Seasonal distribution and habitat use patterns of elk in the Jack Morrow Hills Planning Area, Wyoming

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1.0 INTRODUCTION

The Jack Morrow Hills (JMH) Planning Area supports a resident elk population that has been a valuable public wildlife resource for nearly 60 years. These elk are managed by the Wyoming Game and Fish Department (WGFD) and locally referred to as the Steamboat elk herd. Observations from the late 1800’s and Native American petroglyphs suggest elk historically occupied the JMH (Christiansen 2000). Whether a portion of these elk were year-around residents is unknown, however, it is generally speculated that the JMH provided winter range for elk that migrated long distances to the high-elevation summer ranges of northwest Wyoming (Allred 1950, Julian 1970, Ryder et al. 1986). Regardless, unregulated hunting extirpated most elk in the state by the early 1900’s. And, although anecdotal accounts suggest a small remnant population may have persisted in the JMH (Lockman 1978, BLM 2004), beginning in the 1940’s the WGFD initiated a series of elk transplants in hopes of re-establishing a migratory elk herd in the JMH region (Allred 1950, Henderson 1955, Lockman 1978). Between 1946 and 1967 the WGFD transplanted 408 elk in the Steamboat-Boars Tusk-White Mountain area (Julian 1970).

Translocation efforts were largely successful for establishing a resident elk herd, but not a migratory herd. The first hunting permits were issued in 1953 and were intended to reduce haystack depredation near Eden. By the 1960’s however, the population continued to increase, elk hunts became more popular, and approximately 75 permits were issued each year. Elk hunting was discontinued in 1970 and 1971 because of large dune buggy rallies that apparently displaced elk (Ryder et al. 1986). Archery hunting was re-opened in 1972 and 1973. And since 1975, rifle and archery hunting permits have been available every year, although permit numbers have fluctuated with annual population estimates that have ranged from 300 to 1,900 animals. Today, the WGFD manages the Steamboat elk herd for 1,200 animals and issues approximately 350 permits per year.

2.0 STUDY OBJECTIVES

This study was designed to identify and describe the distribution and habitat selection patterns of the Steamboat elk herd before mineral development, such that subsequent comparisons can be made if or when development occurs.

3.0 STUDY AREA

The JMH Planning Area encompasses approximately 972 mi$^2$ (622,430 acres) in southwest Wyoming (Figure 1). The BLM administers 92% (574,800 acres) of the land surface and federal minerals. The study area includes portions of 3 counties (Fremont, Sweetwater, and Sublette), 5 Areas of Critical Environmental Concern (ACEC: Steamboat Mountain, Greater Sand Dunes, White Mountain Petroglyphs, Oregon Buttes, and South Pass Historic Landscape), and 7 Wilderness Study Areas (WSA: Oregon Buttes, Honeycomb Buttes, Greater Sand Dunes, Buffalo Hump, Whitehorse Creek, South Pinnacles, and Alkali Draw). Livestock grazing occurs in 15 allotments of various sizes. The active permitted use is approximately 26,830 AUMs, of which approximately 12% (3,203 AUMs) is sheep and 88% (23,627) is cattle (BLM 2004).
The study area contains a variety of minerals, including potash, gold, coal, oil shale, oil, natural gas, and coalbed methane (BLM 2004). While the existing mineral development is limited, the potential for increased oil and gas development is high. Approximately two-thirds of the JMH Planning Area is considered to have moderate-high oil and gas potential (BLM 2004: Map 69). And, approximately one-half of the area has coalbed methane potential (BLM 2004: Map 70).

Elevations range from 6,500 to 8,700 ft (2,000 - 2,650 m). The area is generally characterized as a high-elevation cold desert with variety of sagebrush and mixed shrub-grassland communities. The vegetative ecosystem of the JMH has been assigned the highest biodiversity significance rating by the Wyoming Natural Diversity Database (WYNDD). We refer readers to BLM 2004 or the WYNDD website (http://uwadmnweb.uwyo.edu/wyndd/) for details on the vegetation communities occurring in the JMH.

Figure 1. Location of Jack Morrow Hills (JMH) Planning Area in southwest Wyoming.
4.0 METHODS

4.1 Capture

We used helicopter net-gunning to capture and radio-collar adult (> 1.5 years) female elk across winter ranges in the JMH. Elk were blindfolded and hobbled to facilitate the handling process and minimize injuries. We fitted elk with store-on-board global positioning system (GPS) radio-collars (TGW 2500, Telonics, Mesa, Arizona) equipped with mortality sensors that changed pulse rate if the collar remained motionless for > 8 hours. The GPS units were programmed to obtain locations every 4 hours (i.e., 6 per day). We located radio-collared elk from fixed-wing aircraft approximately once per month. Collars from elk that died were re-fitted on new elk. We used helicopter net-gunning to retrieve collars at the end of the study period. Annual survival estimates were calculated from telemetry records using the Kaplan-Meier procedure (Kaplan and Meier 1985.)

4.2 Seasonal Distribution

Seasonal distribution patterns were identified for parturition (May 1 – June 30), summer (June 15 - September 15), hunting season (October 15 - 31), and winter (November 15 - March 15) by plotting individual elk locations on 1:250,000 scale maps in ArcView® Geographic Information System (GIS) 3.2 (ESRI, Redlands, California). The kernel estimator was used as an objective means to delineate seasonal core-use areas. Kernel estimates for 95%, 75%, and 50% use were calculated using the Animal Movements Extension for ArcView® with default smoothing parameters.

4.3 Vegetation Mapping and Elk Use

The vegetation map was originally produced by the BLM and contained 25 different vegetation categories, however for the purposes of our resource selection analyses, we reclassified the map into 8 basic categories, including: Big basin sagebrush (*Artemisia* sp.), Wyoming sagebrush (*Artemisia* sp.), mixed shrub (*Chrysothamnus* sp., *Atriplex* sp., *Cercocarpus* sp.), greasewood (*Sarcobatus* sp.), bare ground, grassland, riparian grass/shrub, and tree cover (*Populus* sp., *Juniperus* sp.). Elk use of vegetation categories was examined by developing selection ratios from use-availability data (Manly et al. 2002). Availability was defined as the relative area of each vegetation category in the study area. Use was defined as the relative number of GPS locations that occurred in each vegetation category for each elk. Selection ratios were assigned 90% confidence intervals with a Bonferroni adjustment for a family-wise error rate of $a = 0.1$. Vegetation types were considered selected for if the selection ratio and confidence intervals were > 1.0, selected against if the selection ratio and confidence intervals were < 1.0, and selected in proportion to availability if the selection ratio and confidence intervals contained 1.0.
4.4 Resource Selection Modeling

We identified 6 variables as potential predictors of seasonal elk distribution, including:

- Elevation
- Slope
- Aspect
- Distance to major road
- Distance to cover
- Habitat diversity

We used the SPATIAL ANALYST extension for ArcView® to calculate slope and aspect from a 26 x 26 m digital elevation model (United States Geologic Survey [USGS] 1999). We obtained elevation, slope, and aspect (NE, NW, SW, and SE) values for each of the sampled units using the MILA extension for ArcView. Northeast aspect was used as the reference in the resource selection modeling. Existing major roads were digitized by the BLM from 1:100,000 maps. Major roads were defined as dirt, gravel, and paved roads actively maintained by the county or state (Powell 2003). Cover categories included any vegetation types with trees or shrubs that could reach 2 m in height. Non-cover categories included grassland and bare ground/sand. Shannon’s Diversity Index (SDI) was calculated for each sample unit in FRAGSTATS (McGarigal and Marks 1995) and was based on the 8 vegetation categories identified in Table 3.

Locations of oil and gas well pads were not used in our analysis because they were clustered in a small area on the south-central boundary of the project area. Additionally, 46 of 47 gas wells in the JMHPA were existing producing or abandoned, with only 1 drilling well site during the 2 years of study. Analyzing elk movements in relation to well pads would require the area of interest to be substantially reduced in size and was beyond the scope of this report.

Our approach to modeling winter habitat use consisted of 4 basic steps: 1) estimate the relative frequency of use (i.e., an empirical estimate of probability of use) for a large sample of habitat units for each radiocollared elk during each season, 2) use the relative frequency as the response variable in a multiple regression analysis to model the probability of use for each elk as a function of predictor variables, 3) develop a population–level model from the individual elk models for each season, and 4) map predictions of population–level models from each season. We treated radiocollared elk as the experimental unit to avoid pseudo–replication (i.e., spatial and temporal autocorrelation) and to accommodate population–level inference (Otis and White 1999, Johnson et al. 2000, Erickson et al. 2001).

We estimated relative frequency of use for each radiocollared elk using a simple technique that involved counting the number of elk locations in each of 10,063 systematically sampled circular habitat units across the study area. We chose circular habitat units that had a 250-m radii; an area small enough to detect changes in animal movements, but large enough to ensure multiple locations could occur in each unit. We measured predictor variables on each of the sampled habitat units and conducted a Pearson’s pairwise correlation analysis (PROC CORR; SAS Institute 2000) before modeling to identify multicollinearities and determine if any variables should be excluded from the modeling (|r| > 0.60).
The relative frequency of locations from a radio-collared elk found in each habitat unit was an empirical estimate of the probability of use by that elk and was used as a continuous response variable in a generalized linear model (GLM). We used an offset term (McCullagh and Nelder 1989) in the GLM to estimate probability of use for each radio-collared elk as a function of a linear combination of predictor variables, plus or minus an error term assumed to have a negative binomial distribution (McCullagh and Nelder 1989, White and Bennett 1996).

We obtained a population–level model for each winter by first estimating coefficients for each radio-collared elk. We used PROC GENMOD (SAS Institute 2000) and the negative binomial distribution to fit the following GLM for each radio-collared elk during each winter period:

$$\ln(E[r_i]) = \ln(\text{total}) + \beta_0 + \beta_1 X_1 + \cdots + \beta_p X_p,$$

which was equivalent to:

$$\ln(E[r_i/\text{total}]) = \ln(E[\text{Relative Frequency}_i]) = \beta_0 + \beta_1 X_1 + \cdots + \beta_p X_p,$$

where $r_i$ was the number of locations for a radio-collared elk within habitat unit $i$ ($i = 1, 2, \ldots, 10063$), total was the total number of locations for the elk within the study area, $\beta_0$ was an intercept term, $\beta_1, \ldots, \beta_p$ were unknown coefficients for habitat variables $X_1, \ldots, X_p$, and $E[.]$ denotes the expected value. We used the same offset term for all sampled habitat units of a given elk, thus the term $\ln(\text{total})$ was absorbed into the estimate of $\beta_0$ and ensured we were modeling relative frequency of use (e.g., 0, 0.003, 0.0034, ...) instead of integer counts (e.g., 0, 1, 2, ...). This approach to modeling resource selection estimates the relative frequency or absolute probability of use as a function of predictor variables, so we refer to it as a resource selection probability function (RSPF) (Manly et al. 2002).

We assumed GLM coefficients for predictor variable $k$ for each elk were a random sample from a normal distribution (Seber 1984, Littell et al. 1996), with the mean of the distribution representing the average or population–level effect of predictor variable $k$ on probability of use. We estimated coefficients for the population–level RSPF for each season using

$$\hat{\beta}_k = \frac{1}{n} \sum_{j=1}^{n} \hat{\beta}_{kj},$$

where $\hat{\beta}_{kj}$ was the estimate of coefficient $k$ for individual $j$ ($j = 1, \ldots, n$). We estimated the variance of each population–level model coefficient using the variation between radio-collared elk and the equation

$$\text{var}(\hat{\beta}_k) = \frac{1}{n-1} \sum_{j=1}^{n} (\hat{\beta}_{kj} - \hat{\beta}_k)^2.$$

We used a forward–stepwise model building procedure (Neter et al. 1996) to estimate population–level RSPFs for three seasons: Summer 2003, Summer 2004, and Winter 2003-04. The forward–stepwise model building process required fitting the same models to each elk within a season and using equations (3) and (4) to estimate population–level model coefficients. We used a $t$–statistic to determine variable entry ($a = 0.15$) and exit ($a > 0.20$) (Hosmer and Lemshow 2000). We considered quadratic terms for distance to road and slope during the model.
building process and, following convention, the linear form of each variable was included if the model contained a quadratic form.

We mapped predictions of population–level RSPFs for each winter on 350 x 350 m grids (~20,000 points) that covered the study area. We checked predictions to ensure all values were in the [0,1] interval, such that we were not extrapolating outside the range of the model data (Neter et al. 1996). The estimated probability of use for each grid cell was assigned a value of 1 to 4 based on the quartiles of the distribution of predictions for each map. We assigned grid cells with the highest 25% of predicted probabilities of use a value of 1 and classified them as high use areas, assigned grid cells in the 51 to 75 percentiles a value of 2 and classified them as medium-high use areas, assigned grid cells in the 26 to 50 percentiles a value of 3 and classified them as medium-low use areas, and assigned grid cells in the 0 to 25 percentiles a values of 4 and classified them as low use areas.

5.0 RESULTS

5.1 Capture and GPS Success

We captured and radio-collared 36 elk across winter ranges in the JMH Planning Area, including 29 on April 16, 2003 and 7 on December 19, 2003. Of those 36, we recovered 33 GPS collars. At the time this report was prepared the whereabouts of the other 3 collars (#’s 151.070, 151.440, 151.790) were unknown. Between April 20, 2003 and December 15, 2004 we collected 79,096 GPS locations from 33 different elk. Fix-rate success for GPS collars was 97%, of which 86% were 3-dimensional (i.e., = 4 satellites used to determine locations) locations.

5.2 Survival and Mortality

The estimated annual (June 1, 2003 – May 31, 2004) survival rate for radio-collared elk during 2003-04 was 0.66 (Table 1). Because the study ended in December 2004 survival estimates were not calculated for the entire biological year (June 1- May 31) of 2004-05, however between June 1, 2004 and November 30, 2004 the estimated survival rate was 0.86. Of the 14 documented elk deaths, 13 were attributed to rifle harvest and 1 died of natural causes. Of the 13 radio-collared elk killed by hunters, 9 collars (70%) were returned to agency personnel by hunters and the other 4 were retrieved from the field.


<table>
<thead>
<tr>
<th>Time Period</th>
<th>N₁</th>
<th>N₂</th>
<th>( \hat{S} )</th>
<th>90% CI</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1, 2003 - May 31, 2004</td>
<td>29</td>
<td>11</td>
<td>0.66</td>
<td>0.57 to 0.75</td>
<td>0.07</td>
</tr>
<tr>
<td>June 1, 2004 - November 30, 2004</td>
<td>22</td>
<td>3</td>
<td>0.86</td>
<td>0.77 to 0.95</td>
<td>0.07</td>
</tr>
</tbody>
</table>

N₁: number of available collars, N₂: number of deaths, \( \hat{S} \): survival estimate, CI: confidence interval, SE: standard error
5.3 Seasonal Distribution

5.3.1 Parturition 2003 and 2004

We collected 17,158 locations from 33 radio-collared elk during the parturition periods (May 1 – June 30) of 2003 and 2004 (Figure 2). Elk used much of the JMH Planning Area during peak parturition periods, but most elk use occurred in the central and south-central portions of the study area (Figure 3). Steamboat Rim, La Fonte Canyon, Box Canyon, Johnson Canyon, Steamboat Mountain, and west of Bush Rim received the highest level of use. South Packsaddle Canyon, Monument Ridge, and the area northwest of Freighter Gap also received high levels of elk use. Except for the area west of Bush Rim and south of Parnell Creek, most of the high use parturition areas were contained within the existing parturition ranges identified by the WGFD and BLM.

Figure 2. Locations (n=17,158) collected from 33 radio-collared elk between May 1 – June 30, 2003 and 2004 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
Figure 3. Existing parturition ranges delineated by the Wyoming Game and Fish Department and parturition use areas generated from elk locations (n=17,158) collected May 1 – June 30, 2003 and 2004 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
5.3.2 Summer 2003

We collected 13,845 locations from 26 radio-collared elk during the summer (June 15 – September 15) of 2003 (Figure 4). Elk used much of the JMH Planning Area through the summer of 2003, but most elk use occurred in the central and south-central portions of the study area (Figure 5). An area immediately west of Rock Cabin Creek to South Packsaddle Canyon, and the Steamboat Mountain, Steamboat Rim, Box Canyon, La Fonte Canyon, Monument Ridge, and upper Jack Morrow Creek areas received the highest level of use.

Figure 4. Elk locations (n=13,845) locations collected from 26 radio-collared elk during the summer (June 15 – September 15) of 2003 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
Figure 5. Kernel home ranges (50%, 75%, and 95%) generated for 13,845 elk locations collected from 26 radio-collared elk during the summer (June 15 – September 15) of 2003 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
5.3.3 Summer 2004

We collected 11,845 locations from 23 radio-collared elk during the summer (June 15 – September 15) of 2004 (Figure 6). Elk used much of the JMH Planning Area through the summer of 2004, but most elk use occurred in the central and south-central portions of the study area (Figure 7). The Steamboat Mountain, Johnson Canyon, La Fonte Canyon, Box Canyon, Steamboat Rim areas received the highest level of use.

Figure 6. Elk locations (n=11,845) locations collected from 23 radio-collared elk during the summer (June 15 – September 15) of 2003 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
Figure 7. Kernel home ranges (50%, 75%, and 95%) generated for 11,845 elk locations collected from 23 radio-collared elk during the summer (June 15 – September 15) of 2003 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
5.3.4  Fall – Hunting Season 2003

We collected 3,766 locations from 30 radio-collared elk during the rifle hunting seasons (October 15 – 31) of 2003 and 2004 (Figure 8). Elk used much of the JMH Planning Area through the rifle hunting seasons of 2003 and 2004, but most elk use occurred in the central and south-central portions of the study area (Figure 9). The Jack Morrow Creek area near Box Canyon, La Fonte Canyon, and Johnson Canyon as well as the North Table Mountain area received the highest level of use.

Figure 8. Elk locations (n=3,766) locations collected from 30 radio-collared elk during the rifle hunting seasons (October 15 – 31) of 2003 and 2004 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
Figure 9. Kernel home ranges (50%, 75%, and 95%) generated for 3,766 elk locations collected from 30 radio-collared elk during the rifle hunting seasons (October 15 – 31) of 2003 and 2004 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
5.3.5 Winter 2003-04

We collected 14,700 locations from 23 radio-collared elk during the winter (November 15 – March 15) of 2003-04 (Figure 10). Elk used much of the JMH Planning Area through the winter of 2003-04, but most elk use occurred in the central, south-central, and southwestern portions of the study area (Figure 11). The Alkali Draw, Freighter Gap and Essex Mountain areas received the highest level of use.

Figure 10. Elk locations (n=14,700) locations collected from 23 radio-collared elk during the winter (November 15 – March 15) of 2003-04 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
Figure 11. Kernel home ranges (50%, 75%, and 95%) generated for 14,700 elk locations collected from 23 radio-collared elk during the winter (November 15 – March 15) of 2003-04 in the Jack Morrow Hills (JMH) Planning Area, Wyoming.
5.3.6 Wilderness Study Areas

There are 7 WSAs inside and another 2 outside the JMH Planning Area that were used by radio-collared elk during this study. The 7 inside the JMH Planning Area included Alkali Draw, Buffalo Hump, Honeycomb Buttes, Oregon Buttes, Sand Dunes, South Pinnacles, and Whitehorse Creek (Figure 12). The 2 outside the JMH Planning Area included East Sand Dunes and Red Lake (Figure 12). Among the 9 WSAs, Alkali Draw and Sand Dunes received the most elk use, with 47% and 28% of elk locations, respectively (Table 2). Because WSAs varied in size, we also standardized elk use based on area by dividing the number of elk locations by the square miles of each WSA (i.e., elk density). Again, Alkali Draw and Sand Dunes had the highest elk densities. However, Buffalo Hump, Oregon Buttes, and South Pinnacles had relatively high elk densities considering their small size (Table 2).

Figure 12. Location of Alkali Draw, Buffalo Hump, East Sand Dunes, Honeycomb Buttes, Oregon Buttes, Red Lake, Sand Dunes, South Pinnacles, and Whitehorse Creek Wilderness Study Areas in relation to the Jack Morrow Hills (JMH) Planning Area, Wyoming.
Table 2. Size, number of elk locations, and elk density for Wilderness Study Areas (WSA) in and adjacent to the Jack Morrow Hills (JMH) Planning Area, 2003-2004.

<table>
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<tr>
<th>Wilderness Study Area (WSA)</th>
<th>Area (mi$^2$)</th>
<th>Area (% total)</th>
<th>Elk Locations</th>
<th>Elk (% total)</th>
<th>Elk Density (elk/mi$^2$)</th>
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<tbody>
<tr>
<td>Alkali Draw</td>
<td>27.9</td>
<td>13%</td>
<td>5,913</td>
<td>47%</td>
<td>212</td>
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<tr>
<td>Buffalo Hump</td>
<td>10.1</td>
<td>5%</td>
<td>626</td>
<td>5%</td>
<td>62</td>
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<tr>
<td>East Sand Dunes</td>
<td>19.9</td>
<td>9%</td>
<td>197</td>
<td>2%</td>
<td>10</td>
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<td>Honeycomb Buttes</td>
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<td>30%</td>
<td>610</td>
<td>5%</td>
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<td>Oregon Buttes</td>
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<td>4%</td>
<td>399</td>
<td>3%</td>
<td>43</td>
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<tr>
<td>Red Lake</td>
<td>14.9</td>
<td>7%</td>
<td>70</td>
<td>1%</td>
<td>5</td>
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<tr>
<td>Sand Dunes</td>
<td>44.2</td>
<td>20%</td>
<td>3,545</td>
<td>28%</td>
<td>80</td>
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<tr>
<td>South Pinnacles</td>
<td>17.0</td>
<td>8%</td>
<td>945</td>
<td>8%</td>
<td>56</td>
</tr>
<tr>
<td>Whitehorse Creek</td>
<td>7.8</td>
<td>4%</td>
<td>202</td>
<td>2%</td>
<td>26</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>217</strong></td>
<td><strong>100%</strong></td>
<td><strong>12,507</strong></td>
<td><strong>100%</strong></td>
<td><strong>58</strong></td>
</tr>
</tbody>
</table>

During the course of study (April 20, 2003 – December 20, 2004), 12,507 locations from 30 radio-collared elk occurred in WSAs. We plotted the number of elk locations (n=9,487) in WSAs through a complete calendar year (May 2003 – April 2004) to illustrate seasonal use (Figure 13). Peak elk use of WSAs occurred during winter (January – March). The lowest WSA use was in July.

![Figure 13. Monthly distribution of elk locations in Wilderness Study Areas (WSA), May 2003 – April 2004.](image)

5.4 Vegetation Mapping and Elk Use

Elk selection of vegetation types was similar across the summers of 2003 and 2004 (Table 3). Elk consistently selected for big basin sagebrush, greasewood, and tree cover. Elk consistently
selected against Wyoming sagebrush, mixed shrub, and bare ground/sand. Grasslands were selected in proportion to their availability. Selection patterns were similar during the winter, except big basin sagebrush and mixed shrubs were selected in proportion to their availability (Table 3).

Table 3. Selection ratios of vegetation types by radio-collared elk during summer 2003, summer 2004, and winter 2003-04 in the Jack Morrow Hills (JMH) Planning Area. [(+) selected for, (-) selected against, and (0) selected in proportion to availability]

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Percent of JMH</th>
<th>Habitat Selection for Summer 2003</th>
<th>Habitat Selection for Summer 2004</th>
<th>Habitat Selection for Winter 2003-04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big basin sagebrush</td>
<td>4.7%</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Wyoming sagebrush</td>
<td>29.7%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Grassland</td>
<td>14.5%</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Greasewood</td>
<td>16.7%</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Mixed shrub</td>
<td>15.6%</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Riparian grass/shrubs</td>
<td>3.3%</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Trees: aspen or juniper or mix</td>
<td>1.2%</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Bare ground or sand</td>
<td>14.3%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

5.5 Resource Selection Modeling

Population-level models (Table 4), in the form of resource selection probability functions (RSPF), and associated predictive maps (Figures 14-16) were estimated for 3 time periods: 1) summer 2003, 2) summer 2004, and 3) winter 2003-04.

Table 4. Coefficients for population-level resource selection probability functions (RSPF) of elk in the Jack Morrow Hills (JMH) Planning Area during the summer of 2003, summer of 2004, and winter of 2003-04.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>SE</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Intercept</td>
<td>-34.967</td>
<td>4.021</td>
<td>-30.739</td>
</tr>
<tr>
<td>Elevation (m)</td>
<td>0.009</td>
<td>0.002</td>
<td>0.008</td>
</tr>
<tr>
<td>Shannon's Diversity Index</td>
<td>0.441</td>
<td>0.222</td>
<td>ns*</td>
</tr>
<tr>
<td>Distance (m) to Cover</td>
<td>-0.002</td>
<td>0.000</td>
<td>ns</td>
</tr>
<tr>
<td>Slope (degrees)</td>
<td>0.703</td>
<td>0.065</td>
<td>0.584</td>
</tr>
<tr>
<td>Slope$^2$</td>
<td>-0.040</td>
<td>0.004</td>
<td>-0.032</td>
</tr>
<tr>
<td>Distance (km) to Road</td>
<td>0.927</td>
<td>0.159</td>
<td>0.767</td>
</tr>
<tr>
<td>Distance (km) to Road$^2$</td>
<td>-0.167</td>
<td>0.027</td>
<td>-0.137</td>
</tr>
<tr>
<td>Aspect = SE</td>
<td>-0.199</td>
<td>0.145</td>
<td>-0.287</td>
</tr>
<tr>
<td>Aspect = SW</td>
<td>-0.622</td>
<td>0.230</td>
<td>-0.200</td>
</tr>
<tr>
<td>Aspect = NW</td>
<td>0.057</td>
<td>0.118</td>
<td>0.295</td>
</tr>
</tbody>
</table>

* not significant
5.5.1 Summer (June 15 – September 15) 2003

The population-level model was estimated from a systematic sample of 10,063 habitat units and 13,524 GPS locations collected from 25 adult female elk (Table 4, Figure 14). All 6 predictor variables (i.e., elevation, SDI, distance to cover, slope, distance to road, and aspect) were included in the model (Table 4). Elk selected for areas with high elevations, high diversity, close to cover, gentle slopes, away from roads, and northerly aspects. Areas with the highest probability of use were 2.8 km away from roads and had slopes of 9 degrees (Figure 14).

Figure 14. Predicted probabilities and associated categories of elk habitat use during the summer of 2003 in the Jack Morrow Hills (JMH) Planning Area.
5.5.2 Summer (June 15 – September 15) 2004

The population-level model was estimated from a systematic sample of 10,063 habitat units and 10,528 GPS locations collected from 20 adult female elk (Table 4, Figure 15). Four of the 6 predictor variables (i.e., elevation, slope, distance to road, and aspect) were included in the model (Table 4). Elk selected for areas with high elevations, gentle slopes, away from roads, and northerly aspects. Areas with the highest probability of use were 2.8 km away from roads and had slopes of 9 degrees (Figure 15).

Figure 15. Predicted probabilities and associated categories of elk habitat use during the summer of 2004 in the Jack Morrow Hills (JMH) Planning Area.
5.5.3 Winter (November 15 – March 15) 2003-04

The population-level model was estimated from a systematic sample of 10,063 habitat units and 11,194 GPS locations collected from 19 adult female elk (Table 4, Figure 16). All 6 predictor variables (i.e., elevation, SDI, distance to cover, slope, distance to road, and aspect) were included in the model (Table 4). Elk selected for areas with low elevations, high diversity indices, close to cover, gentle slopes, away from roads, and southeast aspects. Areas with the highest probability of use were 1.2 km away from roads and had slopes of 11 degrees (Figure 16).

Figure 16. Predicted probabilities and associated categories of elk habitat use during the winter of 2003-04 in the Jack Morrow Hills (JMH) Planning Area.
6.0 DISCUSSION

Of the North American ungulates, elk are among the most widely-distributed and most-studied species. Elk are generally known to avoid roads open to vehicular traffic (Lyon 1983, Wittmer and DeCalesta 1985, Grover and Thompson 1986, Rowland et al. 2000), and prefer areas characterized by edge habitat (Thomas et al. 1979, Irwin and Peek 1983, Grover and Thompson 1986, Thomas et al. 1988), where quality forage and cover habitats are in close proximity to one another. Additionally, topographic features such as slope, elevation, and aspect are known to influence the habitat selection patterns of elk (Edge et al. 1987, Skovlin et al. 2004). This knowledge of elk behavior has been incorporated into numerous habitat suitability and other predictive models (Witmer et al. 1985, Wisdom et al. 1986, Sawyer et al. 1997, Roloff et al. 2001, Benkobi et al. 2004) commonly used to improve elk management and guide land-use planning in forested regions.

Although there is a large body of science to support elk management and habitat modeling in montane and forested environments, our knowledge of elk ecology in open desert environments is much more limited. Only a handful of studies have focused on elk populations that occupy desert or non-forested environments, and those have been restricted to non-hunted populations that inhabit land reserves with limited public access in Washington (McCorquodale et al. 1986, McCorquodale et al. 1989, McCorquodale 1991) and Idaho (Strohmeyer and Peek 1996, Stromeyer et al. 1999). Nonetheless, recent range expansions by elk have demonstrated their ability to readily adapt to open environments (Lindzey et al. 1997), requiring managers to re-evaluate the traditional paradigms of forage (i.e., open meadows) and cover (i.e., timber) as they relate to managing elk habitat in non-forested areas. Our approach to identifying predictor variables for modeling seasonal elk use in the JMH was based on the assumptions that forage in desert environments tends to be dispersed more evenly than forage found in forested habitats (McCorquodale et al. 1991), and, in the absence of forest cover, elk likely rely on a combination of shrubs, topography, and low human disturbance for thermal and hiding cover requirements. Thus, we believed slope, aspect, elevation, distance to road, distance to cover, and habitat diversity were appropriate predictor variables of elk use during both winter and summer periods.

All 6 predictor variables were included in the Summer 2003 and Winter 2003-04 models. Distance to cover and habitat diversity did not enter the Summer 2004 model, however the predictions from both summer models were similar. Not surprisingly areas with the highest probability of elk use during the summer were characterized by high elevations, gentle slopes, diverse habitats, northerly aspects, and away from (2.8 km) major roads. High use areas during the winter were similar except they had lower elevations, southerly aspects, and were slightly closer to roads (1.2 km). The proximity of high-use elk habitats to major roads during the winter ($\bar{x} = 1.2$ km) versus the summer ($\bar{x} = 2.8$ km) likely reflects the decrease in human activity that occurs in the winter when many roads become inaccessible to vehicles. If or when human activity increases during the winter, elk will likely distance themselves from roads in a manner similar to summer, altering the amount of winter habitat available to them.

This apparent elk response to decreased human activity was also evident in the daily movement rates of elk during the winter ($\bar{x} = 2.4$ km/day, n = 19, SE = 150) compared to the rifle hunting season ($\bar{x} = 8.8$ km/day, n = 42, SE = 438), when traffic levels in the JMH Planning Area are
highest (Powell 2003). Daily movement rates of elk during the hunting season were approximately 3.5 times greater than daily movements during winter. This response was consistent with Powell (2003), who found daily movement rates of disturbed elk ($\bar{x} = 6.1$ km/day) were significantly greater than undisturbed elk ($\bar{x} = 1.4$ km/day) during the calving season in the JMH. Besides displacing elk, disturbance during the calving season may result in reduced reproductive success (Phillips and Alldredge 2000).

Provided limited human disturbance and adequate forage, elk can meet their cover and forage requirements in open environments (McCorquodale et al. 1986). Outside of the hunting season, current levels of disturbance in the JMH Planning Area appear to be low enough that elk are able to access a variety of seasonal ranges and be successful in the JMH desert environment. However, if or when new land-use changes (e.g., energy development) occur in the JMH, higher road densities and increased levels of human disturbance (i.e., traffic) would likely affect the distribution and habitat use patterns of the Steamboat elk herd. In the absence of suitable security cover, restrictions on vehicular access may be necessary to maintain an area as effective elk habitat (Lyon 1983, Cole et al. 1997). Management of roads and related human disturbance is an important consideration for managing elk populations (Christensen et al. 1993, Gratson and Whitman 2000, Rowland et al. 2000). Road closures have been shown to decrease elk movements and increase survival (Cole et al. 1997). The importance of road management and the effects of human disturbance are likely exacerbated in desert environments like the JMH, where security cover is limited. We encourage managers to use the RSPFs and predictive maps to evaluate future land-use alternatives in the JMH Planning Area.

The seasonal RSPFs and associated predictive maps may assist land managers in 2 important ways. First, they provide detailed information describing and illustrating elk habitat use patterns prior to the anticipated natural gas development that will likely follow the BLM’s record of decision with the Jack Morrow Hills Coordinated Activity Plan (BLM 2004). The predictive maps can be used to identify areas preferred by elk in the winter and summer seasons. Additionally, the predictive maps help identify areas that provide habitat connectivity to pockets of high-use habitats, such as the area north of Boar’s Tusk, near Chicken Springs that connects White Mountain with the Essex Mountain area; or the Joe Hay and Bush Rims connecting the Steamboat Mountain area to the Oregon Butte area; or the east/west ridge that connects Oregon Buttes with the Continental Peak area. Overall, these baseline data document the habitat use and distribution patterns of elk before increased levels of gas development or other mineral extraction occur in the JMH Planning Area, thereby providing agencies and industry with the necessary pre-development information to monitor potential effects on the JMH elk population, if or when significant levels of development occur.

Secondly, the RSPFs provide managers with the ability to model or evaluate how different development or land-use scenarios may affect the habitat use patterns of the JMH elk population. For example, if a series of access roads was proposed, the RSPFs could generate new predictive maps to illustrate how the development may influence winter and summer use by elk. Or, if a set of alternatives were proposed, each could be evaluated in terms of their predicted effect on high-use elk habitat. Additionally, the RSPF’s could be extrapolated beyond the JMH Planning Area to identify other potential elk habitat in the Rock Springs Field Office.
7.0 LITERATURE CITED


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