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Management and Conservation Article

Brown Bear Den Habitat and Winter Recreation in South-Central Alaska

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ABSTRACT Increasing demand for backcountry recreation opportunities during winter (e.g., snowshoeing, helicopter-assisted skiing, snowmobiling) in steep, high-elevation terrain has elevated concern about disturbance to brown bears (*Ursus arctos*) denning on the Kenai Peninsula, Alaska, USA. To help identify areas where such conflicts might occur, we developed a spatially explicit model to predict potential den habitat. The model indicated brown bears selected locations for den sites with steep slopes, away from roads and trails. Den sites were associated with habitat high in elevation and away from potential human contact. We then compared areas with the highest probability of providing den habitat with patterns of snowmobile and nonmotorized recreation on a portion of the Kenai Peninsula. We found limited overlap between the 2 recreation activities and potential den habitat for brown bears. At the landscape scale, however, backcountry skiing overlapped more high-quality den habitat than did snowmobile riding. Our results may be used by land management agencies to identify potential conflict sites and to minimize the potential effects of recreation activities on brown bears in dens.

KEY WORDS Alaska, brown bear, den, disturbance, habitat, Kenai Peninsula, *Ursus arctos*, winter recreation.

Brown bears (*Ursus arctos*) move extensively throughout the Kenai Peninsula, Alaska (Kenai), and use a wide array of resources (e.g., areas of early green-up in the spring, riparian areas and fish streams in the summer, upland berry patches in the autumn, and mountainside den sites in the winter). The persistence of brown bear populations depends primarily on habitat quality, human density, and human behavior (Mattson et al. 1996, McLellan 1998, Apps et al. 2004) and all 3 variables have changed on the Kenai. Increasing land development and human activity on the Kenai causes concern about potential impacts to brown bears (Schwartz and Arthur 1997). In 1998 the Alaska Department of Fish and Game (ADF&G) designated the Kenai brown bear population as one of special concern (Del Frate 1999). Factors that led to this designation included small population size (approx. 275 animals), potential genetic isolation, and human development (e.g., Suring and Del Frate 2002, Suring et al. 2006).

The human population on the Kenai increased from about 9,000 in 1960 to >52,000 in 2006 (Camp 2001; United States Census Bureau, unpublished report), and the population of nearby Anchorage increased from about 83,000 in 1960 to >280,000 in 2006. The Kenai has 2 highways, numerous trails, and several major rivers and lakes that support abundant outdoor recreation opportunities (Fig. 1). Road improvements over the past 20 years decreased vehicular access time from Anchorage and increased the number of day trips for Kenai-based recreation.

Information on landscape-level patterns of brown bear habitat use and human activity during winter is needed to effectively manage the brown bear population on the Kenai. We were concerned with the potential vulnerability of bears in dens and at den emergence to disturbance from winter recreation activities (Linnell et al. 2000). Generally, on the Kenai, brown bears den between October and May. A pattern of den emergence (M first, followed by F without cubs, followed by F with cubs), consistent with other studies (Schoen et al. 1987, Miller 1990, Linnell et al. 2000), occurs between early April and the end of May. Winter recreation on the Chugach National Forest generally ends in April (United States Department of Agriculture Forest Service [USDA FS] 2002). In this study we describe den-site selection by female brown bears, model den habitat on the Kenai Peninsula, evaluate spatial overlap between winter recreation and den habitat, and recommend ways to mitigate the potential effects of winter recreation on brown bears at den sites.

STUDY AREA

The 23,000-km^2 Kenai Peninsula sits at approximately 61°N, 149°W. Located in south-central Alaska between Prince William Sound to the east, Cook Inlet to the west, and the Gulf of Alaska to the south (Fig. 1), the Kenai is connected to the Alaska mainland by a narrow isthmus approximately 18 km wide. The rugged, heavily glaciated Kenai Mountain Range rises to 1,990 m and forms the major physiographic landform on the eastern two-thirds of the peninsula. The Kenai lowlands landform, a glaciated plain with limited relief interspersed with numerous lakes, dominates the western third. Many stream systems on the Kenai supported runs of wild salmon (*Oncorhynchus* spp.). Mean annual precipitation varied from 50 cm to 500 cm, depending on elevation.

The Kenai supported typical northern boreal forest tree species, including white spruce (*Picea glauca*), black spruce

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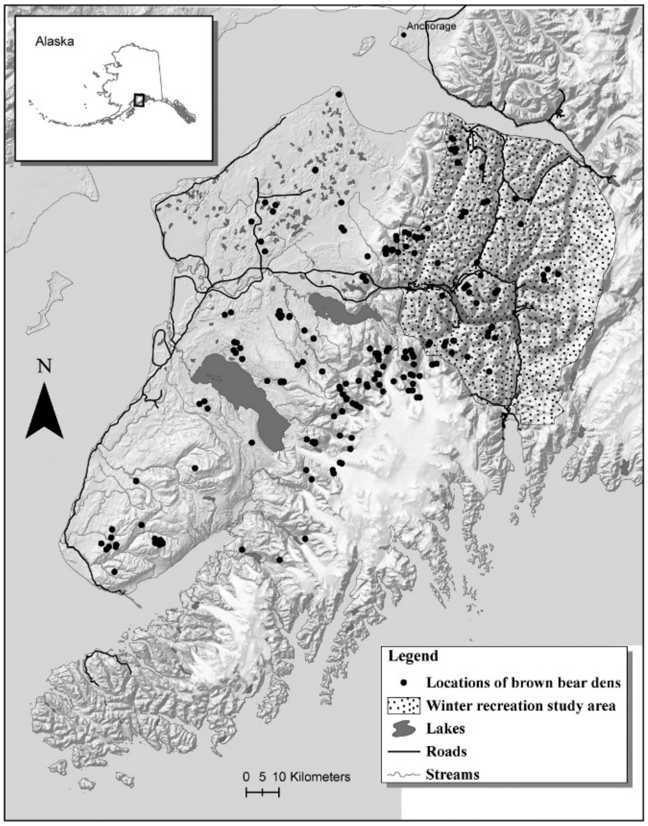

Figure 1. Brown bear den sites, 1995–2003, and winter recreation study area, 2004–2005, on the Kenai Peninsula, Alaska, USA.

(*P. mariana*), black cottonwood (*Populus balsamifera trichocarpa*), quaking aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*). Mosses and low shrubs dominated other lowland peat communities. Mature forest vegetation on dry upland sites included white spruce, paper birch, quaking aspen, or some combination of these species; black spruce dominated poorly drained sites. Tundra vegetation in the Kenai Mountains predominated above 750 m.

We investigated winter recreation use on approximately 5,000 km^2 of the northwestern portion of the study area (Fig. 1). The Seward Highway served as the primary road access for the area and the majority of winter recreation occurred in the general vicinity of this highway corridor. Management prescriptions allowed winter motorized access to approximately 70–85% of this area, with 100% open to some form of winter recreation (USDA FS 2002). The primary winter recreation season, January through April, occurred when consistent snowfalls, warmer temperatures, and increasing daylight hours facilitated access.

METHODS

We captured, collared, and monitored female brown bears for several concurrent population and habitat studies on the Kenai Peninsula (e.g., Graves et al. 2006, 2007; Suring et al. 2006). We used small, fixed-wing aircraft and conventional aerial radiotracking procedures (Mech 1983) to obtain monthly relocations of denned female brown bears fitted with conventional very high frequency radios. Relocations occurred during daylight hours during weather favorable for flying. Because of aerial telemetry error ($\pm$100 m), we used the centroid (geometric center) of multiple relocations to define individual den sites.

We used a Geographic Information System (GIS) to generate habitat covariate estimates at each den site and at 37,861 additional locations we assumed were not used as den sites but were available to bears to use as den sites (ArcGIS 9.2). We selected the set of available locations based on a systematic sample of approximately 350,000 locations established on a 200-m $\times$ 200-m grid with a random start within the known range of brown bears on the Kenai. We sampled a very large number of possible available locations within the study area, and presumably a relatively small number of den sites not identified by radiotelemetry. This ensured that contamination of available locations with sites actually used but unknown by us was extremely low, that the probability of use by bears of any single point in the study area was very small, and that the argument of the exponential function was negative (Manly et al. 2002, Johnson et al. 2006).

We obtained values for the following habitat variables at each den site and each available location: 1) slope (%); 2) elevation (m); 3) distance (km) to nearest salmon spawning stream (ADF&G 1998); 4) distance (km) to nearest road (we merged highways, medium-duty, and unimproved roads after an initial evaluation showed no differences); 5) distances (km) to nearest high- and low-use trail (we designated recreation trails as high use or low use depending on accessibility and distance from human population centers, as in Suring et al. 2006); 6) land cover type (i.e., forest, shrub, herbaceous, and a combination of water–snow–ice) from a land cover map of the Kenai (Ducks Unlimited and Spatial Solutions 1999); and 7) an index of solar radiation (Podruzny et al. 2002, Keating et al. 2007). We derived elevation, slope, and solar radiation metrics from a 30-m digital elevation model.

We used a preanalysis correlation screen to identify multicollinearities (Neter et al. 1985) in the data and removed correlated variables ($r > 0.6$). We did not allow distance to trail and distance to road in the same model because these 2 variables were highly correlated. We used the results of the preanalysis screen, and allowed for quadratic terms for elevation, slope, solar radiation, distance to nearest road, and distances to nearest high- and low-use trails. We then generated resource-selection function (RSF) models using logistic regression (SAS Institute, Inc., Cary, NC). The RSF models provided an estimate of the relative probability of a female brown bear selecting a location for a den given the habitat characteristics at that location. Due to the exploratory nature of this analysis, we focused on a priori selection of variables and not on a priori model building (Burnham and Anderson 2002, Stephens et al. 2005).

We followed many of the marked bears for multiple years and they often used more than one den site. To avoid problems with pseudoreplication, we used the individual bear as the experimental unit ($n = 72$; Erickson et al. 2001) and bootstrapped (Manly 1997) the bears during the model selection process and for estimating model coefficients and standard errors. To do this, we selected a random sample with replacement of 72 bears and their associated den sites, combined the sample of den sites with the sample of available locations, and estimated the likelihood and coefficients for each model. We repeated the procedure 1,000 times. Within each bootstrap replication, we calculated model weights using the Bayesian Information Criterion (BIC; Schwarz 1978, Burnham and Anderson 2002), and then we calculated the average BIC weight across the 1,000 bootstrap replications for each model. We ranked and reported the top 10 RSF models by BIC. This model selection technique is similar to bootstrapping for model selection frequencies (Burnham and Anderson 2002), but allows for a weighted-average approach to predicting relative probabilities of resource selection.

In addition to providing comparisons among models, we used the BIC weights to compute and compare the relative importance of each variable considered in the model ranking process. We calculated importance values for each variable by summing the average BIC weights for all models that contained the variable. Thus, we considered variables in the RSF with higher weights relatively more important when compared to variables in models with less weight. However, even if a variable was not present in the final model, we assigned it some importance if it occurred in other models that had relatively high BIC weights. We estimated coefficients for each model by fitting each model to all of the bear den data and the sample of unused available locations, and we estimated standard errors of model coefficients using the standard deviation of the 1,000 bootstrap estimates. Because odds ratios cannot be calculated for variables with both linear and quadratic terms in a model, we did not compare coefficients in this manner.

Following identification of the top 10 models, we used the validation technique described by Johnson et al. (2006) to assess the predictive power of our RSF models. We validated models following a traditional *k*-fold cross-validation (Fielding and Bell 1997), in which we temporarily dropped den locations used by a random sample of 20% of the 72 collared bears (i.e., 14 bears) and 20% of the available locations (i.e., 7,572 available locations) from the data set. We re-estimated the final model using data from the remaining bears and available locations, repeated this process 40 times, and reported the average slope of the 40 validation runs, along with its 95% confidence interval. An average slope = 1.0 indicated good model performance (i.e., estimated relative probabilities of use were proportional to the true probabilities of use). We also calculated the weighted-average prediction from the top 10 models. To predict relative probability of den-site selection based on the top 10 models, we scaled average BIC weights for these models to sum to one and calculated the weighted mean prediction.

Following validation of the RSF models, we created a predictive map of den habitat using the coefficients from the average weighted prediction from the top 10 RSF models and applied them to a 200 $\times$ 200-m grid covering the study area. This map represents the relative probability of a female brown bear selecting a point on the landscape for a den site.

We mapped spatial patterns of dispersed winter recreation using systematic aerial surveys of 69 sub-watershed sample units (based on sixth-order hydrologic units; size 1–32 km^2) during the winters of 2004 and 2005 (Poe et al. 2006). We stratified sample units by access; 60% of the sub-watersheds were adjacent to accessible parking areas and 40% required access through adjacent sub-watersheds. We surveyed sample units from aircraft on randomly selected days, stratified by weekend (higher use) or weekday (lower use), between mid-January and mid-April. We mapped pathways and destinations used by winter recreationists and locations of individual recreation parties by user type (snowmobile, skier, snowshoer, and aircraft-supported recreationists) on 1:63,560 United States Geological Survey quadrangle maps. We delineated the spatial extent of 16 travel networks representing pathways mapped for snowmobile, backcountry ski, and snowshoe use originating from within the surveyed watersheds. Concurrent with each flight survey, we conducted systematic vehicle counts at 42 parking lots along the Seward highway to establish numbers of recreation users dispersing into the survey area. We developed landscape use profiles for snowmobile, ski, and snowshoe users based on data from a recreation behavior study completed within the study area during 2005 (Poe et al. 2006).

We synthesized the data from these 3 efforts (aerial surveys, parking lot counts, and landscape use profiles) in an agent-based simulation model (RBSim Version 2, see http://www.srnr.arizona.edu/~gimblett/rbsim.html, accessed 14 Aug 2009). In this model, we defined a collection of autonomous decision-making entities called agents based on the principals of Individual-based Modeling as described by Huston et al. (1988). RBSim dispersed agents across the landscape on the 16 travel networks based on behavioral rules defined by the landscape use profiles (e.g., Gimblett et al., 2001). RBSim launched agents onto travel networks for simulated trips representing a period between mid-January and mid-April in numbers proportional to those recorded during parking-lot vehicle counts.

During each simulation (n = 20) of recreation activity on the 16 networks, RBSim recorded agent-use duration values (min) for all line segments and destination nodes. We evaluated the mean durations (i.e., z-values) of time spent at nodes and mid-points of line segments using an inverse distance weighted point-interpolation procedure in ArcGIS. We bounded interpolation by an analysis mask of 1 km in diameter centered over each of the linear networks. This prevented use interpolation from being predicted >500 m from the generalized center for each travel network. The resulting raster surfaces enabled us to predict the seasonal intensity (a relative index of duration for each 60 $\times$ 60-m grid cell) of landscape use by winter recreation type (i.e., snowmobile, nonmotorized recreation, and both recreation types combined) during a simulated season of winter use, mid-January through mid-April.

We classified the mapped results of the bear-den RSF into 5 habitat quality classes, with the high-quality habitat class

Table 1. Values of covariates for 207 brown bear den sites, 1995–2003, and 37,861 additional points on the Kenai Peninsula, Alaska, USA.

Covariate	Min.	Max.	Median	$\bar{x}$
Den sites				
Slope (%)	0.0	116.0	34.0	35.6
Elevation (m)	40.0	1,389.0	700.0	646.3
Distance to road (km)	0.1	44.3	10.8	14.0
Distance to stream (km)	0.1	15.1	3.4	4.3
Distance to high-use trail (km)	0.2	26.8	6.5	8.7
Distance to low-use trail (km)	<0.1	19.2	7.6	7.9
Solar radiation index	−1.0	1.0	−0.1	<−0.1
Additional sites				
Slope (%)	0.0	84.0	4.0	9.8
Elevation (m)	0.0	1,923.0	259.0	392.1
Distance to road (km)	0.0	44.1	5.3	8.6
Distance to stream (km)	0.0	17.6	2.3	3.0
Distance to high-use trail (km)	0.0	41.4	5.6	7.0
Distance to low-use trail (km)	0.0	35.2	6.5	7.6
Solar radiation index	−1.0	1.0	−0.2	−0.1

representing the top 20% of RSF values. We evaluated the total amount and extent of high-quality habitat relative to the extent of the predicted intensity of snowmobile recreation, nonmotorized recreation, and for all recreation combined. To calculate the cumulative intensity of recreation overlap with brown bear habitat, we combined the interpolated intensity values from all raster cells contained within each polygon of high-quality habitat and then divided the summary intensity values by the area of each habitat polygon. Using the resulting cumulative intensity/km^2 we classified each habitat polygon into 3 classes of recreation overlap (i.e., high, medium, and low) with the natural-breaks classification tool in ArcGIS. We assigned a value of zero to habitat polygons that did not overlap areas with predicted recreation. We completed this individually for snowmobile and nonmotorized predicted intensities of use, as well as for both types of recreation combined.

RESULTS

We obtained locations for 207 den sites from 72 radiomarked female brown bears from October to April, 1995–2003. Dens were well-distributed across the study area. Distances between capture locations and the first recorded den site for each bear were not normally distributed; they ranged from 0.7 km to 67 km, with a median distance of 12 km. Dens on the Kenai typically were located in remote sites. Of the 207 dens, 52 were located in forest cover, 76 in shrub cover, 72 in herbaceous cover, and 7 in permanent snow–ice. Overall, brown bears selected locations for den sites with steep slopes ($\bar{x}$ = 35.6%), at moderate-to-substantial distances from roads ($\bar{x}$ = 14.0 km) and high-use ($\bar{x}$ = 8.7 km) and low-use trails ($\bar{x}$ = 7.9 km). This was associated with habitat high in elevation ($\bar{x}$ = 646.3 m) and away from potential human contact associated with roads and trails (Table 1).

The top individual RSF model had a slightly higher weight of evidence (0.37) compared to the next best supported model (0.27; Table 2). However, the evidence ratio (Burnham and Anderson 2002) for model 1 versus model 2 was 1.38, indicating relatively weak support for model 1 compared to model 2. Much of the model weight (88%) was assigned to the top 10 models (Table 2). Each of the top 10 models contained a parameter for slope; 8 of the top 10 models contained a parameter for slope^2 and these 2 variables received the highest importance values (1.000, 0.905). None of the top 10 models contained parameters for elevation, solar radiation, or cover type. The major differences among these 10 models were whether they contained distance to nearest trail or distance to nearest road covariates. Based on the top model, the odds of relative probability of selection increased by exp (0.0371) = 1.0378, or 3.78%, for every 1-km increase in distance from high-use trail. Based on the second best model, the odds of relative probability of selection increased by exp (0.0331) = 1.0336, or 3.36%, for every 1-km increase in distance from road. Yet based on multimodel inference, both variables had high importance values.

The top RSF model (validation slope = 1.06; 95% CI = 0.95–1.17; n = 40) and the average weighted RSF prediction (validation slope = 1.02; 95% CI = 0.91–1.12; n = 40; Fig. 2) performed well during model validation. The relationship between rankings of the probability of habitat selection based on the weighted-average RSF and the top individual RSF was r = 0.94. During validation of the RSF models, the average weighted prediction of relative probability of den-site selection from the top 10 models performed slightly better than the prediction based solely on the top RSF model, but both methods showed a near 1:1 relationship between observed and expected use. Given the relatively low weight of evidence for the top individual model and the high importance values of the distance to trail and distance to road covariates, we felt multimodel inference was more appropriate, was more robust across samples, and would provide more accurate predictions for future data or data collected in another geographic region with similar resource availability. We used the average weighted RSF prediction to compare brown bear den habitat with human use on the Kenai.

The watersheds where we surveyed for winter recreation activity contained 202 km^2 of high-quality brown bear den

Table 2. Top 10 resource-selection models for brown bear den habitat on the Kenai Peninsula, Alaska, USA, 1995–2003. Model coefficients (SE) were based on average Bayesian Information Criterion (BIC) weights from 1,000 bootstrap replications.

Rank	Mean BIC wt	Distance to high-use trail	SE	Distance to high-use trail^2	SE	Distance to low-use trail	SE	Distance to low-use trail^2	SE	Slope	SE	Slope^2	SE	Distance to road	SE	Distance to road^2	SE	Distance to stream	SE
1	0.369	0.0371	0.0243			0.2285	0.0952	−0.0136	0.0046	0.0326	0.0127	0.00063	0.00014						
2	0.268									0.0313	0.0129	0.00060		0.0331	0.0115				
3	0.070									0.0362	0.0124	0.00057	0.00013						
4	0.043	0.0303	0.0225			0.2137	0.0978	−0.0130	0.0047	0.0296	0.0135	0.00066	0.00015					0.0452	0.0446
5	0.042	0.0235	0.0231			0.2278	0.0899	−0.0129	0.0042	0.0780	0.0056								
6	0.020									0.0297	0.0134	0.00061	0.00014	0.0307	0.0117			0.0226	0.0448
7	0.019									0.0313	0.0129	0.00060	0.00013	0.0243	0.0395	−0.00025	0.0011		
8	0.017	−0.0034	0.0711	0.00196	0.0031	0.2496	0.1045	−0.0151	0.0053	0.0319	0.0129	0.00064	0.00014						
9	0.017									0.0307	0.0131	0.00062	0.00014					0.0648	0.0449
10	0.016									0.0753	0.0056			0.0305	0.0111				
Total	0.881																		

habitat. Total predicted winter recreation (motorized and nonmotorized), independent of intensity level, occurred in approximately 16% (or 32 km^2) of this habitat. Half of this overlap occurred in the high-intensity recreation class (Table 3). Nonmotorized recreation (19.8 km^2) overlapped more high-quality den habitat than snowmobile recreation (18.9 km^2). Much area of high-quality habitat overlapped by nonmotorized use (skiing and snowshoeing) occurred in areas of high intensity (54%), whereas the area of high-quality habitat overlapped by snowmobile activity was spread evenly across the 3 intensity classes (Table 3).

DISCUSSION

We described and mapped potential brown bear den habitat to identify where bear–human conflicts may occur so that management actions may be implemented to minimize effects of winter recreation on bears. Bias existed in our bear location data because we obtained den locations only from female brown bears and only from bears captured as a result of aerial searches. We do not have information on where male brown bears den on the Kenai Peninsula; males and females may use den sites with different physiographic characteristics (Lindzey and Meslow 1976). However, Smith et al. (1994) reported that differences in den characteristics among sex, age, and female reproductive classes were generally insignificant. Although captures were not systematic, brown bear dens were well-distributed across the study area. Distances as great as 67 km (median = 12 km) between capture locations and the first recorded den site provided evidence that some bears moved long distances to reach den sites. Thus, we feel confident that our sample of den locations was not substantially biased by limitations in our ability to capture bears randomly across the landscape.

Similar to other studies (Craighead and Craighead 1972), brown bears denned in areas isolated from human activity and development. Reynolds et al. (1974) suggested that bears seek out remote, isolated areas and sites that will accumulate enough snow to insulate them from cold winter temperatures. In our study, brown bears selected such sites on steep slopes (Fig. 3). This was similar to findings reported in Van Daele et al. (1990), Groff et al. (1998), Petram et al. (2004), and Garcia et al. (2007), who reported that terrain was the most important variable affecting winter den-site selection. The steeper slopes that bears selected for den sites may have reflected selection for sites with limited potential for disturbance. However, increased participation in winter recreation, combined with new technologies, facilitates access to areas previously difficult to reach. Thus, the potential for disturbance at these sites exists.

Our model indicated that bears selected den sites away from roads, similar to findings by Huygens et al. (2001), Gaines (2003), Mitchell et al. (2005), Reynolds-Hogland et al. (2007), and Elfström et al. (2008). Bears also avoided placing dens near recreation trails (Fig. 3), similar to Groff et al. (1998). The difference in the effect of low-use trails compared to high-use trails on selection of den sites by brown bears may be related to the intensity of use by humans on the trails. As distance to low-use trails increased, the effect of the trails decreased (Fig. 3).

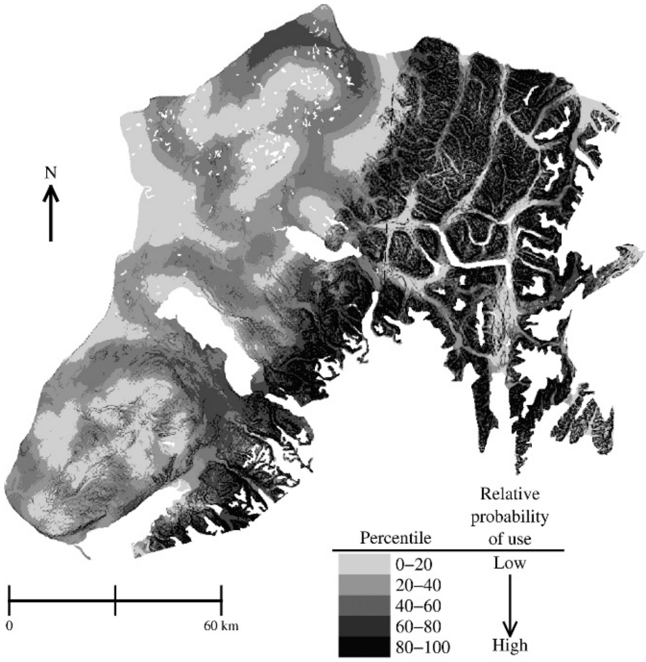

Figure 2. Relative probability of brown bear den-site selection based on the weighted-average predictions using Bayesian Information Criterion weights from top 10 resource-selection function models on the Kenai Peninsula, Alaska, USA, 1995–2003.

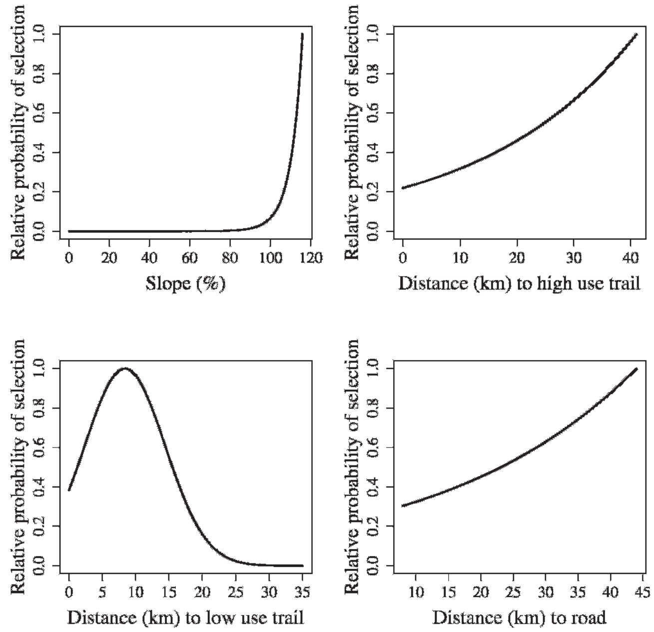

Figure 3. Plots showing the relative probability of den-site selection, 1995–2003, assuming all other variables were held constant at their respective median, for the 4 most important variables in the top 2 models. We plotted relative probability of selection for the observed range of each predictor variable, scaled so the maximum relative probability of selection equals one.

The most widely used den sites were those that were least accessible to humans. Although much of the Kenai is an intact ecosystem with relatively little human use overlapping high-quality brown bear den habitat, given the long history of winter recreation in portions of the study area, it is possible that prior recreation may have displaced denning brown bears from areas they previously used, leading to the limited overlap we observed. However, the way bears select den sites in late autumn may be partially influenced by their behavior during the rest of the year (Reynolds-Hogland et al. 2007). Brown bears on the Kenai generally avoided areas in proximity to roads during spring and summer (Suring et al. 2006), likely because of disturbance and high potential for mortality. Higher densities of roads and trails resulted in an increased likelihood of brown bear mortality (Suring and Del Frate 2002). These factors may have influenced selection of den sites by bears.

Table 3. Overlap of winter recreation activity, 2004–2005, and den habitat for brown bears, 1995–2003, by recreation user type and intensity of recreation use (high, medium, low) on the Kenai Peninsula, Alaska, USA. Den habitat was defined as areas with modeled habitat values in the top 20%.

User type	Area (km^2)	% recreation area overlapped with den habitat	% total den habitat overlapped with recreation area
All recreation			
High	16.2	50	8
Medium	9.4	29	5
Low	6.8	21	3
Total overlap	32.3		16
Total nonoverlap	170.1		84
Total	202.4		
Snowmobile			
High	6.7	35	3
Medium	7.0	37	3
Low	5.2	27	3
Total overlap	18.9		9
Total nonoverlap	183.5		91
Total	202.4		
Nonmotorized (ski–snowshoe)			
High	10.7	54	5
Medium	4.9	25	2
Low	4.2	21	2
Total overlap	19.8		10
Total nonoverlap	182.6		90
Total	202.4		

In the portion of the study area where we evaluated human use, modeled recreation of any type overlapped a relatively small proportion (approx. 16%) of high-quality female brown bear den habitat. In reality, this proportion is probably lower, because our effort to survey human use was stratified to focus on areas likely to have winter recreation activity. Still, although small in total area of overlap, some patches of high-quality habitat for denning bears within the surveyed watersheds hosted a disproportionate amount of high-intensity recreation. Eight percent of high-quality habitat (i.e., 16.3 km^2) located within areas of high-intensity recreation received >50% of the predicted recreation activity (Table 3). The highest amount of overlap between high-quality brown bear habitat and recreation use occurred in Turnagain Pass, where recreation activity overlapped 47% (2.8 km^2 of 5.9 km^2) of high-quality habitat (Fig. 4).

As such, the risk of population impacts to brown bears from snowmobilers, skiers, or snowshoers may currently be

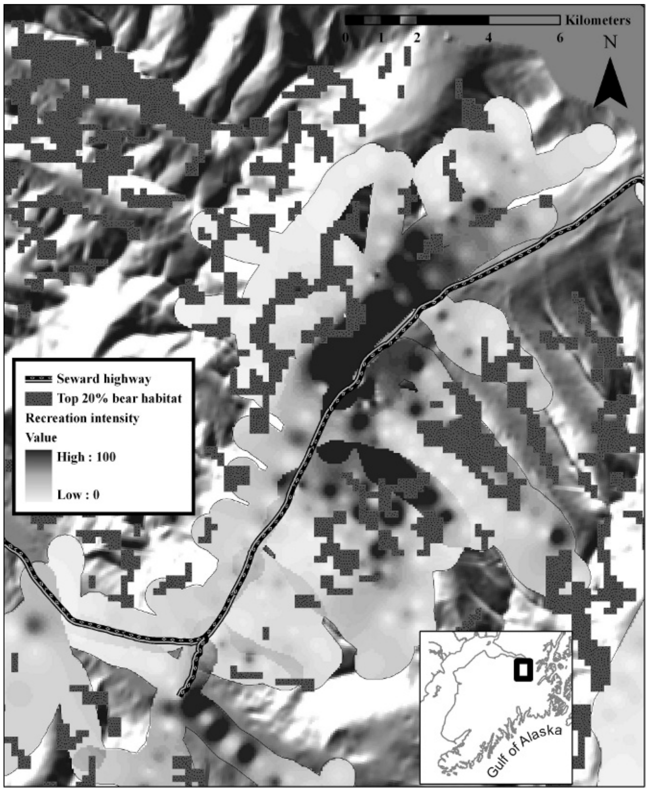

Figure 4. The distribution of brown bear habitat, 1995–2003, and its overlap with recreation intensity, 2004–2005, in the vicinity of Turnagain Pass on the Kenai Peninsula, Alaska, USA.

relatively low. Given little direct overlap, the greatest potential for disturbance from snowmobiles may come from noise in the vicinity of slopes used by denning bears (Andersen and Aars 2008). However, this has not been specifically addressed on the Kenai. Assuming disturbance potential is greatest in high-intensity use areas, research efforts investigating disturbance questions could be implemented in the Turnagain Pass area, which supports high-intensity use by motorized and nonmotorized recreation in separate management areas.

Given that we detected approximately 10 times the amount of terrain tracked by snowmobile versus nonmotorized (ski and snowshoe) activity during flight surveys, we were surprised that nonmotorized recreation overlapped high-quality brown bear den habitat more than motorized recreation. This was true in both total area and proportion of overlap. We found approximately twice as much habitat overlapped by ski and snowshoe activity in the high-intensity class than in the other 2 use-classes, which suggested a greater likelihood of direct overlap among alpine skiers, snowshoers, and bear dens, a logical conclusion based on the preference of bears for mid-slope den locations typical of brown bears elsewhere (e.g., Judd et al. 1986). This finding may or may not be significant. Based on the low density of dens on the landscape and the small likelihood of direct interaction with the den site by winter recreation users, it is reasonable to assume that the noise from nearby snowmobile activity may have greater potential for disturbance effect (Elowe and Dodge 1989, Andersen and Aars 2008) than noise from skiers. However, if alpine skiers and snowshoers go in groups, take dogs, or winter camp, they may disturb denning bears. In consideration of our findings, we recommend measurement of those types of effects.

MANAGEMENT IMPLICATIONS

Female brown bears generally denned in isolated sites on steep slopes; this potentially overlapped with terrain selected by backcountry skiers more than any other user group. Because skiers require foot-power from access points, unless additional access is provided, total overlap of this type of recreation with high-quality den habitat will be minimal and localized. However, if use disperses further into remote areas as a result of aircraft-supported access or the addition of backcountry facilities (e.g., lodges accessible by snow cats or railroad), then overlap of backcountry ski use with den habitat will likely increase faster than increases in overlap associated with snowmobiles. Efforts to maintain the suitability of den habitat for brown bears should include a careful evaluation of the impacts of nonmotorized user groups (Goodrich and Berger 1994) as well as motorized use.

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LITERATURE CITED

Alaska Department of Fish and Game [ADF&G]. 1998. Catalog of waters important for spawning, rearing or migration of anadromous fishes. Alaska Department of Fish and Game, Juneau, USA.

Andersen, M., and J. Aars. 2008. Short-term behavioural response of polar bears (*Ursus maritimus*) to snowmobile disturbance. Polar Biology 31:501–507.

Apps, C. D., B. N. McLellan, J. G. Woods, and M. F. Proctor. 2004. Estimating grizzly bear distribution and abundance relative to habitat and human influence. Journal of Wildlife Management 68:138–152.

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

Camp, J. 2001. 2000 situations and prospects of the Kenai Peninsula Borough. Kenai Peninsula Borough, Community Economic Development Division, Soldotna, Alaska, USA.

Craighead, F. C., and J. J. Craighead. 1972. Grizzly bear prehibernation and denning activities as determined by radio-tracking. Wildlife Monographs 32.

Del Frate, G. G. 1999. Units 7 and 15 brown bear. Pages 55–65 *in* M. Hicks, editor. Management report of survey and inventory activities 1 July 1996–30 June 1998. Federal Aid in Wildlife Restoration Project W-24-5 and W-27-1, Study 4.0. Alaska Department of Fish and Game, Juneau, USA.

Ducks Unlimited and Spatial Solutions. 1999. Kenai Peninsula earth cover classification users guide. Project no. AK-0033-001 and AK-0033-002. Ducks Unlimited, Rancho Cordova, California, USA.

Elfström, M., J. E. Swenson, and J. P. Ball. 2008. Selection of denning habitats by Scandinavian brown bears *Ursus arctos*. Wildlife Biology 14:176–187.

Elowe, K. D., and W. E. Dodge. 1989. Factors affecting black bear reproductive success and cub survival. Journal of Wildlife Management 53:962–968.

Erickson, W. P., T. L. McDonald, K. G. Gerow, S. Howlin, and J. W. Kern. 2001. Statistical issues in resource selection studied with radio-marked animals. Pages 209–242 *in* J. J. Millspaugh and J. M. Marzluff, editors. Radio tracking and animal populations. Academic Press, San Diego, California, USA.

Fielding, A. L., and J. F. Bell. 1997. A review of methods for assessment of prediction errors in conservation presence/absence models. Environmental Conservation 24:38–49.

Gaines, W. L. 2003. Black bear, *Ursus americanus*, denning chronology and den site selection in the northeastern cascades of Washington. Canadian Field-Naturalist 117:626–633.

Garcia, P., J. Lastra, J. Marquínez, and C. Nores. 2007. Detailed model of shelter areas for the Cantabrian brown bear. Ecological Informatics 2:297–307.

Gimblett, R., M. Richards, and R. Itami. 2001. RBSim: geographic simulation of wilderness recreation behavior. Journal of Forestry 99:36–42.

Goodrich, J. M., and J. Berger. 1994. Winter recreation and hibernating black bears *Ursus americanus*. Biological Conservation 67:105–110.

Graves, T. A., S. Farley, M. I. Goldstein, and C. Servheen. 2007. Identification of functional corridors with movement characteristics of brown bears on the Kenai Peninsula, Alaska. Landscape Ecology 22:765–772.

Graves, T. A., S. Farley, and C. Servheen. 2006. Frequency and distribution of highway crossings by Kenai Peninsula brown bears. Wildlife Society Bulletin 34:800–808.

Groff, C., A. Caliari, E. Dorigatti, and A. Gozzi. 1998. Selection of denning caves by brown bears in Trentino, Italy. International Conference on Bear Research and Management 10:275–279.

Huston, M., D. DeAngelis, and W. Post. 1988. New computer models unify ecological theory. BioScience 38:682–691.

Huygens, O., M. Goto, S. Izumiyama, H. Hayashi, and T. Yoshida. 2001. Denning ecology of two populations of Asiatic black bears in Nagano Prefecture, Japan. Mammalia 65:417–428.

Johnson, C. J., S. E. Nielsen, E. H. Merril, T. L. McDonald, and M. S. Boyce. 2006. Resource selection functions based on use–availability data: theoretical motivation and evaluation methods. Journal of Wildlife Management 70:347–357.

Judd, S. L., R. R. Knight, and B. M. Blanchard. 1986. Denning of grizzly bears in the Yellowstone National Park area. International Conference on Bear Research and Management 6:111–117.

Keating, K. A., P. J. P. Gogan, J. M. Vore, and L. R. Irby. 2007. A simple solar radiation index for wildlife habitat studies. Journal of Wildlife Management 71:1344–1348.

Lindzey, F. G., and E. C. Meslow. 1976. Characteristics of black bear dens on Long Island, Washington. Northwest Science 50:236–242.

Linnell, J. D. C., J. E. Swenson, R. Andersen, and B. Barnes. 2000. How vulnerable are denning bears to disturbance? Wildlife Society Bulletin 28:400–413.

Manly, B. J. F. 1997. Randomization, bootstrap and Monte Carlo methods in biology. Second edition. Chapman and Hall, London, United Kingdom.

Manly, B. J. F., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Kluwer Academic, Norwell, Massachusetts, USA.

Mattson, D. J., S. Herrero, R. G. Wright, and C. M. Pease. 1996. Science and management of Rocky Mountain grizzly bears. Conservation Biology 10:1013–1025.

McLellan, B. N. 1998. Maintaining viability of brown bears along the southern fringe of their distribution. Ursus 10:607–611.

Mech, L. D. 1983. A handbook of animal radio-tracking. University of Minnesota Press, Minneapolis, USA.

Miller, S. D. 1990. Denning ecology of brown bears in southcentral Alaska and comparisons with a sympatric black bear population. International Conference on Bear Research and Management 8:279–287.

Mitchell, F. S., D. P. Onorato, E. C. Hellgren, J. R. Skiles, Jr., and L. A. Harveson. 2005. Winter ecology of American black bears in a desert montane island. Wildlife Society Bulletin 33:164–171.

Neter, J., W. Wasserman, and M. H. Kutner. 1985. Applied linear statistical models: regression, analysis of variance, and experimental designs. Second edition. Richard D. Irwin, Homewood, Illinois, USA.

Petram, W., F. Knauer, and P. Kaczensky. 2004. Human influence on the choice of winter dens by European brown bears in Slovenia. Biological Conservation 119:129–136.

Podruzny, S. R., S. Cherry, C. C. Schwartz, and L. A. Landenburger. 2002. Grizzly bear denning and potential conflict areas in the greater Yellowstone ecosystem. Ursus 13:19–28.

Poe, A. J., R. H. Gimblett, M. I. Goldstein, and P. Guertin. 2006. Evaluating spatiotemporal interactions between winter recreation and wildlife using agent-based simulation modeling on the Kenai Peninsula, Alaska. Pages 311–312 *in* D. Siegrist, C. Clivaz, M. Hunziker, and S. Iten, editors. Exploring the nature of management. Proceedings of the Third International Conference on Monitoring and Management of Visitor Flows in Recreational and Protected Areas. University of Applied Sciences, Rapperswil, Switzerland. <http://www.wsl.ch/mmv-3/call/MMV3_proceedings.pdf>. Accessed 14 Aug 2009.

Reynolds, H. V., J. A. Curatolo, and R. Quimby. 1974. Denning ecology of grizzly bears in northeastern Alaska. International Conference of Bear Research and Management 3:403–409.

Reynolds-Hogland, M. J., M. S. Mitchell, R. A. Powell, and D. C. Brown. 2007. Selection of den sites by black bears in the Southern Appalachians. Journal of Mammalogy 88:1062–1073.

Schoen, J. W., L. R. Beier, J. W. Lentfer, and L. J. Johnson. 1987. Denning ecology of brown bears on Admiralty and Chichagof Islands. International Conference on Bear Research and Management 7:293–304.

Schwartz, C. C., and S. M. Arthur. 1997. Cumulative effects model verification, sustained yield estimation, and population viability management of the Kenai Peninsula, Alaska brown bear. Federal Aid in Wildlife Restoration Study 4.27. Alaska Department of Fish and Game, Juneau, USA.

Schwarz, G. E. 1978. Estimating the dimension of a model. Annals of Statistics 6:461–464.

Smith, M. E., J. L. Hechtel, and E. H. Follmann. 1994. Black bear denning ecology in Interior Alaska. International Conference on Bear Research and Management 9:513–522.

Stephens, P. A., S. W. Buskirk, G. D. Hayward, and C. Martínez del Rio. 2005. Information theory and hypothesis testing: a call for pluralism. Journal of Applied Ecology 42:4–12.

Suring, L. H., K. R. Barber, C. C. Schwartz, T. N. Bailey, W. C. Shuster, and M. D. Tetreau. 1998. Analysis of cumulative effects on brown bears on the Kenai Peninsula, south-central Alaska. Ursus 10:107–117.

Suring, L. H., and G. Del Frate. 2002. Spatial analysis of locations of brown bears killed in defense of life or property on the Kenai Peninsula, Alaska, USA. Ursus 13:237–245.

Suring, L. H., S. D. Farley, G. V. Hilderbrand, M. I. Goldstein, S. Howlin, and W. P. Erickson. 2006. Patterns of landscape use by female brown bears on the Kenai Peninsula, Alaska. Journal of Wildlife Management 70:1580–1587.

United States Department of Agriculture Forest Service [USDA FS]. 2002. Final environmental impact statement: Chugach National Forest land management plan revision. U.S. Department of Agriculture Forest Service, Alaska Region R10-MB-480d, Chugach National Forest, Anchorage, USA.

Van Daele, L. J., V. G. Barnes, Jr., and R. B. Smith. 1990. Denning characteristics of brown bears on Kodiak Island, Alaska. International Conference on Bear Research and Management 8:257–267.

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