GRIZZLY BEAR DENNING HABITAT AND DEMOGRAPHIC CONNECTIVITY IN NORTHERN IDAHO AND WESTERN MONTANA

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ABSTRACT—Grizzly Bears (*Ursus arctos*) are protected in the contiguous United States under the federal Endangered Species Act. The conservation strategy for the species encourages population connectivity between isolated Grizzly Bear Recovery Areas through Demographic Connectivity Areas. Another goal is reestablishment of a breeding population in the Bitterroot ecosystem through natural immigration. Using the locations of 362 verified Grizzly Bear den sites and Maxent as a resource selection function, we predicted 21,091 km^2 of suitable denning habitats. Terrain features, distance to roads and land cover best explained suitable denning habitats in northern Idaho and western Montana. The results support the demographic model for population connectivity and independent of other factors there is suitable denning habitat for hundreds of Grizzly Bears in the Bitterroot analysis area. We suggest additions to the Bitterroot Grizzly Bear Recovery Area and that more effective motorized access management be applied to demographic connectivity areas.

Key words: Bitterroot ecosystem, demographic connectivity, den sites, denning, dispersal, Grizzly Bear, northern Rockies, secure core, selection

The Grizzly Bear (*Ursus arctos*) was listed in 1975 as a threatened species under the U.S. Endangered Species Act partially due to isolation and populations in the contiguous U.S. remain isolated (USFWS 2021). Linkage of the isolated Grizzly Bear populations into a genetically-diverse metapopulation (as defined by Hanski and Gilpin 1991) would increase the probability of long-term survival (Allendorf and others 2019; Boyce and others 2001; Servheen and others 2001; Craighead and Vyse 1996). Two models have been advanced to achieve this. The male-mediated model for genetic interchange (Peck and others 2017) would maintain genetic diversity based on long distance dispersals of male Grizzly Bears. The demographic model is based on maintaining areas of secure suitable habitats occupied by resident female Grizzly Bears that are within known dispersal distances for females (Mattson and others 1996; Proctor and others 2015). Due to the much shorter dispersal distances of female Grizzly Bears (McLelland and Hovey 2001; Proctor and others 2004; Graves and others 2014), the demographic model relies on multi-year dispersals. The Conservation Strategy for Grizzly Bear in the Northern Continental Divide Ecosystem (NCDE, USFWS 2018) designated two Demographic Connectivity Areas (DCAs) to provide habitat for resident female Grizzly Bears as shown in Figure 1.

Denning behavior in Grizzly Bears is thought to be an evolutionary adaptation to long winter periods where natural foods are unavailable (Craighead and Craighead 1972). By definition, residential occupancy requires availability of suitable habitats in all four seasons so that the demographic model is dependent upon the presence of suitable denning habitats. Denning habitat for Grizzly Bears has not been previously analyzed across the northern Idaho-western Montana region. We compare our results with other large landscape denning studies in the greater Yellowstone ecosystem (Podruzny and others 2002), Alberta (Pigeon and others 2014) and British Columbia (Ciarniello and others 2005). The central purpose of our study was to identify Grizzly Bear denning habitats within the connectivity areas between Recovery Areas and we evaluate and discuss our results within the context of the demographic model.

METHODS

Study Area

The study area (108,750km^2) includes all or significant portions of four Grizzly Bear Recovery Areas, two Demographic Connectivity Areas and five other potential connectivity areas (USFWS 2000; Proctor and others 2015; Peck and others 2017) as shown in Figure 1. Most of the study area is located within Region 1 of the US Forest Service (USFS) with the exception of the area in northeast Washington within Region 6. It includes the portion of the Bitterroot Recovery Area most likely to receive immigrating Grizzly Bears from the NCDE. Under the influence of the maritime climate pattern this area generally receives greater annual precipitation than areas east of the Continental Divide and south of the Salmon River. A major defining feature is the Bitterroot Mountain Range which runs most of the length of the study area from north to south.

Literature Review

In addition to the review by Linnell and others (2000) we reviewed 30 published papers and reports on denning in North American Grizzly Bears to identify parameters for modeling.

The most frequently reported descriptive statistics were elevation, slope, aspect and landcover as shown in Table 1. Some authors discussed snow for its insulative and security values (Craighead and Craighead 1972), its association with the availability and unavailability of natural food sources including Autumn and Spring (Pigeon and others 2016), as a trigger for final den entry (Craighead and Craighead 1972; Servheen and Klaver 1983) and as part of denning chronologies (Graham and Stenhouse 2014There are no significant differences in den site selection and construction between male and female Grizzly Bears (Aune and Kasworm 1989; Mace and Waller 1997; Pigeon and others 2016) and we did not differentiate between the sexes for our analyses. We derived descriptive information for the verified den sites for slope, elevation, aspect, land cover and remoteness shown in Table 2, Figures 2 and 3 by obtaining values for each den site from ArcGIS Pro and LANDFIRE EVT and calculating minimum and maximum values, the mean, the standard deviation and the range (mean ± one standard deviation). We assumed that Grizzly Bears in our study area would select den sites in higher terrain with relatively steep slopes, away from close proximity to human habitations and areas with high human activity and away from water bodies.

Den Locations

Verified Grizzly Bear den site locations (n = 364) were provided through data sharing agreements with the USFWS and the Montana Department of Fish, Wildlife and Parks (MDFWP). Due to the status of the Grizzly Bear as a federally protected species we agreed the coordinates of the locations would not be shared or displayed in figures. The locations come from four isolated population areas: the western half of the Northern Continental Divide Ecosystem (NCDE West), the Cabinet Mountains, Yaak River-Purcell Mountains and the Selkirk Mountains and come primarily from bears radio-collared for population trend monitoring from

1985-2019 (Mace and Waller 1997; Costello and others 2016; Kasworm and others 2021). Site by site visual analysis using Google Earth Pro revealed two atypical locations that were removed from further evaluation, resulting in study sample n = 362.

Aspect

We found that the distribution of aspect was not uniform. We used the Rayleigh Test of Uniformity in the R circular package (Rao Jammala-Madaka and SenGupta 2001). A test statistic of 0.0965 with P-value of 0.0342 < 0.05 for a circular mean of 166.5738 degrees disproves the null hypothesis that there is a uniform distribution. We did not assess multimodal distribution.

Spatial Autocorrelation of Dens

We tested the 362 den sites for spatial autocorrelation using Moran's I test in ArcGIS Pro (ESRI 2020). The resultant z-score of 31.77 indicates that there is < 1% probability (p = 0.000) that the clustered pattern is the result of random chance. Den sites are often naturally clustered due to use of the same area by the same bear in consecutive years owing to den area fidelity (Aune and Kasworm 1989; Pigeon 2014) and clusters have also been documented from multiple bears contemporaneously. Other factors may be a lack of sufficiently secure and dispersed denning habitat. We developed a model using spatially rarified den locations and compared AUC (area under curve, Jimenez-Valdere 2012) and TSS (True Skill Statistic, Allouche and others 2006) values to a six variable model run with the 362 den locations. The rarified model was based on removing spatial autocorrelation from five den clusters after outliers were removed. Autocorrelation distances were developed using the incremental autocorrelation tool in ArcGIS Pro. First peak z-score values of the five ecosystems were averaged ($\bar{x}$ = 5.6km). We used this lag distance in the SDM toolbox for spatial rarefaction. This process reduced the number of points from 362 to 92. The model using all 362 dens had an AUC score of 0.884 and a TSS of 0.467 while the spatially rarified dens had a lower AUC (0.85) and a higher TSS (0.54). Warren and others (2019) found that model prediction based on withheld occurrences has questionable reliability for estimation of the interactions between environmental gradients and habitat suitability. Based on this and the test scores we retained all 362 dens in subsequent models. The number of dens that are detected is a small fraction of the total dens as a small percentage of the populations are radio-collared. Significant reduction of the sample size would reduce the amount of variation captured by the data set.

Model Development

Maxent (Phillips and others 2004) was used to develop a series of models. We used the default 10,000 background sample points and kept them throughout the process for consistency. Low elevation heavily human populated areas were included to show variation across the large landscape and for contrast between suitable and unsuitable denning habitat (Saupe and others 2012). Model results were evaluated using AUC, TSS, Percent Contribution of the individual variables and visually.

Environmental Variable Creation and Selection

We developed and selected a set of 16 rasters with 10m resolution depicting the environmental variables we used in Maxent as shown in Table 3. Continuous variables were re-projected to WGS 84 then converted to an identical extent and cell location using the Project Raster to Template tool from the Marine Geospatial Ecology Toolset (MGET, Roberts and others 2010). Categorical variables were resampled to 10m using the “nearest” parameter to preserve values then run through MGET for alignment with the continuous environmental variables.

Snow and Trended Elevation

The average annual snow accumulation from the years 1981-2010 was extracted from PRISM (Daly and others 2020) raster data. Two 10m downscaled versions were created using ClimateNA (Wang and others 2016) and by inverse distance weighting. We included snow as an environmental variable for initial model testing. However, ideal snow depths have not been documented in relation to Grizzly Bear denning and precipitation and snow are difficult to model with any specificity in mountainous terrain (Larson and others 2013). The snow variable also had high predictive power which led to misleading model values. Daly and others (1994) established a precipitation-elevation relationship and we found that elevation provided essentially the same information with similar model results as snow accumulation. We eliminated both of the snow accumulation variables and adopted a modified (trend surface) elevation raster based on the following rationale. The study area increases in base elevation from the northwest to the southeast with elevations varying from 222m at the confluence of the Snake and Clearwater Rivers to 1950m near Butte, Montana. Known den sites are clustered in the north and eastern portion of the study area where Grizzly Bear research studies are focused. Model runs using an elevation variable resulted in suitable denning habitat being projected to much lower elevations than one would biologically expect in the southeastern portion of the study area. To compensate for elevation differences across the study area we developed a trended elevation variable with base elevations adjusted using points spaced 500m-1km apart on major rivers. The trended elevation model produced better results except along the Snake River where the large elevation difference in the Hells Canyon area caused an anomaly in the trended surface, giving an appearance of relatively high elevations at the top of the canyon. The study area extent was reduced to eliminate this anomaly.

Distance from Roads, Downhill Ski Resorts and Water

As a proxy for remoteness and disturbance from human activity we created a distance from roads, motorized trails and downhill ski areas 10m raster. Open roads and motorized trail data were extracted from the USFS MUMV data and roads data for state lands in Idaho and Montana. Downhill ski areas were extracted or recreated from ski area parcel polygons (USFS Region 1). Open roads, motorized trails and downhill ski areas were rasterized and a distance surface was created. Initial model runs created a raster surface with a buffer like change in values at ≈ 1206m. There was an ≈ 0.15 drop in probability between the inside of the 1206m distance at similar elevations and outside past the 1206m boundary as shown in Figures 4 and 5. The denning probability decrease past 1206m was likely associated with sampling bias resulting in a small sample size (n = 4) from the interior of the Bob Marshall Wilderness due to Grizzly Bear capture areas being located in more productive and accessible areas (Costello and others 2016; Metzgar and Bader 1992). Denning suitability may decline in interior roadless areas based on factors other than roads and this is accounted for in the other model parameters. Podruzny and others (2002) and Judd and others (1986) concluded that denning habitat is not a limiting factor in the primarily roadless Yellowstone Recovery Area. We assumed that denning habitat is not limiting on the NCDE Grizzly Bear population and that Grizzly Bears have a similar response in the large roadless areas. Distances > 1206m from open roads, the approximate peak in the histogram of den distances from roads as shown in Figure 6 were changed to 1206m as a constant. Fixing distance to road at 1206m effectively removed roads as a significant variable within large Wilderness, National Park or other roadless areas so that the probability of selection in these habitats is primarily based on the other variables, consistent with Podruzny and others (2002), Sorum and others (2019) who did not include roads as a variable. Pigeon and others (2014) used a 1km circular filter to calculate road densities. A zero value would occur in areas ≥ 1.128km from a road which roughly corresponds to the 1206m distance from roads where our verified den numbers reached their maximum. Without the adjustment, den selection probabilities >

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1206m would occur at higher elevations, other factors being equal, than within the 1206m cutoff. For avoidance of water we used distance from water bodies. Combining rasterized National Wetland Inventory water bodies (lakes and wetlands) with rivers and streams (USGS 2004), we created a distance from water raster using the Euclidean Distance tool in ArcGIS Pro.

Land Cover

A 10m or less land cover classification was not available for the study area so we resampled the LANDFIRE 30m vegetation classification data to 10m using nearest to maintain values to make the data compatible with Maxent. Using ArcGIS Pro we attached vegetation type attributes from the LANDFIRE dataset to the 362 den locations. Ninety-five percent of the verified den locations (n = 343) were in the forested classifications and five percent of den locations (n =19) were in the barren rock and sparsely vegetated classification groups. Rock and sparsely-vegetated classifications mostly occur at the highest elevations. Adding the forest/non-forest-sparse vegetation variable reduced overestimation of the relative probability of den selection in rocky and open high elevation habitats and was more consistent with the literature review and the site by site visual analysis.

Standard Deviation of Curvature

We created a standard deviation of curvature raster with a 500m radius (Ironside and others 2018) to identify highly variable areas of the landscape. This also allowed for identification of convex and concave slope complexes.

Correlation Testing

We tested the 16 continuous variables for correlation using a Pearson Correlation Matrix in R Project as illustrated in Figure 7 and shown in Table 3. Most selected variable pairs lacked significance at the ≤ 0.1 p values. Exceptions included the Slope_25m (standard slope calculation from ArcGIS) paired with SD_Curvature_1km and Trended Elevation paired with the Distance from Roads and Ski Area variable. The Slope 25m/SD_Curvature_1km pair was positively correlated because many areas with steep slopes are rough while areas with low slope values usually occur in relatively flat areas with low topographical roughness. When distance from roads and downhill ski areas increases, trended elevation also increases because most roads are located in valley bottoms or sidehills and are not generally constructed on ridgelines.

While the Wetness Accumulation variable showed significant negative correlations with the other variables and would normally be included in a model run, comparing Wetness Accumulation to Distance from Water indicated that there was no contribution of Wetness Accumulation to the model. Distance from water had a contribution of 1.6% and was retained.

Model Evaluation

Using the raster layers and the verified data set we developed and tested 17 models with differing combinations of variables, reporting statistical scores for the top three. We used AUC and TSS to evaluate model fitness. AUC is the area under the Receiver Operating Characteristic plot. AUC values range from 0 to 1 with 0 indicating all predictions are wrong and 1 indicating all predictions are right. Values of TSS range from -1 to 0 and 0 to 1 with zero being co-equivalent to randomness with values trending towards 1 indicating a better model.

Projection of Buffered Polygons (MCP) vs Using the Entire Study Area

To assess the value of projecting a localized model to the entire study area, we compared a restricted background model projection to running the model over the entire study area. Minimum Convex Polygons (MCP) were created around verified den sites from the four Grizzly Bear population areas. The MCPs were then buffered 6.3km based on the radius of an average 125km^2 female grizzly home range (Mace and Waller 1997) expressed as a circle to encompass the range of environmental variables for females with dens at the edge of the MCP**.**

These areas were sampled with the default 10,000 background points and projected to the entire study area. The projected model had a lower AUC (0.846) than the model that was run over the entire study area (AUC = 0.88). We chose the un-projected model based on a slightly higher AUC and the fact that the selected environmental predictors in the final model are fairly consistent throughout the study area. Comparing similar AUC scores may be misleading (Jimenez-Valdere 2012). The higher score of the un-projected model may have been due to the increased variability of environmental predictors in a larger landscape or a function of the random sampling of background data points. Morales and others (2017) cited several papers raising the issue that default parameters may produce over or under fitted results and that Maxent parameters used in research papers were not published. We eliminated parameters used to develop Maxent models to reduce complexity and eliminate issues caused by base elevation difference, snow shadows and lack of den locations in more remote areas due to capture bias. We kept the regularization parameter at 1 for consistency after testing a model using a parameter of 0.1 showing little difference. Data was un-projected (WGS 84). A bias file was incorporated to compensate for the change in raster cell area due to latitude.

We found a combination of linear and quadratic feature parameters created optimal models. Using hinge features only produced a similar model to our Model13_VEG but with a slightly lower AUC so it was eliminated. We eliminated the Extrapolate, Do Clamping and Fade by Clamping parameters to keep the model simple. We selected Model13_VEG based on acceptable AUC and TSS Scores and the inclusion of the standard deviation of curvature for a 1km radius raster. The den sites have a wide ecological amplitude as shown in the histogram of relative probabilities in Figure 7. The majority of dens (82.1%) occur at higher model values with a negative skew showing fewer dens occurring in the extended left tail. Our selected top model was classified by binning by percentile into four categories: Not Denning Habitat, Low, Medium and High and the ranges of relative model probabilities for the categories are shown in Table 4.

Analysis

We used the denning results for the NCDE West as a baseline for a rough comparison with the Bitterroot analysis unit as the NCDE Recovery Area is believed to be at or near K (Costello and others 2016) and there are similarities in habitat security and productivity (Boyce and Waller 2003). The NCDE West analysis unit is 67.4% of the Recovery Area. The current estimated N = 1069 (USFWS 2021) includes a larger Demographic Monitoring Area and assuming ≈ 85% of the population resides within the Recovery Area (n ≈ 900) and assuming equal distribution, ≈ 600 Grizzly Bears reside in the NCDE West. We also reviewed our results in the context of previous Grizzly Bear habitat studies and estimates of K (Merrill and others 1999; Carroll and others 2000; Hogg and others 2001; Boyce and Waller 2003; Mowat and others 2013). The NCDE Conservation Strategy habitat management standards define secure core habitat as areas >500m from an open road and at least $10km^2$ in area. Using these metrics for secure core we evaluated the current habitat situation in the two DCAs and the other identified potential linkage areas.

RESULTS

We selected Model13_Veg with slope, trended elevation, land cover, distance to roads, downhill ski areas and water and standard deviation of curvature at 1km as our best model and the results are shown in Tables 5, 6 and 7, and Figure 8. The highest quality denning habitats comprise < 5% of the study area. The results were consistent with those most often reported in the denning literature and this model shows the highest probability denning habitat in areas with suitable slopes (range), position on the landscape and distance from open roads. While having comparable AUC/TSS, we chose Model13_VEG with the curvature variable over aspect because at a large landscape level bears select den sites on relatively equal aspects. We eliminated the

Three Principal Components Model based on a visual inspection which showed it was too generalized and had a lower AUC than Model13_VEG.

We found support for the demographic model for population connectivity in that denning and secure core habitats are present to abundant in the potential connectivity areas with the exception of the Salish DCA where there were just a few small secure core areas which are spatially disjunct. The Sapphire Complex, where there have been persistent verified observations of Grizzly Bears and where berry-producing shrubs important to Grizzly Bears are abundant (Hogg and others 2001) has the largest amount of secure core habitat > 500m from an open road (2486km^2) in the largest sizes as shown in Table 7.

The Ninemile DCA has contiguous denning habitat likely sufficient to support a small resident population and the presence of female Grizzly Bears with cubs has been verified (Jonkel 2021). The area between the CYE and BE along the northern Bitterroot Divide has high public ownership and secure core areas within short distance of each other. The USFS (2020:83) describes the area as containing year-round suitable habitat similar to that within recovery zones and could be used for either short-term movements or for low population densities between recovery zones.

Measured against the NCDE West metrics it is reasonable to assume suitable denning habitats in the Bitterroot analysis unit could support over 500 Grizzly Bears, which would satisfy the denning requirements for population estimates of N = 321-445 (Boyce and Waller 2003; Mowat and others 2013) calculated for smaller areas than our analysis unit. There is abundant Spring, Summer and Fall Grizzly Bear habitat (Merrill and others 1999; Carroll and others 2001; Boyce and Waller 2003) including broad spatial distribution of key berry-producing plants known to be important to Grizzly Bears (Hogg and others 2001).

Our results were consistent with the literature regarding declining selection in the highest, rockiest and most exposed terrain scoured free of soil and snow. Vegetative cover is an important factor due to the stability the roots provide to the structure of the den. Grizzly Bears line the floor of their dens with vegetative matter including boughs and needles from spruce (*Picea*), fir (*Abies*) and where available, beargrass (*Xerophyllum tenax*) (Craighead and Craighead 1972; Jonkel 1987; Servheen and Klaver 1983). Bedding materials consist of what is available at the den site and not on any preference (Judd and others 1986). While Grizzly Bears have long claws that enable digging for food and den excavation, they cannot dig through solid bedrock. These two factors mitigate against denning in areas of rock devoid of nearby vegetative groundcover. The model may slightly overestimate denning suitability in the highest elevations of the Selway-Bitterroot Wilderness and Glacier National Park unless there is a relative abundance of natural cave-like openings. This is because LANDFIRE EVT did not have classifications for alpine fell-fields or alpine bedrock and scree. At the scale of the study area we considered this insignificant.

Our results showed den selection away from open roads, consistent with the literature on road impacts on Grizzly Bear den selection, population growth and density as shown in Table 8.

Discussion

We suggest there is merit to incorporating additional areas in the Bitterroot Recovery Area, particularly north of the Lochsa River and US 12 as we found relatively abundant denning habitat while Carroll and others (2001) and Merrill and others (1999) identified this area as having large concentrations of contiguous high quality Grizzly Bear habitats in Spring, Summer and Fall.

In comparison to other Grizzly Bear denning studies (Vroom and others 1977; Podruzny and others 2002; Pigeon and others 2014; Mace and Waller 1997), our results were consistent in regards to slope angle, elevation/snow load and ground cover. We found Grizzly Bear dens at all aspects, as did Aune and Kasworm (1989), Judd and others (1986), Podruzny and others (2002), Libal and others (2011). In terms of study area composition containing both protected areas such as Wilderness and Parks and a high road density component, our study area compares to the Alberta study area defined by Pigeon and others (2014) and the British Columbia study area of Ciarniello and others (2005), with similar results in regards to den selection away from roads and areas with higher human activity. Linnell and others (2000) report that Grizzly and Brown Bears generally select dens 1-2km from open roads and our 362 verified dens had a mean distance of 1.96km from open roads and downhill ski areas. By contrast, the Podruzny and others (2002) greater Yellowstone study area, while very similar in size, is primarily remote habitat in roadless Wilderness and National Park and they did not assess the impact of open roads on den site selection. The few roads in their study area are mostly in valley bottoms below denning range and are closed half of the year by snowfall. The greater Yellowstone ecosystem also differs significantly from our study area in climate, elevation, vegetation and primary food sources (Boyce and Waller 2000).

Within our study area, data for ungulate winter ranges and Grizzly Bear spring habitat was not seamless and had inconsistent methods and definitions. Future analyses could determine if denning habitats in close proximity to these resources may or may not be more desirable.

Our results confirm the presence of significant denning habitat in areas previously identified as potential connectivity areas. The primary difference is that our analysis was based on residential occupancy by female Grizzly Bears rather than transitory males.

We suggest these requisites for the demographic model for dispersal.

(1) Denning Habitat and Secure Core within Dispersal Distances—. The availability of denning habitats within secure core areas is a fundamental requirement of the demographic model. These are areas where females can survive and raise offspring who become a source of dispersals.

We suggest Bear Management Units (BMUs) be identified within key connectivity habitats with standards to maintain all currently secure core habitat. Standards based upon scientific data maintained 68% of a BMU in secure core habitat (USFS 1995). The secure core areas should not shift as this disrupts female Grizzly Bears who learn that areas are secure and pass a significant portion of the maternal home range to their female offspring so that sudden shifts in security conditions would not be conducive to the demographic model.

In connectivity habitats, the larger secure areas should be spatially distributed within known dispersal distances for female Grizzly Bears (Mattson and others 1996). From the dispersal information in Graves and others (2014), Proctor and others (2004) and McLellan and Hovey (2001) secure core areas from 0-10km apart might work for 64% and 74% of dispersing females, respectively with 0 representing females who do not disperse from their home ranges, while core from 20-30km apart might work for 22% and 19% of dispersing females, respectively. How Grizzly Bears might best move between and within secure core awaits a future analysis based on habitat quality, least-cost path analysis and circuit theory, as in Proctor and others (2015).

(2) Highway Passage Structures—. Highway and rail transportation corridors are zones that fragment Grizzly Bear populations into isolated demographic units (Proctor and others 2002). The two biggest obstacles to female Grizzly Bear dispersal in the study area are the Interstate 90 corridor and US Highway 93 from Whitefish to Darby, Montana. While a female grizzly with cubs south of I-90 has been documented (Jonkel 2021) the big issue is the number of dispersing

bears and the number that choose to disperse plus the limited number of crossing structures where bears can safely cross highways. These are essential to successful demographic dispersion of Grizzly Bears into historic habitats (Ford and others 2017). Having “multiple shots on goal” would provide a higher likelihood of success.

Expansion in the distribution of an established population and dispersals are driven by male bears (Itoh and others 2012; Peck and others 2017; Eriksen and others 2018) and they are the most likely to first use new denning areas. In the connectivity areas and the Bitterroot ecosystem, in the early phase of recolonization competition for prime denning sites should be minimal. However, since Grizzly Bears rarely re-use dens and dens are often clustered in prime areas (Aune and Kasworm 1989), there could be increased competition for denning sites within smaller demographic units.

We identified ranges of suitable denning habitats but a few Grizzly Bears may select den sites outside these ranges. There are several factors which can lead to poor den site selection in lower terrain. Both literature (Servheen and Klaver 1983) and anecdotal information show orphaned cubs with no experience have denned in valley bottoms or did not den. Sick or injured bears may be forced to select poor den sites due to an inability to travel or dig. As hunting seasons overlap the denning process, some Grizzly Bears have stayed out late in the Fall feeding on gut piles. By the time they move to den the snow depth at higher elevations may force selection of lower elevation sites.

Future Prospects

Recreation activity has the potential to disturb or harm denning Grizzly Bears (Linnell and others 2002). For example, Hilderbrand and others (2000) document a female Grizzly Bear and cubs killed by an avalanche triggered by snowmobiles. Based on the unsupported assumption that bears are largely immune to impacts from both motorized and non-motorized winter recreation the National Forest Plan amendments for NCDE Grizzly Bear habitat management (USFS 2018) have no management standards specific to Grizzly Bears during the denning period. Evidence suggests land managers develop standards that will more adequately protect this resource.

Climate change will affect the denning process and den site selection. Evan and Eisenman (2021) predict that interior areas like the Canadian Rockies and the northern Rocky Mountains of the US will see less change in the rate of snowpack melt and the timing of spring runoff than coastal areas while climate models for Montana show that even in areas > 1800m a 12% reduction in snow water equivalent is expected (Whitlock and others 2017). Musselman and others (2021) found 34% of snow monitoring stations in western North America exhibit increasing winter snowmelt trends. Pigeon and others (2016) note snow depth is associated with food availability and postulate climate change effects are likely to shorten the denning period for Grizzly Bears. A key factor may be the rate of change and whether plant phenology adapts at the same rate. A possible consequence of earlier den emergence is that natural foods may be largely unavailable, leading some bears to seek out human related foods, which leads to management actions and increased mortality. If dependable snowpack levels increase in elevation, it may pose additional challenges for species dependent on higher elevation remote areas in the Rocky Mountains for denning and hunting, including Grizzly Bears, wolverine (*Gulo gulo*) and lynx (*Lynx canadensis*).

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