Research Article

Post-Parturition Habitat Selection by Elk Calves and Adult Female Elk in New Mexico

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ABSTRACT Neonatal survival and juvenile recruitment are crucial to maintaining viable elk (*Cervus elaphus*) populations. Neonate survival is known to be influenced by many factors, including bed-site selection. Although neonates select the actual bed-site location, they must do so within the larger calf-rearing area selected by the mother. As calves age, habitat selection should change to meet the changing needs of the growing calf. Our main objectives were to characterize habitat selection at 2 spatial scales and in areas with different predator assemblages in New Mexico. We evaluated bed-site selection by calves and calf-rearing area selection by adult females. We captured 108 elk calves by hand and fitted them with ear tag transmitters in two areas in New Mexico: the Valle Vidal and Blue Range Wolf Recovery Area. In both study areas, we found that concealing cover structure and distance to that cover influenced bed-site selection of young calves (i.e., <2 weeks of age). Older calves (i.e., 3–10 weeks of age) still selected areas in relation to distance to cover, but also preferred areas with higher visibility. At the larger spatial scale of calf-rearing habitat selection by the adult female, concealing cover (e.g., rocks, shrubs, and logs) and other variables important to the hiding calves were still in the most supported models, but selection was also influenced by forage availability and indices of forage quality. Studies that seek to obtain insight into microhabitat selection of ungulate neonates should consider selection by the neonate and selection by the adult female, changes in selection as neonates age, and potential selection differences in areas of differing predation risk. By considering these influences together and at multiple scales, studies can achieve a broader understanding of neonatal ungulate habitat requirements.

KEY WORDS bed site, *Cervus elaphus*, elk, habitat selection, neonate, predation.

Ungulate population dynamics and demographic trends result from changes within contributing components including adult survival, productivity, neonatal survival, and recruitment, which influence age ratios and herd composition and thus contribute to population performance (Gaillard et al. 1998, Harris et al. 2008). These components, in turn, are influenced by many factors, including predation (Harris et al. 2007, Barber-Meyer et al. 2008), disease and malnutrition (Lyles and Dobson 1993, Peek 2003), hunter harvest (Langvatn and Loison 1999, Vucetich et al. 2005), climatic fluctuations (Lubow and Smith 2004, Marshal et al. 2009), food availability, intraspecific competition (Houston 1982, Mduma et al. 1999), and interspecific competition (Houston 1982, Sinclair 1985). Of the components affecting ungulate population trends, juvenile survival and recruitment influence the maintenance of viable herd composition, age ratios, and population growth rates (Gaillard et al. 2000, Lubow and Smith 2004, Harris et al. 2008). Juvenile survival is much more variable than adult survival and may have a more dominant role in population dynamics (Gaillard et al. 1998, 2000) when adult survival is relatively high and constant. Predation is often the leading cause of mortality for neonates and predation risk can be strongly influenced by the calf-rearing habitat selected by the adult female and habitat features (e.g., bed sites) selected by the neonate itself (Barrett 1981, Pitman 2013).

Habitat selection by parturient adults and neonates can be influenced by many factors including predator presence, forage conditions, and human disturbance. Creel et al. (2005) found that elk moved into more protected wooded areas and reduced use of preferred open grasslands with wolf

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(*Canis lupus*) presence in winter in the Greater Yellowstone Ecosystem. Hebblewhite and Merrill (2009) found that elk in the Canadian Rockies adopted either a migration strategy or shifted habitat use at finer scales to avoid predation during the calving season. Caribou (*Rangifer tarandus*) in British Columbia were also found to shift habitat use to high south facing mountain slopes as an antipredatory strategy during the calving season (Bergerud et al. 1983). Previous research has also found that parturient reindeer (*R. t. tarandus*; Vistnes and Nellemann 2001) and caribou (Dau and Cameron 1986) and their young avoided areas near human activity. Human disturbance of elk during the calving season resulted in a decline in calf:cow ratios in Colorado (Phillips 1998, Phillips and Alldredge 2000), and opening roads led to a decrease in survival rates of Roosevelt elk (*C. c. roosevelti*) in Oregon (Cole et al. 1997). Conversely, Berger (2007) suggested that parturient moose (*Alces alces*) may use human activities along roads to shield them from grizzly bear (*Ursus arctos*) predation during the calving period. Similarly, Hebblewhite and Merrill (2009) found that resident elk in Banff National Park in the Canadian Rockies reduced wolf predation risk at fine spatial scales by using areas close to human activities that wolves avoided.

Habitat selection during the calving period is also influenced by availability of forage, cover, and water. Cover influences bed-site selection of numerous ungulates including red muntjac (*Muntiacus muntjak*) and sambar (*Rusa unicolor*; Brodie and Brockelman 2009), elk (Strohmeyer et al. 1999), pronghorn (*Antilocapra americana*; Canon and Bryant 1997), and mule deer (*Odocoileus hemionus eremicus*; Tull et al. 2001). Other factors, such as forage quality and availability were found to affect parturition-site selection by moose (Bowyer et al. 1999) and survival of wildebeest calves (*Connochaetes taurinus*; Mduma et al. 1999). Because of increased water demands during lactation, water sources may also influence habitat selection by parturient ungulates as found for moose (Leptich and Gilbert 1986, Poole et al. 2007) and elk (Delgiudice and Rodiek 1984, McCorquodale et al. 1986).

Our main purposes for this study were to characterize elk habitat selection at 2 spatial scales, the microhabitats selected by calves for bedding sites, and the calf-rearing area selection by the adult female. Further, we wanted to determine if these characteristics differed in areas with and without wolves. Specifically, our research objectives were to assess the relative importance of topography and vegetation structure on the selection of calf bedding sites and adult calf-rearing areas and to determine any influences guiding site selection, including predator presence, distance to water, and human disturbance. Thus, we predicted that calf bed sites would be closer to water sources and farther from areas of human disturbance earlier in life. We also predicted that bed sites selected earlier in life would have lower visibility and greater concealing cover than sites selected later in life as found for pronghorn fawns (Canon and Bryant 1997). Because bed-site selection by the neonate occurs within the maternal daily range (Van Moorter et al. 2009), we predicted that bed-site selection by calves would be primarily influenced by concealing cover, whereas maternal selection would be much more influenced by forage characteristics, distance to water, and human disturbance, as well as concealing cover.

STUDY AREA

In 2011, we conducted our study in the Blue Range Wolf Recovery Area (BRWRA), which includes portions of west-central New Mexico and east-central Arizona (United States Fish and Wildlife Service [USFWS] 1996). We focused our study in the BRWRA secondary wolf recovery zone on the Gila National Forest and Gila Wilderness Area in western New Mexico (Fig. 1).

The BRWRA encompasses over 17,700 km^2, ranging from lowland rolling hills with moderately steep canyons and sandy washes to high mountains characterized by rugged slopes, cliffs, mesas, and deep canyons. Mountain ranges in the BRWRA include the Black, Mogollon, Pinos Altos, and White mountains (Gordon and McClellan 1954, USFWS 1996). Elevations range from 1,200 m in semi-desert areas and along the San Francisco River to 3,350 m on the peaks of Mount Baldy, the Escudilla, and Mogollon Mountains. Major drainages include the Gila and San Francisco Rivers.

Climatic conditions varied with elevation, with an average annual temperature of 13° C in lower elevations and 4° C in higher elevations (Carrera et al. 2008). Overall annual temperatures ranged from a minimum annual average of −3.1° C to a maximum annual average of 16.4° C (Reed et al. 2006). Annual precipitation increased with elevation, with a mean around 53.3 cm (USFWS 1996, Carrera et al. 2008). Most precipitation fell between mid-July and September in thunderstorms and between December and March at higher elevations as snow (USFWS 1996). Long-term (1987–2013, Beaverhead, NM, approx. 30 km east of study area) mean annual precipitation was approximately 35 cm (± 10 cm [SD]; Western Regional Climate Center [WRCC] 2014*a*); average annual snowfall was 139.3 cm (Reed et al. 2006). Total precipitation during 2010 and 2011 was 26% and 25% below average.

Vegetation communities included montane coniferous forests, coniferous and mixed woodlands, subalpine coniferous forests, juniper savanna, plains, and montane grasslands (Brown 1982, Dick-Peddie 1993). Dominant tree species include ponderosa pine (*Pinus ponderosa*) with pinyon pine (*Pinus cembroides*), juniper (*Juniperus* spp.), aspen (*Populus tremuloides*), fir (*Pseudotsuga menziesii* and *Abies* spp.), mesquite (*Prosopis* spp.), New Mexican locust (*Robinia neomexicana*), Gambel oak (*Quercus gambelii*), and other evergreen oaks (*Quercus* spp.) also present. The understory consisted of sparse shrubs and forbs, with a variety of grasses common in more open stands (USFWS 1996, Reed et al. 2006, Carrera et al. 2008).

Ungulates in the BRWRA included elk, Coues white-tailed deer (*Odocoileus virginianus couesi*), mule deer, pronghorn, bighorn sheep (*Ovis canadensis*), and collared peccary (*Pecari tajacu*). Predators included the Mexican gray wolf (*C. l. baileyi*), mountain lion (*Puma concolor*), black bear (*Ursus americanus*), coyote (*Canis latrans*), and bobcat (*Lynx rufus*). The area was popular for public recreation including

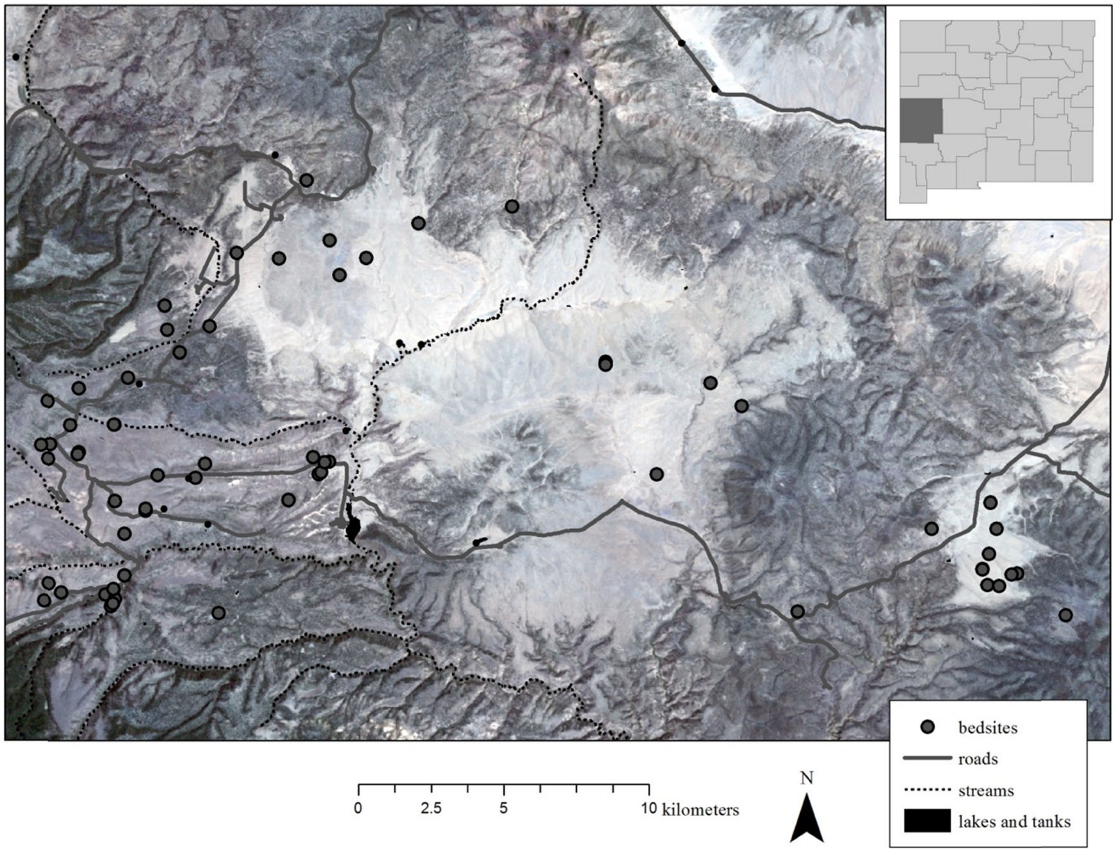

Figure 1. Bed-site locations of tagged elk calves in the Blue Range Wolf Recovery Area in 2011.

both consumptive (e.g., hunting, fishing) and non-consumptive (e.g., hiking, horseback riding, and camping) uses. Most of the BRWRA was accessible to vehicles with several main public roads passing through the BRWRA (USFWS 1996).

In 2012, we continued our study at the Valle Vidal Unit of the Carson National Forest, New Mexico (Fig. 2). Valle Vidal is located in north-central New Mexico in portions of Colfax and Taos Counties and is over 404 km^2 in size (Hassell and Crellin 1985). This area was characterized by flat to rolling prairies from 1,768 m to extensive rugged mountains exceeding 3,658 m. Average temperatures ranged from a low of 4.4° C to 7° C and a high of 27° C to 29° C in July to a low of −18° C to −24°C and a high of 0° C to 7° C in January. Long-term (1906–2013, Red River, NM, approx. 16 km southwest of study area) mean annual precipitation was approximately 54 cm (±10 cm; WRCC 2014*b*) with heavy winter snow and frequent afternoon summer showers (Martin 1976). Total annual precipitation during 2011 and 2012 were 19% and 32% below average.

Vegetation communities of Carson National Forest included coniferous riparian forests, spruce-fir forests, aspen forests, montane grasslands, subalpine grasslands, sagebrush shrublands, and alpine tundra (Vander Lee et al. 2006). Tree species included ponderosa pine, firs, aspen, and limber pine (*Pinus flexilis*) in mixed conifer stands, Colorado pinyon (*Pinus edulis*), and juniper (*Juniperus monoserma* and *J. scopulorum*) in lower elevations, and Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) at higher elevations. Understory shrub and grass species varied with associated overstory and grassland type (Martin 1976).

Ungulates on Carson National Forest included elk, mule deer, bighorn sheep, and pronghorn (Vander Lee et al. 2006). Predators included black bear, mountain lions, coyotes, and bobcats; Mexican wolves were absent. Black bear abundance was estimated to be higher in the Valle Vidal area (17.0 bears/100 km^2) than the BRWRA (9.4 bears/100 km^2; Costello et al. 2001); however, abundance estimates on other predators were not available. The Valle Vidal had limited public vehicular access and provided popular public recreation opportunities including hunting, fishing, hiking, and camping (Hassell and Crellin 1985). More detailed descriptions of the study areas are available in Pitman (2013).

METHODS

We located newborn calves through observation of cow elk in known calving areas in open grasslands and timbered areas. We determined the exact location of hidden calves by observing cow behavior, cows visiting calves to nurse, or direct observation of the calf birth through long-range surveillance of calving areas. We did not approach newborns until the mother had cleaned and nursed her young to avoid potentially influencing initial bonding and imprinting. To further reduce risk of capture-induced abandonment, our capture crews wore latex gloves while handling calves to reduce human scent. We captured calves by hand and fitted them with 23-g very high frequency (VHF) ear tag

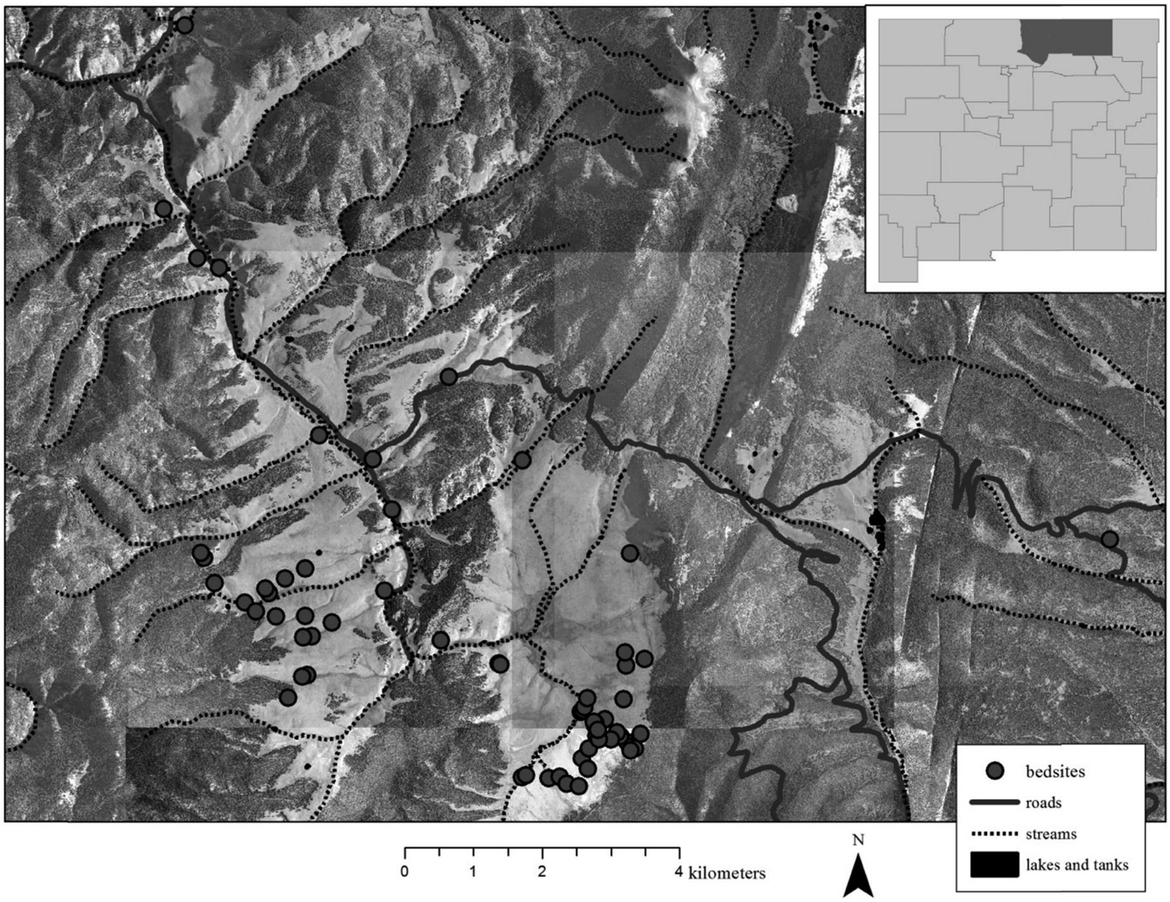

Figure 2. Bed-site locations of tagged elk calves in the Valle Vidal Unit of Carson National Forestand Vermejo Park Ranch in 2012.

transmitters (model M3430; Advanced Telemetry Systems, Isanti, MN). We tagged 37 calves in 2011 in the BRWRA and 71 calves in Valle Vidal in 2012. We processed and released captured calves as quickly as possible (e.g., capture, processing, and release time averaged 9.0 min) to minimize stress on the calf and cow. All capture and handling procedures for elk calves followed acceptable methods (Sikes et al. 2011) and were approved by the New Mexico State University Animal Care and Use Committee (Protocol 2011–2009).

We located calf-bedding sites by radio-tracking tagged calves daily during daylight hours in the summers of 2011 and 2012. When we located a bedded calf, we recorded a global positioning system (GPS) waypoint, along with the distance and bearing to the bedded calf. We did not intentionally disturb calves, and collected data after the calf had moved to a different location to minimize observer impact on calf survival. On average, we revisited sites within 3 weeks after the initial observation to collect data on physical and vegetative characteristics. We did not think this delay in collection time influenced selection patterns because early summers were very dry and we collected data on beds and paired random locations on the same day. We analyzed the bed sites of calves that we accidentally flushed in 1 visit, unless the calf re-bedded in the immediate vicinity. In addition to tracking tagged calves, we also collected data at bed sites of unmarked calves located opportunistically. We investigated all tagged calf mortalities and assessed cause of death.

We matched all bed sites with 2 randomly selected available sites. One random site represented areas available for selection by the calf (i.e., the calf random site), and the other random site represented areas available for selection by the parturient mother (i.e., the adult random site). We determined locations of available sites by randomly selecting a distance and direction from the used site using a random number table. We limited distances for adult random sites to a maximum distance of 750 m, because the straight-line daily movements of cow elk have been found to average around or below this distance during calving season (Vore and Schmidt 2001), late summer (Cole et al. 1997), and early fall (Bowyer 1981). In addition, we set a minimum distance of 100 m to prevent the adult random site from being too close to the used site. We bounded calf random sites by minimum and maximum distances of 50 m and 100 m. We used this minimum distance to avoid spatial dependency with the bed site and the maximum distance prevented overlap with the adult random site and represents a distance above which the calf was unlikely to travel on its own.

We evaluated all sites (bed sites, calf random sites, and adult random sites) and collected data on physical features and vegetation characteristics at each site. We recorded data using CyberTracker Software Version 3.284 (CyberTracker Conservation, Cape Town, South Africa). We evaluated vegetation at sites using a variation of the line intercept method (Elzinga et al. 1998, Higgins et al. 2005). We established 2 perpendicular lines that intersected at the calf location site (Waldrip and Shaw 1979), and assessed all vegetation characteristics along these lines (Tull et al. 2001). We used 30-m intersecting lines for comparisons of bed sites and adult random sites. We used 10-m intersecting lines for comparisons of bed sites and calf random sites because a smaller area was believed to influence calf bed-site selection than the adult area selection. We measured vegetation structure at each site including percent grass cover, grass greenness, canopy cover, and distance to the nearest concealing cover. We defined concealing cover as vegetation (e.g., shrubs, bunch grasses, and down timber) or rock cover tall enough and wide enough to conceal a bedded calf on at least 1 side.

We placed a 1-m^2 quadrat at plot center, 5 m, and 15 m along the transect lines and estimated percent cover and greenness of grasses within each quadrat using Walker's ranking method (i.e., 0, 1–10, 11–25, 26–50, 51–75, 76–90, 90–99, and 100%; Walker 1976). We determined total percent ground cover and greenness for the plot by averaging the midpoints of all individual estimates. We assessed percent cover of shrubs, logs, and rocks by measuring the length of intercept along transect lines. We determined canopy cover using a convex spherical densiometer, and recorded measurements at plot center, 5 m, and 15 m along each transect line. We modified densiometer measurements to adjust for overlap (Strickler 1959). We averaged grass cover, grass greenness, and canopy cover measurements within each site. We recorded thermal cover as the number of plants (i.e., bunchgrass, shrubs, and trees) within 5 m of plot center that could provide thermal cover to a bedded calf.

We recorded visibility estimates at each site using a 1.5-m cover pole with alternating 0.1-m black and white bands (Robel et al. 1970, Griffith and Youtie 1988). We placed the cover pole at plot center, and we estimated the proportion of a bedded calf and a standing adult cow that would be visible at the site in all 4 cardinal directions at 10 m, 25 m, and 50 m. We took visibility measurements for standing cows at the average shoulder height of 1.4 m on the cover pole (Hudson et al. 2002). We measured the height of bedded calves during captures and used the average of 0.3 m for bedded calf visibility assessments on the cover pole. We recorded all visibility measurements at a height of 76 cm, the average height of an adult Mexican gray wolf (Parsons 1998, Brown 2002). Within each measurement level (i.e., standing cow, bedded calf), we determined the percentage of each of the 0.1-m bands on the cover pole concealed by vegetation using Walker's ranking method (Walker 1976).

We measured distances from all sites to areas associated with high human activity (i.e., maintained roads, buildings, and campgrounds) and distance to nearest water source using ArcGIS 10.0 (ESRI, Redlands, CA). Ground-truthing during the field season verified the locations of buildings, campgrounds, maintained roads, and water sources.

Statistical Analysis

We considered individual tagged calves as sampling units. We treated selected bed sites and paired random sites as used and available resource units, respectively. Because of logistical constraints we typically sampled only 1 bed site per time period (i.e., early and late age) for the majority of our radio-tagged calves and opted to devote more resources to adding more individual calves to our sample rather than visiting multiple bed sites for each individual calf. However, we did collect data on multiple bed sites for a few calves. For those calves we randomly selected 1 bed site within each time period to include in analyses. To avoid issues with multicollinearity, we first examined all predictor variables for correlation. If variables were correlated (i.e., $r = 0.60$), we removed 1 or more variables from the analyses. We developed 24 a priori models based on combinations of variables potentially influencing calf microhabitat (i.e., bedsite) selection. We also developed an additional 24 a priori models based on combinations of variables potentially influencing adult calf-rearing area selection (see Table S1, available online at www.onlinelibrary.wiley.com). We included 11 variables in the analyses; however, we included no more than 3 variables in any specific model because of small sample sizes. Roughly half of the models for microhabitat selection and calf-rearing area selection were the same models, and half of the models were specific to either calf or adult selection. We included some forage models that we built to investigate adult selection in the calf analysis so that we included all variables in some models in each analysis.

We used logistic regression (PROC LOGISTIC) with used and available site data in SAS Enterprise 5.1 (SAS Institute, Inc., Cary, NC) to estimate the parameters of an exponential model and determined whether the relative risk of selection differed with changes in the explanatory habitat variables. In most cases, we used paired logistic regression ($K = n$) to take advantage of the paired data and more powerful testing. In analyses with small sample sizes ($n \leq 13$), we analyzed data unpaired to avoid estimation problems encountered when attempting to run paired analyses with small samples. We used an information-theoretic approach to select the best-fitting model using Akaike's Information Criterion (AIC_c) corrected for small sample sizes (Burnham and Anderson 2002). We considered models with ΔAIC_c values <2.0 to be competing models. We calculated model-averaged parameter estimates (±SE) and 90% confidence intervals for variables in competing models using multi-model averaging (Burnham and Anderson 2002) across all a priori models. We calculated relative risk by exponentiation of the model-averaged parameter estimates of the exponential model and 90% confidence limits (Keating and Cherry 2004, Lele et al. 2013).

We investigated differences in bed-site selection and adult calf-rearing area selection during and after the first 2 weeks of life (i.e., early and late season) to determine if certain characteristics influenced selection differently as calves aged. To assess these differences, we again used logistic regression to estimate the parameters of an exponential resource selection function model for early and late season measuring habitat variables at 2 scales. We measured habitat variables in early season at 10-m diameter bed locations and paired calf random sites, in early season at 30-m diameter bed locations and paired adult random sites, in late season at 10-m diameter bed locations and paired calf random sites, and in late season at 30-m diameter bed locations and paired adult random sites for each study area.

RESULTS

BRWRA Early Versus Late Age Calf Microhabitat Selection

In the early age calf analysis for the BRWRA, ($n = 41$; included 8 unmarked calves), the highest ranked model included distance to nearest concealing cover and visibility for the bedded calf (Table 1; model weight [w_i] = 0.63). Relative risk (RR) of selection decreased by 33.5% with every 1-m increase in distance to the nearest concealing cover (RR = 0.665; Table 2) and decreased by 12% with every 1% increase in visibility at the bedded-calf level (RR = 0.879; Table 2). Moderately supported models included the distance to nearest concealing cover, amount of thermal cover, percentage of ground cover, and distance to water (Table 1).

For calves greater than 2 weeks of age ($n = 13$), all top ranked models ($w_i = 0.23$, 0.26, and 0.39) included distance to nearest concealing cover. The visibility estimate at the bedded-calf level and percent slope were additional factors in the higher ranked models (Table 1). Relative risk of selection decreased by 63.5% with every 1-m increase in distance to nearest concealing cover (RR = 0.365). However, the relative risk of selection increased by 8.7% with every 1% increase in visibility for the bedded calf (RR = 1.087; Table 2).

BRWRA Early Versus Late Summer Adult Calf-Rearing Area Selection

For cows with calves less than 2 weeks of age ($n = 41$) in the BRWRA, we found considerable model uncertainty (Table 1), but the top 5 models all included distance to nearest concealing cover. Three of these models also included percent grass cover and percent grass greenness. Three models included other cover-related variables such as percent ground cover and thermal cover (Table 1). The top 2 models had more than twice the support ($w_i = 0.26$ and 0.28) of the third highest ranking model. Relative risk of selection decreased by 42.1% with every 1-m increase in distance to nearest concealing cover (RR = 0.579; Table 2).

For cows with calves older than 2 weeks of age ($n = 13$), the individual model best describing relative risk of selection included distance to nearest concealing cover and percent grass cover (Table 1; $w_i = 0.71$). The second highest ranking model ($w_i = 0.09$) included distance to nearest concealing cover, percent grass cover, and grass greenness. Relative risk of selection decreased by 68.3% with every 1-m increase in distance to nearest concealing cover (RR = 0.317), increased by 9.8% with every 1% increase in grass cover (RR = 1.098), and increased by 8.7% with every 1% increase in visibility at the bedded-calf level (RR = 1.087; Table 2).

Valle Vidal Early Versus Late Age Calf Microhabitat Selection

In the Valle Vidal ($n = 54$; data were not available for all tagged calves), the top-ranked model ($w_i = 0.59$) describing relative risk of selection for calves less than 2 weeks of age included distance to nearest concealing cover and amount of thermal cover (Table 3). Relative risk of selection decreased by 87.6% with every 1-m increase in distance to nearest

Table 1. Models that formed a distinctly superior group for the relative risk of selection for early age (<2 weeks) and late age (>2 weeks) elk calf microhabitat bed-site selection and adult calf-rearing area selection in Blue Range Wolf Recovery Area, New Mexico, 2011. We present the number of parameters (K), log-likelihood, Akaike's Information Criterion adjusted for small sample size (AIC_c), ΔAIC_c, and Akaike weights (w_i).

	Model[a]	K	−2Log-likelihood	AIC_c	ΔAIC_c	w_i
Early calf selection	Cover distance + calf visibility	2	21.84	26.16	0.00	0.6293
	Cover distance + thermal cover	2	25.52	29.83	3.67	0.1001
	Cover distance + ground cover	2	25.70	30.01	3.85	0.0917
	Cover distance + ground cover + water distance	3	23.90	30.54	4.39	0.0701
Late calf selection	Cover distance + slope	3	19.53	28.20	0.00	0.3913
	Cover distance + calf visibility	3	20.33	28.99	0.79	0.2631
	Cover distance	2	24.04	29.24	1.04	0.2332
	Cover distance + thermal cover	3	23.92	32.59	4.39	0.0436
Early adult selection	Cover distance + grass cover	2	16.49	20.80	0.00	0.2798
	Cover distance + ground cover	2	16.67	20.98	0.18	0.2558
	Cover distance + ground cover + thermal cover	3	15.79	22.44	1.64	0.1235
	Cover distance + grass cover + greenness	3	15.91	22.56	1.76	0.1162
	Cover distance + grass cover + thermal cover	3	15.97	22.62	1.81	0.1130
Late adult selection	Cover distance + grass cover	3	23.93	32.60	0.00	0.7086
	Cover distance + grass cover + greenness	4	23.80	36.80	4.20	0.0867
	Cover distance + grass cover + thermal cover	4	23.93	36.93	4.33	0.0813
	Cover distance + ground cover	3	30.16	38.83	6.23	0.0315
	Adult visibility + calf visibility	3	30.31	38.97	6.37	0.0293

[a] Variable notation: calf visibility = bedded calf average visibility based on Robel pole measurements; adult visibility = standing adult average visibility based on Robel pole measurements; cover distance = distance to nearest concealing cover; ground cover = percent ground cover including logs, shrubs, and rocks; grass cover = percent grass cover; greenness = percent grass greenness; thermal cover = thermal cover within 5 m of plot center; slope = percent slope of the site; water distance = distance to nearest water source.

Table 2. Relative risk, lower and upper 90% confidence limits, and model-averaged coefficient estimates and standard error for variables included in best-approximating models for the relative risk for bed-site selection in early age (<2 weeks) and late age (>2 weeks) calf microhabitat selection and adult calf-rearing area selection in Blue Range Wolf Recovery Area, New Mexico, 2011.

			90% Confidence limits		Model-averaged coefficients	
	Variable[a]	Relative risk	Lower CL	Upper CL	Estimate	SE
Early calf selection	Cover distance	0.665	0.516	0.857	−0.408	0.154
	Calf visibility	0.879	0.789	0.978	−0.129	0.065
	Ground cover	1.126	0.978	1.296	0.119	0.085
	Thermal cover	1.084	0.972	1.209	0.081	0.066
	Water distance	0.983	0.962	1.004	−0.017	0.013
Late calf selection	Cover distance	0.365	0.187	0.710	−1.009	0.405
	Calf visibility	1.087	1.001	1.179	0.083	0.049
	Slope	0.928	0.862	0.999	−0.074	0.045
	Thermal cover	0.977	0.870	1.096	−0.024	0.070
Early adult selection	Cover distance	0.579	0.359	0.937	−0.545	0.291
	Grass cover	0.986	0.938	1.038	−0.014	0.031
	Ground cover	0.971	0.797	1.182	−0.029	0.119
	Greenness	0.958	0.868	1.057	−0.043	0.059
	Thermal cover	1.069	0.917	1.249	0.068	0.094
Late adult selection	Grass cover	1.098	1.017	1.186	0.094	0.047
	Greenness	1.006	0.975	1.037	0.006	0.019
	Cover distance	0.317	0.121	0.830	−1.148	0.585
	Adult visibility	0.962	0.926	0.999	−0.039	0.025
	Calf visibility	1.087	1.016	1.162	0.083	0.041
	Thermal cover	1.003	0.901	1.116	0.003	0.065

[a] Variable notation: calf visibility = bedded calf average visibility based on Robel pole measurements; adult visibility = standing adult average visibility based on Robel pole measurements; cover distance = distance to nearest concealing cover; ground cover = percent ground cover including logs, shrubs, and rocks; grass cover = percent grass cover; greenness = percent grass greenness; thermal cover = thermal cover within 5 m of plot center; slope = percent slope of the site; water distance = distance to nearest water source.

concealing cover (RR = 0.124) and increased by 47.5% with each unit increase in thermal cover (RR = 1.475; Table 4). Other high ranking models included distance to nearest concealing cover, with percent slope and percent ground cover also present in some models (Table 3).

In the Valle Vidal ($n = 20$), we found more model uncertainty for selection by calves greater than 2 weeks of age. The top 4 competing models included visibility for the bedded calf, with 3 of the models also including distance to roads and buildings, percent ground cover, or percent grass cover (Table 3). Relative risk of selection increased by 6.4% with every 1% increase in visibility at the bedded-calf height (RR = 1.064) and increased 17% for every 1% increase in grass cover (RR = 1.174; Table 4).

Table 3. Models that formed a distinctly superior group for the relative risk of selection for early age (<2 weeks) and late age (>2 weeks) calf microhabitat bed-site selection and adult calf-rearing area selection in Valle Vidal, New Mexico, 2012. We present the number of parameters (K), log-likelihood, Akaike's Information Criterion adjusted for small sample size (AIC_c), ΔAIC_c, and Akaike weights (w_i).

	Model[a]	K	−2Log-likelihood	AIC_c	ΔAIC_c	w_i
Early calf selection	Cover distance + thermal cover	2	12.52	16.75	0.00	0.5975
	Cover distance	1	17.30	19.38	2.62	0.1608
	Cover distance + slope	2	16.66	20.89	4.14	0.0755
	Cover distance + ground cover	2	17.19	21.43	4.67	0.0578
Late calf selection	Grass cover + ground cover	2	13.57	18.28	0.00	0.2520
	Grass cover + greenness	2	14.51	19.22	0.94	0.1576
	Calf visibility	1	17.26	19.48	1.20	0.1381
	Calf visibility + road distance	2	15.60	20.30	2.03	0.0915
Early adult selection	Cover distance + ground cover	2	17.13	21.36	0.00	0.2402
	Cover distance + grass cover	2	17.61	21.85	0.48	0.1886
	Cover distance + grass cover + greenness	3	15.70	22.18	0.82	0.1597
	Cover distance + ground cover + thermal cover	3	16.61	23.09	1.73	0.1012
	Cover distance + grass cover + thermal cover	3	16.76	23.24	1.88	0.0938
Late adult selection	Grass cover + greenness	2	9.46	14.16	0.00	0.7020
	Cover distance+ grass cover + greenness	3	9.02	16.52	2.35	0.2168
	Cover distance + grass cover	2	15.95	20.65	6.49	0.0274
	Grass cover + ground cover	2	17.49	22.20	8.03	0.0127
	Cover distance + grass cover + thermal cover	3	15.66	23.16	9.00	0.0078

[a] Variable notation: calf visibility = bedded calf average visibility based on Robel pole measurements; cover distance = distance to nearest concealing cover; ground cover = percent ground cover including logs, shrubs, and rocks; grass cover = percent grass cover; greenness = percent grass greenness; thermal cover = thermal cover within 5 m of plot center; slope = percent slope of the site; road distance = distance to the nearest maintained road, building, or campground.

Table 4. Relative risk, lower and upper 90% confidence limits, and model average coefficient estimates and standard error for variables included in best-approximating models for the relative risk for bed-site selection in early age and late age calf microhabitat selection and adult calf rearing area selection in Valle Vidal, New Mexico 2012.

			90% Confidence limits		Model-averaged coefficients	
	Variable	Relative risk	Lower CL	Upper CL	Estimate	SE
Early calf selection	Cover distance	0.124	0.214	0.579	−2.089	0.939
	Thermal cover	1.475	1.039	2.093	0.388	0.213
	Slope	1.069	0.982	1.165	0.067	0.052
	Ground cover	1.031	0.878	1.209	0.030	0.082
Late calf selection	Calf visibility	1.064	1.014	1.116	0.062	0.029
	Road distance	1.002	0.997	1.008	0.003	0.003
	Ground cover	0.890	0.729	1.086	−0.116	0.121
	Grass cover	1.174	1.011	1.364	0.161	0.091
	Greenness	0.862	0.723	1.026	−0.148	0.106
Early adult selection	Cover distance	0.121	0.035	0.417	−2.109	0.802
	Grass cover	1.027	0.979	1.077	0.026	0.029
	Ground cover	1.056	0.962	1.159	0.054	0.056
	Greenness	1.071	0.972	1.179	0.069	0.059
	Thermal cover	1.083	0.826	1.420	0.079	0.165
Late adult selection	Grass cover	1.220	1.005	1.482	0.199	0.118
	Greenness	0.847	0.737	0.973	−0.166	0.085
	Cover distance	1.321	0.610	2.859	0.278	0.469
	Ground cover	1.010	0.993	1.027	0.010	0.011
	Thermal cover	1.019	0.926	1.122	0.019	0.058

[a] Variable notation: calf visibility = bedded calf average visibility based on Robel pole measurements; cover distance = distance to nearest concealing cover; ground cover = percent ground cover including logs, shrubs, and rocks; grass cover = percent grass cover; greenness = percent grass greenness; thermal cover = thermal cover within 5 m of plot center; slope = percent slope of the site; road distance = distance to the nearest maintained road, building, or campground.

Valle Vidal Early Versus Late Summer Adult Calf-Rearing Area Selection

In the Valle Vidal ($n = 54$), all of the top-ranked models ($w_i = 0.24$, 0.19, 0.16, 0.10) describing relative risk of selection for adult females with calves less than 2 weeks of age included distance to nearest concealing cover. Three models also included percent grass cover, whereas 1 model included percent grass greenness, and 2 models included percent ground cover and thermal cover (Table 3). Relative risk of selection decreased by 87.9% with every 1-m increase in distance to nearest concealing cover (RR = 0.121; Table 4).

In the Valle Vidal late summer adult-scale analysis ($n = 20$), the top model ($w_i = 0.70$) included percent grass cover and percent grass greenness, and the second highest ranking model also included distance to the nearest concealing cover (Table 3). Relative risk of selection increased by 22.0% with every 1% increase in grass cover (RR = 1.220) and decreased by 15.3% for every 1% increase in grass greenness (RR = 0.847; Table 4).

DISCUSSION

Overall patterns of elk habitat selection were very similar between Valle Vidal and the BRWRA. For calves less than 2 weeks of age, concealing cover, short distances to that cover, and low visibility influenced bed-site selection. When these same calves were older than 2 weeks of age, shorter distances to concealing cover still influenced bed-site selection; however, calves then began to select areas with higher visibility. This pattern was consistent in both study areas. Elk calves less than 2 weeks of age are in the initial hiding phase with hiding as their only means of protection from predation. Later in the summer, calves still rely on cover for protection but are more mobile and have a greater ability to flee and evade approaching predators. By selecting bedding locations with higher visibility, these older and more mobile calves are likely afforded an increased opportunity to detect approaching predators from farther distances.

Even when not measuring visibility directly, comparable results have been reported in other studies that assessed the influence of cover on habitat selection of neonates of differing age classes. Young pronghorn fawns in Texas selected sites with greater shrub density when compared with older fawns (Canon and Bryant 1997). Ground cover and concealment were found to decrease at bed sites of older age roe deer (*Capreolus capreolus*) fawns in France (Van Moorter et al. 2009). In the Northern Great Plains, white-tailed deer fawns initially used areas with high levels of tree canopy cover and basal area, but this use decreased as fawns aged (Grovenburg et al. 2010). These decreases in use of cover as neonates age may also indicate selection for habitats with increased visibility as reported here.

Although calves may choose the actual bedding site, they must do this within the general constraints of the area chosen by the nursing mother (Van Moorter et al. 2009). Thus, calves are bedding in areas selected by the adult that should simultaneously meet calf hiding cover requirements and requirements of the lactating cow. Selection patterns differed when we expanded the spatial extent from the microhabitats selected at calf bedding sites to general calf-rearing areas selected by the adult. In early summer in both study areas, cows with calves less than 2 weeks of age selected calf-rearing areas with increased cover, shorter distances to cover, and higher available forage compared to available sites. Later in the summer when their calves were greater than 2 weeks of age, cows selected areas with less focus on concealing cover and heavier emphasis on higher forage availability and increased visibility. However, although female elk were selecting areas with higher forage cover, they were not selecting areas with the greenest grass. The greenest grasses at our sites were typically young, shorter growth of higher forage quality, but limited in biomass. The amount of forage available up to some threshold minimum to facilitate sufficient intake, rather than forage quality, can contribute more to habitat selection as was reported for wildebeest in the Serengeti (Wilmhurst et al. 1999).

Studies on parturition site and bed-site selection are common (Huegel et al. 1986, Fox and Krausman 1994, Butler et al. 2009, Rearden et al. 2011). However, studies investigating neonatal microhabitat selection that incorporate the constraining decisions by adults, even indirectly, are relatively uncommon. The few studies that have addressed neonatal and adult selection simultaneously reported results comparable to ours. Van Moorter et al. (2009) found that roe deer fawn survival was primarily influenced by availability of good bed locations within the maternal home range rather than bed selection of the fawn itself, and that older age fawns selected beds in areas of higher forage accessibility. Wallace and Krausman (1990) determined that elevation of selected elk cow and calf microhabitats varied with seasonal snowmelt and green-up, which influence forage availability and quality. Canon and Bryant (1997) found that percent grass cover was greater at pronghorn fawn bedding sites than at random sites. They further reported that percent grass cover was greater at beds of surviving than non-surviving fawns, indicating the effect of adult habitat selection and forage availability on neonatal survival.

Surprisingly, distance to water was not in our most supported models of habitat selection at either spatial scale or study site. Previous research reports that distance to water influences habitat selection, especially for parturient ungulates or adult ungulates with very young calves (Leptich and Gilbert 1986, McCorquodale et al. 1986) because of the higher water requirements of lactating females and young. However, distance to water does not appear to be influencing parturition site selection in some areas, as was found for desert mule deer in Arizona (Fox and Krausman 1994). Because water sources were readily available throughout Valle Vidal, we did not expect that water would be a limiting factor at that site. However, the BRWRA study area had far fewer available water sources and we expected water to influence calf-rearing area selection especially during the first 2 weeks of life. Perhaps elk obtained sufficient moisture content from forage, and free water may not be as important as expected for this time period in these areas when compared to other habitat characteristics. Additionally, areas of human activity did not affect bed-site selection at either of our study areas, although other studies on various herbivores with young have reported both selections farther from (Vistnes and Nellemann 2001, Dau and Cameron 1986) and closer to (Berger 2007, Hebblewhite and Merrill 2009) areas of human use. Human activity during our study may not have been high enough to provoke a response.

Elk within and outside of Mexican wolf reintroduction areas selected microhabitats similarly, regardless of predator assemblage composition. Because no mortalities of tagged calves were attributed to wolves, wolves did not appear to have a major impact on calf survival at this time period in our study (Pitman 2013). However, our sample size was limited for the BRWRA and sources of calf mortality for unmarked calves are unknown. Some previous studies have found wolf predation on elk calves to occur mainly in winter rather than summer (Barber et al. 2005, Creel et al. 2007). Conversely, Metz et al. (2012) reported that in Yellowstone National Park elk calves make up a larger proportion of wolf kills during summer than previously reported by others. Yet, even with the reintroduction of wolves to the Greater Yellowstone Ecosystem, black bears were still the most common cause of predation mortality for elk neonates (Smith et al. 2006, Barber-Meyer et al. 2008). With wolf predation risk lower in summer than winter months, calves may face similar risks of black bear predation throughout areas with and without wolves, and black bears are known to be a major cause of mortality in neonatal ungulates (Zager and Beecham 2006). In addition, wolves and bears use similar habitat conditions, with bears commonly scavenging wolf kills (Smith et al. 2003). This supports our findings that elk habitat selection patterns were similar in both study areas regardless of the predator community composition.

Neonatal survival and recruitment are important components of population dynamics, influencing age ratios and variability in population growth rates of ungulates (Gaillard et al. 1998, Gaillard et al. 2000; Lubow and Smith 2004, Harris et al. 2008). Neonate survival can be influenced by habitat characteristics selected by the adult female and bed sites selected by the neonate (Barrett 1981, Pinard et al. 2011, Rearden et al. 2011, Pitman 2013). Therefore, understanding factors potentially influencing neonatal predation risk and survival, including microhabitat selection, are important in sound management of ungulates. This microhabitat selection is influenced by calf-rearing area selection by the adult cow, which has often not been considered in other studies. It is also important to consider the changing needs of calves as they age. Our study illustrates that the relative importance of different habitat characteristics changes with calf age and when the interacting selection and forage needs of the adult are considered. Because the needs of neonatal and parturient adult ungulates differ, and these needs change through time, multiple scales of selection should be considered when designing and interpreting future microhabitat selection studies of neonates (Boyce et al. 2003).

MANAGEMENT IMPLICATIONS

Many managers use burning, thinning, and brush removal in habitat improvement programs in attempts to improve habitat quality for elk (Lyon and Christensen 2002). Based on our findings, we recommend that such projects be implemented in a manner that provides some heterogeneity in conditions across the calving area so as to provide some areas of greater hiding cover needed by elk calves early in life when they are most susceptible to predation and some more open areas with increased visibility to benefit older calves during late summer when they are more mobile and can better detect and evade predators. Properly managed livestock grazing has also been used as a tool in elk management (Lyon and Christensen 2002). Previous studies have shown that elk and cattle compete for forage on spring ranges and that elk avoid areas used by cattle in rotational grazing (Lyon and Christensen 2002, Miller 2002). Delaying livestock grazing to mid to late summer in key calving areas would help ensure parturient cow elk and hiding neonates are not displaced from traditional calving and calf-rearing areas, parturient and lactating cow elk have access to needed forage, and that grass hiding cover requirements of neonates are met in the early summer when they are more vulnerable. We recommend these findings be considered in the planning of future habitat improvement projects for elk in the Southwest and management of elk calving areas. If future management actions are taken to improve habitat during the calf-rearing season, the interacting selection of adult cows and calves must be considered so that the cover needs of the calf and forage needs of the adult are met.

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LITERATURE CITED

Barber, S. M., L. D. Mech, and P. J. White. 2005. Yellowstone elk calf mortality following wolf restoration: bears remain top summer predators. Yellowstone Science 13:37–44.

Barber-Meyer, S. M., L. D. Mech, and P. J. White. 2008. Elk calf survival and mortality following wolf restoration to Yellowstone National Park. Wildlife Monographs 169.

Barrett, M. W. 1981. Environmental characteristics and functional significance of pronghorn fawn bedding sites in Alberta. Journal of Wildlife Management 45:120–131.

Berger, J. 2007. Fear, human shields and the redistribution of prey and predators in protected areas. Biology Letters 3:620–623.

Bergerud, A. T., H. E. Butler, and D. R. Miller. 1983. Antipredator tactics of calving caribou: dispersion in mountains. Canadian Journal of Zoology 62:1655–1575.

Bowyer, R. T. 1981. Activity, movement, and distribution of Roosevelt elk during rut. Journal of Mammalogy 62:574–582.

Bowyer, R. T., V. Van Ballenberghe, J. G. Kie, and J. A. K. Maier. 1999. Birth-site selection by Alaskan moose: maternal strategies for coping with a risky environment. Journal of Mammalogy 80:1070–1083.

Boyce, M. S., M. G. Turner, J. Fryxell, and P. Turchin. 2003. Scale and heterogeneity in habitat selection by elk in Yellowstone National Park. Ecoscience 10:421–431.

Brodie, J. F., and W. Y. Brockelman 2009. Bed site selection of red muntjac(*Muntiacus muntjak*) and sambar (*Rusa unicolor*) in a tropical seasonal forest. Ecological Research 24:1251–1256.

Brown, D. E. 1982. Biotic communities of the American Southwest – United States and Mexico. Desert Plants 4:1–342.

Brown, D. E. 2002. The wolf in the southwest. High-Lonesome Books, Silver City, New Mexico, USA.

Burnham, K. P., and D. R. Anderson 2002. Model selection and mulitmodelinference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, New York, USA.

Butler, D. A., S. P. Haskell, W. B. Ballard, M. C. Wallace, C. M. Britton, and M. H. Humphreys. 2009. Differences in timing of parturition, birthing sites, and bedding sites of fawns in sympatric populations of deer. Southwestern Naturalist 54:261–271.

Canon, S. K., and F. C. Bryant 1997. Bed-site characteristics of pronghorn fawns. Journal of Wildlife Management 61:1134–1141.

Carrera, R., W. Ballard, P. Gipson, B. T. Kelly, P. R. Krausman, M. C. Wallace, C. Villalobos, and D. B. Wester. 2008. Comparison of Mexican wolf and coyote diets in Arizona and New Mexico. Journal of Wildlife Management 72:376–381.

Cole, E. K., M. D. Pope, and R. G. Anthony. 1997. Effects of road management and survival of Roosevelt elk. Journal of Wildlife Management 61:1115–1126.

Costello, C. M., D. E. Jones, K. A. Green-Hammond, R. M. Inman, K. H. Inman, B. C. Thompson, R. A. Deitner, and H. B. Quigley. 2001. A study of black bear ecology in New Mexico with models for population dynamics and habitat suitability. Final Report, Federal Aid in Wildlife, Restoration Project W-131-R, New Mexico Department of Game and Fish, Santa Fe, USA.

Creel, S., D. Christianson, S. Liley, and J. A. Winnie. Jr., 2007. Predation risk affects reproductive physiology and demography of elk. Science 315: 960.

Creel, S., J. Winnie, Jr., B. Maxwell, K. Hamlin, and M. Creel. 2005. Elk alter habitat selection as an antipredator response to wolves. Ecology 86:3387–3397.

Dau, J. R., and R. D. Cameron 1986. Effects of a road system on caribou during calving. Rangifer Special Issue 1:95–101.

Delgiudice, G. D., and J. E. Rodiek 1984. Do elk need free water in Arizona? Wildlife Society Bulletin 12:142–146.

Dick-Peddie, W. A. 1993. New Mexico vegetation: past, present, and future. University of New Mexico, Albuquerque, USA.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management, Denver, Colorado, USA.

Fox, K. B., and P. R. Krausman 1994. Fawning habitat of desert mule deer. Southwestern Naturalist 39:269–275.

Gaillard, J.-M., M. Festa-Bianchet, and N. G. Yoccoz. 1998. Population dynamics of large herbivores: variable recruitment with constant adult survival. Trends in Ecology and Evolution 13:58–63.

Gaillard, J.-M., M. Festa-Bianchet, N. G. Yoccoz, A. Loison, and C. Toïgo. 2000. Temporal variation in fitness components and population dynamics of large herbivores. Annual Review of Ecology and Systematics 31:367–393.

Gordon, L. S., and J. McClellan 1954. Investigations of game species on the Gila National Forest. New Mexico Department of Game and Fish, Santa Fe, USA.

Griffith, B., and B. A. Youtie 1988. Two devices for estimating foliage density and deer hiding cover. Wildlife Society Bulletin 16:206–210.

Grovenburg, T. W., C. N. Jacques, R. W. Klaver, and J. A. Jenks. 2010. Bed site selection by neonate deer in grassland habitats on the Northern Great Plains. Journal of Wildlife Management 74:1250–1256.

Harris, N. C., M. J. Kauffman, and L. S. Mills. 2008. Inferences about ungulate population dynamics derived from age ratios. Journal of Wildlife Management 72:1143–1151.

Harris, N. C., D. H. Pletscher, and M. Thompson. 2007. Cause-specific mortality of Rocky Mountain elk calves in westcentral Montana. Transactions of the North American Wildlife and Natural Resources Conference 72:339–347.

Hassell, M. J., and J. S. Crellin 1985. Valle Vidal opens to the public. Rangelands 7:73–74.

Hebblewhite, M., and E. H. Merrill 2009. Trade-offs between predation risk and forage differ between migrant strategies in a migratory ungulate. Ecology 90:3445–3454.

Higgins, K. F., K. J. Jenkins, G. K. Clambey, D. W. Uresk, D. E. Naugle, J. E. Norland, and W. T. Barker. 2005. Vegetation sampling and measurement. Pages 524–553 in and C. E., Braun, editor Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Houston, D. B. 1982. The northern Yellowstone elk: ecology and management. Macmillan, New York, New York, USA.

Hudson, R. J., J. C. Haigh, and A. B. Bubenik. 2002. Recreational use of elk. Pages 199–257 in D. E., Toweill, and J. W., Thomas, editors North American elk: ecology and management. The Wildlife Management Institute, Gardners, Pennsylvania, USA.

Huegel, C. N., R. B. Dahlgren, and H. L. Gladfelter. 1986. Bedsite selection by white-tailed deer fawns in Iowa. Journal of Wildlife Management 50:474–480.

Keating, K. A., and S. Cherry 2004. Use and interpretation of logistic regression in habitat-selection studies. Journal of Wildlife Management 68:774–789.

Langvatn, R., and A. Loison 1999. Consequences of harvesting on age structure, sex ratio and population dynamics of red deer *Cervuselaphus* in central Norway. Wildlife Biology 5:213–223.

Lele, S. R., E. H. Merrill, J. Keim, and M. S. Boyce. 2013. Selection, use, choice and occupancy: clarifying concepts in resource selection studies. Journal of Animal Ecology 82:1183–1191.

Leptich, D. J., and J. R. Gilbert 1986. Characteristics of moose calving sites in northern Maine as determined by multivariate analysis: a preliminary investigation. Alces 22:69–81.

Lubow, B. C., and B. L. Smith 2004. Population dynamics of the Jackson elk herd. Journal of Wildlife Management 68:810–829.

Lyles, A. M., and A. P. Dobson 1993. Infectious disease and intensive management: population dynamics, threatened hosts, and their parasites. Journal of Zoo and Wildlife Medicine 24:315–326.

Lyon, L. J., and A. G. Christensen 2002. Elk and land management. Pages 557–581 in D. E., Toweill, and J. W., Thomas, editors North American elk: ecology and management. The Wildlife Management Institute, Gardners, Pennsylvania, USA.

Marshal, J. P., J. W. Cain, III, V. C. Bleich, and S. S. Rosenstock. 2009. Intrinsic and extrinsic sources of variation in the dynamics of large herbivore populations. Canadian Journal of Zoology 87:103–111.

Martin, W. C. 1976. Some aspects of the natural history of Colfax and eastern Taos counties, New Mexico. Pages 97–102 in R. C. Ewing and B. S. Kues, editors. Guidebook of Vermejo Park. The New Mexico, Geological Society, 27th Field Conference, 30 September – 2 October 1976, Santa Fe, USA.

McCorquodale, S. M., K. J. Raedeke, and R. D. Taber. 1986. Elk habitat use patterns in the shrub-steppe of Washington. Journal of Wildlife Management 50:664–669.

Mduma, S. A. R., A. R. E. Sinclair, and R. Hilborn. 1999. Food regulates the Serengeti wildebeest: a 40-year record. Journal of Animal Ecology 68:1101–1122.

Miller, W. 2002. Elk interactions with other ungulates. Pages 435–447 in D. E., Toweill, and J. W., Thomas, editors North American elk: ecology and management. The Wildlife Management Institute Gardners, Pennsylvania, USA.

Parsons, D. R. 1998. "Green fire" returns to the southwest: reintroduction of the Mexican wolf. Wildlife Society Bulletin 26:799–807.

Peek, J. M. 2003. Wapiti. Pages 877–888 in G. A., Feldhamer B. C., Thompson, and J. A., Chapman, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Phillips, G. E. 1998. Effects of human-induced disturbance during calving season on reproductive success of elk in the upper Eagle River Valley, Colorado. Dissertation, Colorado State University, Fort Collins, USA.

Phillips, G. E., and A. W. Alldredge 2000. Reproductive success of elk following disturbance by humans during calving season. Journal of Wildlife Management 64:521–530.

Pinard, V., C. Dussault, J.-P. Ouellet, D. Fortin, and R. Courtois. 2011. Calving rate, calf survival, and habitat selection of forest-dwelling caribou in a highly managed landscape. Journal of Wildlife Management 76: 189–199.

Pitman, J. W. 2013. Microhabitat selection and mortality site characteristics of elk (*Cervuscanadensis*) calves and adult elk calf-rearing habitat selection in areas of differing predation influences in southern and northern New Mexico. Thesis. New Mexico State University, Las Cruces, USA.

Poole, K. G., R. Serrouya, and K. Stuart-Smith. 2007. Moose calving strategies in interior montane ecosystems. Journal of Mammalogy 88: 139–150.

Rearden, S. N., R. G. Anthony, and B. K. Johnson. 2011. Birth-site selection and predation risk in Rocky Mountain elk. Journal of Mammalogy 92:1118–1126.

Reed, J. E., W. B. Ballard, P. S. Gipson, B. T. Kelly, P. R. Krausman, M. C. Wallace, and D. B. Wester. 2006. Diets of free-ranging Mexican gray wolves in Arizona and New Mexico. Wildlife Society Bulletin 34:1127–1133.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Sikes, R. S., and W. L. Gannon The Animal Care and Use Committee of the American Society of Mammalogists. 2011. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 92:235–253.

Sinclair, A. R. E. 1985. Does interspecific competition or predation shape the African ungulate community? Journal of Animal Ecology 54:899–918.

Smith, B. L., E. S. Williams, K. C. McFarland, T. L. McDonald, G. Want, and T. D. Moore. 2006. Neonatal mortality of elk in Wyoming: environmental, population, and predator effects. U.S. Department of Interior, U.S. Fish and, Wildlife Service, Biological. Technical Publication, BTP-R6007-2006, Washington, D.C., USA.

Smith, D. W., R. O. Peterson, and D. B. Houston. 2003. Yellowstone after wolves. BioScience 53:330–340.

Strickler, G. S. 1959. Use of the densiometer to estimate density of forest canopy on permanent sample plots. USDA Forest Service Research Note 180, Portland, Oregon, USA.

Strohmeyer, D. C., J. M. Peek, and T. R. Bowlin. 1999. Wapiti bed sites in Idaho sagebrush steppe. Wildlife Society Bulletin 27:547–551.

Tull, J. C., P. R. Krausman, and R. J. Steidl. 2001. Bed-site selection by desert mule deer in southern Arizona. Southwestern Naturalist 46: 354–357.

United States Fish and Wildlife Service. 1996. Reintroduction of the Mexican wolf within its historic range in the southwestern United States final environmental impact statement. U.S. Fish and Wildlife Service Albuquerque, New Mexico, USA.

Van Moorter, B. V., J. Gaillard, P. D. McLoughlin, D. Delorme, F. Klein, and M. S Boyce. 2009. Maternal and individual effects in selection of bed sites and their consequences for fawn survival at different spatial scales. Oecologia 159:669–678.

Vander Lee, B., R. Smith, and J. Bate. 2006. Ecological and biological diversity of the Carson National Forest. Pages 1402–1457 in Ecological and Biological Diversity of National Forests in Region 3. Southwest Forest Assessment Project, The, Nature Conservancy, Tucson, Arizona, USA.

Vistnes, I., and C. Nellemann 2001. Avoidance of cabins, roads, and power lines by reindeer during calving. Journal of Wildlife Management 65: 915–925.

Vore, J. M., and E. M. Schmidt 2001. Movements of female elk during calving season in northwest Montana. Wildlife Society Bulletin 29: 720–725.

Vucetich, J. A., D. W. Smith, and D. R. Stahler. 2005. Influence of harvest, climate, and wolf predation on Yellowstone elk, 1961–2004. Oikos 111:259–270.

Waldrip, G. P., and J. H. Shaw 1979. Movements and habitat use by cow and calf elk at the Wichita Mountains National Wildlife Refuge. Pages 177–184 in M. S., Boyce, and L. D., Hayden-Wing, editors North American elk: ecology, behavior, and management. University of Wyoming, Laramie, USA.

Walker, B. H. 1976. An approach to the monitoring of changes in the composition and utilization of woodland and savanna vegetation. South African Journal of Wildlife Research 6:1–32.
Wallace, M. C., and P. R. Krausman 1990. Neonatal elk habitat in central Arizona. Pages 69–75 in and R. D., Brown, editor The biology of deer. Springer, New York, New York, USA.
Western Regional Climate Center [WRCC]. 2014*a*. RAWS USA Climate Archive. http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?nmXBEA. Accessed 16 May 2014.
Western Regional Climate Center [WRCC]. 2014*b*. New Mexico Climate summaries. <http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?nm7323>. Accessed 16 May 2014.
Wilmhurst, J. F., J. M. Fryxell, B. P. Farm, A. R. E. Sinclair, and C. P. Henschel. 1999. Spatial distribution of Serengeti wildebeest in relation to resources. Canadian Journal of Zoology 77:1223–1232.
Zager, P., and J. Beecham 2006. The role of American black bears and brown bears as predators on ungulates in North America. Ursus 17:95–108.

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