Wildlife Biology 2017: wlb.00277
doi: 10.2981/wlb.00277

Subject Editor and Editor-in-Chief: Ilse Storch. Accepted 4 October 2016

Mountain goat resource selection in relation to mining-related disturbance

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Industrial development can have important direct and indirect effects on wildlife populations. Resource selection function (RSF) modeling provides a powerful tool for assessing the effects of industrial development on spatial use patterns of wildlife. Among North American large mammal species, mountain goats *Oreamnos americanus* are particularly sensitive to human disturbance. In this study mountain goat seasonal resource selection patterns were examined using GPS radio collar (n = 79 individuals) and remote sensing data in a GIS framework across a 491 km^2 regional mountain range in southeast Alaska, 2005–2015. The resulting global RSF model was then applied across a limited spatial extent centered on an industrial mining site in order to assess whether mining activity altered expected spatial use patterns at different distances from the mine. Using a quasi treatment–control experimental framework we examined the occurrence of spatially explicit mine disturbance thresholds. In general, resource selection modeling indicated that mountain goats selected for steep, rugged terrain in close proximity to cliffs in areas with high solar exposure; and they selected for lower elevations in winter than in summer. Mountain goat selection for rugged terrain and proximity to cliffs was stronger in winter than summer. RSF model applications indicated that mountain goat use of predicted habitat in close proximity to the mine was lower than expected at distances up to 1800 m in winter and 1000 m in summer. Because lower elevation winter habitat is closer to mining activity than summer habitat, a greater percentage (42%) of winter habitat within the analysis area was affected by mining activity. The resulting net loss of functional winter habitat carrying capacity is likely to have long-term negative implications for the local mountain goat population. In places where mining is proposed, development should avoid areas within 1800 m of mountain goat winter habitat. In places where mining is already occurring within disturbance thresholds (such as this study), long-term monitoring and more detailed field studies should be conducted to more fully understand population-level consequences of disturbance and identify practicable mitigation measures that have a high probability of success.

Industrial development can have important direct and indirect effects on wildlife populations (Joslin 1986, Berger and Daneke 1988, McDonald and McDonald 2002, Hurley 2004, Sawyer et al. 2006, Ciuti et al. 2012, Northrup et al. 2015, Cristescu et al. 2016). Although direct mortality associated with industrial development is a concern, indirect effects are likely to be more widespread even if more difficult to detect analytically. In this context, Frid and Dill (2002) provide a useful conceptual framework to address indirect disturbance related effects. Specifically, they suggested that disturbance can be viewed as a form of predation risk. Similar to the "landscape of fear" concept (Laundre et al. 2001, 2010), spatial variation in disturbance can be expected to alter selection pressure, individual fitness and population dynamics. Consequently, understanding how human and industrial disturbance alter animal behavior and resource use across a given landscape can provide important insights about anthropogenic effects on wildlife populations as well as the appropriate management responses to such threats.

Resource selection modeling provides a powerful tool for assessing the effects of industrial development on spatial use patterns of wildlife (McDonald and McDonald 2002, Northrup et al. 2015, Cristescu et al. 2016). Resource selection function (RSF) models integrate information about use and availability of ecologically relevant habitat characteristics in order to quantitatively predict the relative probability of use across a given landscape. Such models are based on ecological theory and posit that animals distribute themselves across a given landscape in ways that maximize their fitness (Sutherland 1996). Thus, RSF modeling provides a robust framework for describing habitat-use relationships and distribution of important habitats in natural and human-altered environments.

Among North American large mammal species, mountain goats *Oreamnos americanus* are particularly sensitive to human disturbance (Côté 1996). Previous studies have documented negative effects of human and industrial disturbance on mountain goat foraging behavior, movement patterns and population dynamics (Foster and Rahs 1983, Joslin 1986, Côté 1996, Goldstein et al. 2005, Côté et al. 2013, St-Louis et al. 2013, Richard and Côté 2016). In this context carefully understanding and, potentially, mitigating human and industrial disturbance in areas inhabited by mountain goats is important for ensuring sustainable mountain goat populations. Nonetheless, significant threats associated with industrial development exist throughout the range of the species (Festa-Bianchet and Côté 2008) and, in many cases, knowledge is lacking to adequately predict site- and context-specific responses needed to inform decision making.

In this study we examined mountain goat seasonal resource selection patterns using GPS radio collar and remote sensing data in a GIS framework across a 491 km^2 regional mountain range in southeast Alaska. We then applied the resulting global RSF model across a limited spatial extent centered on an industrial mining site to assess whether mining activity altered expected spatial use patterns across a continuum of different distances from the mine. Using a quasi treatment–control experimental framework we examined the occurrence of spatially explicit mine disturbance thresholds to provide guidance for future management, monitoring and mitigation. Overall, the intent of the study was to test the hypothesis that mountain goat resource selection is altered by proximity to industrial disturbance, and that effect distance thresholds exist and correspond to previously described thresholds for comparable types of disturbance (sensu Côté 1996, Goldstein et al. 2005, Côté et al. 2013).

Study area

Mountain goats were studied in a 491 km^2 area located in a mainland coastal mountain range east of Lynn Canal, a marine fjord located between Juneau and Haines in southeast Alaska (Fig. 1). The study area was located in the Kakuhan Range oriented along a north–south axis and bordered on the south by Berners Bay (58°76′N, 135°00′W) and on the north by the Katzehin River (59°27′N, 135°14′W). Approximately 300–600 mountain goats inhabited the study area (2005–2011; White et al. 2012b). Mountain goats in this area migrate seasonally between alpine habitats in summer and lower elevation forested sites in winter (White 2006, White et al. 2012b).

The Kensington Mine, a hard rock gold mine, is located at the southern end of the study area, immediately south of Lions Head Mountain in the Johnson, Slate and Sherman creek watersheds. A majority of aboveground mining activity occurs in four principal locations situated between 200–300 m a.s.l.. The overall mine 'footprint' comprises 56.6 km^2 of patented claims; a significant amount of activity is at low elevation (< 300 m) and underground. This study occurred during both the construction and production phases of the mine and possible sources of disturbance to mountain goats in the vicinity included blasting, heavy equipment operation, helicopter operation and vehicle traffic. Mining activity occurred during all months of the year, though exploration activity was more frequent during late-spring and summer.

Elevation within the study area ranges from sea level to 2070 m. This area is an active glacial terrain underlain by late cretaceous–paleocene granodiorite and tonalite geologic formations (Stowell 2006). Specifically, it is a geologically young, dynamic and unstable landscape that harbors a matrix of perennial snowfields and small glaciers at high elevations (i.e. > 1200 m) and rugged, broken terrain that descends to a rocky, tidewater coastline. The northern boundary of the area is defined by the Katzehin River, a moderate volume (~1500 cfs; USGS, unpubl.) glacial river system, and apparent barrier to mountain goat movement (White et al. 2012b), that is fed by the Meade Glacier, a branch of the Juneau Icefield.

The maritime climate in this area is characterized by cool, wet summers and relatively mild snowy winters. Annual precipitation at sea level averages 1.4 m and winter temperatures are rarely less than –15°C and average –1°C (Haines, AK; National Weather Service, Juneau, AK, unpubl.). Elevations at 790 m typically receive ~6.3 m of snowfall, annually (Eaglecrest Ski Area, Juneau, AK, unpubl.). Predominant vegetative communities occurring at low-moderate elevations (< 460 m) include Sitka spruce *Picea sitchensis* – western hemlock *Tsuga heterophylla* coniferous forest, mixed conifer muskeg and deciduous riparian forests. Mountain hemlock *Tsuga mertensiana* dominated 'krummholtz' forest comprises a subalpine timberline band occupying elevations between ~460–760 m. Alpine plant communities are composed of a mosaic of relatively dry ericaceous heathlands and moist meadows dominated by sedges, forbs and wet fens. Avalanche chutes are common in the study area and bisect all plant community types and often terminate at sea level.

Methods

Mountain goat capture

Mountain goats were captured using standard helicopter darting techniques and immobilized by injecting 2.4–3.0 mg of carfentanil citrate, depending on sex and time of year (Taylor 2000), via projectile syringe fired from a Palmer dart gun (Cap-Chur, Douglasville, GA). During handling, all animals were carefully examined and monitored following standard veterinary procedures (Taylor 2000) and routine biological samples and morphological data were collected. Following handling procedures, the effects of the immobilizing agent were reversed with 100 mg of naltrexone hydrochloride per 1 mg of carfentanil citrate (Taylor 2000, White et al. 2012b). The State of Alaska Animal Care and Use Committee approved all capture procedures.

GPS data

Telonics TGW-3590 and TGW-4590 GPS radio collars (1.4 kg; Telonics, Inc., Mesa, AZ) were deployed on most animals captured. GPS radio collars were programmed to collect location data at 6-h intervals (collar lifetime: 2–3 years). Complete datasets for each individual were remotely

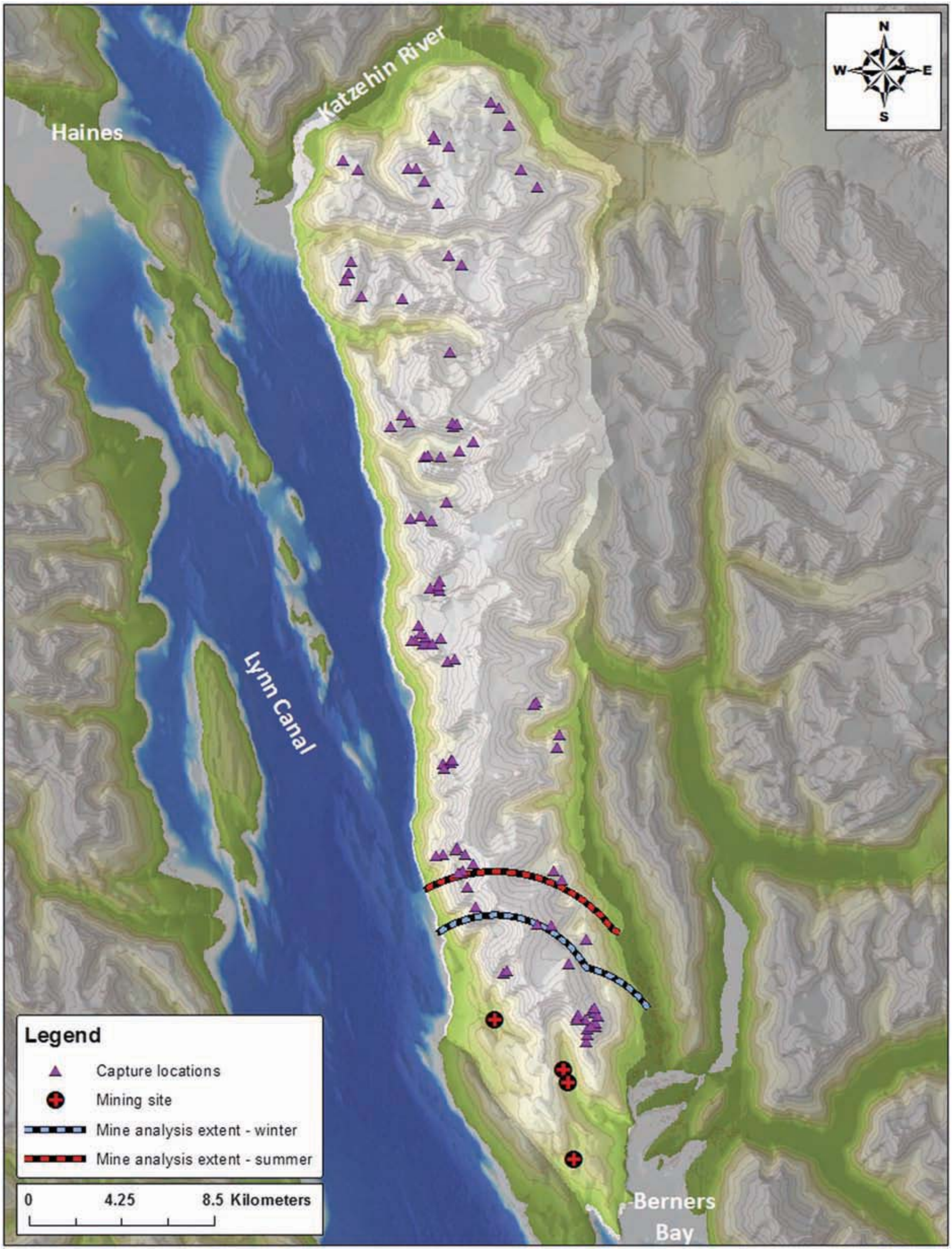


Figure 1. Map depicting the geographical extent of the study area used to develop the 'global' summer and winter RSF models, Lynn Canal, AK. The light blue and red lines delineate the winter and summer extents used in the mine proximity analyses (based on the 95th percentile movement distances of mountain goats that spatially overlapped with the mine). The purple triangles indicate the mountain goat capture locations, and the red crosses depict mine activity sites.

downloaded (via fixed-wing aircraft) at 8-week intervals or downloaded manually following collar release. Location data were post-processed and filtered for 'impossible' points and 2D locations with PDOP (i.e. position dilution of precision) values greater than 10, following D'Eon et al. (2002) and D'Eon and Delparte (2005).

RSF model development

Resource selection function (RSF) models (i.e. Boyce et al. 2002) were developed using mountain goat GPS location data and remote sensing covariate data layers in a GIS framework in order to describe ecological relationships and identify where important seasonal habitats occurred in the study area. Mountain goat resource selection was analyzed separately for the winter (15 December–14 April) and summer (15 June–30 September) seasons, based on previously described differences in seasonal altitudinal distribution (White 2006, White et al. 2012b).

A resource selection function can be defined as: a model that yields values proportional to the probability of use of a given resource unit (Boyce et al. 2002). Specifically, we employed a logistic regression-based 'used' versus 'available' study design to estimate resource selection patterns at the population-level (i.e. first-order selection, Johnson 1980). In order to estimate resource availability in the study area, we randomly selected locations throughout the study area at a density of 100 locations per km^2, a density determined to reliably describe resource availability patterns in our study area based on simulation analyses (sensu Northrup et al. 2013). The study area was geographically defined by the Kakuhan Range, and based on seasonal and annual movement distances and spatial deployment of GPS radio-collars; each pixel in the study area could have been encountered and selected by mountain goats. Mountain goat GPS locations (i.e. 'used') and 'available' locations were then intersected (using GIS) with a suite of biologically relevant remote sensing data layers (Table 1). Vegetative covariates were not used because: 1) existing landcover maps did not have adequate resolution and accuracy and, 2) the terrain variables considered previously enabled development of highly predictive RSF models (White et al. 2012a). We examined correlations between all covariate combinations ($r > 0.7$) and only used covariates in model that were not correlated. These data were then analyzed using logistic regression (GLM function, stats package, program R, ver. 2.13.1 <www.r-project.org>) to derive selection coefficients for each covariate by individual animal. With the exception of the 'distance to cliffs' variable both linear and quadratic terms were used to describe selection functions for each variable.

Table 1. Variables used for modeling mountain goat resource selection, Lynn Canal, southeast Alaska.

Variable[1]	Definition
Elevation	elevation (m)
Slope	slope (degrees)
Distance to escape terrain	distance to areas with slope > 50 degrees
Solar radiation (1 Jan)[2]	solar radiation calculated for 1 January
Solar radiation (1 Aug)[2]	solar radiation calculated for 1 August
VRM[3]	vector ruggedness measure

[1]Variables were standardized for by subtracting the mean and dividing by the standard deviation: elevation, $y = (x - 805.2831)/459.3702$; slope, $y = (x - 27.4894)/14.9201$; distance to escape terrain, $y = (x - 175.3112)/195.2089$; solar radiation (1 Jan), $y = (x - 12.7190)/9.4410$; solar radiation (1 Aug), $y = (x - 3742.861)/900.9018$; VRM, $y = (x - 0.0188)/0.0243$.
[2]Calculated using the solar radiation algorithm in ArcGIS 10 (Fu and Rich 2002).
[3]Calculated using methods described in Sappington et al. (2007).

The median inter-individual coefficient value (and confidence interval) was computed for each covariate (i.e. the "two-stage" modeling framework; Fieberg et al. 2010) and stratified by season (winter versus summer). The median coefficient values were used because they are more robust to skewness in inter-individual coefficient value distributions than mean values. Covariates were considered significant if confidence intervals did not overlap zero. Significant coefficient values were then multiplied by respective covariate remote sensing data layers in GIS using the following equation:

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n) \quad (1)$$

Where, w(x) represents a resource selection function (RSF) that is proportional to the probability of use of variables $x_1 + x_2 + \dots + x_n$. The resulting output was then used to generate a continuous raster surface representing relative probability of mountain goat use across the landscape. In addition, we calculated the contrast validation index (CVI; Hirzel et al. 2006, Fedy et al. 2014) in order to objectively identify important mountain goat habitat. The CVI method employs an optimization routine to generate a binary classification that maps the area containing the greatest number of use locations in the smallest footprint of predicted habitat. The predictive performance of RSF models was validated using k-fold cross validation (Boyce et al. 2002).

Mine proximity analysis

If an RSF model is robust (i.e. as determined via k-fold cross-validation) then the amount of mountain goat use should be positively correlated with the RSF value within a given spatial extent. Thus, to examine the effects of mine activity on mountain goat resource selection patterns, we divided the proportion of mountain goat GPS locations ('observed') by the expected proportional use ('expected') within buffers spaced at 200 m intervals from mining activity sites. The areal footprint of the four mining activity sites varied between 7.7–2.6 ha and were considered to be generally indicative of point sources of consistent, intense mining related activity; roads were not considered since disturbance was intermittent, spatially variable and difficult to accurately index. Calculation of buffer-specific selection ratios (i.e. observed/expected) allowed for assessment of the extent to which mountain goats selected predicted habitat at different distances from the mine. This analysis assumes that mountain goats will select resources similarly in all areas, but that access, or use, of resources was altered by proximity to the mine. As described above, predicted habitat represents the additive relative probability of use of multiple independent variables, conditional on the terrain characteristics (i.e. elevation, distance to escape terrain, etc.) within a given 5-m^2 pixel. Thus, our analysis focused on examining whether mine proximity alters expected proportional use of habitat patches rather than testing whether selection functions for given independent variables vary with respect to mine proximity. While the latter subject can be informative (i.e. Cristescu et al. 2016) it was not the focus of our analyses.

Observed use was calculated by dividing the number of GPS locations within each buffer by the total number of locations in all buffers (maximum buffer extent was based on the 95% percentile of all locations in proximity to the mine; i.e. 4800 m and 6800 m for winter and summer, respectively). Expected proportional use was based on the RSF volume within each buffer divided by total RSF volume of all buffers, weighted by the simulated random distribution of GPS locations across the analysis area (i.e. to account for spatial displacement of the mine and capture site locations; Supplementary material Appendix 1). (This approach is conceptually similar to previously described methods used to weight locations in RSF models based on habitat-specific GPS error probabilities, Wells et al. 2011, Webb et al. 2013). The resulting 'observed/expected' selection ratios were used to assess whether mountain goats used areas near the mine differently than areas further away (i.e. distances where mine effects would not be expected – a quasi 'treatment–control' framework). This approach also descriptively enabled detection of threshold distances of putative mine disturbance. Selection ratios within each buffer were then compared to the median selection ratio (for all buffers) to derive buffer-specific relative selection ratios, a potentially more intuitive metric for evaluating mountain goat response to mine developments. Thus, thresholds were defined as the distance at which selection ratios were no longer negative, relative to the median value for all distances from the mine.

Individual mountain goats selected for this analysis included only animals whose 95% percentile movement distances overlapped with mine development. This ensured that only animals that were potentially exposed to mine activity and inhabited areas within a distance approximate to the diameter of their home range were considered in analyses. (In practice, animals considered for the analysis were captured on ridges or alpine bowls immediately above the mine, or in close proximity – i.e. 2–4 km away). This approach also ensured that the distribution of animals and associated GPS locations were roughly homogenous throughout the analysis area, and that all animals considered for analysis would have access to suitable habitats both near and far from the mine.

Results

Mountain goat capture and handling

Mountain goats were captured during August–October 2005–2015. Overall, 118 animals were captured using standard helicopter darting methods; complete GPS location data sets were compiled from 79 individual animals (the remainder of animals were either deployed with VHF collars or GPS collars have not yet released).

Resource selection modeling

GPS location data collected from 70 individual animals (total locations = 49 141) were used to derive summer RSF models (Table 2). For winter modeling, GPS location data from 75 individual animals were used (total locations = 53 569) to develop RSF models (Table 2). These analyses included all mountain goats in the study area, irrespective of whether animals inhabited areas near the mine. Because the mine extent included a discrete geography, we felt our models would be more spatially robust if GPS location data collected from all animals were used to develop RSF models. We considered using models that included only animals that inhabited areas outside of the mining extent but determined that both data sets yielded nearly identical models (Supplementary material Appendix 2).

Overall, resource selection was modeled using five terrain variables (Table 1, 2). In general, mountain goat selection patterns for most terrain variables were different during winter and summer. Slope was the only variable for which seasonal selection patterns did not differ substantially; however, solar radiation metrics were not strictly comparable between seasons (Table 2). Overall, mountain goats selected for areas close to cliffs with moderately steep, rugged slopes that had moderate-high solar exposure. Within this context, mountain goats selected for low elevation areas during winter and moderate-high elevation areas during summer. Mountain goats selected for more rugged areas (i.e. high VRM values) and distances closer to cliffs during winter, as compared to summer. K-fold cross validation results indicated that resource selection models accurately predicted actual use patterns of GPS-marked mountain goats (Table 3).

Mine proximity analysis

To assess the relationship between distance to the mine and mountain goat selection patterns, we used GPS location data collected from 18 mountain goats in summer (total locations = 14 910) and 17 mountain goats in winter (total locations = 15 386; Fig. 2, 3). The analysis extent, as

Table 2. RSF model coefficients used for predicting mountain goat resource selection in Lynn Canal, southeast Alaska.

	Winter			Summer		
Model variable	Coefficient	LCI	UCI	Coefficient	LCI	UCI
Elevation	–7.513	–10.293	–6.399	1.290	0.859	1.988
Elevation^2	–3.248	–4.170	–2.639	–4.296	–4.797	–3.714
Distance to escape terrain	–3.332	–4.107	–2.732	–0.926	–1.144	–0.705
Slope	0.481	0.356	0.653	0.602	0.412	0.773
Slope^2	–0.243	–0.354	–0.154	–0.441	–0.515	–0.384
Solar radiation (1 Jan)	1.377	0.933	1.552	–	–	–
Solar radiation (1 Jan)^2	–0.901	–1.344	–0.516	–	–	–
Solar radiation (1 Aug)	–	–	–	0.344	0.253	0.442
Solar radiation (1 Aug)^2	–	–	–	–0.096	–0.182	–0.006
VRM	0.669	0.481	0.804	0.231	0.170	0.297
VRM^2	–0.251	–0.318	–0.203	–0.029	–0.066	–0.016

Table 3. K-fold cross-validation results describing predictive performance of summer and winter RSF models developed for predicting mountain goat resource selection in Lynn Canal, southeast Alaska.

	Winter		Summer	
Set	r_s	p-value	r_s	p-value
1	0.98	<0.01	1.00	<0.01
2	0.83	0.01	1.00	<0.01
3	0.99	<0.01	1.00	<0.01
4	0.84	<0.01	1.00	<0.01
5	1.00	<0.01	1.00	<0.01
Average[1]	1.00	<0.01	1.00	<0.01
Overall[2]	0.91	<0.01	0.98	<0.01

[1]Average = The mean expectation for each of 10 RSF quantile bins is compared to the mean observed in each bin across the five folds.
[2]Overall = The expectations for each of 10 RSF quantile bins is pooled across the five folds and compared to the pooled observations.

determined by the 95th percentile of mountain goat GPS locations, was 4800 m (from the mine) for winter and 6800 m for summer. As expected, mountain goats exhibited more constrained movement during winter than summer (White et al. 2012b). Mountain goat annual population estimates in a survey area (comprised of 19.9 km^2 of predicted summer habitat) surrounding the mine varied between 92 ± 14 and 27 ± 9 total animals during the period of study (White unpubl.). The population was in a declining phase (–15.2%/year) that was at least partially attributable a succession of severe winters; survey areas further north declined at greater rates however adjacent areas were stable (White unpubl.). The proportion of marked animals in the local population varied between 5% and 20% annually over the course of the study.

Visual examination of mapped GPS locations and predicted mountain goat winter habitat clearly reveals an absence of winter mountain goat GPS locations in habitat patches situated in close proximity to the mine (Fig. 2). Selection ratio analysis results provide more quantitative detail and indicate that selection ratios were lower than the median for all nine buffers between 0–1800 m from the mine (Fig. 4). In contrast at distances beyond 2000 m from the mine, selection ratios were above the median in 79% of the cases (11 of 14 buffers; Fig. 4). Consequently, the relative selection ratio analyses indicated that mountain goats were avoiding winter range habitats at distances up to a 1800 m threshold from mine activity centers.

Examination of summer habitat relationships indicated that selection ratios were consistently below the median for all five buffers between 0–1000 m from the mine (Fig. 5). Substantial variation (but of more limited amplitude) existed in selection ratios in the 18 buffers between 1200–4600 m from the mine (Fig. 5). However, selection ratios in all 11 buffers between 4800–6800 m from the mine were substantially larger than the median (Fig. 5). Thus, the results indicate that mountain goats tended to avoid summer habitats between 0 to1000 m from the mine, exhibited limited evidence for selection or avoidance of habitats at moderate distances, but strongly selected for habitats 4800–6800 m from the mine.

The CVI method enabled quantitative determination of important summer and winter habitats by defining RSF value cut-points that optimize the amount of observed locations within a minimum amount of area. The winter CVI analyses yielded a RSF cut-point value of 19.97 and included 85.5% of the observed mountain goat locations. The summer CVI analyses identified a RSF cut-point value of 0.16 and included 86.4% of mountain goat locations. Subsequent mapping of important habitat indicated that much less predicted summer habitat occurs in close proximity to the mine, as compared to winter habitat (Fig. 6). This occurs because mountain goats select for high elevation habitats in summer and lower elevation habitats in winter (Table 2). Thus, summer habitats are more spatially separated from the low elevation mining sites, as compared to winter habitats. For example, 327.6 ha of important winter habitat, and 45.7 ha of important summer habitat was predicted at distances between 0–1000 m from the mine.

In order to further examine mine effects on mountain goat habitat up to the 1800 m mine distance threshold, buffer-specific selection ratios were multiplied by the amount of predicted important habitat in each buffer to estimate the amount of habitat actually used and compared to the amount that was available. At distances between 0–1800 m from the mine, 694.5 ha of high value winter habitat was predicted yet only 0.4% (2.8 ha) of such habitat was actually used. For comparison, 642.6 ha of summer habitat were located within 1800 m, of which 69.9% (449.7 ha) were used.

Discussion

Mountain goat resource selection

Our analyses describe a strong affinity of mountain goats for areas with steep, rugged terrain in close proximity to cliffs, a pattern previously described for the species in southeastern Alaska (Fox et al. 1989, White et al. 2012a) and elsewhere (Festa-Bianchet and Côté 2008). In fact, terrain characteristics can be considered a key prerequisite for predicting mountain goat habitat, irrespective of season. However, during winter, mountain goat selection is further constrained to include lower elevation habitats that are typically vegetated with closed-canopy conifer forest. Such habitats have reduced snow depths (Kirchhoff and Schoen 1987) and thus greater forage availability (Fox 1983, White et al. 2009) and reduced costs of locomotion (Dailey and Hobbs 1989). Nonetheless, snow shedding characteristics of steep terrain also reduce snow depth resulting in use of non-forested habitats in some cases (particularly in low snow years or if sites are characterized by high solar radiation). In locations where steep terrain continuously extends from high elevation summer range to sea level, such as along Lynn Canal, mountain goats will winter at extremely low elevations, including on cliffs immediately above the high tide line.

Mountain goats selected more strongly for rugged terrain (high VRM) and distances closer to cliffs during winter, as compared to summer. The detection of these differences in resource selection patterns differs from an earlier RSF analyses conducted in this area (which did not detect seasonal differences in selection for VRM or distance to cliffs; White et al. 2012a). The primary difference between the two analyses relate to the resolution of the digital elevation

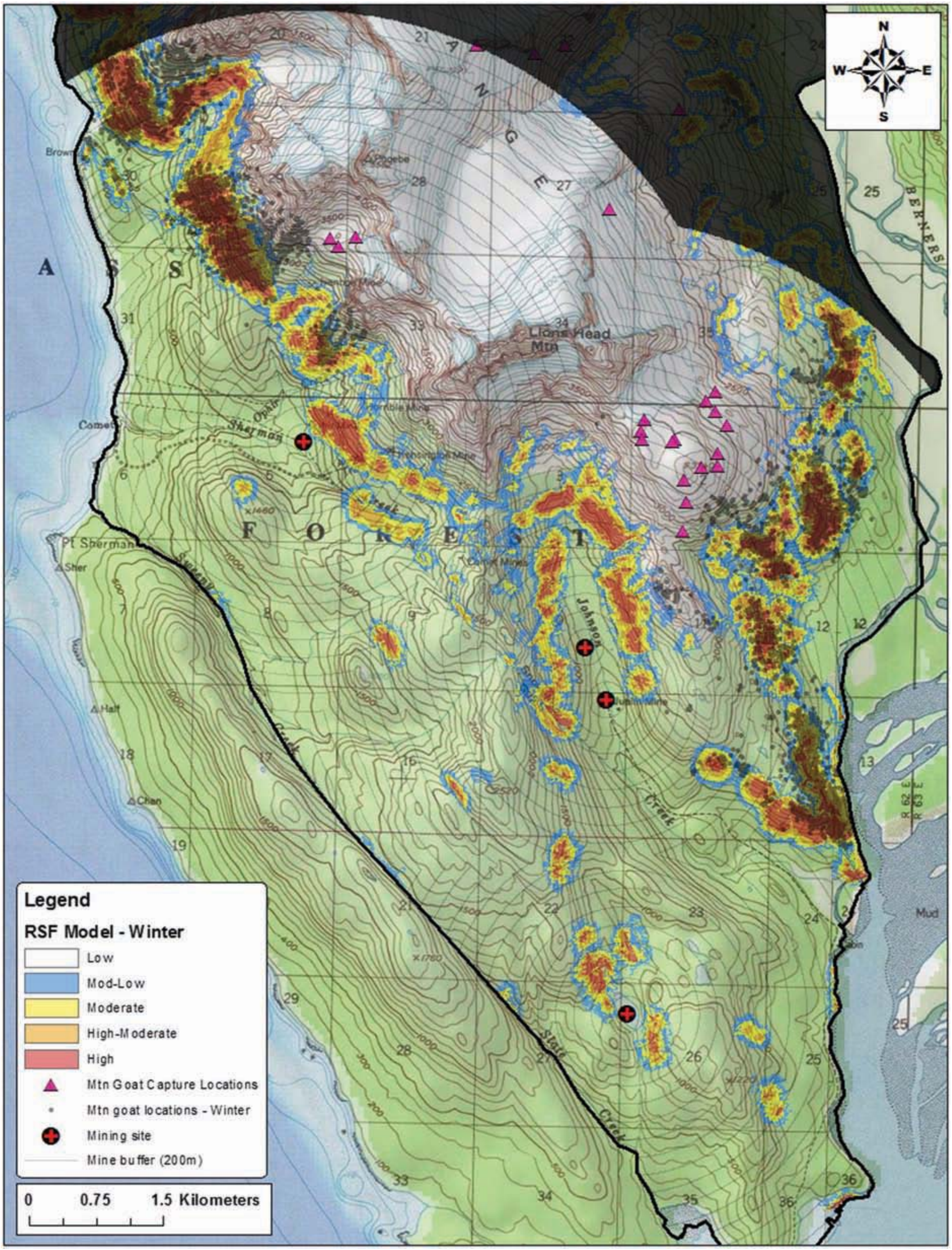


Figure 2. Map depicting mountain goat use of predicted winter habitat in the vicinity of the Kensington Mine, Lynn Canal, southeast Alaska. Winter mountain goat GPS locations (grey dots) and capture sites (purple triangles) are plotted along with mine activity centers (red crosses) and 200 m concentric buffers (grey lines). RSF model predictions, which describe the relative probability of use, are color-coded based on the quantile distribution of RSF scores.

model (DEM) used to develop the terrain variables used in RSF analyses. The White et al. (2012a) analyses used a 24 m pixel DEM (SRTM), whereas the current analysis used a substantially higher resolution 5 m pixel DEM (IfSAR). Thus, the higher resolution IfSAR DEM enabled detection of finer-scale patterns in selection than was possible with the

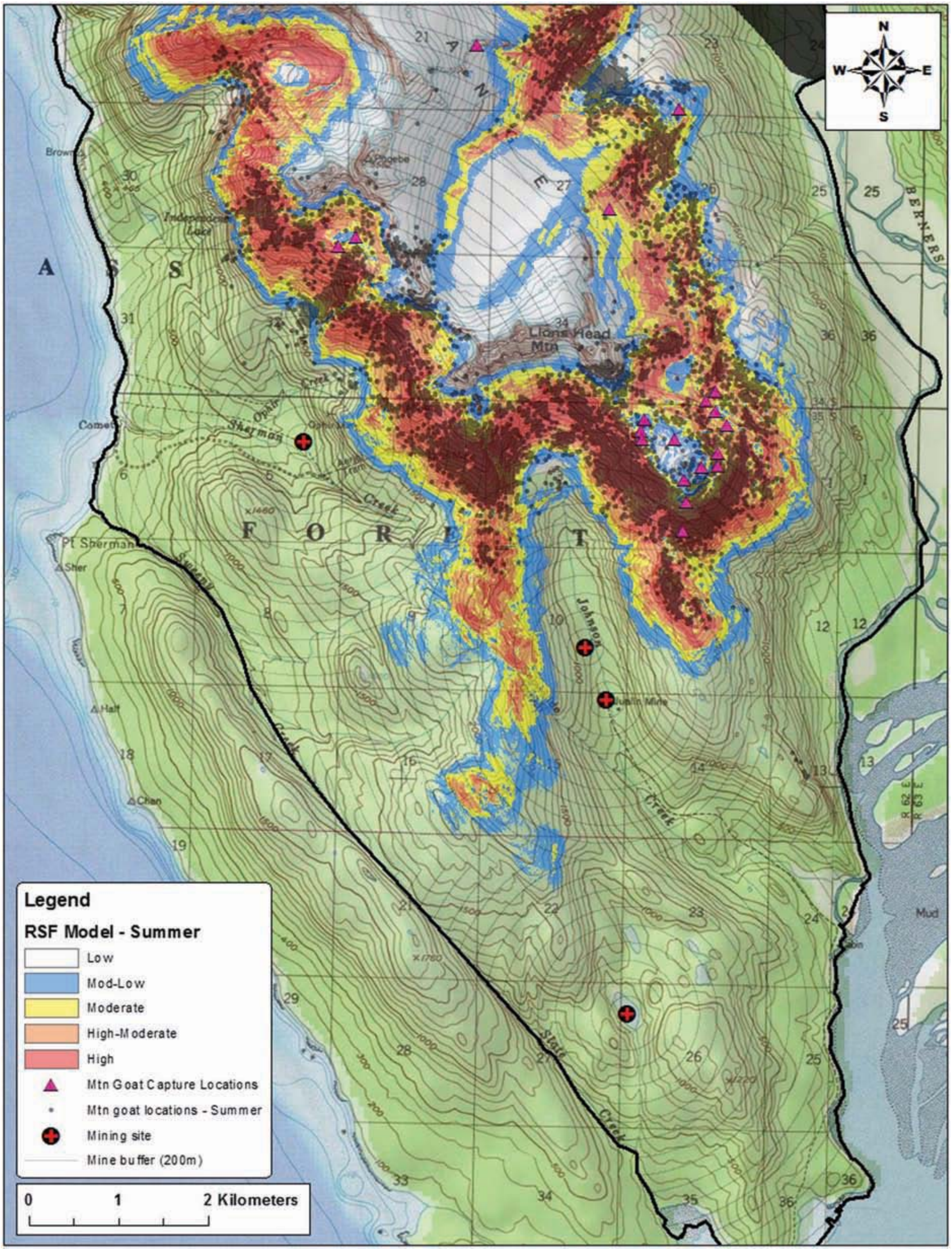


Figure 3. Map depicting mountain goat use of predicted summer habitat in the vicinity of the Kensington Mine, Lynn Canal, southeast Alaska. Summer mountain goat GPS locations (grey dots) and capture sites (purple triangles) are plotted along with mine activity centers (red crosses) and 200-m concentric buffers (grey lines). RSF model predictions, which describe the relative probability of use, are color-coded based on the quantile distribution of RSF scores.

coarser-grained SRTM DEM. Fine-scale seasonal variation in selection for habitat features associated with escape terrain suggest that the perceived risk of predation may be higher in winter than summer. Locomotory impedance caused by deep winter snow is likely to limit the ability of mountain goats to escape attacks by wolves and could exert strong

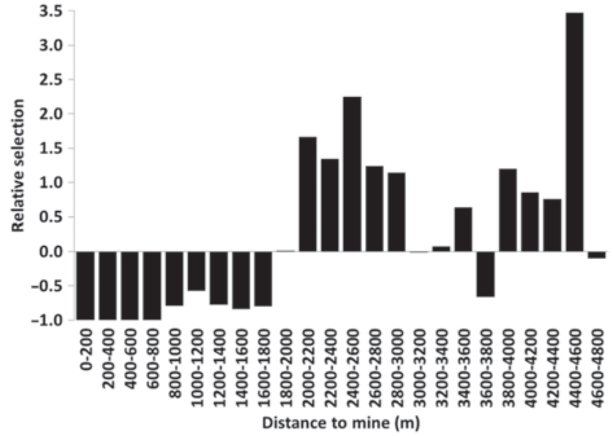


Figure 4. The relationship between winter mountain goat selection (i.e. observed/expected use), relative to median selection (0.69) for the analysis extent, and distance from the mine, calculated within concentric 200-m interval buffers radiating away from mine activity, Lynn Canal, southeast Alaska.

selection pressure for enhanced use of rugged habitats near cliffs, even if food resources are less available in such microsites. Whereas during summer, mountain goats may be able to stray farther from rugged terrain and cliffs to access a broader array of foraging sites and still avoid a net increase in predation-risk because they have increased mobility in snow-free conditions.

Mine proximity analyses

Our analyses indicate that mining activity altered mountain goat behavior and, specifically, selection of predicted winter and, to a lesser extent, summer habitat. In particular, mountain goat selection of wintering habitats within 1800 m of mining activity was substantially lower than expected. This finding is consistent with previous studies suggesting that mountain goats are sensitive to disturbance associated with helicopter overflights at distances up to 2000 m (Côté 1996, Goldstein et al. 2005, Côté et al. 2013). While helicopter overflights represent one type of disturbance associated with mining activity in our study area other potential types of disturbance include blasting, heavy equipment, and mill site machinery operation. Because blasting and mechanized human travel have also been documented to alter mountain goat behavior and population dynamics (Joslin 1986, St-Louis et al. 2013), it is unclear what types of disturbance were most relevant to the observed patterns of habitat avoidance. As such, we concluded that the cumulative disturbance associated with mining activity is responsible for the observed pattern. In the future, detailed efforts to link temporal and site specific disturbance factors to mountain goat movement patterns and habitat selection could provide a more detailed understanding of the effects of different types of disturbance and associated distance thresholds. Other factors capable of influencing mountain goat habitat selection patterns such as predator abundance or snow climate are unlikely to explain the observed pattern. Snow depth is unlikely to vary at such a small geographic scale (i.e. within 2000 m) and, due to “human shield” effects (sensu Berger 2007), predator activity is likely reduced in close proximity to mine and human activity.

Mountain goat habitat use within the 1800 m distance threshold is reduced to a greater extent during winter than summer (though summer habitat use was, on average, less than expected). Richard and Côté (2016) documented this pattern of increased aversion to habitats associated with human disturbance during winter, as compared to summer, in an Alberta mountain goat population. In that study, seasonal differences in mountain goat use of disturbed areas was

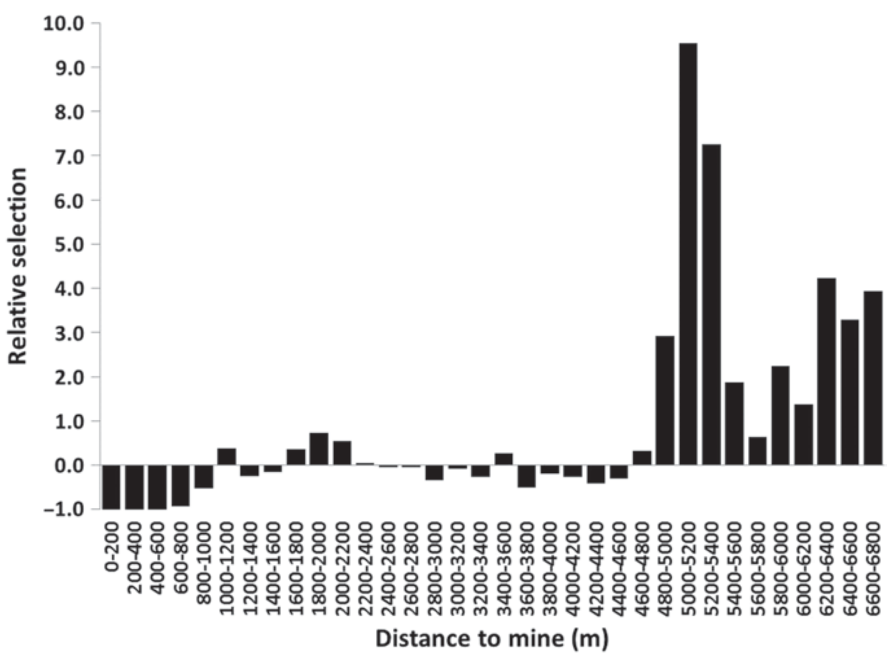


Figure 5. The relationship between summer mountain goat selection (i.e. observed/expected use), relative to median selection (0.72) for the analysis extent, and distance from the mine, calculated within concentric 200-m interval buffers radiating away from mine activity, Lynn Canal, southeast Alaska.

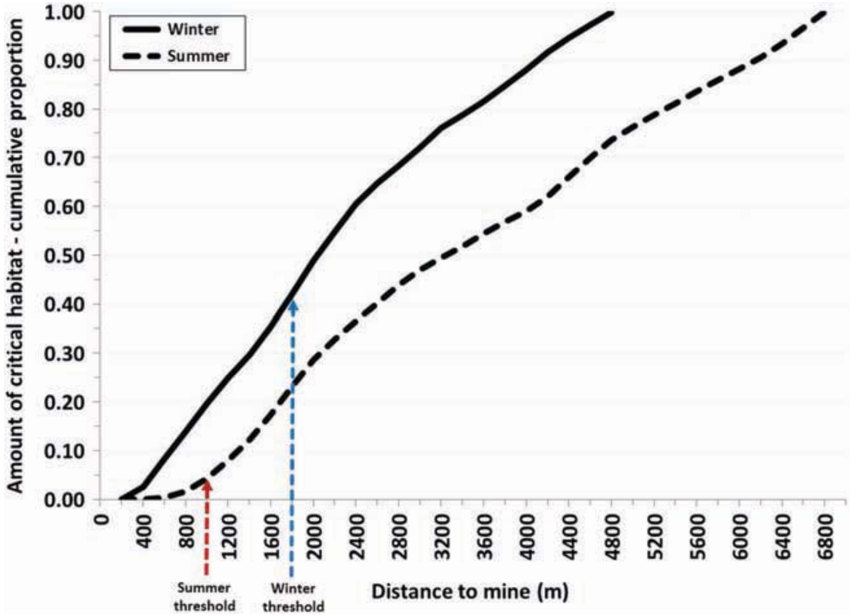


Figure 6. The relationship between cumulative proportion of winter and summer habitat, within 200-m buffers, and proximity to the Kensington Mine, Lynn Canal, southeast Alaska. Summer and winter disturbance thresholds are depicted and based on observed versus expected use of predicted habitat.

largely attributed to corresponding differences in the amount of activity during winter versus summer. However, in our study area mining activity does not exhibit a similar pattern of seasonal fluctuation. Instead, seasonal nutritional and energetic constraints are likely to be the key determinants of mountain goat response to mining activity in this study. During winter, mountain goats experience severe energetic and nutritional challenges associated with availability and quality of food resources and, perhaps more importantly, high costs of locomotion in deep snow (Fox 1983, Dailey and Hobbs 1989, Fox et al. 1989, White et al. 2009). Consequently, mountain goats exhibit an extremely conservative bioenergetic strategy during winter that is characterized by restricted movement (White 2006, Richard et al. 2014). Indeed, most mountain goat mortality occurs in late winter (White et al. 2011) and in our study area was most often associated with malnutrition (White et al. 2012b). Thus, mountain goats are expected to be less tolerant of habitats prone to disturbance during winter than they are in summer, given the high costs of moving away from acute disturbances during winter. This is coupled with the fact that the landscape position of mining activity in this study was in closer proximity to winter versus summer mountain goat habitat.

The spatial distribution and relative abundance of mountain goat habitat relative to mine proximity has important implications for the carrying capacity of local populations. Because of the severe nutritional and energetic constraints that occur during winter, mountain goat populations are generally considered to be limited by availability of winter habitat (Fox et al. 1989). Further, because of the more strict winter habitat selection patterns, as compared to those in summer, mountain goat winter habitat is less abundant across a given landscape. In this study, winter habitat was 1.7 times less abundant than summer habitat, as defined by CVI analyses. In addition, because available winter habitat occurs at lower elevation than summer habitat, it is closer to low elevation mining sites (Fig. 6). For example, the amount of habitat within 1000 m of the mine is about 7.2 times higher for winter (327.6 ha) than for summer (45.7 ha). When referenced with the previously described season-specific mine disturbance threshold distances, 42% of the overall winter habitat available to mountain goats in our analyses area was within the 1800 m winter disturbance threshold whereas only 1.6% of available summer habitat was within the 1000 m summer disturbance threshold (Fig. 6). Consequently, by negatively influencing use of available wintering habitats in close proximity to the mine, mining activity has putatively reduced the functional winter range carrying capacity for the local mountain goat population.

Previous studies have examined the "zone of influence" (ZOI) of industrial activity on northern ungulate populations, specifically caribou *Rangifer tarandus* (Polfus et al. 2011, Boulanger et al. 2012, Johnson and Russell 2014,). In comparison, ZOI effects on caribou appear to be larger than that described in this study for mountain goats. However, when considering the effects of the ZOI on functional loss of habitat for local populations as a result of industrial disturbance such effects are more pronounced from mountain goats relative to caribou. For example, in our study we describe a functional loss of 42% of winter range and 5% of summer range, as compared to 8 and 2% loss of high quality winter and summer habitat, respectively, for woodland caribou in northern Canada (Polfus et al. 2011). Such differences may relate to the differences in the spatial juxtaposition of industrial activities and habitat as well as home range size, fidelity and movement tendencies of the different species. To our knowledge, our analysis represents the first effort to examine ZOI in an alpine ungulate and highlights how species with highly specialized habitat requirements may be uniquely constrained by industrial disturbance.

Management implications and recommendations

Based on our analyses, industrial projects such as mining that involve blasting, heavy equipment operation and helicopter overflights should be situated at distances greater than 1800 m from mountain goat winter habitat in order to avoid impacts on local populations. However, given that mining activity is already occurring within 1800 m of a significant portion (42%) of the available winter range in our study area it is important to closely monitor demographic and other effects on the locally affected population. Mountain goats that had access to areas within the disturbance distance thresholds also ranged as far as 4800 m in winter and 6800 m in summer from the mine site. Thus, the 'disturbance shadow' extended a significant distance from the actual mining activities. Within this spatial extent we expect mining effects, such as the significant reduction of functional winter range carrying capacity, to have the most acute population level effects.

In general, factors influencing spatial and temporal patterns in carrying capacity such as winter snowfall may influence the extent to which spatially-linked disturbance effects alter population dynamics. During severe winters carrying capacity is reduced due to burial of food resources and increased costs of locomotion (Fox 1983, Dailey and Hobbs 1989, Fox et al. 1989, White et al. 2009). Under such conditions net reduction in functional winter range due to disturbance effects may be most significant and exacerbate energetic challenges associated with severe winter conditions. In this study, total winter snowfall during six of the last ten winters has been above average (National Weather Service, Juneau, Alaska). As a result, local and regional mountain goat populations have declined (White et al. 2012b) and highlight the consequences of severe winters and the frequency of which they can occur. Thus, considering interactions between natural variability in environmental conditions and disturbance effects is likely to be an important precondition for designing effective conservation strategies.

Initiation and maintenance of long-term monitoring programs in areas where industrial disturbance may be influencing wildlife is critical for understanding effects and designing effective mitigation strategies. In our study, continued utilization of high-resolution GPS location data can enable assessment of whether mountain goat use of wintering habitats within disturbance thresholds increases (i.e. habituation to mining disturbances) or decreases (i.e. sensitization) over time. Such data is also valuable for assessing whether currently affected wintering habitats are re-colonized once industrial disturbance activity ceases. Long-term data collection also allows for expanded analytical opportunities such as investigating whether use patterns and disturbance thresholds differ for males versus females or between mild versus severe winters. For example, larger sample sizes could allow for statistical assessment of whether females are more strongly affected by disturbances, than males – a likely scenario given previous observations of mountain goats (Festa-Bianchet and Côté 2008). Finally, compilation of spatial and temporal records relating to disturbance activities can offer more detailed insights into what types of disturbance are most relevant and provide opportunities to understand habitat use–disturbance relationships in more detail. For example, examination of movement responses to acute disturbances (sensu Cadsand 2012) could provide a deeper understanding of why animals do not use disturbed habitats to the extent expected.

Acknowledgements – The State of Alaska Department of Transportation and Public Facilities (DOT&PF), Federal Highway Administration (FHWA), and Coeur Alaska provided primary funding for this project. Additional funding was provided by the ADF&G and the U. S. Forest Service (USFS, Tongass National Forest). Reuben Yost (DOT&PF), Tim Haugh (FHWA), Carl Schrader (Department of Natural Resources), David Thomson (ADF&G), Jackie Timothy (ADF&G-DHR), Kate Kanouse (ADF&G-DHR), and Brian Logan (USFS) coordinated project funding. Kimberlee Beckmen, Lem Butler, Stephanie Crawford, John Crouse, Eran Hood, Jeff Jemison, Jamie King, Brian Lieb, Steve Lewis, Karin McCoy, Jeff Nichols, Dale Rabe, Chad Rice, Greg Snedgen, Peter Strow, Mike Van Note, Mark Battian and Jamie Womble assisted in field, lab and/or office work. Aaron Shafer conducted mountain goat genetic analyses and has contributed greatly to our understanding of the topic in the study area. Joe Northrup provided assistance and advice relative to resource selection modeling. Joe Northrup, Anthony Crupi, Tom Paul, Patti Harper, Ryan Scott, Kate Kanouse, and Rod Flynn provided helpful editorial comments. Fixed-wing survey flights were conducted by Lynn Bennett, Mark Morris, Jacques Norvell, Chuck Schroth, Pat Valkenburg, Doug Larsen, and Mark Pakila. Helicopter support was provided by Rey Madrid, Mitch Horton, Andy Hermansky, Eric Main, Christian Kolden, John Weeden (Temsco Helicopters) as well as Chuck Schroth (Fjord Flying Service). Coordination of ground activities and administrative support was provided by Peter Strow, Kevin Eppers, Clyde Gillespie, Frank Bergstrom and Al Gillan (Coeur Alaska) and Coastal Helicopters.

References

Berger, J. and Daneke, D. 1988. Effects of agricultural, industrial, and recreational expansion on frequency of wildlife law violations in the central Rocky Mountains, USA. – Conserv. Biol. 2: 283–289.

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

Boulanger, J. et al. 2012. Estimating the zone of influence of industrial developments on wildlife: a migratory caribou *Rangifer tarandus groenlandicus* and diamond mine case study. – Wildl. Biol. 18: 164–179.

Boyce, M. S. et al. 2002. Evaluating resource selection functions. – Ecol. Modell. 157: 281–300.

Cadsand, B. A. 2012. Responses of mountain goats to heliskiing activity: movements and resource selection. – MS thesis, Univ. of Northern British Columbia, Prince George, BC.

Ciuti, S. et al. 2012. Effects of humans on behavior of wildlife exceed those of natural predators in a landscape of fear. – PLoS ONE 7(11):e50611.

Côté, S. D. 1996. Mountain goat response to helicopter disturbance. – Wildl. Soc. Bull. 24: 681–685.

Côté, S. D. et al. 2013. Do mountain goats habituate to helicopter disturbance? – J. Wildl. Manage. 77: 1244–1248.

Cristescu, B. G. et al. 2016. Large omnivore movements in response to surface mining and mine reclamation. – Sci. Rep. 6: 19177.

Dailey, T. V. and Hobbs, N. T. 1989. Travel in alpine terrain: energy expenditures for locomotion by mountain goats and bighorn sheep. – Can. J. Zool. 67: 2368–2375.

D'Eon, R. G. and Delparte, D. 2005. Effects of radio-collar position and orientation on GPS radio-collar performance, and implications of PDOP in data screening. – J. Appl. Ecol. 42: 383–388.

D'Eon, R. G. et al. 2002. GPS radiotelemetry error and bias in mountainous terrain. – Wildl. Soc. Bull. 30: 430–439.

Fedy, B. C. et al. 2014. Habitat prioritization across large landscapes, multiple seasons and novel areas: an example using greater sage-grouse in Wyoming. – Wildl. Monogr. 190: 1–39.

Festa-Bianchet, M. and Côté, S. D. 2008. Mountain goats: ecology, behavior and conservation of an alpine ungulate. – Island Press.

Fieberg, J. J. et al. 2010. Correlation and studies of habitat selection: problem, red herring or opportunity? – Phil. Trans. R. Soc. B 365: 2187–2200.

Foster, B. R. and Rahs, E. Y. 1983. Mountain goat response to hydroelectric exploration in northwestern British Columbia. – Environ. Manage. 7: 189–197.

Fox, J. L. 1983. Constraints on winter habitat selection by the mountain goat (*Oreamnos americanus*) in Alaska. – PhD thesis, Univ. of Washington, Seattle, WA.

Fox, J. L. et al. 1989. Relation between mountain goats and their habitat in southeastern Alaska. – Gen. Tech. Rep. PNW-GTR-246. Pacific Northwest Research Station, Juneau, AK.

Frid, A. and Dill, L. 2002. Human-caused disturbance as a form of predation-risk. – Conserv. Ecol. 6(1): 11.

Fu, P. and Rich, P. M. 2002. A geometric solar radiation model with applications in agriculture and forestry. – Comput. Electronics Agric. 37: 25–35.

Goldstein, M. I. et al. 2005. Mountain goat response to helicopter overflights in Alaska. – Wildl. Soc. Bull. 33: 688–699.

Hirzel, A. H. et al. 2006. Evaluating the ability of habitat suitability models to predict species presences. – Ecol. Modell. 199: 142–152.

Hurley, K. 2004. Northern wild sheep and Goat Council position statement on helicopter-supported recreation and mountain goats. – Proc. 14th Bienn. Symp. of the Northern Wild Sheep and Goat Council 14: 49–63.

Johnson, C. J. and Russell, D. E. 2014. Long-term distribution responses of a migratory caribou herd to human disturbance. – Biol. Conserv. 177: 52–63.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. – Ecology 61: 65–71.

Joslin, G. 1986. Mountain goat population changes in relation to energy exploration along Montana's Rocky Mountain Front. – Proc. 5th Bienn. Northern Wild Sheep and Goat Council 5: 253–271.

Kirchhoff, M. D. and Schoen, J. W. 1987. Forest cover and snow: implications for deer habitat in southeast Alaska. – J. Wildl. Manage. 51: 28–33.

Laundre, J. W. et al. 2001. Wolves, elk and bison: reestablishing the "landscape of fear" in Yellowstone National Park, USA. – Can. J. Zool. 79: 1401–1409.

Laundre, J. W. et al. 2010. The landscape of fear: ecological implications of being afraid. – Open Ecol. J. 3: 1–7.

McDonald, T. L. and McDonald, L. L. 2002. A new ecological risk assessment procedure using resource selection models and geographic information systems. – Wildl. Soc. Bull. 30: 1015–1021.

Northrup, J. M. et al. 2013. Practical guidance on characterizing availability in resource selection functions under a use-availability design. – Ecology 94: 1456–1463.

Northrup, J. M. et al. 2015. Quantifying spatial habitat loss from hydrocarbon development through assessing habitat selection patterns of mule deer. – Global Change Biol. 21: 3961–3970.

Polfus, J. L. et al. 2011. Identifying indirect habitat loss and avoidance of human infrastructure by northern mountain woodland caribou. – Biol. Conserv. 144: 2637–2646.

Richard, J. H. and Côté, S. D. 2016. Space use analyses suggest avoidance of a ski area by mountain goats. – J. Wildl. Manage. 80: 387–395.

Richard, J. H. et al. 2014. The effect of snow on space use of an alpine ungulate: recently fallen snow tells more than cumulative snow depth. – Can. J. Zool. 92: 1067–1074.

Sappington, J. M. et al. 2007. Quantifying landscape ruggedness for animal habitat analysis: a case study using bighorn sheep in the Mojave Desert. – J. Wildl. Manage. 71: 1419–1426.

Sawyer, H. et al. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. – J. Wildl. Manage. 70: 396–403.

St-Louis, A. et al. 2013. Factors influencing the reaction of mountain goats towards all-terrain vehicles. – J. Wildl. Manage. 77: 599–605.

Stowell, H. H. 2006. Geology of southeast Alaska: rock and ice in motion. – Univ. of Alaska Press.

Sutherland, W. J. 1996. From individual behavior to population ecology. – Oxford Univ. Press.

Taylor, W. P. 2000. Wildlife capture and restraint manual. – Alaska Dept of Fish and Game, Anchorage, AK.

Webb, S. L. et al. 2013. Developing spatially-explicit weighting factors to account for bias associated with missed GPS fixes in resource selection studies. – Wildl. Biol. 19: 257–273.

Wells, A. G. et al. 2011. GPS bias correction and habitat selection by mountain goats. – Remote Sensing 3: 435–459.

White, K. S. 2006. Seasonal and sex-specific variation in terrain use and movement patterns of mountain goats in southeastern Alaska. – Proc. Bienn. Symp. of the Northern Wild Sheep and Goat Council 15: 183–193.

White, K. S. et al. 2009. Effects of snow on Sitka black-tailed deer browse availability and nutritional carrying capacity in southeastern Alaska. – J. Wildl. Manage. 73: 481–487.

White, K. S. et al. 2011. Mountain goat survival in coastal Alaska: effects of age, sex and climate. – J. Wildl. Manage. 75: 1731–1744.

White, K. S. et al. 2012a. Modeling resource selection of mountain goats in southeastern Alaska: applications for population management and highway development planning. – Proc. Bienn. Symp. of the Northern Wild Sheep and Goat Council 18: 32–42.

White, K. S. et al. 2012b. Mountain goat population ecology and habitat use along the Juneau Access road corridor, Alaska. Wildlife Research Final Report. – Alaska Dept of Fish and Game, Juneau, AK.

Supplementary material (available online as Appendix wlb-00277 at <www.wildlifebiology.org/appendix/wlb-00277>). Appendix 1–2.

Wildlife Biology

WLB-00277

White, K. S. and Gregovich, D. P. 2016. Mountain goat resource selection in relation to mining-related disturbance. – Wildlife Biology doi: 10.2981/wlb.00277

Appendix 1

Calculating expected use

The expected proportion of mountain goat locations in a given buffer can be based on the amount of RSF volume in the buffer divided by the total. This relationship logically assumes that mountain goats should spend more time in buffers with higher quality habitat (i.e. high RSF volume), than in buffers with lower quality habitat. However, the distribution on mountain goat locations in any given buffer is also related to where mountain goats were captured and the animals' central tendency movement patterns. For example, the further a given animal was captured from the mine site the less of a chance it would have had to spend time in high quality habitat patches within buffers near the mine. Thus if a capture site location and central tendency movement patterns are not accounted for selection ratios might underestimate the actual use of buffers near the mine, particularly if capture sites are relatively far away from the mine sites.

To account for this possible bias, the expected proportion of mountain goat locations in a given buffer (i.e. based on RSF volume) was weighted based on the distance a given animals' capture site was from the mine and its associated central tendency movement distribution. Specifically, the distance from capture site was calculated for each GPS location collected for a given animal, and stratified by season. Exactly emulating the resulting individual-based distance to capture site frequency distribution, points with a random azimuth were then plotted (i.e. radiating in random directions from the capture site but simulating the central movement tendency and movement capabilities of a given animal). The distance to the mine was then calculated for each point. The procedure was conducted for each individual animal, by season. For each season, all animal locations were then pooled and assigned to each 200 m distance to mine buffer. The proportion of simulated locations in each buffer was then used to weight the expected proportion of locations in a given buffer (i.e. based on RSF volume). Thus the resulting expected proportion was weighted based on the RSF volume in a given buffer and the expected proportion of animal locations in the buffer based on the capture location, central movement tendency and number of locations each individual contributed to the data set. Use of this weighting procedure limited bias associated with spatial displacement of capture sites relative to the mine and resulted in a more conservative assessment of mine effects on mountain goat spatial use patterns. That is, the chance of performing a type 1 error (i.e. incorrectly predicting an effect that does not exist) is lower using this method than would be the case if using non-weighted expected proportions of use.

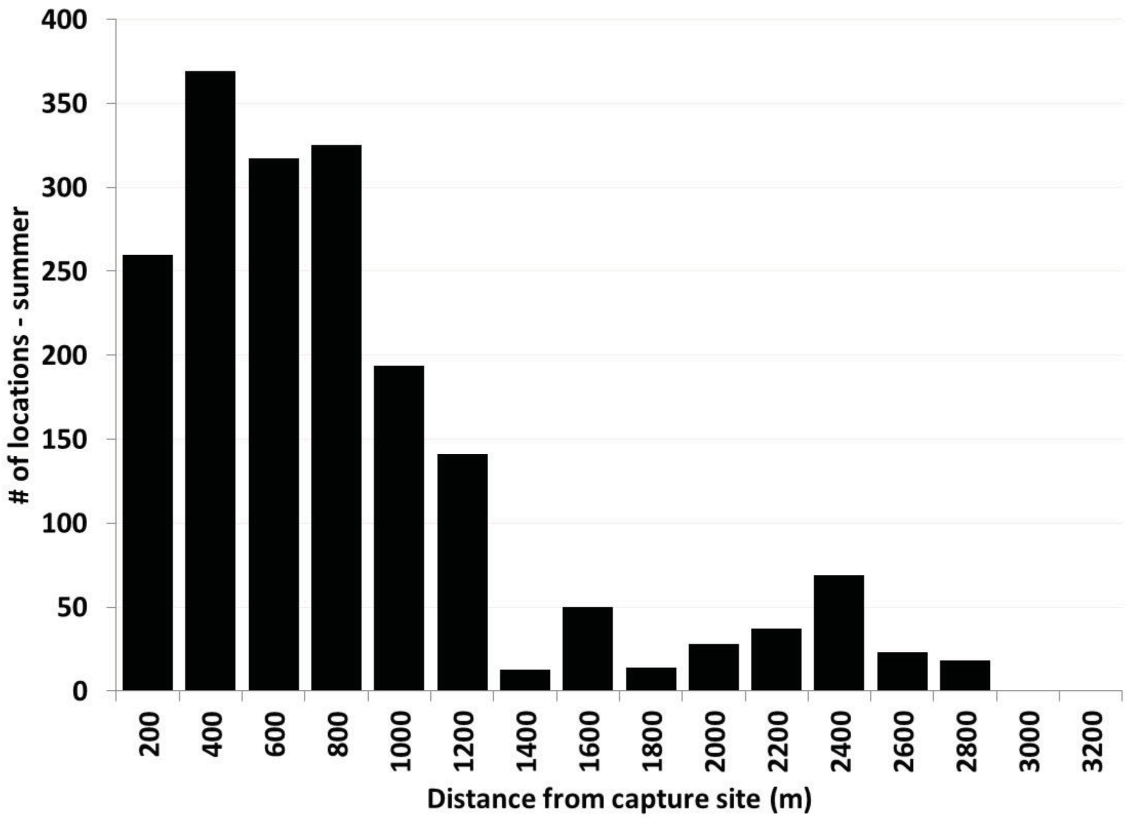
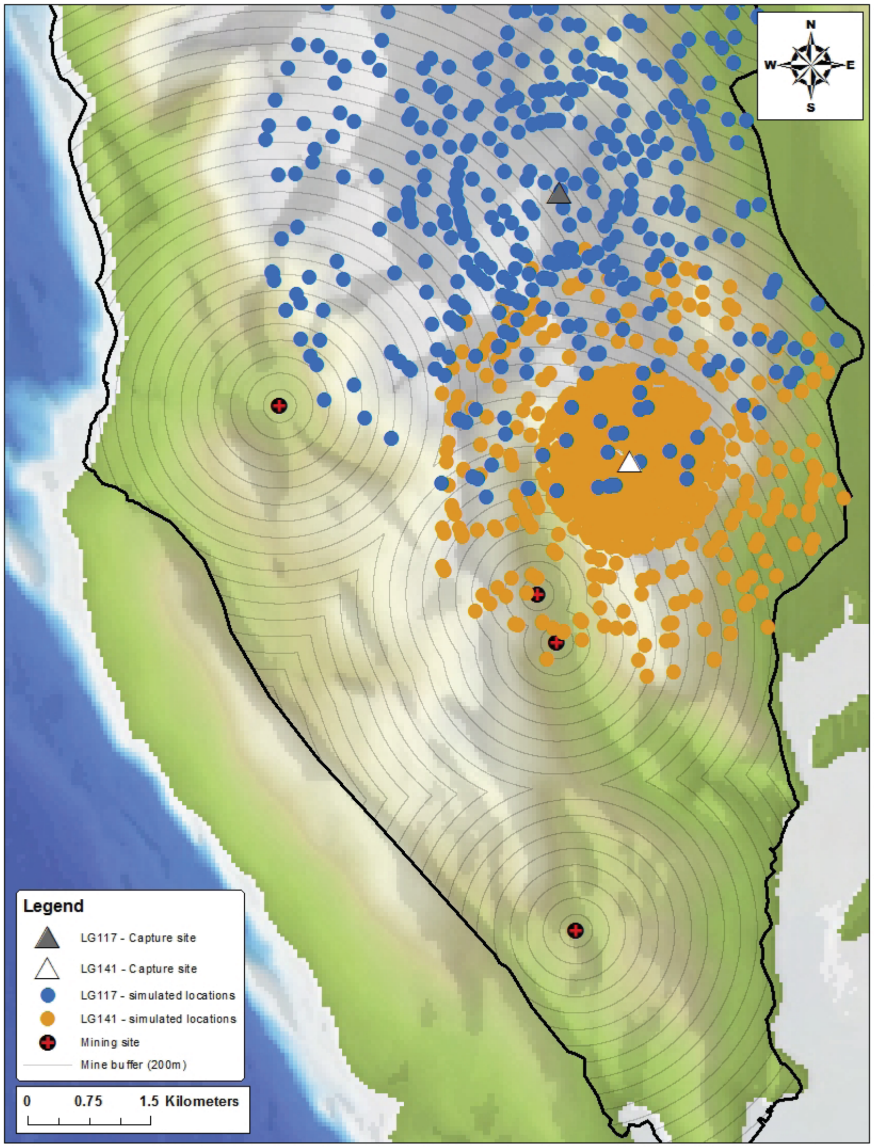


Figure A1.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Legend
LG117 - Capture site
LG141 - Capture site
LG117 - simulated locations
LG141 - simulated locations
Mining site
Mine buffer (200m)
0 0.75 1.5 Kilometers

Figure A2.

Appendix 2

Comparison of RSF coefficients between data sets including all mountain goats versus only mountain goats outside of the mine area

Table A1. Winter RSF model coefficients used for predicting mountain goat resource selection in Lynn Canal, southeast Alaska.

	All mountain goats (n = 75)			Non-mine mountain goats only (n = 58)		
Variable	median	LCI	UCI	median	LCI	UCI
Elevation	-7.51	-10.29	-6.40	-6.68	-9.04	-5.40
$Elevation^2$	-3.25	-4.17	-2.64	-2.49	-3.30	-1.77
Dist cliffs	-3.33	-4.11	-2.73	-3.35	-4.13	-2.49
Slope	0.48	0.36	0.65	0.56	0.40	0.72
$Slope^2$	-0.24	-0.35	-0.15	-0.24	-0.33	-0.12
Solar	1.38	0.93	1.55	1.38	0.80	1.63
$Solar^2$	-0.90	-1.34	-0.52	-1.58	-2.47	-0.89
VRM	0.67	0.48	0.80	0.57	0.44	0.70
VRM^2	-0.25	-0.32	-0.20	-0.21	-0.28	-0.14

Table A2. Summer RSF model coefficients used for predicting mountain goat resource selection in Lynn Canal, southeast Alaska.

	All mountain goats (n = 70)			Non-mine mountain goats only (n = 52)		
Variable	median	LCI	UCI	median	LCI	UCI
Elevation	1.29	0.86	1.99	1.33	0.86	2.25
$Elevation^2$	-4.30	-4.80	-3.71	-4.04	-4.64	-3.33
Dist cliffs	-0.93	-1.14	-0.71	-1.02	-1.31	-0.33
Slope	0.60	0.41	0.77	0.62	0.41	0.86
$Slope^2$	-0.44	-0.51	-0.38	-0.40	-0.48	-0.31
Solar	0.34	0.25	0.44	0.25	0.05	0.36
$Solar^2$	-0.10	-0.18	-0.01	-0.10	-0.19	-0.01
VRM	0.23	0.17	0.30	0.26	0.16	0.38
VRM^2	-0.03	-0.07	-0.02	-0.04	-0.07	-0.02

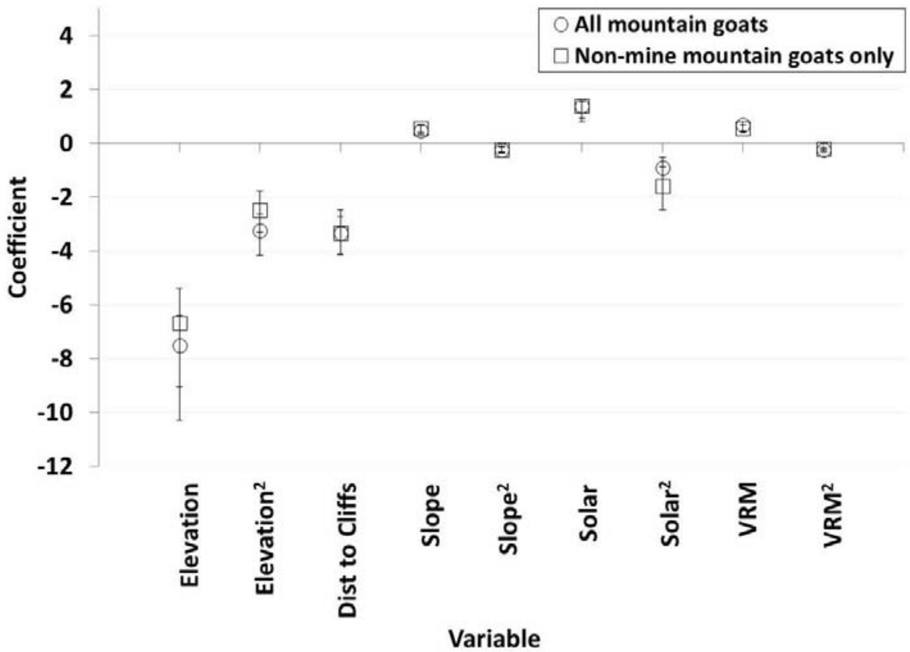

Figure A3. Winter RSF model coefficients used for predicting mountain goat resource selection in Lynn Canal, southeast Alaska.

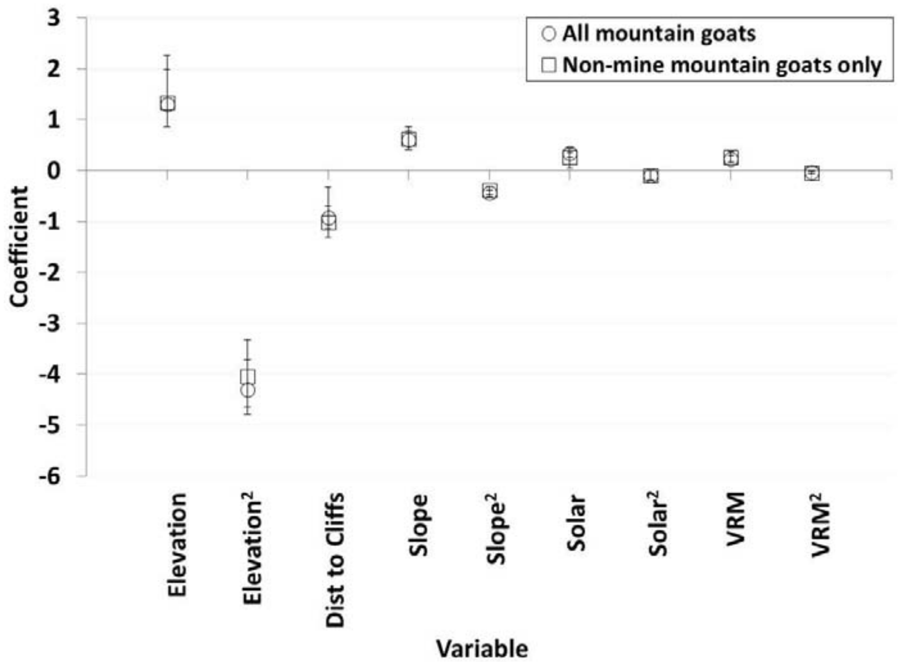

Figure A4. Summer RSF model coefficients used for predicting mountain goat resource selection in Lynn Canal, southeast Alaska.