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Parturition of Mule Deer in Southern Utah: Management Implications
and Habitat Selection

Eric D. Freeman

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

Parturition of Mule Deer in Southern Utah: Management Implications and Habitat Selection

Eric D. Freeman

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Master of Science

Mule deer (*Odocoileus hemionus*) are an ecologically, economically, and socially important species across much of the western United States. As such, populations and habitat are intensely managed by state game agencies. However, populations have been declining in recent decades and several factors have been implicated (e.g., climate, predation, competition, and habitat availability). Population dynamics of mule deer are driven by a combination of survival of adults and juveniles and reproductive rates. While adult female mule deer typically have consistently high annual survival rates (85% annually), juveniles are more easily affected by stressors (biotic and abiotic conditions) and therefore their annual survival rates are generally low and highly variable. In an effort to better understand the effects of management on—and the habitat needs for—reproduction and recruitment, we examined the potential effects of male-biased harvest on recruitment in populations of mule deer and the selection of sites for parturition by mule deer females.

Changes in buck:doe ratio due to male-biased harvest may alter rates of pregnancy, timing of parturition, and synchrony of parturition if inadequate numbers of males are present to fertilize females during their first estrous cycle. If rates of pregnancy or timing of parturition are influenced by decreased buck:doe ratios, recruitment may be reduced. This results from fewer births, later parturition (resulting in lower survival of fawns), and a less synchronous parturition period (increasing the proportion of neonates exposed to predation). Our objectives were to compare rates of pregnancy, timing of parturition, and synchrony of parturition between exploited populations of mule deer with relatively high (Piceance Basin) and relatively low (Monroe Mountain) buck:doe ratios. We determined rates of pregnancy via ultrasonography and timing of parturition via expulsion of vaginal implant transmitters. We found no differences in rates of pregnancy, timing of parturition, or synchrony of parturition between Monroe Mountain and Piceance Basin. This suggests that the relatively low buck:doe ratios typical of heavily harvested populations do not have unintended or indirect impacts on population dynamics because recruitment remains unaffected.

Because neonate ungulates are most vulnerable to predation during parturition and shortly thereafter, selecting sites for parturition can have direct fitness consequences. We investigated the selection of sites for parturition by mule deer. We utilized vaginal implant transmitters to identify sites of parturition. We then obtained and compared macro- and micro-habitat features between sites of parturition and associated random sites. Parturient females selected sites based on topography, habitat-type, and obscurity. Enhanced understanding of habitat variables that are selected for parturition provides insight into the life history or behavior of a species and allows managers to ensure that suitable habitat is available for this stage of life-cycles.

Keywords: habitat selection, parturition, pregnancy, sex ratio, synchrony, ungulate management

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CHAPTER 1

Effects of Male-Biased Harvest on Mule Deer: Implications for Rates of Pregnancy, Synchrony, and Timing of Parturition

ABSTRACT

Evaluating how management practices influence the population dynamics of ungulates may enhance future management of these species. For example, in mule deer (*Odocoileus hemionus*), changes in buck:doe ratio due to male-biased harvest may alter rates of pregnancy, timing of parturition, and synchrony of parturition if inadequate numbers of males are present to fertilize females during their first estrous cycle. If rates of pregnancy or parturition are influenced by decreased buck:doe ratios, recruitment may be reduced (e.g., fewer births, later parturition resulting in lower survival of fawns, and a less synchronous parturition that potentially increases susceptibility of neonates to predation). Our objectives were to compare rates of pregnancy, synchrony of parturition, and timing of parturition between exploited mule deer populations with a relatively high (Piceance, CO; 26 bucks per 100 does) and a relatively low (Monroe, UT; 14 bucks per 100 does) buck:doe ratio. We determined rates of pregnancy via ultrasonography and timing of parturition via vaginal implant transmitters. We found no differences in rates of pregnancy (98.6% and 96.6%; $z = -0.821$; $p = 0.794$), timing of parturition (estimate = 1.258; SE = 1.672; $t = 0.752$; $p = 0.454$), or synchrony of parturition ($F = 1.073$; $p = 0.859$) between Monroe Mountain and Piceance Basin, respectively. The relatively low buck:doe ratio on Monroe Mountain was not associated with a protracted period of parturition. This finding suggests that relatively low buck:doe ratios typical of heavily harvested populations do not influence population dynamics because recruitment remains unaffected.

INTRODUCTION

The exploitation of ungulates potentially alters characteristics of populations such as sex ratio, age structure, population size, and genetic variation (Langvatn and Loison 1999, Strickland et al. 2001, Patterson and Power 2002, Festa-Bianchet 2003, Allendorf et al. 2008, Monteith et al. 2013). For example, limiting male harvest of Colorado mule deer (*Odocoileus hemionus*) populations on a statewide basis resulted in increased adult buck:doe ratios, indicating that a greater proportion of adult males (relative to younger age classes) had previously been harvested (Bishop et al. 2005, Bergman et al. 2011). In a population of Norwegian moose (*Alces alces*), 70% of males were harvested before 3 years of age (Solberg et al. 2002). Both examples indicated that a portion of the population was preferentially harvested, resulting in a sex-age structure that was skewed when compared to unharvested populations. Similarly, males with large horns or antlers are preferentially harvested from many populations, potentially removing genetic variation coding for these traits (Coltman et al. 2003, Allendorf et al. 2008, Monteith et al. 2013). Because harvest of most ungulate populations is male-biased, sex ratios are often skewed toward females (Ginsberg and Milner-Gulland 1994). This common scenario is typified for mule deer in Utah, where estimated buck:doe ratios range from 6 – 28 males per 100 females across most management units (except a few with relatively limited harvest where buck:doe ratios are as high as 60:100), signifying a major shift from a sex ratio at birth that is close to 50:50 (Bernales et al. 2011).

Changes in buck:doe ratio have the potential to impact population dynamics (Milner et al. 2006). For example, increasing the proportion of females in a population generally increases the reproductive capacity of that population as long as there are adequate numbers of males for breeding (Caughley 1977). In contrast, an increase in the proportion of adult males may lower recruitment into the population as males can use resources that would otherwise be available to

females and young. An increase of 4.5 bucks per 100 does coincided with a decrease of 7.5 fawns per 100 does in a population of Colorado mule deer (Bishop et al. 2005). In extreme scenarios, when sex ratios become highly skewed toward females, reduced access to mates can result in an increased proportion of females that either do not become pregnant or are bred during their second estrous cycle. Conceptually, this phenomenon is referred to as mate limitation under the allee effect, wherein the low density of one sex results in fewer encounters with receptive mates (Courchamp et al. 1999). Therefore, heavily female-biased sex ratios can lead to fewer fawns and a less synchronous parturition period (White et al. 2001).

The synchrony and seasonality of parturition in ungulates developed under various evolutionary pressures that impact neonate survival (Sadleir 1969, Ims 1990). Variance in survival resulting from timing/synchrony of parturition may result from weather and food availability (seasonality in climate) or predation on newborns (Rutberg 1987, Myrsterud et al. 2002). For example, timing of parturition for populations in temperate regions typically corresponds with increased resource availability to allow for sufficient growth of juveniles before the onset of harsh weather or nutritional shortage (Bunnell 1980, Clutton-Brock et al. 1982). Therefore, an extended birthing season may subject late-born neonates to environmental or nutritional conditions that are less than optimal. Supporting this assertion, individuals born later in the season often have lower survival (Clutton-Brock et al. 1987) or delayed development of body mass (Holand et al. 2003, Saether et al. 2003) causing reduced survival and lower population sizes.

Similarly, in species where predation is a major cause of mortality among neonates (e.g., mule deer), greater synchrony of parturition often results in increased survival of neonates (Sinclair et al. 2000). While there are several ways in which synchrony of parturition can impact

juvenile survival, a predator swamping effect is the best documented consequence that synchrony has on juvenile ungulates (Rutberg 1987). For example, wildebeest (*Connochaetes taurinu*) neonates born at the peak of the parturition period are more likely to survive than those born earlier or later (Estes 1976). Neonates are highly vulnerable for only a short time following birth and if parturition is condensed, vulnerable neonates are only available to predators for a limited time (Whittaker and Lindzey 1999, Testa 2002). However, if parturition is drawn-out, susceptible neonates are available for a longer time period, resulting in increased predator-related mortality. Therefore, changes in rates of pregnancy and timing/synchrony of parturition, potentially caused by an altered sex ratio, may influence neonate survival and population growth (White et al. 2001).

Populations of mule deer are extensively exploited and have fluctuated over the past several decades with a decreasing trend across much of western North America. Proposed mechanisms for declines include predation, severe weather, vehicle collisions, and habitat destruction (Ballard et al. 2001). Whereas research examining these causes of mule deer decline has increased in recent years, evaluations of the impacts of harvest or management strategies used to mitigate these and other factors affecting mule deer populations remain relatively rare (Festa-Bianchet 2003). Therefore, evaluating mechanisms whereby specific management strategies (e.g. increasing herd production, average age, etc.) may influence population growth can improve the effectiveness of management actions.

Our objective was to determine the influence of relatively low buck:doe ratios on rates of pregnancy, timing of parturition, and synchrony of parturition. Specifically, we evaluated these metrics in two populations with differing sex ratios. If the hunting-induced alteration of buck:doe ratios reduces access to mating partners enough to reduce the percentage of females that are bred

during their first estrus cycle then we would expect that pregnancy rates would be lower, dates of parturition would be later, and variance among dates of parturition would be greater in the population with a lower buck:doe ratio. If rates of pregnancy decrease, timing of parturition is altered, or synchrony of parturition is decreased in a population with lower buck:doe ratios, we will conclude that managing populations for increased production has unintended, indirect impacts that negatively influence population dynamics.

STUDY AREA

We selected two study areas to enable a comparison between mule deer populations. Monroe Mountain is located in south-central Utah (39°10' - 39°46' N latitude) and is managed by the Utah Division of Wildlife Resources as general season unit 23. During December 2011 the Monroe Unit had one of the lowest buck-to-doe ratios in the state of Utah—14 bucks per 100 does. The Piceance Basin is located in western Colorado and is managed by Colorado Parks and Wildlife as game management unit 22 (GMU 22; 39°48' - 40°08' N latitude), which is within data analysis unit 7 (DAU-7). The sex ratio estimate for this area of Colorado was 26 bucks per 100 does in December of 2011. Although these are not extreme sex ratios, these populations were representative of the low and high end of the general spectrum found in exploited populations. These estimates of buck:doe ratios were obtained from samples taken on the winter range found in our study areas. Biologists with extensive experience classifying these specific populations (>5 years for 2 in observers in both study areas) conducted helicopter or ground surveys during the mule deer rut (late November - early January) and classified all individuals that they encountered as fawns, does, or bucks. Classifications are done during this time because bucks and does are together and sightability is likely most similar for the two sexes (Stent 2011). In Utah, 1,468 individuals were classified and the estimated population size was 6,800 (21.6%). In Colorado DAU-7, 7,894 individuals were classified from an estimated population size of

45,000 – 50,000 individuals (~ 16.6%). Population size is not estimated for GMU 22 (a segment of DAU-7), but 534 individuals were classified within GMU-22 boundaries. Land ownership in both study areas was divided between federal agencies (Forest Service and Bureau of Land Management), state lands, and private land-holdings. Habitat types were similar for both study sites and included areas dominated by sagebrush (*Artemisia tridentata*), serviceberry (*Amelanchier alnifolia*), mountain mahogany (*Cercocarpus ledifolius*), piñon pine (*Pinus edulis*), juniper (*Juniperus osteosperma*), Gambel oak (*Quercus gambelii*), aspen (*Populus tremuloides*), and several conifer species (e.g. ponderosa pine [*Pinus ponderosa*], Douglas Fir [*Pseudotsuga menziesii*]).

METHODS

In March 2012, we captured female mule deer (via helicopter net-gunning; Barrett et al. 1982, Krausman et al. 1985, White and Bartmann 1994) at both study areas (Figure 1). At each study area, captures were conducted at four separate regions of winter-range to ensure our samples were dispersed and comparable. For each female captured, we determined pregnancy via transabdominal ultrasonography (E.I. Medical Imaging portable ultrasound; Smith and Lindzey 1982). We fitted pregnant females with VHF radio-collars (Telonics, Mesa, AZ, USA and Advanced Telemetry Systems Inc., Isanti, MN, USA) and vaginal implant transmitters (VIT; Advanced Telemetry Systems Inc., Isanti, MN, USA). We inserted VITs, using a vaginoscope, until the antennae protruded ≤ 2 cm from the female's vagina. We also assessed body size (hind foot length, chest and neck girth), condition (body condition score method; Cook et al. 2007, Cook et al. 2010), and age (estimation based on tooth wear and eruption pattern; Severinghaus 1949, Robinette et al. 1957) of each captured individual prior to release.

Between the original capture and parturition, we located collared females using radio telemetry. During March and April, individuals were located sporadically from the ground or a

fixed-wing aircraft. In early May, we attempted to locate every female twice a week. Beginning the last week of May we located each female at least every other day, continuing until every VIT had been expelled.

When an expelled VIT was detected (pulse rate was doubled; 80 pulses per minute), we located the VIT, determined if it was expelled at a birth site and recorded a date of parturition for that individual. Because some VITs are expelled prior to parturition (Bishop et al. 2011), we included only those parturition dates where VIT expulsion was corroborated by additional evidence (i.e. birth site identification and observation of neonates or females). We identified birth sites using a suite of characteristics indicative of parturition (e.g., matted down vegetation, blood, and the remains of afterbirth; Bishop et al. 2011). We also attempted to locate the parturient female, observed her behavior and body condition, and determined if she was still pregnant. As part of a larger study, we captured and collared fawns associated with VITs that had been expelled. This corroborative evidence allowed us to confirm what day a fawn was born (based on hoof growth, wet pelage, distance from birth site, and condition of the umbilicus; Haugen and Speake 1958, Robinette et al. 1973, Sams et al. 1996, Lomas and Bender 2007).

We used pregnancy testing and parturition dates obtained from females at both study sites (Monroe and Piceance) to compare rates of pregnancy and timing/synchrony of parturition. We utilized a z-test of proportions to compare rates of pregnancy and a Levene's test to compare within-year variance of parturition dates between sites. Each of these tests was performed using the one-tailed hypothesis that mule deer from Piceance (the area with a higher buck:doe ratio) should have higher pregnancy rates and a more synchronous parturition period. We used a general linear model to evaluate potential differences in timing of parturition. Our model included the population of origin, age, and body condition of each individual as explanatory

variables for the date of parturition. This approach allowed us to account for factors (age and condition) that potentially affect date of parturition. Whereas we report calendar dates for ease of interpretation, these analyses were performed using Julian dates. Additionally, to enable a comparison to previous documentation of mule deer parturition, we computed the percentage of births that occurred in an 18-day period (Bowyer 1991).

RESULTS

We captured 69 female mule deer at Monroe Mountain, UT and 120 female mule deer at Piceance Basin, CO. Ultrasonography revealed that 68 of 69 (98.6%) of the Monroe females and 116 of 120 (96.6%) of the Piceance females were pregnant. These rates of pregnancy were not different between populations ($z = -0.821$; $p = 0.794$).

We obtained dates of parturition for 36 females in the Monroe population and 58 females in the Piceance population. This reduced sample was the result of mortality, extended migration, collar failure, difficulty locating some expelled VITs in a timely manner, and uncertainty concerning whether some VITs were expelled at parturition (making parturition estimates for these individuals unsuitable or unreliable; criteria for this determination are described in methods). Dates of parturition in the Monroe population occurred between 1 June and 30 June ($\bar{x} = 13$ June, $SE = 1.00$ days) and in the Piceance population between 31 May and 12 July ($\bar{x} = 10$ June, $SE = 1.02$ days). Both distributions demonstrated a slight positive skew (Figure 2). We found no difference in timing of parturition between the two populations (estimate = 1.258, $SE = 1.672$, $t = 0.752$, $p = 0.454$; Figure 2).

Variance (a measure or surrogate for parturition synchrony) was 37.0 ($SD = 6.1$ d) in the Monroe population and 60.2 ($SD = 7.8$ d) in the Piceance population. Using a Levene's test, we found no difference in the variance among dates of parturition between the two populations ($F = 1.073$ $p =$

0.859; Figure 2). Likewise, 91.6% of the births that we detected in the Monroe population and 89.8% of the births that we detected in the Piceance population occurred in an 18-day period.

DISCUSSION

Rates of pregnancy did not differ between populations with relatively high and low buck:doe ratios. This finding indicates that mate limitation under the allee effect (which implies that reproduction is decreased because the density of individuals of the opposite sex is not high enough) is not occurring at the buck:doe ratios that we sampled and most adult females in both populations had mating opportunities. As we performed ultrasounds in early March it is also possible that a higher percentage of females (than we documented) were originally impregnated (Robinette et al. 1955). The rates of pregnancy in both populations are well within or greater than the range of variation that has been previously documented for mule deer. Examples include 93% pregnancy in each of two Colorado populations (Andelt et al. 2004, Bishop et al. 2009) and 94% in a Utah population (Robinette et al. 1955). Additionally, the high fertilization rates that we observed are consistent with reports from other harvested populations of ungulates (Mysterud et al. 2002). Whereas rates of pregnancy are pertinent and important, females being bred during their second estrous cycle would still have been classified as pregnant. If this occurred with greater frequency in the population with a lower buck:doe ratio, parturition would likely be later in the year and less synchronized.

Timing of parturition has evolved to maximize fitness (Sadleir 1969). The peak of the birthing season should be early enough in the year to allow juveniles to build sufficient fat stores for the coming winter (limiting the impact of abiotic conditions) and concurrent with the period of greatest resource availability so as to support lactating females (Millar 1977, Robinette et al. 1977, Rutberg 1987). Low buck:doe ratios may elongate or delay the birthing season if a decreased proportion of females are fertilized during their first estrous cycle, potentially reducing

the survival of late-born fawns (Clutton-Brock et al. 1987). We found no difference in mean timing of parturition between populations with a relatively high and low buck:doe ratio, suggesting conception for the majority of deer in the first estrous cycle, regardless of buck:doe ratio. Both of the mean dates of parturition that we observed fell within the range of reported variation (early June – late July; gestation averages 203 days) for populations in the Western United States (Robinette et al. 1977, Bowyer 1991, Lomas and Bender 2007, Long et al. 2009). In contrast to our analyses of free ranging populations, a statistically significant difference existed between mean dates of parturition (4-5 days earlier with higher bull:cow ratio) in a comparison of captive caribou populations (Holand et al. 2003). While a variety of factors influence date of parturition, we have either accounted for these factors (age and condition) or there are not large differences between the two populations (latitude, climate, habitat type, etc.; McGinnes and Downing 1977, Rachlow and Bowyer 1998).

Synchrony of parturition was not influenced by buck:doe ratio (as demonstrated by the lack of difference in the variance of parturition dates between populations). This lack of difference indicates that most females were bred during their first estrus cycle, resulting in a highly synchronized period of parturition. If most females were not bred during their first estrous cycle we would expect to see multiple distinct peaks in our dates of parturition data. Similar to our findings, 80% of births in a California mule deer population and 95% of captures of mule deer neonates in a different Colorado population occurred in an 18-day period (Bowyer 1991, Pojar and Bowden 2004). Additionally, standard deviations for periods of parturition that have been previously published include 7.4 days in California (Bowyer 1991), 7.3 in Oregon (Long et al. 2009), and 6.9 days in Washington (Steigers Jr and Flinders 1980), which are comparable to our results. Observations of a captive caribou population resulted in similar

conclusions – no difference in synchrony of parturition between higher and lower bull:cow ratios (Holand et al. 2003). The lack of difference in synchrony of parturition that we observed indicates that relatively low buck:doe ratios likely do not reduce population growth through increased predation resulting from an elongated time-period when susceptible neonates are available (Estes 1976, Rutberg 1987).

We recognize that there are other means by which male harvest or skewed buck:doe ratios may influence populations. For example, genetic diversity may decrease as a large proportion of males or males with specific traits are harvested (Coltman et al. 2003). Additionally, when the proportion of males is decreased, younger individuals may participate more actively in the rut. The relatively few remaining males may then invest more energy to fertilize all available females (Saether et al. 2003). These changes have the potential to result in increased energy expenditure and decreased body mass for males in a population (Solberg and Saether 1994).

Examinations of the mechanisms by which low buck:doe ratios are theorized to decrease fawn:doe ratios are lacking. Our data provide empirical evidence that was previously unavailable suggesting that there is not a correlation between observed buck:doe ratios and rates of pregnancy or timing/synchrony of parturition in mule deer populations. We recognize that additional years and populations (with a greater range of buck:doe ratios) would strengthen our analysis, but these data are costly to collect and unavailable. The advent of VITs has improved our ability to accurately identify dates of parturition, allowing for comparisons that were previously unavailable or anecdotal. Our data support previous assertions that relatively low buck:doe ratios are not impacting recruitment in mule deer populations. For example, lower buck:doe ratios were not correlated to decreased fawn:doe ratios during the winter after birth,

indicating that low buck:doe ratios were not negatively impacting fawn survival (Bishop et al. 2005, Bergman et al. 2011). Although data that describe synchrony of parturition are available for many species (including mule deer), no comparative data exists between free ranging populations with differing sex ratios.

MANAGEMENT IMPLICATIONS

There was no difference in rates of pregnancy or synchrony of parturition between populations with different buck:doe ratios. The relatively low buck:doe ratios typical of heavily harvested populations do not appear to influence population dynamics via rates of pregnancy or synchrony of parturition. Whereas some populations have buck:doe ratios as high as 60:100, the range of variation that we tested (14 – 26 bucks per 100 does) is representative of many, if not most, harvested populations. Increasing buck:doe ratios above 14 bucks per 100 does should not be used as a management strategy for increasing rates of pregnancy or for modifying the timing/synchrony of parturition.

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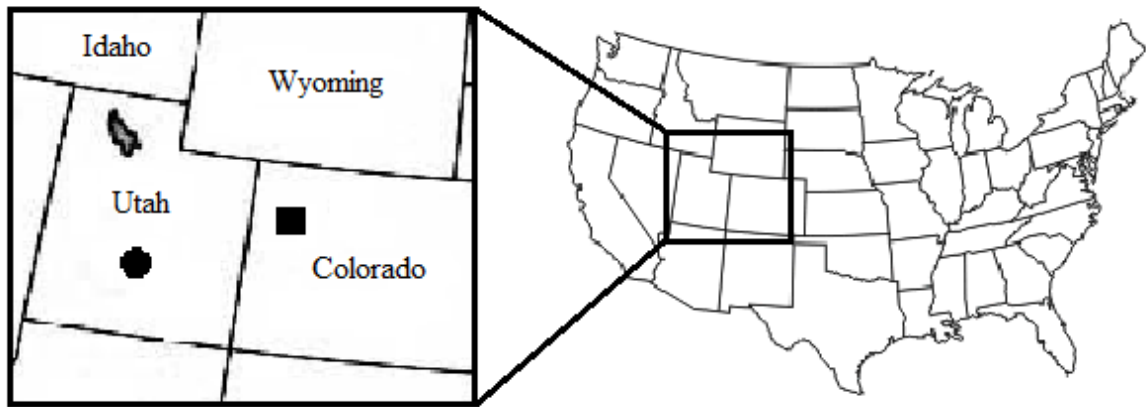


Figure 1. Map of the United States of America with an inset showing the locations of the study populations in the Intermountain West. The Monroe Mountain, UT location is represented as a filled circle and the Piceance Basin, CO location as a filled square. Dates of parturition for mule deer (*Odocoileus hemionus*) were collected from each site in 2012.

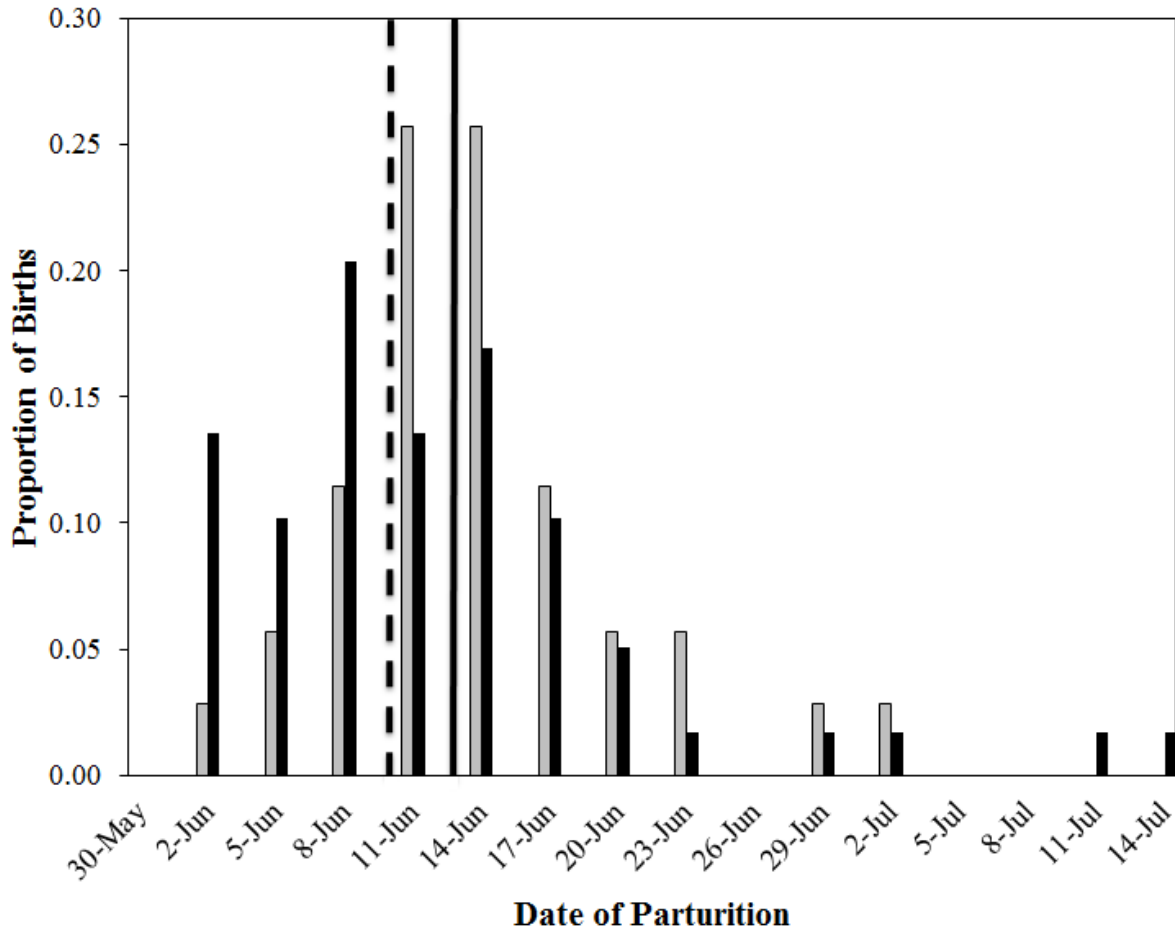


Figure 2. Proportion of births by mule deer (*Odocoileus hemionus*) that occurred during each 3-day period of the 2012 parturition season. Grey bars illustrate parturition from a population with 14 bucks:100 does (SD = 6.1; Monroe, UT) and black bars illustrate parturition from a population with 26 bucks:100 does (SD = 7.8; Piceance Basin, CO). Mean dates of parturition are represented as solid and dashed lines, respectively.

CHAPTER 2

Selection of Sites for Parturition by Mule Deer in Southern Utah

ABSTRACT

Habitat selection by ungulates is influenced by climate, availability and quality of forage, and risk of predation. As female ungulates experience different reproductive stages, the relative influence of these factors on habitat selection likely shifts. In particular, rearing offspring presents females with the challenge of meeting the needs of juveniles for security while satisfying nutritional demand of adults during lactation. Because neonate ungulates are most vulnerable to predation during parturition and shortly thereafter, selecting sites for parturition can have direct fitness consequences. We investigated the selection of parturition sites by mule deer. We utilized vaginal implant transmitters to identify sites of parturition on Monroe Mountain in south-central Utah. We obtained macro- (e.g., topographic and habitat-type parameters) and microhabitat (e.g., horizontal/vertical obscurity and forage abundance) measures at each site of parturition and associated random sites. We then used the classifier random forest to discriminate between used and random sites based on a suite of explanatory variables. At the macrohabitat scale, parturient females selected (on average) higher elevations, increased slopes, reduced ruggedness, decreased topographic visibility, east-facing aspects, reduced conifer cover, and increased oak/mountain brush cover. At the microhabitat scale, selection was most strongly influenced by hiding cover (both horizontal and vertical). In contrast, measures of herbaceous forage did not help discriminate between parturition and random sites. Mule deer appear to select sites for parturition that provide a suitable microclimate and concealment from predators for neonates. These factors are likely more important than forage considerations because sites of parturition are inhabited for a relatively short period of time when neonates are most vulnerable.

INTRODUCTION

Habitat selection by ungulates is influenced by climate (and seasonal changes in weather), availability of forage, and risk of predation. Environments that decrease energy expenditure, provide suitable forage, and decrease the chance of being predated should enhance survival and reproduction. For example, elk (*Cervus canadensis*) and mule deer (*Odocoileus hemionus*) are more likely to utilize areas with canopy cover in the summer than in spring or fall, likely decreasing the energy expended on regulation of body temperature (Ager et al. 2003). Likewise, mule deer often inhabit areas with increased slope, hiding cover, or other attributes that are theorized to decrease encounters with predators (Riley and Dood 1984, Fox and Krausman 1994, Lendrum et al. 2012)

Interactions or trade-offs between these factors (climate, forage quality, predation risk) likely drive selection of one habitat over another. For example, the seasonal changes in weather regimes of temperate regions cause differences in the availability and quality of forage (Hobbs et al. 1981, Baker and Hobbs 1982). Other examples include relationships between foraging opportunities and predation risk, and forage quality and the costs of foraging (Bowyer et al. 1999, Pierce et al. 2004). If a positive relationship exists between the availability of forage and the risk of predation, a trade-off exists wherein ungulates may give up better foraging opportunities to reduce risk of predation (Bowyer et al. 1998a).

As female ungulates experience different life history stages, the relative influence of climate, forage, and risk of predation on habitat selection likely shifts (Long et al. 2009). For example, rearing offspring presents females with a unique situation where selection is influenced by the needs of juveniles. These needs vary with the precociousness of offspring (as neonates age and among species). As juveniles are more susceptible to predation, females may sacrifice quality forage to select areas that offer better hiding cover and allow them to successfully rear

offspring (Nicholson et al. 1997, Rachlow and Bowyer 1998). Conversely, the nutritional demands of lactation on female ungulates are highest shortly after parturition, necessitating the availability of quality forage (Sadleir 1982). Because neonate ungulates are most vulnerable to predation during parturition and shortly thereafter, selecting sites for parturition can impact the fitness of female ungulates and their offspring (Ballard et al. 2001, Poole et al. 2007).

Data describing sites selected for parturition provide insight into the life history or behavior of a species and allow managers to ensure that suitable habitat is available for this stage of life. For example, ensuring the availability of hiding cover is essential when managing for parturition habitat of elk (Barbknecht et al. 2011). Female moose (*Alces alces*) select birth sites based on micro-habitat characters, but use landscape level features in proportion to their availability (Bowyer et al. 1999). This differs from selection of sites for parturition by female caribou (*Rangifer tarandus*), where sites are preferentially selected based on landscape-scale habitat type (Barten et al. 2001). Similarly, moose select sites for parturition with higher quality forage than that available at random sites, while forage availability and quality is of little importance for parturition sites of elk (Barbknecht et al. 2011). These differences likely reflect differences in the life histories of these ungulate species (e.g., moose likely remain near parturition sites longer and thermal benefits of landscape characteristics may be less important for larger species).

While mule deer are one of the most abundant species of ungulate in the western United States, relatively little is known about their selection of sites for parturition. Based on movement patterns obtained using GPS collars, female mule deer selected areas with nearby water sources, steeper slopes, northwest aspects, and open canopies around the time of parturition in Oregon (Long et al. 2009). However, because female mule deer attend to neonates only briefly around

the time of parturition, analysis of movement data cannot identify sites of parturition and does not allow for microhabitat analyses. Likewise, mule deer selected sites under juniper trees, with steeper slopes, and higher elevations more often than white-tailed deer, but these data do not compare selection to availability (Butler et al. 2009). Low fawn:doe ratios have been implicated in recent declines of mule deer populations and an improved understanding of habitat selection during parturition may enhance our ability to manage this species.

We investigated the selection of sites for parturition by mule deer in southern Utah. Our objective was to identify habitat characteristics related to climate, forage availability, and risk of predation that females were selecting for parturition. Specifically, we compared use of habitat relative to availability at both a macro- and micro-habitat scale. We determined the relative importance of, 1) topographic variables, 2) ecological habitat type, 3) visibility, 4) horizontal and vertical hiding cover, and 5) shrub, forb, and grass availability and species richness.

STUDY AREA

We located sites of parturition on Monroe Mountain in south-central Utah (39°10' - 39°46' N and 111°50' – 112°15' W). The Utah Division of Wildlife Resources manages this area as unit 23 for mule deer. Elk and pronghorn (*Antilocapra Americana*) are the only additional ungulates that occupy this range, while potential predators of mule deer inhabiting this area are mountain lions (*Puma concolor*), bobcats (*Lynx rufus*), black bears (*Ursus americanus*) and coyotes (*Canis latrans*). Elevations across this unit range from 1603 m near the town of Richfield, Utah to 3421 m at Monroe Peak. Mule deer use of winter range to summer range generally follows this elevation gradient. Habitat types vary across the mountain and include areas dominated by sagebrush (*Artemisia tridentata*), mountain mahogany (*Cercocarpus ledifolius*), pinion pine (*Pinus edulis*), juniper (*Juniperus osteosperma*), gamble oak (*Quercus gambelii*), aspen (*Populus tremuloides*), and several additional conifer species.

METHODS

In March 2012 and 2013 we captured adult female mule deer via helicopter net-gunning (Barrett et al. 1982, Krausman et al. 1985, White and Bartmann 1994). Captures took place at four regions of winter-range within our study area and samples were dispersed throughout the capture regions to ensure a representative sample. For each female captured, we determined pregnancy via transabdominal ultrasonography (E.I. Medical Imaging portable ultrasound; Smith and Lindzey 1982) and fitted 65 pregnant females with VHF radio-collars (Telonics, Mesa, AZ, USA and Advanced Telemetry Systems Inc., Isanti, MN, USA) and vaginal implant transmitters (VIT; Advanced Telemetry Systems Inc., Isanti, MN, USA). We inserted VITs, using a vaginoscope, until the antennae protruded ≤ 2 cm from the female's vaginal opening. We also assessed body size (hind foot length, chest and neck girth), condition (body condition score method; Cook et al. 2007, Cook et al. 2010), and age (estimation based on tooth wear and eruption pattern; Severinghaus 1949, Robinette et al. 1957) of each captured individual prior to release. We utilized VITs with a temperature sensitive switch that changed from 40 to 80 beats/minute when expelled from the deer.

We located females using radio telemetry between the time they were captured and the time of parturition. During March and April, individuals were located sporadically from the ground or a fixed-wing aircraft. In early May, we attempted to locate and monitor the VIT frequency of every female twice per week. Beginning the last week of May we located each female and monitored her VIT frequency at least every other day, continuing until every VIT had been expelled.

When an expelled VIT was detected, we located the VIT, determined if it was expelled at a parturition site, and recorded coordinates of the parturition site and a date of parturition for that individual. Because some VITs expel prior to parturition (Bishop et al. 2011), we included only

those parturition sites where VIT expulsion was corroborated by additional evidence. For example, we identified birth sites using a suite of characteristics indicative of parturition (e.g., matted down vegetation, blood, the remains of afterbirth, and fresh fecal pellets or tracks; Bishop et al. 2011). We also attempted to locate the parturient female—observed her behavior and body condition, and determined if she was still pregnant. Lastly, as part of a larger study, we captured and collared fawns associated with VITs that had been expelled. This often allowed us to confirm whether and what day a fawn was born (based on hoof growth, wet pelage, distance from birth site, and condition of the umbilicus; Haugen and Speake 1958, Robinette et al. 1973, Sams et al. 1996, Lomas and Bender 2007).

Macro-habitat data collection

We utilized a geographic information system (GIS) to examine selection of parturition sites at a macrohabitat scale (ArcMAP 10, ESRI). We compared characteristics of parturition sites to those of randomly located points (obtained using ArcGIS 10). We generated random points (one for each birth site) by creating a polygon that encompassed Monroe Mountain, UT. We considered the area enclosed by the polygon as that available for parturition for this population (Figure 1).

To examine selection for vegetative cover type at a macro-scale, we created a 200-m buffer around each parturition and random point (Barbknecht et al. 2011). We then derived percent cover within the buffer of 8 different vegetation classes. We utilized vegetation coverages provided by the Fish Lake National Forest (FLNF) and the Southwest GAP analysis. Two coverages were used because the FLNF data did not cover the entire extent of the study area, but was likely more up-to-date and finer scale. Classes included deciduous-aspen, deciduous-oak/mountain brush, evergreen-conifer, evergreen-juniper, sagebrush *spp.*, grassland,

riparian, and other (agriculture, non-vegetated area, desert shrubs, water; all of which had very low availability across the study area).

Using a 10-m Digital Elevation Model (DEM), we obtained data describing the physical features of each parturition and random site. We extracted elevation, slope (degree), aspect, curvature (a metric for which negative values indicate a convex landscape and positive values indicate a concave landscape), and total curvature (a metric for relative elevation changes or ruggedness within an area; Jenness DEM Surface Tools) for each site. We calculated these values for each site at three different scales (point, averaged across a 50-m buffer, and averaged across a 500-m buffer). We utilized these buffers based on literature describing mule deer behavior (flight distance and awareness distance; Freddy et al. 1986, Miller et al. 2001).

Additionally, we employed the viewshed function in ArcMAP to calculate the percent of the area visible within a 50-m and 500-m buffer around each site. To correct for issues associated with the circular nature of common aspect values, we calculated the degree to which the aspect at a site diverged from West and North (0 - 180° for both parameters). To investigate human influences on selection of parturition sites, we calculated the distance from roads using the near function in ArcMAP.

Micro-habitat data collection

We collected microhabitat data at each parturition site and at one or two associated reference sites (in 2012 we began collecting data at only one reference site but adjusted to two reference sites a short time into the field season and through 2013). Reference sites were located 200-m from the parturition site in random directions. This 200-m radius is representative of the area or distance that a mule deer may move or make local habitat-use decisions in the short time before parturition.

At each site we collected several cover and forage availability metrics. We used a spherical densiometer to measure overhead canopy cover, averaging the readings taken in the 4 cardinal directions to obtain a percent cover of canopy for each site. We took these measurements from both a standing and a kneeling position in an attempt to obtain data applicable to an adult female and a bedded/hiding fawn. Additionally, we ocularly estimated the percent canopy cover of trees within a 25-m radius of each site. We used a 120-cm cover pole placed in the center of the parturition site and at 15-m from the parturition site in each cardinal direction to measure horizontal cover at each site. Our cover pole was divided into four 30-cm sections and we determined the percent coverage of each section and then averaged these percentages. We took readings in each of the four cardinal directions and averaged them. Additionally, we used only the averages from the bottom 30-cm section and the bottom 60-cm for additional parameters. We collected these data in an attempt to get more fine-scale information about the importance of horizontal cover (e.g., is the 60-cm directly above ground level more important than the 120-cm when selecting a site for parturition). We obtained two cover pole readings in each direction, one looking inward from 15-m (hiding cover at site) and one looking outward with the pole placed 15-m from the site (visibility from each site) in an effort to determine if hiding cover or visibility played a more prominent role in selection of sites of parturition. Additionally, we took Robel pole (Robel et al. 1970) readings at 5, 10, and 15-m from each site (both looking in and out) in an effort to determine whether patch size influenced selection. Our Robel pole was 120-cm tall and measurements involve recording the height of the lowest obscured segment in each of four directions and averaging the readings. We used a Robel method for these additional measurements because of time constraints.

We utilized the line-intercept method to measure shrub abundance and the point-intercept method to measure abundance of herbaceous forage. We sampled along two 50-m transects that were centered on the site and ran in the cardinal directions. We recorded the cumulative crown cover by species for shrubs and trees less than 1-m tall and divided woody vegetation into shrub and browse (a subset of shrub) categories. We also recorded the height of shrubs (up to 1-m) that were within 5-m of the site (on the transects) and calculated average shrub height, percent shrub cover and percent total cover (heights x lengths) for the nearest 5-m to the site. We assessed the availability of herbaceous plants (grasses or forbs) by recording presence or absence at each meter point along transects. We calculated percent cover by dividing totals by 100 (points or meters). Additionally, we calculated species richness for the grass and forb communities by totaling the species present at each site.

Data analysis

We utilized a random forest approach to differentiate between parturition and random sites (Cutler et al. 2007). We performed two separate analyses, one at the macro- and one at the micro-habitat scale, because we used different sets of random sites for these two analyses. We included year in the micro-habitat analysis to account for annual variation in vegetative growth. We used the randomForest package in program R for each of these analyses (Team 2010). Random forest is a non-parametric classification system that builds a user-specified number of classification trees, scrambles the data for each explanatory variable, and ascertains the decrease in predictive ability of the tree when each variable is scrambled. The decrease in the predictive ability of classification trees resulting from the scrambling of individual variables is then averaged across all trees to provide a mean decrease in accuracy (MDA) for each variable. Because random forest is a truly random classifier, results vary from run to run and we ran

10,000 iterations to ensure the stability of our results (Strobl et al. 2009). We utilized a random forest approach (as opposed to logistic regression) because it maintains a high degree of accuracy and provides a ranking of variable importance (MDA) when classifying large numbers of variables, complex interactions, and multi-collinearity among variables (Cutler et al. 2007, Strobl et al. 2009). Because the importance (MDA values) of irrelevant parameters varies randomly around zero, we considered variables to be potentially informative if their MDA values were somewhat larger (ideally with a natural break in the data points) than the absolute value of the largest negative MDA. After identifying variables with MDA values indicative of significance, we calculated means and standard errors for parturition and random sites to establish effect sizes (strength and direction) and ascertain biological significance.

RESULTS

We identified 34 and 32 parturition sites in 2012 and 2013, respectively. We utilized two additional sites from 2013 for the macro-habitat analysis because we felt that these VITs had been removed from the actual site of parturition but remained nearby (found stashed in rodent middens). This reduced sample (68 sites from 130 VITs) was the result of female mortality, migration out of the study area, collar failure, and uncertainty concerning whether some VITs were expelled at parturition (making parturition estimates for these individuals unsuitable or unreliable; criteria for this determination are described in methods). These sites were matched with 70 random sites at the macrohabitat scale and 123 random sites at the microhabitat scale.

We compiled data for 27 macrohabitat characteristics, of which 8 had MDA values that indicate the parameters are informative and discriminate between parturition and random sites (Figure 2). Of the 8 general habitat types that we classified, only percent cover of conifers and oak/mountain brush were predictive of habitat selected for parturition. Percent cover of conifers was almost four times greater at random sites than at parturition sites, while percent cover of

oak/mountain brush was nearly five times greater at parturition sites (Figure 3). Informative topographic parameters (in order of relevance or MDA values) included elevation, east-west aspect (500-m scale), total curvature (a ruggedness metric; 50-m and 500-m scale), slope (50-m scale), and the area visible in a 50-m radius (viewshed). Elevation was higher, aspect was more east-facing, slopes were greater, total curvature (ruggedness) was lower, and less area was visible within 50-m at parturition sites than at random sites (Figure 4). Uninformative parameters from the macro-habitat analysis included several habitat types, north-south aspect, curvature (concave or convex), distance to roads, and several additional parameters related to topography that were informative at one scale (point, 50-m average, or 500-m average), but not another (Table 1).

We compiled data for 26 micro-habitat characteristics, of which 6 had MDA values that were higher than the absolute value of the smallest negative and followed a natural break in the data (Figure 5). These included two measures of canopy cover (obtained with a spherical densiometer), three cover-pole measures (60 and 120-cm averages observed outward and 120-cm average observed inward), and one Robel pole measure (5-m distance observed outward). Each of these measures indicated either that canopy cover or horizontal hiding cover (obscurity) was greater at sites of parturition than at the paired random sites (Figure 6). Of the remaining parameters, 8 received some support (MDA values that are slightly higher than the absolute value of the smallest negative MDA and confidence intervals that generally do not overlap, but no clear break in the data) and 12 were considered uninformative (Table 2). Several additional patterns are evident in our data. For example, horizontal obscurity measurements that were taken from the site looking outward were generally better discriminators between parturition and random sites than those same measurements taken from the same distance looking inward (in every case but one). Additionally, no parameters that quantified herbaceous forage availability

were informative and only a single parameter quantifying shrub cover (browse cover) received any support.

DISCUSSION

Mule deer selected sites for parturition at both the macro- and micro-habitat scale. Several parameters from both of our analyses had discriminatory value in differentiating between parturition and random sites. Informative parameters indicated a disproportionate use (when compared to availability) of various topographic features, habitat types, and hiding cover. With a few notable exceptions, our results are generally comparable to other ungulate species for which selection of parturition sites has been investigated (Bowyer et al. 1999, Barten et al. 2001, Barbknecht et al. 2011).

Mule deer females preferentially selected east-facing slopes for parturition (relative to availability; Figure 4). East-facing slopes provide neonate fawns with increased solar insolation in the morning hours, likely aiding in thermoregulation and drying time after parturition (Dwyer 2008). In contrast, elk exhibit selection for south-facing slopes at parturition (Barbknecht et al. 2011). This disparity may result from differences in thermoregulatory needs and timing of parturition, as elk give birth to larger offspring and earlier in the year when north-facing slopes are often still snow-covered to some extent. Parturient mule deer also selected for (oak-mountain brush) and against (conifers) specific habitat types (Figure 3). Coniferous habitats are often found on cooler northerly aspects and complete canopies limit the penetration of sunlight (Barbknecht et al. 2011). Similarly, parturient mule deer in Oregon selected against patches with a high degree of canopy cover (conclusions based on data from GPS-collars; Long et al. 2009). Conifer patches in our study area generally have little understory, potentially increasing predation risk and reducing forage availability. In contrast, oak/mountain brush habitats often

have an extensive shrubby understory, which likely enhances hiding cover for neonates in these areas.

The remaining topographic characteristics that parturient females selected in greater proportion than their availability are more difficult to interpret and understanding the topography of the study area is beneficial. Monroe Mountain is a large plateau with varying topography across the top. Parturient females selected higher elevations, increased slope, decreased ruggedness, and decreased visibility of the landscape in greater proportion than their availability (Figure 4). Based on these data and field observations, females were selecting sites on steep slopes (similar to Long et al. 2009) near ridgelines or knolls on top of the plateau. Slopes near ridgelines or knolls would have higher elevations than the remainder of the plateau, increased slope and decreased topographic visibility (percent of area observable within 50-m; viewshed) as the topography falls away from these sites, and decreased ruggedness than the perimeter of the plateau and steep/rocky canyons. Selection for these macrohabitat characteristics likely reduces the frequency of contact between neonates and predators, therefore decreasing the risk of predation (Riley and Dood 1984, Farmer et al. 2006). For example, coyotes (*Canis latrans*) often use easily traveled terrain and mountain lions often use terrain with lower elevations and increased ruggedness (Riley and Malecki 2001, Dickson and Beier 2002, Gladders 2003, Long et al. 2009).

Vertical and horizontal measures of hiding cover were best able to differentiate between parturition and random sites at the microhabitat scale (Figure 6). Paired random sites were usually found in the same habitat type as parturition sites and, within the patch selected for parturition, mule deer were selecting for areas with increased canopy cover (~ 60-65%; in contrast to selection against conifer patches that likely had the highest degree of canopy cover).

Selection for a partial canopy cover and increased concealment cover may be a thermoregulatory or predation avoidance behavior—or both (Fox and Krausman 1994, Bowyer et al. 1999, Dwyer 2008, Long et al. 2009). In contrast, we found no correlation between sites of parturition and availability of herbaceous forage. Mule deer neonates move up to 600 m in the first 24 h after parturition and any consideration of herbaceous forage availability at the microhabitat scale may be unnecessary (Johnstone-Yellin et al. 2006, Barbknecht et al. 2011). Avoidance of predators is likely of greater importance than quality of forage at parturition sites of mule deer because the microhabitat is specific to the parturition event. However, black-tailed deer fawns bed in areas with greater availability of quality forage when compared to availability (Bowyer et al. 1998a). Difference between bedding and parturition sites may be related to the mobility of offspring as they age or the energetic demands of lactation on the mother (Barbknecht et al. 2011). Percent cover of browse species was moderately informative when discriminating between parturition and random sites. Selection of browse cover may be a artifact of selection for shrubby hiding cover but against coniferous habitats (browse cover excludes shrub-like conifer and juniper growth). Alternatively, females are selecting for areas with increased browse available for foraging.

The remaining discriminatory parameters each address measures of horizontal obscurity. Measurements that were taken from the site looking outward were generally (in every case but one) better discriminators between parturition and random sites than those same measurements taken from the same distance looking inward. This makes intuitive sense as females are selecting sites based on what they see (although both methods have been used in previous examinations; Bowyer et al. 1998b, Barbknecht et al. 2011) and we recommend measurements be taken looking outward. Additionally, there was a pattern suggesting that measurements taken

with a taller cover pole were more discriminatory than a shorter cover pole (similar to Main and Coblenz 1996). This finding indicates that shorter vegetation (< 30-cm) is either less important or similar across the landscape. Similarly, the cover pole was more discriminatory than the Robel pole (both measures were taken at 15 m), indicating that additional time spent collecting data with a cover pole is likely worthwhile. However, the Robel pole reading taken at 5 m looking outward was among the most discriminatory parameters, suggesting that cover closest to the site (< 5 m) is of greater importance (compared to 10 or 15 m) for parturient females.

Few data are available describing the selection of parturition sites by mule deer and we provide insight into the natural history of this socially, economically, and ecologically important species (Fox and Krausman 1994, Butler et al. 2009, Long et al. 2009). Additionally, we provide information describing macro- and micro-habitat needs of parturient mule deer. The advent and improvement of VITs allows for increased accuracy in locating and describing sites of parturition. As neonates are most vulnerable during and shortly after parturition and low fawn:doe ratios have been implicated in recent declines of mule deer populations, the improved understanding of habitat selection during parturition that we provide enhances our ability to manage this species (Bowyer et al. 1998b, Ballard et al. 2001).

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Table 1. A subset of macro-habitat characteristics collected from parturition sites of mule deer (*Odocoileus hemionus*) and random sites on Monroe Mountain, UT. Mean decrease in accuracy (MDA) values indicate the relative discriminatory value of each variable between birth and parturition sites.

Parameter	MDA	Parturition		Random	
		Mean	SE	Mean	Random SE
AspectNS	0.255	102.032	5.496	87.325	6.134
AspectNS 50-m	0.245	131.639	2.902	136.817	2.971
Slope 50-m	0.240	15.315	0.621	14.961	0.798
Curvature 500-m	0.226	-0.004	0.046	-0.049	0.049
Curvature 50-m	0.216	0.010	0.004	0.002	0.004
Habitat_Aspen	0.203	11.689	2.798	14.314	3.718
Point Slope	0.142	15.167	0.967	14.711	1.199
Habitat_Sage	0.128	41.407	4.306	40.501	4.622
Distance-to-road	0.093	396.491	36.269	478.658	60.524
Habitat_Other	0.065	0.342	0.179	1.872	0.949
Total Curvature	-0.010	0.017	0.002	0.026	0.005
Habitat_Juniper	-0.050	25.704	4.316	29.083	4.399
AspectNS 500-m	-0.056	106.968	5.023	104.707	5.177
Viewshed 500-m	-0.067	20.669	1.208	21.946	1.236
AspectEW	-0.086	113.219	6.316	93.498	6.374
Curvature	-0.087	-0.029	0.302	-0.400	0.252
Habitat_Riparian	-0.091	0.115	0.089	0.650	0.335
AspectEW 500-m	-0.108	118.844	6.228	104.012	6.558
Habitat_Grass	-0.242	3.239	1.904	1.458	0.941

Table 2. A subset of microhabitat characteristics collected from parturition sites of mule deer (*Odocoileus hemionus*) and random sites on Monroe Mountain, UT. Mean decrease in accuracy (MDA) values indicate the relative discriminatory value of each variable between birth and parturition sites.

Parameter	MDA	Parturition Mean	Parturition SE	Random Mean	Random SE
Robel (out) 15-m	0.352	101.250	2.669	88.843	2.631
Cover (in) 30-cm	0.349	90.152	1.617	87.191	1.636
Browse Cover (%)	0.315	31.556	2.615	28.889	1.704
Cover (in) 60-cm	0.302	86.215	1.915	78.245	2.010
Robel (out) 10-m	0.280	96.182	3.263	81.588	2.723
Robel (in) 15-m	0.273	102.693	2.822	85.713	2.917
Robel (in) 10-m	0.244	96.277	3.241	77.224	3.000
Robel (in) 5-m	0.228	79.326	4.090	58.069	3.051
Cover (out) 30-cm	0.195	90.574	1.604	87.860	1.487
Shrub Cover (5-m, %)	0.183	0.367	0.027	0.332	0.020
Total Shrub Cover (%)	0.113	0.244	0.023	0.207	0.015
Mean Shrub Height	0.112	52.553	2.619	45.900	1.610
Grass Richness	0.063	3.121	0.231	2.821	0.153
Shrub Cover (%)	0.059	34.829	2.444	32.174	1.558
Herbaceous Cover (%)	0.036	20.621	1.996	19.854	1.294
Tree Cover (%)	0.024	37.067	3.156	27.045	2.256
Forb Richness	-0.015	1.939	0.194	2.317	0.190
Grass Cover (%)	-0.027	14.576	1.632	13.593	1.003
Herbaceous Richness	-0.095	5.061	0.363	5.138	0.268
Forb Cover (%)	-0.175	6.045	0.862	6.260	0.695

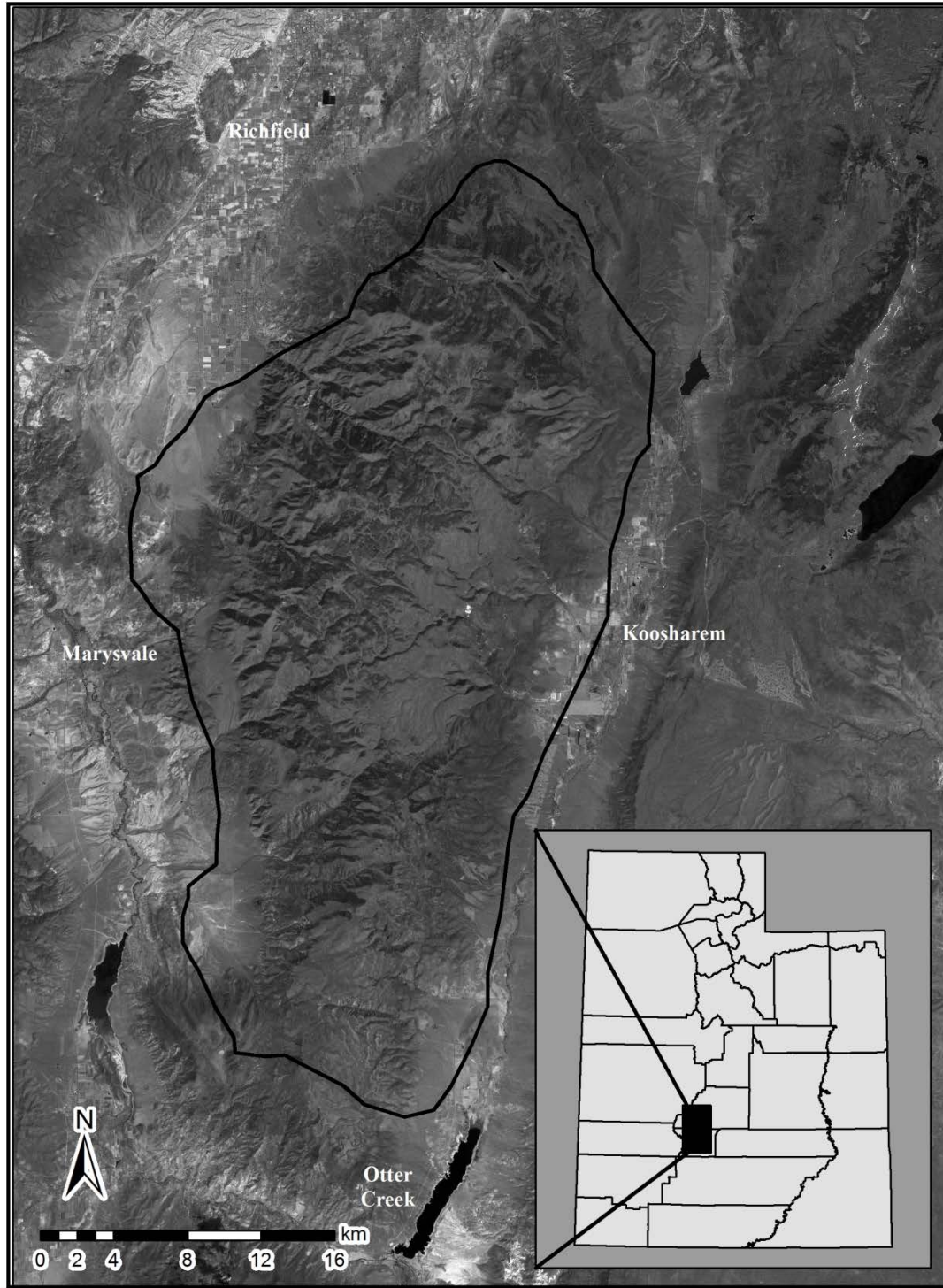


Figure 1. The polygon delineates the study area near Richfield, Utah where we collected macro- and micro-habitat data describing parturition sites of mule deer (*Odocoileus hemionus*).

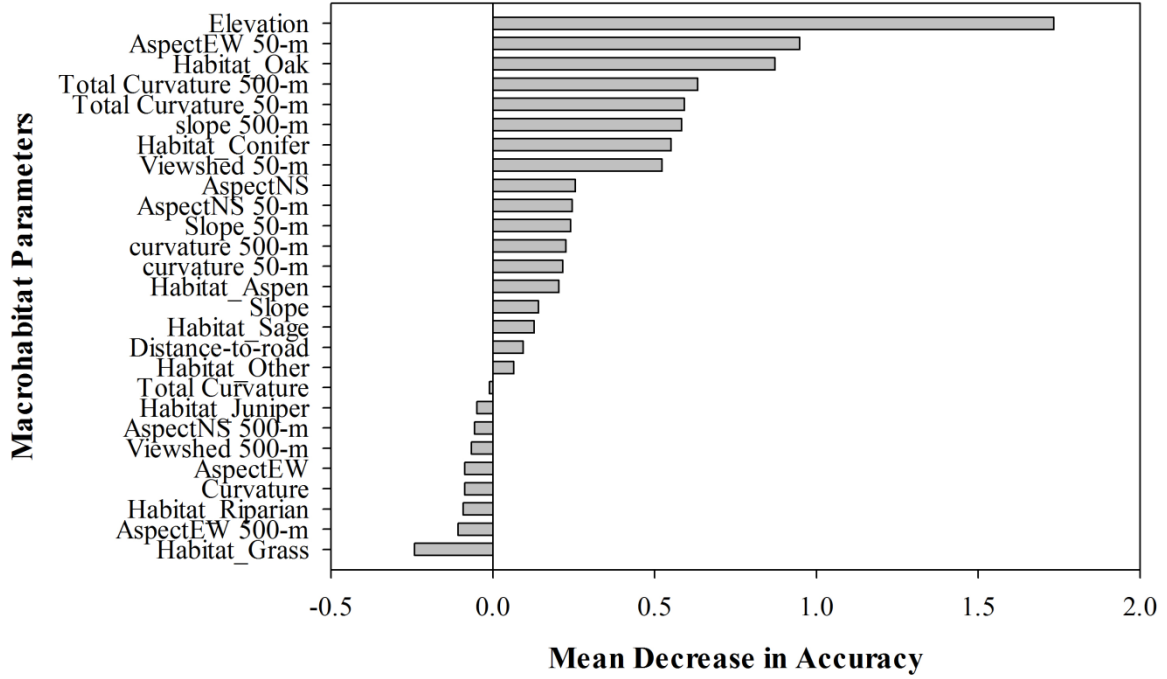


Figure 2. Macrohabitat characteristics collected at parturition sites of mule deer (*Odocoileus hemionus*) and random sites on Monroe Mountain, UT. Rankings indicate the relative ability of each variable to discriminate between parturition and random sites. Explanations for variables on the Y-axis are found in the methods section.

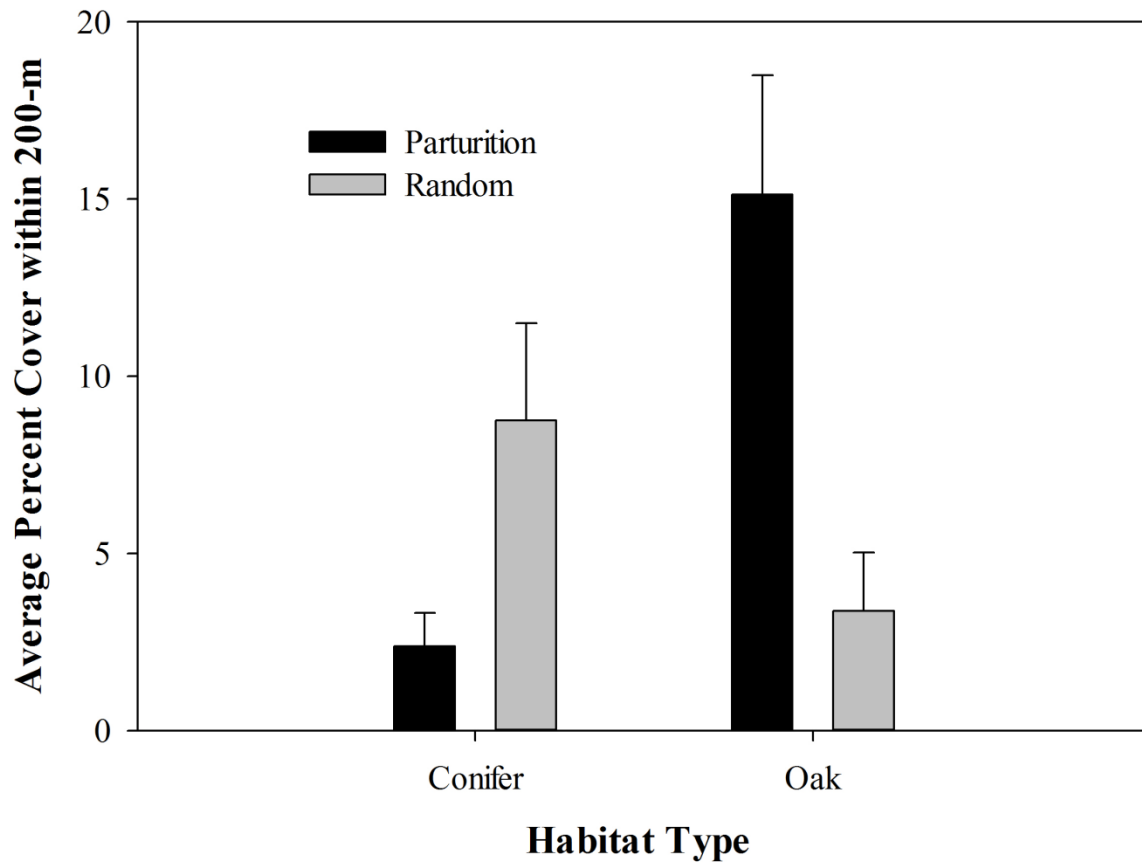


Figure 3. Means (\pm SE) of vegetation types identified as discriminatory (using a random forest classification) between parturition sites of mule deer (*Odocoileus hemionus*) and random sites on Monroe Mountain, Utah.

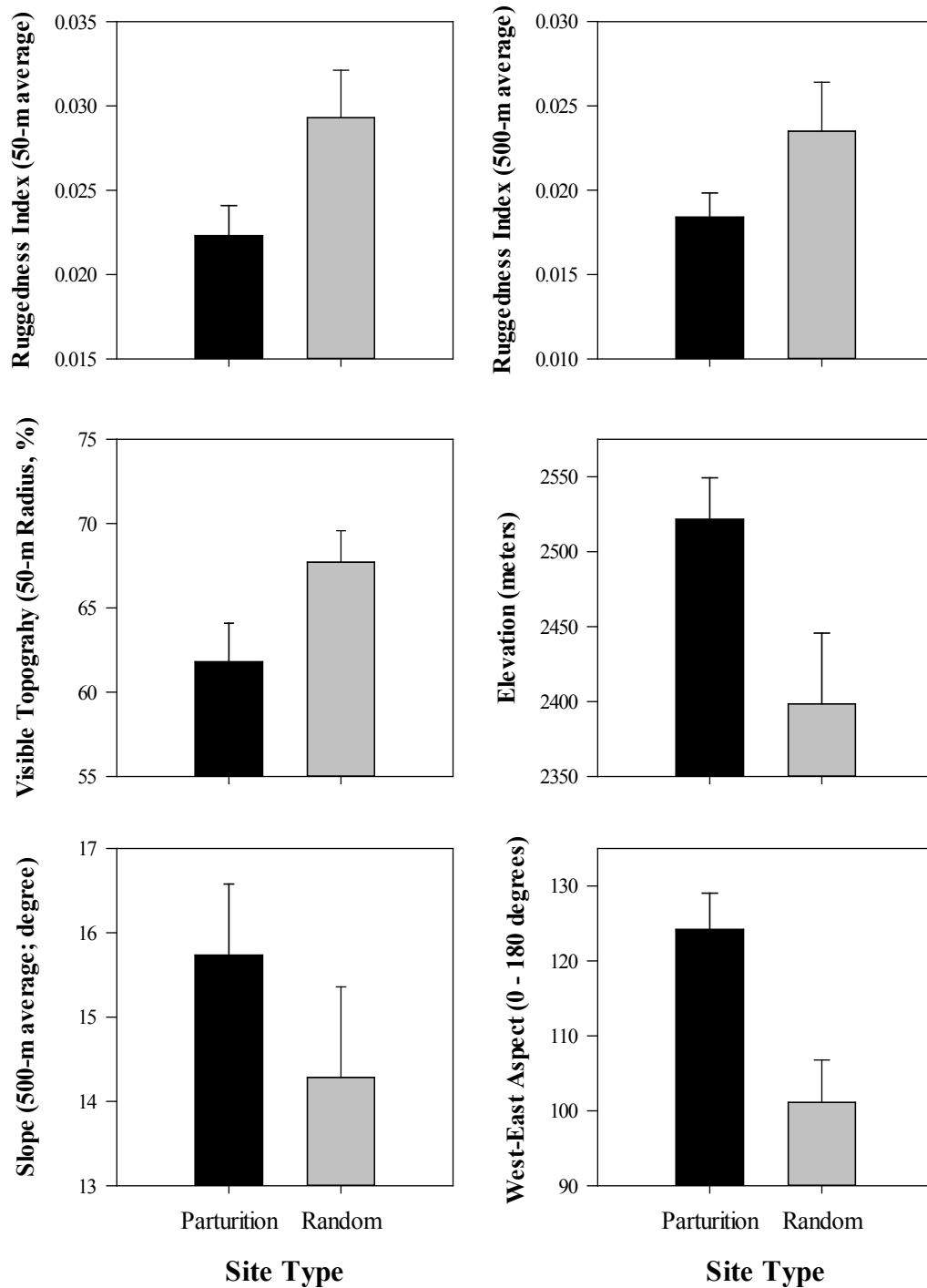


Figure 4. Means (\pm SE) of topographic variables identified as discriminatory between parturition sites of mule deer (*Odocoileus hemionus*) and random sites on Monroe Mountain, Utah.

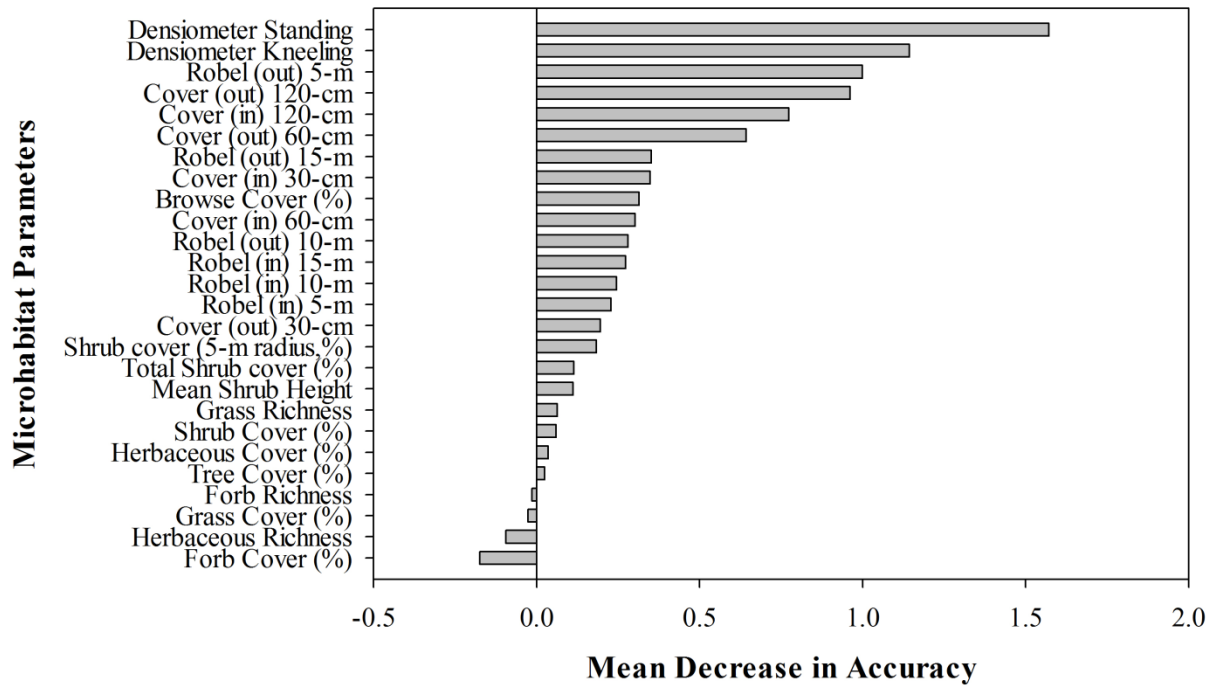


Figure 5. Microhabitat characteristics collected at parturition sites of mule deer (*Odocoileus hemionus*) and random sites on Monroe Mountain, UT. Rankings indicate the relative discriminatory value of each variable between parturition and random sites. Explanations for variables on the Y-axis are found in the methods section.

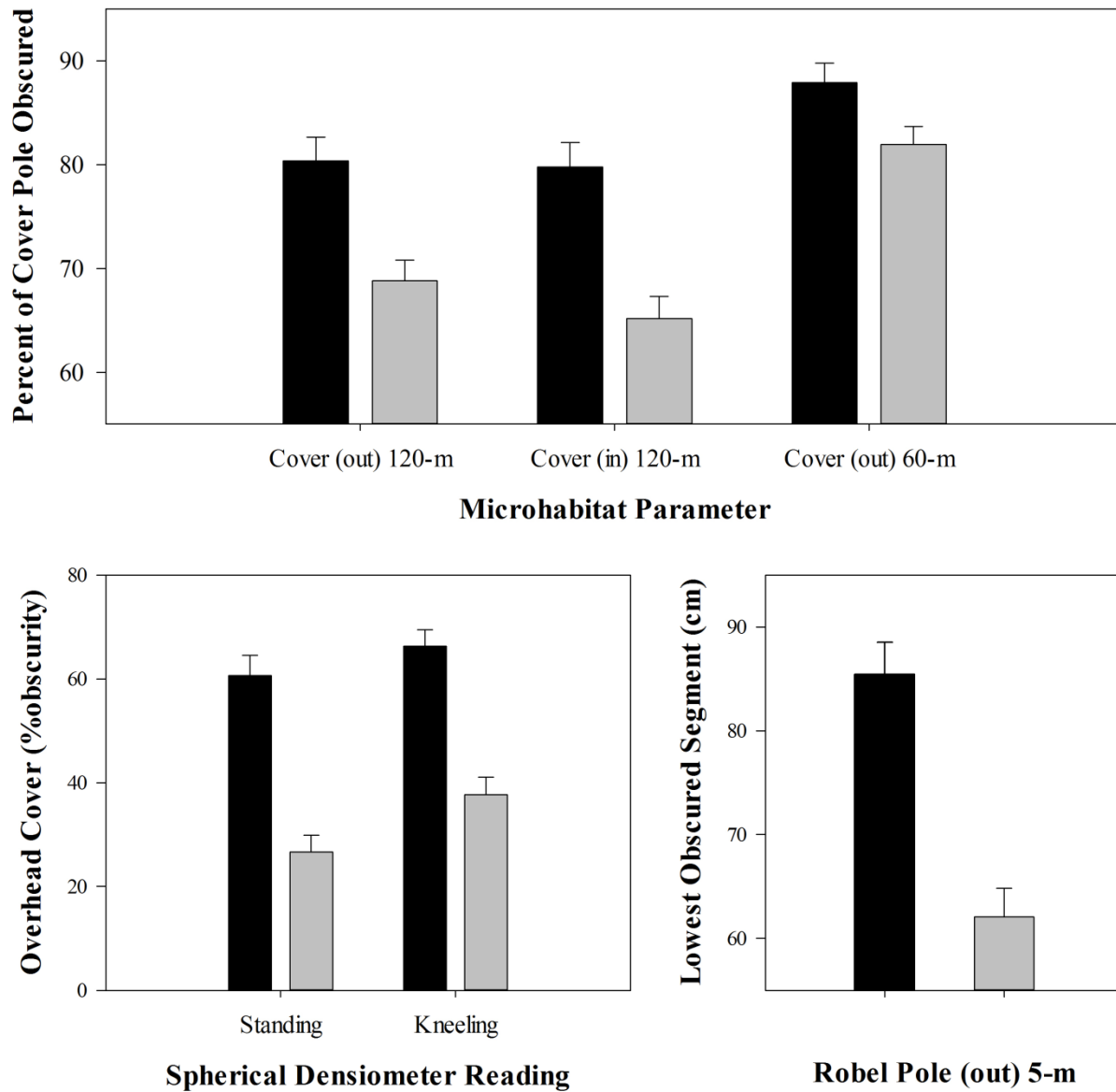


Figure 6. Means (\pm SE) of microhabitat variables identified as discriminatory between parturition sites of mule deer (*Odocoileus hemionus*) and random sites on Monroe Mountain, Utah.