Wildlife Society Bulletin; DOI: 10.1002/wsb.902

Original Article

Aligning Mountain Lion Hunting Seasons to Mitigate Orphaning Dependent Kittens

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ABSTRACT Hunting results in direct numerical effects and numerous indirect effects on game species. One indirect effect occurs when a female is killed; and as a consequence, her dependent offspring die, negatively affecting recruitment rates. The mountain lion (*Puma concolor*) is a hunted species across much of its range. It is almost always illegal to harvest a female with dependent young; however, females frequently travel separately from their kittens, and the occasional unintentional harvest of females with dependent young is unavoidable. We studied the denning periods for female mountain lions in northwest Wyoming, USA, from June 2001 to December 2016, but more intensively between January 2013 and December 2016 with Global Positioning System (GPS) technology. During the intensive period, we measured the amount of time females spent away from the den, distance and time females traveled during each foraging trip, and distance traveled during the entire denning period. We also compared the timing of dens with mountain lion hunting seasons. We recorded parturition dates between 6 June and 4 November. On average, females utilized 4.2 ± 0.5 (SE) dens/denning period, with denning periods persisting 45.8 ± 2.6 (SE) days. The average total distance traveled by females during their 6-week denning period was 154 km ($\pm$18.8 km). On average, females were closest or most likely to be with their kittens at 1600, and furthest from den sites at 0200 and 0600. Utilizing our mean denning period of 46 days, delaying mountain lion hunting until 1 November would avoid the denning period for 85% of dens, and delaying until 1 December would avoid 91% ($n = 31$). Our research provides information to guide managers in aligning hunting seasons to mitigate orphaning kittens when they are youngest and most vulnerable, and provide hunters the best opportunities to detect and protect dependent young.

KEY WORDS hunting season, indirect effects, kittens, mountain lion, *Puma concolor*, recruitment.

Hunting and harvest result in direct numerical effects on game species, as well as numerous indirect effects that can be more difficult to monitor or quantify (e.g., cascading changes in age or social structures; Frank et al. 2017). One such indirect effect occurs when a female is killed and, as a consequence, her dependent offspring are orphaned and die (Laundré and Hernández 2008). Among most felids (Family Felidae), females are the sole providers of parental care (Clutton-Brock 1991). Further, the felid species that hunt the largest prey exhibit the longest parental investment (Kitchener 1999).

Mountain lions (*Puma concolor*) are the most widespread felid in the Americas. In North America, mountain lion populations have rebounded impressively and continue to expand into former range, following the cessation of poisoning and bounty systems in nearly every western state by 1965 (Mattson and Clark 2010). Mountain lions hunt alone, hunt prey larger than themselves, and exhibit long maternal care (1–2 yr; Logan and Sweanor 2001, Feldhamer et al. 2003). Female mountain lions spend an estimated 82% of their adult lives caring for dependent young (Gittleman 1986). Mountain lion kittens are most vulnerable during the first 3 months of life, and orphans <6 months do not survive (Logan and Sweanor 2009, Elbroch and Quigley 2012). Scant anecdotal evidence suggests that survival of orphaned kittens increases after 6 months of age and more reliably increases again for kittens >1 year of age (Logan and Sweanor 2009, Elbroch and Quigley 2012).

Mountain lions are also a managed game species across much of their range in the United States and Canada (Quigley and Hornocker 2009). With experience and the aid of educational materials provided in some jurisdictions, many hunters can reliably differentiate between males and females in the field (e.g., 70% correct sex determination by hunters in WA, USA, where additional training is provided; Beausoleil and Warheit 2015). Sex determination remains imperfect, however, creating difficulties in managing sex-specific

Received: 2 February 2018; Accepted: 24 May 2018

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harvest as a means of mitigating indirect effects of female harvest on dependent young and population-level recruitment. Today, it is widely illegal to hunt females when accompanied by their offspring; however, females often travel without their kittens (Barnhurst and Lindzey 1989, Laundré and Hernández 2008). These combined factors make the unintentional harvest of females with dependent young an unavoidable reality in harvest management of mountain lions (Barnhurst and Lindzey 1989).

Previous studies used Very-High-Frequency radio collars to estimate the amount of time that female mountain lions spend with their young to aid managers in determining potential indirect effects that female harvest may have on kitten survivorship and recruitment (Barnhurst and Lindzey 1989, Maehr et al. 1989, Logan and Sweanor 2001, Laundré and Hernández 2008). Here, we employed Global Positioning System (GPS) satellite collars to assess female movement patterns while denning to determine the duration of the denning period and examine the amount of time that female mountain lions spent away from their kittens, thereby leaving them vulnerable to being orphaned. We also assessed the timing of denning behaviors with regard to the start of mountain lion hunting seasons in the northern Rocky Mountains states to assess if adjustments could be made to mitigate the possibilities of orphaning kittens of the youngest age class. Humans remain the leading cause of mortality for mountain lions, regardless of population growth across the west (Quigley and Hornocker 2009). Adjusting managed hunting seasons may provide the best means of mitigating negative effects associated with the unintended mortality of females with dependent young.

STUDY AREA

Our study area encompassed approximately 2,000 km^2 of the southern Greater Yellowstone Ecosystem in Teton County, Wyoming, USA, and included portions of the Bridger-Teton National Forest, Grand Teton National Park, and the National Elk Refuge north of Jackson, Wyoming (Fig. 1). Elevation in the study area ranged from 1,800 m in the valleys to >3,600 m in the mountains. The area was characterized by short summers and long winters with frequent snowstorms. Average summer temperatures were 6.9° C, and average winter temperatures were −7.2° C (Gros Ventre SNOTEL weather station). Precipitation occurred mostly as snow, and maximum snow depths ranged from 100 cm at lower elevations to >245 cm at intermediate and higher elevations (≥2,000 m). Additional details on habitats, flora, and fauna are found in Elbroch et al. (2013).

METHODS

Mountain Lion Capture

Our capture protocols for mountain lions followed guidelines outlined by the American Society of Mammalogists (Sikes et al. 2011), and approved by 2 independent Institutional Animal Care and Use Committees (IACUC): the Jackson IACUC (Protocol 027-10EGDBS-060210) and National Park Service IACUC (IMR_GRTE_Elbroch_Cougar_2013–2015). Each winter, from late November through March, 2000 to 2016, we used trailing hounds to force mountain lions to retreat to a location where we could safely approach and capture them. When capturing a female with kittens, we kept trailing hounds on leash until the female separated from her kittens and was a sufficient distance away from them to minimize the chances that the hounds would circle back to them. We immobilized mountain lions with ketamine (4.0 mg/kg) and medetomidine (0.075 mg/kg), and monitored their temperature, heart rate, and respiration at 5-min intervals while they were processed, sampled, and fit with a satellite GPS collar (Lotek, Newmarket, ON, Canada; or Vectronic, Berlin, Germany). Once animals were completely processed, we reversed the effects of the capture drugs with Atipamezole (0.375 mg/kg), and observed the mountain lions as they departed capture sites on their own.

Identifying and Counting Dens

We programmed collars to acquire location data 12 or 24 times/day and received and uploaded data to Google Earth daily. We identified spatially aggregated GPS points, termed "clusters" (Anderson and Lindzey 2003), and conducted field investigations of all clusters at which a mountain lion remained within 150 m for ≥4 hr at any time of day (Elbroch et al. 2015). Characteristics of den site clusters include their longevity (lasting several weeks), and that each female looped back to the same location repeatedly as she foraged and returned to the den to care for her kittens (Fig. 2). We confirmed den sites through the discovery of kittens, or through associated sign such as a characteristic carpet of fur in a protected enclave. The presence of kittens was then later corroborated through the interpretation of tracks (e.g., females accompanied by kittens), visual sightings, or as recorded upon motion-triggered cameras placed at kill sites (Elbroch and Quigley 2016).

We defined the "denning" period as the time from parturition to when kittens began accompanying their mothers to kill sites. We defined a "den" as the physical structure and location where kittens and females spent time, including the natal den and subsequent additional dens to which females moved their kittens during the denning period. Therefore, during each denning period we counted not just the natal den, but also the total number of individual den sites utilized by each family group throughout the denning period. We employed a *t*-test to determine whether den visitations by researchers influenced the number of times a female moved her kittens during the denning period; more specifically, we compared the average number of dens utilized by females that were not visited with the number of dens utilized by females that were visited with $\alpha = 0.05$.

Time and Distance Calculations

Based upon time stamps of GPS locations, we calculated the total time of the denning period (first time stamp to last time stamp associated with the den site), and estimated the time females spent with or away from their kittens during the denning period. We defined female location data within 60 m of a known den to be time spent with their young,

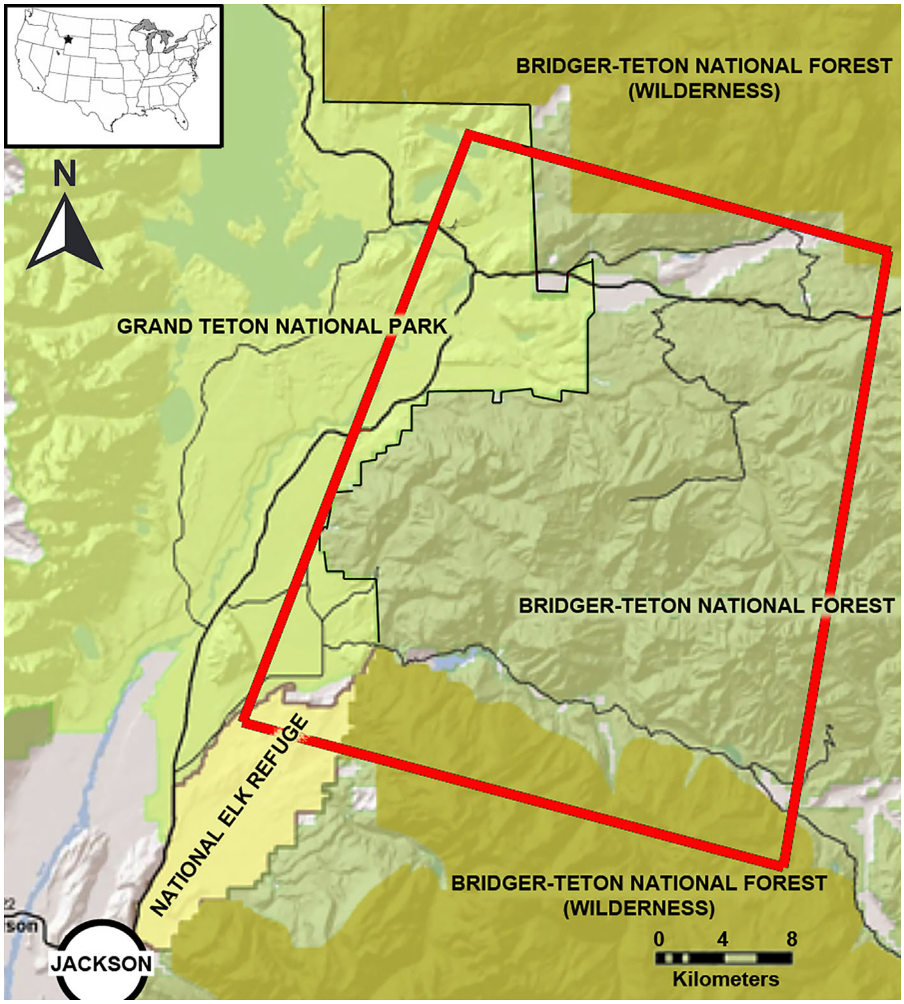

Figure 1. The study area in the southern Greater Yellowstone Ecosystem, Teton County, Wyoming, USA. The inset map depicts the location in the lower United States, and the red rectangle highlights our primary research area in which we followed mountain lions during 2013–2016.

because that was the distance threshold within which we found tracks of kittens exploring while their mothers were away. Location points outside of this buffer were considered time spent away from their young. We also calculated the proportion of female location data present in the den at 2-hr intervals throughout the 24-hr time period (0000–2400) to determine at which times females were most often with and away from their offspring.

To examine movement metrics of foraging mothers, each time a female left her den to forage, we calculated the total time she was away (in hours), the total length of the loop (in meters, calculated by summing the great circle distances between consecutive GPS locations), and the maximum straight-line distance she traveled from the den site (in meters). We also summed the total distance of all foraging and feedings trips from the den to examine the total distance each female traveled during the denning period. To account for potential bias introduced by unequal sampling of mountain lions (i.e., a different no. of dens included in analyses per female), we first averaged within-individual metrics for time and distance before reporting means and standard errors for the group as a whole.

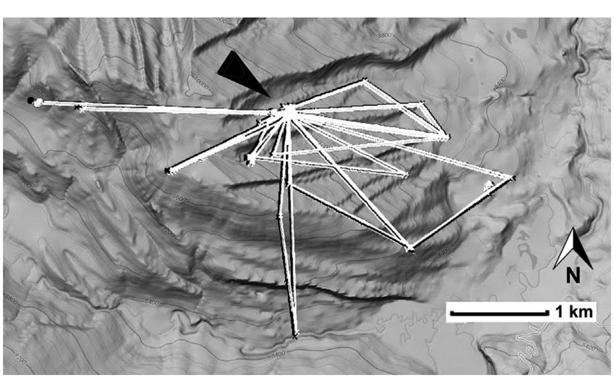

Figure 2. Location data of a mountain lion den site from 2013 in Wyoming, USA, showing the typical pattern of travelling bouts that return to a central point (reprinted from Elbroch et al. 2015).

Denning Period Overlap with Mountain Lion Hunting Seasons

We used parturition dates from research published in Elbroch et al. (2015) and this study ($n = 34$ total dens), in combination with the mean denning period as determined by this research ($n = 12$) to determine how mountain lion denning periods in the northern Rocky Mountain overlapped with 2017 mountain lion hunting periods in Montana, Wyoming, Idaho, Utah, and Colorado, USA.

RESULTS

Dens and Denning Periods

We documented and examined 12 dens from 6 female mountain lions between January 2013 and December 2016 (Supporting Information Appendix SA, available online). Dens occurred from mid-summer through early winter. The earliest parturition was 6 June, and the latest 4 November. We visited 6 of 12 dens while they were active. Researcher visitations did not influence the number of times a female moved her kittens ($t_{10} = 0.16$, $P = 0.41$). On average, females utilized 4.2 ± 0.5 (SE) dens/denning period, and the denning periods persisted 45.8 ± 2.6 days.

Time and Distance Metrics

On average, females spent $48.9 \pm 4.5\%$ (range = 41.6–70.93%) of their time >60 m from 12 den sites (Supporting Information Appendix SB, available online). Each time they left the den, females traveled an average of 5.65 km (±0.64 km) before returning, and were gone for an average of 19.2 hr (±2.7 hr) on each foray. The average total distance traveled by a female during their 6-week denning period was 154 km (±18.8 km). The average straight-line distance from a female to her den was 1,045 m (±141 m), and the maximum straight-line distance for all foraging trips was 8.99 km.

The time of the day females were closest to 12 den sites, or most likely with their kittens, was 1600 (Fig. 3; $\bar{x}$ distance = 563 m ± 200 m). On average, 60% of female locations were in the den during this time. The time of day females were furthest $\bar{x}$ from their kittens was at 0200 ($\bar{x}$ distance = 1,254 ± 257 m) and 0600 ($\bar{x}$ distance = 1,208 ± 169 m). At these times, on average only 39% and 42% of female locations were within the den.

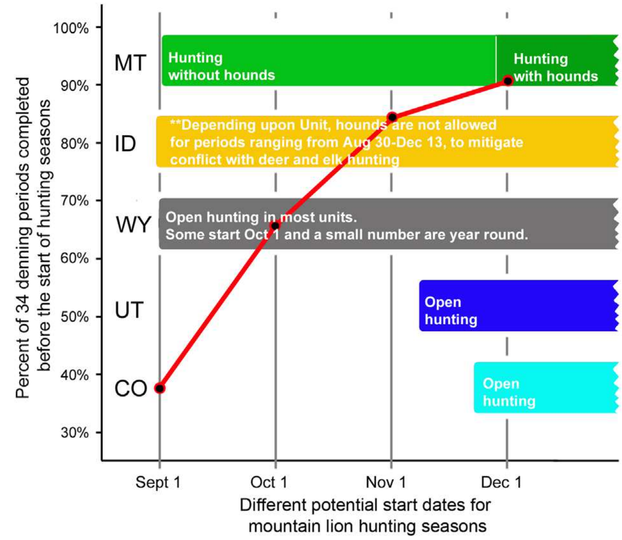

Figure 4. The mountain lion hunting periods for 5 Rocky Mountain states, and (in red) the percent of 34 den periods that would be avoided should hunting start on one of 4 different dates (e.g., a 1 Dec start date would avoid 91% of 34 denning periods).

Denning Period Overlap with Mountain Lion Hunting Seasons

Inclusive of dens reported in Elbroch et al. (2015), we documented 34 parturition dates, the latest of which was 4 November. All kittens were moving with their mothers to kill sites by 10 December. Utilizing our mean denning period of 46 days calculated above, a 1 November start to a mountain lion hunt season would avoid the denning period for 85% of dens ($n = 29$), and a 1 December start to the hunting season, 91% ($n = 31$; Fig. 4).

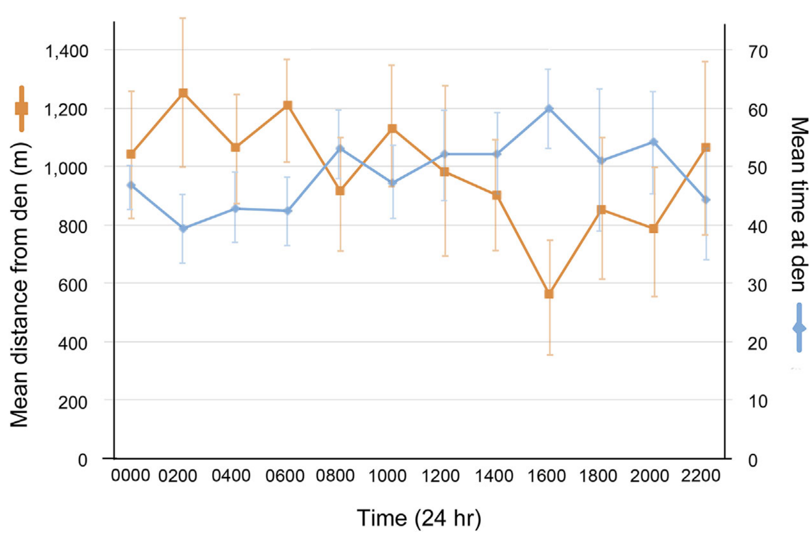

Figure 3. A comparison of the average distance (±SE) mountain lion females are from dens and percent time (±SE) females are at the den in Wyoming, USA, during 2013–2016. We defined percent time at the den as the percent of female location data within 60 m of a den site, at 2-hr intervals over the course of a 24-hr period.

DISCUSSION

Harvest is the strongest driver of mountain lion population dynamics wherever hunting is practiced, and anthropogenic causes remain a significant source of mortality even where hunting is not allowed (Cooley et al. 2009, Thompson et al. 2014, Vickers et al. 2015). Accordingly, conservation scientists and wildlife managers are beginning to address the indirect effects of hunting to improve management practices and expand our ability to predict the cascading effects of management decisions such as hunting quotas (Frank et al. 2017). As long as female mountain lion harvest is practiced, the orphaning of dependent kittens is unavoidable (Barnhurst and Lindzey 1989), because mothers frequently travel separately from kittens of every age. Nevertheless, older kittens travel with their mothers more often, providing hunters better opportunity to identify and protect females with dependent young (Barnhurst and Lindzey 1989, Laundré and Hernández 2008). Our research provides information to guide managers in aligning hunting seasons to mitigate orphaning kittens when they are youngest and most vulnerable.

Mountain lion harvest in northern states is generally influenced by snow, which facilitates the tracking process with trailing hounds. For this reason, both the distribution of mountain lion harvest and methods employed in hunting mountain lions are skewed. In early autumn before reliable snow, mountain lion harvest is lower than in winter months, as well as disproportionately accomplished opportunistically without the use of hounds (Martorello and Beausoleil 2003). For example, over a 5-year period in Wyoming, only 8.4% of all females legally hunted were killed in September and October, whereas greater than twice this number of females were harvested in half the time during the month of November (19.5% of females; WGFD 2006). Martorello and Beausoleil (2003), however, argue that opportunistic hunting without hounds makes females more vulnerable to harvest, and thus even though hunting levels in northern states are no doubt reduced in September and October, the effect of these hunts may impact females disproportionately at that time.

In our study, females were at the den with their kittens approximately 51% of the time. In comparison, Laundré and Hernández (2008) estimated that females were with their denning offspring only 2.3–12.2% of the time. This disparity may have been due to different methods and the greater opportunity to gather additional data provided by GPS technology. Further, our results indicated that females may be away from their kittens at any time of day, but were most likely to be farthest from the den between 0200 and 0600. Such activity patterns reflect the nocturnal and crepuscular hunting patterns of this species (Murphy and Ruth 2009), but also align with the time of day a hunter is most likely to search for and locate fresh mountain lion tracks to pursue with hounds. In contrast, the time period a female was most likely to be with her kittens in the den was in late afternoon or early evening, when hunters are least likely to begin a chase.

MANAGEMENT IMPLICATIONS

In order to give hunters the best chance of detecting dependent kittens, we recommend that managers within the northwestern United States delay the opening of mountain lion hunting seasons to 1 December, or at minimum delay hound hunting seasons until this time. In this way, managers ensure that most mountain lion dens are completed, and hunters have better opportunities to detect kittens via tracks and sign. Female mountain lions travel great distances from their kittens, regardless of their age, and such separation between female and dependent young may result in an indirect effect of harvest on recruitment that is likely difficult to detect or monitor with current management strategies. We encourage aligning denning periods and hunting seasons to minimize this risk and, in the process, support the shared goals of hunters, managers, conservation scientists, and wildlife advocates, of maintaining healthy mountain lion populations.

ACKNOWLEDGMENTS

We thank our funders—The Summerlee Foundation, the Community Foundation of Jackson Hole, the National Geographic Society, the Wyoming Wildlife Foundation, Pace University, EcoTour Adventures, PC Fund for Animals Charitable Trust, The Tapeats Fund, The Lee and Juliet Folger Fund, L. Westbrook, the Scully Family, R. and L. Haberfeld, Hogan LLC, L. and R. Holder, S. and L. Robertson, R. and L. Heskett, F. and B. Burgess, J. Morgan, A. Smith, D. Bainbridge, T. Thomas, and many additional donors that contributed through the Community Foundation of Jackson Hole's Old Bill's Fun Run, many of which were anonymous. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. Special thanks to B. Smith, S. Smith, and J. Smith for their assistance in mountain lion capture and collaring. Thank you to P. Lendrum, N. Wight, C. McFarland, A. Tyson, J. Feltner, J. Kay, and J. Williams for contributions to fieldwork. Thank you to C. Anderson, Associate Editor and several anonymous reviewers for their feedback and contributions to the manuscript.

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Associate Editor: Anderson.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's website. Appendix A: Individual den attributes. Appendix B: Movement attributes for individual denning periods.