ANALYSIS OF KILL SITE PARAMETERS TO BETTER UNDERSTAND HUNTING BEHAVIORS OF MOUNTAIN LIONS (*PUMA CONCOLOR*)

by

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ABSTRACT

The understanding of activity patterns and hunting behaviors can provide insight into life history and predator-prey dynamics. The mountain lion, *Puma concolor*, occupies the largest geographical range of any terrestrial mammal in the western hemisphere. Mountain lions live in a variety of habitats including mixed forests, high elevation plateaus, shrub communities, open steppe, valley bottoms with steep slopes, and riparian habitats. Previous research has shown their activity patterns occur primarily during the nocturnal and crepuscular periods. The primary prey of mountain lions are mule deer and elk, but they also rely on smaller prey such as American beaver and North American porcupine among others. I investigated characteristics of mountain lion kills in response to diel cycle and lunar illumination. Data were collected between 4 March 2011 to 27 April 2015 on a total of 1,234 predation events from 24 different mountain lions fitted with Global Positioning System (GPS) collars in Colorado and Wyoming. My three objectives were: to provide descriptive characteristics on mountain lion kill sites, evaluate selectivity of kills made across the diel cycle and over varying degrees of lunar illumination, and to assess whether there are seasonal differences in the proportion of kills made across the diel cycle, and across the lunar illumination categories. I constructed 95% Bonferroni adjusted confidence intervals and Manly's alpha selectivity index scores to assess selectivity or avoidance of specific categories. I used R to run chi-square tests and found that there was a significant difference between lunar illumination categories and during the summer season. The greatest proportion of kills occurred during periods with greatest lunar illumination (>90 %). There was a significant difference in prey selection at the lowest level (<10%) of lunar illumination when compared to the total percent prey composition. Diel cycle also had significant effects on mountain lion kills. Understanding mountain lion hunting behaviors will aid in management of this predator as well as management of its prey populations. In an era of technological advances and urban growth and development, these management practices will allow us the knowledge and tools to successfully cohabitate with this iconic species.

I. INTRODUCTION

The mountain lion (*Puma concolor*) is the most abundant large felid in North America and the most wide-ranging carnivore in the western hemisphere (Young and Goldman 1946; Pierce and Bleich 2003). Mountain lions serve as top-down regulators in a variety of ecosystems making them a key component in conservation planning (Beier 2010). They inhabit vast, interconnected areas where, as a flagship species, conservation efforts for mountain lions may benefit many other species (Beier 2010; Mills 2007). Mountain lions can have impacts on ecosystem dynamics disproportionate to their numbers, and by this definition, may be considered a keystone species (Meffe and Carrol 1997; Laundré 2008). For example, Ripple and Beschta (2006) found that in areas of Zion National Park without mountain lions, there were more large herbivores, less trees, increased stream bank erosion, and decreased biodiversity in riparian habitats.

The legal status of mountain lions in the United States varies among states. As of 2008, they are considered big game in AZ, CO, ID, MT, NE, NM, OR, SD, UT, and WA, furbearers in ND, trophy game in WY, protected in CA, and unprotected non-game in TX (Anderson and Lindzey 2003). In order to provide comprehensive management plans for this carnivore, a thorough understanding of its ecology is needed. Behavioral adaptations and factors affecting hunting and prey selection must first be understood (Murphy and Ruth 2010). Factors affecting prey selection and prey vulnerability include physical characteristics of prey (e.g. size and shape), prey behavior (e.g. age and habitat use), and abiotic factors (e.g. snow depth and temperature) (Murphy and Ruth 2010). Mountain lions may be influenced by specific factors contributing to prey selection such as experience, age, size, or individual preference (Murphy and Ruth 2010). In the literature, there is a broad range of sample sizes for prey items and percent occurrence of prey in diet. Toweill and Meslow (1977) had a sample size of 18 prey items, while Ross and Jalkotzy (1996) included 334 prey items. Bartnick et al. (2013) included 539 kill sites in a study investigating variation in predation habits of mountain lions.

The best hunting habitat for mountain lions is one that provides cover for them to stalk their prey, yet allows for ample visibility (Laundré and Hernández 2000). A variety of habitats meet these criteria, including mixed forests, high elevation plateaus, shrub communities, open steppe, valley bottoms with steep slopes, and riparian zones (Laundré and Hernández 2000). Habitat selection among mountain lions has been shown to mitigate the effects of competition by scavengers (Elbroch and Wittmer 2013). In Patagonia, for example, lions were most susceptible to harassment and displacement by Andean condors at kills located in open steppe habitats (Elbroch and Wittmer 2013). Onorato et al. (2011) found no variation in sex or season for habitat selection by Florida panthers, but found a significant difference across diel cycle. Resource selection studies are typically associated with prey or foraging patterns and habitat selection. Mountain lions may exhibit selective foraging behaviors and, differential predatory behavior may be dependent on multiple factors contributing to prey selection (Iriarte et al. 1990). These factors may include the time of day a kill was made and lunar illumination among kills during the nocturnal period.

Research on the relationship between activity patterns and mountain lion hunting behaviors is limited. Beier et al. (1995) examined movement patterns (mean distance, number of travel bouts, percent of time traveling) compared across nocturnal and diurnal periods of diel cycle. These patterns were further broken down into different behavior categories, killed large mammal (>21kg), killed small mammal (<20kg), copulated, hunted or traveled with no kill, and fed on previously killed large mammal. Beier et al. (1995) focused on some aspects of hunting behaviors across the diel cycle, but did not investigate lunar illumination. According to Beier et al. (1995), mountain lions hunt primarily during the crepuscular and nocturnal periods. There has been variation among study sites with some studies showing the greatest activity during the twilight period, and some areas resulting in mainly nocturnal activity (Beier et al. 1995). Since mountain lions hunt mainly during low to no light periods, the effects of lunar illumination on hunting behaviors is of interest. Yet, few studies have considered the relationship between lunar phase and hunting behaviors.

Prugh and Golden (2014) conducted a meta-analysis on responses of nocturnal mammals to lunar cycles. They considered 58 different studies on 59 nocturnal mammals. Two of the hypotheses they tested included one focusing on visual-acuity and the other on habitat-mediation. The visual-acuity hypothesis stated that prey species that rely primarily on vision would be more active in nocturnal periods with greater illumination, yet predators relying mainly on vision would be less active (Prugh and Golden 2014). The habitat-mediated hypothesis proposed that prey species activity would be most affected in open areas, during periods with greatest illumination (Prugh and Golden 2014). The only large carnivore included in the analysis was the African lion (*Panthera leo*) and they found that activity was strongly inhibited by moonlight (Prugh and Golden 2014). Cozzi et al. (2012) examined activity data collected from Global Positioning System (GPS) collars on the African large predator guild, comprised of five carnivores:

the African wild dog (*Lycaon pictus*), cheetah (*Acinonyx jubatus*), leopard (*Panthera pardus*), spotted hyena (*Crocuta crocuta*), and the African lion. Within the African large predator guild, wild dogs and cheetahs showed significant differences in activity patterns between full moon and new moon periods while lions and hyenas did not vary over the lunar cycle. The effects of diel cycles and light availability on cheetah behavior were also examined based on behavioral observations and activity scores from data loggers. Cheetah feeding activity was not affected by moonlight intensity. However, mobile activity at night significantly increased with increasing moonlight levels, while daytime activity significantly decreased (Broekhuis et al. 2014). Rockhill et al. (2013) studied bobcat movements using activity data from GPS collars and found that the majority of movements occurred during the crepuscular period and that movement increased based on the amount of illumination (Rockhill et al. 2013).

Few current research studies investigating illumination have included the mountain lion. Using camera trap data, Harmsen et al. (2010) looked at jaguar (*P. onca*) and mountain lion activity patterns in relation to their main prey in Belize. Jaguar activity decreased with brighter nocturnal illumination in areas containing armadillos while mountain lion activity did not vary with moonlight, although their main prey did. Lucherini et al. (2009) examined the activity pattern segregation of carnivores in the High Andes (Argentina, Bolivia, and Chile) using motion sensitive camera data. This study included the Andean cat (*Leopardus jacobitus*), Pampas cat (*L. pajeros*), culpeo (*Lycalopex culpaeus*), mountain lion, and the mountain vizcacha (*Lagidium viscacia*). Although Lucherini et al. (2009) suggested that predator activity was not influenced by lunar illumination levels, the authors noted that the sample size in this study was small (n=49 photos) and further research including a larger sample size would be beneficial.

Objectives

My research examined mountain lion hunting behaviors by looking at prey composition, the proportion of kills made in response to diel cycle, season, and illumination. I also investigated whether mountain lions selected specific time periods or specific lunar phases when making a kill. Due to the activity patterns of mountain lions during the diel cycle, I predicted the highest proportion of kills would occur during crepuscular and nocturnal periods, and the lowest proportion would occur during the day. In association with the visual-acuity hypothesis and the habitat-mediated hypothesis posed by Prugh and Golden (2014), I expected that activity would be suppressed during periods with greater lunar illumination and I expected that more kill sites would occur in closed cover versus open cover during those lunar illumination periods. Additionally, due to decreased activity levels, I hypothesized that during greater lunar illumination, smaller prey would be selected for over larger prey. My objectives were:

1) *Descriptive Characteristics:* Provide descriptive characteristics on mountain lion kill sites including total species, sex and age classes of primary prey, kills separated by diel cycle, all compared between female and male mountain lions.

2) *Selectivity:* Evaluate selectivity of kills made across the diel cycle and over varying degrees of lunar illumination as well as by prey species.

3) *Seasonality:* Assess whether there are seasonal differences in the proportion of kills made across the diel cycle, and across the lunar illumination categories.

II. METHODS

These data were collected and made available by the collaborative efforts of the Garfield-Mesa Lion project and Panthera's Puma Program. The data collected by Panthera's Puma Program are part of an ongoing multi-faceted study. Panthera strives to protect the puma and learn the best management practices by conducting innovative behavior and ecology research (https://www.panthera.org/initiative/puma-program). With my research I hope to contribute to Panthera's overall efforts.

Study Sites

Telemetry and kill site data from two different study sites were included in this analysis, Colorado and Wyoming. These sites represent a broad range of habitats occupied by mountain lions allowing a comprehensive investigation into predation events on the most widely distributed terrestrial carnivore in the Americas (Elbroch and Rinehart 2011). The Colorado site predominantly included the High Lonesome Ranch and surrounding private lands, as well as Bureau of Land Management (BLM) public lands near De Beque, CO totaling approximately 1,100 km^2 (Elbroch et al. 2014). Two main cover classes were present at this site with lower elevations between 1,500 and 1,700 m asl (above sea level) and higher elevations ranging from 1800 to 3000 m asl. Lower elevations were dominated by a mixed pinyon pine-juniper (*Pinus edulis* and *Juniperus spp.*) forest, with patches of Gambel oak (*Quercus gambeli)* and rangeland shrub assemblages (*Artemisia spp.* and *Atriplex spp.*) while the higher elevations contained Douglas fir (*Pseudotsuga mensiesii*), lodgepole pine (*Pinus contorta*) and quaking aspen

(*Populus tremuloides*). Temperatures ranged from -10° C in winter to 33.8° C in summer, with a mean annual temperature of 8.1° C. Average annual precipitation was 295 mm. Primary prey species inhabiting this site were elk (*Cervus elaphus*), and mule deer (*Odocoileus hemionus*). Smaller mountain lion prey included American Beaver (*Castor canadensis*), and North American porcupine (*Erethizon dorsatum*). Multiple competitors were present in the area including American black bears (*Ursus americanus*), coyotes (*Canis latrans*), Golden eagles (*Aquila chrysaetos*), and gray foxes (*Urocyon cinereoargenteus*) (Elbroch et al. 2014).

The second study site was 2,300 km^2 of the Southern Yellowstone Ecosystem, including Grand Teton National Park, the National Elk Refuge, and the Bridger-Teton National Forest (Elbroch et al. 2013). Three cover classes were considered in this area. The first cover class contained sagebrush (*Artemisia spp.*) lowlands and riparian habitats dominated by cottonwoods (*P. angustifolia*) and willow (*Salix spp.*). A mixed forest characterized the second cover class with dominant tree species including quaking aspen, Douglas fir, and lodgepole pine. The dominant species in the third cover class were Engelmann spruce (*Picea engelmannii*), and subalpine fir (*Abies lasiocarpa*) (Bartnick et al. 2013). Elevations ranged from 1,800 m asl in the first cover class, to over 3,600 m asl in the third cover class (Knight 1996). Annual precipitation averaged 424mm with a total annual snowfall of 206 cm (Annual Climatological Summary, NCDC). Temperatures ranged from -17° C in the winter to 28° C in the summer with an annual mean of -5° C. The primary competitors were wolves (*Canis lupus*), black bears, and grizzly bears (*Ursus arctos*). Additional carnivores at this site included coyotes and red foxes (*Vulpes vulpes*). This study site supported a multi-prey system including elk, mule deer, moose

(*Alces alces*), bison (*Bison bison*), pronghorn antelope (*Antilocapra americana*), and, in smaller numbers, bighorn sheep (*Ovis canadensis*), mountain goats (*Oreamnos americanus*), and white-tailed deer (*Odocoileus virginianus*) (Bartnick et al. 2013; Elbroch et al. 2013). Smaller prey in the area included American badger (*Taxidea taxus*), striped skunk (*Mephitis mephitis*), North American porcupine, and American beaver (Murphy et al. 1999).

Data Collection

Data were collected from mountain lions fitted with GPS collars programmed to acquire coordinates at two hour intervals and transmit them every 3 days through Argos satellites, twice daily through Iridium satellites, or every 4 hrs through Globalstar satellites (Elbroch et al. 2014). Location clusters indicating potential kill sites were defined as two or more locations which were ≤150 m apart within ≥4 hours (Elbroch et al. 2014). These locations were examined thoroughly by field investigation. I defined the time of kill following the first GPS time stamp transmitted within the cluster examined.

Field Collection

Researchers visited each site represented by a cluster. Locations were logged into handheld GPS units and the sites were thoroughly examined for prey remains such as hair, feathers, hooves, bone fragments, or body remains (e.g. rumen in ungulates). Once identified as a kill site, the exact GPS waypoint was marked at the carcass or remains. Information collected from a kill site included GPS coordinates, individual mountain lion identification code, date of observation, whether the carcass was cached and cache placement, general habitat, dominant tree/shrub species, slope, canopy cover (0-25%, 26-50%, 51-75%, 76-100%), prey species killed, prey sex (if available), prey age (adult ungulates are aged by tooth wear while other prey may be categorized as adult, sub-adult, yearling, fawn/calf, etc.), utilization (proportion of animal consumed: 0-25%, 26-50%, 51-75%, 76-100%) (Fig. 1A, 1B).

Data Compilation

I compiled and analyzed data sets from the Colorado and Wyoming study sites, containing a total of 1,234 predation events validated in the field from 24 different mountain lions, 14 female and 10 male, across a four-year time span (March 2011 – April 2015) (Table 1). Important notes were made on each individual mountain lion including age at capture, length of time monitored, and number of kills documented (Table 1). Data collected from the Colorado site were from 432 predation events of 11 different mountain lions, 5 female and 6 male, from 4 March 2011 - 11 December 2012. Wyoming data were collected from 802 predation events of 13 different mountain lions, 9 female and 4 male, from 1 April 2012 - 27 April 2015. Data collection from both study sites followed identical protocol and technician training under the same leadership, thus minimizing observer bias.

Statistical Analyses of Descriptive Characteristics

I organized each predation event by diel cycle, categorized as day (1 hr after sunrise - 1 hr before sunset), night (1 hr after sunset - 1 hr before sunrise), or crepuscular (two hr period surrounding sunrise and sunset for a total of four hrs per day) (Ackerman 1982, Beier et al. 1995), and compared between female and male mountain lions. Sunrise and sunset times were acquired from the Astronomical Applications Department of the US Naval Observatory (http://aa.usno.navy.mil/index.php). I organized predation events by kill times across diel cycle (1 hr intervals) and compared differences between male and female mountain lions. Time intervals were assigned on a daily basis.

I investigated the total percent composition of prey species and compared between female and male mountain lions. Prey species was observed within diel cycle and compared between male and female mountain lions. Prey species occurring in small proportions were grouped together based on size and type. All birds were grouped together. Mammals were grouped based on size alone; small mammals were considered <1 kg, medium sized mammals were 1-15 kg, and large mammals were >15 kg (Iriarte et al. 1990). I also investigated the interaction of time of day (diel cycle) and prey species to determine differences in time of day when particular prey were being killed. I compared differences in age class and sex of the two primary prey species between male and female mountain lions

I compared canopy cover at each kill site based on the total kills, and then by segment of diel cycle (daytime, crepuscular, and nocturnal periods). Canopy cover was included for the proportion of kill sites that occurred in each of four canopy cover categories (0-25%, 26-50%, 51-75%, 76-100%). Cloud cover and canopy cover were also investigated specifically for the kills which fit the lunar illumination criteria. Cloud cover was obtained from the National Center for Environmental Information (NCEI) of the National Oceanic and Atmospheric Administration (NOAA). These data were supplied by the nearest weather station to each study area. Data were reported as categorical (clear, scattered, broken, overcast, or a combination of each). Cloud cover was then quantified by the degree of classification as given by NOAA (National Oceanic and Atmospheric Administration 2015): clear = 0% cover, scattered = 31.25% cover, broken= 75%, and overcast = 100% cover. In the case where multiple categories were listed, the mean was calculated and recorded. Effects of cloud cover were examined within varying degrees of lunar illumination so that differences between categories of cloud cover may be compared.

Statistical Analyses of Selectivity

I examined selectivity based on a study design II (Manly et al. 2002) in which individual animals and resources are identified and measured, while availability is measured at the population level. Selectivity is measured by comparing the use of a resource to the availability of that resource in the environment (Krebs 1999). I used R version 3.1.2 (2013 The R Foundation for Statistical Computing) to conduct Chi-square tests to examine any deviations from expected use of diel time periods, lunar illumination categories, and composition of prey species. To support the Chi-square tests, I used Manly's alpha selectivity indices along with confidence intervals with a Bonferroni correction (α/n) (Neu et al. 1974) to determine which resources were used more or less than expected. I investigated whether the percentage of kills fell within the lower and upper bounds of the 95% confidence intervals and then determined utilization as either more (M) or less (L), than the predicted amount. Preference was further shown with a Manly's alpha index greater than 1/m (m = the total number of categories), indicating utilization was more (M) than the available. Avoidance was shown with a Manly's alpha index less than 1/m, indicating utilization was less (L) than available (Krebs 1999; Manly et al. 2002).

I verified that each lion had at least one kill in each category of day, crepuscular, and nocturnal periods before further investigation to help minimize any individual variation (Table 2). I recorded predation events in the appropriate one-hour time interval (0001 - 0100 h, 0101 – 0200 h, etc.) of the diel cycle in which the kill was made. I calculated the percentage of total kills made in each interval. I conducted a Chi-square test which tested the null hypothesis there is no difference in the percentage of kills among time intervals of the diel cycle (mountain lions kill in equal proportions throughout the day). Confidence intervals were constructed along with Manly's alpha values so I could determine utilization.

Lunar Illumination levels were quantified using the time of sunrise, sunset, moonrise, and moonset. The lunar illumination value was based on the fraction of the moon illuminated, ranging from 0 to 1. Times and values were obtained from the Astronomical Applications Department of the US Naval Observatory (http://aa.usno.navy.mil/index.php). Lunar illumination values were divided into four categories: <10%, 11-50%, 51-89%, and >90%. These categories were adapted from Rockhill et al. (2013) and correspond to lunar phases, <10% represents a new moon, 11-50% equals waxing/waning crescent moon, 51-89% equals waxing/waning gibbous moon, and >90% represents a full moon. Kills which fit the criteria: 1) occurred at night and 2) occurred between the time of moonrise and moonset were analyzed for lunar illumination. Moonrise and moonset times were acquired from the Astronomical

Applications Department of the US Naval Observatory (http://aa.usno.navy.mil/index.php).

For lunar illumination analysis, I selected only those kills that occurred at night and between moonrise and moonset (Table 2). I considered selectivity for lunar illumination in a similar manner as done for diel cycle. I calculated observed values by dividing the number of kills which occurred in each lunar illumination category by the total number of kills. Availability was calculated using multiple criteria: 1) how many days across the total study period occurred in each lunar illumination category, and 2) verification that moonrise occurred during the nocturnal hours. I conducted another Chi-square test on the null hypothesis that mountain lions have the number of kills equal to the expected number of kills based on the available frequency. Confidence intervals were calculated using observed values compared with expected values to determine utilization. If the expected number of kills fell within the confidence intervals, then mountain lions killed prey proportionally across lunar illumination periods. If the expected number of kills fell below the confidence interval, then mountain lions kill more prey in that lunar illumination period than the other categories, which would indicate selectivity. If the expected number of kills was above the confidence interval, then mountain lions killed fewer prey than predicted in that category, indicating avoidance. I used Manly's alpha selectivity index to show preference or avoidance and to support the Chi-square tests and confidence intervals.

To examine whether mountain lions select prey species during periods of lunar illumination, I arranged number of kills into seven groups according to prey species: mule deer, elk, porcupine, beaver, large mammals, small/medium mammals, and birds.

Any single prey species occurring at ≤ 2% of the total prey were grouped into the appropriate mammal category (large, small/medium) or bird category. Using Chi-square, I compared differences between the observed number of kills for each prey and the expected number of kills for each prey based only on kills occurring during periods of lunar illumination at night. Observed percentages of prey were calculated as the actual number kills of each prey type per total number of kills. Expected percentages were calculated by multiplying the number of kills for each species by the total percent prey composition of that species. To support the chi-square tests and to determine where any specific differences might occur, I constructed Bonferroni adjusted 95% confidence intervals. Utilization was investigated as whether the expected values fell within the lower and upper bounds of the confidence intervals. I also used Manly's alpha selectivity index to determine prey selectivity within lunar illumination.

Statistical Analyses of Seasonality

I examined the distribution of kills by prey species across four seasons (astronomical) by grouping predation events by the appropriate astronomical season (based on solstices and equinoxes) in which they occurred. I then sorted predation events by diel time interval Prey composition was also examined within each season. Seasonality was assessed in a similar manner as selectivity. Confidence intervals were calculated as well as Manly's selectivity indices to determine any seasonal variation. A chi-square test was run for each season between observed values and expected values to test for significant deviations. I also assessed seasonal variation between percent composition of kills by female and male mountain lions.

III. RESULTS

Prey Species Composition

A total of 37 prey species were documented from the mountain lion kill site investigations (Fig. 2). The greatest proportion of kills were mule deer at 40%, followed by 36% elk, 7% porcupine, 5% beaver, and 2% each of coyote (*Canis latrans*), bighorn sheep (*Ovis canadensis*), and pronghorn (*Antilocapra americanus*). Species occurring in less than 2% of the total kills were grouped together (Table 3). Medium sized mammals made up the largest proportion at 3% which included 35 individuals from 9 different species: American badger (*Taxidea taxus*), 2 bobcat (*Lynx rufus*), cottontail (*Sylvilagus spp.*), 3 marmot (*Marmota flaviventris*), muskrat (*Ondatra zibethicus*), 9 raccoon (*Procyon lotor*), 6 red fox (*Vulpes vulpes*), 3 snowshoe hare (*Lepus americanus*), and 9 striped skunk (*Mephitis mephitis*). Large mammals made up 1% and included 16 individuals from 7 different species: black bear, cougar, domestic sheep (*O. aries*), 6 moose (*Alces alces*), 3 unknown ungulates, 3 white-tailed deer (*Odocoileus virginianus*), and wolf (*Canis lupus*). Small mammals comprised less than 1% and included 5 individuals from 4 species: American marten (*Martes americana*), Northern pocket gopher (*Thomomys talpoides*), 2 red squirrels (*Tamiasciurus hudsonicus*), and white-footed mouse (*Peromyscus leucopus*). Birds represented 1% and included 17 individuals from 11 species: American coot (*Fulica americana*), Canada goose (*Branta canadensis*), great gray owl (*Strix nebulosi*), great horned owl (*Bubo virginianus*), magpie (*Pica pica*), pheasant (*Phasianus colchicus*), pine siskin (*Carduelis pinus*), raven (*Corvus corax*), 6

Ruffed grouse (*Bonasa umbellus*), sandhill crane (*Grus canadensis*), and 2 wild turkeys (*Meleagris gallopavo*).

Female mountain lions killed a total of 782 individuals representing 31 species while males killed a total of 452 individuals from 18 species (Fig. 3, 4). Mule deer made up the greatest percentage of prey killed by female mountain lions (41%, 323), followed by elk (37%, 293) while male mountain lions killed the most elk (38%, 169), followed by mule deer (35%, 156). Variation in use between males and females was also found among those prey species represented in small amounts. The percent composition of kills by female mountain lions was rather equally distributed among the smaller groups: 3.8% North American porcupine, 3.3% bighorn sheep, 2.7% coyote, 2.4% American beaver, 2.2% pronghorn, 3.5% medium mammals, 1.5% birds, 1.3% large mammals, and 0.6% small mammals. Male mountain lions, however, had an unequal distribution of kills among these groups: 12.6% North American porcupine, 8.4% American beaver, 1.8% coyote, 0.4% bighorn sheep, 0.4% pronghorn, 2.0% medium mammals, 1.3% large mammals, and 0.9% birds.

Sex and Age Classes of Primary Prey

The number one prey species for both female and male mountain lions was mule deer (Fig. 5, 6). The greatest percentage of kills by male mountain lions consisted of fawns at 41.4% (70), followed by adults at 24.8% (42). Yearlings and sub-adults represented 12.4% (21) and 11.8% (20) of kills, respectively, and the smallest proportion was of unknown age class at 9.5% (16). In fawns, more males were killed than females at

67.4% and 32.5%. In adult mule deer, more females (30%) were killed than males (7%), while more yearling males (38.1%) were killed than females (19%). More sub-adult females (60.0%) were killed than sub-adult males (30.0%). The top two prey percentages killed by female mountain lions were fawns at 44.3% (143), followed closely by adults at 38.1% (123). Yearlings and sub-adults represented 8.7% (28) and 6.2% (20) of kills, respectively. The lowest percentage killed by females was the unknown age class at 2.8% (9). Again, sex could be determined for few fawns, but females (5.6%) were killed slightly more than males (3.5%). Among adults, more females (60.2%) were killed than males (23.6%). In yearlings, slightly more females (28.6%) were killed than males (25.0%), and in sub-adults, there was a greater percentage between females and males at 50.0% and 35.0%.

The second most used prey species by both female and male mountain lions was elk (Fig. 7, 8). Female mountain lions killed the most calves, representing 52.9% (155) of kills, followed by adults at 25.9% (76), yearlings at 12.3% (36), 3.4% sub-adults (10), and 5.5% (16) of unknown age class. In calves, more females were killed at 11.0%. A greater percentage of adult females (75.0%) were killed than male adults (23.7%), which was similar to yearlings with more females killed than males, 44.4% and 11.1%, respectively. In sub-adults, more females (50.0%) were killed than males (40.0%). The greatest percentage of kills by male mountain lions consisted of calves at 48.7% (76). The second highest percentages of kills, 25.6% (40), were adults, followed by 10.9% (17) yearlings, 8.9% (14) sub-adults, and 5.7% (9) of unknown age class. In calves, more females were killed at 81.3%. More females than males were killed among adult elk

(87.5%) and yearlings (47.1%). Yet in sub-adults, more males (42.9%) were killed than females (35.7%).

Canopy Cover

The greatest percentages of the total number of kill sites under canopy, 31%, occurred in both the highest (76-100%) and lowest (0-25%) canopy cover. Twenty percent of kill sites occurred under 51-75% canopy and 16% occurred under 26-50% cover. Canopy cover was undetermined in 2% of kills. In a similar manner, the greatest percentage of kills (30%) during crepuscular periods occurred in the highest and lowest cover categories. Twenty-three percent of kill sites occurred in the second highest canopy cover (51-75%), while 16% of kill sites were found under 26-50% cover. The highest percentage of daytime kill sites (34%) occurred under the greatest amount of cover, 76-100%, yet the next highest, 26% of kill sites, were in the lowest cover, 0-25%. Twenty percent of kill sites were under 51-75% cover, while 18% were under 26-50% cover. The nocturnal period had most kill sites, 34%, in the least cover, 0-25%. The next highest proportion of kill sites, 30%, occurred in the most cover. Quite a bit lower at 18% and 15% were kills located under 51-75% cover and 26-50% cover, respectively.

Canopy and Cloud Cover during Lunar Illumination Periods

Canopy cover of kill sites occurring during the lunar illumination periods followed a similar pattern as total kills. The greatest number of kill sites, 35%, occurred under the lowest canopy cover, 0-25%. Twenty-nine percent of kill sites occurred in the greatest canopy cover, 76-100%, followed by 22% in 51-75% cover, and 14% occurred under 26-50% canopy cover.

Cloud cover at kills during lunar illumination periods showed the majority of kills, 54%, occurred on nights with 0-25% cloud cover. The next highest percentage, 26% of kills, occurred on nights with 76-100% cloud cover. Ten percent of kills each occurred in the remaining two categories, 26-50% cloud cover, and 51-75% cloud cover.

Diel Cycle

The majority of kills (54%, 666) occurred at night, followed by daytime (30%, 371) and crepuscular kills (16%, 197) (Fig. 9). Because there were more females in the study, female mountain lions made 63.5% of kills while males made 36.5%. During the crepuscular period, females made 137 (11.1%) kills while males made 60 kills (4.9%), respectively. Both females and males made twice as many kills during the day (21.0%, 259 and 9.1%, 112), respectively than during the crepuscular period. Males made twice as many kills at night (22.6%, 279) compared to day, and females made the greatest number of kills (31.4%, 387) during the night.

There were distinctive peaks in kills during crepuscular and nocturnal periods (Fig. 10). The crepuscular period showed peaks occurred from 0501-0900 h as well as between 1701-2100 h. The greatest percentage of kills, 7.4%, in any time period occurred from 2201-2300 h, while the smallest percentage of kills was 1.0% occurring from 1301-1400 h. Male and female mountain lions showed similar patterns across the diel cycle (Fig. 11). The greatest percentage of kills for male mountain lions, 8.9%, occurred from 2001-2100 h, while the greatest percentage of kills for females, 7.0%, occurred between

2201-2300 h. The smallest percentage of kills for males was 0.7% from 1501-1600 h, and for females was 1.0% from 1301-1400 h.

Daytime kills included 371 individuals from 22 species (Fig. 12). Mule deer represented the greatest percentage of kills at 46.1%, followed by elk at 33.7%. The remainder of kills was composed of North American porcupines (5.9%), pronghorn (2.7%), coyotes (2.4%), American beaver (2.2%), and bighorn sheep (2.2%). Birds made up 1.6% and included American coot, great horned owl, magpie, pine siskin, ruffed grouse, and sandhill crane. Large mammals made up 1.3% and were comprised of American black bear, moose, and unknown ungulate. Marmot, snowshoe hare and striped skunk made up 1.1% of medium mammals while 0.8% of small mammals consisted of American marten, northern pocket gopher and white-footed mouse.

Kills made during the crepuscular period included 197 individuals from 16 species (Fig. 13). The majority of kills were elk (41.9%) and mule deer (41.4%). The remaining prey were (in decreasing amounts) American beaver (3.5%), North American porcupines (3.0%), bighorn sheep (2.5%), and coyotes (1.0%). Medium mammals (4.0%) included bobcat, cottontail, marmot, red fox, raccoon, and snowshoe hare. Large mammals made up 1.0% of the kills and included white-tailed deer and wolf while ruffed grouse was the only bird also making up 1.0%. No small mammals were recorded as killed during the crepuscular period.

Kills during the nocturnal period consisted of 666 individuals representing 27 species (Fig. 14). Elk were the highest percentage at 36.2% of kills, followed by mule deer at 35.9%. The remaining kills were composed of 8.9% North American porcupine, 6.3% American beaver, 2.7% coyote, 2.3% bighorn sheep, and 1.2% pronghorn. Medium sized mammals (3.6%) included American badger, bobcat, marmot, muskrat, raccoon, red fox, snowshoe hare, and striped skunk. Large mammals made up 1.4% of kills and included cougar, domestic sheep, white-tailed deer, moose, and unknown ungulate. Birds also contributed to 1.4% of kills and included Canada goose, great gray owl, pheasant spp., raven, ruffed grouse and wild turkey. Red squirrels were the only small mammals represented in nocturnal kills and made up 0.3%.

Selectivity and Diel Cycle

I rejected the null hypothesis that there is no difference in time of day when mountain lions make kills (χ^2 = 115.67, df = 23, p = 2.486^{e-14}). There were ten time intervals which were disproportionately used to make kills, four were utilized more than predicted and six were utilized less than predicted (Table 4). The time periods which were selected for and utilized more were 0001-0100 h, 2001-2100 h, 2201-2200 h, and 2301-2399 h. The time intervals selected against and utilized the least were 0901-1000 h, 1101-1200 h, 1301-1600 h, and 1701-1800 h. The remaining time interval categories fell within the confidence intervals. When using Manly's alpha selectivity index, there were 11 categories which were utilized more and 13 categories were utilized less than the available (Table 4). The categories utilized more based on the confidence intervals were supported by the Manly's alpha selectivity results.

Selectivity and Lunar Illumination

There was a significant difference in kills made among the lunar illumination categories. I rejected the null hypothesis (χ^2 = 14.90, df = 3, p <0.001) that there is no difference between the percentage of kills made by mountain lions in each lunar illumination category compared to the proportion of available number of days in each category. Using the 95% confidence intervals, there were three categories which were used disproportionately compared to availability. The illumination category greater than 90% was utilized more than the other four categories while two categories (<10%, 51-89%) were utilized less (Table 5). The results from Manly's alpha selectivity index showed the two categories with lower illumination (<10%, 11-50%) were utilized less while the categories with higher illuminations (51-89%, >90%) were utilized more (Table 5).

The null hypothesis that the percent composition of prey for mountain lions in each lunar illumination category would equate to the total percent composition of prey was rejected for the lowest illumination category (<10%) ($\chi^2 = 13.211$, df = 6, p = 0.040) (Table 6). I accepted the null hypothesis for the remaining illumination categories. All prey types regardless of lunar illumination fell within the 95% confidence intervals (Tables 7, 8, 9, 10). Manly's alpha selectivity results showed there were four prey types utilized more in the <10% illumination category while three prey types were utilized less (Table 7). Prey utilized more included mule deer, elk, beaver, and large mammals. Prey utilized less were porcupine, small/medium mammals, and birds. Prey utilized more in the 11-50% lunar illumination category based on Manly's alpha selectivity index included: elk, beaver, large mammals, and small/medium mammals while mule deer, porcupine, and birds were utilized less (Table 8). For the 51-89% lunar illumination using Manly's alpha, five prey types were utilized more including: mule deer, elk, porcupine, large mammals, and small/medium mammals while beaver and birds were utilized less

(Table 9). The greatest illumination category (>90%) had three prey types utilized more based on Manly's alpha (Table 10). Prey utilized more were porcupine, beaver, and birds while prey utilized less included: mule deer, elk, large mammals, and small/medium mammals.

Seasonality

The only season which had a significant difference based on the chi-square tests run for lunar illumination was summer (χ^2 = 8.039, df = 3, p = 0.045) (Table 11). I rejected the null hypothesis for summer, that the observed number of mountain lion kills would equal the expected number of kills for each category. Yet in spring, fall, and winter, the null hypothesis was accepted (Table 11).

Seasonality and Lunar Illumination

When assessing lunar illumination selectivity by season, the 95% confidence intervals showed that most mountain lion kills occurred in >90% illumination in spring and summer (Tables 12, 13). In fall, the category utilized most was 51-89% lunar illumination; none of the illumination categories were utilized more than others during winter (Tables 14, 15). The category utilized the least was the lowest illumination (<10%) during summer, fall and winter while there were no differences between categories during spring. Using Manly's alpha indices, the category utilized more in spring was >90% while the other three categories were utilized less (Table 12). Summer and fall both agreed that 51-89%, and >90% were utilized more while the lowest categories, <10%, and 11-50% were utilized less (Tables 13, 14). During winter, the lowest category, <10% was utilized the least while the other three categories were utilized more (Table 15).

Seasonality and Diel Cycle

Chi-square tests indicated there were three seasons in which the distribution of kills across the diel cycle differed significantly from the expected. The null hypothesis stating the observed percentage of kills to be equal across diel cycle was rejected for spring, summer, and winter. The null hypothesis was accepted for the fall season (Table 16).

For the spring season, confidence intervals showed that most kills occurred during 2201-2300 h. The fewest kills occurred during 1301-1600 h, and 1801-1900 h (Table 17). Using Manly's alpha selectivity index, more kills took place between 1801-0500 h, and 0701-0900 h. The fewest kills occurred from 0501-0700 h, and 1001-1800 h (Table 17). During the summer season, the confidence intervals showed more kills occurred from 2301-0000 h, while fewer kills occurred from 1301-1400 h, and 1501-1700 h (Table 18). Manly's alpha values showed that the hours which had more kills were between 2001-0400 h, 1001-1100 h, and 601-0900 h. The hours with the fewest kills using Manly's alpha were 0401-0600 h, 0901-1000 h, and 1101-2000 h (Table 18). In the fall season, there were no categories used more than others using confidence intervals. Categories used less using confidence intervals were 0501-0600 h, 0901-1000 h, 1101-1200 h, and 1301-1500 h (Table 19). Manly's alpha values showed the hours when more kills occurred were 0101-0200 h, 1601-2300 h, 1201-1300 h, and 0601-0900 h. The hours with the fewest kills using Manly's alpha were 0201-0600 h, 0901-1200 h, and 1301-

1600 h (Table 19). The winter season had two time intervals which more kills occurred using confidence intervals, 0001-0100 h, and 2001-2100 h. Confidence intervals showed that hours with the fewest kills were 2201-2300 h, 0501-0800 h, 0901-1400 h, and 1701-1800 h (Table 20). When using Manly's alpha, the hours with more kills were 1801-0300 h, 0401-0500 h, and 0801-0900 h. The hours with the fewest kills were between 0301-0400 h, 0501-0800 h, and 0901-1800 h (Table 20).

Females and males did show some seasonal variation (Fig. 15, 16). For the fall season, female mountain lions had the most kills occur at 9.27% from 2201-2300 h while males made the most kills, 15.94% from 2001-2200 h. The hours in which the fewest kills occurred during the fall were 1.32% from 1101-1200 h for females and 0.0% each for 0901-1000 h, and 1301-1400 h for males. For the spring season, females made the most kills, 7.62%, from 0201-0300 h, and males the most kills, 12.24% from 2201-2300 h. The hours with the fewest kills for females were 0.46% from 13:01-14:00 h, and 0.0% from 1401-1500 h for males. In the summer, females made the most kills, 8.33% from 0801-0900 h, while males made the most kills from 2301-0000 h at 11.38%. The hours with the least amount of kills for females were 0.46% each from 1301-1400 h, and 1501-1600 h, and then 0.60% from 1501-1600 h for males. During winter, the most kills for females was 9.84% from 2201-2300 h, and the greatest percentage of kills for males was 13.24% from 0001-0100 h. The fewest kills were at 0.52% each from 1701-1800 h, and 1101-1200 h, for females while the fewest kills for males were 0.0% each for 0501-0700 h, 1001-1100 h, 1201-1300 h, and 1501-1600 h.

IV. DISCUSSION

A potential source of error in these data and my analyses is the methodology used to estimate time of kill (see Methods). Since all kill sites were physically validated in the field, there is no error in the actual occurrence of a kill. Another study with radio-tracked mountain lions found that tracks, and multiple direct observations, suggested kills occurred <1 hour from the time the mountain lion arrived at a kill site (Beier et al. 1995). A difference of ±1 h is unlikely to affect many of the parameters within the scope of my study, including prey composition, sex and age classes of primary prey, selectivity by lunar illumination, prey selectivity by lunar illumination, and lunar illumination by season. The parameters that may have been affected by this estimation include the classification of kills into day, crepuscular, and nocturnal periods, as well as the specific time interval the kills were assigned to. Yet, these would most likely would be unaffected by a discrepancy of one hour, leaving the categorization of the day, crepuscular, and nocturnal periods largely unaffected. Further research incorporating accelerometer data may help to minimize any error associated with the estimation of time of kill. Accelerometer data allows for the classification of different behaviors such as low acceleration movement, high acceleration movement, resting, eating, and grooming (Wang et al. 2015). Using those data could provide a more comprehensive approach to analyzing the effects that diel cycle and lunar illumination may have on Mountain lion hunting behaviors.

Most kills occurred during the nocturnal hours, followed by the daytime period which was surprising. In my study, the crepuscular period represented a total of four hours per day while specific daytime and nocturnal hours varied daily. The four-hour crepuscular period represented 16% of the total day while the nocturnal and daytime periods represented 42% each, respectively. With the aforementioned proportions, the daytime period was utilized the least. This was supported by previous findings in which 81% of mountain lion movement occurred during the crepuscular or nocturnal periods (Sweanor et al. 2008). Another study which looked at radio-tracked mountain lions also concluded that most of their movement patterns were in the nocturnal and crepuscular hours with a strong peak near the evening crepuscular period (Beier et al. 1995). The designation of four hours for the crepuscular period may have caused discrepancies with some of the existing research because some studies have classified the crepuscular period as 1.5 hours surrounding sunrise/sunset for a total of six hours per day (Sweanor et al. 2008). This would undoubtedly increase the proportion of kills occurring in the crepuscular period. The difference between females and males were similar for the crepuscular and daytime period, with both sexes killing twice as much during the day than the crepuscular period. During the nocturnal period, females killed 1.5 times more than in the daytime period while males killed more than twice than that of the daytime period (Fig. 2). These data suggest that males may utilize the nocturnal period more than females.

Mountain lion activity is likely influenced by the activity patterns and vulnerability of their prey (Curio 1976, Beier et al. 1995, Eberhardt et al. 1984, Kufeld et al. 1988). One of their primary prey species, mule deer, are most active in the late afternoon and crepuscular periods (Eberhardt et al. 1984, Kufeld et al. 1988, Beier et al. 1995). A meta-analysis by Iriarte et al. (1990) looked at the frequency of occurrence of prey items in the diet of mountain lions across eight different studies. One study in Utah (Ackerman et al. 1984) had deer contributing the vast majority of large prey at 61.3%, medium prey made up 20.4%, while small prey made up 10.1% of their diet. Robinette et al. (1959) in Nevada and Utah found mountain lions' diet was made up of 73.3% large prey, with deer contributing 64.5% of that category. Medium prey made up 20.7% while small prey made up 3.8%. In this study, mountain lions had a greater percentage at 76.3% made up of mule deer and Elk. If other large prey species (pronghorn, Bighorn sheep, coyotes, and others were added, the total large mammal composition increases to 83.8%, followed by 14.5% medium prey, and >1% small prey. Although my study had a higher large mammal percentage and a lower small mammal percentage in comparison to the Utah and UT/NE studies, which were the closest in proximity to my study sites, my results were more closely aligned to studies in Oregon (Toweill and Meslow 1977), and California (Dixon 1925). In all of these eight studies, North American porcupine was found to be among the top four prey items. Similarly, I found North American porcupine (7.1%) to be the third highest prey item found during kill site investigations. Another kill site study by Anderson and Lindzey (2003) in Southeastern Wyoming and found that mule deer kills made up 59%, elk 20%, pronghorn 8%, followed by North American porcupine at 7%. Prey composition of mountain lions in my study showed mule deer and elk in similar proportions to each other, contrary to that of Anderson and Lindzey (2003), yet their study site was in southeastern Wyoming, which may account for the difference in elk proportions. The proportion of small mammals may have been underestimated during kill site investigations. The incorporation of fecal analysis in the future may aid in the detection of additional small prey items that may have been unaccounted for.

Although findings were not surprising for the total prey composition, the differences between male and female mountain lions were suggestive that the two sexes may have dissimilar hunting patterns. Variation was found among their smaller prey items as well. For females, the percent composition ranged from 0.64% small mammals to 3.83% North American porcupine (Fig. 6). For males, prey species composition ranged from 0.0% small mammals to North American Porcupine at 12.64% (Fig. 7). For the age class and sex composition of their primary prey, males and females had similar patterns. Elk calves and deer fawns were killed in greatest numbers (greatest percentage) by both sexes. Both female and male mountain lions both killed more female elk and mule deer, agreeing with Mattson et al. (2007), while Anderson and Lindzey (2003) concluded that male mountain lions killed more male elk and deer. Anderson and Lindzey also indicated that female mountain lions killed the most mule deer and males killed more elk, while I found that mule deer was the number one prey species for both sexes.

Analysis of time period use indicated use greater than expected for portions of the diel cycle. The hours in which the confidence intervals and Manly's alpha values both agreed as periods used more than expected were from 2001-2100 h and 2201-0100 h,.Hours utilized less than expected were 0901-1000 h, 1101-1200 h, 1301-1600 h, and 1701-1800 h. Anderson and Lindzey (2003) reported similar results showing the proportion of kills increasing between 1901-2200 h, and peaking from 2201-0200 h. while a different study (Beier et al. 1995) using radio-tracked mountain lions and direct observations showed the most kills occurred between 1800-2100 h, followed by a considerable drop between 2100-0300 h.

My statistical analyses supported data indicating fewer kills occur in the lowest amount of illumination, or during a new moon, while, more kills occurred during periods with more light, or during a full moon. This did not support my original hypothesis that hunting activity would be suppressed during periods with greater light. The meta-analysis by Prugh and Golden (2014) showed that foraging rates and habitat use by a number of species might be severely impacted by lunar cycles (Prugh and Golden 2014). Lunar illumination might assist predatory behaviors in mountain lions. Because mountain lions are primarily visual hunters (Kleiman and Eisenberg 1973), moonlight may increase their ability to successfully stalk and subdue prey. Cloud cover and canopy cover might affect impacts of lunar illumination however, the majority of kills occurred on clear nights. Half of those kills occurring on clear nights, then occurred on nights that had 76-100% cloud cover. Due to these proportions, the effects that cloud cover may have on lunar illumination are negligible. Differences between daytime and nighttime cloud cover has been examined and regions have been shown to exhibit greater cloud cover during the day than at night, and over oceans as opposed to land (Hahn et al. 1995). Also, due to different levels of clouds, much of the scattered light is not lost but is directed downward thereby contributing to cloud illumination (Hahn et al. 1995).

Canopy cover might also impact the degree of lunar illumination. However, I found that most kill sites were found in 0-25% cover during lunar illumination periods. As for the total kill sites, equal proportions were found between the lowest cover and the highest cover. During the daytime period specifically, most kill sites were found to be in heavy cover, 76-100%. This could be due to the amount of sunlight affecting the carcass. Canopy cover percentage was taken at the feeding site, which was not necessarily where the kill took place. A carcass may be dragged approximately 0-80 meters (Beier et al. 1995). During the nocturnal period, most kill sites were in the least amount of cover. Mountain lion kills may be dragged to heavier cover during the day to help improve cooling, minimize spoilage, and to reduce visibility to competitors (Robinette et al. 1959, Beier et al. 1995, Laundre and Hernandez 2003, Mattson et al. 2007). These factors support why a carcass may be cached in greater cover during the day, but less cover when cached at night.

Chi-square results for prey selectivity by lunar illumination showed a significant difference for the lowest category, <10% lunar illumination. The rejection of the null hypothesis concluded that for the lowest amount of illumination, prey are not killed in a similar proportion to their overall prey composition. Although the confidence intervals showed that all prey categories fell within the confidence intervals regardless of illumination level, the manly's alpha results did show some differences. The results suggest that mountain lions may prefer mule deer, elk, beaver, and large mammals during periods with low light availability or during a new moon. Although the results were not significant, another interesting note is that in periods with the greatest illumination or during a full moon, porcupine, beaver, and birds seem to be preferred while larger prey including: mule deer, elk, large mammals, and small/medium mammals are utilized the least. This supports one of my original hypotheses that during periods of greater illumination, smaller prey would be selected for over larger prey. An explanation for this may posit the idea that larger prey may be more aware of predation risk in brighter periods of light. Moonlight has been shown to suppress activity in some species, but the results herein support that moonlight may have a significant part in sustaining high visual acuity (Prugh and Golden 2014). Lunar cycles likely have a major impact on foraging rates and habitat use among many species, but may additionally affect predatory habits and future research in this area would be beneficial in the ecology evolution of nocturnal mammals (Prugh and Golden 2014).

The only season which had a significant difference in the lunar illumination categories was summer (P = 0.045). Confidence intervals and Manly's alpha values agreed that >90% illumination was utilized more in spring and summer. During summer, fall and winter, both tests agreed the <10% illumination category was utilized the least. The Chi-square results across diel cycle by season showed spring, summer, and winter were significantly different. These three seasons rejected the null hypothesis of proportional use throughout the day. Confidence intervals and Manly's alpha values agreed that in spring, 2201-2300 was utilized the most, while 1301-1600 was utilized the least. During summer both tests agreed, 2301-0000 was utilized the most and 1501-1700 was utilized the least. For fall, the tests only agreed upon categories which were utilized the least and included 0501-0600, 0901-1000, 1101-1200, and 1301-1500. During winter, confidence intervals and Manly's alpha values agreed that 0001-0100, 2001-2100, and 2201-2300 were used the most. The categories utilized the least were 0501-0800, 1001-1400, and 1701-1800. Most of the seasons had some overlap between which hours were utilized more or less. The earliest hour in which the most kills occurred was from 2001-2100, and the latest hour was from 0001-0100. Out of the four seasons, fall had the fewest number of predation events which may have impacted the results. Season may not be the important factor regarding lunar illumination. Beier et al. (1995) found no season effect for any variable when examining the movement patterns of Mountain lions.

Investigating the number of kills across diel cycle by hour, I was able to account for seasonal variation in amount of daylight, since the number of hours of daylight does vary not only by season, but daily at a fine-scale. This gave a better understanding of utilization across diel cycle as opposed to grouping kills solely into crepuscular, day, and nocturnal periods and investigating season based on those categories.

Investigating the impacts of predation and knowing which predictors have a greater influence will help in understanding the population dynamics of their prey. To support this, Rockhill et al. (2013) suggested that it would be beneficial to include illumination or lunar phase as a 4th dimension to be used in modeling and examining the population dynamics of prey (Rockhill et al. 2013). This study provides a potential for further explaining mountain lion predatory behavior patterns. As habitat loss and fragmentation continues to occur due to an increasing human population, there are bound to be more human-mountain lion encounters. Sweanor et al. (2008) provided some descriptive characteristics examining spatial and temporal aspects of Mountain lions regarding human activity with hopes that their study could help future research efforts reveal any significant explanatory variables. By investigating the factors which may affect hunting strategies, mountain lion behavioral studies may be used to help manage those issues and mitigate conflicts (Logan and Sweanor 2010). Future research incorporating a human component such as proximity of trails to kill sites, or proximity to roads, could be beneficial in understanding these large predators. The prey of North American mountain lions is quite different to that of South American mountain lions (Iriarte et al. 1990), thus, the incorporation of other study sites extending into the southern hemisphere and the tropics could be illuminating in this realm of research.

V. MANAGEMENT IMPLICATIONS

Understanding the activity patterns and hunting behaviors will allow for better management of mountain lions as well as their prey populations. These results allow us to better understand more specific periods of mountain lion activity across diel cycle and by lunar illumination. Ranch managers and similar property owners may benefit by incorporating appropriate actions in their management practices during periods of increased mountain lion activity (Ruth and Murphy 2010). This can also help the general public, in a number of ways. The best time periods for recreating could be integrated into parks, schools, wildlife management areas, etc. thus minimizing potential conflicts during periods where mountain lions may be actively hunting (Murphy and Ruth 2010). In an era of technological advances and urban growth and development, management practices will allow us the knowledge and tools, to successfully cohabitate with this iconic species.

Table 1. Individual mountain lion data. This table shows the identification number, sex, age at capture in years, number of total kills included in data compilation, and the monitoring period in days for each of the 24 total mountain lions, 10 male and 14 female.

Puma ID	Sex	Age at capture (years)	# of Kills	Monitoring Period (days)
P01-CO	M	2.10	94	343
P03-CO	M	1.95	54	282
P05-CO	M	0.50	9	44
P06-CO	M	7.72	41	243
P07-CO	M	5.89	58	370
P08-CO	F	5.24	44	313
P09-CO	F	3.80	31	217
P10-CO	F	5.11	61	245
P11-CO	F	3.41	7	30
P12-CO	F	4.19	20	165
P13-CO	M	1.90	13	119
F047-WY	F	4.58	76	861
F049-WY	F	6.00	67	746
F051-WY	F	4.08	98	1095
F057-WY	F	8.58	7	65
F061-WY	F	4.83	199	1118
F096-WY	F	1.50	53	384
F097-WY	F	1.42	28	125
F099-WY	F	0.92	16	73
F109-WY	F	7.42	76	1113
M029-WY	M	4.00	68	321
M062-WY	M	2.00	6	103
M068-WY	M	1.92	42	259
M085-WY	M	6.00	66	509

Table 2. Kills by individual mountain lion separated in diel cycle. The final column represents the number of kills factored into the illumination selectivity results which were kills made at night and while the moon was out.

Puma ID	Sex	Total kills	Crepuscular kills	Daytime kills	Night kills (total)	*illumination*
P01	M	94	9	20	65	*32*
P03	M	54	6	14	34	*18*
P05	M	9	4	0	5	*2*
P06	M	41	6	5	30	*17*
P07	M	58	7	22	29	*17*
P08	F	44	8	18	18	*7*
P09	F	31	5	11	15	*6*
P10	F	61	12	17	32	*18*
P11	F	7	2	2	3	*2*
P12	F	20	2	6	12	*5*
P13	M	13	3	3	7	*4*
F047	F	76	19	26	31	*17*
F049	F	67	5	37	25	*14*
F051	F	98	22	36	40	*24*
F057	F	7	1	2	4	*2*
F061	F	199	39	52	108	*62*
F096	F	53	10	12	31	*18*
F097	F	28	3	8	17	*10*
F099	F	16	0	6	10	*5*
F109	F	76	9	26	41	*19*
M029	M	68	9	21	38	*22*
M062	M	6	0	3	3	*2*
M068	M	42	7	9	26	*17*
M085	M	66	9	15	42	*18*
Totals		1,234	197	371	666	*358*

Table 3. Prey species grouped by size and type occurring in the smallest proportions. Small mammals were classified as less than 1 kilogram and included a total of 5 individuals of 4 species. Medium mammals were between 1 and 15 kg and included 35 individuals from 9 species while large mammals were greater than 15 kg including 16 individuals from 7 species. Birds were grouped together and included 17 individuals from 11 species.

Small Mammals (<1kg)	Medium Mammals (1-15 kg)	Large Mammals (>15kg)	Birds
American Marten	American badger	Black Bear	American Coot
Northern Pocket Gopher	Bobcat (2)	Cougar	Canada goose
Red squirrel (2)	Cottontail	Domestic sheep	Great gray owl
White Footed Mouse	Marmot (3)	Moose (6)	Great Horned Owl
	Muskrat	Unknown Ungulate (3)	Magpie
	Raccoon (9)	White-tailed deer (3)	Pheasant
	Red fox (6)	Wolf	Pine Siskin
	Snowshoe hare (3)		Raven
	Striped Skunk (9)		Ruffed grouse (6)
			Sandhill Crane
			Wild turkey (2)

Table 4. Summary of selectivity results of total kills across diel cycle using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of total kills made across diel cycle and the expected percent composition for each category H_O in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.042 indicate preference while scores lower suggest avoidance. Null hypothesis of equal proportional use was rejected ($\chi^2 = 115.67$, df = 23, p = 2.486^{e-14}).

		Percent Composition				Utilization	
Time interval	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
0001-0100	81	0.066	0.042	0.048-0.084	0.066	M	M
0101-0200	67	0.054	0.042	0.038-0.071	0.054	-	M
0201-0300	73	0.059	0.042	0.042-0.076	0.059	-	M
0301-0400	55	0.045	0.042	0.029-0.060	0.045	-	M
0401-0500	53	0.043	0.042	0.028-0.058	0.043	-	M
0501-0600	43	0.035	0.042	0.021-0.048	0.035	-	L
0601-0700	48	0.039	0.042	0.025-0.053	0.039	-	L
0701-0800	51	0.041	0.042	0.027-0.056	0.041	-	M
0801-0900	64	0.052	0.042	0.036-0.068	0.052	-	M
0901-1000	29	0.024	0.042	0.012-0.035	0.024	L	L
1001-1100	46	0.037	0.042	0.023-0.051	0.037	-	L
1101-1200	24	0.019	0.042	0.009-0.030	0.019	L	L
1201-1300	39	0.032	0.042	0.019-0.044	0.032	-	L
1301-1400	13	0.011	0.042	0.003-0.018	0.011	L	L
1401-1500	24	0.019	0.042	0.009-0.030	0.019	L	L
1501-1600	18	0.015	0.042	0.006-0.023	0.015	L	L
1601-1700	37	0.030	0.042	0.018-0.042	0.030	-	L
1701-1800	35	0.028	0.042	0.016-0.041	0.028	L	L
1801-1900	50	0.041	0.042	0.026-0.055	0.041	-	M
1901-2000	60	0.049	0.042	0.033-0.064	0.049	-	M
2001-2100	86	0.070	0.042	0.051-0.088	0.070	M	M
2101-2200	72	0.058	0.042	0.041-0.075	0.058	-	M
2201-2300	91	0.074	0.042	0.055-0.093	0.074	M	M
2301-0000	75	0.061	0.042	0.043-0.078	0.061	M	M

Table 5. Summary of results of illumination selectivity of total kills using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of total kills which occurred during periods of lunar illumination across the four categories and the expected percent composition of days available for each category in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.25 indicate preference while scores lower suggest avoidance. Hypothesis of proportional use was rejected ($\chi^2 = 14.90$, df = 3, p <0.001).

		Percent Composition				Utilization	
Illumination	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
<10%	24	0.067	0.139	0.033-0.101	0.127	L	L
11-50%	99	0.277	0.322	0.216-0.337	0.226	---	L
51-89%	130	0.363	0.317	0.298-0.428	0.301	L	M
>90%	105	0.293	0.222	0.231-0.355	0.346	M	M

Table 6. Chi-square results of prey selection by lunar illumination. The lowest illumination category (<10%) had a significant p-value which rejected the null hypothesis that the percent composition of prey in each illumination category would equate to the total percent composition of prey. The remaining categories did not show a significant difference and the null hypotheses were accepted.

	<10%	11-50%	51-89%	>90%
χ2	13.211	5.762	2.035	9.450
df	6	6	6	6
P	**0.040**	0.450	0.916	0.150

Table 7. Summary of results of prey selectivity during <10% lunar illumination using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills which occurred during <10% lunar illumination across the main prey types and the expected percent composition of total kills. All categories fell within the appropriate confidence intervals for all prey types. Utilization for prey is represented as 'M' for more or 'L' for less. α scores higher than 0.14 indicate preference while scores lower suggest avoidance.

	Percent Composition					Utilization	
Prey	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
Mule Deer	10	0.417	0.346	0.158-0.596	0.293	-	M
Elk	11	0.458	0.374	0.197-0.628	0.299	-	M
Porcupine	1	0.042	0.087	0.000-0.234[a]	0.117	-	L
Beaver	1	0.042	0.070	0.000-0.204[a]	0.145	-	M
Large Mammals	1	0.042	0.070	0.000-0.204[a]	0.145	-	M
Small/Medium Mammals	0	0.000	0.039	0.000-0.141[a]	0.000	-	L
Birds	0	0.000	0.014	0.000-0.076[a]	0.000	-	L

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

Table 8. Summary of results of prey selectivity during 11-50% lunar illumination using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills which occurred during 11-50% lunar illumination across the main prey types and the expected percent composition of total kills. All categories fell within the appropriate confidence intervals for all prey types. Utilization for prey is represented as 'M' for more or 'L' for less. α scores higher than 0.14 indicate preference while scores lower suggest avoidance.

	Percent Composition					Utilization	
Prey	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
Mule Deer	29	0.417	0.346	0.175-0.469	0.128	-	L
Elk	45	0.458	0.374	0.326-0.499	0.184	-	M
Porcupine	4	0.042	0.087	0.000-0.159	0.071	-	L
Beaver	7	0.042	0.070	0.004-0.136	0.153	-	M
Large Mammals	9	0.042	0.070	0.017-0.136	0.197	-	M
Small/Medium Mammals	4	0.000	0.039	0.000-0.089	0.157	-	M
Birds	1	0.000	0.014	0.000-0.044	0.110	-	L

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

Table 9. Summary of results of prey selectivity during 51-89% lunar illumination using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills which occurred during 51-89% lunar illumination across the main prey types and the expected percent composition of total kills. All categories fell within the appropriate confidence intervals for all prey types. Utilization for prey is represented as 'M' for more or 'L' for less. α scores higher than 0.14 indicate preference while scores lower suggest avoidance.

		Percent Composition				Utilization	
Prey	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
Mule Deer	44	0.338	0.346	0.232-0.454	0.147	-	M
Elk	49	0.377	0.374	0.268-0.483	0.151	-	M
Porcupine	13	0.100	0.087	0.032-0.150	0.174	-	M
Beaver	6	0.046	0.070	0.000-0.127	0.099	-	L
Large Mammals	12	0.092	0.070	0.027-0.127	0.199	-	M
Small/Medium Mammals	5	0.038	0.039	0.000-0.083	0.148	-	M
Birds	1	0.008	0.014	0.000-0.040	0.083	-	L

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

Table 10. Summary of results of prey selectivity during >90% lunar illumination using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills which occurred during >90% lunar illumination across the main prey types and the expected percent composition of total kills. All categories fell within the appropriate confidence intervals for all prey types. Utilization for prey is represented as 'M' for more or 'L' for less. α scores higher than 0.14 indicate preference while scores lower suggest avoidance.

		Percent Composition				Utilization	
Prey	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
Mule Deer	41	0.390	0.346	0.268-0.466	0.135	-	L
Elk	29	0.276	0.374	0.164-0.496	0.088	-	L
Porcupine	13	0.124	0.087	0.041-0.157	0.171	-	M
Beaver	11	0.105	0.070	0.028-0.134	0.179	-	M
Large Mammals	4	0.038	0.070	0.000-0.134	0.065	-	L
Small/Medium Mammals	4	0.038	0.039	0.000-0.088	0.117	-	L
Birds	3	0.029	0.014	0.000-0.043	0.245	-	M

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

Table 11. Chi-square results for the number of kills occurring during the lunar illumination categories by season. Summer had a significant p-value rejecting the null hypothesis while spring, fall, and winter were not significant and the null hypotheses were accepted.

	Spring	Summer	Fall	Winter
$\chi 2$	5.105	8.039	5.857	2.708
df	3	3	3	3
P	0.164	**0.045**	0.118	0.438

Table 12. Summary of results of illumination selectivity of kills made in spring using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills made in spring which occurred during periods of lunar illumination across the four categories and the expected percent composition of days available for each category in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.25 indicate preference while scores lower suggest avoidance.

		Percent Composition				Utilization	
Illumination	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
<10%	11	0.11	0.162	0.030-0.190	0.166	---	L
11-50%	25	0.25	0.322	0.139-0.361	0.190	---	L
51-89%	31	0.31	0.317	0.191-0.429	0.239	---	L
>90%	33	0.33	0.200	0.209-0.451	0.404	M	M

Table 13. Summary of results of illumination selectivity of kills made in summer using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills made in spring which occurred during periods of lunar illumination across the four categories and the expected percent composition of days available for each category in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.25 indicate preference while scores lower suggest avoidance.

		Percent Composition				Utilization	
Illumination	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
<10%	4	0.039	0.122	0.000-0.089	0.085	L	L
11-50%	29	0.284	0.352	0.170-0.399	0.214	---	L
51-89%	33	0.324	0.301	0.204-0.443	0.284	---	M
>90%	36	0.353	0.225	0.231-0.475	0.416	M	M

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

Table 14. Summary of results of illumination selectivity of kills made in fall using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills made in spring which occurred during periods of lunar illumination across the four categories and the expected percent composition of days available for each category in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.25 indicate preference while scores lower suggest avoidance.

	Percent Composition					Utilization	
Illumination	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
<10%	2	0.032	0.123	0.000-0.089	0.074	L	L
11-50%	16	0.254	0.311	0.113-0.395	0.233	---	L
51-89%	31	0.492	0.328	0.330-0.654	0.428	M	M
>90%	14	0.222	0.239	0.088-0.357	0.266	---	M

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

Table 15. Summary of results of illumination selectivity of kills made in winter using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills made in spring which occurred during periods of lunar illumination across the four categories and the expected percent composition of days available for each category in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.25 indicate preference while scores lower suggest avoidance.

	Percent Composition					Utilization	
Illumination	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
<10%	7	0.075	0.149	0.005-0.146	0.135	L	L
11-50%	29	0.312	0.301	0.188-0.435	0.276	---	M
51-89%	35	0.376	0.320	0.247-0.505	0.313	---	M
>90%	22	0.237	0.229	0.123-0.350	0.275	---	M

Table 16. Chi-square results for each season across diel cycle. Spring, summer, and winter had significant results which rejected the null hypothesis. The fall season did not have a significant p-value so the null hypothesis was accepted.

	Spring	Summer	Fall	Winter
$\chi 2$	46.488	51.588	22.852	58.519
df	23.000	23.000	23.000	23.000
P	**0.003**	**0.001**	0.469	**0.000**

Table 17. Summary of selectivity results of kills made in spring across diel cycle using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills made in spring across diel cycle and the expected percent composition for each category in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.042 indicate preference while scores lower suggest avoidance.

		Percent Composition				Utilization	
Time interval	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
0001-0100	22	0.059	0.042	0.028-0.091	0.066	-	M
0101-0200	25	0.068	0.042	0.034-0.101	0.054	-	M
0201-0300	26	0.070	0.042	0.036-0.104	0.059	-	M
0301-0400	19	0.051	0.042	0.022-0.081	0.045	-	M
0401-0500	14	0.038	0.042	0.012-0.063	0.043	-	M
0501-0600	20	0.054	0.042	0.024-0.084	0.035	-	L
0601-0700	16	0.043	0.042	0.016-0.070	0.039	-	L
0701-0800	15	0.041	0.042	0.014-0.067	0.041	-	M
0801-0900	12	0.032	0.042	0.009-0.056	0.052	-	M
0901-1000	9	0.024	0.042	0.004-0.045	0.024	-	L
1001-1100	13	0.035	0.042	0.011-0.060	0.037	-	L
1101-1200	10	0.027	0.042	0.005-0.049	0.019	-	L
1201-1300	12	0.032	0.042	0.009-0.056	0.032	-	L
1301-1400	3	0.008	0.042	0.000-0.020	0.011	L	L
1401-1500	4	0.011	0.042	0.000-0.025	0.019	L	L
1501-1600	4	0.011	0.042	0.000-0.025	0.015	L	L
1601-1700	12	0.032	0.042	0.009-0.056	0.030	-	L
1701-1800	10	0.027	0.042	0.005-0.049	0.028	-	L
1801-1900	8	0.022	0.042	0.002-0.041	0.041	L	M
1901-2000	19	0.051	0.042	0.022-0.081	0.049	-	M
2001-2100	21	0.057	0.042	0.026-0.088	0.070	-	M
2101-2200	25	0.068	0.042	0.034-0.101	0.058	-	M
2201-2300	32	0.086	0.042	0.049-0.124	0.074	M	M
2301-0000	19	0.051	0.042	0.022-0.081	0.061	-	M

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

Table 18. Summary of selectivity results of kills made in summer across diel cycle using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills made in spring across diel cycle and the expected percent composition for each category in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.042 indicate preference while scores lower suggest avoidance

		Percent Composition				Utilization	
Time interval	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
0001-0100	24	0.063	0.042	0.031-0.094	0.063	-	M
0101-0200	17	0.044	0.042	0.017-0.071	0.044	-	M
0201-0300	26	0.068	0.042	0.035-0.101	0.068	-	M
0301-0400	19	0.050	0.042	0.021-0.078	0.050	-	M
0401-0500	15	0.039	0.042	0.014-0.065	0.039	-	L
0501-0600	14	0.037	0.042	0.012-0.061	0.037	-	L
0601-0700	19	0.050	0.042	0.021-0.078	0.050	-	M
0701-0800	21	0.055	0.042	0.025-0.085	0.055	-	M
0801-0900	26	0.068	0.042	0.035-0.101	0.068	-	M
0901-1000	11	0.029	0.042	0.007-0.051	0.029	-	L
1001-1100	20	0.052	0.042	0.023-0.081	0.052	-	M
1101-1200	9	0.023	0.042	0.004-0.043	0.023	-	L
1201-1300	12	0.031	0.042	0.008-0.054	0.031	-	L
1301-1400	3	0.008	0.042	0.000-0.019	0.008	L	L
1401-1500	9	0.023	0.042	0.004-0.043	0.023	-	L
1501-1600	2	0.005	0.042	0.000-0.015	0.005	L	L
1601-1700	6	0.016	0.042	0.000-0.032	0.016	L	L
1701-1800	10	0.026	0.042	0.005-0.047	0.026	-	L
1801-1900	9	0.023	0.042	0.004-0.043	0.023	-	L
1901-2000	13	0.034	0.042	0.010-0.058	0.034	-	L
2001-2100	19	0.050	0.042	0.021-0.078	0.050	-	M
2101-2200	25	0.065	0.042	0.033-0.098	0.065	-	M
2201-2300	18	0.047	0.042	0.019-0.075	0.047	-	M
2301-0000	36	0.094	0.042	0.056-0.132	0.094	M	M

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

Table 19. Summary of selectivity results of kills made in fall across diel cycle using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills made in spring across diel cycle and the expected percent composition for each category in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.042 indicate preference while scores lower suggest avoidance

		Percent Composition				Utilization	
Time interval	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
0001-0100	11	0.050	0.042	0.012-0.088	0.050	-	M
0101-0200	10	0.045	0.042	0.009-0.082	0.045	-	M
0201-0300	9	0.041	0.042	0.007-0.075	0.041	-	L
0301-0400	9	0.041	0.042	0.007-0.075	0.041	-	L
0401-0500	8	0.036	0.042	0.004-0.069	0.036	-	L
0501-0600	4	0.018	0.042	0.000-0.041	0.018	L	L
0601-0700	10	0.045	0.042	0.009-0.082	0.045	-	M
0701-0800	10	0.045	0.042	0.009-0.082	0.045	-	M
0801-0900	10	0.045	0.042	0.009-0.082	0.045	-	M
0901-1000	4	0.018	0.042	0.000-0.041	0.018	L	L
1001-1100	8	0.036	0.042	0.004-0.069	0.036	-	L
1101-1200	3	0.014	0.042	0.000-0.034	0.014	L	L
1201-1300	12	0.055	0.042	0.015-0.094	0.055	-	M
1301-1400	3	0.014	0.042	0.000-0.034	0.014	L	L
1401-1500	4	0.018	0.042	0.000-0.041	0.018	L	L
1501-1600	6	0.027	0.042	0.000-0.055	0.027	-	L
1601-1700	10	0.045	0.042	0.009-0.082	0.045	-	M
1701-1800	12	0.055	0.042	0.015-0.094	0.055	-	M
1801-1900	13	0.059	0.042	0.018-0.100	0.059	-	M
1901-2000	15	0.068	0.042	0.025-0.112	0.068	-	M
2001-2100	19	0.086	0.042	0.038-0.135	0.086	-	M
2101-2200	5	0.023	0.042	0.000-0.049	0.023	-	M
2201-2300	16	0.073	0.042	0.028-0.118	0.073	-	M
2301-0000	9	0.041	0.042	0.007-0.075	0.041	-	L

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

Table 20. Summary of selectivity results of kills made in winter across diel cycle using Bonferroni adjusted 95% confidence intervals and Manly's alpha selectivity index. Comparison of the observed percent composition of kills made in winter across diel cycle and the expected percent composition for each category in the total time period of the study, 2011-2015. Utilization for total kills represented as 'M' for more or 'L' for less. α scores higher than 0.042 indicate preference while scores lower suggest avoidance.

		Percent Composition				Utilization	
Time interval	# of Kills	Observed	Expected	95% CI	Manly's	(CI)	(Manly's)
0001-0100	24	0.092	0.042	0.046-0.138	0.092	M	M
0101-0200	15	0.057	0.042	0.020-0.094	0.057	-	M
0201-0300	12	0.046	0.042	0.013-0.079	0.046	-	M
0301-0400	8	0.031	0.042	0.003-0.058	0.031	-	L
0401-0500	16	0.061	0.042	0.023-0.099	0.061	-	M
0501-0600	5	0.019	0.042	0.000-0.041	0.019	L	L
0601-0700	3	0.011	0.042	0.000-0.028	0.011	L	L
0701-0800	5	0.019	0.042	0.000-0.041	0.019	L	L
0801-0900	16	0.061	0.042	0.023-0.099	0.061	-	M
0901-1000	5	0.019	0.042	0.000-0.041	0.019	L	L
1001-1100	5	0.019	0.042	0.000-0.041	0.019	L	L
1101-1200	2	0.008	0.042	0.000-0.022	0.008	L	L
1201-1300	3	0.011	0.042	0.000-0.028	0.011	L	L
1301-1400	4	0.015	0.042	0.000-0.035	0.015	L	L
1401-1500	7	0.027	0.042	0.001-0.053	0.027	-	L
1501-1600	6	0.023	0.042	0.000-0.047	0.023	-	L
1601-1700	9	0.034	0.042	0.005-0.064	0.034	-	L
1701-1800	3	0.011	0.042	0.000-0.028	0.011	L	L
1801-1900	20	0.077	0.042	0.034-0.119	0.077	-	M
1901-2000	13	0.050	0.042	0.015-0.084	0.050	-	M
2001-2100	27	0.103	0.042	0.055-0.152	0.103	M	M
2101-2200	17	0.065	0.042	0.026-0.104	0.065	-	M
2201-2300	25	0.096	0.042	0.049-0.143	0.096	M	M
2301-0000	11	0.042	0.042	0.010-0.074	0.042	-	M

[a]An impossible negative confidence lower bound limit has been replaced by 0.000.

PREY CARCASS INVESTIGATION / SITE SEARCH FORM Examined By: __________
TETON COUGAR PROJECT (Revised 06/2014) Entered By: ___________
Cat ID________________________
Collar time stamp for GPS point: __________________**Carcass exam Date**: ________
WHAT DID YOU FIND? (Choose 1): **KILL** **SCAVENGING** **BED** **NOTHING**

SITE DESCRIPTION (For ALL Data Types):

General Location ________________________________ **Habitat:** 1)Riparian 2) Lake or Pond 3) Willow Bottom 4) Sagebrush 5) Forest 6) Meadow 7) Other____________

Dominant Tree/Shrub Species 1) Doug fir 2) Lodgepole 3) Subalpine Fir 4) Aspen 5) Cottonwood 6) Englemann Spruce
7) Willow 8) Sagebrush 9) Other

Topography: N slope, S slope, E slope, W slope, Bench, Wide Drainage, Narrow Drainage, Flat

Describe area of carcass or bed: Heavy cover, Intermediate, Open
Canopy cover (%): 0-25 25-50 50-75 75-100

Kills/Scavenging: **Prey species**: ________________________________

Carcass: WGS84: _________________________ ________________(DECIMAL DEGREES)
Cache: WGS84: ___________________ ________________(DECIMAL DEGREES)

Sex: M) male F) female U) unknown
Age: 1) lamb/fawn/calf (<1 yr) 2) yearling (1-2 yrs) 3) subadult (2-3 yrs) 4) adult (>3 yrs) 5) unknown

If >3 yrs, age in months (FROM BOOK):_________________

Young in utero? Y N UK

SITE EVIDENCE AND ASSESSMENT OF CARNIVORE INVOLVEMENT:
Carcass Cached? Y N UK Type of debris: ____
____
Carcass hidden beneath tree/shrub or in open? ____
Drag marks present? Y N UK Distance dragged: _____m. Blood and hair in drag marks? Y N UK

Scavengers Present (Y / N) **(circle scavenger present and record number observed, Sightings or Sign)**
1) Coyote____/ sign 2) Raven ____/ sign 3) Golden Eagle ____/ sign 4) Bald Eagle ____/ sign
5) Magpie ____/ sign 6) Fox ____/ sign 7) Grizzly Bear _____/ sign
8) Black Bear ____/ sign 9) Unk Bear ____/ sign 10)Wolf ____/ sign 11) Marten _____/ sign
12) Other (specify)_____________________________/ sign 99) No Scavengers

Figure 1A. Front page of the prey carcass investigation/site search form. Form is completed in the field at kill site.

Was there a video camera? Y N If yes, date range: ___________________________________

How many cameras?

List scavengers detected via video camera:

Was the cat displaced? ________ By What? _______________

CARCASS DESCRIPTION, UTILIZATION, AND CONDITION (PREMORTUM):

Utilization

No. of days between. carcass abandonment and carcass examination: _________ (known or estimated).

Utilization: 1 = 76-100% no soft tissue; most or all bones exposed; generally disarticulated (wolf kills)

2 = 51-75% all organs consumed, all or most soft tissue consumed, soft tissue may remain on either rump or quarters; most bones exposed; partial to slight disarticulation

3 = 26-50% some organs may remain; rump and quarters largely intact; front quarters, head/neck largely intact; some bones exposed; no disarticulation.

4 = 0-25% most organs remain intact; most soft tissue intact; little if any bone is exposed; hide is largely intact on both flanks; skeleton articulated

Circle parts of the body remaining:

Condition (Only kills NOT Scavenging):

Bone Marrow: 1) solid 2) medium 3) soft

Color: 1) white 2) pink 3) red 4) white w/ red cortex 5) apple jelly 6) brown

Hair sample for sexing?? Yes / No

Associated with a known kill? Yes / No

Bed: WGS84: ___________ _____________ (DECIMAL DEGREES) Elev._____ Slope ____Aspect

General description (downfall?, cliff? etc):

Canopy cover (%) over bed: 0-25 25-50 50-75 75-100

If beneath tree/shrub, what species?________________

If a tree, what DBH?___________________ inches/cm

COMMENTS: ____

Figure 1B. Back page of the prey carcass investigation/site search form. Form is completed in the field at kill site.

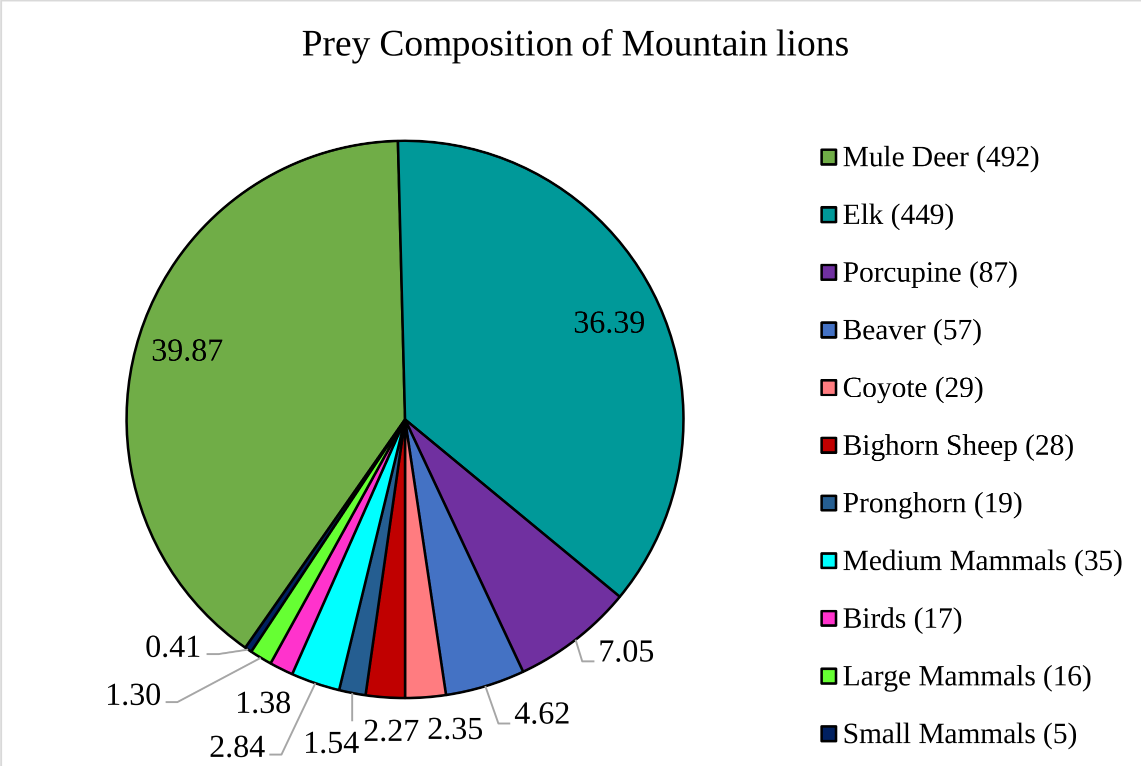

Figure 2. Prey species which comprised the majority of mountain lion kills. The greatest proportion of kills were mule deer at 40%, followed by 36% of elk, 7% porcupine, 5% beaver, and 2% each of coyote, bighorn sheep, and pronghorn. Species occurring in less than two percent were grouped. Birds were grouped together and represented one percent. Mammals were grouped together based on size: small mammals (<1kg), medium mammals (1-15kg), and large mammals (>15kg). Medium mammals made the largest proportion at 3%, then large mammals at 1% and smallest mammals comprised less than one percent.

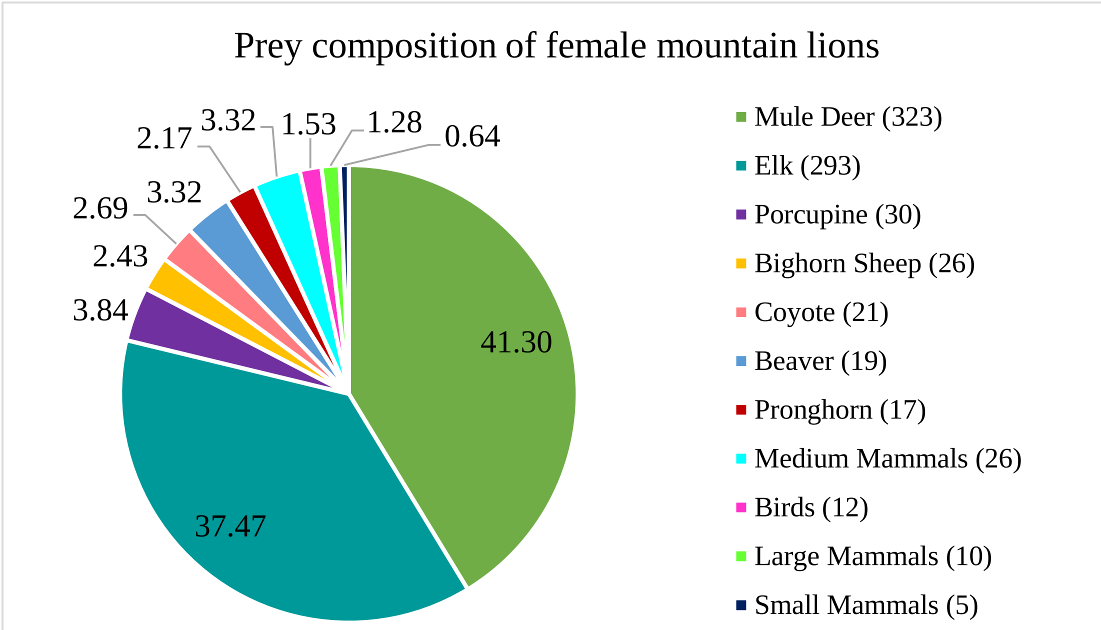

Figure 3. Prey species composition of female mountain lions. The highest proportion of kills were mule deer at 41%, followed by 37% elk, 4% porcupine, 3% bighorn sheep, 3% coyote and 2% each of beaver and pronghorn. Species occurring in less than two percent were grouped. Birds were grouped together and represented 2%. Mammals were grouped together based on size: small mammals (<1kg), medium mammals (1-15kg), and large mammals (>15kg). Medium mammals made up 3%, followed by large mammals at 1% and less than one percent of small mammals.

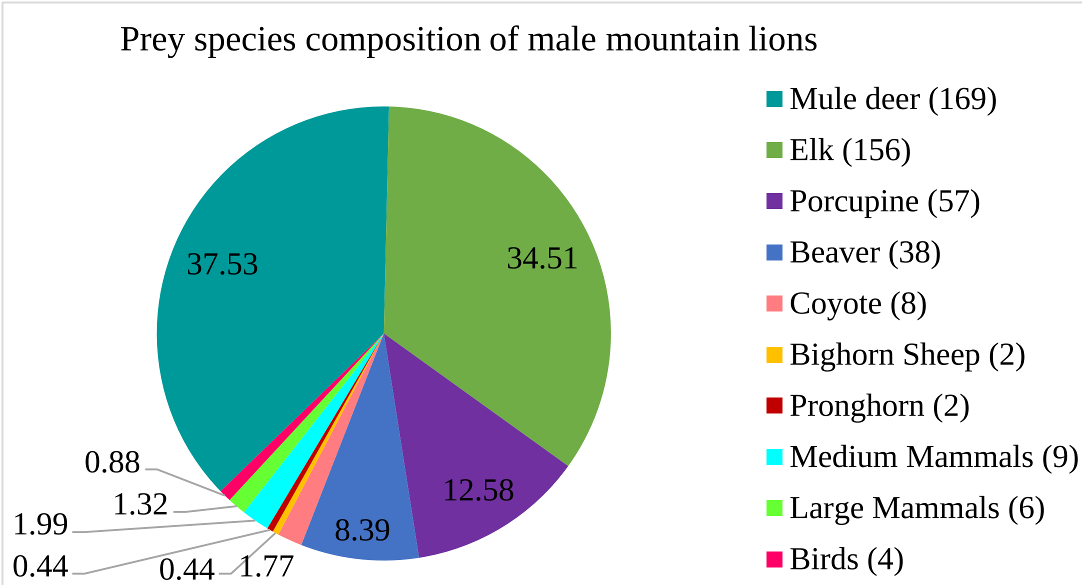

Figure 4. Prey species composition of male mountain lions. The highest proportion of kills were mule deer at 38% followed by elk at 35%, 13% porcupine, 8% beaver, 2% coyote and less than one percent each of bighorn sheep and pronghorn. Species occurring in less than two percent were grouped. Birds were grouped together and represented 1%. Mammals were grouped together based on size: small mammals (<1kg), medium mammals (1-15kg), and large mammals (>15kg). Medium mammals made up the most at 2% followed by large mammals at 1% and no small mammals were documented.

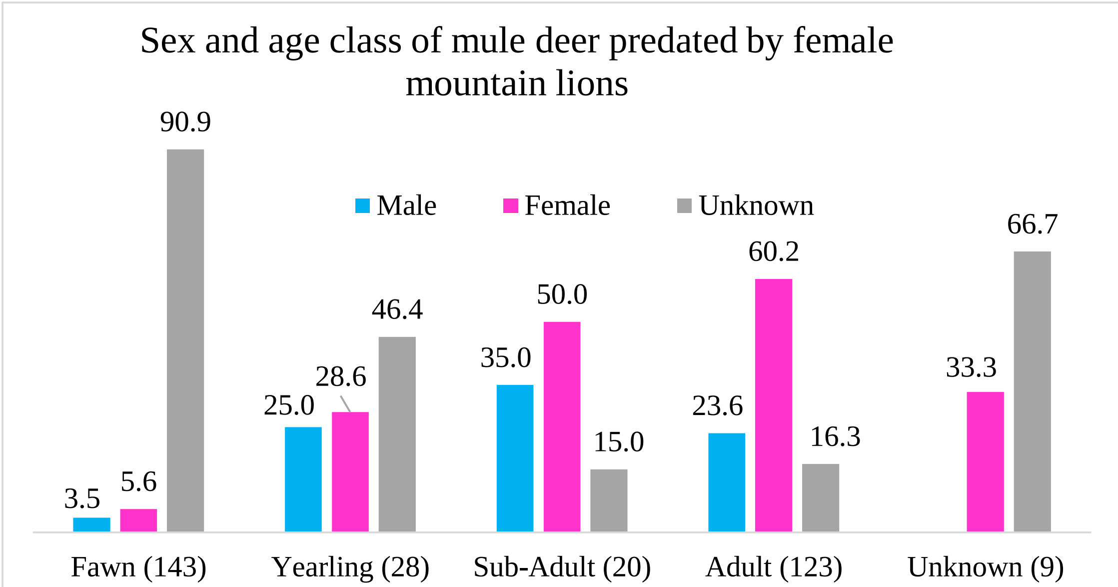

Figure 5. Sex and age class of mule deer predated by female mountain lions. The percentage of each sex preyed upon is shown for each age class with the total number of individual predation events of each age class displayed at the bottom.

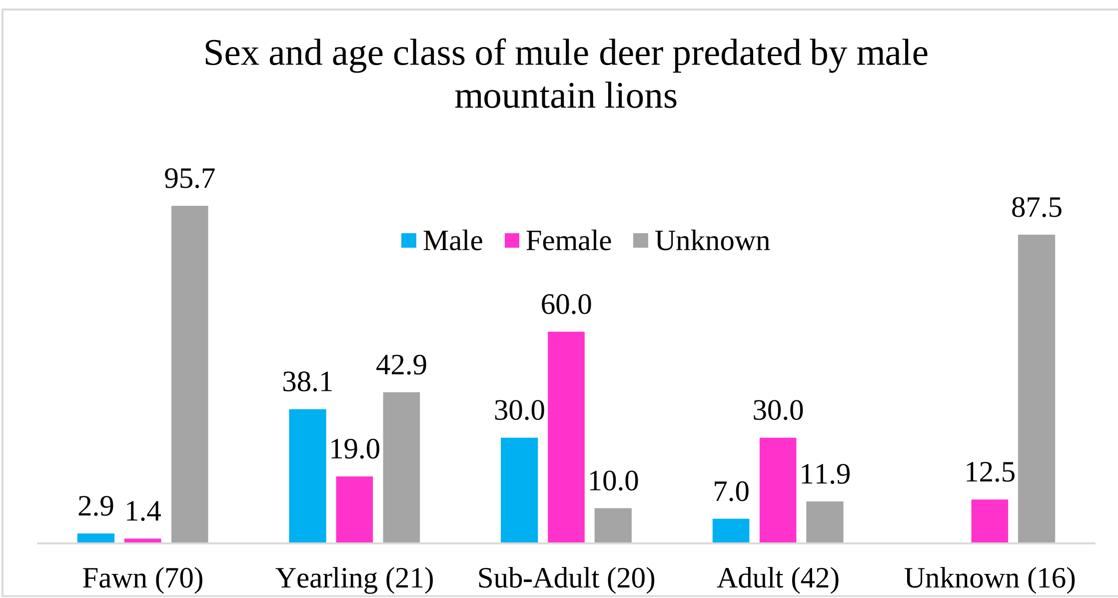

Figure 6. Sex and age class of mule deer predated by male mountain lions. The percentage of each sex preyed upon is shown for each age class with the total number of individual predation events of each age class displayed at the bottom.

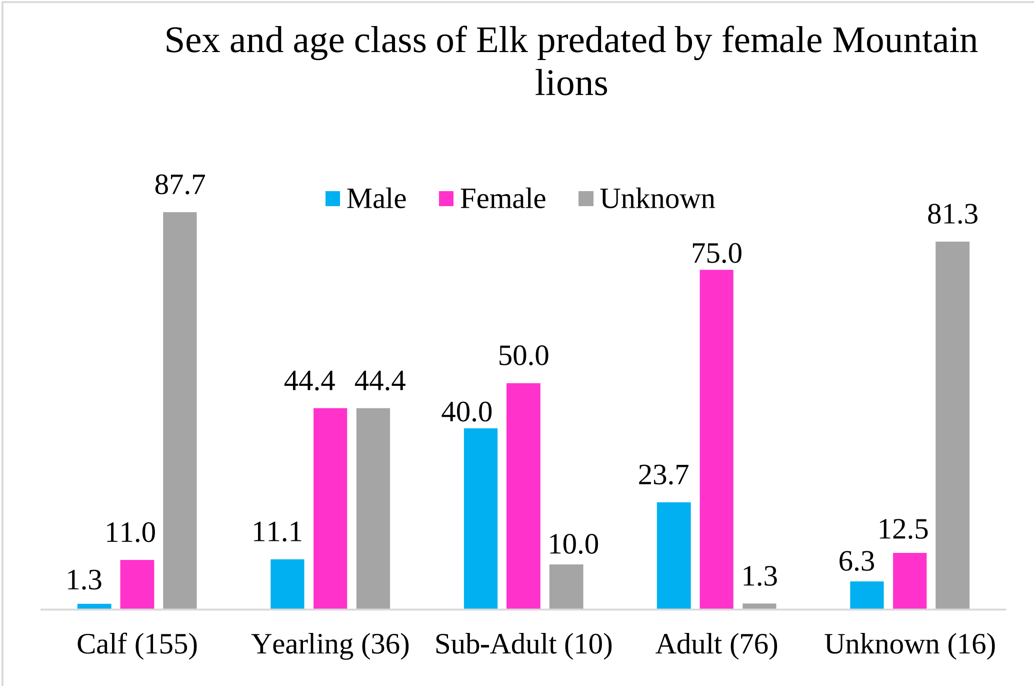

Figure 7. Sex and age class of elk predated by female mountain lions. The percentage of each sex preyed upon is shown for each age class with the total number of individual predation events of each age class displayed at the bottom.

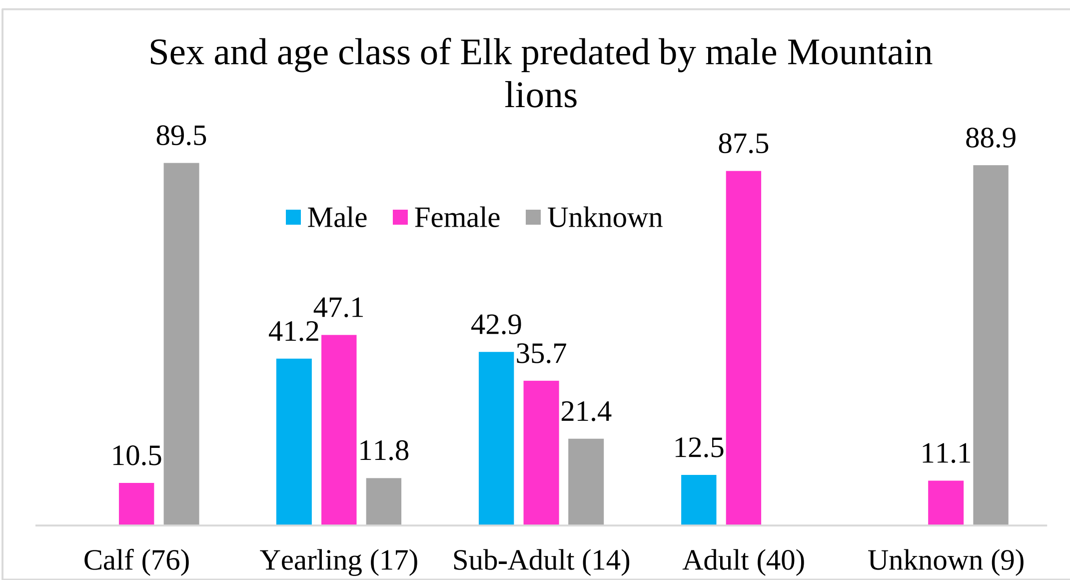

Figure 8. Sex and age class of elk predated by male mountain lions. The percentage of each sex preyed upon is shown for each age class with the total number of individual predation events of each age class displayed at the bottom.

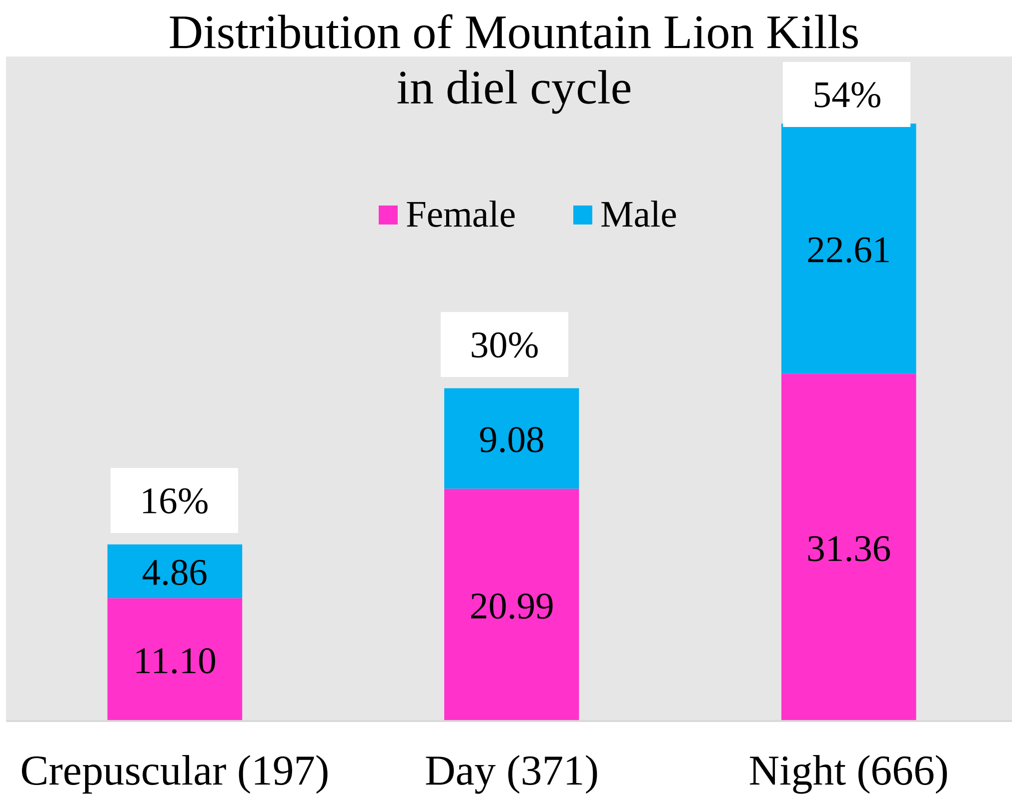

Figure 9. Total mountain lion predation events in diel cycle. Most kills occurred at night (54%), followed by day (30%), then during the crepuscular period (16%). Male mountain lions are represented by blue and female mountain lions are represented by pink.

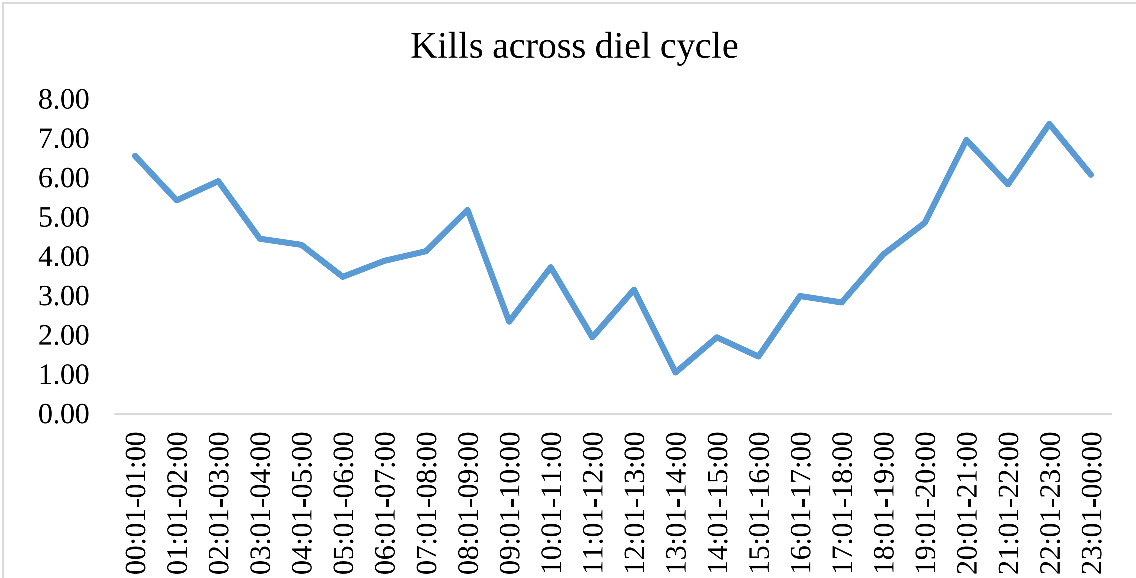

Figure 10. Total mountain lion predation events across diel cycle by time interval. The crepuscular period showed peaks from 0501-0900 as well as between 1701-2100. The highest percentage of kills occurred from 2201-2300, 2001-2100, and 0001-0100. The lowest percentage of kills occurred from 1301-1400, 1501-1600, 1101-1200, and 1401-1500.

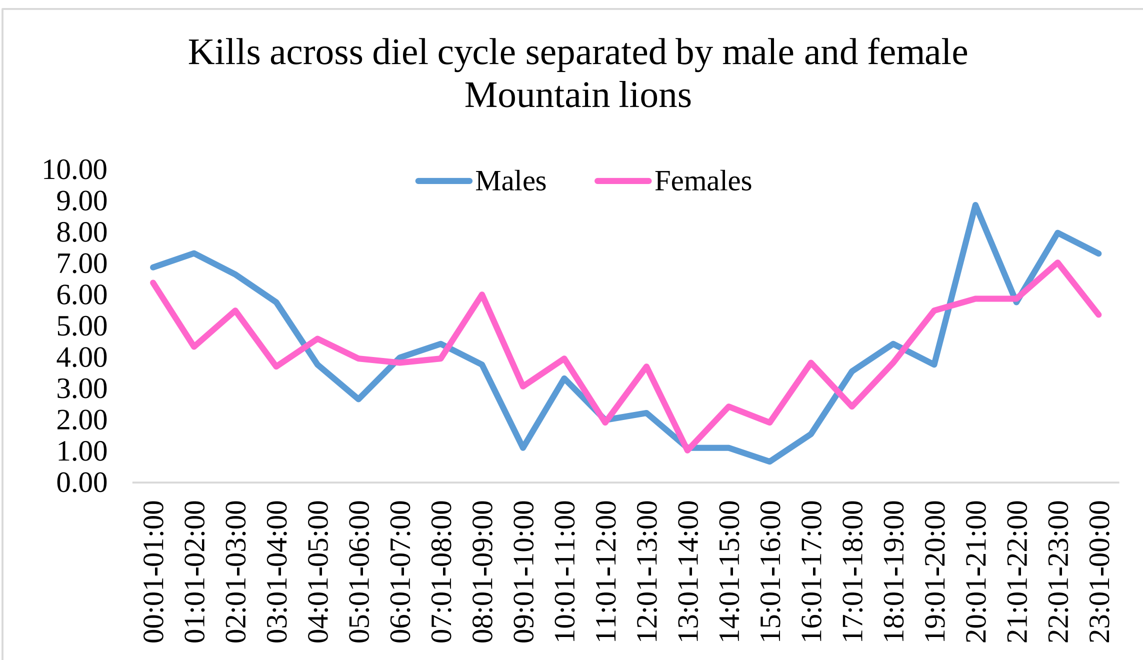

Figure 11. Mountain lion predation events across diel cycle separated by males and females. Most kills for male mountain lions occurred from 2001-2100, 2201-2300, 2301-0000, and 0001-0100 while most kills for females occurred between 2201-2300, from 0001-0100, and also 0801-0900 The lowest percentage of kills for males was from 1501-1600, 0901-1000, and 1401-1500 while for females the lowest percentage was between 1301-1400, 1101-1200, and 1501-1600.

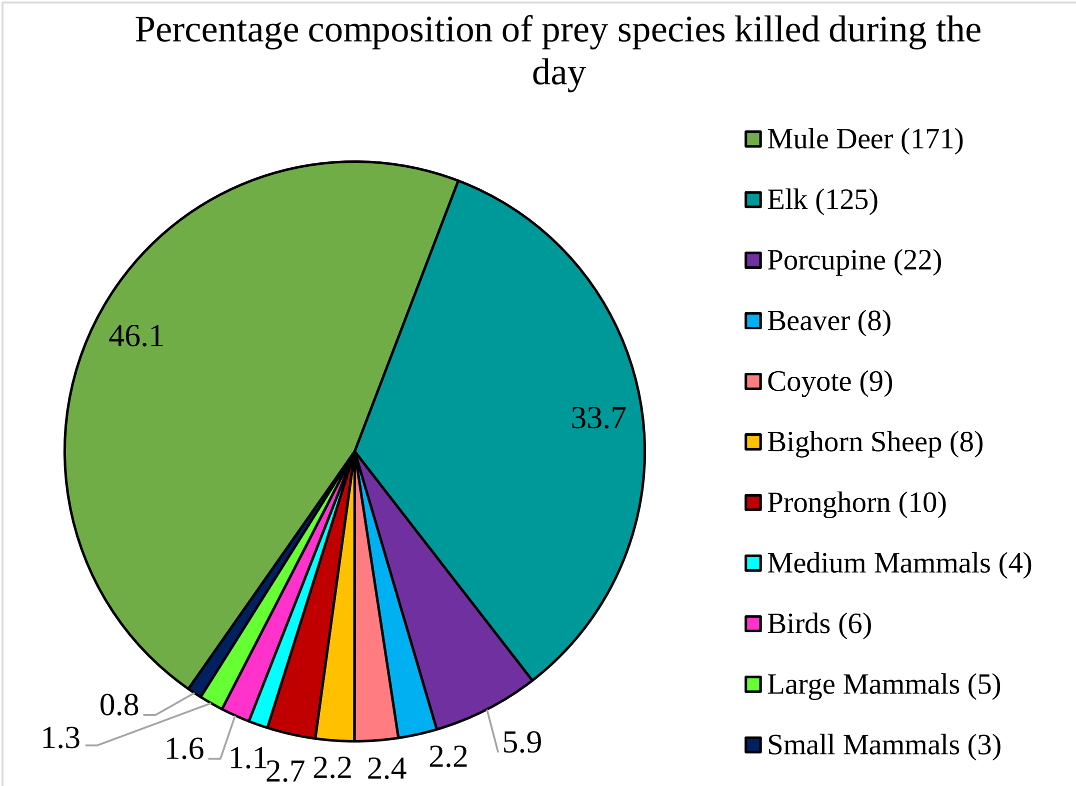

Figure 12. Percentage composition of prey species killed by mountain lions during the day. The highest proportion of kills were mule deer at 46%, followed by elk at 34%, porcupine at 6% and pronghorn at 3%. Beaver, coyote, and bighorn sheep occurred at 2% each. Birds made up 2%, followed by large mammals and medium mammals both at 1% and small mammals made up less

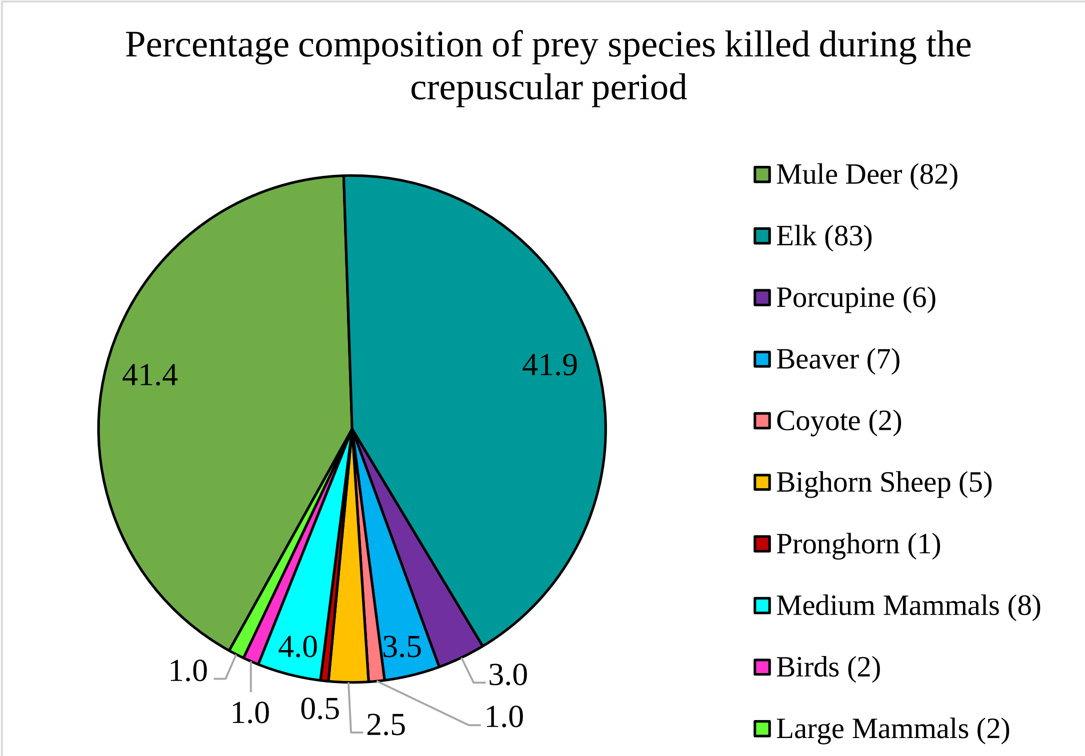

Figure 13. Percentage composition of prey species killed by mountain lions during the crepuscular period. The highest proportion of kills were elk at 42 %, followed by mule deer at 41%, beaver at 3.5%, porcupine at 3%, and bighorn sheep at 2.5%. Coyote occurred at 1% and pronghorn made up less than 1%. Medium mammals comprised 4%, and birds and large mammals both made up 1%.

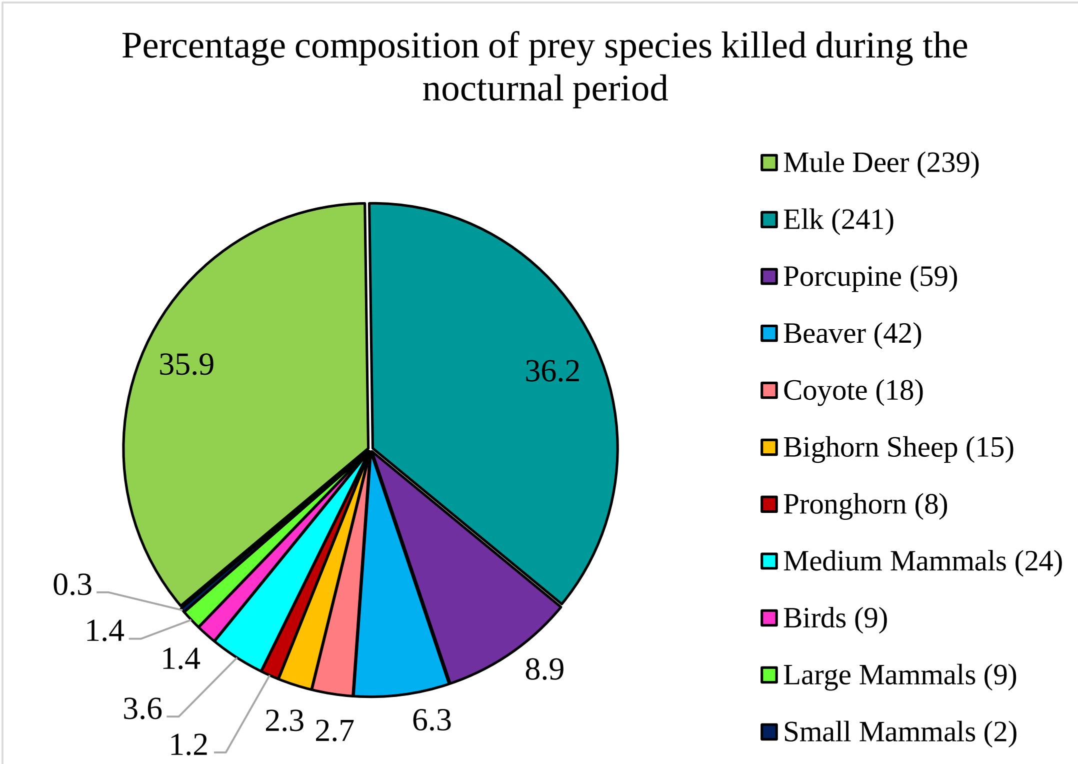

Figure 14. Percentage composition of prey species killed by mountain lions during the nocturnal period. The highest proportion of kills were elk and mule deer both at 36%, followed by porcupine at 9%, beaver at 6%, coyote at 3%, bighorn sheep at 2%, and pronghorn at 1%. Medium mammals made up 4%, followed by large mammals and birds both at 1.4% and less than 1% was comprised of small mammals.

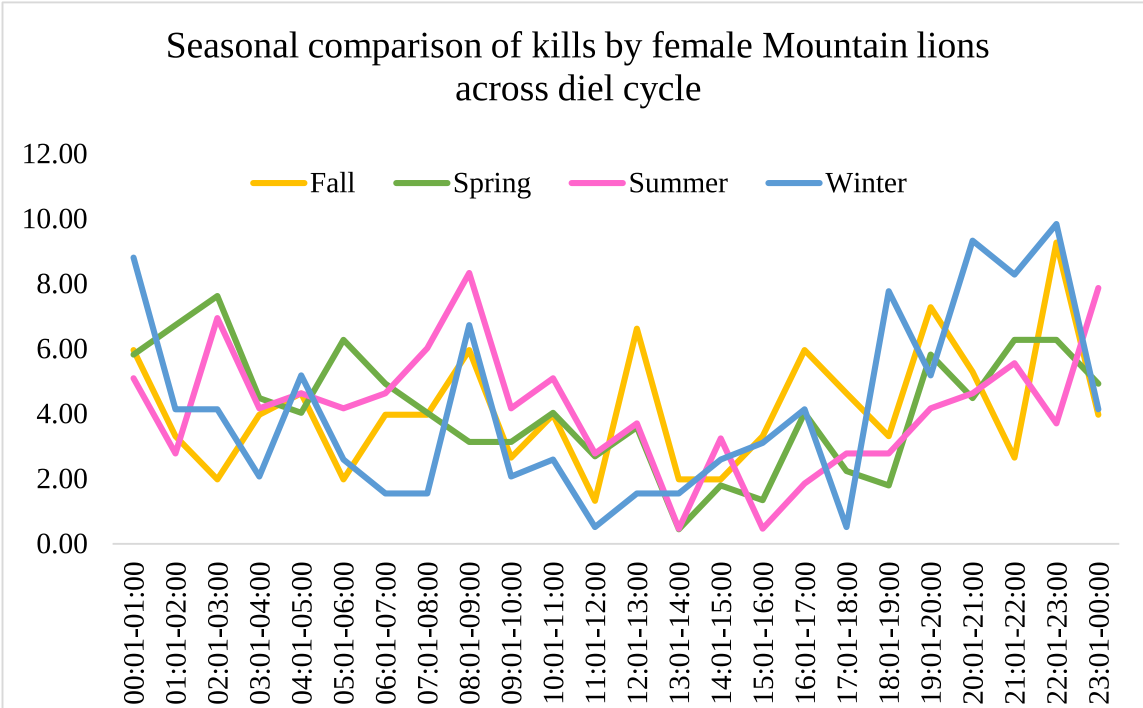

Figure 15. Seasonal comparison of kills from female mountain lions across diel cycle using 24 time intervals.

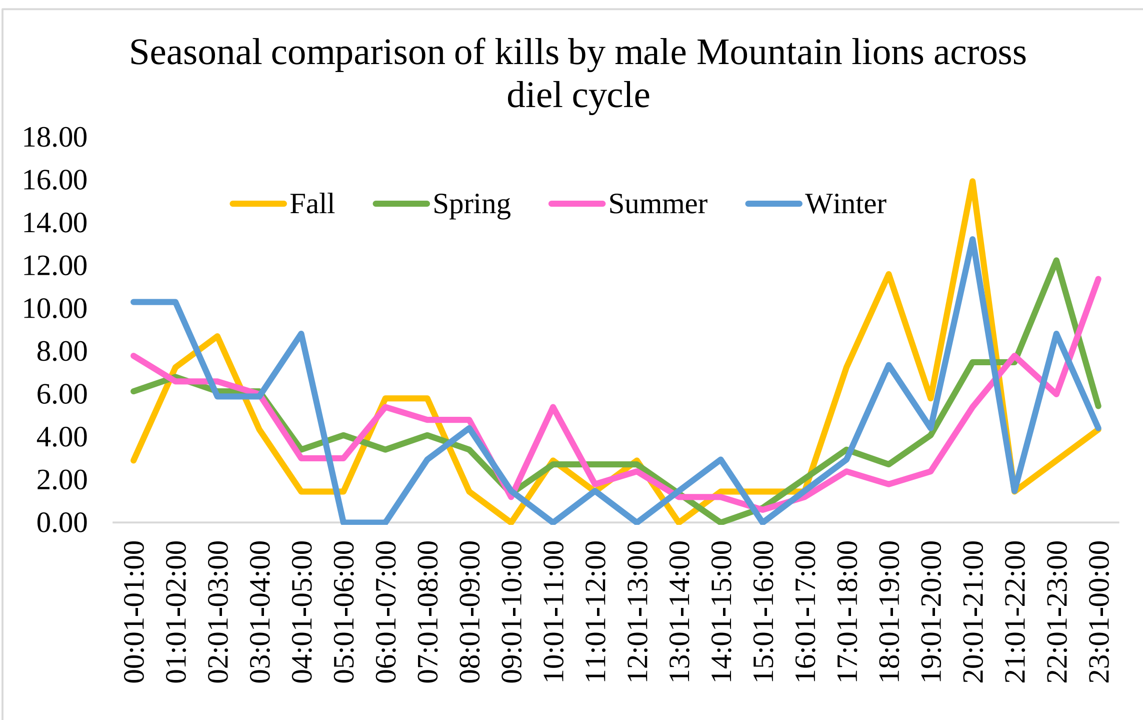

Figure 16. Seasonal comparison of kills from male mountain lions across diel cycle using 24 time intervals.

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