Spatial Use, Habitat Selection, and Diets of Wolverines along the Proposed Juneau Access Improvements Road Corridor, Southeast Alaska

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Final Wildlife Research Report, ADF&G/DWC/WRR-2012-05

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Spatial Use, Habitat Selection, and Diets of Wolverines along the Proposed Juneau Access Improvements Road Corridor, Southeast Alaska

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Abstract

We studied spatial use, habitat selection, and diet of wolverines (*Gulo gulo*) in the proposed road corridor of the Juneau Access Improvements Project (JAIP), Southeast Alaska, during 2006 to 2011. The primary purpose of this research was to provide information on wolverine movement and habitat selection necessary to manage the population after the proposed road was constructed. We captured 15 (7 males, 8 females) wolverines during 2008 to 2011. We recorded movements and habitat selection on 12 wolverines (6 males, 6 females) from Global Positioning System (GPS) radiocollars over 8 to 124 days. Initially, we got a low successful fix rate from the GPS collars (12–38% successful fixes). Later (2009–2011), we got a higher successful fix rate (51–70%). Male wolverines had a median home range of 521 km^2 (100% convex polygon (CP, range = 288–4,981 km^2), nearly 4 times larger than that of females (71 km^2, range = 17–202 km^2). Using adaptive kernel (AK) home range estimates, male wolverines had a median home range of 323 km^2 (95% AK, range = 104–1,397 km^2), compared to females (58 km^2, range = 21–139 km^2). As an index to trapping vulnerability, we recorded that 2 of 6 female wolverines and 5 of 6 males had locations within 1 km of the proposed road corridor. Wolverine M2 was caught by a trapper near the Craig River on the Iskut River in British Columbia in 2010. This wolverine had travelled at least 330 km.

In a resource selection function (RSF) model analysis, we found that collared wolverines had a positive selection coefficient for shrub and unvegetated habitat variables and negative coefficient for elevation and slope physical variables. Wolverines made extensive use of the valley sides throughout the Berners Bay area. These areas corresponded to low- to mid-elevation (< 1,000 m) with moderate slope (30%). Forest, herbaceous, and glacier habitats were not significant factors in the RSF analysis. We found Spearman's rho values were > 0.9 with *P*-values < 0.001 in 4 of the 5 (80%) cross-validation trials, which indicates a useful RSF model.

We used stable isotope analysis to describe diets of captured wolverines. Using a Bayesian multisampling dual-isotope, multiple-source stable isotope mixing model, we determined the diet and diet variation from $\delta^{13}C$ and $\delta^{15}N$ in clotted red blood cell and hair of wolverines and potential prey. We found the $\delta^{13}C$ for males ranged from -25.9 to -24.3 and $\delta^{15}N$ ranged from 4.3 to 4.9 for both clotted red blood cells and hair. For females, $\delta^{13}C$ ranged from -26.2 to -24.7 and $\delta^{15}N$ ranged from 4.4 to 5.9 for both clotted red blood cells and hair. We found no significant differences in $\delta^{15}N$ between mean clotted red blood cells and hair, but we found the means for $\delta^{13}C$ significantly different with the hair being slightly less depleted. We didn't find any significant differences between mean male and female ratios for $\delta^{13}C$, but for males the mean of $\delta^{15}N$ ($\bar{x}$ = 4.3 vs. 4.8) was slightly lower. All captured wolverines preyed at the same trophic level on various herbivores, both mammal and bird. Diets of wolverines on average consisted of 27% Sitka black-tailed deer (*Odocoileus hemionus sitkensis*), probably carrion, and 17% large ungulate prey, probably mountain goat (*Oreamnos americanus*) and moose (*Alces alces*) carrion, 21% sooty grouse (*Dendragapus fuliginosus*), 12% ptarmigan (*Lagopus* spp.), and 10% mountain rodents, probably hoary marmots (*Marmota caligata*). Minor diet contributions included North American beavers (*Castor canadensis*) and conifer eaters (probably mostly porcupines, *Erethizon dorsatum*). Thus, wolverines consumed mostly ungulate carrion and birds. We found considerable variation in the diets of individual wolverines. The percentage of deer in the diet varied from 5% to 39% and large ungulate varied from 1% to 18%. Grouse ranged from

16% to 49% and ptarmigan ranged from 0 to 14%. Mountain rodents ranged from 0 to 15%. We found no evidence of wolverines using marine resources, particularly salmon.

If the proposed road is built, Alaska Department of Fish and Game's wildlife management staff will monitor wolverine harvests in the project area. More research will be needed to determine sustainable harvest levels.

***Key words*:** GPS collars, *Gulo gulo*, diets, habitat selection, home range, movements, roads, Southeast Alaska, spatial use, stable isotope analysis, wolverine.

Introduction

The wolverine (*Gulo gulo*) is one of the most rare and least-known carnivores in North America (Banci 1994, Ruggiero et al. 2007). Wolverines occur at low densities and tend to be found in areas removed from human influence (Banci 1994, Aubry et al. 2007). Because of this, relatively little was known about wolverine ecology until recently (Banci 1994, Squires et al. 2007). Research has shown that wolverines are susceptible to human disturbance (Krebs et al. 2007), that suitable denning habitat is a critical habitat component for wolverine population persistence (Magoun and Copeland 1998, Copeland et al. 2010), and that harvest is an additive mortality that can significantly affect population demographics and cause local extirpation of wolverine populations (Hornocker and Hash 1981, Krebs et al. 2004, Squires et al. 2007).

Wolverines are managed as both furbearers and big game in Alaska. In Game Management Units (GMUs) 1–5 in Southeast Alaska, current season dates for hunting are 1 September to 15 February (1 wolverine bag limit) for hunting and 10 November to 15 February (no bag limit) for trapping. These regulations are set by the Alaska Board of Game (BOG). Alaska Department of Fish and Game (ADF&G) staff seals harvested wolverines, looking at the pelt and affixing a locking tag. Based on sealing records from Southeast Alaska, 19 wolverines (on average) were harvested in GMUs 1–4 annually over the last 12 years; 42% of these were taken from Units 1C and 1D in northern Southeast Alaska. Over those same 12 years, 0–4 wolverines were harvested in the Berners Bay area annually. Although sealing provides managers with useful information about each animal sealed (e.g., sex, condition of animal, general location of harvest, and trends of harvest), it provides no information about wolverine ecology or insight about current population levels or harvest rates.

In Southeast Alaska, access into wolverine habitats during the winter trapping season is logistically challenging because of limited roads. Near Juneau, Alaska, the Alaska Department of Transportation and Public Facilities (DOT&PF) is planning to construct an all-season highway that will extend the existing highway from Juneau approximately 50 miles northwest (DOT&PF 2006). This road will pass through habitats occupied by wolverines and provide significantly increased access to these areas. Increased access to wolverine habitats could increase harvest rates. In addition, habitats used by female wolverines for denning and kit rearing may be affected from recreational snow machine riders, potentially resulting in conflicts with female wolverines at their dens (Magoun and Copeland 1998, Copeland et al. 2010).

Knowledge of wolverine ecology and population dynamics is limited and field studies are needed to fill critical information gaps (Ruggiero et al. 2007). This knowledge is especially true in coastal areas like Southeast Alaska (Magoun et al. 2007). Information on basic ecology, including home range size and habitat use, movements, dispersal characteristics, and diet are needed to determine factors affecting wolverine abundance and ultimately to ensure sustainable populations (Krebs et al. 2004, Lofroth and Ott 2007). By understanding the role and relative importance of these factors, we will be able to appropriately manage this species in a responsible manner consistent with ADF&G's Division of Wildlife Conservation (DWC) mission to conserve and enhance Alaska's wildlife and habitats and provide for a wide range of public uses and benefits.

During 2008–2012 the Federal Highway Administration (FHWA) and DOT&PF funded this study of wolverine spatial relationships, abundance, habitat selection, and diet in Berners Bay, Southeast Alaska. The study's goals were to better understand the population of wolverines in a portion of the proposed road corridor so that we can better manage them, and to help identify mitigation measures that may be needed should the proposed road be constructed. Specific objectives were to 1) determine spatial-use patterns (i.e., home range, movements) and habitat selection of wolverines in the project study area; 2) derive a wolverine population estimate; and 3) investigate wolverine food habits.

Although it was an initial objective, we were unable to estimate the population of wolverines in Berners Bay. Early in the study, it became apparent that the logistical constraints of working in the Berners Bay area would make it difficult to perform either a DNA-based mark-recapture estimate from hair snagging or an estimate based on camera traps (Magoun et al. 2007, Royle et al. 2011). These techniques were determined to be too costly given the characteristics of the area and the funding that was available.

Study Area

We studied wolverine ecology in the watershed complex associated with Berners Bay (lat 58° 46' N, long 134° 56' W; 60 km north of Juneau, Alaska; Fig. 1), primarily in drainages potentially intercepted by the Juneau Access Improvements Project (DOT&PF 2006; Fig. 1). Four large rivers (Antler, Berners, Gilkey, and Lace) and several smaller watersheds drain into Berners Bay. Elevation within the study area ranges from sea level to >1900 m. The area has a maritime climate with cool, wet summers and relatively warm, snowy winters. Summer temperatures average 13.9° C while winter temperatures average -3.2° C (Haines, AK; National Weather Service, Juneau, AK; http://www.arh.noaa.gov/clim/. Annual precipitation at sea-level averages 140 cm. Berners Bay is an intensely glaciated landscape. The study area contains rugged topography interrupted in a few areas by river valleys and glacial outwash plains. The mountains have moderate to steep forested slopes, interrupted by raised benches, bare rock cliffs, and steep avalanche chutes.

The terrestrial habitat in Berners Bay consists mostly of coastal coniferous rainforest dominated by western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), and some scattered mountain hemlock (*T. mertensiana*), Alaska or yellow cedar (*Chamaecyparis nootkatensis*), and red alder (*Alnus rubra*). These forests typically extend from sea level to an elevation of approximately 750 m, with subalpine and alpine habitats at higher elevations. Deciduous forest or mixed deciduous/coniferous forest communities, dominated by black cottonwood (*Populus balsamifera*), are found in limited areas, primarily in association with floodplains of larger rivers. Interspersed within the forest are open, poorly drained areas, including muskeg and bog communities. The subalpine and alpine areas, with steep slopes and limited soil, support low shrub and dwarf shrub communities, and a variety of grasses, wildflowers, ferns, and mosses; above this, glaciers and snowfields dominate.

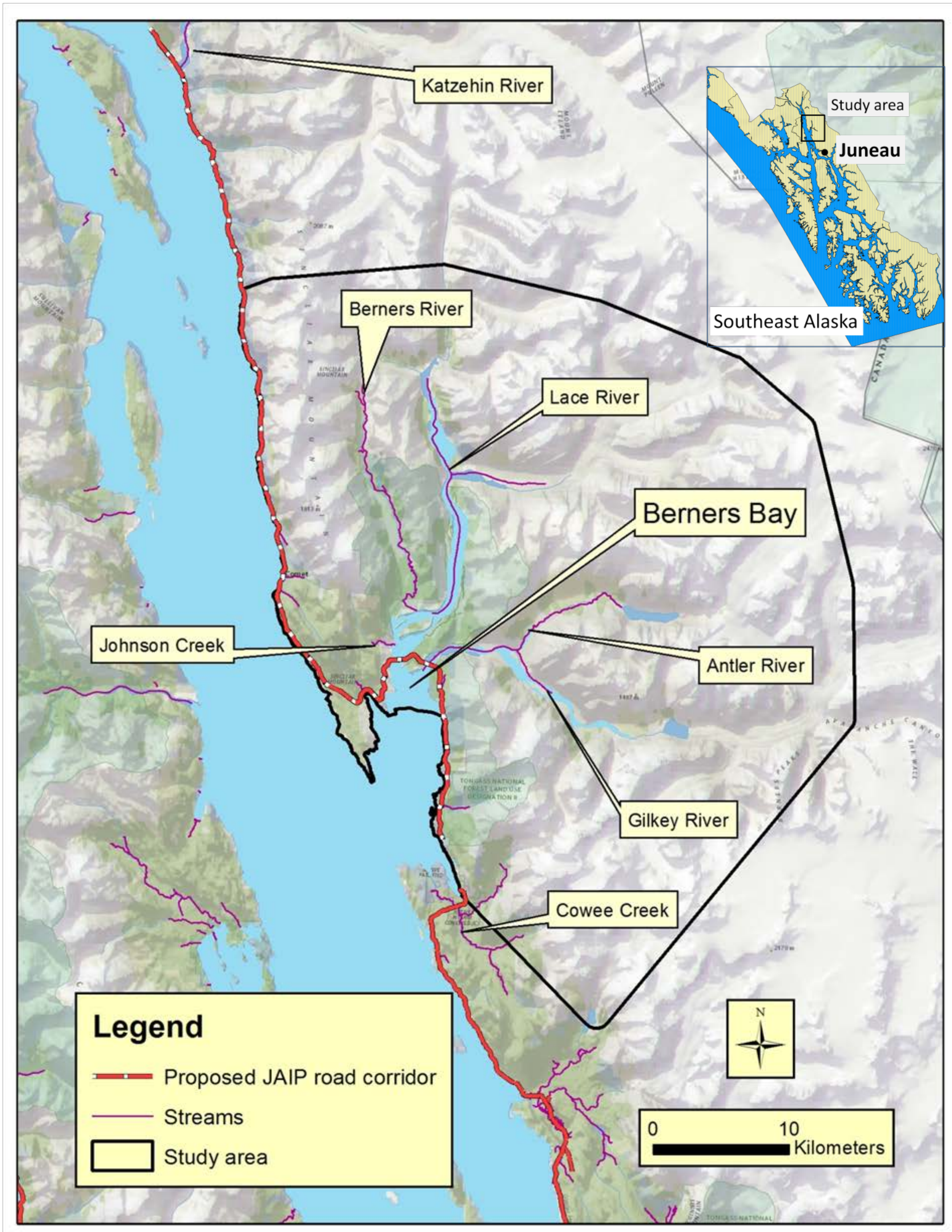

Figure 1. Study area for the Juneau Access Improvements Project (JAIP) in northern Southeast Alaska, showing proposed road route. Berners Bay is located 45 km north of Juneau.

Potential wolverine prey in Berners Bay includes Sitka black-tailed deer (*Odocoileus hemionus sitkensis*), moose (*Alces alces*), mountain goats (*Oreamnos americanus*), North American beavers (*Castor canadensis*), hoary marmots (*Marmota caligata*), porcupines (*Erethizon dorsatum*), long-tailed voles (*Microtus longicaudus*), red squirrels (*Tamiasciurus hudsonicus*), sooty grouse (*Dendragapus fuliginosus*), and ptarmigan (*Lagopus* spp*.)*. Snowshoe hares (*Lepus americanus)* are present but uncommon. Many streams in the study area support spawning Pacific salmon (*Oncorhynchus* spp.) during the late summer and fall, and wolverines probably take advantage of this food source as well. Other larger predators in Berners Bay include brown (*Ursus arctos*) and black bears (*U. americanus*), wolves (*Canis lupus*), and coyotes (*C. latrans*).

Methods

Capture and Handling

We captured wolverines using modified box-traps (Copeland et al. 1995) made from red alder or rough-cut western hemlock (Fig. 2). We felled red alder trees to obtain logs of approximately 15–20 cm diameter and 183 cm length. We obtained rough-cut 15 cm × 20 cm western hemlock from a local timber mill. We prepared these materials for trap construction in Juneau and deployed trap material with the aid of a helicopter. We constructed traps (183 cm long, 102 cm wide, and 86 cm high) on-site and felled 1 tree at each site to use for the lid lever-arm and support. In addition to wooden traps, we attempted to capture wolverines using modified culvert-style traps using plastic culvert material or a plastic water tank modified with a drop door and trigger (Fig. 2). Beginning in 2010, we put a remote camera at each trap site to record wolverine activity.

We situated traps to intercept travel routes of wolverines, usually along riparian corridors or at the base of valley-side slopes, or at sites with natural attractants (e.g., winter-killed goat carcasses). We constructed traps beneath the canopies of large trees to reduce snow accumulation on the trap lids. We baited traps with parts of beaver, mountain goat, black-tailed deer, moose, and salmon carcasses. We looped wire around or through the bait and pulled it snug against the back of the trap. We placed a layer of conifer boughs on the trap floor to prevent bait from freezing to the floor and to provide bedding for captured animals. We stapled a 91 cm × 91 cm piece of plastic tarp on the lid at the back of the trap to provide additional shelter from rain or melting snow for animals in the trap.

We captured wolverines during the time when brown and black bears were denning and thus would not molest traps (roughly December–April). Between capture seasons, all traps were left in the field with the bait and triggers removed and lids shut. We reassembled traps (mounted triggers and trap lids) and pre-baited traps 3–5 days prior to trapping. Early on, we used a very high frequency (VHF) trap-site transmitter (TBT-500, Telonics, Mesa, AZ) on each trap to monitor trap closures at least every other day. Later, we used a Global Positioning System (GPS) messenger (SPOT Personal Tracker, Spot LCC, Chantilly, VA) with a modified trigger to alert us if a trap was tripped. We visited all traps once every 7 days regardless of whether the trap was tripped to check for excessive snow and ice buildup on the lid and trigger mechanism.

We trapped wolverines only in the drainages of Berners Bay (Fig. 3). In 2008, we constructed traps at the end of the current Glacier Highway near Cowee Creek and at the lower reaches of Berners Bay.

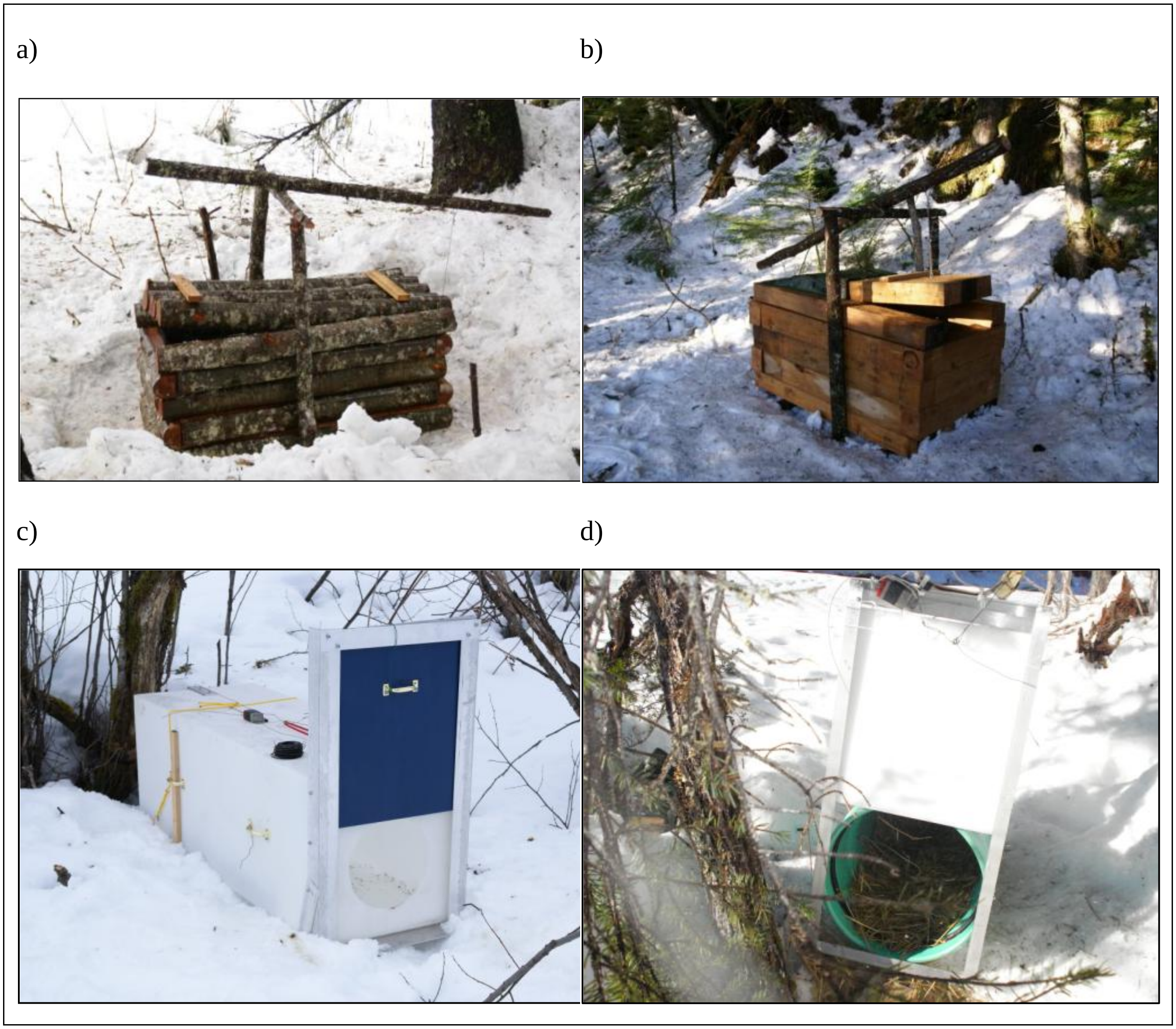

Figure 2. Different trap types used to capture wolverines in Berners Bay, Alaska, 2008–2011: a) modified box-trap made from red alder logs; b) modified box-trap made from rough-cut western hemlock; c) portable trap made from a plastic water tank modified with a drop door and trigger, and d) portable trap made from plastic culvert.

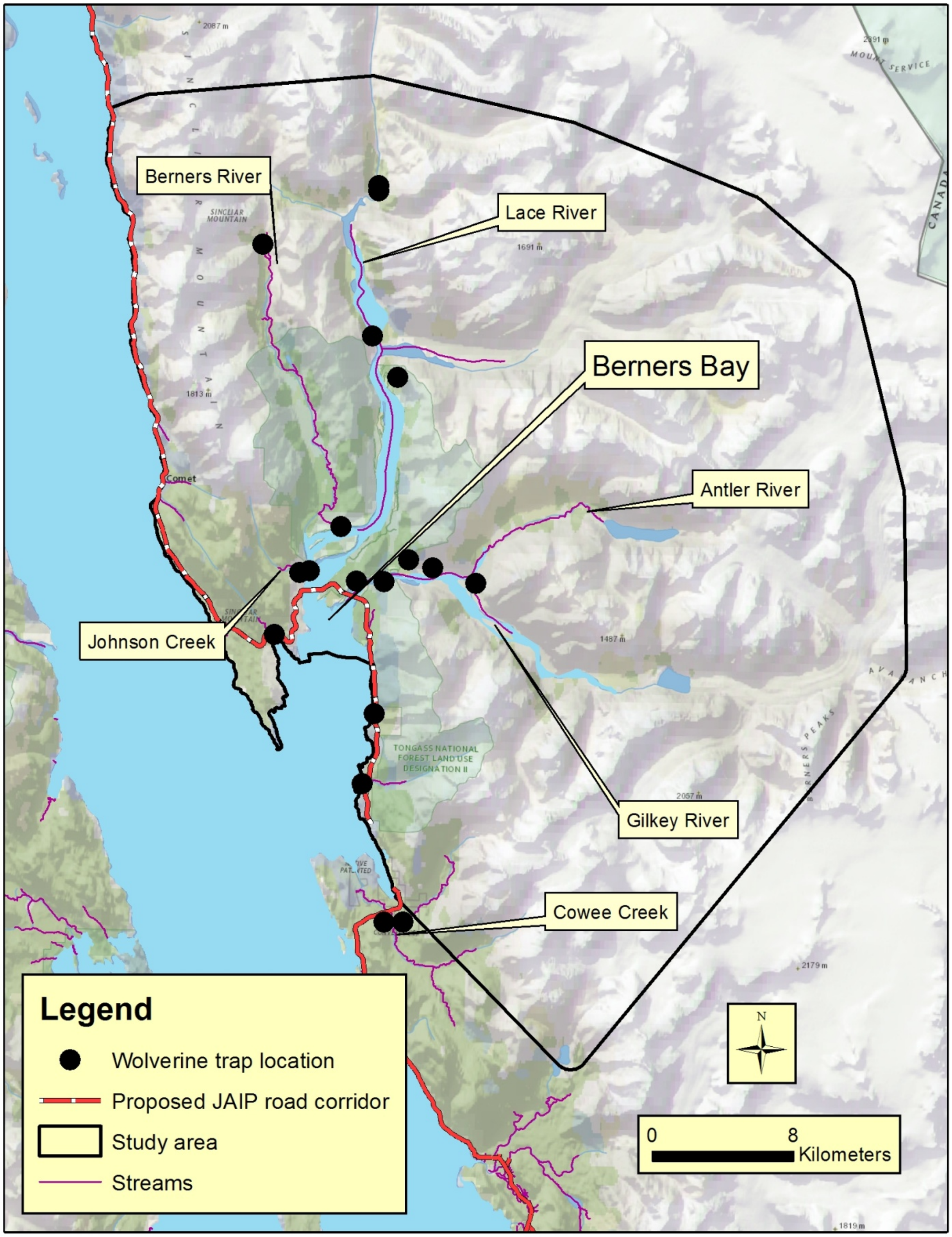

Figure 3. Wolverine trap locations in Berners Bay, Southeast Alaska, 2008–2012.

During 2009–2010, we constructed more traps and placed them farther up the Lace, Antler, and Berners rivers. We did not trap along Lynn Canal and the Katzehin River areas because the budget was not sufficient to allow us to include that larger geographical area.

We encountered American marten (*Martes americana*) at almost every trap site and had problems with them tripping wolverine traps or eating baits. Initially, to avoid catching marten in wolverine traps, we live-trapped them (Tomahawk model 203, Tomahawk Live Trap Co., Tomahawk, WI) and released them approximately 10 miles from traps to lessen the chance of recapturing them. Later, we designed a trigger mechanism that would not be tripped by lighter-weight marten, but would be tripped by the heavier-weight wolverines.

We followed capture and handling guidelines presented by the American Society of Mammalogists (Gannon et al. 2007) and approved by ADF&G's Animal Care and Use Committee (ACUC # 07-20). We visually estimated the weight of captured wolverines to determine the amount of immobilizing drug to use. We immobilized wolverines using a mixture of ketamine (8 mg/kg) and medetomidine (0.3 mg/kg) or tiletamine hydrogen chloride (HCl) and zolazepam HCl (Telazol®; 13 mg/kg) administered with a jab-stick (Zoolu Arms of Omaha, Omaha, NE). We collected blood and hair for stable isotope analysis. We recorded gender, weight, body measurements, and physical condition. We attempted to age animals based on tooth wear and took a set of photographs of each animal's teeth to compare with known-aged specimens. We examined mammary glands of females for evidence of current or previous lactation. Each animal received a small (5 cm x 0.5 cm) colored ear tag (Minitag, Dalton ID Systems, Ltd., Oxon, United Kingdom) in each ear.

Once processing was complete and the clinical effectiveness time of the ketamine had expired (approximately 45 min), we returned the animal to the trap and administered atipamezole (0.2 mg/kg) to reverse the effects of medetomidine. Animals sedated with Telazol® were placed back in the trap once they showed signs of recovery. We secured the trap door open and allowed the animals to leave the trap site on their own. Nontarget animals were not sedated and were allowed to leave on their own by securing the door open and leaving the vicinity of the trap.

We consider a trap set for 1 night was a trap night (TN). We used wolverine captures/100 TN as a measure for capture rate.

We outfitted each animal with a GPS radiocollar (Lotek Wireless, Inc. Newmarket, Ontario) to gather location data for each animal. We used different collar models as the technology evolved and we were able to utilize collars bought but unused by another researcher. During winter 2008, we used a store-on-board GPS collar (Lotek GPS_3300S). In winter 2009, we used 2 new models of GPS collars, a remotely downloadable version (Lotek GPS_7000 SLU) and a store-on-board GPS collar (Lotek GPS_6000SL). In addition, we used the older model store-on-board GPS collar (Lotek GPS_3300S) after the new collars were all deployed. In 2010 and 2011, we used the GPS_7000 SLU and GPS_6000SL collars. We deployed collars with a programmable, remote-release mechanism set, so collars would come off animals 24 weeks after capture. We experimented with different fix schedules and satellite search times to maximize the time over which the collar would collect locations while minimizing the length of time between fixes. We recorded the number of successful locations per the total number fix attempts (i.e., successful fix rate) of each collar.

We attempted to locate and monitor all marked wolverines periodically with standard VHF telemetry by fix-winged aircraft (Mech 1974) to maintain contact with each animal, check for dropped collars, and check for mortality events. When animals were located, we attempted to download data from the remotely downloadable collars. Thus, our data consists of locations generated from captures, the GPS radiocollars, and locations from standard VHF telemetry. We attempted to retrieve each dropped collar as soon as conditions permitted after we detected the collar was stationary.

SPATIAL DATA ANALYSIS

We estimated space use for all animals with GPS data points. We used 2 different methods to determine space use. We computed a 100% minimum convex polygon (CP) using Hawth's Tools (www.spatialecology.com) for comparison with other studies of wolverine home range. Also, we computed an adaptive kernel (AK) home rage with least-squares cross-validation to select the appropriate smoothing parameter using the program Animal Space Use 1.2 (Horne and Garton 2007). Kernel estimators are thought to be more accurate estimators of space use (Worton 1989, Seaman and Powell 1996, Horne and Garton 2006). We used the 95% contour to minimize the influence of extraordinary movements in the estimation of space use; the 50% contour was used to measure the core use areas of each animal. We used ArcGIS version 9.3 (ESRI, Inc., Redlands, CA) to analyze each animal's location data to estimate movement rates and interactions.

We recorded the number of wolverine locations within 1 km of the proposed road corridor for each animal. We used this number as an index to trapping vulnerability.

HABITAT SELECTION

Resource Selection Function model development

We developed resource selection function (RSF) models (Boyce et al. 2002) using GPS locations from wolverines captured in Berners Bay and mapped habitat variables in a geographic information system (GIS) framework. We looked at 1st-order selection (Johnson 1980) at the population level using a Design II approach (Manly et al. 2002). In this way, we measured the resources used for each wolverine and compared the result to available resources at the population level. We used winter (December–April) to summer (May–September) for this analysis because it was the time during which we obtained GPS location data. Because we wanted to develop a model for all wolverines, we did not separate the wolverines by gender and reproductive status.

We delineated a study area for habitat selection using the 99% isopleths of a kernel density estimation (KDE) function in the Geospatial Modeling Environment (GME; Beyer 2011). We constrained the study area to border on the south at Eagle River. This raster was then clipped to the shoreline to obtain the final study area. Habitat selection was analyzed within this area using a logistic regression approach in which used locations are contrasted with available (random) points (Boyce et al. 2002, Manly et al. 2002). The used locations comprised all GPS locations collected from wolverines in the Berners Bay area. The available points, either physical features or habitats, were chosen randomly within the study area.

We used a two-stage modeling approach in which the GPS points for each wolverine were analyzed against the pool of available points (Fieberg et al. 2010). This approach resulted in a separate logistic regression equation for each wolverine. Equation coefficients were then averaged to obtain an overall model. Significance of model coefficients in this approach is indicated by confidence intervals that exclude zero. Models were built using the GLM function in the R statistical environment (R Development Core Team 2011, http://www.r-project.org). Such models result in RSFs describing the relationship between animal use and model factors via the equation:

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n)$$

Where $w(x)$ represents an RSF that is proportional to the probability of use of variables $x_1 + x_2 + \ldots + x_n$.

All used and available locations were attributed a suite of terrain and landcover variables. The terrain variables were derived from the Shuttle Radar Tomography Mission Digital Elevation Model (SRTM-DEM). The landcover variables were largely derived from a database of terrestrial ecological systems (Albert and Schoen 2006).

In initial data investigations, a number of the potential terrain factors were ruled out of further analysis because either they 1) were highly-correlated with other variables; or 2) they did not appear to have strong correlations with wolverine use locations. The final set of variables was then pared down to those physical variables that had both strong correlations to wolverine use in single factor (univariate) models as well as a reasonable biological basis for their effect. Because the time frame over which we gathered GPS locations on wolverines was limited, we developed one model to describe wolverine habitat selection in Berners Bay corresponding to winter to early autumn (27 January–21 September). Most animals' GPS locations corresponded to spring and early summer.

Model validation

The habitat selection model was validated using the *k*-fold cross-validation method (Boyce et al. 2002; Johnson et al. 2006). In the *k*-fold cross-validation method, a set of 'validation' data is removed from the total pool of data, leaving the 'training' data. A new model is built using only the training data and the original model factors. This new model is then tested to see how accurately it predicts the removed validation data. The variable k represents the number of times this process is iterated. Typically (and here), $k = 5$ is chosen, the training data being built on $1-(k/n)$ of the data and validated using k/n of the data, where n is the total number of wolverines ($n = 12$).

Each of the 5 resulting models was then used to generate RSF scores for all the available (= random) points and for all of the point locations from the wolverines in the removed, validation set. The RSF scores for the available points were then split into 10 equal-sized bins ranked in increasing order. The mean RSF score of each bin is divided by the sum of these means to yield the expected proportion of locations in each bin. The RSF scores of the validation-set wolverines were similarly split using the same breakpoint values used to split the available points. This yields the observed proportion of values in each bin.

These sets of expected and observed proportions were then analyzed against each other using Spearman's rank correlation and linear regression. Larger Spearman's rank correlation coefficient (rho) values approaching 1 (with low P-values) indicate concordance between the ranking of observed versus expected values (Boyce et al 2002). Regression analysis results in optimum performance when the slope approaches 1, the y-intercept approaches 0, and the adjusted *r*-squared approaches 1. Such optimal results indicate proportionality between observed and expected results (Johnson et al. 2006; Wiens et al. 2008). An additional comparison of the bin-wise mean expected and observed proportions across all cross-validations provided an integrated summary of performance.

DIET

We investigated the diet of wolverines using stable isotope analysis (SI) from live-captured animals (Ben-David et al. 1997). We sampled clotted whole blood and hair from most live-trapped wolverines that were obtained during captures. All wolverine samples and samples available from potential wolverine prey species (i.e., mountain goats, and moose) were sent to Dr. Merav Ben-David at the University of Wyoming for SI analysis. Samples for SI analysis were dried at 60^{o}-70^{o} C for 48 h and then ground to fine powder using a dry tissue grinder (Glenn Mills Co. Chicago, IL.). Subsequently, all samples were weighed into a miniature tin cup (4 by 6 mm) for combustion. We used a Carlo-Erba series 2 C/N analyzer attached to a VG Optima mass spectrometer to obtain the stable isotope ratios (Ben-David et al. 1997). Each sample was analyzed in duplicate and results were accepted only if the variance between the duplicates did not exceed that of the peptone standard ($\delta^{13}C_{std}$ = -15.8, $\delta^{15}N_{std}$ = 7.0, CV = 0.1). Isotope values are expressed in delta notation (δ) as:

$$\delta X = \left(\frac{Rsample}{Rstandard} - 1\right) 1000,$$

where *X* is ^{13}C or ^{15}N, and *R* is $^{13}C/^{12}C$ or $^{15}N/^{14}N$. We report the $\delta^{13}C$ and $\delta^{15}N$ for each wolverine sample. In addition, we listed means of clotted blood cells for mountain goat and moose samples that were captured in the Berners Bay area.

Because we did not have samples of all types of potential wolverine foods from our study area, we used isotope values for beavers from the Yukon during late summer (Milligan and Humphreys 2010), salmon from Southeast Alaska during late summer (Szepanski et al. 1999), arctic ground squirrels from the Yukon during summer (Ben-David et al. 1999), Sitka black-tailed deer from Southeast Alaska during autumn (R. Flynn, ADF&G, personal communication), red squirrels from Southeast Alaska during autumn (R. Flynn, ADF&G, personal communication), sooty grouse from Southeast Alaska (Ben-David 1996), and ptarmigan from South-central Alaska during winter (H. Golden, ADF&G, personal communication). Unfortunately, we did not have samples from hoary marmots and porcupines. We assumed that arctic ground squirrels (*Spermophilus parryii*), although they did not occur in the study area, were a surrogate for hoary marmots as they represent a similar trophic level and eat similar types of foods (Hansen 1975, McLean 1985). We categorized these values as mountain rodents. We assumed that porcupines were similar to red squirrels because porcupines feed on conifer needles and the inner bark of spruce and hemlock trees in the autumn and winter. We considered red squirrels and porcupines together as conifer eaters.

We employed multivariate analyses of variance (MANOVA; Johnson and Wichern 1988) to detect differences in the diets of wolverines as manifested by their $\delta^{13}C$ and $\delta^{15}N$ values with gender and tissue type (clotted red blood cells and hair) as independent variables. We plotted ratios of ($\delta^{13}C$ and $\delta^{15}N$) for each wolverine sample to compare with potential prey items (either from this study or from the literature).

We used a Bayesian multisampling dual-isotope, multiple-source mixing model (SISUS: Stable Isotope Sourcing Using Sampling, Erhardt 2007) to estimate of the contribution of each prey item to the diet of individual wolverines. We used discrimination values that were developed for another mustelid (mink) from feeding trials (Ben-David, 1996; Hobson, 1991). When either mammalian or avian resources were consumed, we used discrimination values of 2‰ for carbon and 3‰ for nitrogen and used discrimination values of 1‰ for carbon and 2‰ for nitrogen when fish resources were consumed.

The mixing model requires that isotopic values of all prey be significantly different from each other. We used MANOVA to test whether the food items were significantly different. We combined any food items that were not significantly different.

This model assumes that each individual predator consumes all possible types of prey. Therefore, this model will tend to overestimate the proportion of food items that are rarely consumed and underestimate the proportion of commonly used prey. Consequently, we presented proportions in the diet from the mixing model, but actually considered the proportions as an index of prey consumption.

Results

CAPTURE AND HANDLING

We constructed most traps during January to February 2008, but added 2 traps in 2010. In total, we constructed 4 traps from alder, 9 from hemlock, and 2 from plastic. Over the course of the study, we lost several traps due to decomposition of the wood, destruction by bears, and vandalism by humans. We operated traps usually from midwinter to the time when either bears began to visit traps or we had deployed all available collars.

2008—Between 14 January 2008 and 1 May 2008, we captured 4 individual wolverines (2 males and 2 females) 9 times in 701 TN (Table 1) resulting in a capture rate of 1.28 captures/100 TN. We had a capture rate for individual wolverines of 0.57 captures/100 TN. Upon recapture, we downloaded location data from GPS collars on wolverines that retained them (M1 twice, F1 once) and deployed a new collar on wolverines that had dropped their original collars (F1 and F2; Table 1). Male wolverines weighed 14–15 kg and females weighed 8–9 kg.

Wolverines escaped from traps 2 times because of a malfunction in the bait attachment. A modified carabiner was used to connect the trigger wire to the wire surrounding the bait. In both cases, the animal was able to free the bait from this carabiner without triggering the trap and escape with the bait. We subsequently removed all carabiners and replaced them with locking connectors that could not be unlatched by an animal.

Nontarget species captured included marten and a domestic dog (*Canis familiaris*) in 2008. In addition, brown and black bears tripped traps but were not caught or were able to escape (identified by tracks at site). Two traps were partially destroyed by bears on the last day of trapping.

Table 1. Capture results for 7 male and 8 female wolverines trapped in Berners Bay, Southeast Alaska, 2008–2011.

Animal ID	Capture date	Capture event	Collar type[1]	Collar information	Collar fate	Time period for GPS locations[2]
Females						
F1	4/15/08	1	SOB	Original capture	Downloaded	04/15/08–04/30/08
	4/20/08	2		Collar left on animal, lost	Lost	
	4/29/08	3	SOB	Recovered at drop site	Downloaded	
F2	4/18/08	1	SOB	Collar not recovered		
	4/28/08	2	SOB	Collar not recovered	Lost	04/28/08–05/10/08
F3	2/11/09	1	SOB	Collar not recovered	Lost	No data
F4	2/14/09	1	SOB	Collar not recovered	Lost	No data
F5	2/13/10	1	DL	Caught by a trapper 03/30/2012	Retrieved	02/13/10–02/27/10[3]
F6	2/27/10	1	DL	Collar did not release	Lost	03/01/10–09/21/10
F7	3/10/10	1	DL	Collar recovered at drop site	Downloaded	03/10/10–05/10/10
F8	3/22/11	1	DL	Collar not recovered	Downloaded	03/22/11–07/07/11
Males						
M1	3/21/08	1	SOB	Original capture	Downloaded	03/21/08–06/15/08
	3/29/08	2		Recapture; collar left on animal	Downloaded	
	4/22/08	3		Recapture; collar left on animal	Downloaded	
	2/22/09	4	SOB	Removed 2008 collar; new collar	Lost	
M2	4/22/08	1	SOB	Collar recovered by trapper in 2010	Downloaded	04/22/08–06/16/08
M3	1/27/09	1	DL	Original capture	Downloaded	01/27/09–05/31/09
	2/08/09	2		Collar did not release and was lost	Lost	
M4	2/11/09	1	DL	Collar did not release and was lost	Downloaded	02/11/09–04/27/09
M5	2/18/09	1	DL	Collar dropped early and recovered	Downloaded	02/18/09–03/22/09
M6	2/22/09	1	SOB		Lost	No data
M7	2/19/10	1	DL	Collar recovered from dead animal	Downloaded	02/20/10–06/06/10

[1] SOB refers to store-on-board collars and DL refers to remotely downloadable collars.
[2] Total time period when GPS locations for this animal were obtained.
[3] We were unable to download collar upon retrieval from trapper because the collar was damaged.

2009—Between 14 January 2009 and 22 February 2009, we captured 7 individual wolverines (5 males and 2 females) 8 times in 237 TN resulting in a capture rate of 3.37 captures/100 TN (Table 1). We had a capture rate for individual wolverines of 2.95 individual captures/100 TN. We anesthetized and collared each wolverine upon initial capture. One recaptured wolverine was not anesthetized on its second capture because only 1 week had elapsed since the collar was deployed; this animal was released immediately after identification. Male wolverines weighed 13–14 kg and females weighed 10–11 kg.

Nontarget species captured in 2009 included marten and a red fox (*Vulpes vulpes*).

2010—Between 1 February 2010 and 30 March 2010, we captured 4 individual wolverines (1 male and 3 females) during 734 TN. The capture rate was 0.54 captures/100 TN. We anesthetized and collared each wolverine upon capture. The male wolverine weighed 12 kg and females weighed 9–11 kg.

No nontarget species were captured in 2010.

2011—Between 10 February 2011 and 15 March 2011, we captured 1 female wolverine during 170 TN resulting a capture rate of 0.59 captures/100 TN (Table 1). We anesthetized and collared this wolverine upon capture; she weighed 8 kg.

No nontarget species were captured in 2011.

MOVEMENTS

2008—Wolverine M1 was collared originally on 21 March 2008 (Table 1). He was recaptured on 29 March 2008 and retained his collar. We downloaded his collar at that time. He was recaptured a third time on 22 April 2008. He still had his collar, and we downloaded it and replaced the battery. M1's collar did not release on 7 October 2008 as scheduled. We were able to subsequently recapture this animal in 2009 to remove the collar.

Wolverine F1 was captured and collared on 15 April 2008 (Table 1). She was captured again on 20 April 2008 and her collar was downloaded. On 29 April 2008, F1 was captured a third time, but had lost her original collar and was given a new collar. On 30 April 2008, F1 dropped her second collar. On 3 May 2008, we attempted to collect both of F1's dropped collars. We found her second collar in a small cave formed by snow drifting over a large rock on a steep slope. There were signs of porcupine roosting in the cave. The collar was found wedged between the rock and snow. We located F1's first collar in a band of cliffs, but determined that it was in a deep cleft in the cliffs and was unreachable. F1's status at this time is unknown.

Wolverine F2 was first captured and collared on 18 April 2008 (Table 1). She was recaptured on 28 April 2008 without that collar and was given a new collar at that time, and we got GPS locations until 10 May 2008. Her first collar was located on 25 June 2008, but was not recovered before winter snows made it inaccessible. Subsequently this collar stopped transmitting and therefore, we were unable to recover it. She was last located on 25 June 2008 by standard telemetry; F2's status is unknown.

Wolverine M2 was captured and collared on 22 April 2008 (Table 1). We did not aerially locate him after his capture despite several attempts to listen for his collar throughout the study area and as far south as Juneau. After the 2009 field season, we presumed that this animal dispersed from the study area or that the collar failed. Subsequently, M2 was killed in December 2009 by a trapper on the Craig River, a tributary of the Iskut River (a tributary of the Stikine River) in British Columbia. His collar was returned by the trapper and downloaded.

2009—We recaptured wolverine M1 on 22 February 2009 (Table 1). With the use of a remotely-triggered camera, we had documented him on 2 occasions near one trap. He was wearing his collar from 2008, which we removed. We fitted him with a new GPS collar upon recapture. He was located several times using aerial telemetry, but his collar did not release. Eventually, we were unable to locate his collar, likely due to malfunction, and the collar was lost.

We captured M3 on 27 January 2009 and fitted him with a remotely downloadable collar (Table 1). We subsequently recaptured him on 8 February 2009 but released him without anesthetizing him. We remotely downloaded his collar on several occasions and were able to collect most GPS locations from it. His collar did not release as scheduled and we were unable to recover it.

We captured M4 on 11 February 2009 and fitted him with a remotely downloadable collar (Table 1). We remotely downloaded his collar twice and have data through 27 March 2009. Since then, we failed to locate his collar either because of dispersal or collar failure.

We captured M5 on 18 February 2009 and fitted him with a remotely downloadable collar (Table 1). He slipped his collar on 22 March 2009. We recovered it on 29 September 2009 in an avalanche chute in the upper East Fork of Lace River (Fig. 4).

We captured M6 on 22 February 2009 and fitted him with a store-on-board GPS collar (Table 1). He was subsequently located on several occasions from the air, but he was not located again before his collar was scheduled to release. He either dispersed from the area or the collar failed; his collar was lost.

We captured wolverine F3 on 11 February 2009 and fitted her with a store-on-board GPS collar (Table 1). She was located from the air on several occasions before her collar was scheduled to release, but she was not located anytime after the scheduled date of release. She either dispersed from the area or the collar failed.

We captured wolverine F4 on 14 February 2009 and fitted her with a store-on-board GPS collar (Table 1). She was located from the air on several occasions before her collar was scheduled to release, but she has not been located anytime after the scheduled date of release. She dispersed from the area or the collar failed.

2010—We captured wolverine F5 on 13 February 2010 and fitted her with a remotely downloadable radiocollar (Table 1). We remotely downloaded her collar on several occasions until we lost contact after 27 February 2010. On 30 March, 2012, a trapper targeting wolves along Cowee Creek snared her (about 25 km from her original capture site). We collected the collar, but the collar was damaged.

We captured wolverine M7 on 19 February 2010 and fitted him with a remotely downloadable collar (Table 1). We downloaded his collar on several occasions. He died 6 June 2010 (based on GPS data) but his carcass and collar were not recovered until 16 July 2010. Because of the long delay in recovery, we were unable to determine the cause of death (Fig. 5).

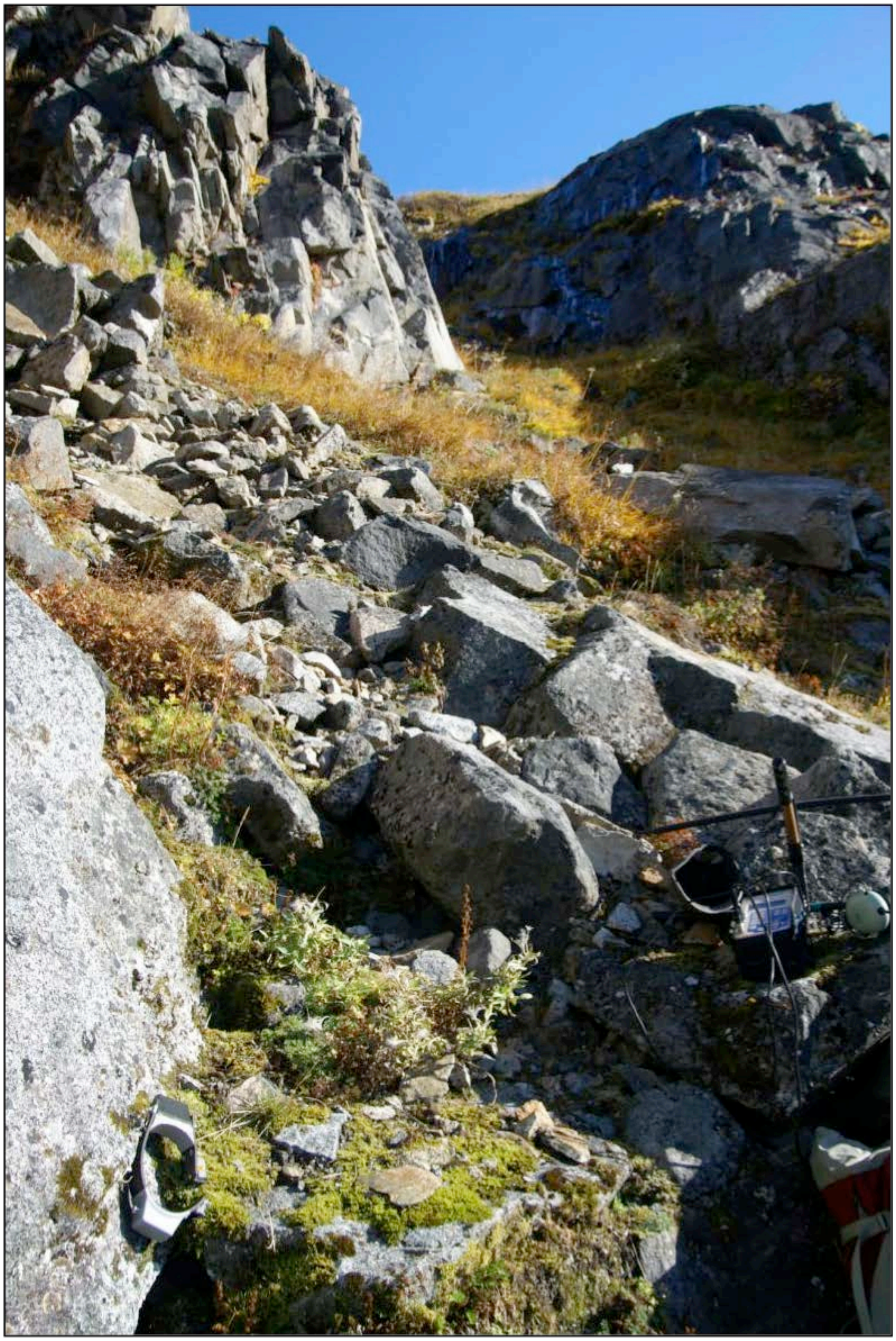

Figure 4. Wolverine M5's dropped GPS collar (lower left corner of photo) in Berners Bay, Southeast Alaska.

Figure 5. Location of wolverine M7's remains in upper Antler River, Berners Bay, Southeast Alaska, 2011. The cause of death was unknown.

We captured wolverine F6 on 27 February 2010 and fitted her with a remotely downloadable collar (Table 1). We downloaded her collar on several occasions until we lost contact after 21 September 2010; we presume she dispersed from the area or the collar failed.

We captured wolverine F7 on 10 March 2010 and fitted her with a remotely downloadable collar (Table 1). We downloaded her collar on several occasions until her collar fell off on 10 May 2010. We recovered her collar.

2011—We captured wolverine F8 on 22 March 2011 and fitted her with a remotely downloadable collar (Table 1). We downloaded her collar on several occasions until we lost contact after 7 July 2011 and presume she dispersed from the area or the collar failed. In March 2012, we identified her in a photo taken by our remote trail camera located along the Gilkey River with her collar still on.

GPS Location Data

Fix Rate—We experimented with different fix schedules and satellite search times in an attempt to maximize the time over which the collar would collect locations, while minimizing the length of time between fixes (i.e., the fix rate). The initial schedule on M1 yielded a 12% fix success (20 fixes over 171 attempts; 70 seconds [s] max time) over 8 days (21–29 March). The second schedule on M1 yielded 19% fix success (105 fixes over 549 attempts; 120 s max time) over 24 days (29 March–22 April). F1's collar yielded 36% fix success (39 fixes over 108 attempts; 120 s max time). F1's second fix success was 38% (35 fixes over 93 attempts; 120 s search time). F2's second collar yielded 31% fix success (88 fixes over 283 attempts; 120 s search time).

The collar fix success rates were higher during 2009 to 2011 period, with male collars yielding 70% and females 51% successful fixes. This corresponded with use of a new model of collar, and improved technology. However, wolverine use of mountainous and forested habitats limits satellite acquisition of GPS fixes.

Home Range—We estimated space use of wolverines in the Berners Bay area based on GPS location data from 6 male and 6 female wolverines over periods ranging from 2 to 26 weeks during the winter to early autumn (Table 2). Male wolverines had a median home range of 521 km^2 (100% CP, range = 288–4,981 km^2), nearly 4 times larger than that of females (71 km^2 range = 17–202 km^2).

Using AK home range estimates, male wolverines had a median home range of 323 km^2 (95% AK, range = 104–1,397 km^2; Table 2; Fig. 6), compared to females (58 km^2 range = 21–139 km^2; Table 2; Fig. 7). Core use areas (50% AK) were much smaller, averaging 18 km^2 for males and 9 km^2 for females (Figs. 6 and 7).

During 15 April 2008–30 April 2008, F1's collar was only worn for 8 days. During this time she traveled over a 21 km^2 area (Fig. 7). She stayed mostly in the valley bottoms, never climbing higher than 800 m before dropping her collar.

We tracked F2 during 28 April 2008–10 May 2008, when she ranged about 62 km^2. She spent most time on the mountain range between the Berners and Lace rivers, with 1 foray across the Berners River valley to investigate a mountain goat carcass (collared mountain goat that died over the winter; K. White, ADF&G, personal communication). During the 2 weeks she wore her collar, she covered this area 3 times, including crossing a 1,100 m high ridge on several occasions.

During 13–28 February 2010, we tracked F5 for only 2 weeks. During this time, she used an area of 40 km^2. Her use area contained the proposed road corridor near the mouth of Berners Bay. She was trapped on 30 March 2012 at Cowee Creek about 25 km from the original capture site.

We tracked F6 during 1 March 2008–21 September 2010. Her use area of 67 km^2 was in the mountain range between the Berners and Lace rivers. Her range was similar to F2's. No part of the road corridor was within her observed use area.

We tracked F7 during 11 March 2010–10 May 2010. F7's use area was mostly between Lynn Canal and Berners Bay on the peninsula south of the Kakuhan Range. The proposed road would bisect her range.

During 11 March 2011–07 July 2011, we tracked F8 for 4 months. Her use area (139 km^2) was entirely between the East Fork of the Lace River and the Antler River.

During 21 March 2008–15 June 2008, M1's home range area was 180 km^2. During this time, he made repeated circuits of his home range, regularly covering the approximately 26 km length of this area in a day or two and crossing the approximately 1,500 m ridge that runs the length of this area on several occasions (Fig. 6). Many of his locations were in habitat used by wintering mountain goats (White et al. 2012; K. White, ADF&G, personal communication). This

Table 2. GPS collar and spatial use information for 6 female and 6 male wolverines monitored in Berners Bay, Southeast Alaska, 2008–2011.

Animal ID	Dates monitored	No. days	No. locations	100% CP (km^2)	95% adaptive kernel (km^2)	50% adaptive kernel (km^2)	No. of locations within 1 km of the road corridor	Percent of locations within 1 km
Females								
F1	4/15/08–4/30/08	8	76	42	21	2	0	0
F2	4/28/08–5/10/08	13	92	64	62	7	0	0
F5[1]	2/13/10–2/28/10	13	30	17	40	6	1	3.3
F6	3/01/10–9/21/10	51	282	97	67	14	0	0
F7	3/11/10–5/10/10	59	154	78	55	4	71	46.1
F8	3/11/11–7/07/11	102	249	202	139	26	0	0
Mean		41	147	83	64	9	12	8
Median		32	123	71	58	6		
Males								
M1	3/21/08–6/15/08	86	411	294	180	14	39	9.5
M2[2]	4/22/08–6/16/08	56	421	4981	1397	52	5	1.2
M3	1/27/09–5/31/09	124	3134	288	104	4	12	0.4
M4	2/11/09–4/27/09	75	922	1085	596	19	58	6.3
M5	2/18/09–3/09/09	19	484	698	399	5	15	3.1
M7	2/20/10–6/06/10	115	291	344	247	15	0	0
Mean		79	944	1281	467	18	21	3.4
Median		80	452	521	323	14	14	2.1

[1] This animal was caught by a wolf trapper on 03/30/2012. The collar was damaged and we sent it back to the factory for downloading.
[2] This animal was caught by a trapper about 330 km from his original capture location.

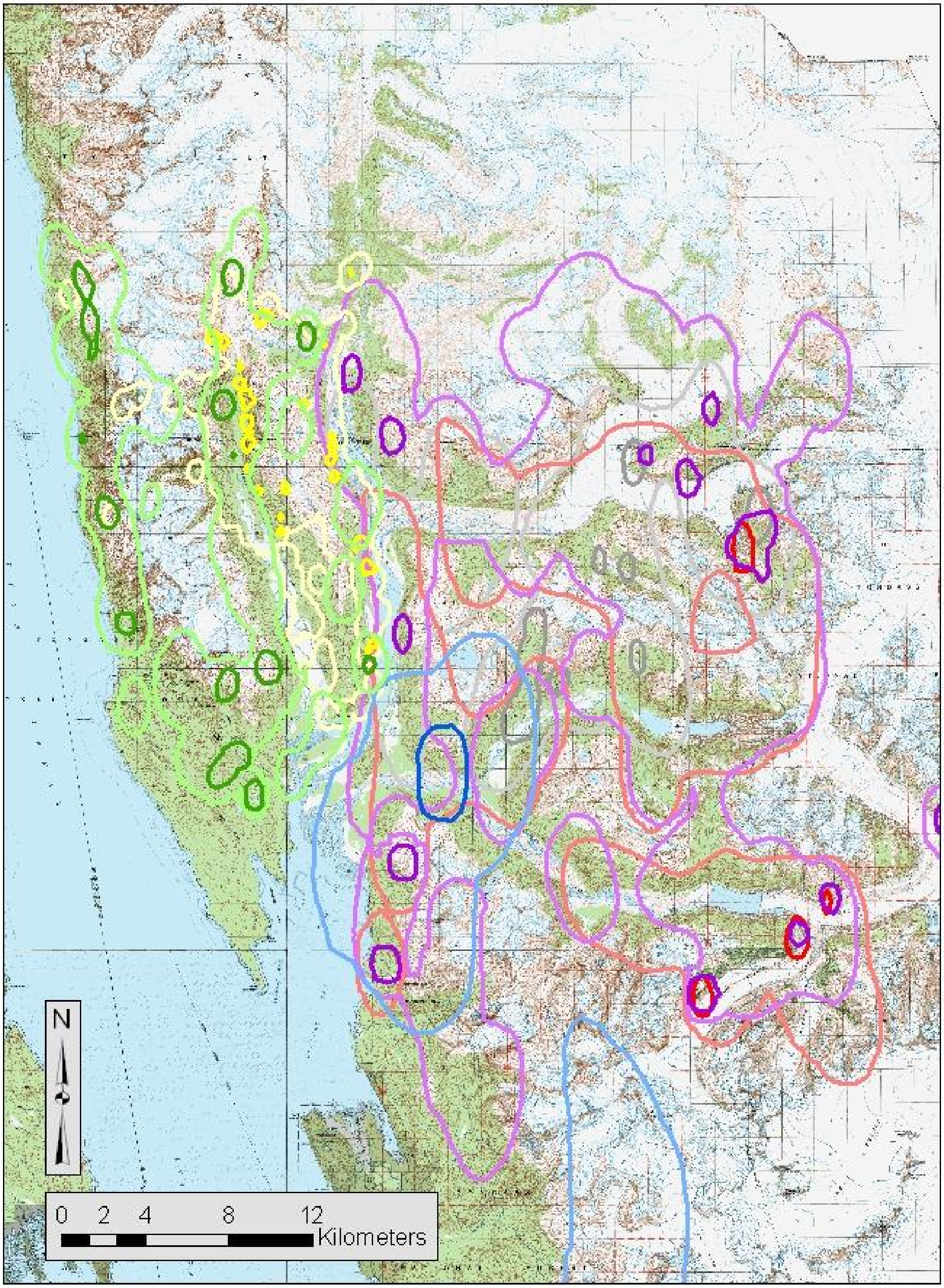

Figure 6. Larger (95%) and smaller (50%) adaptive kernel spatial use areas of 6 male wolverines in Berners Bay, Southeast Alaska. Colors indicate different animals: M1 = green; M2 = blue; M3 = yellow; M4 = purple; M5 = red; and, M7 = gray. Note, most of M2's use area is not shown as it is outside the Berners Bay study area.

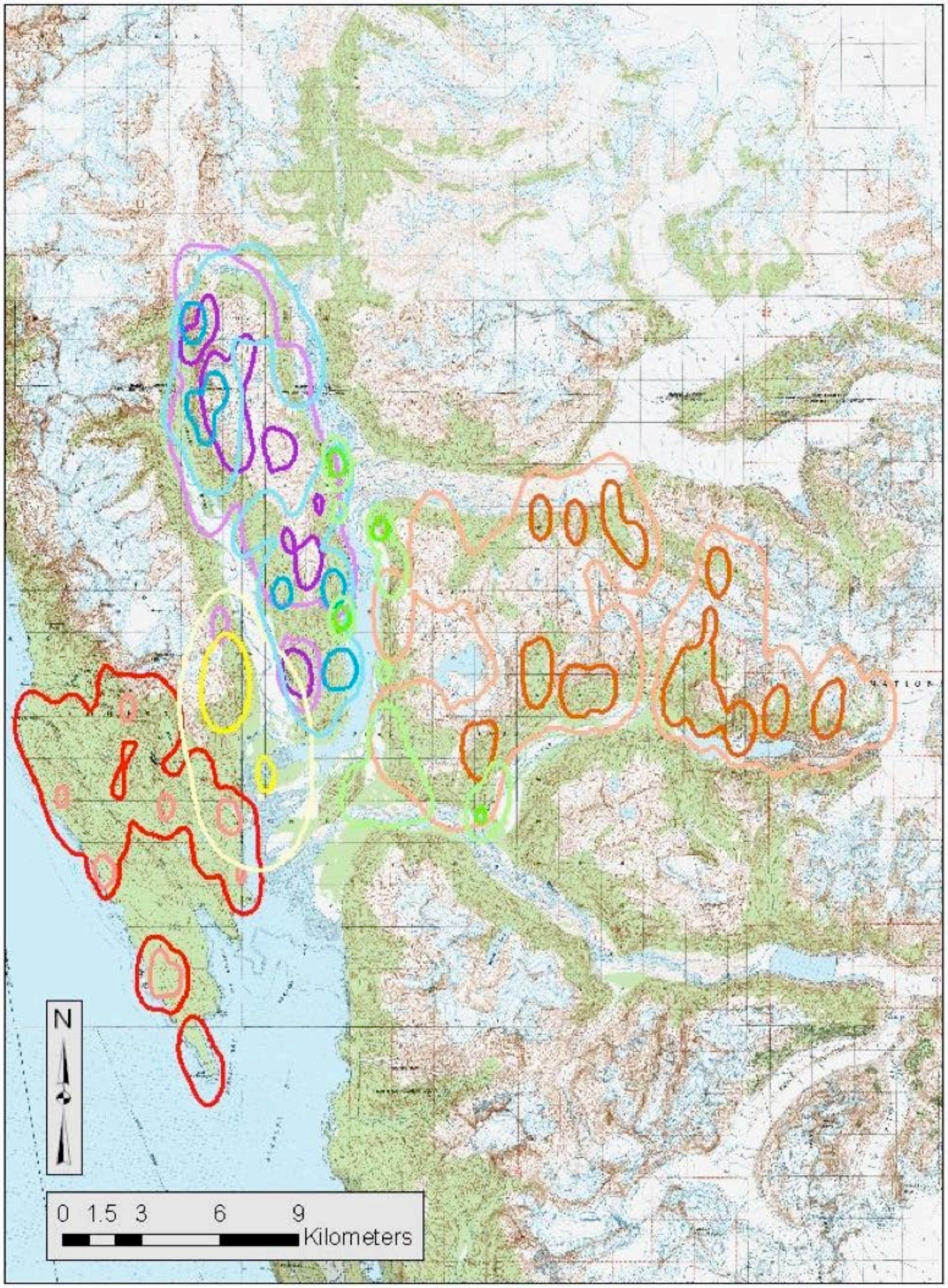

Figure 7. Larger (95%) and smaller (50%) adaptive kernel spatial use areas of 6 female wolverines in Berners Bay, Southeast Alaska. Colors indicate different animals: F1 = green; F2 = blue; F5 = yellow; F6 = purple; F7 = red; and, F8 = orange.

animal's use area contained much of the proposed road corridor from Comet Beach north.

Between 27 January 2009 and 31 May 2009, wolverine M3 spent most of his time on the mountain range between the Berners and Lace rivers, using an area of 104 km^2. He made a few forays west to into the Kakuhan Range. The proposed road corridor would not intersect his range.

Between 11 February 2009 and 27 April 2009, wolverine M4 used a larger area (596 km^2) from north of the East Fork of the Lace River to south of the Gilkey River. His use area contained portions of the proposed road corridor on the east side of Berners Bay.

Between 18 February 2009 and 9 March 2009, wolverine M5's use area was smaller (399 km^2) but encompassed an area similar to M4's. In fact, these animals were in the same place at the same time on several occasions, apparently at goat carcasses. This close social interaction suggests that these animals may be related.

Between 20 February 2010 and 16 July 2010, wolverine M7's use area was smaller (247 km^2) than the previous 2 animals, but occupied the same general area in the following year.

Distance to the proposed road—We recorded that 2 of 6 female wolverines had locations within 1 km of the proposed road corridor (Table 2). Also, 5 of 6 males had locations within 1 km of the proposed road corridor. One female (F7) had 46.1% of her locations within 1 km of proposed road and the road corridor would bisect her home range. All males but 1 would probably be vulnerable to trapping along the proposed road. For males, the percentage of locations within 1 km of the road ranged from 0 to 9.5 percent.

Dispersal—Wolverine M2 was caught by a trapper near the Craig River on the Iskut River in British Columbia in April 2010 (Fig. 8). Following straight-line distance, the wolverine travelled at least 330 km over 2 years. Also, we acquired photographs of 2 collared wolverines that were taken by trappers on Montana Creek near Juneau in December 2011 and Eagle River in May 2011. Although we could not identify the individual wolverines from the photographs and thus do not know at which site each animal was captured, it is about 30 km from Eagle River and 45 km to Montana Creek from the nearest possible capture site. Also, a trapper caught wolverine F5 along upper Cowee Creek on 30 March 2012; about 25 km from her capture site.

Because we caught only 1 wolverine in different years (M1 in 2008 and 2009), we suspect there is a lot of turnover in this wolverine population, (i.e., many new animals entering and leaving the population each year). We caught 4 of the 15 wolverines more than once in a single year, so we do not think they are particularly trap shy.

Habitat Selection

Resource Selection Function model

We developed a RSF for wolverines for the period from winter (late January) to early autumn (mid-September) based on the GPS locations we gathered from radiocollared wolverines. This period roughly corresponds to the time when female wolverines are rearing kits from their natal den through dispersal (Magoun and Copeland 1998).

We evaluated physical and habitat variables (Table 3) for resource selection. Wolverines showed a different proportion of habitat used than was available in the landscape. In

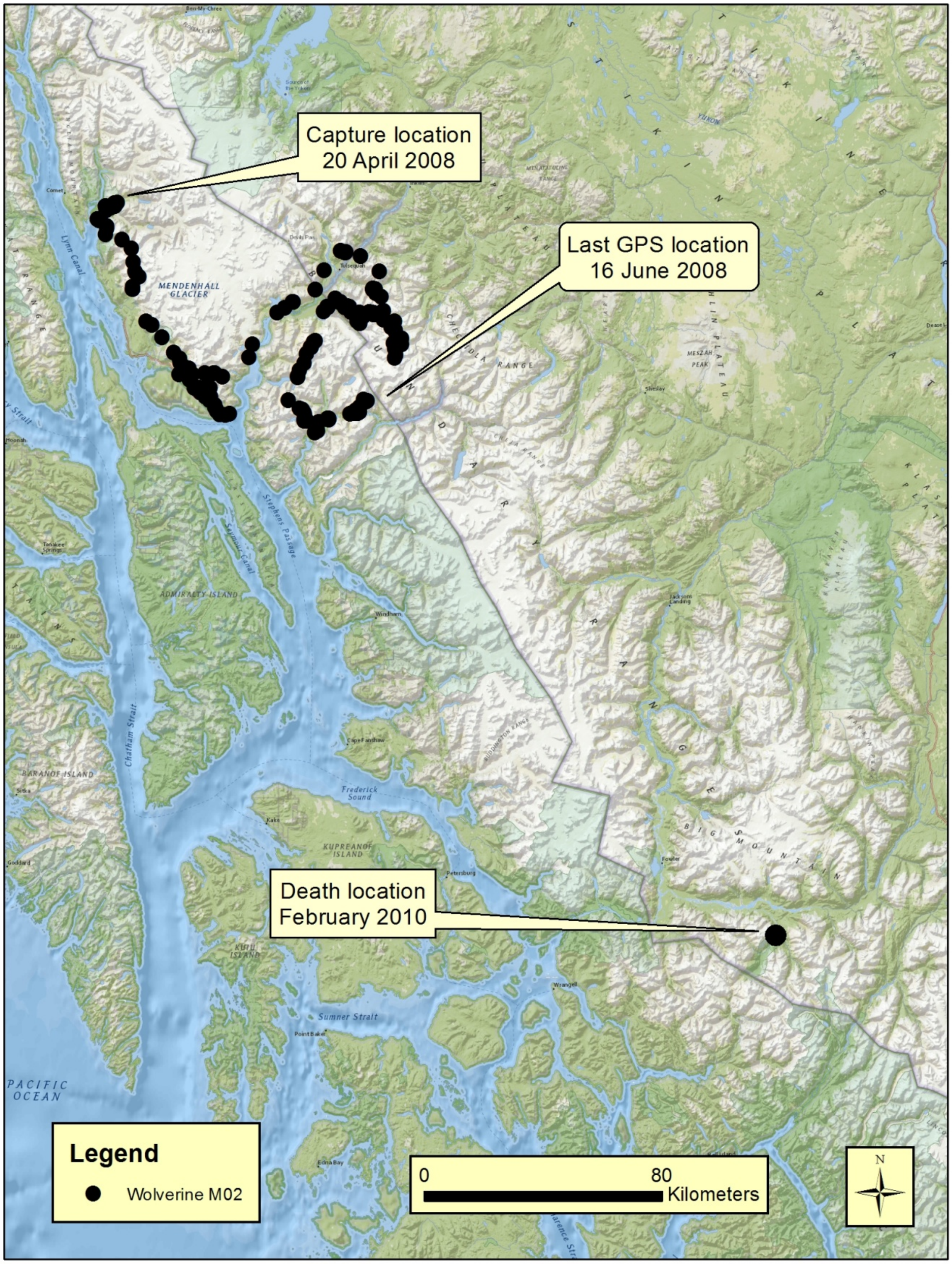

Figure 8. Locations of wolverine M2, including his original capture location in Berners Bay, Southeast Alaska, and his death location near the Iskut River, British Columbia.

the final model, we chose elevation and slope for physical variables and shrub and unvegetated for landcover classes (Figs. 9 and 10; Table 4).

We recorded some variation in habitat selection by individual wolverines, but the RSF is an average of all wolverines. We did not analyze habitat selection by gender or age class because our sample size was too small for individual groupings.

We found that collared wolverines selected the valley sides throughout the Berners Bay area. These areas corresponded to low to mid elevation (< 1,000 m) with moderate slope (30%). The vast majority of points recorded appear to be when wolverines were moving between areas, presumably between areas that contained food sources. In terms of habitat types, wolverines significantly chose shrub and unvegetated habitats. These categories translate to avalanche chutes, and areas farther up slopes or valleys that contained fewer forested areas. The unvegetated habitat class was totally snow covered during winter into early summer and probably contained many overhangs and caves that wolverines tend to use.

Model validation

We found Spearman's rho values were > 0.9 with P-values < 0.001 in 4 of the 5 (80%) cross-validation trials, which indicates a useful model (Table 5). Adjusted R^2 from regression models were $\geq$ 0.88, except in cross-validation 3, also indicating a strong correlation observed and expected proportions. Cross-validation 3 showed the lowest performance. Although Spearman's rho was significant, the adjusted R^2 was much lower than the other cross-validation trials (0.19). The 2 left-out animals in this cross validation happened to be the two animals for which the fewest locations were obtained (n = 30 and n = 47). Probably, the habitat selection of these 2 animals was not adequately characterized by these small sample sizes.

DIET

We obtained stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) for 5 captured female wolverines (3 blood samples and 5 hair samples) and 7 captured male wolverines (3 blood samples and 8 hair samples) (Table 6). In addition, we received results of mountain goats (36) and moose (27) samples (clotted red blood cells) that were captured either within or near Berners Bay (Table 7). For male wolverines, the values of $\delta^{13}C$ for 11 samples ranged from -25.9 to -23.7 ($\bar{x}$ = -24.3, SE = 0.18) and $\delta^{15}N$ ranged from 3.8 to 4.8 ($\bar{x}$ = 4.3, SE = 0.09) for both clotted red blood cells and hair (Table 6). For 8 females samples, $\delta^{13}C$ ranged from -26.2 to -23.9 ($\bar{x}$ = -24.3, SE = 0.29) and $\delta^{15}N$ ranged from 4.2 to 5.8 ($\bar{x}$ = 4.8, SE = 0.19) for both clotted red blood cells and hair (Table 6). We found significant difference in the ratios between mean clotted red blood cells and hair (MANOVA, P = 0.02), with the means for hair being slightly less depleted in $\delta^{15}N$.

Table 3. Physical and landcover factors used in resource selection function (RSF) analysis for wolverines in Berners Bay, Southeast Alaska, 2008–2011.

Variable	Definition	Source data[1]
Terrain		
Elevation	Distance above sea level (m)	SRTM-DEM
Slope	Steepness or gradient of incline (%)	SRTM-DEM
Landcover		
Glacier	Areas covered by permanent glaciers	Terrestrial Systems Database
Unvegetated	Landcover types covered by snow, rock, or sparse alpine vegetation	Terrestrial Systems Database
Herbaceous	Landcover types dominated by sedges, grass, and other herbaceous plants	Terrestrial Systems Database
Shrub	Landcover types dominated by deciduous shrubs	Terrestrial Systems Database
Forest	Landcover types dominated by trees	Terrestrial Systems Database

[1] The terrain variables were derived from the Shuttle Radar Tomography Mission Digital Elevation Model (SRTM-DEM). The landcover variables were derived from a database of terrestrial ecological systems (Albert and Schoen 2006).

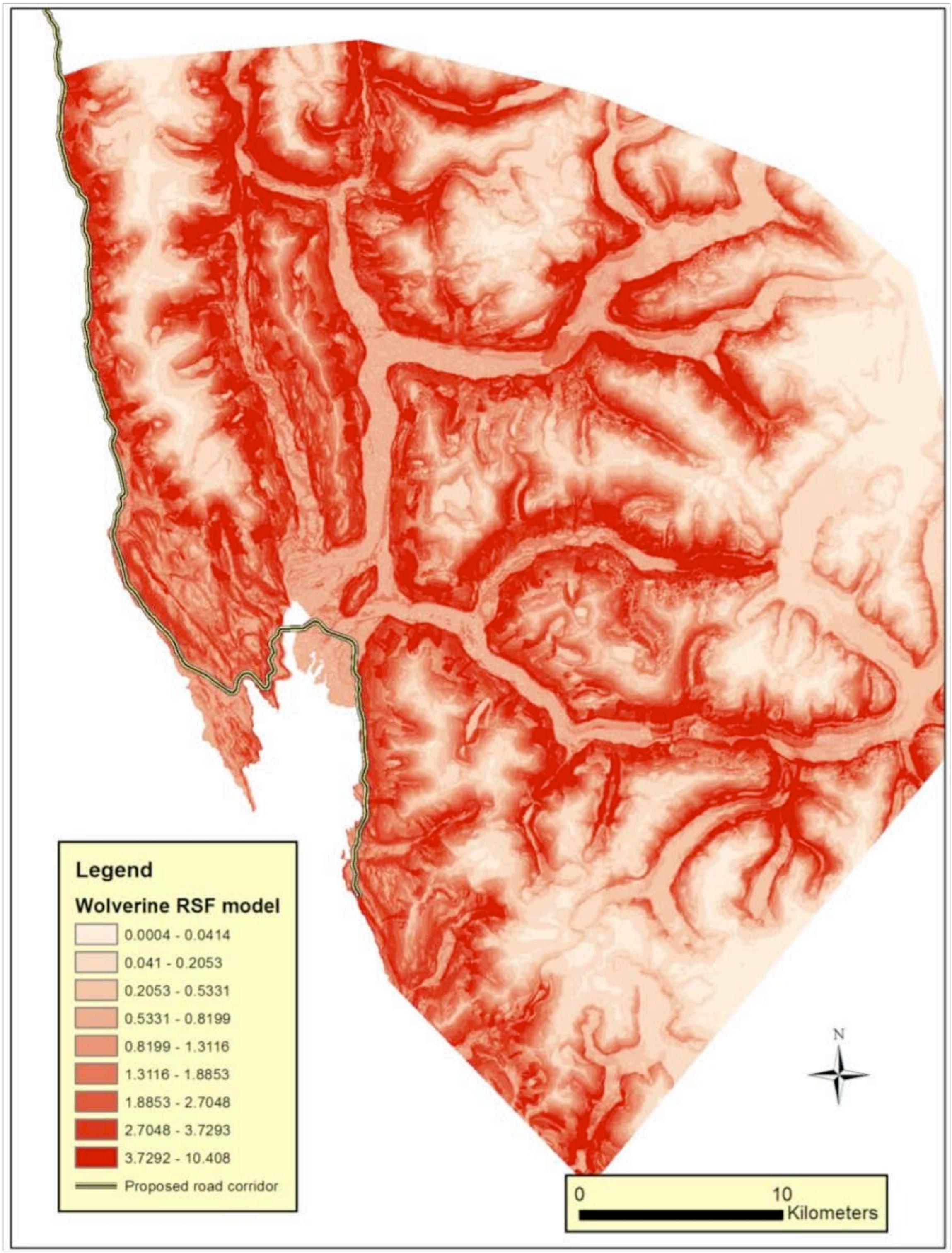

Figure 9. Predicted relative probability of resource selection for wolverines in Berners Bay, Southeast Alaska, 2008–2011.

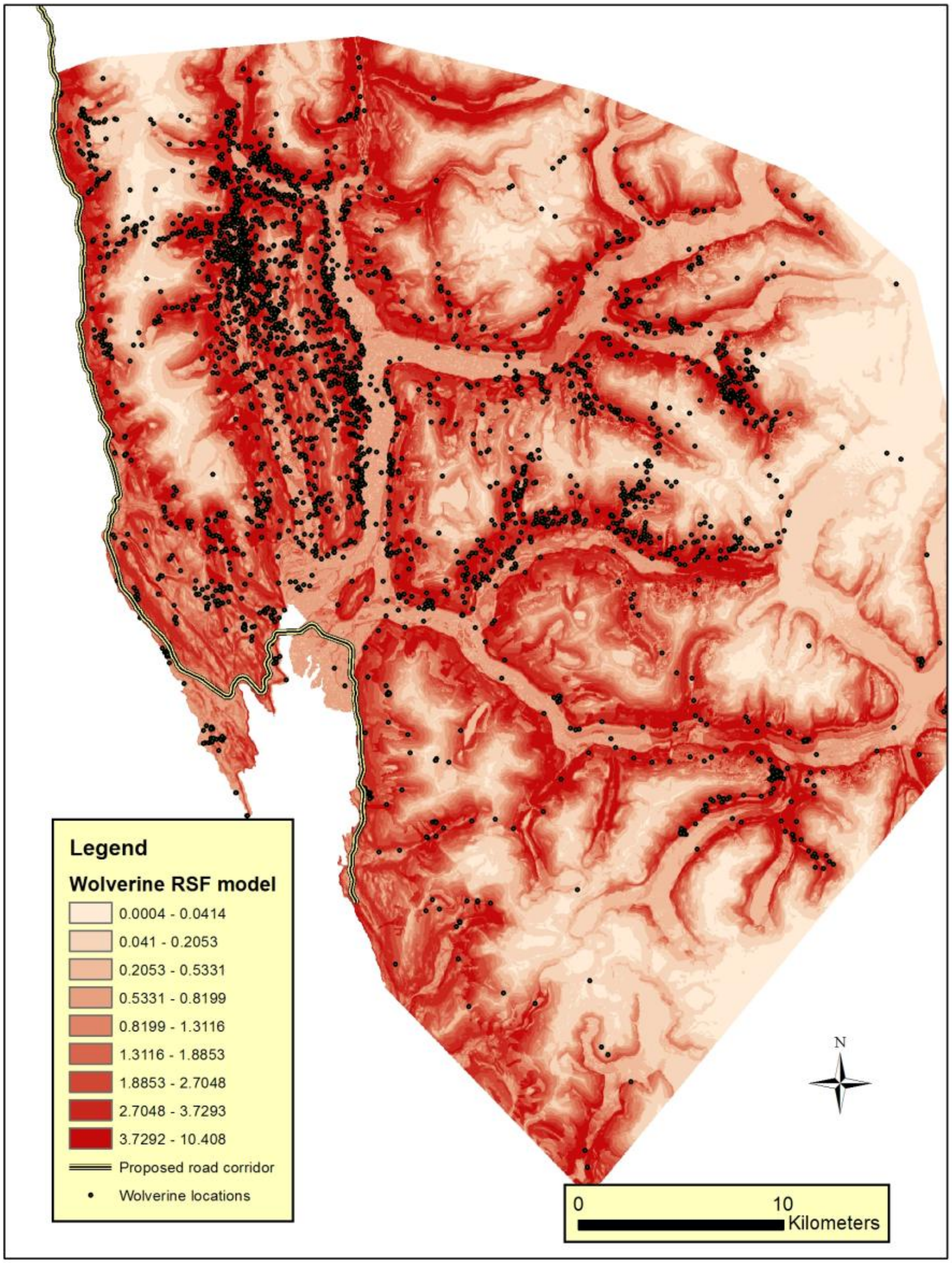

Figure 10. Predicted relative probability of resource selection by wolverines in Berners Bay, Southeast Alaska, with individual wolverine points overlain for reference.

Table 4. Resource selection function (RSF) weighted mean coefficients for wolverines in Berners Bay, Southeast Alaska, 2008–2011.

Variable	Weighted mean	Confidence interval Lower	Confidence interval Upper
Elevation	-1.456	-1.849	-1.062
Elevation^2	-0.413	-0.730	-0.096
Slope	0.449	0.186	0.712
Slope^2	-0.405	-0.500	-0.311
Shrub	0.818	0.504	1.131
Unvegetated	0.949	0.447	1.452

Table 5. Wolverine resource selection function (RSF) model performance on cross-validation. Data on habitat selection collected during 2008–2011 from Berners Bay, Southeast Alaska.

	Spearman's correlation		Linear regression				
			Slope		*y*-intercept		
Cross-validation	r_s	*P*-value	Coefficient	Significant[a]	Coefficient	Significant[b]	Adjusted-R^2
1	1.00	<0.001	1.30	N	-0.03	N	0.91
2	0.93	<0.001	0.77	Y	0.02	N	0.88
3	0.86	0.002	0.58	N	0.04	N	0.19
4	0.99	<0.001	1.03	N	-0.003	N	0.98
5	0.99	<0.001	0.94	N	0.005	N	0.93
Mean	0.99	<0.001	0.93	N	-0.007	N	0.96

[a]slope significantly different than 1 ($P < 0.05$); N = No, Y = Yes
[b]*y*-intercept significantly different than 0 ($P < 0.05$)

Table 6. Stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) from captured wolverines in Berners Bay, Southeast Alaska, 2008–2011.

Wolverine	Date	Material[a]	$\delta^{13}C$	$\delta^{15}N$
Females				
F1	04/15/2008	RB	-23.9	5.8
F1	04/15/2008	Hair	-23.8	4.7
F2	04/18/2008	RB	-23.8	5.2
F2	04/18/2008	Hair	-24.0	4.2
F3	02/11/2009	RB	-26.2	4.4
F3	02/11/2009	Hair	-24.8	4.5
F4	02/14/2009	Hair	-23.9	4.3
F7	03/11/2010	Hair	-24.1	4.9
Means			-24.3	4.8
Males				
M1	03/21/2008	RB	-24.9	4.4
M1	03/21/2008	Hair	-23.9	4.7
M1	02/19/2009	Hair	-24.2	3.9
M2	04/22/2008	RB	-24..2	4.4
M2	04/22/2008	Hair	-23.9	4.0
M3	01/27/2009	Hair	-23.9	4.7
M4	02/11/2009	RB	-25.9	4.3
M4	02/11/2009	Hair	-24.5	4.6
M5	02/18/2009	Hair	-24.2	3.8
M6	02/19/2009	Hair	-23.7	4.5
M7	02/19/2010	Hair	-24.3	4.2
Means			-24.3	4.3
Overall mean			-24.3	4.5

[a] RB = clotted red blood cells.

Although we found slight differences, we computed a mean value based on both clotted red blood cells and hair for each individual wolverine for use in the mixing model. We didn't find any significant differences between mean male and female ratios (MANOVA, P = 0.82). Diets of wolverines showed some individual variability in the $\delta^{13}C$ ($\bar{x}$ = -24.31, SD = 0.69) and $\delta^{15}N$ ratios ($\bar{x}$ = 4.5, SD = 0.46) (Table 6).

We found that our mountain goat samples were different from moose (MANOVA, P = 0.001). Mountain goats were less depleted for $\delta^{13}C$ ratios ($\bar{x}$ = -25.6, SD = 0.51) compared to moose ($\bar{x}$ = -26.01, SD = 0.37, P < 0.001). For $\delta^{15}N$, we found no differences between the means of mountain goats ($\bar{x}$ = 0.8, SE = 0.09) and moose ($\bar{x}$ = 0.9, SE = 0.11, P = 0.16). Although we found slight differences in the $\delta^{13}C$ values, we combined mountain goat and moose into a large ungulate group for the mixing model analysis (Table 7). The stable isotope values of other food items that we used in the mixing model have been listed in Table 7.

We plotted the stable isotope values ($\delta^{13}C$ and $\delta^{15}N$) for the wolverines against the potential food items (Fig. 11). Initially, we ran the staple isotope analysis with salmon as a component in wolverines' diets. We found no evidence of salmon in the diet of wolverines, so we eliminated salmon from future runs to minimize the number of food items in the mixing model. The convex hull produced by the mixing model included all the potential food items, thus we were able to obtain a solution for every wolverine (Fig. 12).

Diets of wolverines on average consisted of 27% deer and 17% large ungulate prey, probably carrion (total of 44% carrion), 21% grouse, 12% ptarmigan, and 10% mountain rodents, probably hoary marmots (Table 8). Other items were minor contributions to wolverines' diets averaging < 10% (beavers 7% and conifer eaters 5%, probably mostly porcupines). Because we did not find any differences in stable isotope ratios, we assumed there were no gender differences.

Table 7. Stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) that were used in diet composition models for wolverines. We combined the values for mountain goats and moose from this study into a large ungulate category. The sources of the other food items are described in the methods.

Food item	$\delta^{13}C$	$\delta^{15}N$
Large ungulate (mountain goats and moose)	-25.8	0.9
Conifer eaters (red squirrels and porcupines)	-22.6	2.7
Mountain rodents (arctic ground squirrel and hoary marmot)	-25.2	2.2
Ptarmigan	-24.6	-0.1
Beavers	-24.7	3.3
Sitka black-tailed deer	-28.6	3.6
Grouse	-26.7	-0.3
Salmon (combination of pink, chum, and coho salmon)	-19.9	12.1

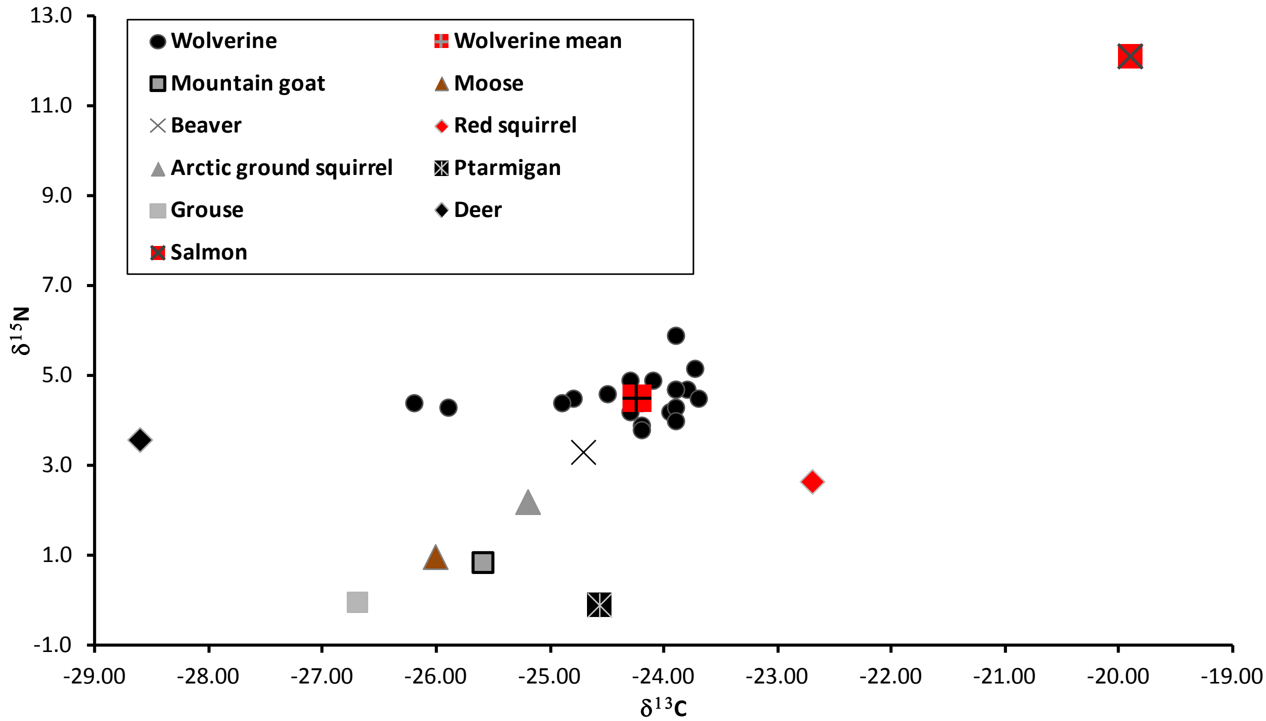

Figure 11. Stable isotope values (δ^{13}C and δ^{15}N) for wolverines captured in winter, 2008–2011, Berners Bay, Southeast Alaska. Wolverine samples are from clotted red blood cells and hair. Mountain goat and moose values are from clotted red blood cells that were captured in Berners Bay in autumn and late winter, 2008-2011. We used isotope values for beavers from the Yukon during late summer (Milligan and Humphreys 2010), salmon from Southeast Alaska during late summer (Szepanski et al. 1999), arctic ground squirrels from the Yukon during summer (Ben-David et al. 1999), Sitka black-tailed deer from Southeast Alaska during autumn (R. Flynn, ADF&G, personal communication), red squirrels from Southeast Alaska during autumn (R. Flynn, ADF&G, personal communication), grouse from Southeast Alaska (Ben-David 1996), and ptarmigan from Southcentral Alaska during winter (H. Golden, ADF&G, personal communication).

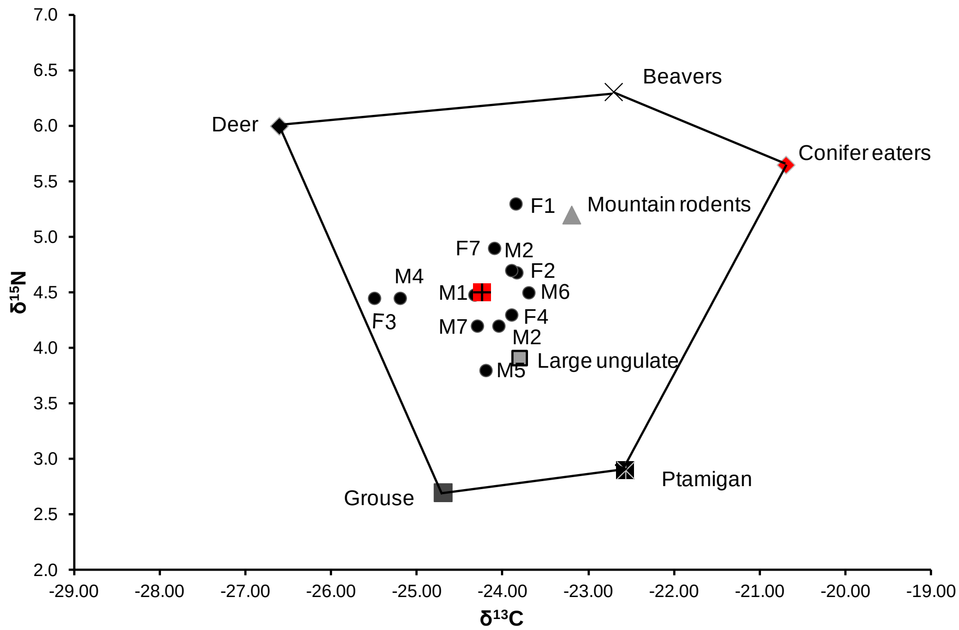

Figure 12. The convex hull showing the solution space for the stable isotope analysis after accounting for discrimination factors using the program SISUS. All the individual wolverines (circles, M = male and F = female) and the mean of the wolverine samples collected from Berners Bay (red box), Southeast Alaska are plotted. In addition, the mean values for the food items after the discrimination factors have been applied are plotted. We combined the values for moose and mountain goats into a large ungulate category. We considered the values for arctic ground squirrel surrogates for hoary marmots and categorized these values as mountain rodents. Also, we assumed that porcupines were similar to red squirrels and considered them together as conifer eaters.

We found variation in the diets of individual wolverines (Table 8). The proportion of deer in the diet varied from 0.05 to 044 and large ungulate (moose and mountain goats) from 0.01 to 0.20. These food items were probable mostly carrion. Grouse ranged from 0.14 to 0.49 and ptarmigan ranged from 0 to 0.14. Mountain rodents ranged from 0 to 0.15. Beavers and confer eaters were minor food items to most animals.

Discussion

MOVEMENTS

This research was designed to investigate the spatial-use patterns (i.e., home range, movements, dispersal) of wolverines in the Berners Bay portion of the Juneau Access Improvements Project study area. Based on our sample of wolverines, we found wolverine home ranges to be large and variable (range = 42–1,085 km^2; 100% CP).

Table 8. Diet proportions of wolverines from Berners Bay, Southeast Alaska, as determined by stable isotopes ratios ($\delta^{13}C$ and $\delta^{15}N$) from blood and hair samples from captured animals using the program SISUS, 2008–2011.

Wolverine	Large ungulates[a]	Conifer eaters[b]	Mountain rodents[c]	Ptarmigan	Beavers	Deer	Grouse
Females							
F1	0.18	0.05	0.10	0.12	0.08	0.24	0.25
F2	0.18	0.08	0.15	0.13	0.11	0.05	0.16
F3	0.01	0.00	0.00	0.00	0.00	0.44	0.54
F4	0.20	0.06	0.12	0.14	0.09	0.14	0.25
F7	0.16	0.07	0.14	0.12	0.11	0.27	0.14
Males							
M1	0.16	0.04	0.09	0.11	0.07	0.25	0.27
M2	0.19	0.05	0.10	0.13	0.07	0.15	0.31
M3	0.18	0.07	0.15	0.13	0.11	0.20	0.16
M4	0.05	0.01	0.03	0.03	0.02	0.39	0.47
M5	0.14	0.04	0.08	0.09	0.06	0.11	0.49
M6	0.20	0.08	0.15	0.14	0.11	0.13	0.18
M7	0.15	0.04	0.08	0.10	0.06	0.19	0.37
Overall[d]	0.17	0.05	0.10	0.15	0.07	0.27	0.21

[a] Large ungulates represent mountain goats and moose.
[b] Red squirrels also represent porcupines.
[c] Mountain rodents represent hoary marmots.
[d] For the overall diet proportions, we applied the mixing model to the mean stable isotope ratios ($\delta^{13}C$ = -24.3 and $\delta^{15}N$ = 4.5)

Part of this variability can be explained by sex, with males having much larger home ranges than females (Table 1). Also, wolverines move long distances, either within their home ranges or while dispersing. Because of these long distance movements, wolverines can become vulnerable to trapping. We found that 2 of 6 females and 5 of 6 males ventured within 1 km of the proposed road corridor. These animals would be vulnerable to trapping by individuals using the proposed road corridor for access.

We utilized 2 types of traps, a modified box trap and a portable plastic trap. The modified box traps were most successful, but required obtaining enough wood to build the trap and a large and more expensive helicopter (a Eurocopter AS350 rather than a Hughes 500 or a Bell Jet Ranger) to sling the materials to the site for construction. In addition, these traps once constructed were permanently located and could not be moved without deconstruction and slinging with a helicopter. We designed the plastic traps so that they could be easily relocated to multiple locations using the smaller sized helicopters (Hughes 500 or Bell Jet Ranger) that we were using to access the sites. However, these traps did not catch any wolverines and require more work to increase their effectiveness.

Unfortunately, we could not calculate a population estimate to guide ADF&G's management of this species in the Berners Bay area. From studies in other locations, we know that wolverines occur in low densities (Lofroth and Krebs 2007, Royle et al. 2011). The large home ranges we found suggest low population numbers.

HABITAT SELECTION

Wolverines selected the side slopes from the edges of valley bottoms to treeline and above. In winter, mountain goats may frequent some of these habitats and often goat carcasses end up in avalanche chutes after falls (K. White, ADF&G, personal communication). In addition, other wolverine prey (e.g., porcupine and ptarmigan are also found in these areas during winter months. As spring changed to the summer, wolverines continued to use these habitats, likely as more winter carrion became available as snow melted, but also as small and medium-sized mammals (e.g., hoary marmot) became active.

Our analysis suggests similarities between wolverine habitat use in Southeast Alaska and habitat use elsewhere in North America, despite differences in occurrence of terrain and prey species (Hornocker and Hash 1981, Whitman et al. 1986, Banci and Harestad 1990, Copeland et al. 2007, Krebs et al. 2007). Wolverines also used low to midslope areas that support wintering ungulates during winter and midslope subalpine avalanche habitats in spring and summer where small mammals and birds may be more abundant and accessible.

Among the wolverines we monitored, there was some variation in use of the different habitat variables. In general, elevation use was consistent except for animal F1, which used only low elevation areas. However, her sample was rather limited in time, which probably caused this artifact. Use of slopes, as well as use of shrub and unvegetated habitats, varied among all animals and probably depended on what was available within each animal's specific range.

DIET

Our stable isotope analysis suggests that in winter, all wolverines in Berners Bay preyed at the same trophic level on various herbivores, both mammal and bird. Diets of wolverines on average consisted of 27%

deer, probably carrion, and 17% large ungulate prey, probably also carrion. Thus, 44% of wolverine diets were ungulate carrion. Birds combined for 36% of the average diets with grouse at 21% and ptarmigan at 15%. Other items were minor contributions (i.e., averaging ≤ 10%) to the diet, (mountain rodents 10%, beavers 7%, and conifer eaters 5%,). We found no evidence of wolverines using marine resources (i.e., salmon).

While in general the diets were similar, we found variation in the proportions of different prey types in the diets of individual wolverines. The proportion of deer in the diets varied from 0.05 to 0.39 and large ungulate varied from 0.01 to 0.18, but total carrion in the diet varied from 0.23 to 0.45. Likewise, grouse ranged from 0.16 to 0.49 and ptarmigan ranged from 0 to 0.14, but total birds ranged from 0.29 to 0.54. Thus, wolverines consumed mostly carrion and birds. Other food items form a lesser proportion of wolverines' diets, including mountain rodents (0 to 0.15), beavers (0 to 0.11), and conifer eaters (0 to 0.08).

Throughout their range, wolverines tend to feed on large ungulates during winter (Magoun 1987, Banci 1994, Landa et al. 1997, Lofroth et al. 2007, Dalerum et al. 2009). Most authors list ungulate carrion as being particularly important for wolverines (Banci 1994, Lofroth et al. 2007) and wolverines were seen feeding on winter-killed mountain goats in Berners Bay (K. White, ADF&G, personal communication). However, other prey species also are used during winter. In the Yukon, Banci (1994) lists snowshoe hares, porcupines, red squirrels, and birds, as well as ungulate carrion as important items in wolverine diets. Snowshoe hares are rare in Berners Bay, but mountain goats, moose, porcupines, red squirrels, and ptarmigan are common. We were surprised to find substantial deer in the diets of wolverines. Deer are found throughout the study area, but in lesser amounts than in surrounding areas. In northern Alaska, similar other species (i.e., ground and tree squirrels, porcupines, ptarmigan) are found in wolverine diets (Magoun 1987, Dalerum et al. 2009).

Lofroth et al. (2007) found regional variation was related to differences in prey availability between his study areas in British Colombia. Moose, caribou (*Rangifer tarandus*), and hoary marmots were abundant and common prey items within both study areas. Mountain goats and porcupine were more abundant and more frequent prey items in the Columbia Mountains, while snowshoe hare and beaver were more abundant and more frequent prey items in the Omineca Mountains.

We were surprised that the wolverines in Berners Bay did not use marine foods, especially salmon. Drainages in Berners Bay host runs of 4 salmon species, including late runs of coho salmon (*O. kisutch*). However, this area hosts a relatively dense brown bear population that utilizes these salmon runs extensively (Flynn et al. 2012) and this could cause wolverines to avoid this abundant resource to avoid conflict (van Dijk et al. 2008).

Recommendations

Regardless of whether the road is or is not built, ADF&G's wildlife management staff will continue to monitor wolverine harvests in the project area through required sealing of furs by trappers. Access as a result of road construction would make monitoring all the more important. If harvests exceed levels that are believed to be sustainable, changes to the current management strategy will be considered and proposals for modified regulations will be presented to the

BOG. Changes could include season closures by emergency order, a harvest quota, or rotating open seasons. State trapping regulations prohibit trapping within one-quarter mile of the coast between the end of Thane Road, the farthest south that roads currently reach in the Juneau system, and the end of Glacier Highway at Echo Cove, to the north. If or when the access road is built, ADF&G will recommend to the BOG that this trapping restriction be added to the entire coast in the area encompassing the proposed road corridor. More research will be needed to determine sustainable wolverine harvest levels.

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