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**Response of Mountain Lions to Dogs:  
Is There a Differential Displacement After Capture With Dogs Versus Box Traps?**

By

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THESIS

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## Abstract

Human-predator conflicts are an important current issue, but resolution of these conflicts through lethal management is increasingly problematic, leading to an interest in nonlethal alternatives. Hazing, which involves harassing wildlife, has been increasingly advocated as a non-lethal solution to human-predator conflicts. However, the efficacy of hazing is not well documented, especially in mountain lions. We used data on 76 mountain lions equipped with radio collars, 34 that were hazed with hounds and 42 that were not hazed (control), to determine if hazing lions with dogs has potential for reducing human-mountain lion conflicts by deterring lions from returning to sites of conflict. We used daily GPS locations following release to compare the rates of return and distances over time from the capture sites for the control group and the hazed group. Distance from the capture site was similar for hazed and control lions through 45 days following release, with the exception of a slightly greater distance for hazed lions shortly after release. Almost all lions (97.6% of control group; 94.1% of hazed group) returned to within 6 km of the capture site at some point during the 45 days following release, and most (88.1% of control group; 76.5% of hazed group) returned to within 1 km, with no significant difference between hazed and control lions. An analysis using best-fitting general linear models showed that 2 factors, sex being male and increasing distance from urbanization, had negative effects on the number of times mountain lions returned to the vicinity of the capture site at either the 6-km or 1-km distance. Therefore, aside from the possibility of a modest short-term effect, we did not find evidence that hazing with dogs in association with a capture event is an effective method for displacing mountain lions from a conflict location.

## 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, 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 (Logan et al. 1996, Nisi et al. 2022). Areas with high rates of lethal control may even become “mortality sinks” for mountain lions (Cunningham et al. 2001).

Non-lethal approaches are increasingly used as an alternative to lethal control (Shivik 2004), and in California, Senate Bill 132 was passed in 2013 which required the use of nonlethal measures for managing mountain lions (Mountain Lions 2013). 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 dogs (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 (Pierce and Bleich 2003).

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), though the percentage of diet that is made up of domestic livestock is variable (Cunningham et al. 1999, Smith et al. 2016). In many cases when humans are attacked, the mountain lions treat the humans as prey (Pierce and Bleich 2003; Wang et al. 2019). A decrease

in suitable habitat for mountain lions due to urbanization and agriculture creates more potential for human-mountain lion interactions (Ernest et al. 2000), 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), nonlethal 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 was to determine if hazing mountain lions with dogs has potential for reducing human-mountain lion conflicts by deterring lions from returning to sites of conflict. We hypothesized that if hazing with dogs is effective, hazed lions would be displaced a greater distance and would be less likely to return than lions that had not been hazed.

## **Methods**

We based our analysis on radiolocation data on mountain lions from multiple telemetry studies conducted throughout 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 (hazed) and 1 that did not (control). Lions that were hazed were captured by being chased and treed by hounds. After being anesthetized and processed, the lion was barked at, but not chased, by restrained hounds again after it returned to consciousness and was released. Most hounds were blue tick coonhounds working in teams of 2-6; the breeds of some hounds used in hazing were not identified. The control lions experienced no exposure to dogs; they were caught in box traps baited with deer

meat, anesthetized and processed, then released. For each captured lion, sex was determined, 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 lions were fitted with a GPS radio collar and were released at their points of capture. Radio collars were programmed to record GPS locations at least once per day, and we used these data to determine if hazing with dogs has potential for displacing mountain lions from a location of conflict with humans.

To compare post-release movements of hazed and control lions, we calculated the haversine distance of each 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 substantially reduced our sample size after that time. The number of GPS locations recorded per day varied greatly, both among lions and among days for an individual lion. GPS locations were rarified to a fix rate of 1 location per lion per day using a random selection process. Lions that lacked a GPS location for a given day were excluded from calculations for that day. No lions with more than 2 days of missing location data were included in this 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 1 km or 6 km of their capture site at any time during the 45-day period, beginning on the third day after 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 reflects movement ecology of mountain lions. A 2-day delay was allowed for 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 hazed and control 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 hazing (Table 1). 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 lion was within either 1 km or 6 km of its capture site. Sex, age class, and treatment type (hazed 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  $\Delta\text{AICc} \leq 2$  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 and confidence intervals were then reported using the highest ranked model that included that variable for the relevant distance criterion. 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 hazed (12 males, 22 females) and 42 that were not hazed (23 males, 19 females). Mean distance from the capture site over time showed a similar pattern for both hazed and control 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 hazed lions was 10-22% greater than that for control lions. However, confidence intervals overlapped extensively, suggesting the difference was not statistically significant.

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

The GLM analysis yielded 2 models for the 6-km return distance and 3 models for the 1-km distance that had a  $\Delta\text{AICc} \leq 2$  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 ( $\Delta\text{AICc} = 0.89$ ) 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,  $P = 0.25$ ; 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,  $P = 0.001$ ; Distance from urbanization: -3.83, 95% CI = -6.51 – -1.15,  $P = 0.006$ ; 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 model ranked next ( $\Delta\text{AICc} = 0.83$ ) indicated that the number of days returned was influenced by sex, distance from urbanization, and treatment type (hazed versus control). However, the variable of treatment type was not statistically significant (-1.71, 95% CI = -4.55 – 1.12,  $P = 0.24$ ; Figure 4). The third-ranked model ( $\Delta\text{AICc}=1.91$ ) 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,  $P = 0.55$ ; 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,  $P = 0.002$ ; Distance from urbanization: -1.95, 95% CI = -3.34 – -0.57,  $P = 0.007$ ). The analysis for distance from urbanization revealed an outlier (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-lion conflicts (Elbroch 2020), but efficacy is unknown. It is possible that mountain lions fear dogs because of their resemblance to wolves (*Canis lupus*), a potential enemy of mountain lions (Elbroch 2020). Limited evidence suggests that mountain lions might show an aversive reaction to dogs; capturing mountain lions using dogs resulted in a short-term shift in lion locations (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 hounds, followed by broadcasting sound recordings of baying hounds, appeared to impart some degree of avoidance (McBride et al. 2005).

Nonetheless, we did not find that mountain lions hazed with dogs were displaced farther from the capture site than were lions that were not hazed. Likewise, hazed 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 of a slightly greater displacement of hazed 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 hazing response in other studies of predator hazing; yearling black bears and subadult 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 hazing 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 lions had some degree of exposure to humans.

Our study suffered from an important limitation; we did not compare responses of hazed versus unhazed lions, but instead we compared responses of lions captured with and without the use of dogs. 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 lions after 5 days (ca. 7-10 km), hazed 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<sup>2</sup>, 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.

Our findings do not support the use of hazing with dogs to change spatial locations of mountain lions as a means of reducing conflicts with humans. However, research on black bears indicated that the response to 2 stimuli in combination, hazing with dogs and nonlethal projectiles, was greater than the response to nonlethal projectiles alone (Leigh and Chamberlain 2008, Comeau 2013, Klip 2018). For mountain lions, perhaps hazing with dogs could be coupled with other negative stimuli to enhance the effect.

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## Figures

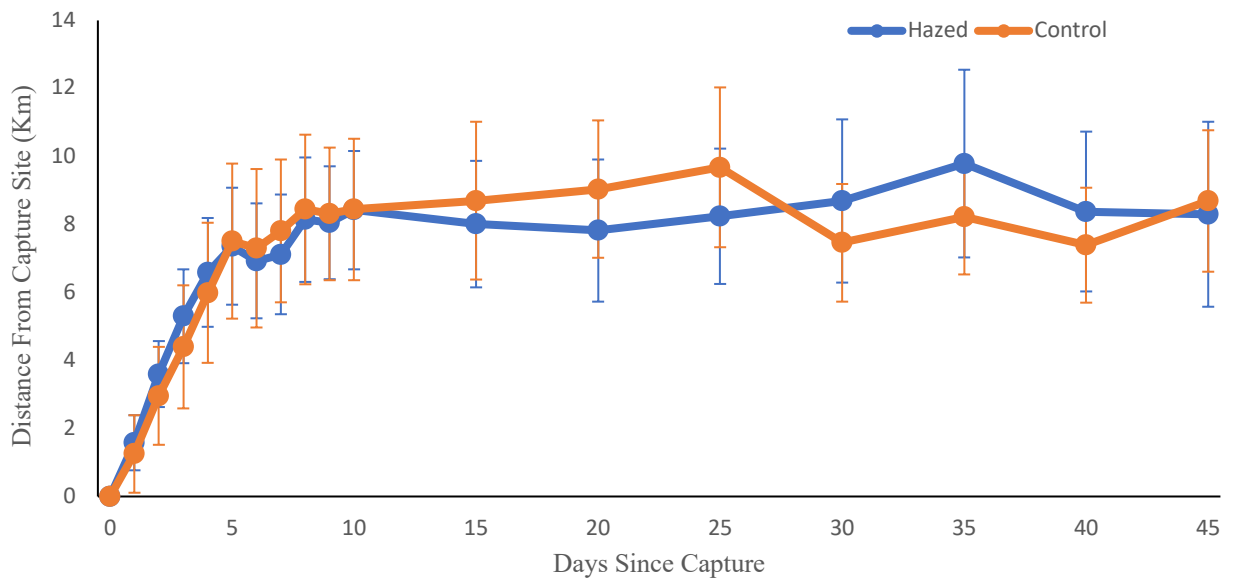


Figure 1. Mean distance from the capture site for hazed and control mountain lions, at 1-day intervals up to day 10, and at 5-day intervals thereafter. Vertical bars are 95% confidence intervals.

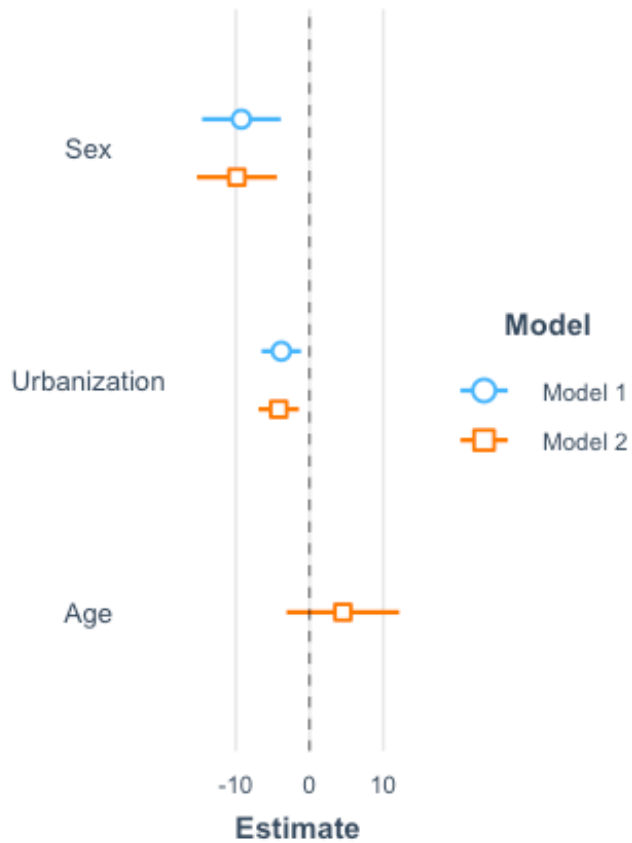


Figure 2. Coefficient estimates based on the top models according to AICc and 95% confidence intervals for the 2 best models for explaining the number of days returned by mountain lions to within a 6-km distance of their capture sites. Urbanization refers to the variable of distance from urbanization and age refers to the variable of age class.

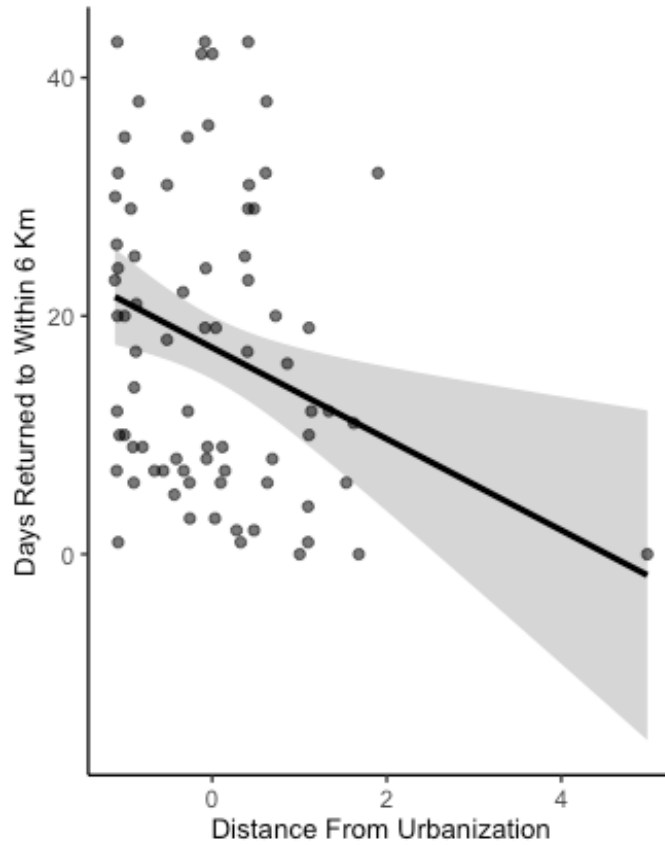


Figure 3. Relation between distance from urbanization and number of days that mountain lions have returned to within a 6-km distance of their capture sites. Shaded areas represent 95% confidence intervals.

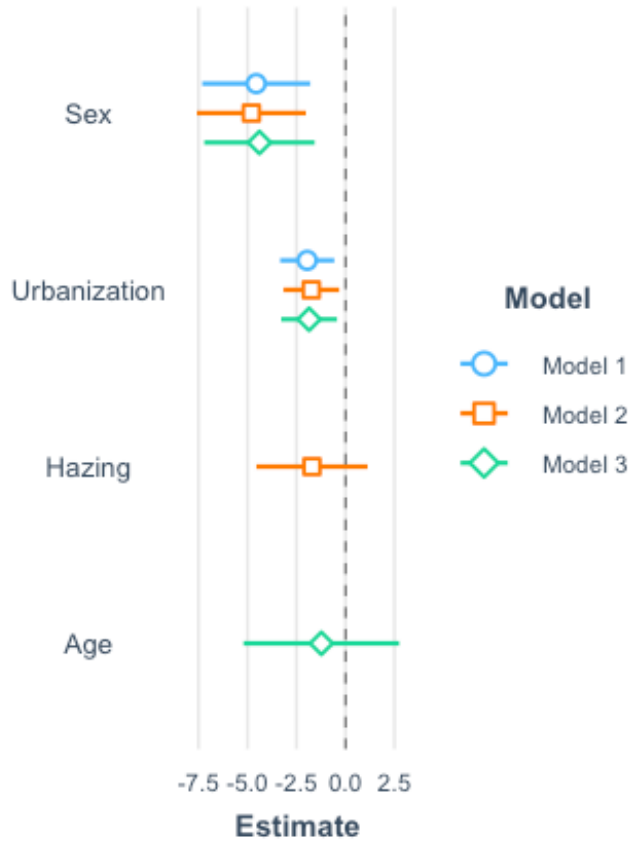


Figure 4. Coefficient estimates based on the top models according to AICc and 95% confidence intervals for the 3 best models for explaining the number of days returned by mountain lions to within a 1-km distance of their capture sites. Urbanization refers to the variable of distance from urbanization, age refers to the variable of age class, and hazing refers to the variable of treatment type.

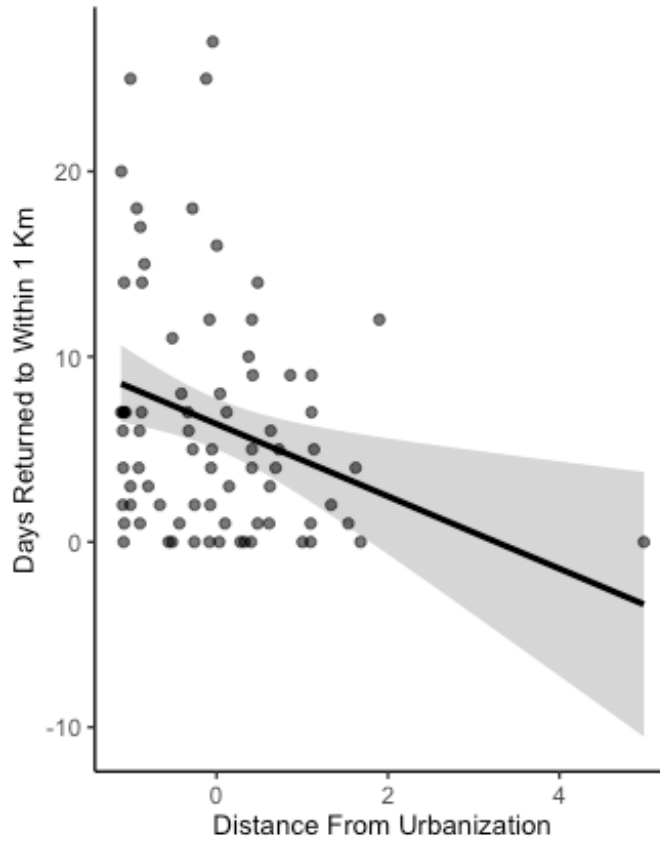


Figure 5. Relation between distance from urbanization and number of days that mountain lions have returned to within a 1-km distance of their capture sites. Shaded areas represent 95% confidence intervals.

Table 1. Variables used in Generalized Linear Models.

Variable	Representation	Source
Sex	Binary	Recorded at Capture
Distance from Urbanization	Scaled Continuous	ESRI Urbanization Layer
Hazing/Control	Binary	Recorded at Capture
Age Class	Binary	Recorded at Capture