Habitat Modeling for American Badgers in the East Kootenay Region of British Columbia

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ABSTRACT

American badgers (*Taxidea taxus*) are considered threatened or endangered in British Columbia because of large home ranges, declining populations, loss of habitat and prey, and potential for high mortality from roadkills and shooting. We radiotagged and located 13 badgers 790 times in the East Kootenay region (including the upper Columbia and upper Kootenay drainages) of southeast British Columbia from 1996 to 1999. For 10 of these animals, we analyzed habitat selection at two nested spatial scales based on soil types, forest cover, terrain and human influence variables. At the broader scale, habitat attributes of badger and paired random locations were compared in landscapes of 2.75 km radius separated by 11.4 km. At the finer scale, paired landscapes were 25 m in radius and were separated by 2.75 km. For each variable, we assessed univariate differences between used and random landscapes for each badger, at each scale. At least 7 badgers showed consistent associations with 26 variables, and we considered these variables in multivariate modeling. Best-fit multiple logistic regression (MLR) models were highly significant over null models ($P < 0.0001$), achieving overall correct classifications > 80.4%. At the broad scale, the most important predictors of badger habitat selection were overstory canopy closure (negative), and regosolic soils, presence of cover and open range (positive). At the fine scale, the best predictors were glaciofluvial soils (positive) and canopy closure (negative). The overall pattern of selection indicated preference for open sites. The IDFdm (Dry Mild Interior Douglas-fir), IDFun (Undifferentiated Interior Douglas-fir) and PPdh (Dry Hot Ponderosa Pine) biogeoclimatic subzones contributed disproportionately to higher quality badger habitat, as did private lands and Indian reserves, which are predominantly located in those subzones. These subzones and lands, which represent only a minority of the analysis area, should therefore be the focus of habitat protection and management activities. On Crown lands, priority areas for management include lower Findlay Creek, the confluence of the Lussier River and Coyote Creek, north of Skookumchuck, and the northwest corner of Skookumchuck Prairie.

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1. INTRODUCTION

American badgers have recently been up-listed to "red" status in British Columbia, meaning that they are considered threatened or endangered (Cannings et al. 1999). Large home ranges, declining populations, loss of habitat and prey, and potential for high mortality from roadkills and shooting are the principle reasons for the this listing. They are limited to south-central and southeastern British Columbia (Rahme et al. 1995).

Badgers are adapted to capturing fossorial prey, which is their primary diet in most locations (Salt 1976, Lampe 1982). However, badgers are opportunistic feeders and supplement their diet with a wide variety of mammals, birds, eggs, reptiles, amphibians, invertebrates and plants (Messick 1987). There has been little research done to describe badger habitat associations. Generally, they have been studied in open, often agricultural landscapes (Todd 1980, Warner and Ver Steeg 1995) and shrub-steppe habitats (Messick and Hornocker 1981), although they are known to occur from below sea level to elevations greater than 3,660 m (Lindzey 1982). The majority of the badger's range is in treeless areas, but includes savannah and forest (Ibid.). Despite their threatened status in BC, this is the first radiotelemetry-based research on badgers in Canada.

We describe an analysis of badger habitat associations in the East Kootenay region of southeastern British Columbia. Our specific objectives were to: (a) determine habitat selection patterns based on radiotelemetry data; (b) develop a predictive habitat model based on soil types, forest cover, terrain and human influence; and (c) interpret results to provide local habitat management recommendations.

2. STUDY AREA

We captured badgers in portions of the upper Columbia and upper Kootenay valleys of southeastern British Columbia (the East Kootenay region) from 49°30'N to 50°50'N. This included the Ponderosa Pine, Interior Douglas-fir, and Montane Spruce biogeoclimatic zones (PPdh, IDFun, IDFdm, and MSdk subzones; Braumandl and Curran 1992). We monitored study animals moving beyond these boundaries and assessed habitat over a broader area, thus including subzones of the Interior Cedar-Hemlock

(ICHmk, ICHmw), Engelmann Spruce – Subalpine Fir (ESSFdk, ESSFwm) and Alpine Tundra (AT) zones (Ibid.). Most of the study area fell within or adjacent to the East Kootenay Trench ecosection of the Southern Rocky Mountain Trench ecoregion, which is part of the Southern Interior Mountains ecoprovince (Demarchi 1996). Potential fossorial prey in the East Kootenay includes Columbian ground squirrels (*Spermophilus columbianus*), which are widespread in open habitats at the lowest and highest elevations and in disturbed areas at mid elevations, and northern pocket gophers (*Thomomys talpoides*), which are restricted to the lowest elevations at the southernmost portion of the study area.

3. METHODS

3.1 Trapping and Radiotelemetry

We trapped badgers at burrow sites, surgically implanted them with intraperitoneal transmitters, and released them back at the original burrow (Newhouse and Kinley, 2000). Monitoring frequency ranged from daily to monthly depending upon funding availability and weather. Between 1996 and 1999, we generally located animals weekly from April to September and twice-monthly from October to March. We located animals from the air using a telemetry-equipped Cessna 172 aircraft. We then located badger burrows on the ground for 530 of the 679 locations used in this analysis. Most locations therefore represent burrow sites. Universal Transverse Mercator (UTM) grid coordinates of the locations were recorded using 1:20,000 forest cover maps, 1:20,000 color air photos, and georeferenced 1:20,000 black and white orthophotos. We assumed that most badger locations were associated with a maximum ±25 m error because we located badgers in their burrows and were generally able to discern objects of less than 5 m diameter on air photos. Radiolocations were considered independent and included in the sample only when study animals were known to have moved from a burrow between sequential fixes.

3.2 GIS Habitat Data

A GIS habitat database was assembled for the study area, extending to all lands within a minimum 15 km radius of badger radiolocations. Data were compiled from 1:20,000 Forest Inventory Planning (FIP; Resources Inventory Branch 1995), 1:20,000 Terrain Resources Information Management (TRIM; Surveys and Resource Mapping Branch 1992), and digital files of soil associations, originally mapped at 1:50,000 (Terrestrial Studies Branch 1976). Other data sources were digital files for the 1:250,000 National Topographic System, provincial Biogeoclimatic Ecosystem Classification, and Ministry of Environment, Lands and Parks coverages for private land and Indian reserves.

From digital data, we derived variables associated with soil composition, forest overstory, terrain, and human influence (Table 1). We expected that the ecology of the badger, a fossorial carnivore, would be influenced by soil composition. Our analysis therefore considered the occurrence of 5 soil parent materials, 5 soil orders, and 5 soil textures commonly occurring within the study area, as well as soil drainage and gravel composition (Table 1). The structure and composition of the forest overstory may also influence badger ecology and the abundance and availability of certain prey species. Although stand age may influence badger habitat selection, we expected that any relationship would be non-linear. Therefore, we derived 3 stand age classes, reflecting gross structural differences among dominant species within the study area, and which conform to the age class convention of the provincial forest inventory system. "CANOPY" depicted the ocular cover of the stand overstory. "SITE" reflected site productivity based on stand age and height as calculated by species-specific equations (Thrower et al. 1991). Overstory species composition may indicate ecosystem associations and climatic variability. Individual or grouped species were considered for analysis if their spatial composition was > 5% of the study area. In addition, we derived a "COVER" variable reflecting all lands having any forest cover. The variable "WATER" was derived from TRIM hydrology, depicting streams and the perimeter of lakes as a surrogate for potential riparian habitats. Marsh and swamp lands identified by FIP data were considered within the variable "MARSH". Because human disturbances may influence ground squirrel abundance and another study has found a correlation between badger activity and linear disturbances (Warner and Ver Steeg 1995), we considered 2 variables associated with road disturbances: "LINEAR" considered the density of all linear disturbances (roads and powerlines), and "HIGHWAY" considered only those lands within the road allowance of a paved highway. We derived 4 variables depicting different types of non-forested lands. As defined by FIP data, "ALPINE" depicted alpine tundra, "CULTIVAT" depicted cultivated lands, "OPENRANG" depicted open range, and "URBAN" depicted urban development, including golf courses. Terrain variables included elevation ("ELEV") and "SLOPE", and aspect was described by 2 ratio-scale (0→100) variables depicting north→south ("SOUTH") and east→west ("WEST") aspects. A terrain ruggedness index, "TERRAIN", was derived by adapting a technique (Beasom et al. 1983) for GIS using 150 m elevation contours, yielding a continuous (0→100) variable that is relative to the scale of contour data and pixel size.

We derived each variable as a separate raster layer within the GIS. Data were rasterized to 50 m resolution (cell size), approximating the assumed maximum spatial error of badger locations. At each spatial scale, continuous (ratio-scale) variables reflected mean composition with the landscape, and dichotomous (1/0) variables reflected proportional composition. All GIS applications employed the software *Idrisi for Windows* 2.01 (Clark Labs 1997).

Table 1. Independent variables derived for analyses of badger habitat selection within the East Kootenay, British Columbia, 1996 – 1999. Variables depict the average proportion or value of attributes within a defined landscape.

Variable	Description
PAR_MOR	Morainal parent material (%)
PAR_GLLA	Glaciolacustrine parent material (%)
PAR_GLFL	Glaciofluvial parent material (%)
PAR_FLUV	Fluvial parent material (%)
PAR_COLL	Colluvial parent material (%)
SOI_PODZ	Podzolic soils (%)
SOI_BRUN	Brunisolic soils (%)
SOI_CHER	Chernozemic soils (%)
SOI_REGO	Regosolic soils (%)

Table 1 continued

Variable	Description
SOI_LUVI	Luvisolic soils (%)
TEX_SL	Sandy loam soil texture (%)
TEX_SIL	Silt loam soil texture (%)
TEX_SICM	Silty clay loam and organic soil texture (%)
TEX_S	Sandy soil texture (%)
TEX_FSL	Fine sandy-loam soil texture (%)
GRAVEL	Not gravelly (10) → very gravelly (30) soils
DRAINAGE	Very poorly (10) → rapidly (60) drained soils
AGE_1	Overstory stand age < 20 yrs, including non-forested cutblocks (%)
AGE_2-6	Overstory stand age 21 – 120 yr (%)
AGE_7-9	Overstory stand age > 121 yr (%)
CANOPY	Overstory canopy closure (%)
SITE	Forest stand site index
SPP_MESC	Mesic conifer composition (%): Subalpine fir (*Abies lasiocarpa*), spruce (*Picea spp.*), western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*).
SPP_FD	Douglas-fir (*Pseudotsuga menziesii*) composition (%)
SPP_DEC	Deciduous species composition (%)
SPP_P	Lodgepole (*Pinus contorta*) and western white (*P. monticola*) pine composition (%)
SPP_PY	Ponderosa pine (*P. ponderosa*) composition (%)
SPP_L	Larch (*Larix occidentalis*) composition (%)
COVER	Presence of overstory forest cover
WATER	Proximity to Water (TRIM hydrology)
MARSH	Proximity to "Marsh" non-productive forest
LINEAR	Proximity to linear disturbance
HIGHWAY	Proximity to paved highways
ALPINE	"Alpine tundra" non-productive forest composition (%)
CULTIVAT	"Cultivated" non-productive forest composition (%)
OPENRANG	"Open Range" non-productive forest composition (%)
URBAN	"Urban" non-productive forest composition (%)
ELEV	Elevation (m)
SLOPE	Slope (%)
SOUTH	North→south aspect (0→100)
WEST	East→west aspect (0→100)
TERRAIN	Terrain Ruggedness Index (0→100)

3.3 Analysis Design

We designed our analysis in accordance with Thomas and Taylor's (1990) Study Design 3, with inferences relevant at the individual level. This acknowledged that (1) capture effort was not equal or random throughout the study area, (2) the animal sample was relatively small, and (3) the radiolocation sample varied considerably among animals. We did not analyze data for animals with < 10 radiolocations.

For each study animal, we analyzed habitat selection at two nested spatial scales, following methods described by Apps et al. (2000). At each level, we sampled landscape composition at badger radiolocations and at paired locations of fixed distance but random azimuth from badger locations. At level 1, the broader analysis scale, badger and paired random locations were separated by 11.4 km, representing the radius of the largest area we consider potentially available to badgers in moving between sequential radiolocations. We considered our data to be independent at this distance because we observed movements of 11.4 km or less between 95% of sequential radiolocations for 7 (5M; 2F) of 10 resident study animals. We defined the used landscape at level 1 as that within a 2.75 km radius of badger locations, representing the minimum movement between 50% of sequential locations for 7 (5M; 2F) of 10 resident study animals. Habitat data were aggregated to this landscape-scale using a GIS moving window routine (Bian 1997). The 2.75 km also represented the radius of available area at level 2, the finer analysis scale. This was over 5 times longer than the 0.5 km radius of the minimum mappable unit of the smallest scale polygon data (soils; 1:50,000) used in this analysis. Thus, this finest analysis scale is still broad enough to detect habitat relationships. We defined the radius of the used landscape at level 2 as the minimum ±25 m accuracy assumed for badger locations, matching the raster resolution of habitat variables. Neither lands for which data were not available nor water bodies were considered part of the surrounding landscape when running the moving window routine, and random locations were excluded from these areas. At each analysis level, we extracted habitat attributes associated with badger and random landscapes to a database.

For each of the 42 variables, we assessed univariate differences between used and random landscapes for each badger, at each scale, using Student's *t*-tests ($\alpha = 0.001$). For each variable, we evaluated homogeneity of habitat selection among badgers using analysis of variance ($\alpha = 0.001$). Variables with which ≥ 7 of 10 badgers exhibited consistent associations ($P < 0.1$) were considered for multivariate modeling.

We employed multiple logistic regression (MLR) to derive probabilistic resource selection functions (RSF; Manly et al. 1993) for the pooled sample of badgers and across the two spatial scales. "Badger use" landscapes and random landscapes represented the dichotomous dependent variable. However, the design differed from the scale-dependent univariate analyses in that paired random locations occurred at distances ranging from 2.75 km to 11.4 km, spanning the two spatial scales. We screened variables for multicollinearity by pooling data among badgers and examining linear regression Tolerance statistics (Menard 1995). Where problematic collinearity occurred (tolerance < 0.2; Ibid.), we used Pearson correlation coefficients to identify offending variables. Of highly correlated pairs, variables that were less significant in univariate analyses among most animals were excluded from multivariate modeling. We employed a jackknife procedure to estimate the mean RSF coefficient and 95% confidence intervals for the pooled sample of 10 badgers. This involved deriving a separate model for each ($n - 1$) sample of individuals, thereby accounting for variability in habitat selection among animals and providing an assessment of model stability. To account for unequal samples among individuals, we weighted each location (data case) relative to the individual with the largest sample, such that all study animals contributed equally to model development. To determine the significance of each mean coefficient, we divided it by its asymptotic standard error and squared the resulting quotient to derive the Wald statistic, which approximates a chi-square distribution (Hosmer and Lemeshow 1989). Estimated coefficients reflected the relative contribution of each variable in discriminating badger habitat use from random points available to them. We evaluated the improvement of the fitted model over the null model according to the reduction in –2loglikelihood ratios (Ibid.), and we evaluated model performance from classification success across a range of probability cutpoints.

Following the resource selection probability function of Manly et al. (1993: equation 5.1), we applied the best-fit MLR badger habitat model to our GIS database using algebraic overlays. This produced a probability surface of badger habitat selection for the study area.

3.4 Model Fit Against Sightings Data

From 1996 to 1999, badger sightings were obtained by contacting government resource managers, forest company employees and contractors, wildlife researchers, ranchers and naturalists, by distributing a poster requesting sighting information, and through radio interviews and public presentations. We subjectively assessed the accuracy of the badger habitat model by assessing its fit against 309 badger sightings reported to have occurred within the study area from 1968 to 1999. We did not conduct a quantified validation because several habitat variables may influence sightability, biasing such an analysis. Reported sightings were assigned an accuracy level based on each observer's level of certainty and description of the location. Sightings were treated as circular polygons with diameters equivalent to accuracy levels. For each sighting polygon, we determined the mean predicted habitat probability value from the MLR algorithm. We then plotted badger habitat classification success rates across cutpoint probability levels.

4. RESULTS

Univariate habitat associations differed among badgers for most variables. However, habitat selection was consistent among study animals for 26 variables, which we considered for multivariate habitat modeling (Table 2). Of these, we excluded the variables PAR_FLUV, PAR_COLL, AGE_79, SITE, ELEV and TERRAIN from analyses due to multicollinearity with other variables, and we considered the remaining variables to be non-redundant.

Table 2. Univariate habitat selection by badgers in the East Kootenay, British Columbia, 1996 – 1999. Significance of t-tests is indicated by: +/- ($P < 0.1$), ++/- - ($P < 0.01$), and +++/- - - ($P < 0.001$). Sample size for each animal is given in parentheses.

Variable	Level[1]	F/01 (162)	F/03 (142)	F/05 (28)	F/07 (72)	M/02 (57)	M/04 (81)	M/06 (38)	M/09 (47)	M/11 (22)	M/12 (30)	Heter
PAR_MOR	1	o	- - -	+++	-	o	o	-	+	o	o	*
	2	- - -	o	o	o	-	o	-	O	o	o	
PAR_GLLA	1	+++	+++	o	-	+++	+	++	-	+++	+++	
	2	o	+++	+	o	o	++	+	o	++	o	*
PAR_GLFL	1	+++	o	o	+++	+++	+++	+++	-	-	+	*
	2	+++	++	o	o	++	+++	++	+	+	o	
PAR_FLUV	1	+++	+++	o	+++	+++	+	++	+	o	+++	*
	2	-	- - -	o	o	o	o	o	-	-	+	*
PAR_COLL	1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -	-	*
	2	- - -	- - -	o	o	- - -	- - -	-	o	o	-	
SOI_PODZ	1	- - -	- -	o	- - -	- - -	- - -	- -	o	-	- - -	*
	2	o	o	o	o	o	o	o	o	o	-	*
SOI_BRUN	1	+++	o	+	+++	++	+++	++	+++	o	o	*
	2	+++	+++	+	o	+	+	o	++	++	o	*
SOI_CHER	1	o	o	o	-	o	o	o	-	-	o	*
	2	o	o	o	o	o	o	o	o	o	o	*
SOI_REGO	1	+++	+++	o	+++	+++	o	+++	+++	++	+++	*
	2	-	- - -	o	o	o	o	o	-	-	+	*
SOI_LUVI	1	-	- - -	-	- - -	-	- -	- - -	- - -	o	++	*
	2	o	o	o	o	o	o	o	o	-	o	
TEX_SL	1	- -	++	o	+++	-	+++	+	o	o	+++	*
	2	o	o	-	o	o	+	-	o	-	+	
TEX_SIL	1	- - -	o	o	- - -	o	- - -	- - -	+	++	+++	*
	2	- - -	- - -	o	o	- -	-	o	-	o	o	
TEX_SICM	1	+++	o	o	- - -	+++	o	-	- -	-	-	*
	2	-	o	o	+	o	-	o	o	o	o	*
TEX_S	1	o	o	o	+++	o	+	o	++	+++	o	*
	2	o	o	o	o	o	o	o	o	++	o	
TEX_FSL	1	+++	o	o	+++	+++	++	+++	o	-	-	*
	2	+++	++	o	o	+++	+	++	o	o	o	*

Table 2 continued

Variable	Level[1]	F/01	F/03	F/05	F/07	M/02	M/04	M/06	M/09	M/11	M/12	Heter
GRAVEL	1	---	---	o	+	---	+	o	+++	-	o	*
	2	---	--	o	o	--	o	---	o	o	o	*
DRAINAGE	1	o	---	o	+++	-	+++	o	o	o	++	*
	2	++	+++	o	o	+	++	o	++	+	o	*
WATER	1	---	+++	o	+++	o	---	o	o	+	o	*
	2	-	-	o	-	o	o	o	o	o	o	
MARSH	1	+++	+++	o	+++	+++	o	o	o	o	o	*
	2	-	---	o	o	-	+	o	o	o	o	*
LINEAR	1	+++	+++	o	+++	+++	+++	+++	+++	+	+++	*
	2	-	+++	o	o	o	+	o	o	o	o	
HIGHWAY	1	+++	+++	+	+++	+++	+	++	o	+++	+++	*
	2	o	o	o	o	o	+	o	o	o	o	
OPENRANG	1	+++	+++	+++	+++	+++	+++	+++	o	+++	o	*
	2	+++	+	++	o	o	+	+	o	+	o	
URBAN	1	+++	+++	o	+++	+++	o	++	o	o	+++	*
	2	o	o	o	o	o	o	o	o	o	o	
CULTIVAT	1	+++	+	+	+++	+++	+++	++	o	+++	o	*
	2	+++	o	o	o	++	o	o	o	o	o	*
ALPINE	1	---	---	-	---	---	---	o	o	-	---	*
	2	o	o	o	o	o	o	o	o	o	o	
COVER	1	---	---	---	---	---	o	--	o	-	+++	*
	2	---	o	-	o	o	--	o	o	o	+	*
AGE_1	1	---	---	++	---	-	o	+	o	-	+++	*
	2	o	-	-	o	o	+	o	o	o	++	*
AGE_26	1	+++	+++	--	---	o	o	--	o	o	---	*
	2	---	+	o	--	o	o	o	o	o	o	
AGE_79	1	---	---	---	-	---	o	o	o	---	---	*
	2	---	--	o	++	-	-	o	o	o	o	*
CANOPY	1	---	---	---	---	---	-	---	---	-	---	*
	2	---	---	o	-	-	---	-	--	o	o	
SITE	1	---	---	---	---	---	o	-	--	-	+++	*
	2	---	-	-	o	-	-	o	o	o	++	*
SPP_MESC	1	---	---	---	---	---	---	o	o	o	o	*
	2	-	-	o	-	o	o	o	o	o	+	*

Table 2 continued

Variable	Level[1]	F/01	F/03	F/05	F/07	M/02	M/04	M/06	M/09	M/11	M/12	Heter
SPP_FD	1	---	---	---	o	---	+++	o	++	-	--	*
	2	--	o	o	o	o	-	o	o	o	o	
SPP_DEC	1	---	o	+++	-	-	-	+++	o	o	+++	*
	2	o	-	o	-	+	o	o	o	o	o	
SPP_P	**1**	---	---	--	---	---	---	--	---	-	+++	*
	2	--	o	o	-	-	o	o	o	o	o	
SPP_PY	1	o	o	+	+++	o	+++	++	+++	o	o	*
	2	o	o	+	o	o	+	o	o	o	o	
SPP_L	**1**	---	-	o	---	---	o	-	---	o	--	*
	2	o	o	o	o	o	o	o	o	o	o	
ELEV	**1**	---	---	-	---	---	---	---	---	---	--	*
	2	---	---	-	o	--	---	-	o	o	---	*
SLOPE	**1**	---	---	-	---	---	---	---	---	---	---	*
	2	---	--	o	o	---	---	-	+	o	---	*
SOUTH	1	+++	+++	o	o	+++	+	o	--	o	o	*
	2	+	+	o	o	+	+	o	+	o	o	
WEST	1	+++	+++	---	+++	+++	++	---	-	---	o	*
	2	+	o	o	o	++	o	o	-	o	++	
TERRAIN	**1**	---	o	o	---	---	---	---	---	---	--	*
	2	--	-	o	o	o	o	o	o	o	o	

[1] Bold font denotes variables with consistent habitat associations among badgers ($n \geq 7$; $P < 0.1$), and which were included in multivariate habitat analysis.

* *F*-tests for heterogenous selection among animals significant at $P < 0.001$.

Best-fit MLR models produced from all n - 1 study animal samples were highly significant over null models ($\chi^2 > 1616.1$, 20 df, $P < 0.0001$), achieving overall correct classifications > 80.4% (cutpoint $P = 0.5$). Parameters associated with the combined MLR model suggested that, of the variables we considered, CANOPY, SOI_REGO, COVER, and OPENRANG at level 1, and PAR_GLFL and CANOPY at level 2 were the most important ($R < -0.10$ or $R > 0.10$) predictors of badger habitat selection in our study area (Table 3). Contributing somewhat less to the model ($R < -0.04$ or $R > 0.04$) were the variables CULTIVAT, HIGHWAY, SPP_L, SOI_PODZ, ALPINE and PAR_GLLA at level 1, and SOI_BRUN and ELEV at level 2 (Table 3). In discriminating between badger and random locations, the model achieved the highest overall predictive success at probability cutpoints of 0.3 – 0.6 (Figure 1). The fact that the optimum cutpoint appears to be < 0.5 reflected the model's somewhat conservative allocation of "badger habitat". This was expected, considering that some random locations likely occurred within suitable badger habitat. Application of the MLR badger habitat selection model to our GIS database also suggested that the model was highly efficient in predicting badger habitat use across the entire study area (Appendix 1).

Table 3. Multiple logistic regression model parameters of badger habitat selection in the East Kootenay, British Columbia, 1996 - 1999.

Variable	Level	β	SE	*P*	*R*
CANOPY	1	-0.997	0.094	<0.001	-0.172
SOI_REGO	1	0.105	0.013	<0.001	0.135
COVER	1	0.076	0.010	<0.001	0.132
OPENRANG	1	0.047	0.007	<0.001	0.101
CULTIVAT	1	0.079	0.014	<0.001	0.097
HIGHWAY	1	0.175	0.050	<0.001	0.055
SPP_L	1	0.046	0.015	0.002	0.049
SOI_PODZ	1	0.045	0.014	0.001	0.048
ALPINE	1	0.044	0.014	0.002	0.046
PAR_GLLA	1	0.018	0.006	0.002	0.045
SOI_BRUN	1	0.014	0.010	0.158	0.018
LINEAR	1	0.029	0.022	0.194	0.012
SPP_P	1	0.026	0.024	0.266	0.011
SLOPE	1	-0.007	0.010	0.464	-0.009
SOI_LUVI	1	-0.001	0.011	0.938	0.002
PAR_GLFL	2	0.011	0.002	<0.001	0.114
CANOPY	2	-0.224	0.033	<0.001	-0.108
SOI_BRUN	2	0.008	0.002	<0.001	0.062
ELEV	2	-0.002	0.001	0.002	-0.050
OPENRANG	2	0.004	0.002	0.038	0.025
Constant		-5.467	1.128		

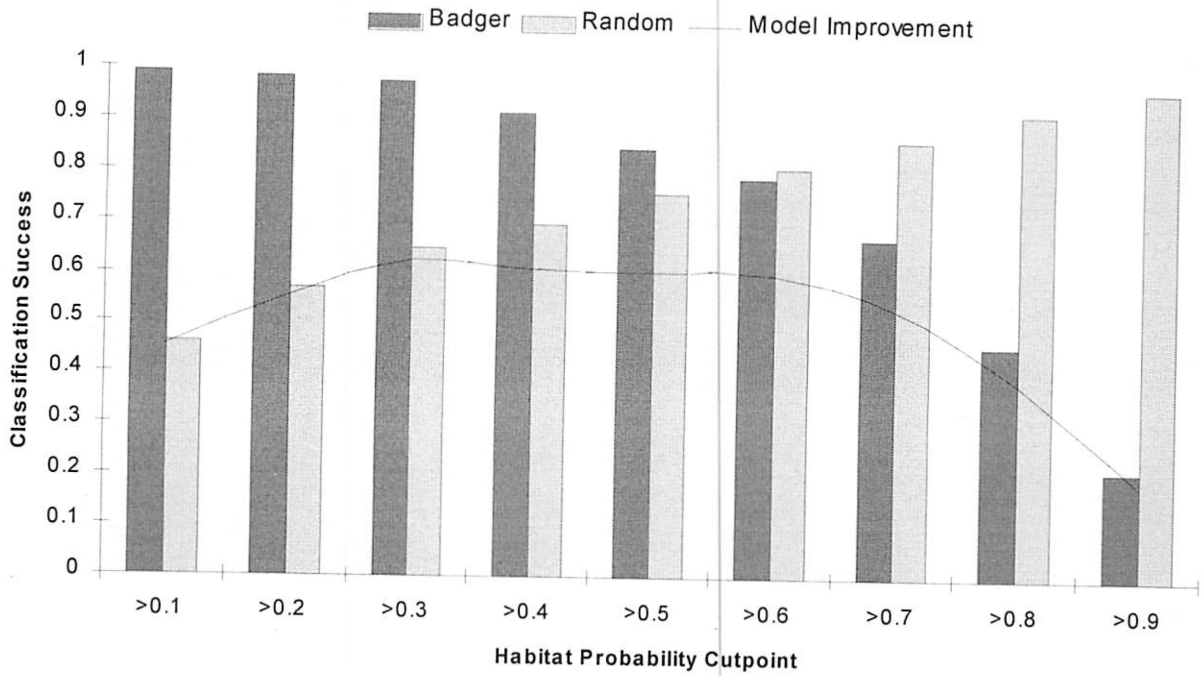

Figure 1. Predictive efficiency of badger habitat model across cutpoint probability levels in the East Kootenay, British Columbia. Model improvement (correctly classified badger minus incorrectly classified random) indicates the optimal classification cutpoint.

Of 309 badger sightings within the study area, 277 occurred within areas for which we had enough data to determine habitat probability. At a cutpoint probability levels of $P > 0.5$, the model was correct in classifying 74% of these sightings as occurring within badger habitat (Figure 2).

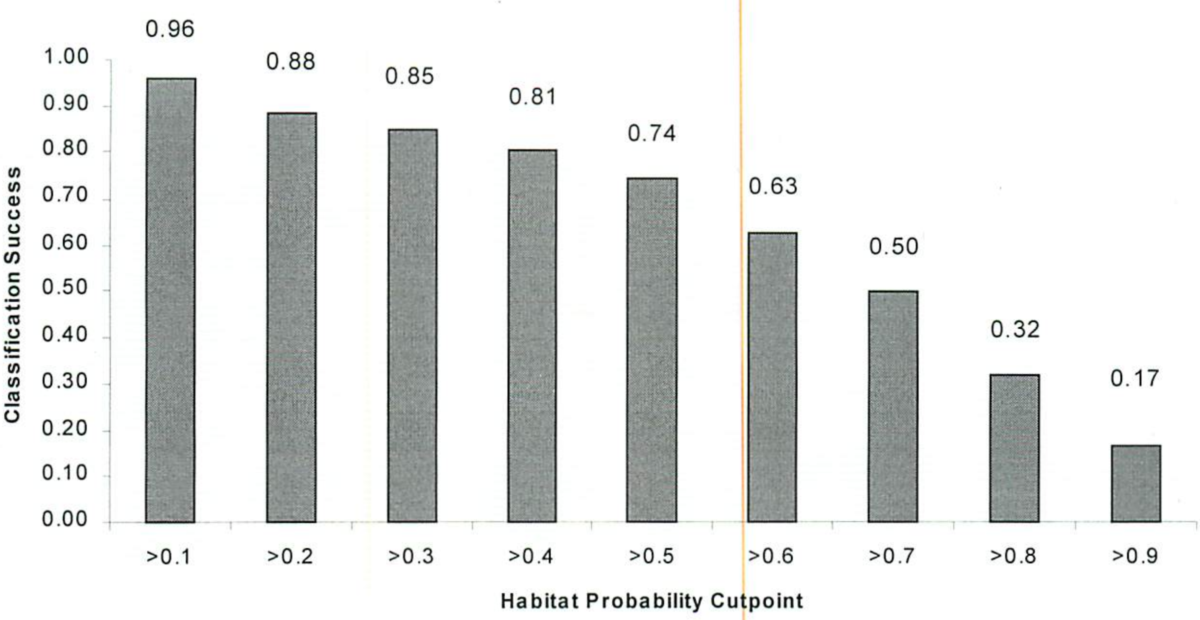

Figure 2. Assessment of badger habitat model fit against independent sightings data, East Kootenay, British Columbia, 1996 - 1999.

Of the nine biogeoclimatic subzones in the study area, IDFdm contributed the greatest amount of badger habitat at cutpoints of $P > 0.2$ to $P > 0.8$, despite occupying only about 13% of the analysis area (Figure 3). The PPdh and IDFun also contributed disproportionately to the higher habitat probability classes, with PPdh contributing 47% of the total habitat in the study area at a cutpoint of $P > 0.9$. All other subzones either provided proportionately less habitat with increasing cutpoint or provided little habitat at any cutpoint.

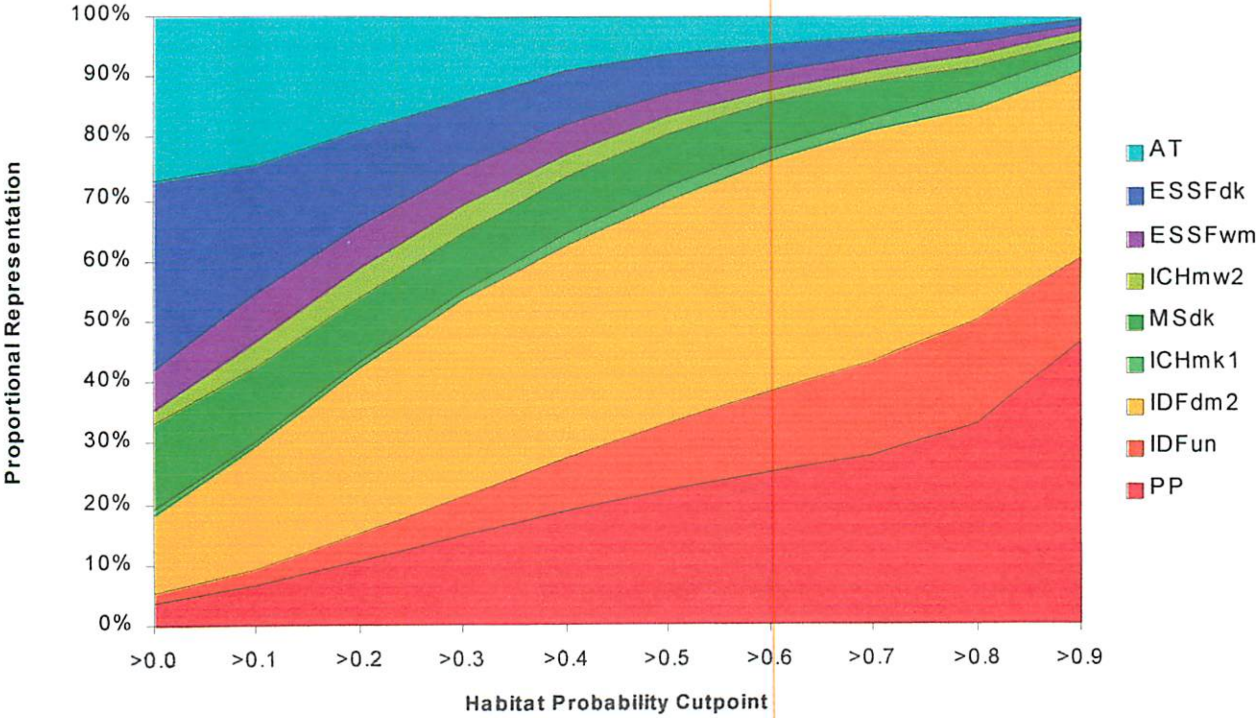

Figure 3. Biogeoclimatic subzone representation of total badger habitat, East Kootenay, British Columbia.

Crown land constituted 78% of the land in the study area. However, it provided proportionately less habitat at increasing cutpoint values, with a decline to about 39% at a cutpoint of $P > 0.9$ (Figure 4). Parks also provided proportionately less habitat at higher cutpoints. In contrast, private land only comprised 9% of the total study area, but accounted for a much higher proportion of badger habitat defined at progressively higher cutpoints, with private land providing 55% of the habitat at a cutpoint of $P > 0.9$. Indian reserves also formed a larger proportion of habitat at higher cutpoints.

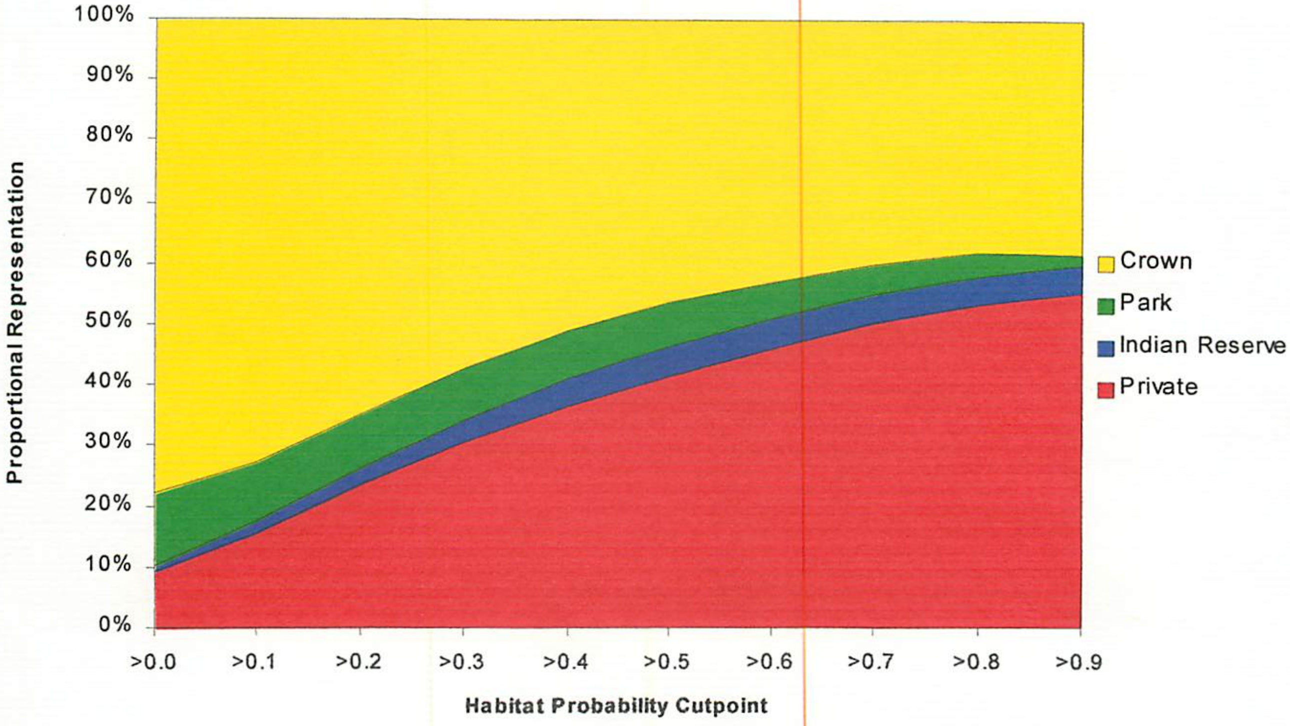

Figure 4. Jurisdictional representation of total badger habitat, East Kootenay, British Columbia.

5. DISCUSSION

Habitats preferred by badgers were generally associated with relatively open forest or non-forest. At the broad scale, badgers showed a negative association with canopy and positive associations with open range, cultivated land, highway rights-of-way, alpine tundra and linear disturbances. At the fine scale, associations were negative with canopy and positive with open range. This was consistent with the habitats dominant in other badger studies, and was likely related to availability of the most abundant fossorial prey, Columbian ground squirrels, which generally live in areas of low canopy closure (Stevens and Loft 1988). The preference for cover at broad scales but not at the fine scale, coupled with the preference for low canopy closure at both scales, is consistent with the observed regular use of sites where cover was present but canopy closure low, such as Christmas tree permits and open stands of Douglas-fir, western larch and ponderosa pine.

The strong relationship with regosolic soil at the broad scale was likely an artifact of this soil type's distribution, rather than an attraction of badgers to it. Regosolic soils lack well defined soil horizons and are usually young. In our study area, they were generally found in alpine areas or river systems. Because of the expanse of the Columbia River wetlands and the Kootenay River floodplain, a significant amount of regosol occurred in the valley bottoms, immediately adjacent to where badger use was concentrated. Regosols in these areas would almost certainly not have been used for burrows, because they are generally rock, mud or under water. As would be expected, regosol was not selected at the fine scale.

Friability of soils would be expected to contribute to badger habitat selection, particularly because our model was based on burrow sites. However, soil texture, gravel component and drainage were not good predictors of badger habitat quality. It is possible that the maps used to derive these variables were not sufficiently fine to reflect conditions in the immediate vicinity of burrows. Glaviofluvial parent material was an important predictor at the fine scale, perhaps because glaciofluvial soils are associated with preferred vegetative attributes that were not considered in this analysis.

6. MANAGEMENT IMPLICATIONS

Several factors indicate that the model represents a good predictor of relative badger habitat quality within the study area. There was (1) a high success rate in classifying data from which it was derived; (2) generally a good match in the location of badgers relative to habitat cutpoints between the sightings data and the model output; and (3) an animal sample size that probably represented one-third to half of the population within the radiotelemetry study area, based on extensive searches, location of sightings, and knowledge of home range size. Model parameters can therefore confidently be applied to the GIS database within the study area bounds to spatially predict badger habitat distribution. Doing so highlights areas with concentrations of habitat which may be suitable as priority areas for badger habitat management, such as lower Findlay Creek, the confluence of the Lussier River and Coyote Creek, north of Skookumchuck, and the northwest corner of Skookumchuck Prairie.

Several limitations to the badger habitat model must be recognized in its management application. The model does not necessarily reflect how badgers select habitat outside the time and space from which the data were collected, so may not accurately predict habitat quality for badgers outside of the analysis area. Another limitation is that it can only be extrapolated to areas where appropriate digital habitat data are available. Thirdly, even our broadest analysis level is not broad enough to account for factors that may affect badger species persistence at a regional or provincial scale, such as general land-use patterns or climate. Furthermore, although many of the variables that we considered have been influenced by humans (e.g. LINEAR, OPENRANG, CANOPY, COVER, overstory species), the model does not account for the influence of direct human-caused mortality, such as shooting or vehicle collisions. Finally, the derived model is based on relatively coarse-scale analyses across the entire study area, and cannot account for habitat selection patterns at scales finer than the variables we considered. Specifically, although we expect that badgers will respond to variation in vegetative structure within open habitats, the forest cover data we used provides no detail on the structure within non-forested habitats. In our study area, open habitats vary considerably in grazing history, grass species composition, and shrub components. We expect that Terrain Ecosystem Mapping (Resources Inventory Committee 1995), when completed for the study area, will facilitate more detailed modeling of badger habitat suitability.

The proportion of higher quality habitat occurring in each biogeoclimatic zone demonstrates that the IDFun, PPdh and IDFdm biogeoclimatic subzones should be the focus of any management initiatives. Private land and Indian reserves are also disproportionately important in supporting badger habitat, either because such land occurs almost exclusively within the IDF and PP, or possibly due to some difference in management practices compared to parks or Crown land. Regardless, private stewardship initiatives may be a key element towards successful conservation of badgers.

Although the variables and coefficients within the habitat model presently are the best habitat predictors, they likely represent mainly surrogates of attributes to which badgers respond directly. The model therefore represents not a prescriptive but a decision-support tool. Coupled with our general understanding of badger ecology, our results suggest that the current trend of increasing forest canopy in former grassland and open forests within the East Kootenay Trench due to fire suppression (Gayton et al. 1995) may be decreasing badger habitat quality. We surmise that forest thinning and burning, which are now being introduced to the Trench through ecological restoration programs, will enhance badger habitat. This should be tested through pre-and post-restoration monitoring. We also suggest that future research verify or adapt this model based on additional badger radiotelemetry data, and should also focus on ground squirrel habitat requirements and responses to habitat manipulations.

7. ACKNOWLEDGEMENTS

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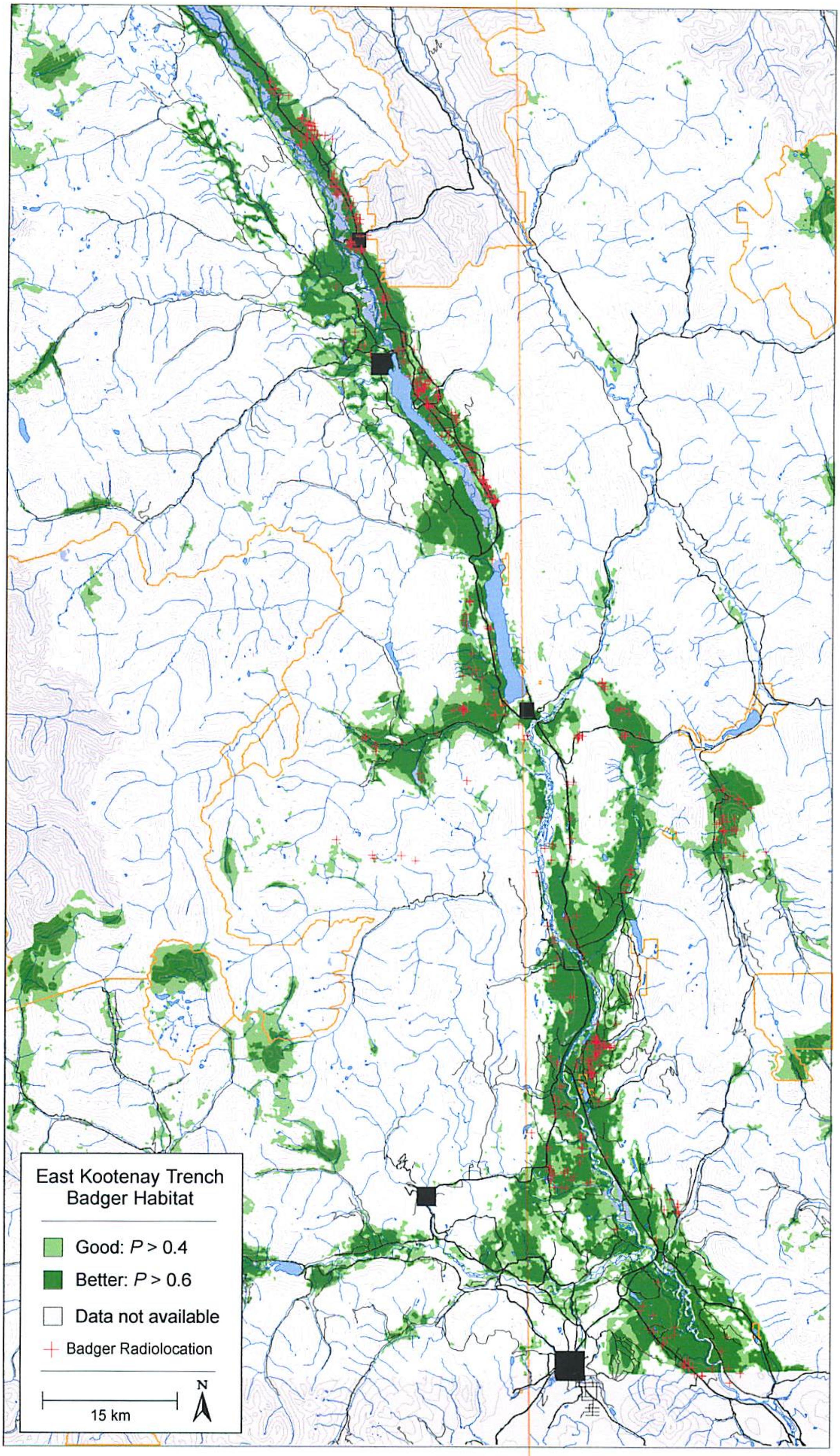

APPENDIX 1. Badger radiolocations and predicted habitat in the East Kootenay,British Columbia.