

PREY USE BY MALE AND FEMALE COUGARS  
IN AN ELK AND MULE DEER COMMUNITY

By

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Abstract

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Male and female predators may select for different species, sexes, and ages of prey because of sexually dimorphic body size where larger males select for larger prey. I tested for sexually dimorphic prey use by cougars (*Puma concolor*) from 2003 – 2008 in central Washington State. I predicted that males would kill a greater proportion of larger prey (elk) (*Cervus elaphus*), while females and females with offspring would kill smaller prey (mule deer) (*Odocoileus hemionus*) more frequently. I investigated 436 potential cougar predation sites identified by Global Positioning System (GPS) clusters ( $\geq 2$  locations within 50 m on the same or consecutive day) and successfully located prey remains at 345 sites from 18 cougars (9M, 9F) (1-261 days post predation). I found 127 prey remains at female GPS clusters, 111 at females with offspring clusters and 107 at male clusters. I detected 184 mule deer, 142 elk and 17 other remains from 4 other species. I used log-linear modeling to detect differences in prey use and age of prey killed among cougar reproductive classes. Females and females with offspring killed more mule deer than elk (62% vs. 38%), while males killed more elk than mule deer (55% vs. 45%) ( $P < 0.01$ ). Males killed 4 times as many adult elk than females (24% vs.

6%) and females killed about twice as many adult mule deer than males (26% vs. 15%). There were no differences in cougar kill intervals among reproductive classes ( $P > 0.05$ ). Mean kill interval for all cougars was 6.9 days/kill, (SD = 3.94 days, range = 0.6 – 19.8 days, n = 136 inter-kill intervals). Cougars stayed at elk kills 4.81 days and 3.10 days for mule deer. The duration spent on kills differed among cougar reproductive classes ( $P < 0.01$ ) and seasons ( $P < 0.01$ ), with females remaining on kills longer than males (4.72 days vs. 3.43 days). Males had greater effects on elk and females had greater effects on mule deer. Managers should take sexually dimorphic prey use into account when prescribing hunting of predators as a method for prey conservation.

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## INTRODUCTION

In almost all analysis and management of predator-prey dynamics, both sexes of predators are assumed to have equivalent effects on prey population growth (Robinson et al. 2002, Sinclair et al. 2006). However, body size of prey killed is often correlated to predator body size with larger predators killing larger prey (Karanth and Sunquist 2000). In predator species such as cougars, leopards, and African lions, males and females could select different species, sexes and age classes of prey (Hornocker 1970, Ross and Jalkotzy 1996, Murphy 1998, Karanth and Sunquist 2000, Anderson and Lindzey 2003) because of their sexually dimorphic size (avg. male weight 72 kg vs. female weight 43 kg) (this study), and associated behavioral differences (Murphy 1998, Pierce et al. 2000, this study). Males could have relatively greater effects on larger species of prey whereas females could have relatively larger effects on smaller species (Hornocker 1970, Shaw 1977, Mills et al. 1992, Turner et al. 1992, Ross and Jalkotzy 1996, Ross et al. 1997, Murphy 1998, Nowak 1999, Logan and Sweanor 2001, Anderson and Lindzey 2003).

Such sexually dimorphic prey use could have pronounced effects for predator-prey management. For example, both male and female cougars were heavily hunted to reduce their effects on declining prey in southern British Columbia (Lambert et al. 2006) and northern Washington (Robinson et al. 2008). However, heavy hunting resulted in a declining female component but a stable to increasing male component because of compensatory male immigration (Robinson et al. 2008, Cooley et al. 2009 *In press, a,b*).

If larger prey such as elk are the conservation target, hunting of both male and female cougars might have little beneficial effect because females might not kill many elk and males may compensate via immigration. However, if smaller prey such as mule

deer are the conservation target, only hunting of female cougars might have a pronounced beneficial effect.

Until recently, prey selection and kill intervals in most of the cougar literature were based on intensive VHF radio-tracking studies which often yielded low sample sizes (Shaw 1977, Harrison 1990, Beier et al. 1995, Murphy 1998, Nowak 1999, Cooley et al. 2007) and usually did not allow examination of possible differences between cougar sex and reproductive classes. Anderson and Lindzey (2003) were among the first to employ GPS technology to examine sex-specific prey use because of greater sample size and they inferred that males killed more adult elk and females killed more adult mule deer.

In this study I collected data on cougar prey use from females, females with offspring and males to test the hypothesis that male cougars would kill larger prey (adult elk), and females would kill smaller prey (juvenile and adult mule deer). I also tested for differences in kill intervals (kills/cougar/unit time) to determine if different reproductive classes of cougars have kill intervals that may result in disproportionate greater or lesser effects on prey species.

## STUDY AREA

This study was conducted on an approximately 1,800 km<sup>2</sup> portion of western Kittitas County near the town of Cle Elum, Washington (47° N, 121° W) during May 15 - August 15 2003-2008 (Figure 1.1). The study area is bound by the Cascade Mountains to the west (Snoqualmie Pass) and to the north (Alpine Lakes Wilderness and Enchantment Lakes), open agriculture lands to the south-southeast and a patchwork of U.S. Forest Service, Washington Department of Natural Resources, Washington Department of Fish and Wildlife (WDFW) and privately owned timber lands to the south. Interstate 90 (I-90) and four State Route (SR) highways, SR 10, 903, 970, and 97 intersect the study area. Rural residential development encompasses most of the valley bottoms. Elevations range from 462 m to 2,279 m. This area lies in a rain shadow of the Cascade Mountains and is characterized by hot, dry summer conditions and cold winters. Annual precipitation averages 54 cm. Mean annual temperature ranges from -7°C in January to 28°C in July. During winter, westerly winds are strongest, allowing moisture to rise over the Cascade Crest into the eastern slope foothills (Ferguson 1999) where 80% of the annual precipitation falls as snow (average snowfall is 160 cm) (Wright and Agee 2004, Cooley et al. 2009 *In press, b*).

This area is part of the Cascade Mixed Forest ecoregion (Bailey et al. 1994). Vegetative communities are comprised of shrub steppe at lower elevations (below 550 m) transitioning upwards to ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*). Grand fir (*Abies grandis*), western hemlock (*Tsuga heterophylla*), and Douglas fir occupy mid elevations. Silver fir (*Abies amabilis*), sub-alpine fir (*Abies lasiocarpa*), Englemann spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta*)

occupy elevations > 1,550 m (Franklin and Dyrness 1988). Common understory plants include antelope bitterbrush (*Purshia tridentata*), snowberry (*Symphoricarpos albus*), vine maple (*Acer circinatum*), evergreen ceanothus (*Ceanothus velutinus*), and oceanspray (*Holodiscus discolor*).

Potential cougar prey includes mule deer and elk which are abundant and occur throughout the study area. Mountain goats occur at higher elevations but in low numbers. Other potential prey include wild turkeys (*Meleagris gallopavo*), beaver, mountain beaver (*Aplodontia rufa*), ruffed grouse (*Bonasa umbellus*), blue grouse (*Dendragapus obscurus*), and snowshoe hare (*Lepus americanus*).

## METHODS

### Captures

We searched for cougar tracks in snow from 2001-2008 using 4x4 trucks, snowmobiles, and on foot when sufficient snowfall was present (Cooley et al. 2009 *In Press a, b*). Trained hounds were released on fresh tracks to tree cougars (Hornocker 1970). We also used box traps (1.23 x 1.23 x 3.69 m) as a secondary means of capture. Traps were placed at cougar predation sites and/or placed in areas of known cougar travel paths. Traps were baited with deer and elk carcasses. We covered traps with brush and tree branches for concealment and security and thermal cover for the captured animal. Box traps were the primary capture method in human-occupied areas where the use of dogs was not feasible (Logan et al. 1999).

Cougars were immobilized with ketamine hydrochloride (100mg/ml) at a dosage of 1.0 mL per 23 kg body mass using a 3.0 mL plastic projectile dart fired from a CO<sup>2</sup> powered Dan Inject dart gun (Dan Inject North America, Fort Collins, CO, USA) into the hindquarter as recommended by (Ross and Jalkotzy 1992, Spreadbury et al. 1996, Lambert et al. 2006). We fastened a safety net at the base of the tree to reduce the risk of injury in case the cougar fell (Cooley et al. 2007). Cougars were immobilized in the tree and were lowered down with a rope attached to one of their legs. Once on the ground or removed from the box trap, cougars were administered an intramuscular injection of xylazine hydrochloride (100mg/ml) at a dosage of 0.1 mL per 23 kg body mass. Cougars were classified as (kitten < 1 yr, subadult 1-2 yrs, or adult > 2 yrs) (Lambert et al. 2006, Cooley et al. 2007) based on gum-line recession (Laundre et al. 2000) and their physical appearance.

We fitted Televilt GPS collars (model: Simplex, Tellus, or Posrec; Lindesberg, Sweden) on subadult and adult cougars during the winters of 2001-2004. We deployed GPS collars (model: Lotek 4400, Ontario, Canada) on resident adult cougars during the 2005 - 2006 winter. After collaring, cougars were administered (2mg/ml) yohimbine hydrochloride, a chemical antagonist to xylazine hydrochloride, at a dosage of 2.0 mL per 23 kg body mass. We handled all animals in accordance with Washington State University Animal Care (IACUC permit 3133), and Animal Welfare Assurance Committee (permit A3485-01).

## **Locating Kills**

Simplex collars were programmed to acquire satellite location coordinates at six hour intervals while Lotek collars were set for four hour intervals. Simplex and Tellus collars were scheduled to transmit stored data back to a remote download receiver every four to six weeks within a specified three day window to download the data, whereas Lotek collars had on-demand download capability. Cougars were located approximately every two weeks by ground telemetry or fixed-wing aircraft for the purpose of remotely downloading GPS location data from the collars.

I plotted GPS locations onto maps of the study area using Terrain Navigator (Maptech 2002). Potential predation sites were defined as  $\geq 2$  locations (clusters) within 50 m recorded on the same or consecutive day (Anderson and Lindzey 2003). I assumed prey found at the cluster locations were killed by the cougar (Pierce et al. 2000, Anderson and Lindzey 2003, Cooley et al. 2007). The center of each cluster location was loaded into a handheld GPS unit (Garmin eTrex Vista) which I used to navigate to a potential

predation site. I used a compass to navigate using the bearing from the GPS unit when overstory canopy limited use from blocked satellite reception.

I searched all potential cougar predation sites (1-261 days post predation) during May - August 2003 - 2008. I searched for prey remains by walking directly to the center location of the GPS cluster. If prey remains were not evident at this location I began walking 10 m (Anderson and Lindzey 2003) wide circles around the center location until I found remains. If I did not locate remains  $\leq 100$  m from the center, I ended the search. I assessed the condition of prey remains similar to Anderson and Lindzey (2003) to determine if they were consistent with the time period of the suspected predation event.

At each putative predation site I recorded the presence or absence of prey remains, prey species sex and age, and any physical evidence that a cougar was at the site (Shaw 1987, Anderson and Lindsey 2003, Cooley et al. 2007). I determined the sex based entirely on the presence of the skull; otherwise I placed the species into an “unknown” sex category. Male deer and elk were identified by the presence of antlers or a skull with antler pedicels. Females were identified by the absence of these characteristics. I classified a kill as an “unknown species” when there was not adequate evidence at the site to determine the species. I aged deer and elk as  $\leq 1$  year, 1 - 2 years or  $\geq 2$  years using tooth wear and replacement of the lower jaw bone (Schroeder and Robb 2005), but combined  $\leq 1$  year and 1 - 2 years into a juvenile age class to increase sample size and classified prey  $\geq 2$  years of age as adults.



## Prey Use

I used log-linear modeling (Knoke and Burke 1980, Wielgus et al. 2002, SYSTAT Engelman 2007) to test for differences between male and female use of prey species and prey age classes. I first conducted a separate chi-square test of homogeneity to test whether I could combine the observations of prey used by females and/or females with offspring. By combining the two classes, I increased statistical power for my log-linear model by increasing the number of samples per cell and decreasing the number of cells (8 vs. 16), (Wielgus et al. 2002). My sample size satisfied the minimum number of samples per cell, 5, required to run the log-linear model (Knoke and Burke 1980, SYSTAT Engelman 2007).

I used a forward-selection hierarchical log-linear model (Knoke and Burke 1980; Engelman 2007) and tested for all relevant main effects: reproductive class of cougar (male or female), prey species (mule deer or elk), and age of prey (juvenile or adult), and all two-way interactions (reproductive class X prey species, reproductive class X age of prey and prey species X age of prey). I then tested a three-way (reproductive class X prey species X age of prey) interaction. Standardized parameter estimates (s.p.e.) were used to highlight relative importance of interaction terms (Engelman 2007). Deviations from 0 may be interpreted as z scores (e.g. a z-score  $\geq 1.64$  indicates the given interaction term was significant at  $P \leq 0.10$ ) with relatively larger scores indicating larger interaction effects.

## **Kill Intervals**

Kill intervals were estimated by calculating the number of days between two consecutive kills (inter-kill interval). I identified inter-kill intervals as occurring in summer (May 1 to November 30) or winter (December 1 to April 30) that reflected the seasonal elevation shifts for cougars and prey (Maletzke et al. 2005). I used ArcView 9.3 (ESRI 380 New York St, Redlands, CA 92373-8100) to identify the first GPS point associated with a confirmed predation event. I then identified the next consecutive predation event using the same method. I subtracted the date of the first GPS point from the date of the second GPS point and divided by either four or six (the number of satellite fix attempts/day) to estimate the time period between two kills. To be assured each kill and associated inter-kill interval were consecutive, I assessed location data within the inter-kill interval to determine whether a kill may have been missed in the field. If a kill was not investigated and occurred within the inter-kill interval, then that interval was excluded.

I calculated the mean kill rates for individual animals within each cougar reproductive class seasonally (summer and winter) and annually. I calculated species specific kill rates as the time (inter-kill interval) that it took a cougar to appear at a consecutive kill of the same species (e.g., mule deer to consecutive mule deer kill). I then combined intervals for individuals within each sex and reproductive class to calculate mean kill intervals for each reproductive class. I used factorial ANOVA and Tukey's post-hoc analysis for multiple comparisons of means to test for differences in kill intervals among: prey species, season, reproductive class, reproductive class X season and reproductive class X species kill intervals. Significance was set at alpha ( $P \leq 0.05$ ).

## **Duration Spent on Kills**

The time a cougar spent on a kill was calculated similar to the kill intervals. I subtracted the date of the last GPS point of the confirmed predation event from the date of the first GPS location and divided the difference by four or six to calculate the time a cougar was associated with a predation site. I used the same statistical test for identifying differences of the duration spent on kills as I did for detecting differences in kill intervals.

## **Estimated Annual Prey Killed**

I estimated the maximum number of deer and elk killed by one cougar in each cougar reproductive class based on their proportions of deer and elk killed and their species specific kill rates. This method is based on 100% survival during the year for all cougars. I used the proportion of deer and elk killed by each reproductive class, multiplied by 365 days/year to estimate the days each reproductive class was associated with a deer and elk kill. I then used that estimate divided by the species specific kill intervals to estimate the maximum annual number of deer and elk killed.

I then estimated the realized kills which were based on survival rates of cougars in our study area (Cooley et al. 2009 *In press, b*). I estimated the daily survival of a cougar in each reproductive class by using the annual survival rate raised to the power of 1/365. I then used the daily survival rate raised to the power of 183, where 183 is the geometric mean of the annual survivorship function which estimated the average number of days a cougar was alive in one year. I used the average number of days alive in a year multiplied by the hypothetical maximum number of deer and elk killed by one cougar in

each reproductive class to estimate the realized kills in one year for each cougar reproductive class.

### **Distance Moved Off Kills**

I used ArcGIS 9.3 and the Home Range Tools (HRT) extension (Rodgers et al. 2007) to display travel paths for each GPS point associated with a predation event and used Hawth's Tools (Beyer 2004) to estimate length of the travel paths between GPS points. I recorded the number of times a cougar moved > 100 m from predation sites and returned and calculated the mean line length of travel paths associated with points leaving and returning to a site. I used a separate-variance one-tailed t-test to test whether males would leave kills more often and travel further distances away from sites than females before returning.

## RESULTS

### Prey Use

I investigated 436 GPS cluster locations as potential predation sites for 18 adult cougars (9 F and 9 M). I detected prey remains at 345 of these sites (Table 1.1). Of the 345 kills, 53% (n = 184) were mule deer and 41% (n = 142) were elk for a total of 94% (n = 326) large mammal kills (Table 1.2). Other prey included mountain goats (n = 3), beaver (n = 4), coyote (n = 5), domestic dog (n = 1), and 6 unidentifiable ungulates. I detected 127 prey killed by female cougars, 111 by females with offspring, and 107 by males. Females killed 57% (n= 73) mule deer and 36 % (n = 46) elk. Females with offspring killed 63% (n = 70) mule deer and 33% (n = 37) elk. By contrast, males killed 38% (n= 41) mule deer and 55% (n = 59) elk.

There was no seasonal difference in prey use for male ( $\chi^2_1 = .025$ ,  $P = 0.88$ ) and females with and without offspring ( $\chi^2_1 = 1.84$ ,  $P = 0.17$ ). For all reproductive classes of cougars combined, there were no seasonal differences in use of mule deer or elk ( $\chi^2_1 = .208$ ,  $P = 0.65$ ). Summer kills were 57% mule deer (n = 100) and 43% (n = 76) elk. Winter kills were 56% mule deer (n = 84) and 44% elk (n = 66).

The log-linear model with all two-way interaction terms fit the data at ( $P = 0.07$ ) and no other simpler models fit the data ( $P > 0.10$ ). However, the saturated model with the three-way interaction term had the best fit ( $P < 0.01$ ) (Table 1.3).

Overall, juvenile prey were killed more frequently than adults ( $P < 0.01$ ; standardized parameter estimate (s.p.e.) = 4.935). Juvenile elk were killed more frequently than juvenile mule deer, however, adult mule deer were killed more than adult

elk ( $P < 0.01$ ; s.p.e. = 2.70). For both species combined, female cougars killed relatively more juveniles and males killed relatively more adults ( $P = 0.06$ , s.p.e. = 1.90). For all prey ages combined, females killed relatively more deer while males killed relatively more elk ( $P < 0.01$ ; s.p.e. = 4.43). For age and species interactions, females killed relatively more adult mule deer and juvenile elk, while males killed relatively more adult elk and juvenile mule deer ( $P = 0.07$ , s.p.e. = 1.80) (Table 1.4).

In summary, the proportion of male elk kills was greater than females (59% vs 37%) and the proportion of adult elk killed by males was four times that of females (24% vs 6%). For elk, male cougars killed 13 (38%) bulls and 21 (62%) cows. Female cougars killed 5 (12%) spike bulls and 38 (88%) cows. Females did not kill any branched antlered bulls. For mule deer, males killed 2 (14%) bucks and 12 (86%) does. Females killed 13 (24%) bucks and 41 (76%) does.

## **Kill Intervals**

Species specific (e.g., elk to elk or mule deer to mule deer) kill intervals were higher for mule deer than elk (6.49 days/kill vs 9.78 days/kill). Kill intervals did not differ between seasons, or among cougar sex and reproductive classes (Table 1.5).

## **Duration spent on kills**

The duration spent on kills was greater for elk than mule deer (4.81 vs 3.10 days) ( $P < 0.01$ ). The duration spent on kills was also greater during winter than summer (4.43 vs 3.35 days) ( $P < 0.01$ ). Females without offspring spent more time on kills than females with offspring and males (4.72 vs 3.65 vs 3.43) ( $P < 0.01$ ). Cougars spent more time on

elk kills during summer (4.05 days) and winter (5.69 days) than mule deer kills during summer (2.82 days) and (3.42 days) winter ( $P = 0.01$ ) (Table 1.6).

### **Estimated Annual Prey Killed**

Per capita maximum annual kills based on 100% survival of cougars were 15 deer and 20 elk for males, 33 deer and 13 elk for females, and 36 deer and 14 elk for females with offspring. Realized per capita annual kills based on actual cougar survivorship in the study area was 12 deer and 16 elk for males, 30 deer and 12 elk for females, and 33 deer and 13 elk for females with offspring.

### **Distance Moved Off Kills**

I combined solitary females and family group distances because there was no statistical difference between the two classes. There was no difference in the number of times females and males left kills and returned ( $t_{109} = 1.59, P > 0.05$ ). Female cougars left their associated predation sites and returned to 49% of them while males returned to 51%. However, females and males differed in the distance traveled to and from kills ( $t_{60} = -3.90, P = < 0.01$ ) with females traveling an average of 684 m (range = 100 - 3,325 m, SE = 24.73) from predation sites while males averaged 1,622 m (range = 101 - 8,330 m, SE = 41.64).

## DISCUSSION

### Prey Use

Male and female cougars used prey differently and could have disparate effects on prey population growth. Females killed more mule deer and males killed more elk, suggesting that they could have different effects on prey population growth rates. Furthermore, males killed more adult elk and females killed more adult mule deer, suggesting that males may have a considerably greater effect on population growth of elk and females may have a greater effect on population growth of mule deer.

Male and female differences in prey use concur with suggestions by Hornocker (1970), Ross and Jalkotzy (1996), Murphy (1998), and Anderson and Lindzey (2003). Females with and without offspring appeared to avoid killing adult elk, suggesting that female cougars may avoid the risk associated with larger, stronger prey (Murphy 1998, Nowak 1999). Females may seek smaller prey such as mule deer or elk calves that may provide less biomass, but a more consistent food source (Pierce et al. 2000), especially when females are accompanied by offspring. Males may take advantage of larger prey (elk), perhaps because this allows them to gorge and travel greater distances (see movements section).

Females, with and without offspring killed mule deer more frequently than elk, regardless of the season. However, during summer, females and females with offspring killed juvenile elk more frequently than they did juvenile mule deer, similar to that suggested by Hornocker (1970), Murphy (1998), and Nowak (1999). Females may select for elk calves due to their smaller size compared to adults and their inexperience in



predation avoidance (Hornocker 1970, Spreadbury 1996, Murphy 1998) during early summer. However, because elk calves are larger than mule deer fawns, their remains may have been more readily detected at GPS location clusters.

## **Kill Intervals**

Kill intervals were lower on elk than on mule deer, probably due to their larger size. Ackerman (1986) and Laundre (2005) estimated energetic requirements for cougars based on daily movements and suggested males and females with offspring have greater energetic needs than females without offspring. Murphy (1998) showed similar rates for these sex classes and agreed with McNab's (1988) assumption that metabolic requirements are correlated to body weight.

My results did not support the hypothesis of McNab (1988) nor findings by Murphy's (1998) and Shaw's (1977) female kill intervals since there were no differences observed here. It could be that calculating kill intervals from GPS data is more efficient and provides more precise locations than from previous VHF radiotracking. The higher kill intervals for females without offspring observed in my study and by Anderson and Lindzey (2003), may be attributed to the higher frequency of fawns and calves killed, and the greater probability that investigators will detect remains of these smaller prey compared to studies utilizing VHF telemetry to locate kill sites because of diminished accuracy and less frequent location records (Murphy 1998, Cooley et al. 2007).

Estimating annual prey killed by cougars is usually based on 100% survival of cougars (Nowak 1999) and thus over-estimates the actual prey killed in one year. My data show that annual kill estimates based on survivorship are lower than reported

elsewhere 42 (this study) vs. 47 (Nowak 1999) for female cougars and 46 (this study) vs. 52 (Murphy 1998) for females with offspring. Estimates should take into account the actual survivorship of different cougar reproductive classes.

## **Duration Spent on Kills and Movements**

Male cougars remained at predation sites the shortest duration regardless of the size of prey or the species killed. Murphy (1998) made similar observations supporting Pierce et al.'s (2000) assumption that adult males may gorge and leave. Murphy (1998) suggested that males that remain near kills to thoroughly consume them may lose breeding opportunities. A male's large body mass may allow them to kill larger prey - which would permit them to gorge and make long range movements in defense of their large home ranges and search for estrus females (Anderson et al. 1992, Pierce et al. 2000).

My movement data support these hypotheses. While females and females with offspring showed no difference in movement patterns or distances traveled from kills, males differed in their travel patterns and distances traveled from predation sites. Although males left predation sites the same number of times as females, they traveled twice the distance (1,622 m vs. 684 m) and had greater variability in the range of distance traveled. The movement patterns exhibited by males (Figure 1.2) in relation to predation sites highlighted the behavioral differences between males and females (Figure 1.3). This male behavior occurred more frequently where large prey was present at predation sites that would permit the male to leave the kill and return to feed.

## Management Implications

I demonstrated that sex and reproductive class of cougar should have different effects on prey populations. Altering the sex composition of a cougar population through harvest may offset predation on one species, but may exacerbate predation on another. For example, heavy hunting of cougars has been shown to initiate a compensatory male immigration response (Cooley et al. 2009 *In press, a,b*) with little or no reduction in males. Heavy hunting of cougars to reduce predation on species like elk could therefore have little or no positive effects. Conversely, heavy hunting has been shown to reduce the number of females, which could result in reduced predation on mule deer (Robinson et al. 2008, Cooley et al. 2009 *In press, a,b*). Managers should consider the effects of predator harvest on numbers of males and females, not predators in general as the sex and reproductive classes exhibit vastly different effects on prey.

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Table 1.1 Prey species (n, [%]) detected at 345 GPS location clusters of females, females with offspring and male cougars in central Washington, USA, 2003 – 2008.

Prey	Females (n = 127)	Females with offspring (n = 111)	Males (n = 107)
Mule Deer	73 (57)	70 (63)	41 (38)
Elk	46 (36)	37 (33)	59 (55)
Coyote	3 (2)	0 (0)	2 (2)
Beaver	1 (1)	0 (0)	3 (3)
Mountain Goat	2 (2)	0 (0)	1 (1)
Domestic Dog	0 (0)	0 (0)	1 (1)
Unknown	2 (2)	4 (4)	0 (0)

Table 1.2 Mule deer and elk detected (n, [%]) at 326 GPS location clusters from individual cougars in central Washington, USA from 2003 – 2008.

Cougar ID	Sex	Prey	
		Mule Deer (n = 184)	Elk (n = 142)
150	M	6 (66)	3 (33)
184	M	10 (71)	4 (29)
154	M	0	2 (100)
173	M	5 (45)	6 (55)
174	M	4 (27)	11 (73)
190	M	7 (21)	27 (79)
191	M	2 (67)	1 (33)
140	M	1 (50)	1 (50)
151	M	6 (60)	4 (40)
163	F	10 (67)	5 (33)
147	F	1 (25)	3 (75)
197	F	28 (54)	24 (46)
158	F	22 (51)	21 (49)
156	F	28 (80)	7 (20)
145	F	40 (74)	14 (26)
160	F	8 (73)	3 (27)
152	F	6 (60)	4 (40)
181	F	0	2 (100)

Table 1.3 Log-linear model. Tests of relevant main effects: reproductive class, species, age, 2-way interaction effects: age X species, reproductive class X age, reproductive class X species, and 3-way interaction effects: reproductive class X species X age.

	Chi-Sq	DF	P-value
Repro Class <sup>a</sup>	22.18	1	< 0.01
Species	0.45	1	0.50
Age <sup>b</sup>	25.68	1	< 0.01
Age X Species	7.37	1	< 0.01
Repro class X Age	3.51	1	0.06
Repro Class X Species	20.86	1	< 0.01
Repro Class X Species X Age	3.23	1	0.07
Likelihood Ratio $\chi^2$	0.00		< 0.01

<sup>a</sup> Cougar reproductive classes

<sup>b</sup> Age of prey

Table 1.4 Age composition (n, [%]) of elk and mule deer detected at 294 GPS location clusters for male and female cougars in central Washington, USA, 2003 – 2008.

Age Class	Females		Males	
	Elk	Mule Deer	Elk	Mule Deer
Juvenile	65 (32)	73 (36)	37 (40)	19 (21)
Adult	13 (6)	51 (26)	22 (24)	14 (15)
<b>Total</b>	<b>78 (38)</b>	<b>124 (62)</b>	<b>59 (64)</b>	<b>33 (36)</b>

<sup>a</sup> Percentages were calculated separately for male and female cougars

Table 1.5 Analysis of variance tests of kill intervals by cougars based on : species, season, reproductive class, reproductive class X season, and reproductive class X species in central Washington, USA from 2003 – 2008.

Variable	$\bar{x}^a$	SD	n <sup>b</sup>	$\bar{x}$	SD <sup>c</sup>	n	$\bar{x}$	SD	n	F, P <sup>d</sup>
Species	<b>Mule Deer</b>			<b>Elk</b>						4.183, 0.04
	6.49	3.61	44	9.78	4.24	32				
Season	<b>Winter</b>			<b>Summer</b>						.307, 0.58
	6.77	3.94	61	6.98	3.92	75				
Repro Class <sup>e</sup>	<b>Females</b>			<b>Females with offspring</b>			<b>Males</b>			1.092, 0.34
	6.69	4.00	48	6.32	3.76	44	7.66	3.90	44	
Repro Class X Season	<b>Females</b>			<b>Females with offspring</b>			<b>Males</b>			0.993, 0.37
Winter	6.14	3.44	18	6.90	4.42	18	7.14	4.02	25	
Summer	7.16	4.40	30	5.92	3.30	26	8.37	3.74	19	
Repro Class X Species	<b>Females</b>			<b>Females with offspring</b>			<b>Males</b>			0.72, 0.48
Mule Deer	6.29	3.43	20	6.43	3.55	21	9.10	5.11	3	
Elk	10.14	4.71	10	8.35	4.02	9	10.02	4.30	14	

<sup>a</sup> Average kill interval (days between two consecutive kills) for each variable.

<sup>b</sup> Number of kill intervals for each variable.

<sup>c</sup> Standard deviation

<sup>d</sup> F-statistic and P-value from ANOVA output.

<sup>e</sup> Cougar reproductive classes

Table 1.6 Analysis of variance tests of the duration (days) cougars were associated with predation sites based on: species, reproductive class, species X season, reproductive class X season, reproductive class X species, and reproductive class X species X season in central Washington, USA from 2003 – 2008 for 326 mule deer and elk kill sites investigated.

Variable	$\bar{x}^a$	SD	n <sup>b</sup>	$\bar{x}$	SD <sup>c</sup>	n	$\bar{x}$	SD	n	F, P <sup>d</sup>
Species	<b>Mule Deer</b>			<b>Elk</b>						37.29, < 0.01
	3.10	1.91	184	4.81	3.50	142				
Season	<b>Winter</b>			<b>Summer</b>						18.56, < 0.01
	4.43	3.08	150	3.35	2.54	176				
Repro Class <sup>e</sup>	<b>Females</b>			<b>Females with offspring</b>			<b>Males</b>			11.72, < 0.01
	4.72A	3.25	119	3.65	2.43B	107	3.43B	2.62	100	
Species X Season	<b>Mule Deer</b>			<b>Elk</b>						6.79, 0.01
Winter	3.42A	2.08	84	5.69B	3.64	66				
Summer	2.82A	1.72	100	4.05B	3.20	76				
Repro Class X Season	<b>Females</b>			<b>Females with offspring</b>			<b>Males</b>			.802, 0.44
Winter	5.24A	3.21	46	3.80B	2.94	46	4.27B	2.99	58	
Summer	3.98A	3.21	73	3.08AB	1.93	61	2.64B	1.62	42	
Repro Class X Species	<b>Females</b>			<b>Females with offspring</b>			<b>Males</b>			1.83, 0.16
Mule Deer	3.58A	2.08	73	2.89A	1.71	70	2.57A	1.78	41	
Elk	5.87A	4.19	47	4.34B	3.23	37	4.29B	2.89	59	
Repro Class X Species X Season	<b>Females</b>			<b>Females with offspring</b>			<b>Males</b>			1.19, 0.30
Mule Deer w <sup>g</sup>	4.39A	2.17	33	3.02A	1.73	29	2.51A	1.84	22	
Mule Deer s	2.91A	1.75	40	2.80A	1.71	41	2.65A	1.76	19	
Elk s	5.28A	4.03	33	3.65A	2.27	20	2.64A	1.54	23	
Elk w	7.37A	4.37	13	5.15A	4.01	17	5.34A	3.07	36	

<sup>a</sup> Average days spent on kills for each variable.

<sup>b</sup> Observed number of prey killed for each variable.

<sup>c</sup> Standard deviation.

<sup>d</sup> F-statistic and P-value from ANOVA output.

<sup>e</sup> Cougar reproductive classes.

<sup>f</sup> Different letters across rows indicate a statistical difference ( $P \leq 0.05$ ) between comparisons.

<sup>g</sup> W = winter, S = summer



Figure 1.1 Cle Elum study area location in Upper Kittitas County, Central Washington, USA  
2003-2008.

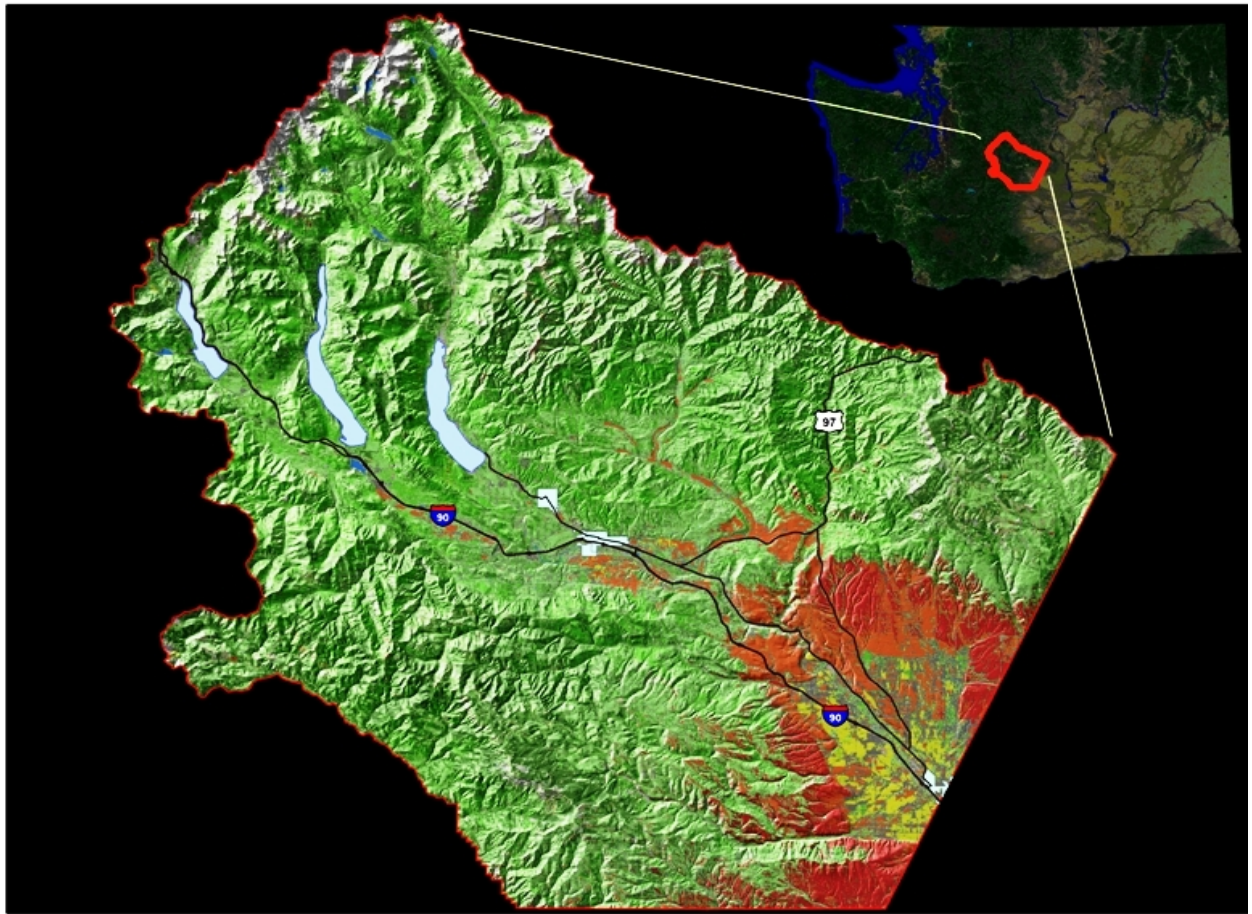


Figure 1.2 Movement patterns around predation sites for two adult male cougar in central, Washington, USA.

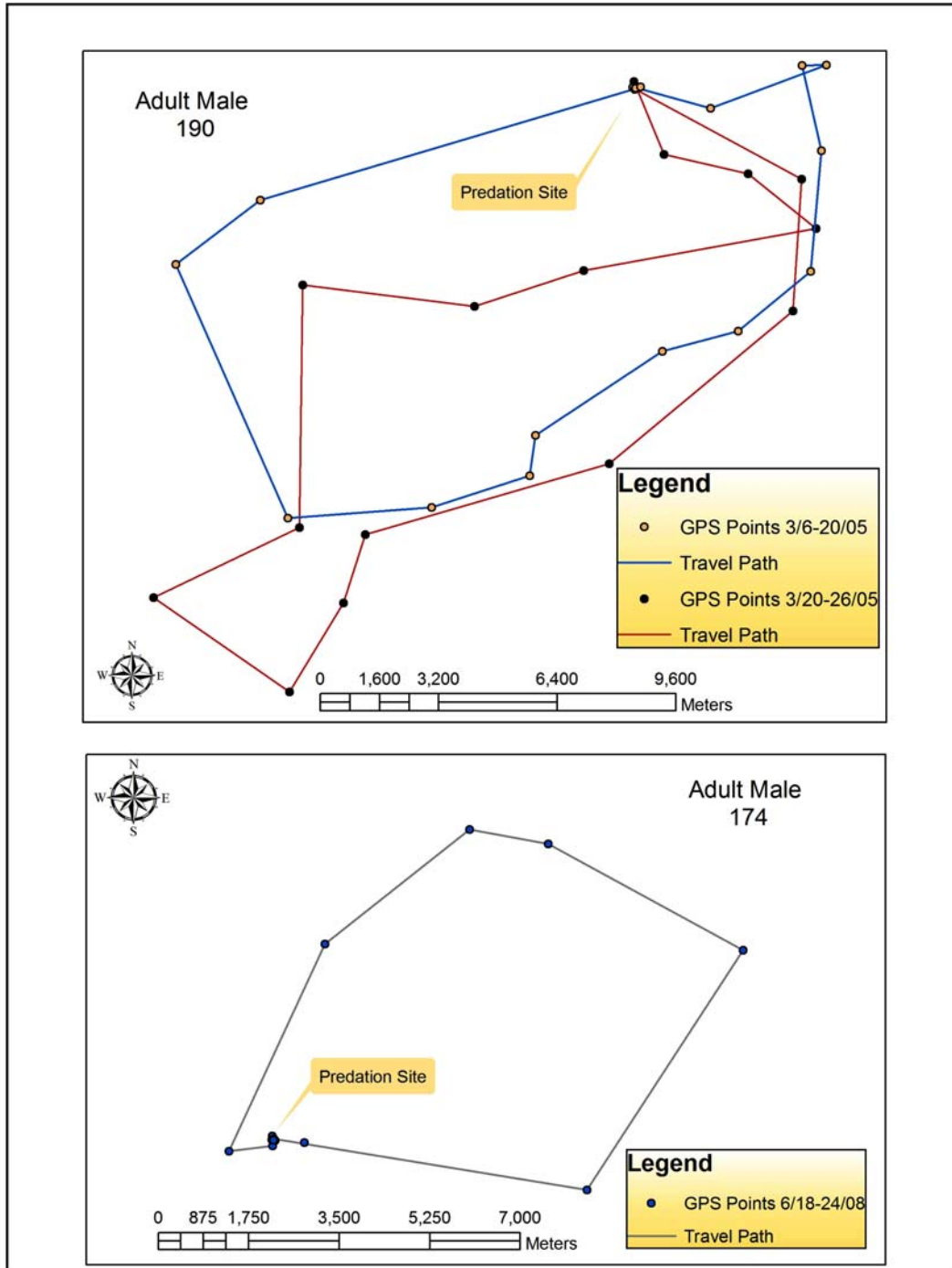


Figure 1.3 Movement patterns around predation sites for two adult female cougars in central Washington, USA.

