Badger Resource Selection in the Rocky Mountain Trench of British Columbia

Trevor A. ***Kinley****, Jesse* ***Whittington****, & Alan D.* ***Dibb****, Parks Canada Agency;*
Nancy J. ***Newhouse****, Nature Conservancy of Canada*

Abstract

Conservation of species at risk requires an understanding of resource-selection patterns and habitat distribution. We used 1,795 radio-telemetry locations from 55 study animals to model resource selection for an endangered population of American badger (*Taxidea taxus jeffersonii*, eastern population) in the Rocky Mountain Trench of British Columbia. The badgers were associated with low elevations, shallow slopes, high solar radiation, and low crown closure. They selected higher elevations only on sites with shallow slopes or high solar radiation. Compared to mesic low-elevation forests, badgers selected locations where the climax ecoclass was riparian forest or very open low-elevation forest. In comparison to Douglas-fir stands, badgers selected clearings, moist forest, and open range. They avoided lodgepole pine stands, western larch stands, and wet areas. Relative to the Brunisol soil order, they avoided Podzolic – Luvisolic and Regosolic-Gleysolic orders. Compared to Morainal soil parent material, the badgers avoided colluvial, rock, aeolian, and anthropogenic and selected for glaciolacustrine parent material. Results were consistent both with expectations from other provincial studies and with cover types used by Columbian ground squirrels (*Spermophilus columbianus*), which are their main prey. Our model provides a spatially explicit tool to prioritize areas for restoration or critical habitat designation. Reduction of crown closure would benefit badgers, and would probably be the most advantageous on Brunisolic or Chernozemic soils and glaciolacustrine parent material.

KEYWORDS: American badger; British Columbia; critical habitat; habitat restoration; resource selection function; Taxidea taxus jeffersonii (badger)

Introduction

American badgers (*Taxidea taxus jeffersonii*) occur throughout much of southern British Columbia. Due in part to habitat loss, the two populations of badgers within British Columbia are both listed as “endangered” by the federal government (COSEWIC 2012) and are red listed by the provincial government with a ranking of G5S1 (Conservation Data Centre 2011). Badger protection and recovery will depend on understanding where badgers occur and which resources they select. Moreover, there is a statutory requirement in the Canadian Species at Risk Act (Parliament of Canada 2002) to designate “critical habitat” for taxa listed as endangered.

JEM
Vol 14, No 3
JOURNAL OF Ecosystems & Management

Kinley, Trevor A., Whittington, Jesse, Dibb, Alan D., & Newhouse, Nancy J. Badger Resource Selection in the Rocky Mountain Trench of British Columbia. *Journal of Ecosystems and Management 14*(3):1–22. http://jem-online.org/index.php/jem/article/viewFile/566/500

Critical habitat has not yet been identified for badgers in British Columbia, but habitat quality has been considered for several land-use processes, such as planning provincial "wildlife habitat areas" (Kinley 2009; Paige & Darling 2010), forest harvesting (Weir & Almuedo 2010), and development permit areas (Regional District of East Kootenay 2008). These habitat designations were developed through expert opinion and habitat suitability analyses. Apps et al. (2002) developed a spatially explicit badger habitat model for the northern portion of the East Kootenay area of southeastern British Columbia, based on preliminary radio-telemetry data. That model included both permanent and temporally fluctuating explanatory variables: soils, hydrography, linear features, cover type, vegetation indices, topography, terrain, and forest stand characteristics. It provided a tool to assess local habitat quality, but covered a limited area. Given this and the collection of much more radio-telemetry data (Kinley & Newhouse 2008), we expanded upon this original, localized model, and developed a resource selection function (RSF) model for all badger range within the British Columbia portion of the Rocky Mountain Trench. Our objective was to identify areas of high-quality badger habitat, which could then aid future designation of critical habitat and facilitate other land-use planning processes.

Badger foraging in British Columbia varies regionally among the South Cariboo (Packham & Hoodicoff 2004), Thompson-Okanagan (Hoodicoff 2003; Weir et al. 2003), and East Kootenay (Kinley & Newhouse 2008) study areas. Badgers consume many species in all regions. However, badger burrows in the South Cariboo were associated with signs of mice (*Cricetidae*), voles (*Arvicolidae*), marmots (*Marmota* spp.), muskrats (*Ondatra zibethicus*), and ground squirrels (*Spermophilus* spp.). Those in the Okanagan were associated with all of those taxa except muskrats. Burrows in the East Kootenay (where marmots are absent at low elevations and ground squirrels are common), however, were strongly associated with the burrows of Columbian ground squirrels (*S. columbianus*) (Newhouse & Kinley 2001). South Cariboo badger burrows were also commonly located in aeolian soils, which are very rare in the East Kootenay (Jungen 1980; Wittneben 1980; Lacelle 1990). Despite those differences, the distribution of badgers in British Columbia is correlated with the distribution of their primary prey; agricultural land, grasslands, or open forests; and soils that can be easily excavated (Newhouse & Kinley 2001; Apps et al. 2002; Hoodicoff 2003; Weir et al. 2003, Packham & Hoodicoff 2004; Kinley & Newhouse 2008).

Methods

Our study area was centred on the Rocky Mountain Trench in southeastern British Columbia, which lies between the Rocky Mountains and the Purcell Mountains. The research from which we drew our radio-telemetry data (Kinley & Newhouse 2008) had a larger study area, but we restricted our analysis to the Rocky Mountain Trench because it was the main physiographic unit of interest. We first defined the study area as the British Columbia portion of the East Kootenay Trench ecosection (Demarchi 1996)—from the border of Montana in the United States (49° N) to the approximate northern extent of the contiguous badger range in the Rocky Mountain Trench (Weir & Almuedo 2010), which is 50 km northwest of Radium Hot Springs in British Columbia (51° N). We extended the study area into ecologically similar areas east and west to include (a) those portions of the Interior Douglas–fir (IDF) biogeoclimatic zone (Meidinger & Pojar 1991) that are outside of but contiguous with the Trench, and (b) land encircled by the above extensions of the IDF zone. The resulting study area (Figure 1) was 4,775 km^2, with elevations ranging from 695 to 2,217 m and a number of biogeoclimatic zones, including Ponderosa Pine, IDF, Montane Spruce, Interior Cedar–Hemlock, and Engelmann Spruce–Subalpine Fir

(Meidinger & Pojar 1991; Kinley & Newhouse 2008). The area closely matched lands historically defined by frequent, stand-maintaining fires that resulted in a landscape dominated by open forests and grasslands (Anderson et al. 2006).

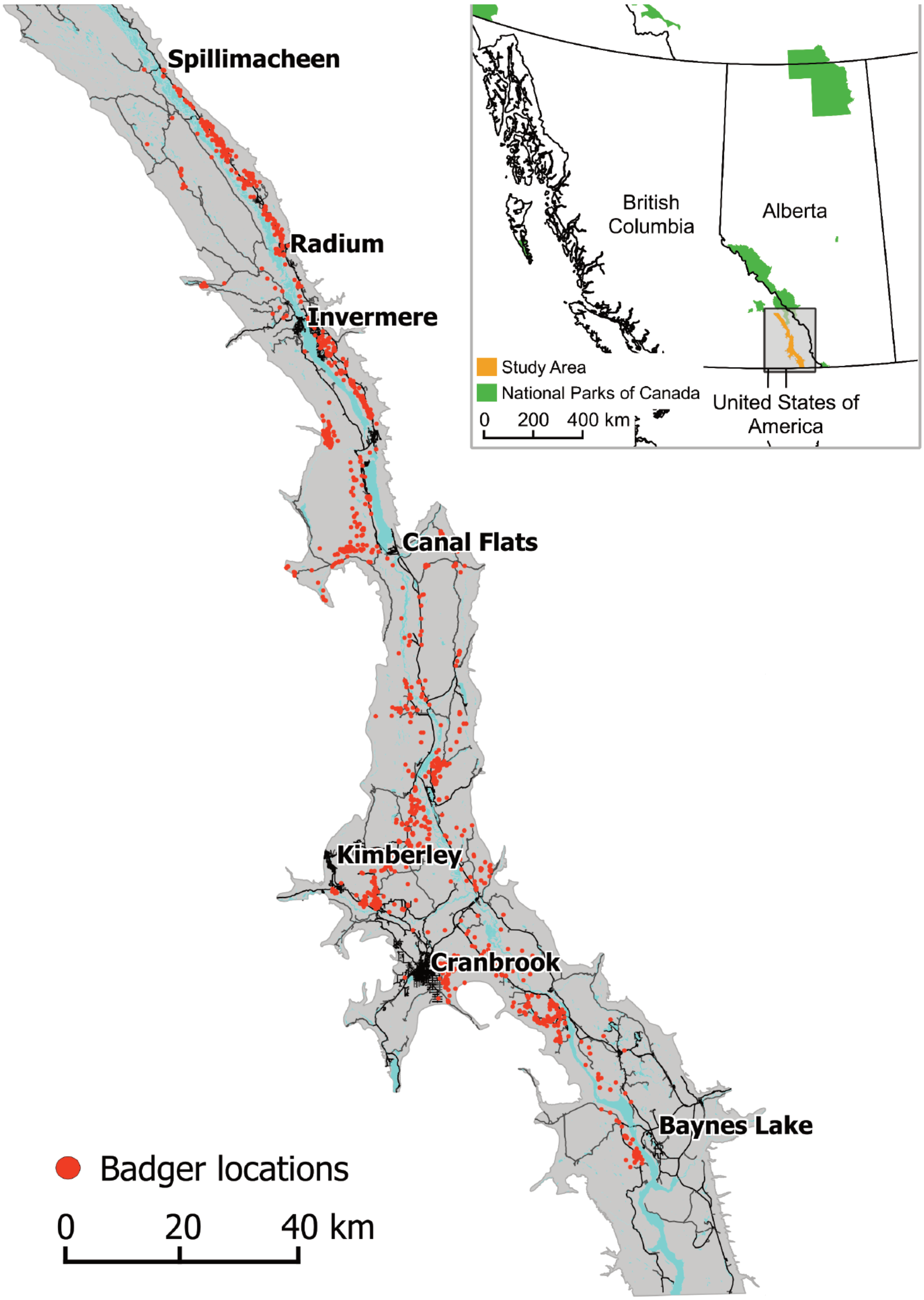


Figure 1: Rocky Mountain Trench badger study area and badger telemetry data.

We obtained very high frequency (VHF) radio-telemetry data from a 1996–2006 study of badgers in the East Kootenay region in which badgers were monitored year-round (Kinley & Newhouse 2008). Data included 2,257 locations from 56 animals, including residents, animals translocated to a portion of the study area to re-establish the local population, and descendents of translocated badgers. We then removed sequential records for individual badgers that were < 4 days apart (n = 314), to minimize spatial autocorrelation and thus increase the likelihood that sequential telemetry locations represented independent habitat-use decisions. We also removed duplicate records (n = 67) in cases where multiple study animals occurred at the same location at the same time (e.g., females and kits), as we assumed that such situations represented single habitat selection decisions. We then removed locations that were outside of our study area (n = 75) or were mapped as watercourses or bodies of water (http://geobc.gov.bc.ca/; n = 6). We used the remaining 1,795 telemetry locations from 55 badgers (Figure 1) to estimate habitat use. There were 1–128 records per badger (median = 24, mean = 32) with a mean time and distance between sequential locations of 16.1 days and 4.1 km, respectively. Telemetry locations were not uniformly distributed but badgers had opportunities to use all portions of the study area. For example, there were only a few telemetry locations on the west side of the study area—from just south of Invermere northward (Figure 1)—but that area was visited by six badgers that could have concentrated their activity there if the conditions had been suitable. The distribution of telemetry locations roughly matched the > 1,000 badger sightings in the Rocky Mountain Trench reported by the public (Kinley 2011).

We compared topographic, land cover, and soil-related attributes (Table 1) of badger locations to random locations spread throughout our study area. Our scale of resource selection was between the second order (home range) and third order (habitat component) scales of selection defined by Johnson (1980). We created 10 random locations for each badger location, resulting in 17,950 locations to define available habitat. We first graphically compared the distribution of badger locations and random locations for each explanatory variable. We then compared badger locations and random locations using a generalized linear mixed model (GLMM) with a logit link and a random effect for individual badgers.

Table 1: Explanatory variables considered in predicting badger habitat in the Rocky Mountain Trench, British Columbia

Variable	Class	Description	Units	Data Source
elev		Elevation above sea level	km	digital elevation model (30-m resolution)
slope		Slope	degrees	
aspect_s[1]		Southerly aspect: 1=south, -1=north	-1 * cosine(aspect)	
aspect_w[1]		Westerly aspect: 1=west, -1=east	-1 * sine(aspect)	
solar		Total annual diffuse and direct radiation	watt-hr * m^{-2} * 100000^{-1} ecoclass	
ecoclass		Ecological classification (climax for site)[2]	categorical	Predictive Ecosystem Mapping (PEM) for B.C. http://www.cortex.ca/PEM-Guide-Web-30Mar05.pdf
	meslo[3]	- moderate to closed canopy forest (mesic sites) in IDF, MS or ICH		
	grass	- grassland in PP or IDF		
	other. cover	- any forest in ESSF except riparian; forest on rocky sites in ICH, IDF or MS; non-forest (except grassland) in any zone		
	ripar	- riparian forest in any zone		
	vopen	- very open forest (dry sites) in IDF or PP		

Variable	Class	Description	Units	Data Source
crown		Crown closure. Non-forested areas assigned a value of 0.	percent	Vegetation Resource Inventory (VRI) http://www.for.gov.bc.ca/hts/vri/index.html Additional VRI-standard files from D. Gilbride, Parks Canada, Radium Hot Springs, BC and B. Pope, Canfor Corporation, Cranbrook, BC.
forest age		Forest age in years (2010 - year of origin). Non-forested areas assigned a value of 0.	years	
veg		Leading tree species	categorical	
	douglas.fir[3]	- Douglas-fir		
	lodgepole.lar	- lodgepole pine, western larch		
	moist.forest	- western redcedar, Engelmann or hybrid white spruce, subalpine fir, alpine larch, whitebark pine, all broadleaf trees		
	non.forest	- no tree species listed		
	ponderosa.pine	- ponderosa pine		
	clearing	- managed for agriculture		
	open.range	- non-forested rangeland		
	rocky	- alpine, alpine forest, gravel pit, sand, clay bank, rock, ice, non-productive forest, non-prod. burn, non-commercial forest		
	urban.nsr	- urban (settlement, industrial site, road, linear disturb.); non-regenerated cutblock		
	wet	- lake, river, gravel bar, brush, swamp, wetland, hayfield, meadow		
soil order		Order from Canadian System of Soil Classification[4]	categorical	Digital files from Jungen (1980), Wittneben (1980) and Lacelle (1990) provided by D. Filatow, Ministry of Forests, Lands and Natural Resource Operations, Kelowna, BC[5]
	brunisol[3] -	brunisol		
	chernozem	- chernozem		
	podz.luvi	- podzol or luvisol		
	rego.gley	- regosol or gleysol		
parent material		Soil parent material[4]	categorical	
	morainal[3]	- morainal		
	colluv.other	- colluvial, rock, aeolian6, anthropogenic, no data		
	fluvial	- fluvial		
	glaciofluvial	- glaciofluvial		
	glaciolacustrine	- glaciolacustrine		
texture		Soil texture[4]	ordinal	
	fine	- moderately fine and medium		
	coarse	- moderately coarse and coarse		
seep		Does the soil receive seepage?[4]	yes or no	
shallow		Soil depth <1 m to bedrock?[4]	yes or no	

Notes: 1. aspect assigned a value of 0 when slope < 5°; 2. expected climax vegetation referenced to the following biogeoclimatic zone: ICH = Interior Cedar – Hemlock, IDF = Interior Douglas-fir, ESSF = Engelmann Spruce – Subalpine Fir, MS = Montane Spruce, PP = Ponderosa Pine; 3. reference category; 4. up to three soil associations are identified per map polygon; soil characteristics refer to the most common association for the polygon associated with the telemetry or random location; 5. drainage, graveliness and stoniness classes were not assigned consistently in relation to soil association across map sheets, so those variables were not considered; 6. due to rarity (1% of study area), aeolian included in "other" despite potential value to badgers

Based on previous badger literature (Apps et al. 2002; Weir et al. 2003; Packham & Hoodicoff 2004; Kinley & Newhouse 2008; Weir & Almuedo 2010), we hypothesized that badger occurrence would be correlated with soil characteristics (suitable for burrowing by badgers and their main local prey, the Columbian ground squirrel), land cover (badgers would prefer open forests and non-forested areas), and terrain (badgers would prefer lower elevations, shallow slopes, southern aspects, and high solar radiation; Table 1). Where soil or land cover maps had slight gaps between them, we assigned cells in that gap the median value of the surrounding area, within a radius of 150 m. For each variable we chose the most commonly available category as the reference category. We centred continuous explanatory variables to assist with model convergence (Harrell 2001). We plotted univariate comparisons between used and available locations for each explanatory variable, and removed explanatory variables that clearly showed neither selection nor avoidance. Then, we removed correlated explanatory variables with variance inflation factors > 2.0 or correlation coefficients > 0.6 (Fox 2002). Using Akaike's Information Criterion, we then compared AIC_c values for all subsets of the remaining variables (Burnham & Anderson 2002) including interactions between elevation and slope, as well as elevation and solar radiation, because we predicted that badgers would use higher elevations in areas with shallow slopes or more solar radiation. We selected and model averaged coefficients and standard errors with a ΔAIC_c of < 4.0 from the top-ranked model.

We built the model using 80% of the locations and validated it with the remaining 20%. We assessed model performance by examining the ability of the model to differentiate between badger locations and random locations. We used the area under the receiving operating characteristic curve (ROC) and the Spearman rank correlation coefficients between summed RSF scores and area-adjusted frequencies of used locations (Boyce et al. 2002). We classified and mapped predicted RSF scores into habitat quality classes of very low, low, high, and very high. We first defined the cutoff between low and high habitat quality, using the RSF score where sensitivity (proportion of true positives) equalled specificity (proportion of true negatives) (Hosmer & Lemeshow 2000). We chose this method to maximize model discrimination (Freeman 2007). We then subdivided each of those two classes (low into very low and low; high into very high and high) based on the median RSF value of available habitat. Data analyses were conducted in R 2.13 (R Development Core Team 2010) using the lme4 (Bates & Maechler 2010), PresenceAbsence (Freeman 2007), and sp (Bivand et al. 2008) packages.

Results

Badger distribution was influenced by elevation, slope, solar radiation, ecoclass, crown closure, leading tree species, soil order, and parent material (Table 2, Table 3, Appendix 1). Badgers were positively associated with areas having low elevations, shallow slopes, high solar radiation, and low crown closure (Table 3). They selected higher elevations if the area had shallow slopes or high solar radiation. Compared to mesic low-elevation forests, they selected climax ecoclasses of riparian and very open low-elevation forests. Despite the apparent strong selection for grassland (Appendix 1), grassland was not selected in the model because it was positively correlated with open range (0.58), clearings (0.48), and low crown closure (0.36). Compared to Douglas-fir forests, badgers selected clearings, moist forest, and open ranges. They avoided lodgepole pine forests, western larch forests, and wet areas. Compared to the Brunisolic soil order, they avoided Podzolic, Luvisolic, Regosolic, Gleysolic orders. Compared to morainal soil parent material, badgers avoided colluvial, rock, aeolian, anthropogenic and selected for glaciolacustrine parent material. The lack of selection for glaciofluvial-based soils, despite the univariate results (Appendix 1), was due in part to a high correlation (0.91) between this parent material and the Regosolic and Gleysolic soil orders.

The top-ranked model (Table 2) included elevation, slope, solar radiation, ecoclass, crown closure, leading tree species, soil order, and parent material as well as elevation:slope and elevation:solar radiation interactions. Lower-ranked models all had a $\Delta AIC_c > 4$, so we retained the top-ranked model and model averaging was not required. The model performed reasonably well with an ROC value of 0.82 and Spearman-ranked correlation coefficients of 0.988 and 0.985 for the 80% of locations used to build a model and the 20% of locations used to validate the model, respectively.

We removed south aspect, west aspect, forest age, soil texture, soil seepage, and shallow soils from our candidate set of models because they either showed high multicollinearity with other explanatory variables or they graphically showed little difference between used and available locations (Appendix 1). Aspect was highly correlated with solar radiation, forest age was highly correlated with crown closure, and soil texture had a variance inflation factor of > 2.0. There was little difference between the distribution of used and available locations for shallow soils or soils having seepage.

Table 2: Comparison of the top 10 badger RSF models ranked by ΔAIC_C. We compared AICc values for all possible combinations of explanatory variables.

Model	K[1]	Deviance	AICc	AICc
Elev + slope + solar + ecoclass + crown + veg + soil order + parent material + elev*slope + elev*solar	27	9690	9744	0
Elev + slope + solar + crown + veg + soil order + parent material + elev*slope + elev*solar	23	9714	9760	16
Elev + slope + solar + ecoclass + crown + veg + soil order + parent material + elev*slope	26	9735	9787	44
Elev + slope + solar + ecoclass + crown + veg + soil order + parent material + elev*solar	26	9748	9800	56
Elev + solar + ecoclass + crown + veg + soil order + parent material + elev*solar	25	9756	9806	62
Elev + slope + solar + crown + veg + soil order + parent material + elev*slope	22	9766	9810	66
Elev + slope + solar + ecoclass + crown + veg + soil order + parent material	25	9764	9814	71
Elev + slope + solar + crown + veg + soil order + parent material + elev*solar	22	9774	9818	74
Elev + solar + ecoclass + crown + veg + soil order + parent material	24	9771	9819	76
Elev + solar + crown + veg + soil order + parent material + elev*solar	21	9782	9824	80

Notes: 1. K = number of parameters. See Table 1 for definition of variables.

Discussion

Badgers selected resources consistent with expectations for agricultural land, grassland or open forests, and soils where burrowing was feasible (Newhouse & Kinley 2001, Apps et al. 2002, Hoodicoff 2003, Weir et al. 2003, Packham & Hoodicoff 2004). Although our study area only slightly overlapped the mountain ranges adjacent to the Rocky Mountain Trench, there was sufficient topographic variability that badger activity was associated with the flatter, sunnier, low-elevation sites typical of the valley bottom. This is not surprising, given that our study area occurred at the northern extent of badger range (Weir & Almuedo 2010; COSEWIC 2012). Badgers selected areas with no or limited forest cover, which was consistent with badger selection in the Cariboo region (Packham & Hoodicoff 2004), the Thompson-

Table 3: Badger RSF model coefficients and standard errors for the top-ranked model from Table 2.

Variable	B	SE	Z	p
Intercept	-2.452	0.072	-33.9	<0.001
Elevation	-1.182	0.333	-3.5	<0.001
Slope	-0.008	0.006	-1.4	0.169
Solar	3.862	0.623	6.2	<0.001
Crown	-0.027	0.002	-11.2	<0.001
Ecoclass: reference=Meslo				
Grass	0.052	0.099	0.5	0.602
Other.cover	0.043	0.123	0.3	0.729
Ripar	0.299	0.151	2.0	0.048
Vopen	0.386	0.084	4.6	<0.001
Vegetation: reference=Douglas.fir				
Clearing	1.442	0.132	10.9	<0.001
Lodgepole.lar	-0.753	0.143	-5.3	<0.001
Moist.forest	0.538	0.158	3.4	0.001
Open.range	0.506	0.123	4.1	<0.001
Ponderosa.pine	-0.109	0.128	-0.9	0.392
Rocky	-0.189	0.188	-1.0	0.315
Urban.nsr	0.144	0.110	1.3	0.191
Wet	-1.122	0.299	-3.7	<0.001
Soil order: reference=Brunisol				
Chernozem	-0.095	0.102	-0.9	0.355
Podz.luvi	-1.064	0.110	-9.7	<0.001
Rego.gley	-1.445	0.258	-5.6	<0.001
Parent material: reference=Morainal				
Colluv.other	-0.931	0.136	-6.8	<0.001
Fluvial	0.200	0.210	1.0	0.340
Glaciofluvial	-0.030	0.067	-0.5	0.651
Glaciolacustrine	0.723	0.096	7.6	<0.001
Elevation:slope	-0.231	0.032	-7.1	<0.001
Elevation:solar	15.619	2.169	7.2	<0.001

Okanagan region (Weir et al. 2003), an earlier analysis that overlapped our study area (Apps et al. 2002), and the province in general (Weir & Almuedo 2010). In particular, open ranges and agricultural land were strongly selected by badgers. This is consistent with the distribution of the Columbian ground squirrel, which is the primary local prey species of badgers (Newhouse & Kinley 2001, Kinley & Newhouse 2008), and which is normally found in locations with little tree cover (Ministry of Environment, Lands and Parks 1998). Selection patterns were weak for some soil attributes. This may be in part because soil maps included up to three unique soil associations per polygon and badgers sometimes used secondary soil types that were not typical of the leading associations we used to define soil characteristics. However, badgers strongly selected glaciolacustrine soil and avoided colluvial parent material, which was consistent with the relative ease of burrowing for badgers and their prey. Glaciolacustrine soils lack the gravity-deposited rock fragments that define colluvium, or the unsorted deposits (including many cobbles and boulders), typical of moraines.

High- to very high-quality badger habitat was distributed throughout the southern Rocky Mountain Trench, mainly on the valley floor and some tributary valleys (Figure 2, Appendix 2). Areas with the lowest habitat value generally occurred at higher elevations along the western side of the Trench. Where our study area overlapped with that of Apps et al. (2002), aggregations of high-quality habitat were similar.

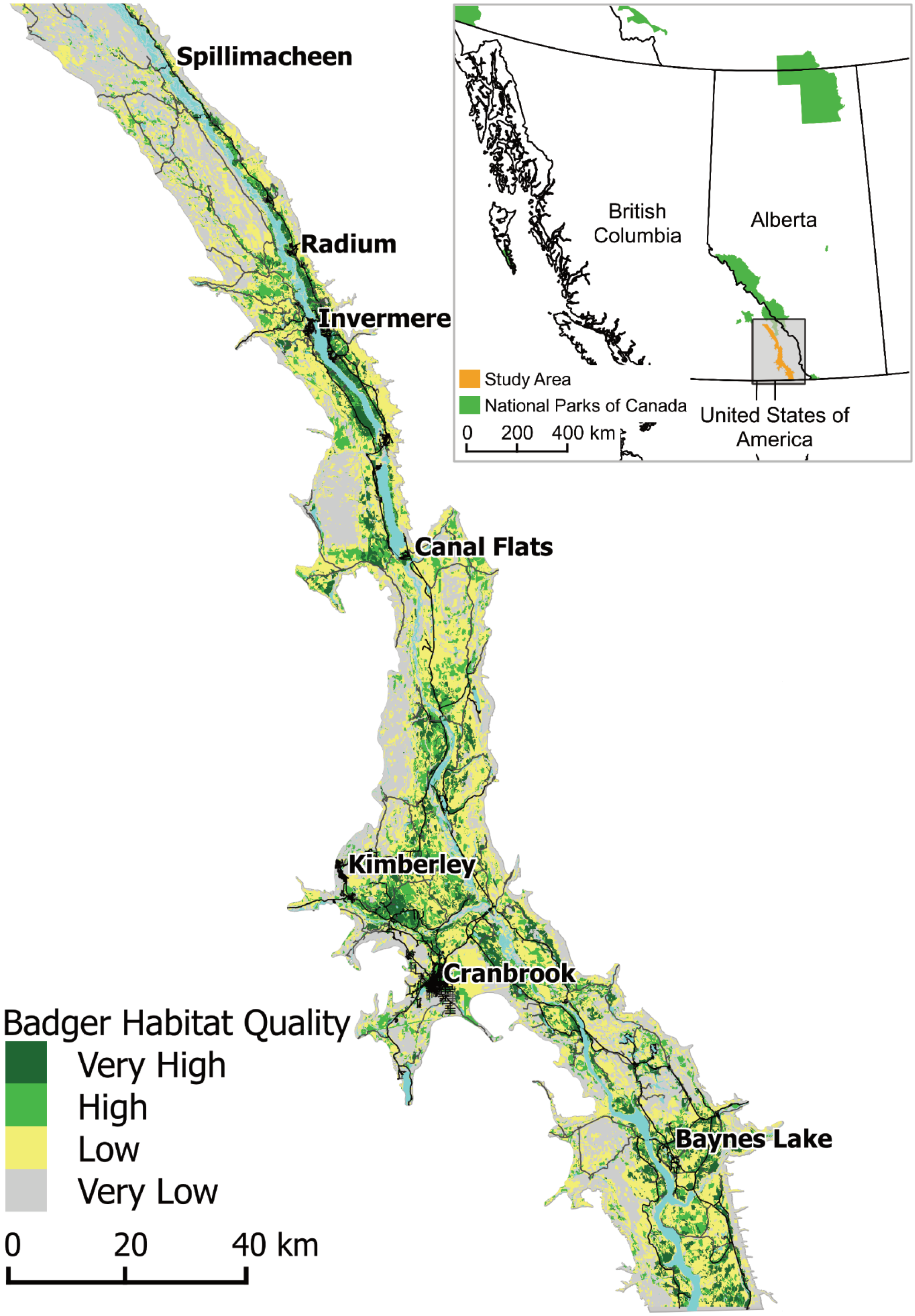


Figure 2: Distribution of badger habitat in and adjacent to the Rocky Mountain Trench, British Columbia.

Our RSF model does not define "critical" habitat but it does provide a tool to prioritize areas with regard to their habitat value. Habitat-quality predictions in Figure 2 and Appendix 2 may not reflect recent changes to land cover and crown closure through logging or urban development. For operational-level applications, univariate results and model coefficients can be used to comparatively assess habitat values for areas of interest.

Predicting the potential effects of landscape change on badgers should be done cautiously because some explanatory variables used in this analysis are surrogates for other factors that affect badger distribution and demographics, such as ground squirrel abundance. However, the consistent selection across variables for classes or values associated with less tree cover strongly suggests that the in-growth of coniferous forests through fire suppression has a negative effect on badger habitat quality. Ongoing thinning and burning to restore the open conditions that historically occurred within this fire-maintained ecosystem (Anderson et al. 2006) should improve badger habitat quality within the Rocky Mountain Trench. Such restoration actions would probably provide the most benefit to badgers if they occurred in areas with Brunisolic or Chernozemic soils on glaciolacustrine parent material.

Acknowledgements

Our work was based on telemetry data collected from 1996 to 2006 through the East Kootenay Badger Project, which had numerous financial and logistical supporters (Kinley & Newhouse 2008). The modelling presented here was funded by the Species at Risk Recovery Action and Education Fund of Environment Canada, with additional in-kind support from Parks Canada. We wish to thank Dave Gilbride and Dan Teleki of Parks Canada, Deepa Filatow of the B.C. Ministry of Forests, Lands and Natural Resource Operations, and Bruce Pope of Canfor Corporation for GIS and data-management support.

References

Anderson, G., S. Bond, D. Gayton, J. Krebs, & D. Petryshen. 2006. Blueprint for action 2006. Rocky Mountain Forest District, Cranbrook, B.C. http://trenchsociety.com/setup/content/Blueprint_for_Action_2006.pdf [Accessed July 15, 2013].

Apps, C.D., N.J. Newhouse, & T.A. Kinley. 2002. Habitat associations of American badgers in southeastern British Columbia. Canadian Journal of Zoology 80:1228–1239.

Bates, D., & M. Maechler. 2010. lme4: linear mixed-effects models using S4 classes. R package version 0.999375-35. http://cran.r-project.org/web/packages/lme4/index.html [Accessed July 15, 2013].

Bivand, R.S., E.J. Pebesma, & V. Gomez-Rubio. 2008. Applied spatial data analysis with R. Springer, New York, N.Y.

Boyce, M.S., P.R. Vernier, S.E. Nielsen, & F.K.A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling 157:281–300.

Burnham, K.P., & D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. 2nd ed. Springer, New York, N.Y.

COSEWIC. 2012. Species profile. American badger *jeffersonii* subspecies. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ont. http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=622#description [Accessed February 10, 2013].

Conservation Data Centre. 2011. BC species and ecosystems explorer. Ministry of Environment, Victoria, B.C. http://a100.gov.bc.ca/pub/eswp/ [Accessed August 5, 2011].

Demarchi, D.A. 1996. An introduction to the ecoregions of British Columbia. Ministry of Environment, Lands and Parks, Victoria, B.C.

Fox, J. 2002. An R and S-plus companion to applied regression. Sage Publications, Thousand Oaks, C.A.

Freeman, E. 2007. PresenceAbsence: an R package for presence-absence model evaluation. USDA Forest Service, Rocky Mountain Research Station, Ogden, U.T.

Harrell, F.E. 2001. Regression modelling strategies with applications to linear models, logistic regression, and survival analysis. Springer-Verlag New York, Inc, New York, N.Y.

Hoodicoff, C.S. 2003. Ecology of the badger (*Taxidea taxus jeffersonii*) in the Thompson region of British Columbia: Implications for conservation. M.Sc. thesis. University of Victoria, Victoria, B.C.

Hosmer, D.W., & S. Lemeshow. 2000. Applied logistic regression. John Wiley & Sons, Inc., New York, N.Y.

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

Jungen, J.R. 1980. Soil resources of the Nelson map area (82F). British Columbia Ministry of Environment, Kelowna, B.C. Soil Survey Report No. 28.

Kinley, T.A. 2009. Effectiveness monitoring of badger wildlife habitat areas: Summary of current areas and recommendations for developing and applying protocols. Ministry of Forests and Range, Victoria, B.C. Forest and Range Evaluation Program Report #25.

Kinley, T.A. 2011. East Kootenay badger project 2010–2011 progress report. Sylvan Consulting Ltd., Invermere, B.C.

Kinley, T.A., & N.J. Newhouse. 2008. Ecology and translocation-aided recovery of an endangered badger population. Journal of Wildlife Management 72:113–122.

Lacelle, L.E.H. 1990. Biophysical resources of the East Kootenay area: Soils. British Columbia Ministry of Environment, Victoria, B.C. Soil Survey Report No. 20.

Meidinger, D.V., & J. Pojar. 1991. Ecosystems of British Columbia. Ministry of Forests, Victoria, B.C. Special Report No. 4.

Ministry of Environment, Lands and Parks. 1998. Inventory methods for pikas and sciurids: Pikas, marmots, woodchuck, chipmunks and squirrels. Resources Inventory Committee, Victoria, B.C. Standards for Components of British Columbia's Biodiversity No. 29.

Newhouse, N.J., & T.A. Kinley. 2001. Ecology of badgers near a range limit in British Columbia. Prepared by Sylvan Consulting Ltd., Invermere, B.C for Columbia Basin Fish and Wildlife Compensation Program, Nelson, B.C, and Parks Canada, Radium Hot Springs, B.C.

Packham, R.M., & C.S. Hoodicoff. 2004. Badger ecology in the Cariboo region of British Columbia, Canada. In: Proceedings of the Species at Risk 2004 Pathways to Recovery Conference, March 2–6, 2004. T.D. Hooper (editor). Species at Risk 2004: Pathways to Recovery Conference Organizing Committee, Victoria, B.C.

Paige, K., & L. Darling. 2010. Evaluating badger wildlife habitat areas: Pilot study results. Ministry of Forests and Range, Victoria, B.C. Forest and Range Evaluation Program Extension Note #14.

Parliament of Canada. 2002. Species at risk act. Canada Gazette 25(3).

R Development Core Team. 2010. R: A language and environment for statistical computing. Vienna, Austria.

Regional District of East Kootenay. 2008. Lake Windermere official community plan. Bylaw No. 2061, 2008. RDEK, Cranbrook, B.C.

Weir, R.D., & P.L. Almuedo. 2010. Badger wildlife habitat decision aid. BC Journal of Ecosystems and Management 10(3):9–13.

Weir, R.D., H. Davis, & C. Hoodicoff. 2003. Conservation strategies for North American badgers in the Thompson and Okanagan regions. Artemis Wildlife Consultants, Armstrong, B.C.

Wittneben, U. 1980. Soil resources of the Lardeau map area (82K). British Columbia Ministry of Environment, Kelowna, B.C. Soil Survey Report No. 27.

Author information

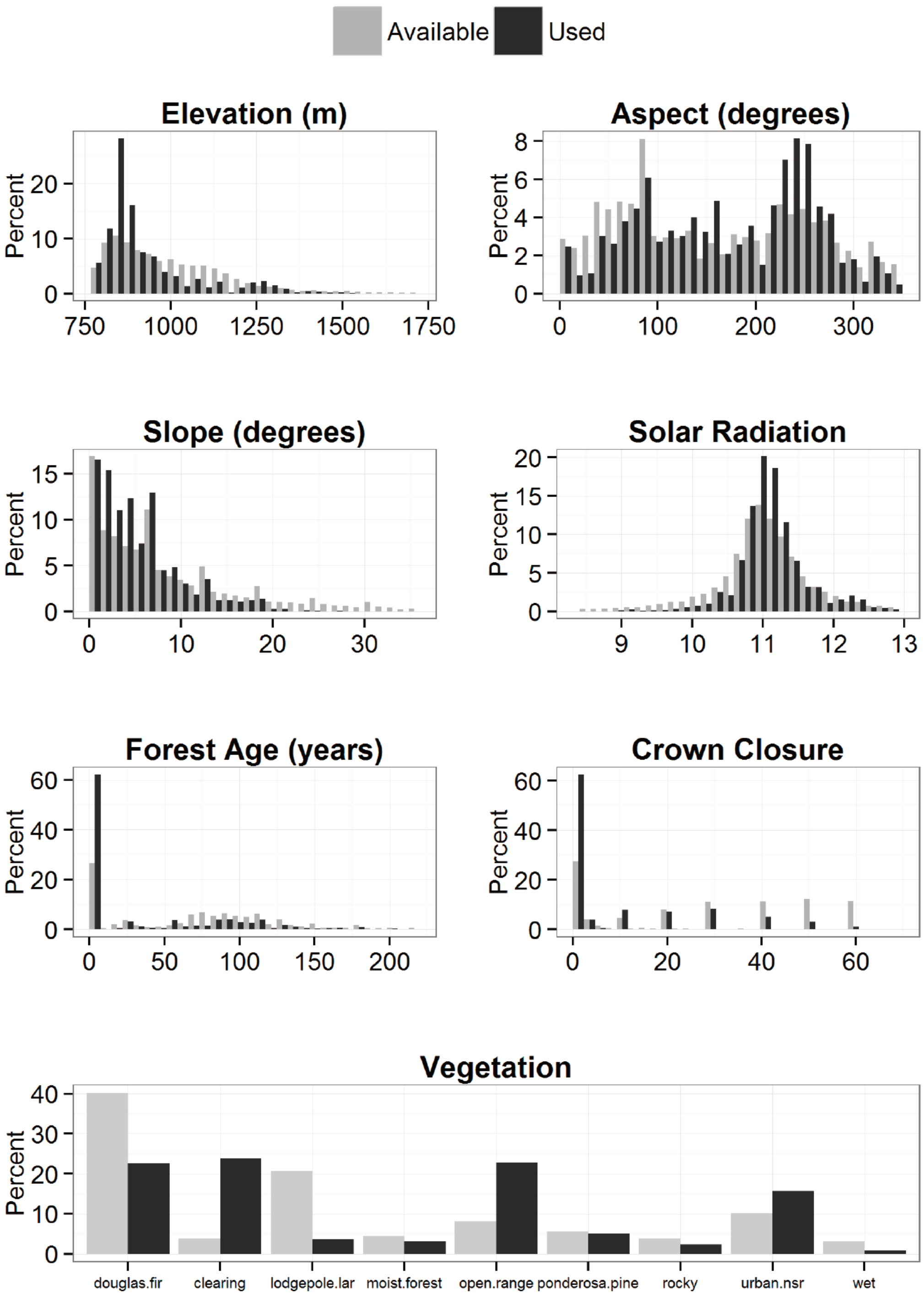
Trevor A. Kinley – Wildlife Crossings Project Manager, Parks Canada Agency, Box 220, Radium Hot Springs, BC V0A 1M0. Email: trevor.kinley@pc.gc.ca

Jesse Whittington – Wildlife Biologist, Parks Canada Agency, Box 900, Banff, AB T1L 1K2. Email: jesse.whittington@pc.gc.ca

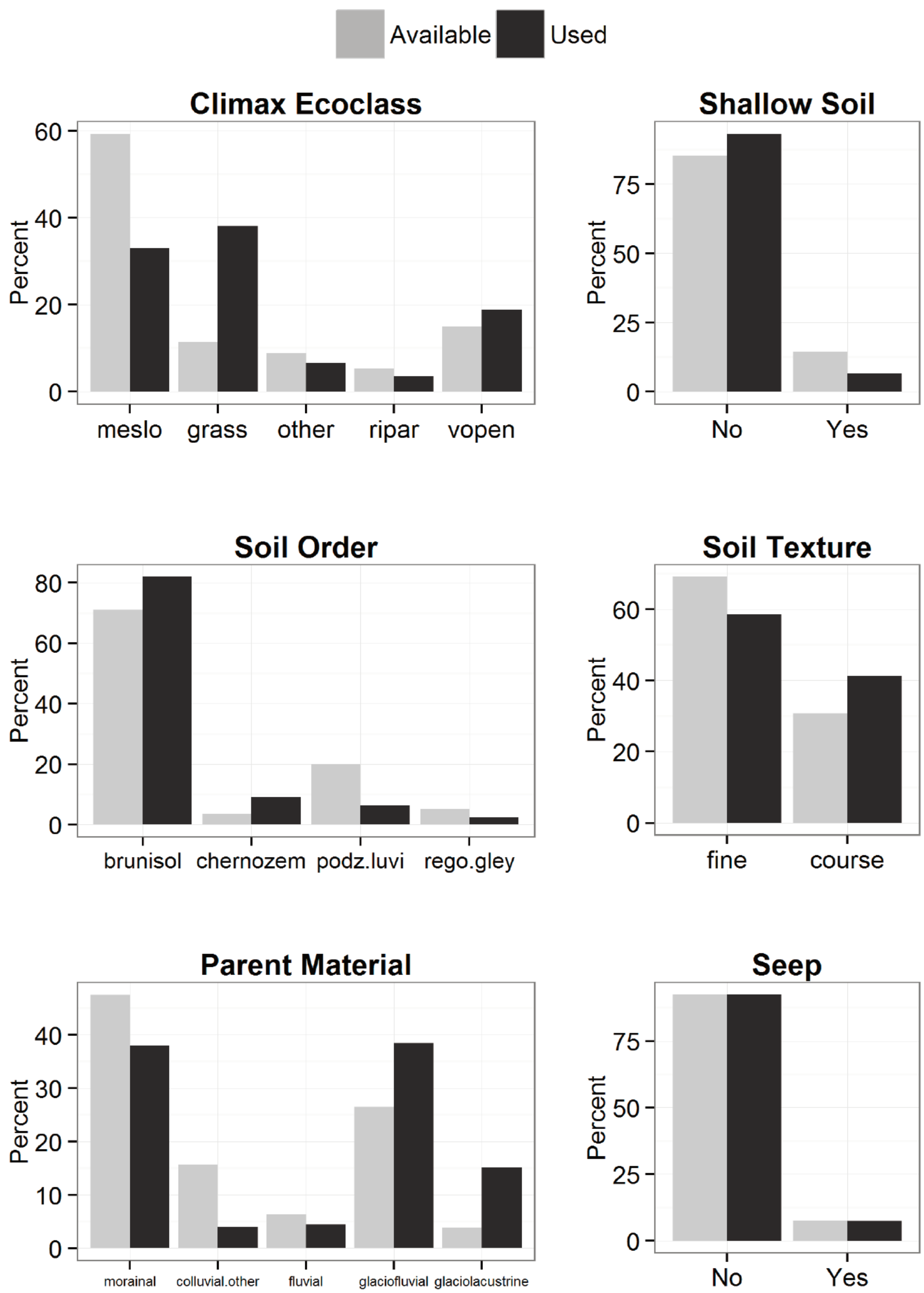
Alan D. Dibb – Wildlife Biologist, Parks Canada Agency, Box 220, Radium Hot Springs, BC V0A 1M0. Email: alan.dibb@pc.gc.ca

Nancy J. Newhouse – Canadian Rocky Mountains Program Manager, Nature Conservancy of Canada, Box 875, Invermere, BC V0A 1K0. Email: nancy.newhouse@natureconservancy.ca

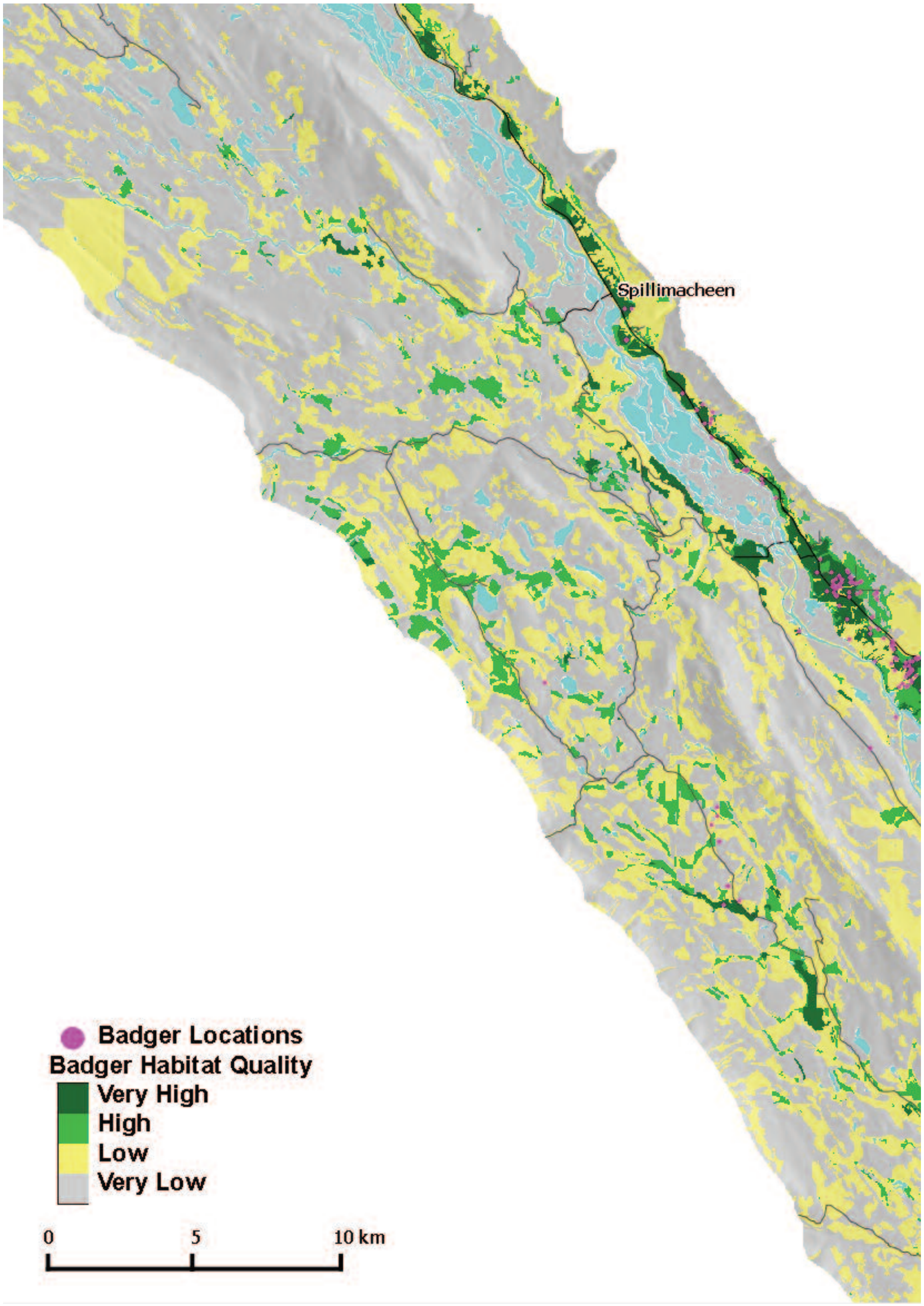
Appendix 1, part 1: Univariate comparisons of badger telemetry locations to random locations for the Rocky Mountain Trench, B.C. (see Table 1 for codes).



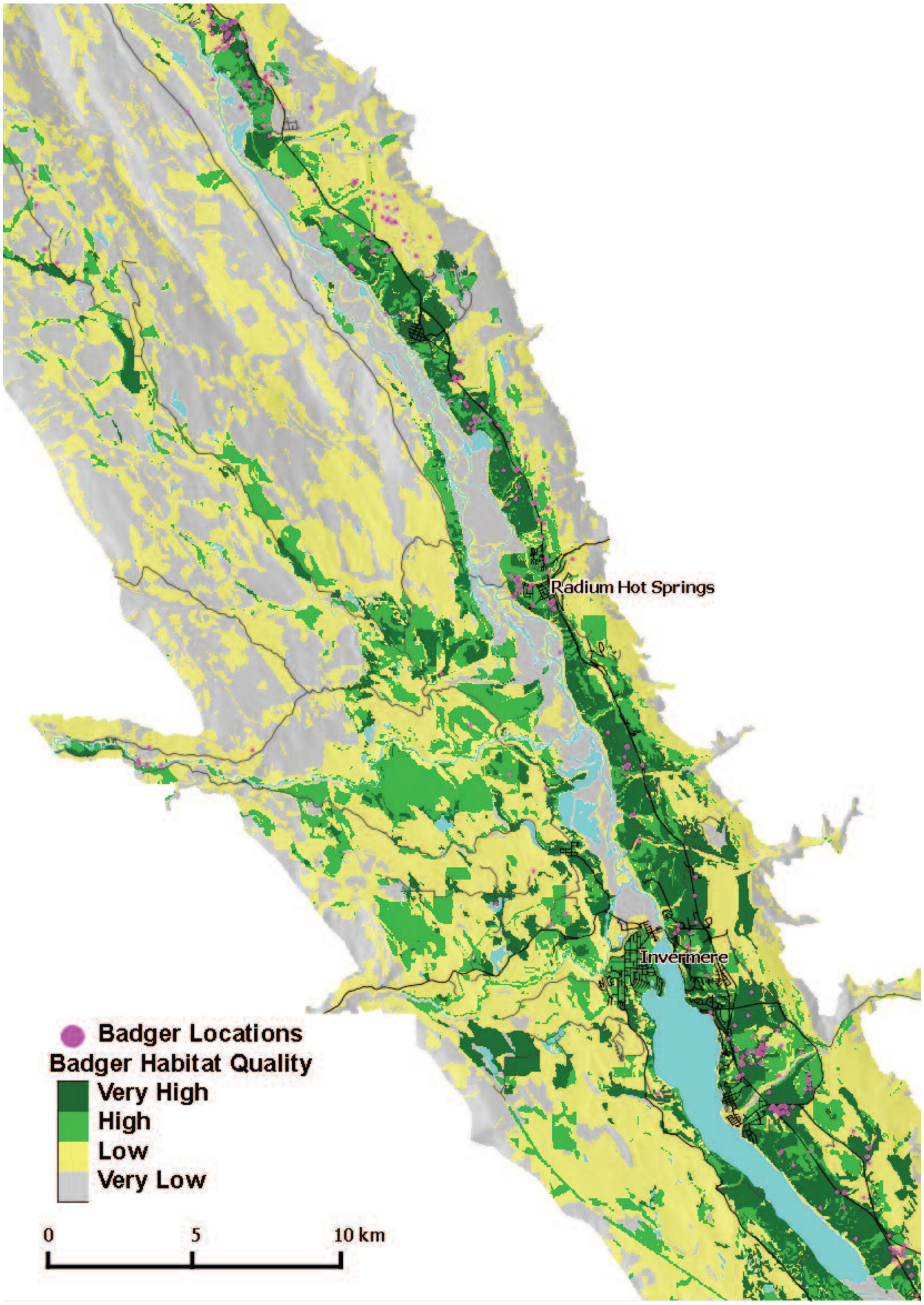
Appendix 1, part 2: Univariate comparisons of badger telemetry locations to random locations for the Rocky Mountain Trench, B.C. (see Table 1 for codes).



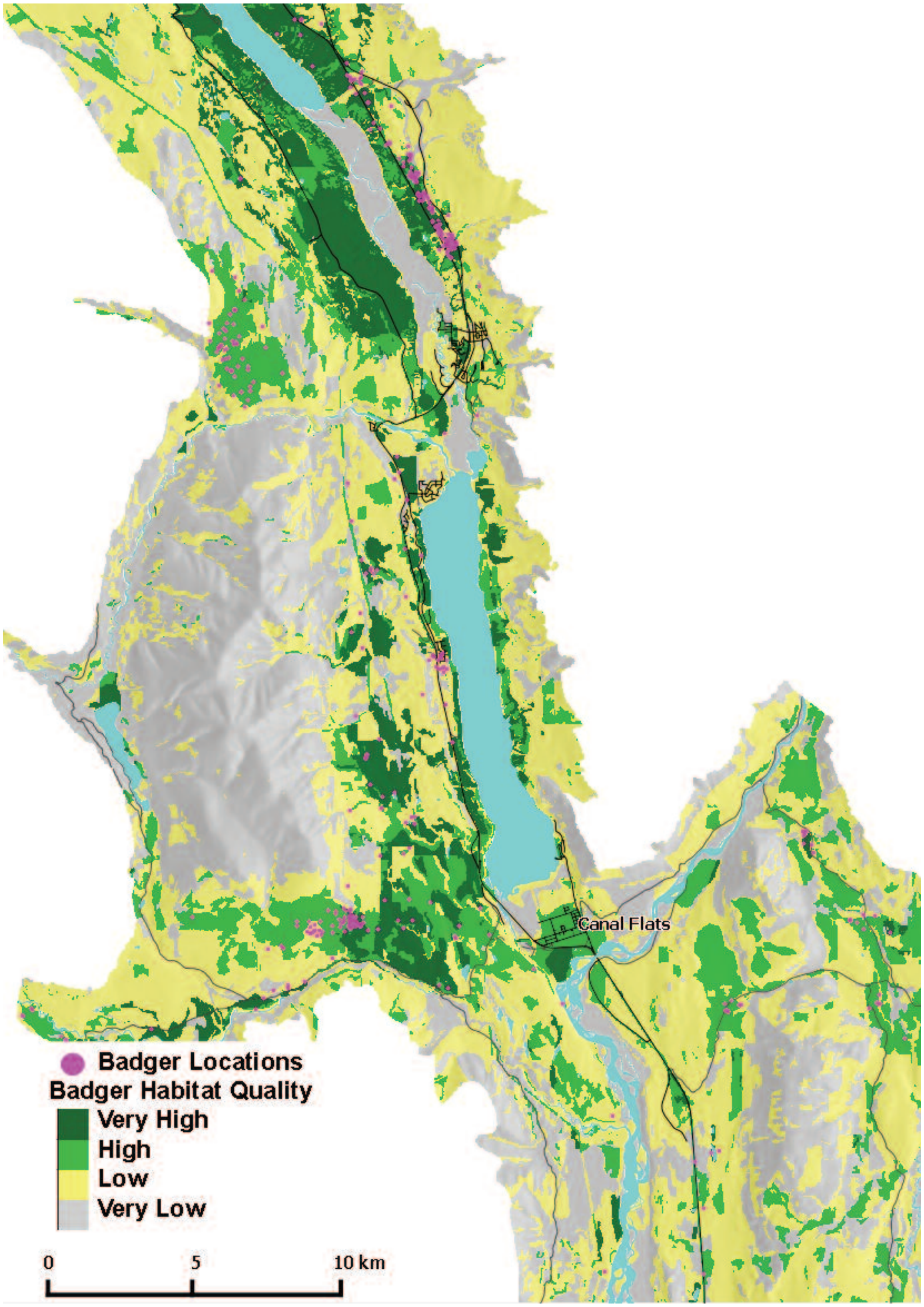
Appendix 2, part A: Badger resource selection function maps ordered north to south for the Rocky Mountain Trench, B.C. (see Figure 2 for composite map).



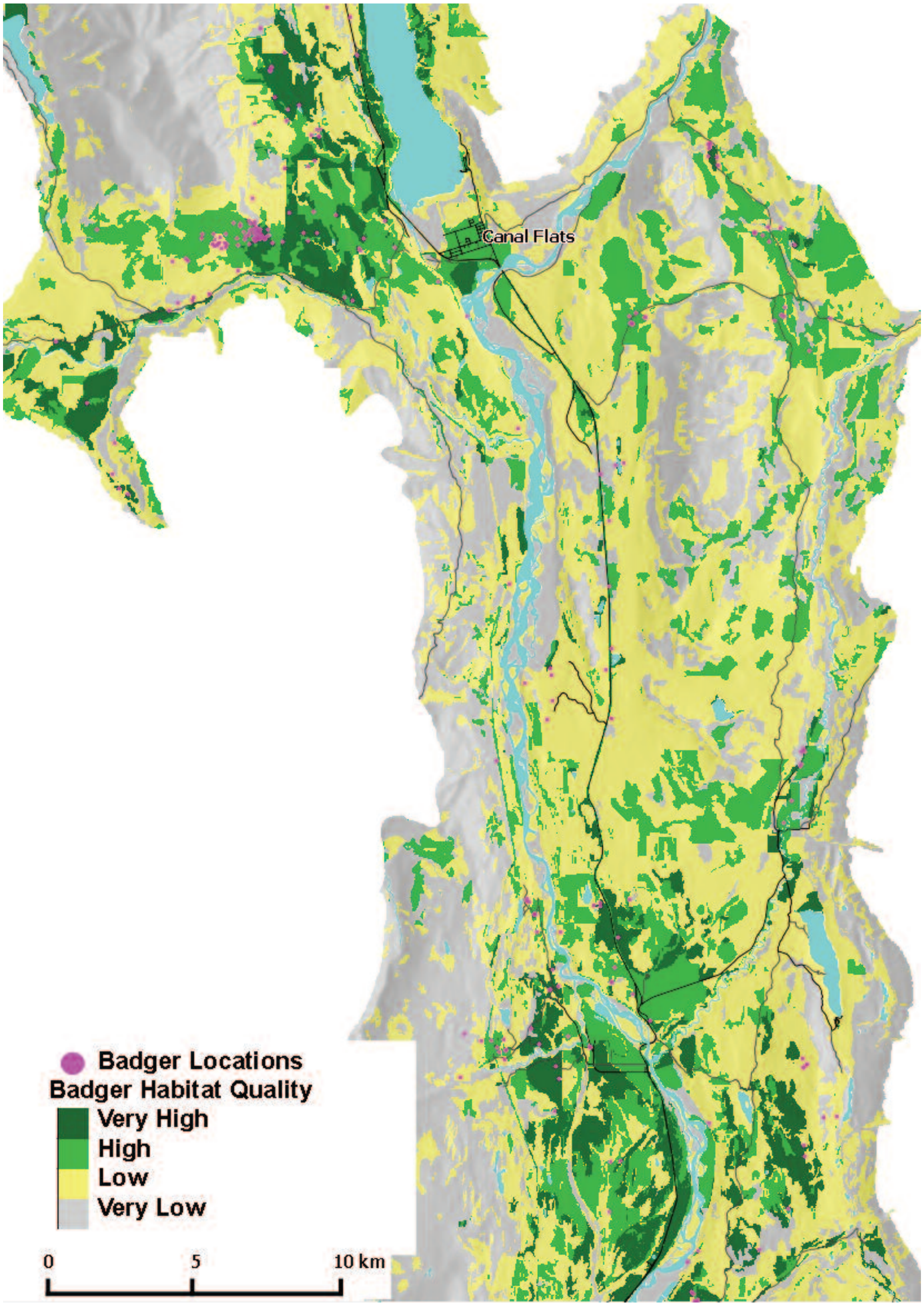
Appendix 2, part B: Badger resource selection function maps ordered north to south for the Rocky Mountain Trench, B.C. (see Figure 2 for composite map).



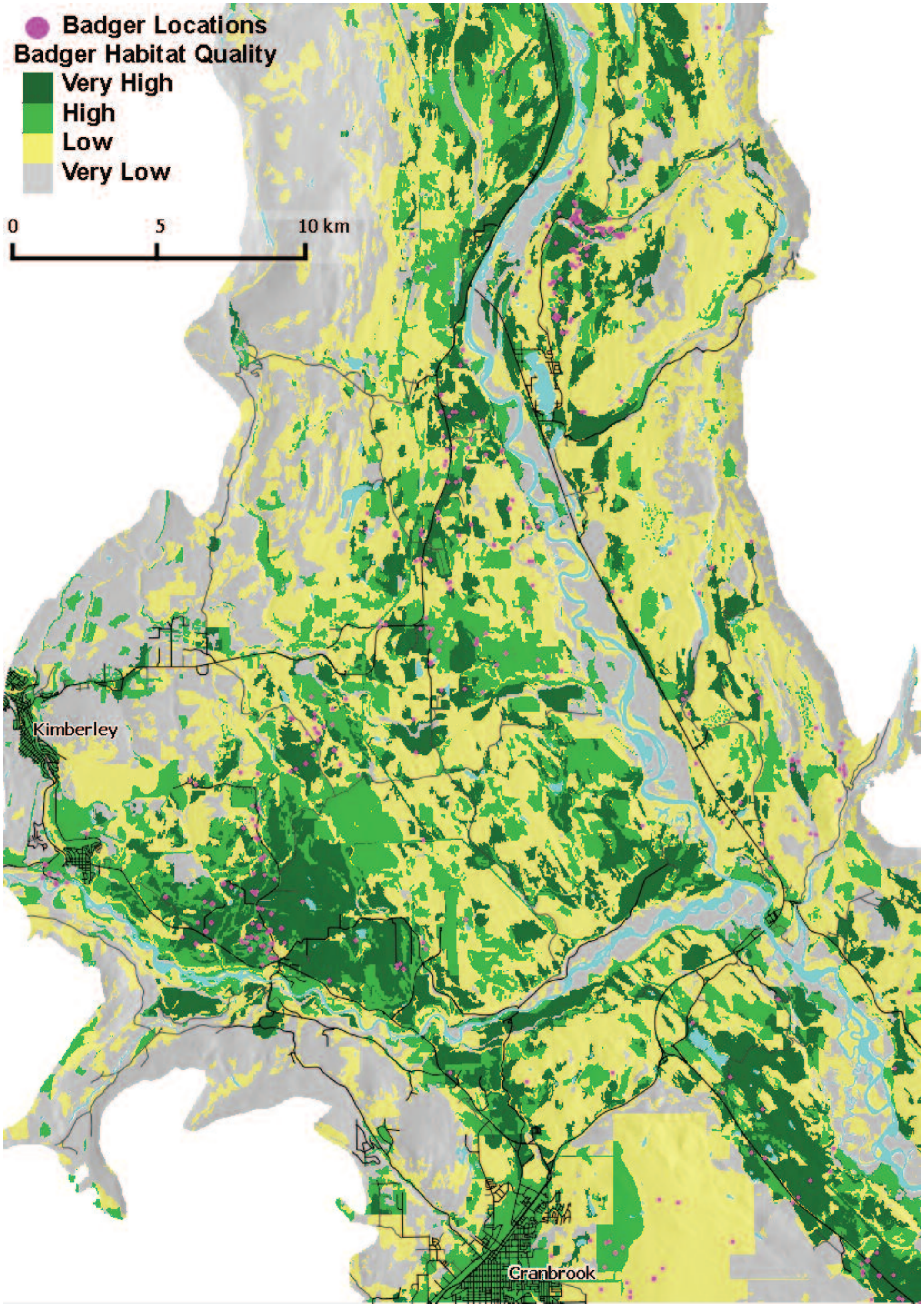
Appendix 2, part C: Badger resource selection function maps ordered north to south for the Rocky Mountain Trench, B.C. (see Figure 2 for composite map).



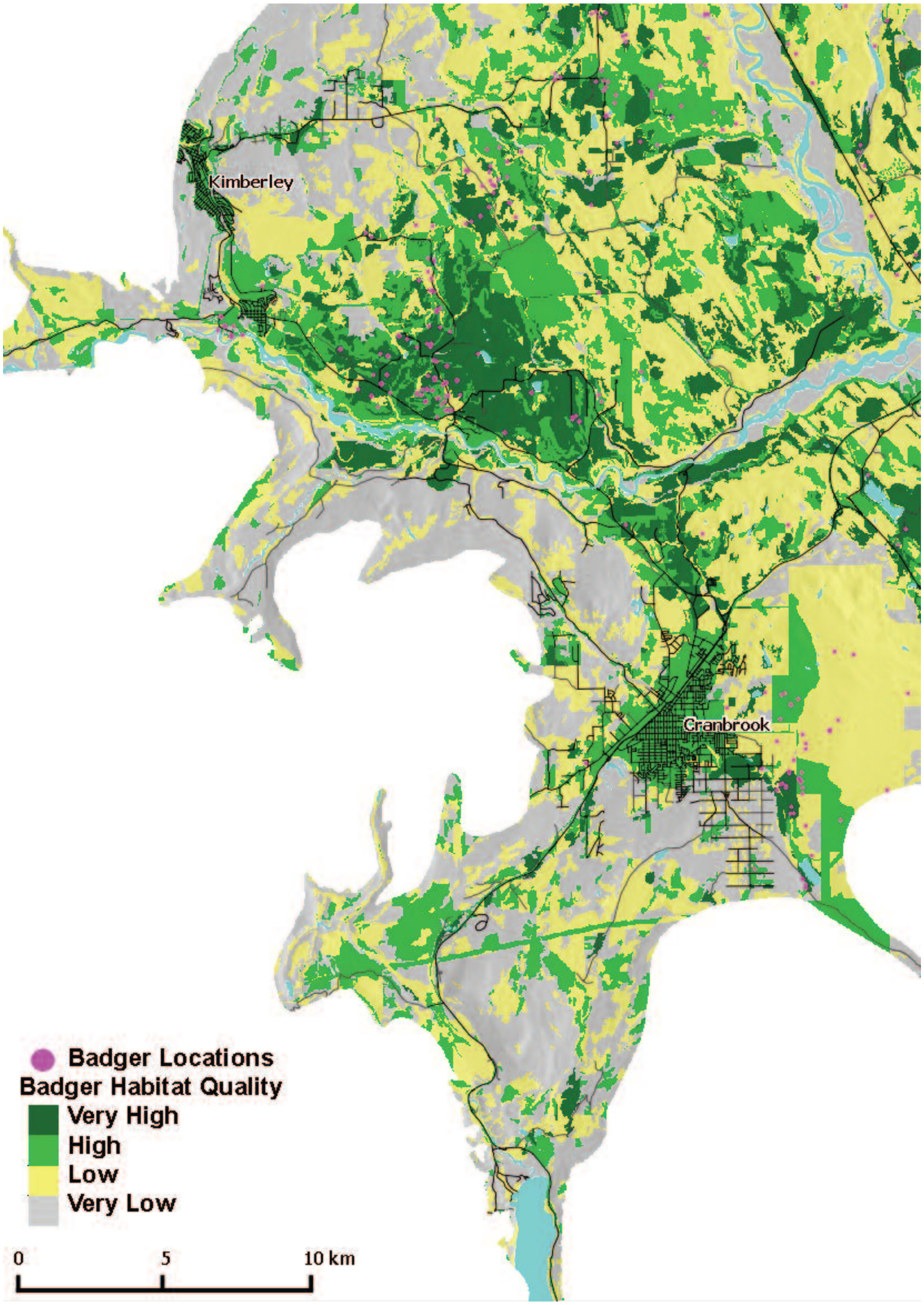
Appendix 2, part D: Badger resource selection function maps ordered north to south for the Rocky Mountain Trench, B.C. (see Figure 2 for composite map).



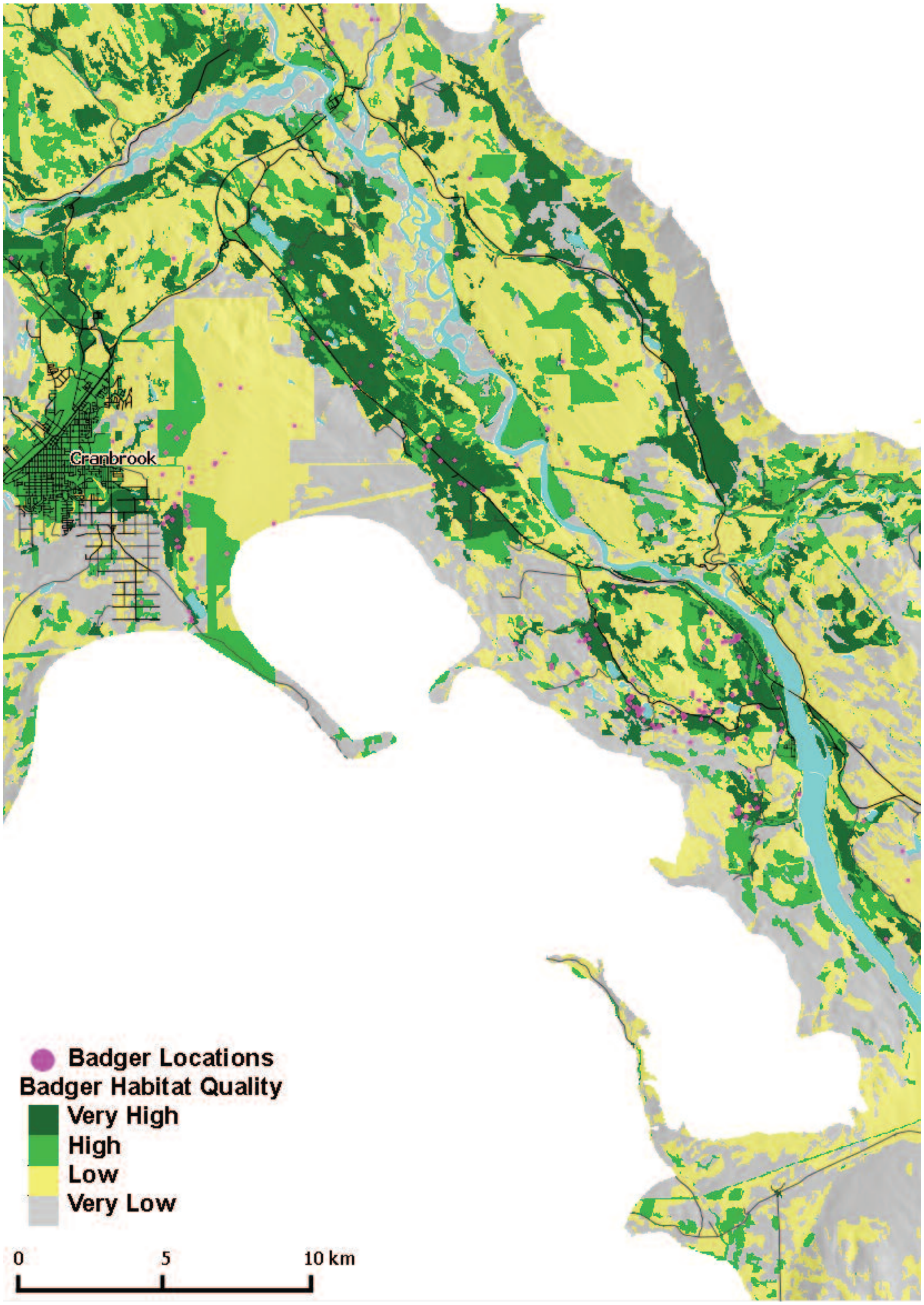
Appendix 2, part E: Badger resource selection function maps ordered north to south for the Rocky Mountain Trench, B.C. (see Figure 2 for composite map).



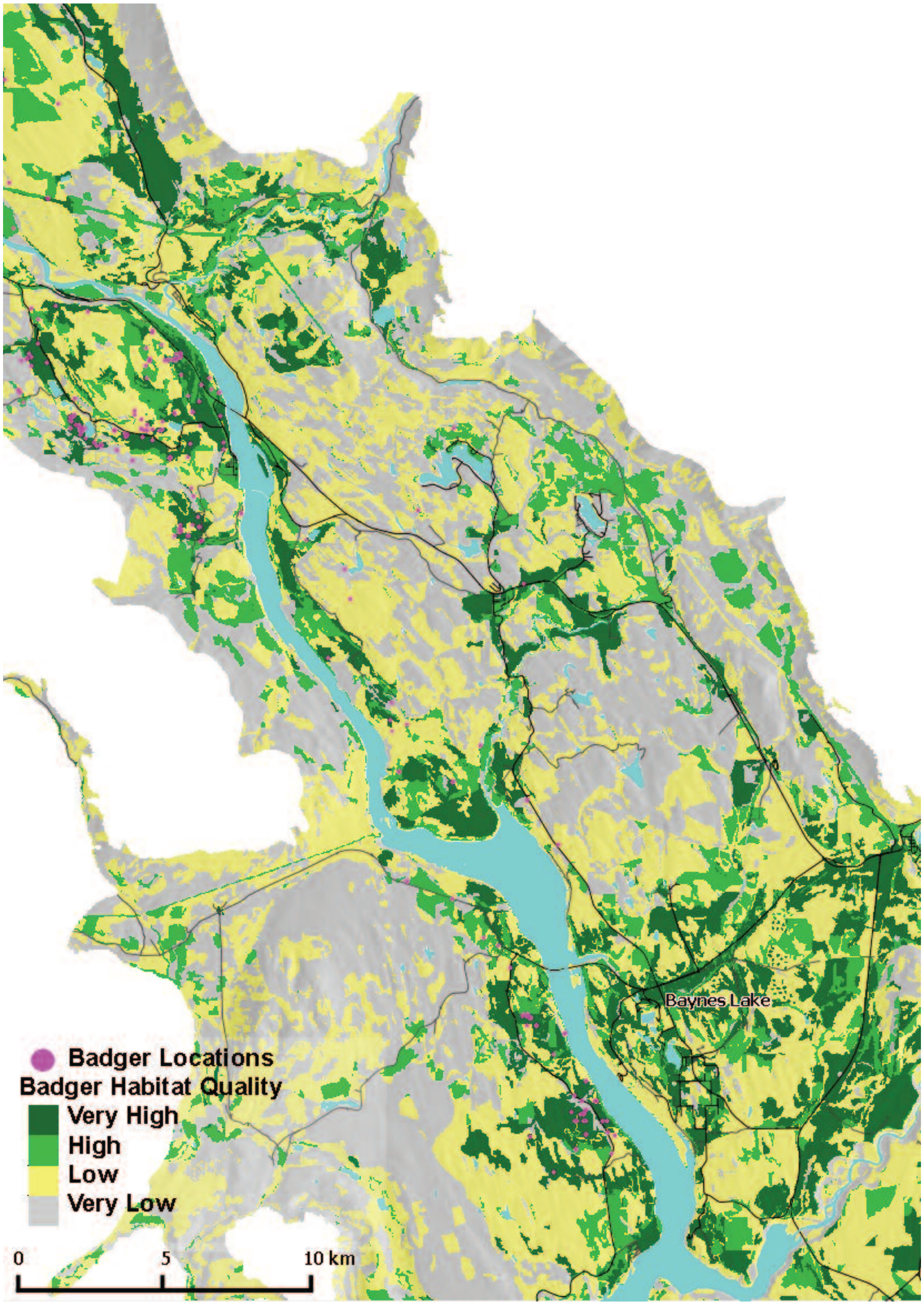
Appendix 2, part F: Badger resource selection function maps ordered north to south for the Rocky Mountain Trench, B.C. (see Figure 2 for composite map).



Appendix 2, part G: Badger resource selection function maps ordered north to south for the Rocky Mountain Trench, B.C. (see Figure 2 for composite map).



Appendix 2, part H: Badger resource selection function maps ordered north to south for the Rocky Mountain Trench, B.C. (see Figure 2 for composite map).



Appendix 2, part I: Badger resource selection function maps ordered north to south for the Rocky Mountain Trench, B.C. (see Figure 2 for composite map).