TC17 Cellular Trail Cameras.

Devices were placed near artificial bait stations where collared male mountain lions were feeding (n=3 encounters; Figure 9), travel paths typically used by mountain lions (n=12 encounters; Figure 10), and trap stations (n=1 encounter; Figure 11). Devices were successful in deterring or causing deviation of animals from their travel path in 87.5% (14/16) encounters. We consider one other occasion to be partially successful since the mountain lion visited the site again within 24 hours. Interestingly, one of the successful encounters involved an uncollared male that reversed course on a trail after encountering a Wasatch call playing a mountain lion whistle – a sound generally assumed to be attractive rather than repelling (Figure 9). This indicates that the effects of deterrents in some cases may be due to the unexpected nature of the sound and/or light versus its exact nature.

Figure 9. M316 approaching an artificial bait station with Margo Gadfly device on tree.

Figure 10. M332 looking at the Campark camera deterrence device prior to leave the trap site.

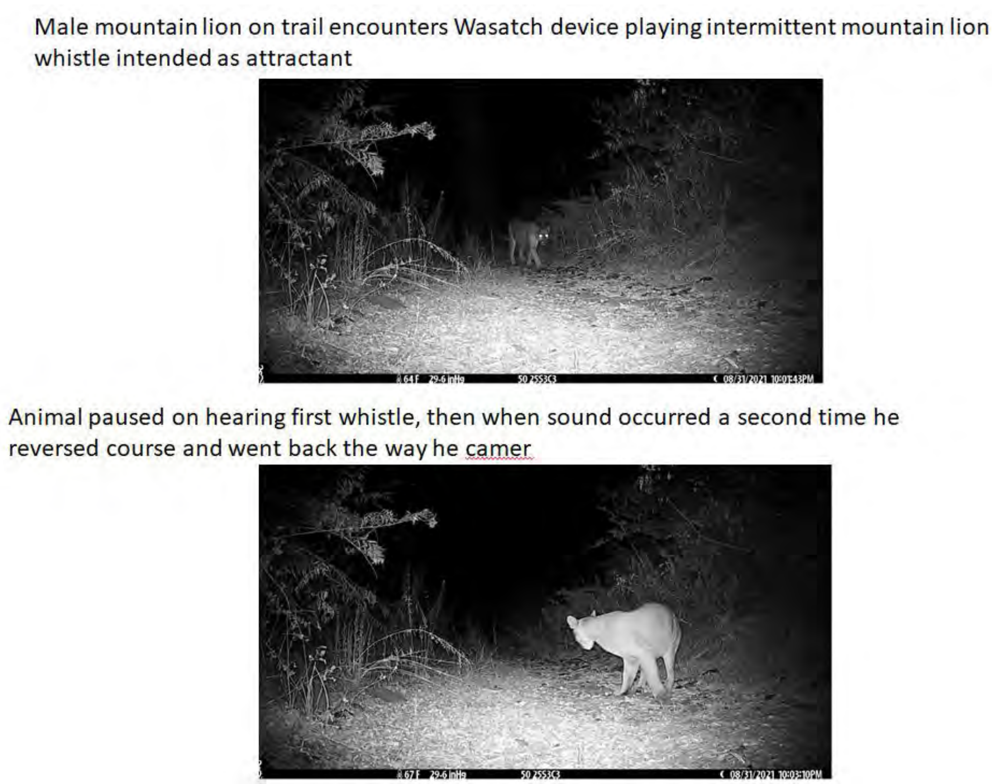

Figure 11. Mountain lion encountering a Wasatch device playing a lion whistle on a trail.

In those cases when the deterrence device was considered ineffective, the behavior of the mountain lion showed indifference or curiosity. In one instance, M321 approached the device

(Margo Gadfly combined with human voice recordings) sniffed it and did not flee the area. This emphasizes the importance of understanding the capabilities of the device being used.

In total, we recorded success of failure of deterrent devices or strategies on 30 occasions (depredation sites, trails, bait sites, trap sites) involving 19 mountain lions (10 M, 5 F, 4 Unknown gender). We could identify 11 of the mountain lions involved (8 males and 3 females) thanks to collaring efforts carried out by our research team.

From all the events that involved Margo Gadfly® (Margo Gadfly® alone or in combination with human voice recordings, n=12), we considered it was effective in 66.6% of the cases (8/12). Wasatch calls® alone or in combination with Gadfly) were effective in 61.5% of the cases (8/13). Campark TC17® was effective in the only instance we could try it on.

As another point of information that may inform strategies of livestock owners to deter mountain lions, our GPS data was recently utilized in an analysis of mountain lion movement and habitat use in relation to light sources on the ground (Barrientos et al. 2023). That analysis indicated that point source light alone on the landscape reduces the likelihood of mountain lion use of habitat and travel through an area. Though brightly lighted livestock pens and approaches to those pens may contribute to overall light pollution in an area, and could be detrimental to some other wildlife species, it could be useful as a tool to prevent depredation by animals like mountain lions that depend on stealth. Likewise, clearing brush and other vegetation from the areas around livestock pens could be beneficial for the same reason of allowing the prey animals to be alerted to the presence of a mountain lion.

We also had the opportunity to test one device (Campark TC17 Cellular Trail Camera®) on artificial bait stations for mountain lions on nine occasions where other species that may predate livestock found the bait and began feeding (black bear, n=3; and coyote, n=6). The device was successful in deterring coyotes in 83.3% (n=5). A single case occurred where a coyote encountered a Gadfly device at a depredation site and it also fled. Black bears were deterred by the Campark cell camera and left in all cases. See further details below.

Coyote events.

Although this species is not the target species of the study, we opportunistically recorded all events involving coyotes since they also cause livestock losses and our testing may aid in the management of the species. Opportunistic testing took place at our artificial bait sites, intended to attract mountain lions prior to a cage-trap capture attempt.

We registered six cases involving coyotes at our bait sites using Campark TC17 cell camera®. We considered the device effective in 83.3% of the cases (n =5). In one case, a coyote did not react to the device and kept feeding on the carcass after habituation to the sounds (Figure 12). In another instance, a coyote came back to the bait station five days later, but it fled when the device turned on. In four cases, human voice plus clapping was enough to deter the coyote from the carcass, in two instances we used conspecific howling and puma vocalizations, respectively, both effective in deterring the coyotes from feeding on the bait.

Figure 12. Coyote feeding on a bait station (white triangle).

Black bear events.

We also tested the Campark TC17 cell camera on black bears that fed on artificial bait stations (n=3). On two occasions a female with cubs was present at the site. The device was effective in deterring the bears in all instances, though one female responded aggressively to the voice from the camera, then led her cubs away (Figure 13). Later she came back to drag the carcass away from the deterrent site.

Figure 13. Female bear exploring the Campark TC17 cell camera before feeding with cubs at an artificial bait station.

Discussion.

Deterrence devices have proven to be effective mitigation tools in mountain lion-livestock conflict (Ohrens et al., 2019; Guerisoli et al., 2021). In our literature search, non-lethal deterrents used in mountain lions include: guard dogs, aversive conditioning, audio and visual deterrents. All non-lethal deterrent evaluations except aversive conditioning (Alldredge et al., 2019) came from South America, and they all agree on the benefits that they provide in reducing livestock depredations (Gonzalez et al., 2012; Zarco-González and Monroy-Vilchis, 2014; Ohrens et al., 2019; Guerisoli et al., 2021). However, the quality of the research designs and subsequent findings varied considerably among studies, adding a certain level of ambiguity to the effectiveness of such devices (Kertson et al., 2022). On the other hand, one of the strengths of those studies lay in the engagement of the community experiencing the conflicts while applying/evaluating non-lethal treatments, highlighting the importance of connecting with local citizens to build trust among parties (Kertson et al., 2022). We consider outreach also fundamental during our efforts in this matter in California.

Auditory and visual deterrents applied in our preliminary study are similar to those found in the literature. Lights, sirens, human recordings, and/or human noises have also been described to be successful in dealing with mountain lion-livestock conflicts (Zarco-González and Monroy-Vilchis, 2014; Ohrens et al., 2019; Guerisoli et al., 2021). One of the novelties of our study is the inclusion of a cell camera that provides video and audio at operator option in real-time, so we can modulate the level of the "human" interaction while trying to deter the mountain lion. Previous research that tested human recordings at mountain lion feeding sites showed that mountain lions fled more frequently, took longer to return, and reduced their overall feeding time by more than half in response to hearing humans (Smith et al., 2017). These results suggest the potential efficacy that this tool may have in deterring mountain lions. However, at this time, we don't have enough occasions to infer the level of effectiveness of this device. We will increase our efforts in applying this tool throughout all our research sites.

We also found in the literature that the successful use of auditory deterrents in mountain lions came from non-commercial (i.e., no marketed available) deterrents (e.g., noises reproduced by a 100-W loudspeaker connected to a sound amplifier and powered by a nine-cell lead–acid battery, Zarco-González and Monroy-Vilchis, 2014). In this study we primarily employed commercially available deterrents so we can advise the purchase of the device to livestock producers/livestock owners in our study area, facilitating the use of the deterrent in all types of livestock operations promptly if a conflict is identified.

Future directions regarding our efforts in deterrence device testing include developing a custom device called an Ora with optional motion and light sensors, programmable sounds, and louder speakers, as well as testing other options that are being utilized or tested by other researchers. These will potentially include the use of motion in deterrent devices, automating of pen gates and feeding bins, new methods of distributing educational materials such as the previously mentioned 4-H curriculum, and other combinations.

Conclusions.

Although our sample size is limited and continuation of this task is advisable to infer more robust conclusions, our preliminary results indicate that some of the the mitigation tools and strategies tested here are effective in the majority of cases. We were able to successfully deter mountain lions, as well as coyotes and bears, in a variety of scenarios. The most promising tools are those devices that include noises (e.g., sirens) and human voices (e.g., recordings and real-time human noises especially when very loud). Overall, initial responses were most pronounced to the Gadfly motion activated units, and the Campark trail cameras, though responses were not the same for all animals, and some returned and triggered the units multiple times. In two cases the animals ignored the device after the first exposure. In other cases where sounds were unique such as voices and even a lion whistle from a predator call, the response of the animals varied between retreat and approach out of curiosity. This emphasizes that generalizations are not completely possible due to each animal's individual personality or characteristics even within a species.

We recommend pairing the use of deterrents with local community outreach and education to ensure a successful coexistence with mountain lions in human-dominated landscapes, reducing livestock depredations due to mountain lions as well as mountain lion mortality due to conflict with humans.

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ATTACHMENT 4

Title
Response of Mountain Lions to Hazing: Does Exposure to Dogs Result in Displacement?

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Response of Mountain Lions to Hazing: Does Exposure to Dogs Result in Displacement?

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ABSTRACT: Hazing has been advocated as a non-lethal solution to human-predator conflicts, but the efficacy of hazing is not well documented, especially for mountain lions. We conducted a study of mountain lions throughout the state of California during 2001-2021 to determine if hazing with dogs has potential for deterring mountain lions from returning to sites of conflict. We used data on 76 mountain lions captured and equipped with radio collars; 34 lions were exposed to barking dogs during capture, then further exposed to barking dogs upon release (dog-exposed), and 42 lions were captured and released without exposure to dogs (control). We found that distance from the capture site was similar for dog-exposed and control mountain lions through 45 days following release, except for a slightly greater distance for dog-exposed lion shortly after release. Almost all mountain lions (94-98%) returned to within 6 km of the capture site during the 45 days following release, and most (77-88%) returned to within 1 km, with no significant difference between dog-exposed and control mountain lions. Therefore, aside from a modest short-term effect, we did not find evidence that hazing with dogs is an effective method for displacing mountain lions from a conflict location.

KEY WORDS: aversive conditioning, dogs, GPS tracking, hazing, mountain lion, non-lethal management, *Puma concolor*

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INTRODUCTION

Conflicts between humans and predators are an important wildlife issue today and arise primarily from depredation on livestock and threats to human safety (van Eeden et al. 2018, Petracca et al. 2019). Depredation incidents can have substantial financial repercussions, costing in the millions of dollars annually (U. S. Department of Agriculture 2010, U. S. Department of Agriculture 2011). Predators can also attack humans; each year an average of 539 people are injured and 0.8 people killed by mammalian predators in the United States (Conover 2019). For example, mountain lions (*Puma concolor*) attacked 74 people and killed 11 people in 10 states in the western United States between 1924 and 2018 (Wang et al. 2019). These attacks may be a result of increased human activity and reduction and fragmentation of suitable mountain lion habitat (Torres et al. 1996).

Lethal removal of offending animals has historically been the primary way of managing depredation (Pierce and Bleich 2003). However, the public is increasingly opposed to lethal predator management (Swan et al. 2017, Sampson and Van Patter 2020). Furthermore, lethal control can impact the viability of local predator populations (Cunningham et al. 2001). For example, in 2019, 73 mountain lions in California were killed under depredation permits (California Department of Fish and Wildlife 2020), and lethal control of mountain lions due to depredation incidents can be the primary source of mortality in non-hunted mountain lion populations (Vickers et al. 2015, Dellinger and Torres 2020, Nisi et al. 2022). Areas with high rates of lethal control may even become "mortality sinks" for some mountain lion populations (Cunningham et al. 2001).

Non-lethal approaches are increasingly used as an alternative to lethal control (Shivik 2004). For example, depredation of livestock may be reduced by modified husbandry practices such as housing animals at night, keeping livestock away from terrain used for hunting by predators, and employing livestock protection animals, including dogs, llamas, and donkeys, (Cunningham et al. 1999, Mazzolli et al. 2002, Ogada et al. 2003). Non-lethal depredation control methods also include transporting "problem" predators to locations away from areas of conflict. However, this method is controversial due to the potentially low survival of translocated predators (Ruth et al. 1998), or the possibility that they will return.

Hazing, which involves harassing wildlife, has been increasingly advocated as a non-lethal solution to human-predator conflicts (Brady 2016, Bonnell and Breck 2017). Hazing is a form of aversive conditioning that uses negative stimuli to induce the animal to move away from the location of conflict (Lackey et al. 2018, Young et al. 2019, Ogden 2021). Efforts to haze predators using loud noises, non-lethal projectiles, or chasing by humans as negative stimuli have produced inconsistent results. Some studies showed promising outcomes (Schirokauer and Boyd 1998, Gillen et al. 1994, Petracca et al. 2019), although the effect often was short-term (Leigh and Chamberlain 2008, Mazur 2010, Comeau 2013), whereas others showed little change in behavior or a mixed response (Beckmann et al. 2004, Rauer et al. 2003, Breck et al. 2017).

Chasing by dogs also has been explored as a negative stimulus to haze predators, especially bears (*Ursus* spp.). However, yet again, results are inconsistent. Some studies reported a substantial change in bear behavior (Honeyman 2008, Comeau 2013, Klip 2018), while others did not (Beckmann et al. 2004, Leigh and Chamberlain 2008).

Mountain lions often prey upon large mammals, including domestic livestock (Pierce and Bleich 2003). In many cases when humans are attacked, the mountain lions treat humans as prey (Pierce and Bleich 2003; Wang et al. 2019). A decrease in suitable habitat for mountain lions due to urbanization and cultivated agriculture creates more potential for human-mountain lion interactions, especially in rangeland agriculture (Beier 1991, Alldredge et al. 2019), and depredation of livestock and issues of human safety will likely increase as humans encroach further into mountain lion habitats (Pierce and Bleich 2003). With increasing public resistance to lethal control of predators (Swan et al. 2017, Sampson and Van Patter 2020), non-lethal alternatives are needed. Hazing with dogs has shown potential for mitigating conflicts involving bears (VerCauteren et al. 2013, Lackey et al. 2018), and this approach has been attempted for mountain lions (McBride et al. 2005); however, the results, although promising, were constrained by a limited sample size.

Our objective for this study was to determine if hazing mountain lions with dogs has potential for reducing human-mountain lion conflicts by deterring mountain lions from returning to sites of conflict. We hypothesized that if hazing with dogs is effective, mountain lions exposed to barking dogs would be displaced a greater distance and would be less likely to return than mountain lions that had not been exposed to dogs.

METHODS

The appropriate design for a study such as ours would be to haze mountain lions with dogs at the location of conflict, then compare their responses to those of other lions that were identified at the location of conflict but not hazed. Such a design is logistically challenging, so instead we capitalized on the hazing effect of dogs when used to tree mountain lions for capture, and we included an additional hazing treatment of restrained, barking dogs (McBride et al. 2005) when the lion was released. We obtained radiolocation data on mountain lions from multiple telemetry studies conducted in 11 counties in northern, central, and southern California across different habitats and seasons over the span of 20 years (2001-2021. In all of the included studies, mountain lions were captured, processed, and released using either of 2 methods, 1 that involved dogs (dog-exposed) and 1 that did not (control). Mountain lions that were dog-exposed were captured by being chased and treed by trained dogs. The dogs were mostly bluetick coonhounds working in teams of 4-8. After being anesthetized and processed, the mountain lion was barked at, but not chased, by restrained dogs again after it returned to consciousness and was released. The control mountain lions experienced no exposure to dogs; they were caught in box traps baited with deer meat, anesthetized and processed in the same way as dog-exposed mountain lions, then released. For each captured mountain lion, sex was determined, identifying tags or tattoos were recorded, and age class (subadult or adult) was estimated based on gum recession, tooth wear, and body size (Ashman et al. 1983, Laundre et al. 2000). All mountain lions were fitted with a GPS radio collar and were released at their points of capture. A variety of radio collar types was used, depending on the time period. Radio collars were programmed to record GPS locations at least once per day.

To compare post-release movements of dog-exposed and control mountain lions, we calculated the distance of each mountain lion from its capture site each day through day 10, then every 5 days through day 45 following release; the first 10 days represented the short-term response, and days 15-45 represented the longer-term response. We chose a duration of 45 days because radio collar loss or malfunction reduced our sample size after that time. The number of GPS locations recorded per day varied greatly, both among mountain lions and among days for an individual mountain lion. GPS locations were rarified to a fix rate of 1 location per mountain lion per day using a random selection process. Mountain lions that lacked a GPS location for a given day were excluded from calculations for that day. Mountain lions with more than 2 days of missing location data were excluded from analysis.

To calculate the likelihood of return to the capture site, we considered a mountain lion to have returned if it remained or came back to within either of 2 distances, 1 km or 6 km, from their capture site at any time during days 3 through 45 following release. The 1-km distance criterion approximated the radius (0.7 km) of the average size of a ranch or farm in California (141 ha; U. S. Department of Agriculture 2017), assuming a circular shape, and represents the likelihood of return to a location of conflict. The 6-km distance approximated the average straight-line distance moved per day by a mountain lion in California (6.4 km; Beier et al. 1995) and reflected movement ecology of mountain lions. A 2-day delay was allowed for mountain lions to exit the vicinity of their capture site and resume normal activities; given a 6.4-km daily movement rate (Beier et al. 1995), 2 days would be required for a mountain lion to exceed the greater of our 2 distance criteria (6 km). We compared proportions of dog-exposed and control mountain lions that returned using a chi-square test of independence.

Predator response to hazing might be influenced by age, sex, and prior exposure to humans (Mazur 2010, Petracca et al. 2019, Young et al. 2019), in addition to hazing treatment. We used Generalized Linear Models (GLM) with a Gaussian distribution to determine the association of these factors with the response of mountain lions to exposure to dogs. We performed 2 analyses, 1 for each of the 6-km and 1-km distance criteria. For each analysis, the response variable was the frequency of return, calculated as the number of days from day 3 through day 45 that a mountain lion was within either 1 km or 6 km of its capture site. Sex, age class, and treatment type (dog-exposed or control) were obtained from capture records. Prior exposure to humans was approximated using distance from the capture site to nearest urbanization, which was calculated using the measure feature on ArcGIS after plotting capture locations on urbanization layers (ESRI 2020). The continuous independent variables were centered and scaled. Generalized linear models using all possible combinations of variables were compared using Akaike Information Criteria (AIC). We included all covariates because available information on potential effects of sex, age, and prior exposure to humans was too sparse to allow generation of a priori expectations. AICc was used instead of AIC to allow for correction for the low ratio of the sample size versus the number of parameters. The model with the lowest AICc was the top model. All models with a ΔAICc ≤2 when compared with the top model were considered to have the same explanatory power. The AICc of the different models was calculated in the package AICcmodavg in R-Studio version 1.3.1093 (R-Studio 2020). The variable coefficients and confidence intervals across the top models were plotted next to each other. The independent variable coefficient estimates, confidence intervals, and Cohen's *d* were then reported using the highest ranked model that included that variable for the relevant distance criterion. Cohen's *d* is a standardized effect size which represents biological magnitude, where *d* = 0.2-0.5 is a small effect size, 0.5-0.8 is a medium effect size, and 0.8 or greater is a large effect size. The larger the effect size, the greater practical significance the difference between the groups has. The coefficients and confidence intervals of statistically significant continuous independent variables were then individually plotted against the dependent variable, using a centered and scaled x-axis since the coefficient estimates were generated using centered and scaled independent variable distributions. Variable coefficients were not statistically significant if they had a high p-value ($P > 0.05$) or a 95% confidence interval that encompassed zero.

RESULTS

Our study totaled 76 mountain lions, 34 that were dog-exposed (12 males, 22 females) and 42 that were not (23 males, 19 females). Mean distance from the capture site over time showed a similar pattern for both dog-exposed and control mountain lions, with an increase in distance until about day 5, when mean distances stabilized at 7-10 km thereafter through day 45 (Figure 1). A possible exception was during days 2-4 after release, when mean distance moved by dog-exposed mountain lions was 10-22% greater than that for control mountain lions. However, confidence intervals overlapped extensively, suggesting the difference was not statistically significant.

For the 1-km radius designation, the proportion of dog-exposed mountain lions that returned to the capture site (76.5%) did not differ ($X^2 = 1.79$, $P = 0.18$) from the proportion of control mountain lions that returned (88.1%). Similarly, for the 6-km radius designation, the proportion of dog-exposed mountain lions that returned (94.1%) did not differ ($X^2 = 0.61$, $P = 0.44$) from the proportion of control mountain lions that returned (97.6%).

The GLM analysis yielded 2 models for the 6-km return distance and 3 models for the 1-km return distance that had a ΔAICc ≤2 from the lowest AICc value, indicating they have explanatory powers that are statistically the same as the highest ranked model for each distance. For the 6-km return distance, the top-ranked model indicated that the number of days returned was influenced by sex and distance from urbanization. The next-ranked model (ΔAICc = 0.89) indicated that the number of days returned was influenced by sex, distance from urbanization, and age class. However, age class was not a statistically significant covariate (4.52, 95% CI = -3.13 – 12.18, $P = 0.25$, Cohen's $d = -1.92$; Figure 2). Using the highest-ranked model, both the sex being male and distance to urbanization (Figure 3) had a negative relationship with the number of days returned (Sex: -9.25, 95% CI = -14.59 – -3.91, $P = 0.001$, Cohen's $d = -1.29$; Distance from urbanization: -3.83, 95% CI = -6.51 – -1.15, $P = 0.006$, Cohen's $d = -1.37$; Figure 3).

For the 1-km return distance, the top-ranked model indicated that the number of days returned was influenced by sex and distance from urbanization. The second-best model (ΔAICc = 0.83) indicated that the number of days returned was influenced by sex, distance from urbanization, and treatment type (dog-exposed versus control).

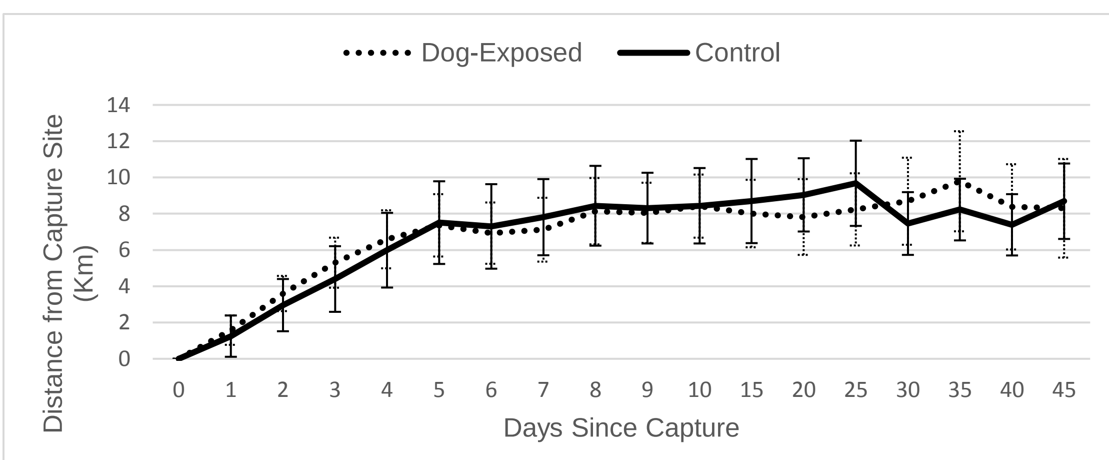

Figure 1. Mean distance from the capture site for dog-exposed and control mountain lions (*Puma concolor*) in California, from 2001-2021, at 1-day intervals up to day 10, and at 5-day intervals thereafter; vertical bars are 95% confidence intervals.

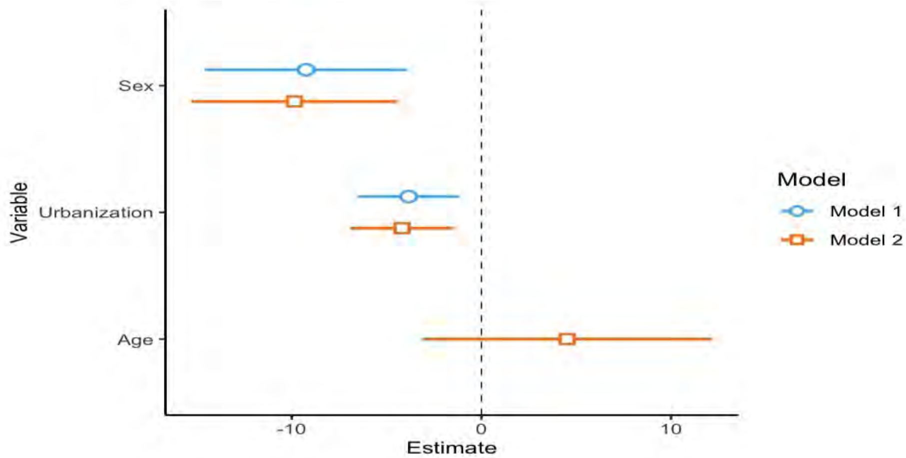

Figure 2. Coefficient estimates based on the top models according to AICc and 95% confidence intervals for the 2 best models for explaining the number of days returned by mountain lions (*Puma concolor*) in California, from 2001-2021, to within a 6-km distance of their capture sites; urbanization refers to the variable of distance from urbanization and age refers to the variable of age class.

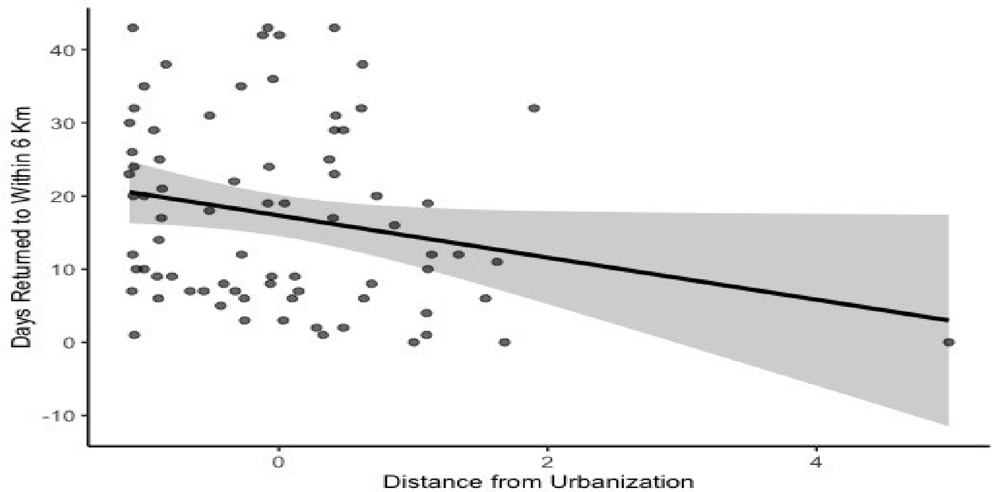

Figure 3. Relation between distance from urbanization and number of days that mountain lions (*Puma concolor*) in California, from 2001-2021, have returned to within a 6-km distance of their capture sites, with shaded areas representing 95% confidence intervals.

However, the variable of treatment type was not statistically significant, though it did indicate that dog-exposed animals took longer to return (-1.71, 95% CI = -4.55 – 1.12, *P* = 0.24, Cohen's *d* = -1.29; Figure 4). The third-ranked model (ΔAICc=1.91) indicated that the number of days returned was influenced by sex, distance from urbanization, and age class. However, the covariate of age class was not statistically significant (-1.23, 95% CI = -5.21 – 2.75, *P* = 0.55, Cohen's *d* = -1.36; Figure 4). Using the top-ranked model, both the sex being male and distance from urbanization (Figure 5) had a negative relationship with the number of days returned (Sex: -4.56, 95% CI = -7.31 – -1.8, *P* = 0.002, Cohen's *d* = -1.29; Distance from urbanization: -1.95, 95% CI = -3.34 – -0.57, *P* = 0.007, Cohen's *d* = -1.37). Visual inspection of the analysis for distance from urbanization revealed an outlier, possibly a dispersing mountain lion (Figures 3 and 5); when the outlier was removed, the negative coefficient estimates for distance from urbanization were weakened for both the 1-km and 6-km distances but did not change which variables had statistically significant coefficients.

DISCUSSION

Hazing has been increasingly advocated as a nonlethal solution for resolving human-predator conflicts, but studies evaluating the effectiveness of hazing have produced inconsistent results, including those investigating the use of dogs for hazing. In the case of mountain lions, hazing with dogs has been implemented to manage human-mountain lion conflicts (Elbroch 2020), but efficacy is unknown. Limited evidence suggests that mountain lions might show an aversive reaction to dogs since capturing mountain lions using dogs resulted in a short-term shift in mountain lion locations away from the

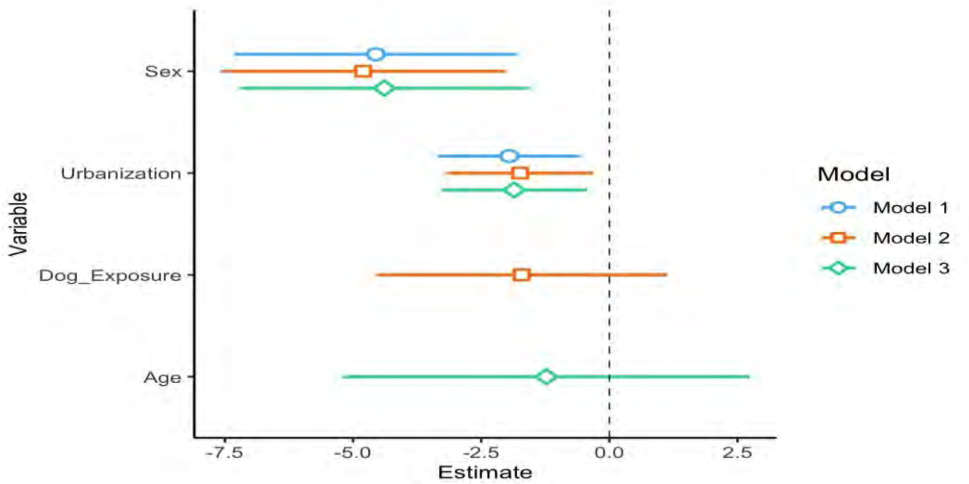

Figure 4. Coefficient estimates based on the top models according to AICc and 95% confidence intervals for the 3 best models for explaining the number of days returned by mountain lions (*Puma concolor*) in California, from 2001-2021, to within a 1-km distance of their capture sites; urbanization refers to the variable of distance from urbanization, age refers to the variable of age class, and dog-exposure refers to the variable of treatment type.

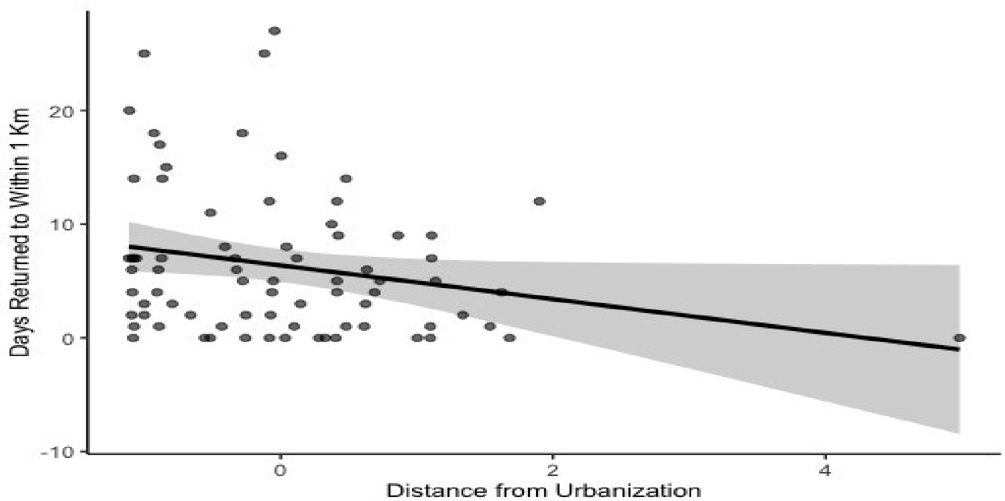

Figure 5. Relation between distance from urbanization and number of days that mountain lions (*Puma concolor*) have returned to within a 1-km distance of their capture sites in California, from 2001-2021, with shaded areas representing 95% confidence intervals.

capture site (Seidensticker et al. 1970), and livestock protection dogs appeared effective in reducing mountain lion predation on domestic livestock (Gonzalez et al. 2012). Moreover, an aversive conditioning attempt with 4 Florida panthers (*Puma concolor*) that involved treeing with dogs, followed by broadcasting sound recordings of baying dogs, appeared to impart some degree of avoidance (McBride et al. 2005).

Nonetheless, we did not find that mountain lions exposed to dogs were displaced farther from the capture site than were mountain lions that were not exposed to dogs. Likewise, dog-exposed mountain lions were not less likely to return to the vicinity of the capture site, at the scale of the presumed location of conflict (1 km) or the scale of mountain lion daily movement patterns (6 km). We did find evidence, though not statistically significant, of a slightly greater displacement of dog-exposed mountain lions the first few days after release, which is consistent with previous work that found a short-term shift in location by mountain lions after being captured using dogs (Seidensticker et al. 1970). Hence, our results are similar to those of studies that reported the lack of a substantial change in behavior of black bears (*U. americanus*) following hazing by dogs at sites of conflict; hazed bears moved somewhat farther from the site than unhazed bears, or delayed their return slightly longer, but almost all hazed bears eventually returned (Beckmann et al. 2004, Leigh and Chamberlain 2008).

Age has influenced the response in other studies of predator hazing; yearling black bears and subadult African lions (*Panthera leo*) were less responsive to hazing than were older animals (Mazur 2010, Petracca et al. 2019). However, we did not find a significant effect of age class on the number of days that mountain lions returned to the capture site. Sex can have an effect as well; adult male African lions were more responsive to hazing than were adult females (Petracca et al. 2019). We found that male mountain lions returned to their capture sites less often than did females. However, because exposure to dogs did not have a significant effect, the cause likely was sex-specific patterns of home range use; male home ranges are larger than those of females (Pierce and Bleich 2003), presumably reducing the number of times a male might be located in a specific area. Prior exposure to humans affected hazing efficacy in black bears and coyotes (*Canis latrans*); those animals conditioned to humans were less responsive to hazing (Mazur et al. 2010, Young et al. 2019). Similarly, we found that mountain lions captured closer to urbanized areas returned more often following release, perhaps because these mountain lions had some degree of exposure to humans.

Our study suffered from an important limitation; we did not compare responses of hazed versus unhazed mountain lions, but instead we capitalized on the hazing effect of dogs used to capture lions, coupled with exposure to barking dogs upon release. The capture and handling experience alone has been considered an aversive agent for black bears (Clark et al. 2002), and the same may be true for mountain lions. The mean distance from the capture site of all mountain lions after 5 days (ca. 7-10 km), exposed to dogs or not, exceeded the mean daily movement distance of mountain lions (6.4 km; Beier et al. 1995). Moreover, this displacement distance was similar to the 8.4-km radius of the size of an average mountain lion home range in California (220 km^2, sexes combined; Pierce and Bleich 2003), assuming a circular shape. These comparisons suggest a substantial displacement from the capture site, even if the mountain lions still returned to the vicinity of the site. Mountain lions show a stronger negative reaction to humans than to dogs (Suraci et al. 2019), and any effect of hazing in our study might be related more to capture stress and proximity to humans rather than to the effect of dogs.

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ATTACHMENT 5

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In Lion Country

What is making cougars in Southern California seem so bold?

By Sylvia Wright

[Please note that paragraph seven contains an inaccuracy. Iris Kenna was not the first person killed by a cougar in California in 80 years. Her death on Dec. 10, 1994, was preceded by that of UC Davis alumna Barbara Barsalou Schoener '75, who was killed nearly eight months earlier.]

When they left the dead deer in the pickup bed on the night of March 5, UC Davis researchers Ken Logan and Linda Sweanor weren't too concerned about leaving the carcass unsecured in cougar country. The 90-pound doe, after all, was four feet off the ground, surrounded by the 16-inch-high truck bed and stiff with death and cold. So they merely joked that one of them should put on night-vision goggles and stand guard. Then they went to bed.

Partners in research and marriage, Logan and Sweanor had spent their careers studying cougars. They were the principal investigators on the most extensive cougar study ever done, in New Mexico's San Andres Mountains in 1985–95. Sweanor's thesis for her 1990 master's degree at the University of Idaho was on cougar social organization; Logan's doctoral dissertation there was on cougar ecology. So, last January, when they settled into rugged Cuyamaca Rancho State Park above San Diego to lead a new UC Davis research project, they had studied cougars more intensively than anyone in the world.

Even so, the Cuyamaca cougars would show them something new.

Biologists began thinking of Cuyamaca's cougars as a breed apart in the late 1980s, when a growing number of visitors reported encounters with cats that were unusually bold. "Typically, lions stay away from people," said Cuyamaca park superintendent Jim Burke. "In 25 years in other California state parks, I had only seen one. But when I got to Cuyamaca, it was pretty common that people were seeing mountain lions. It's a whole different world."

Cuyamaca's woods and meadows are a deer paradise, and deer are the primary prey of cougars (also known as mountain lions, catamounts and pumas). Cuyamaca is also a human paradise; just 40 minutes from metropolitan San Diego, it has 120 miles of trails for hiking, biking and horseback riding and 416,000 visitors annually.

By the 1990s, it seemed like deer, lions and people were often traveling the same trails. Park records show that from 1993 to 2000, visitors reported seeing mountain lions 201 times. Sixteen times, the lion behaved in a way that rangers and game wardens deemed threatening to human safety. Nine times, that behavior led officials to kill the lions. In September 1993 and January 1994, officials took the extraordinary action of closing the entire park to visitors while a potentially dangerous cougar was tracked down. That meant emptying out campgrounds, clearing hikers off the trails and turning away new park visitors.

Then, on Dec. 10, 1994, the worst occurred—a cougar killed school counselor Iris Kenna as she hiked alone near Cuyamaca Peak. It was the first time a cougar had killed a person in California in 80 years. Game warden Lt. Bob Turner of the California Department of Fish and Game watched the site where Kenna's body was found; when a lion arrived there later the same day, Turner shot it. Tests showed it was the animal that had killed Kenna.

In January 1996, a mountain lion charged a woman on horseback in the park. When Fish and Game wardens arrived at that scene a few hours later to investigate, a mountain lion came toward them. Again, Turner had to kill the animal. In 1998, Turner shot four lions in two days after they threatened campers and their dogs at the park's Los Vaqueros horse camp.

In the meantime, just a few miles to the east, researchers from the UC Davis School of Veterinary Medicine were conducting what seemed to be an unrelated study. There, in Anza-Borrego Desert State Park, an endangered population of fewer than 400 bighorn sheep was shrinking fast. Beginning in 1992, wildlife veterinarian and ecologist Walter Boyce, director of the UC Davis Wildlife Health Center, led the effort to find out why. Using novel investigative techniques, including DNA fingerprinting, Boyce and his graduate students discovered that disease was one key factor, but more important was predation: Of the 61 radio-collared sheep that died during the study, cougars killed 42.

"That was entirely unexpected," said Boyce. "We had assumed, based on all the available evidence, that infectious disease was to blame. But as soon as we began following the radio-collared animals, it became obvious that mountain lions were the major cause of death."

Relying heavily on the results of their research, one of Boyce's doctoral students, Esther Rubin, led the writing of the federal recovery plan for the sheep, which by that time numbered about 300. The plan was candid about the cougar issue. It said that if high levels of predation continued, it might be necessary to kill lions to help the bighorn survive. "But the ultimate goal of conservation efforts should be to establish a healthy ecosystem in which lion removal is not necessary," Boyce said. "If we were going to have both bighorn sheep and mountain lions in the Peninsular Ranges, we needed a much better understanding of lion ecology and predator-prey relationships."

Cuyamaca rangers were saying much the same thing about people and mountain lions in their park. "We just didn't have any information," Burke recalls. "We didn't even know how many lions were out there. We talked about it—wouldn't it be great to find out more about the lions and humans, to provide a safe place for both of them?"

For Boyce, when the cougar killed Iris Kenna in Cuyamaca, the two situations merged into one. "That really heightened my awareness that this wasn't a single-species issue or a single-location issue," Boyce said. "The public-safety component of cougar biology was the opposite side of the coin to the endangered-species component, bighorn sheep."

Now Boyce began to envision a new, larger study that would look at the situation long-term on a regional scale. He named it the Southern California Ecosystem Health Project and began the painstaking work of building political and financial support. His key allies were experts like Mark Jorgensen, a resource ecologist for California State Parks, who grew up in the Anza-Borrego Desert and returned from college to work for its preservation; husband and wife team Steve and Alison Torres, the biologists for the California Department of Fish and Game responsible for the management of sheep, mountain lions and deer in the entire state; and Esther Rubin, who had finished her Ph.D. program and was a conservation fellow studying bighorn sheep for the Zoological Society of San Diego.

The ecosystem study that Boyce and his colleagues envisioned was unprecedented. They wanted to concurrently examine the relationships of lions, humans, sheep—and deer, which seemed to be the factor that drew lions into close proximity with both sheep and people. Scientifically, there had never been a study that concurrently examined the relationships of three wildlife species and humans, with a goal of management recommendations for the welfare of all. Geographically, the study area would encompass more than 500 square miles in contiguous lands including Cuyamaca Rancho State Park, Anza-Borrego Desert State Park, Cleveland National Forest and other federal and state lands. Financially, the study would cost at least $1 million for the first three years.

Logistically, the researchers would need to put radio collars on as many deer, sheep and lions as they could catch. UC Davis would employ, besides Boyce, four biologists to work full time on the collaring, tracking and data-analysis elements of the project. Fish and Game would supply extensive support for the collaring and tracking, including helicopter time, hardware and expertise. State Parks would open its files on cougar encounters in the parks, help the UC Davis team survey human activities in the park and give the team wide latitude in capturing and tracking wildlife within park boundaries.

Lastly, there were the political aspects. For a creature that most Californians will never see, the mountain lion is remarkably charismatic. In 1990, Californians approved Proposition 117, banning cougar hunting. In 1996, even after cougar numbers had begun to rise, and the cats had killed Kenna in Cuyamaca and Barbara Schoener near Sacramento, voters again endorsed cougar protection. Yet hunting interests continued to lobby for lion management, while sheep advocates were nervously watching the lions eating away at the Peninsular Ranges bighorn population. In that political climate, Boyce feared the plan to study the lions might be seen as a threat to their protected status. As he worked to build support for the new study, Boyce stressed the importance of objective research: UC Davis intended, he said, "to get good science done, and make it available to wildlife managers and the public so it could be implemented into wise policy decisions to ensure public safety and the best stewardship of natural resources."

By mid-2000, the project was coming together. Boyce had amassed $1 million in cash and in-kind commitments—enough to carry the project for three of the 10 years he felt necessary. An anonymous Southern California conservationist donated $225,000; Mark Jorgensen committed $270,000 from State Parks; Fish and Game's Deer Herd Management Plan Implementation Project gave $220,000 and its Bighorn Sheep Management Plan committed $160,000 of funds it received from U.S. Fish and Wildlife Service; and the Zoological Society of San Diego agreed to cover the costs of Esther Rubin's research. "We were pooling our resources to address questions we're all interested in," said Steve Torres, chief of Fish and Game's Bighorn Sheep and Mountain Lion Conservation program.

With a plan and financing in hand, Boyce now had to find his lead cougar biologists, and he knew the two he wanted: Ken Logan and Linda Sweanor. But Logan and Sweanor were living in Moscow, Idaho, while Logan finished his Ph.D. dissertation on the 10-year San Andres cougar study. Boyce wasn't sure whether, having worked so long in the San Andres wilderness, the pair could be persuaded to come to urbanized San Diego County.

"The San Andres Mountains are one of the last remaining areas where cougar behavior is minimally influenced by people," Boyce explained. "For Ken and Linda, Cuyamaca was exactly the opposite: an area where cougars and people can't avoid each other." In the end, that was what won them over. "They know that cougar preservation has to involve people."

Sweanor, Logan and their 6-year-old son, Ori, moved into a cabin in Cuyamaca Rancho State Park in January. Field biologists Jim Bauer and Casey Lydon signed on as scientific aides, jointly employed by UC Davis and California Department of Fish and Game. Everyoneworking on the project attended a Fish and Game wildlife-capture refresher course. Then, on Jan. 23, Fish and Game biologist Randy Botta was trapping wild turkeys about 400 yards from the cabin when he found lion tracks. To Logan and Sweanor, the size of the pad prints suggested the cat was a male, and a big one. Backtracking, Sweanor found another set of tracks, smaller; it looked like the big male had a female friend in the neighborhood. The research team was elated, particularly Sweanor and Logan. "The biggest thrill was finally being back out in the field again, after being in front of a computer for two years, writing up the San Andres findings," Sweanor said. "It was just nice to be in lion country again."

After finding the tracks nearby, Sweanor and Logan realized that a lion might walk by and see Ori in his bedroom. Next day, Logan walked behind the cabin and saw lion tracks in the snow, five feet from the house. They closed Ori's bedroom curtains.

In the last week of February, six inches of snow fell at the cabin. Logan and Sweanor spent Feb. 23 and 24 working down the mountain with Botta, Boyce and other biologists, radio-collaring deer for the study. On the morning of Feb. 25, Sweanor stepped onto the cabin porch and discovered a cougar had walked under her floorboards in the night. A trail of big paw prints in the snow led directly up to the cabin, disappeared and emerged on the opposite side.

Logan tracked the big male for a mile to the park boundary. Then, confident it would be traveling by the cabin again soon, Logan returned home. He and Sweanor would try to catch and radio-collar this Cuyamaca regular. They would need bait; they asked the park rangers to get them a roadkill deer.

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Mountain lions are carnivores and will eat a wide range of animals. Their favorite food is deer, and they are supremely adapted for killing such large prey. Weighing 70 to 160 pounds and stretching 5 to 7 feet long from nose to tail tip, they are equal in size to most deer. Their short muzzles, long legs and powerful shoulders are heavily muscled for bringing down struggling animals.

Cuyamaca chief ranger Laura Itogawa called Sweanor and Logan late on March 5 with the location of a roadkill doe. "Better get it fast, before someone takes it home for dinner," Itogawa said. Around 10 p.m., Logan wrestled the carcass into the research project's Toyota Tacoma pickup; back at the cabin, he left the dead deer in the pickup bed, tailgate up. He and Sweanor made their jokes about guarding the carcass, then slept.

"The next morning, Ken went out to the truck at about 7," Sweanor recalled. "He came back in and said, 'Well, the carcass is gone.' My first thought was that, like Laura had said, someone had taken the deer for venison. And we went out there, and there was no deer—just two deer hair stuck on the side of the truck."

A cougar apparently had caught wind of the carcass, daringly jumped into the truck to investigate, and hauled the deer out of the truck bed and out of sight. It had carried the carcass so high off the ground that Logan and Sweanor had trouble picking up a drag trail on their hands and knees. When they finally did pick one up, it led them the length of two football fields to a cache in dense chaparral.

"It made us both laugh," Sweanor said. "It was amazing to see that at 10 o'clock one night that carcass was in the back of the truck and by 7 the next morning it was gone, and to have a lion actually find it and take it away so cleanly. We'd never worked with cats that had been in close proximity to humans. But here, there are so many people around, and cats so close to human habitation—it's different. We're definitely going to be learning some new things."

Around the cache site, the biologists set their snares. Two nights later, they made the first lion capture of the new project: a healthy, 4-year-old, 140-pound male. He was tranquilized, fitted with a radio collar, designated Male 1 and released. A day and a half later, Sweanor located his radio signal 5.5 miles northwest of the capture site, near Temescal Creek, in good deer habitat.

On March 28, the team collared a second male. M2 was 2 to 3 years old and weighed 109 pounds. As summer progressed, Logan and scientific aide Bauer settled into a routine of searching for lion signs and settingand checking snares. Sweanor began amassing data on previous human-lion interactions in the park, and she and scientific aide Lydon monitored the collared deer and lions. Bighorn specialist Rubin continued to analyze bighorn sheep data with Boyce and made plans with Fish and Game and State Parks to put radio collars on more sheep in the fall.

On July 14, Logan and Sweanor's daybreak snare-check revealed cougar M3 in a snare in lower Stonewall Creek. He was a youngster, only about 8 to 10 months old and weighing 58 pounds. His mother was nearby. The team had been tracking and trying to catch these individuals for several weeks. M3 was fitted with a radio collar that would expand to accommodate his growth and released. In the next few days, he and his mother were seen at a deer kill two miles south of where he was captured.

By the time the summer visitor season ended in Cuyamaca Rancho State Park, Sweanor was starting to build a picture of the lions' movements. In typical cougar fashion, they covered a lot of ground. M1 tended to ramble throughout the park and to the west, covering a range of at least 140 square miles—three times the size of the park. M2's range covered about 76 square miles, including large areas south and east of the park. M3 and his mother were moving in and out of the park, staying put for a few days each time they killed a deer.

Sometimes, as Sweanor climbs Cuyamaca ridges to scan for M1's radio signal, she thinks back to that night in March when he stole away the deer carcass. "I know that mountain lions are strong. They have very powerful forelegs and claws, and incredibly strong, short jaws with tremendous musculature—much stronger than a wolf. A single lion can pull down a bull elk six times its weight," she mused.

"Still, that cat pulling the deer out of the truck—I would have liked to have seen it myself."

Sylvia Wright writes about the environmental sciences for the UC Davis News Service.
