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HABITAT ASSOCIATIONS OF AMERICAN BADGERS IN SOUTHEAST BRITISH COLUMBIA

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Abstract: American badgers (*Taxidea taxus*) are considered endangered in British Columbia due to habitat loss and unsustainable human-caused mortality. To better understand the nature and severity of human impacts, and to promote conservation planning, we described and modeled badger habitat relationships. At 2 spatial scales, we analyzed selection by 12 radio-implanted, resident badgers for 52 variables of soil composition, forest overstory, land cover, vegetation productivity, terrain, and human influence. Habitat selection was consistent for 31 variables at the broad scale. Soil parent material associations were positive with glaciolacustrine and glaciofluvial, and negative with colluvial. Soil order associations were positive with brunisols and regosols and negative with podzols and luvisols. Association with fine sandy-loam texture was positive. Badgers were negatively associated with forested habitats and positively associated with open range, agricultural or cultivated habitats, and with highways and linear disturbances. Associations were negative with elevation, slope, terrain ruggedness, and both vegetation productivity and moisture. Badgers also exhibited habitat selection for 17 variables at the fine scale. Associations were positive with glaciofluvial soils, fine sandy-loam texture and well-drained soils. Associations were again negative with colluvial soils, forest cover, vegetation moisture, elevation and terrain ruggedness. Associations with open range and southern aspects were positive. Of variables considered, the linear combination of a subset could explain and predict seasonal habitat selection across scales ($P < 0.001$). At this range extent, natural conditions may restrict badger occurrence, increasing their sensitivity to human factors that influence habitat quality and mortality risk.

Introduction

The American badger (*Taxidea taxus*) is a fossorial carnivore that occurs at a northern range limit in southern British Columbia (Rahme et al. 1995). Populations here are considered to be in decline due to loss of habitat and prey, unsustainable mortality due to vehicle collisions, and killing of badgers and their prey as nuisance animals. The subspecies occurring in BC (*T. taxus jeffersonii*) is thus considered endangered provincially (Cannings et al. 1999) and federally (COSEWIC 2000). Although badgers are adapted to hunting fossorial prey, their primary diet throughout their range (Salt 1976, Lampe 1982), they are also opportunistic feeders and supplement their diet with a wide variety of mammals, birds, eggs, reptiles, amphibians, invertebrates and plants (Messick 1987). Badgers in North America have been known to occur from below sea level to elevations >3,660 m. Their range is mostly associated with treeless areas, but includes savannah and forest in some regions (Lindzey 1982). Studies have been conducted in open, often agricultural landscapes (Todd 1980, Warner and Ver Steeg 1995) and shrub-steppe habitats (Messick and Hornocker 1981). Beyond this, there is little known of badger-habitat associations, as is necessary to implement appropriate conservation measures.

We describe an analysis of biotic, abiotic, and human factors associated with badger habitat selection at 2 spatial scales in southeast British Columbia. We also develop and evaluate a multivariate habitat selection model as a means of accounting for badger habitat relationships in conservation planning.

Materials and Methods

Study Area

The study area encompassed approximately 3,000 km^2 within the upper Columbia and upper Kootenay valleys of southeast British Columbia, from 49°30'N to 50°50'N (Fig. 1). It occurred largely within the East Kootenay Trench ecosection (Demarchi 1996) and was primarily composed of the Ponderosa Pine (PP), Interior Douglas-fir (IDF), and Montane Spruce (MS) biogeoclimatic zones (Meidinger and Pojar 1991). Study animals also periodically ranged within the Interior Cedar - Hemlock (ICH), Engelmann Spruce – Subalpine Fir (ESSF) and Alpine Tundra (AT) zones of the adjacent Rocky and Purcell mountain ranges. Within the PP and IDF zones, open stands dominated by ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) respectively were the predominant climax forest types, with upland sites in those zones varying from grassland or shrub steppe to dense forest, depending on site characteristics, history and aspect. Settlement within the East Kootenay Trench was concentrated in the PP and IDF zones, and significant portions of it had been converted to agricultural fields, settlements and transportation corridors. Forest management for timber and Christmas trees had occurred over most of these two zones, but land cover was also largely influenced by fire suppression, resulting in forest in-growth and encroachment into open habitats and grasslands (Gayton et al. 1995). The PP zone was associated with the warmest, driest portions of the Trench floor, and was surrounded by the IDF zone at slightly higher elevations. Above the IDF zone, the MS zone was associated with a climax overstory of hybrid white spruce (*Picea glauca* x *engelmannii*). The ICH zone occurred at corresponding elevations in some valleys tributary to the Trench, and was associated with a climax overstory of western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*). The ESSF zone occurred immediately upslope of the MS and ICH zones and was associated with a climax overstory of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Due to a history of natural and human disturbance, much of the MS, ICH, and ESSF zones were in a mid-successional state, dominated by lodgepole pine (*Pinus contorta*) and to a lesser degree western larch (*Larix occidentalis*). At highest elevations, whitebark pine (*Pinus albicaulis*) and alpine larch (*Larix lyalli*) acceded to AT. Typical annual precipitation ranged from 370 mm in portions of the IDF zone (Achuff et al. 1984) to roughly 900 mm in the ESSF zone (Braumandl and Curran 1992).

Potential fossorial prey included Columbian ground squirrels (*Spermophilus columbianus*), in open habitats throughout the study area, and northern pocket gophers (*Thomomys talpoides*), which were restricted to the PP zone in the southernmost portion of the study area.

Capture and Radiotelemetry

Between 1996 and 2000, we trapped and radio-implanted 20 badgers. Trap stations were placed at active burrows, located with the assistance of direct badger sightings, or by inspecting known Columbian ground squirrel colonies. At burrow entrances, #1$^1/_2$ Soft Catch® (Woodstream Corp., Litiz, Pennsylvania) padded leghold traps were set, baited with ground squirrels, rabbits, beef liver and scent lure and were checked at least daily. Trapped badgers were noosed and hand-injected with either 10 mg/kg of tiletamine hydrochloride/zolazepam hydrochloride mixed at 100 mg/ml, or a combination of 0.3 mg/kg of midazolam mixed at 1.0 mg/ml and 9 mg/kg of ketamine hydrochloride mixed at 100 mg/ml. Surgical implantation of intraperitoneal transmitters (Advanced Telemetry Systems, Isanti, Minnesota) was conducted in a veterinary clinic or in the field (Hoff 1988). Once alert, badgers were released at trap sites or nearby burrows.

Using a Cessna 172 fixed-wing aircraft and standard techniques (Samuel and Fuller 1996), study animals were located weekly during April through September and twice-monthly during October through March when badgers were typically less active, resulting in 967 radiolocations. Each location was referenced to a Universal Transverse Mercator (UTM) grid coordinate to the nearest 10 m using 1:20,000 forest cover maps and 1:20,000 air photos. Ground-based accuracy tests (*n* = 20), using a hand-held GPS unit, suggested that 95% of radiolocations were within 215 m ($\bar{x}$ = 62 ± 63; 1 SD). Because badgers are known to periodically enter torpor, we considered sequential locations to be independent samples only when animals were known to have moved from a burrow between sequential locations.

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 files (FIP; Resources Inventory Branch 1995), 1:20,000 Terrain Resources Information Management files (TRIM; Surveys and Resource Mapping Branch 1992), 1:50,000 soil associations (Terrestrial Studies Branch 1976), 1:250,000 Baseline Thematic Mapping of landcover (BTM; Surveys and Resource Mapping Branch 1995), and Landsat Thematic Mapper (TM) scenes taken during August 1995 and 1996. From digital data, we derived variables reflecting soil composition, forest overstory, land cover, vegetation productivity, terrain, and human influence (Table 1).

As a fossorial carnivore, we expected that badger ecology would be influenced by soil composition. Our analysis therefore considered 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. We expected that any relationship with stand age 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 closure (CANOPY) depicted the ocular cover of the stand overstory. Site index (SITE) reflected forest productivity based on stand age and height as calculated by species-specific equations (Thrower et al. 1991). Overstory species composition indicated 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 variable (COVER) indicating whether a given site was associated with forest overstory cover of any type. We anticipated a potentially negative relationship with areas having permanently wet soil because of poor burrow stability and the presence of water in burrows. Therefore, from TRIM hydrology data, stream networks and lake perimeters were identified as a surrogate for potential riparian habitats (WATER), as were marsh and swamp lands identified from FIP data (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; one (LINEAR) considered the density of all linear disturbances (roads and powerlines), and another (HIGHWAY) considered only those lands within the road allowance of a paved highway. Because other research has suggested that badgers are typically associated with open habitats, we derived 4 variables from FIP data depicting different types of non-forested lands: alpine tundra (ALPINE), cultivated lands (CULTIVAT), open range (OPENRANG), and urban development (URBAN). We considered terrain variables because they are assumed to influence vegetative, habitat structure and soil conditions. These included elevation (ELEV), slope (SLOPE), and aspect as described by 2 ratio-scale ($0 \rightarrow 100$) 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 ($0 \rightarrow 100$) variable that is relative to the scale of contour data and pixel size.

We derived several variables from BTM data of present land cover, allowing us to consider several variables that could not be derived from FIP data. We considered BTM data to be appropriate for this analysis because the minimum mapping unit was 15 ha, approximating the 95% error associated with our telemetry data. We extracted alpine (BT_ALP), areas virtually devoid of trees at high elevations, and avalanche tracks (BT_AVAL). We delineated old forests (>100 yrs; BT_FO), young forests (<100 yrs; BT_FY) and those where timber harvesting had occurred within the past 20 years or more if tree cover was <40% and <6 m in height (BT_LOG). Rangelands (BT_RANG) were unimproved pasture and grasslands based on cover rather than use, and agriculture (BT_AGRI) encompassed any land-based agricultural activity. From Landsat TM data, we derived the Green Vegetation Index (GVI) and the Wet Vegetation Index (WVI) of the Tasseled Cap Transformation (Crist and Cicone 1984), reflecting vegetation productivity and moisture, respectively.

We derived each variable as a separate raster layer within the GIS, with a resolution of 50 m. At each spatial scale (see Analysis Design), continuous variables reflected mean composition within a defined landscape, and dichotomous variables reflected proportional composition. All GIS applications employed the raster-based software *Idrisi 32* (Clark Labs 1999).

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 accounted for unequal capture effort throughout the study area, a relatively small animal sample, and a variable radiolocation sample among animals. We did not include data for animals with <20 radiolocations.

For each study animal, we analyzed habitat selection at two nested spatial scales, following methods described by Apps et al. (2001). 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, within the approximate 1-week sampling interval, 5% of movements between sequential radiolocations were ≥11.4 km for 8 (5M; 3F) of the 12 resident study animals we considered for analysis. We defined the used landscape at level 1 as that within a 2.75 km radius of badger locations, representing the net movement between 50% of sequential locations for 8 (5M; 3F) of 12 resident study animals. Habitat data were aggregated to this landscape-scale using a GIS moving window routine (Bian 1997). This 2.75 km distance also represented the radius of available area at level 2, the finer analysis scale. This was considerably greater than the 218 m radius of the minimum mappable unit of the smallest scale polygon data (BTM) used in this analysis. Thus, given our data, we considered this finest analysis level to be broad enough to detect habitat selection. We defined the radius of the used landscape at level 2 as the 95th percentile of spatial error (±215 m) assumed for badger locations. Neither lands for which data were unavailable 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 52 variables, we assessed univariate differences between used and random landscapes for each badger, at each scale, using Student's *t*-tests (α = 0.05 / 52 variables = 0.001). For each variable, we evaluated homogeneity of habitat selection among badgers using one-way analysis of variance (α = 0.001). For multivariate modeling, we considered only those variables for which the absolute value of the number of badgers exhibiting preference minus the number exhibiting avoidance was ≥6. Although arbitrary, this ensured that variables were only considered if consistent selection was exhibited by at least ½ of the animals, or at least ⅔ if a maximum of ⅓ showed contrary selection.

We employed multiple logistic regression (MLR) to derive probabilistic resource selection functions (Manly et al. 1993) for the pooled sample of badgers and across the two spatial scales. Model output was the probability (*p*) that the variable attributes of any given site represent badger habitat. "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; Menard 1995), 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. To account for unequal samples among individuals, we adjusted the weighting of individual locations in the analysis such that each study animal contributed equally to model development. 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 (–2) loglikelihood ratios (Menard 1995), and we evaluated model performance from classification success across a range of habitat probability cutpoints. All applications employed the software SPSS 10.0 (SPSS Inc. 1999).

Following the resource selection probability function of Manly et al. (1993: equation 8.5), we applied the best-fit MLR habitat model to our GIS database using algebraic overlays. This produced a badger habitat probability surface for the study area, facilitating visual inspection of model fit over our study area.

Results

At the broad scale, badger habitat selection ($P < 0.1$) was consistent among study animals for 31 variables (Table 2: level 1). Soil parent material associations were positive with glaciolacustrine and glaciofluvial, and negative with colluvial. Soil type associations were positive with brunisols and regosols and negative with podzols and luvisols. A positive association with fine sandy-loam texture was also apparent. Badgers were negatively associated with forest cover, as was specifically reflected in results for old (> 120 yr) age classes, lodgepole/white pine, larch, mesic conifers, site productivity, canopy closure and cover from FIP data and old forest and young forest from BTM data. Among non-forest cover types, associations were positive with open range and agricultural or cultivated habitats, and were negative with alpine and avalanche chutes, based both on FIP and BTM data. Badgers were positively associated with highways and linear disturbances. Associations were negative with the Landsat-derived green and wet vegetation indices. Elevation, slope and terrain ruggedness were negatively associated with preferred badger habitats.

At the fine scale (level 2), badger habitat selection ($P < 0.1$) was consistent among study animals for 17 variables. As with level 1, soil parent material associations were positive with glaciofluvial and negative with colluvial, while the association with fine sandy-loam texture was positive. Associations were negative with gravelly soils but positive with well-drained soils. Badgers were again negatively associated with forest cover, specifically mid (21 – 120 yrs) and old (> 120 yrs) age classes, young forest as defined by BTM data, Douglas-fir, canopy closure, forest cover, and site productivity; whereas badgers were positively associated with open range. Badgers were also negatively associated with the Landsat-derived wet vegetation index. Associations with elevation and terrain ruggedness were again negative, and a positive association with southern aspects was apparent.

The best-fit MLR model was highly significant over null models (χ^2 = 1616.1, 20 df, $P <$ 0.001), achieving an overall correct classification of 80.4% (habitat probability cutpoint $p = 0.5$). The predictive subset of variables that best describe badger habitat selection (Table 3) represented both broad and fine scales. In discriminating between badger and random locations, the model achieved the highest overall predictive success at habitat probability cutpoints of $p = 0.5 – 0.6$ (Figure 2). Spatial 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 study area (Appendix 1).

Discussion

Badger Habitat Selection

Badger selection for broad landscapes may be largely influenced by climatic conditions. Long (1972) speculates that American badgers are limited in northward distribution by subarctic climate. The glaciations of the Pleistocene are believed to have displaced badgers southward. Subsequent northward expansion likely occurred during interglacial periods, evidenced by one record in central Alaska dated to the Pleistocene (Long 1972). The distributional limits may be a function of climatic effects directly on badgers. For example, badgers can enter torpor (Harlow 1981), but this may not provide sufficient energy conservation, relative to hibernation, to allow them to survive long northern or alpine winters. Badgers may also be indirectly limited by forest overstory or soil conditions that may limit prey species in temperate forest and alpine ecosystems of northern latitudes and at upper elevations.

In our study area, habitats preferred by badgers were generally associated with non-forest or open-canopied forest. This was reflected in both broad- and fine-scale results and is consistent with dominant habitats associated with other badger study areas. These results may at least partially relate to abundance of the most common fossorial prey, Columbian ground squirrels. In Idaho, concentrations of Belding ground squirrels (*Spermophilus beldingi*) have been positively related to the distribution and abundance of badgers (Todd 1980). In our study area, we expect that Columbian ground squirrels are associated with habitats of low canopy closure. For example, Weddell (1989) found that Columbian ground squirrel burrow densities in Washington and Idaho were greater in native meadow steppe, disturbed steppe and hawthorn thickets than in conifer stands.

The broad-scale associations with soil order that we report may reflect badger preferences for landscapes dominated by generally appropriate climatic and vegetative conditions, whereas textural characteristics, potentially influencing fossorial prey availability and the ability of badgers to burrow, may directly influence habitat preference at finer scales. For example, podzols generally develop under moist coniferous forests and were avoided, while brunisols, which are typical of drier, more open forests at lower elevations, were preferred at the broad scale. Elliot (1983) found that most Columbian ground squirrel burrows in his Idaho study area were in dry cover types with 3-15% soil moisture. Fine sandy-loams with little gravel and good drainage, attributes preferred at the finer scale in our study, may provide optimal conditions for burrows. Burrows within finer soil textures, resulting from a greater silt and clay component, may be prone to saturation and collapse when wet, while very coarse textures may also be prone to collapse even when dry. A high gravel component, which by definition may include particles up to 8 cm in diameter, can also be expected to impair the ability of badgers to dig. Although no other studies have assessed selection of soil types by badgers, Hoff (1998) did characterize his Colorado study area as primarily sandy and loamy soils. Parent material does not always correspond directly to soil characteristics, but colluvium tends to be rocky material deposited by gravity at the base of slopes. Thus, its avoidance by badgers at both scales may relate to its low potential for burrowing.

Our results for regosolic soils illustrate the potential influence of spatial scale on badger habitat selection. These soils lack well-defined horizons, are usually young, and are typically associated with alpine areas or river systems. In our study area, they were most concentrated at the bottom of the Trench, associated with the Kootenay and Columbia river floodplains. Because these soils are generally rock, mud, or seasonally flooded, we do not expect them to be important to badgers. Although badger associations with regosols were positive at the broad scale, we expect that this reflects spurious relationships with other preferred landscape attributes. Consistent with our expectation, badgers did avoid regosolic soils at the fine scale.

Model Fit

Our best-fit multiple logistic regression model suggests that a linear combination of variables can efficiently discriminate badger use from random locations across scales, and the resulting model may be a useful predictor of relative badger habitat quality. The scales at which variables were represented indicate that the model explained broad- and fine-scale variation in the data. As a final assessment of predictive veracity, validation of this model against an independent dataset of different animals during different years within the intended area of extrapolation is required. Until then, our confidence in the model's utility as a decision-support tool is a reflection of the spatial, temporal, and animal representation of our dataset. We expect that our animal sample represented one-third to two-thirds of the population within the study area, based on extensive searches, location of sightings and knowledge of spatial organization.

Management Implications

Several factors may influence the occurrence and distribution of badger populations and the quality of badger habitat within southeastern British Columbia. These may largely relate to climatic conditions, availability of open habitats, and soil characteristics, and may influence badger vital rates directly or through the distribution and abundance of their prey. Although our analysis was limited to a defined range of spatial scale, our broad-scale results provide insight into the factors that may influence badger occurrence at the scale of geographic distribution in this region. Natural conditions may restrict badger occurrence at this northern range extent, and this may render the existing population vulnerable to human factors that influence habitat quality and mortality risk.

The spatial application of our model within the study area demonstrates several key considerations for badger population conservation and locations for habitat protection or enhancement in southeastern British Columbia. Using a habitat probability cutpoint of $p > 0.5$, model output suggests that while the PP and IDF zones represented 18% of the study area, they encompassed 55% of badger habitat, each representing a much greater proportion of probable habitat than any other zone. Similarly, private land, which largely occurred within these zones, represented 9% of the study area but encompassed 35% of probable habitat. In contrast, the 15% protected area representation encompassed only 3% of probable habitat. This suggests that (1) habitat management priorities for badgers should be highest in the PP and IDF zones, (2) private land stewardship should be an important component in habitat conservation efforts, and (3) existing protected areas may be of little value to badger conservation.

Our results suggest that within landscapes defined by preferred climate, terrain, and soil conditions, badgers were generally associated with dry habitats of little forest overstory. Human management has most certainly influenced vegetation composition within the East Kootenay Trench and throughout the northwestern extent of badger range. Despite uncertainty regarding the range of conditions expected under a natural disturbance regime, forest in-growth and encroachment due to fire suppression currently pervades (Gayton et al. 1995). Thus, we expect that badger habitat quality in southern British Columbia is lower than would be expected under natural disturbance and will benefit from current ecological restoration programs intended to return the East Kootenay Trench to historic vegetative conditions. The model we describe may aid in decision-support to this end, but it should not be applied in a prescriptive sense. The variables we have considered may represent only surrogates of attributes to which badgers respond directly. Moreover, it is unlikely that we have considered all variables that influence badger habitat selection within our defined range of spatial scale. In particular, the forest cover data used in this analysis provided little information on vegetative condition within non-forested habitats. In our study area, open habitats vary considerably in grazing history, grass and forb species composition and shrub components, and these may influence badger habitat quality. We advocate pre- and post-restoration monitoring of badger and prey occurrence on treatment sites to maximize the effectiveness of subsequent enhancement prescriptions.

Several of the variables we have considered in this analysis relate directly or indirectly to human influence. However, our model reflects habitat suitability and does not account for badger mortality risk resulting from direct killing and highway mortality or any other factors. Although badgers are legally protected on provincial land in British Columbia, human-caused mortality is a potential conservation issue. Within our study area, the potential significance of this impact on population viability is apparent when we consider the limited distribution of probable badger habitat, its coincidence with highways and private lands, and its minimal representation within protected areas. The wide-ranging nature of badgers in our study area and the proximity of preferred habitats to highways may result in individuals using highway allowances as travel routes. This may result in unsustainably high rates of highway mortality, an issue that may be offset by habitat enhancement in landscapes not associated with highway or urban development.

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Table 1. Independent variables derived for analyses of badger habitat selection in southeast British Columbia, 1996 – 2000. 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 (%)
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 (%)

Table 1. Continued.

Variable	Description
CANOPY	Overstory canopy closure (%)
SITE	Forest stand site index
SPP_MESC	Mesic conifer composition (%): Subalpine fir, spruce (*Picea spp.*), western redcedar, western hemlock.
SPP_FD	Douglas-fir composition (%)
SPP_DEC	Deciduous species composition (%)
SPP_P	Lodgepole and western white (*Pinus monticola*) pine composition (%)
SPP_PY	Ponderosa pine composition (%)
SPP_L	Western larch and alpine larch 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 (%)
BT_AVAL	Snow avalanche tracks
BT_ALP	Alpine tundra (from BTM data)
BT_FO	Old (>100 yrs) forests
BT_FY	Young (<100 yrs) forests

Table 1. Continued.

Variable	Description
BT_LOG	Logged forests
BT_RANG	Rangelands
BT_AGRI	Agricultural lands
GVI	Green vegetation index
WVI	Wet vegetation index
ELEV	Elevation (m)
SLOPE	Slope (%)
SOUTH	North→south aspect (0→100)
WEST	East→west aspect (0→100)
TERRAIN	Terrain Ruggedness Index (0→100)
CURVA	Terrain curvature index

Table 2. Univariate habitat selection by badgers in southeast British Columbia, 1996–2000, at broad (level 1) and fine (level 2) spatial scales. Significance of *t*-tests is indicated by: +/- ($P < 0.1$), ++/- - ($P < 0.01$), and +++/- - - ($P < 0.001$). Sample sizes are indicated below each animal.

		F/01	F/03	F/05	F/07	F/14	M/02	M/04	M/06	M/09	M/11	M/12	M/15	Cons.[a]
Variable	Level	161	142	27	81	40	56	81	38	67	23	42	22	
PAR_MOR	1	o	o	+++	o	o	o	o	-	+++	+	+	- - -	2
	2	- -	o	o	-	+++	-	o	o	o	o	o	o	2
PAR_GLLA	1	+++	+++	o	-	+++	+++	++	++	- -	+++	+++	+++	7
	2	o	+++	o	o	-	o	++	o	o	+++	+	++	4
PAR_GLFL	1	+++	+++	o	+++	+	+++	+++	+++	o	-	o	+	7
	2	+++	+++	o	+++	o	+++	++	o	+	o	o	o	6
PAR_FLUV	1	+++	+++	o	+++	+	+++	+	o	o	-	o	o	5
	2	- -	- - -	o	-	-	o	o	o	-	- -	+++	+	4
PAR_COLL	1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	-	- - -	- - -	o	-	11
	2	- - -	- - -	o	o	o	-	- - -	o	o	o	- -	- -	6
SOI_PODZ	1	- - -	- - -	- -	- - -	-	- - -	- - -	- -	- -	- -	- - -	-	12
	2	o	o	o	o	o	o	o	o	o	o	-	o	1
SOI_BRUN	1	+++	o	++	+++	- - -	+++	+++	++	+++	+	+	o	8
	2	+++	+++	+	o	- -	++	o	o	+	+++	o	-	4
SOI_CHER	1	o	o	o	-	+++	o	o	o	o	-	o	++	0
	2	o	o	o	o	++	o	o	o	o	o	o	o	1
SOI_REGO	1	+++	+++	o	+++	- -	+++	o	+	++	++	o	o	6
	2	- - -	- - -	o	-	o	-	o	o	- -	- -	+++	o	5
SOI_LUVI	1	o	o	-	- - -	-	-	-	- - -	- - -	o	+++	o	6
	2	o	o	o	o	o	o	o	o	o	o	o	++	1

Table 2. Continued.

Variable	Level	F/01	F/03	F/05	F/07	F/14	M/02	M/04	M/06	M/09	M/11	M/12	M/15	Cons.[a]
TEX_SL	1	- - -	o	o	+++	- - -	o	+++	o	- -	o	o	o	1
	2	o	o	o	-	-	o	o	o	o	- -	+++	o	2
TEX_SIL	1	- - -	o	o	- - -	o	o	- - -	-	+	+++	+++	- - -	2
	2	- - -	- - -	o	- - -	+	- -	-	o	o	o	o	o	4
TEX_SICM	1	+++	o	o	- - -	- -	+++	o	o	- - -	- - -	-	o	3
	2	-	o	o	+++	o	-	-	o	o	o	o	o	2
TEX_S	1	o	o	+	+++	-	o	o	o	++	+++	o	o	3
	2	o	o	o	+++	o	o	o	o	o	+++	o	o	2
TEX_FSL	1	+++	+++	o	+++	+++	+++	+++	+++	o	- -	- -	++	6
	2	+++	+++	o	+	o	+++	+	+	++	o	o	o	7
GRAVEL	1	- - -	- - -	o	+	- - -	- - -	o	o	+++	- - -	+	-	3
	2	- - -	- - -	o	- - -	o	-	o	- -	o	o	o	- -	6
DRAINAGE	1	-	o	o	+++	- -	o	+++	o	o	+	+++	-	1
	2	+++	+++	o	o	o	++	+	o	++	++	o	o	6
AGE_1	1	- - -	- - -	+++	- - -	- -	o	o	o	+	o	+++	o	1
	2	o	-	o	o	o	o	o	o	o	o	+++	-	1
AGE_2-6	1	+++	+++	- - -	- -	- - -	o	o	-	-	o	- - -	- - -	5
	2	- - -	+++	- -	- - -	-	o	o	o	-	o	-	-	6
AGE_7-9	1	- - -	- - -	- - -	- -	- - -	- - -	o	o	o	- - -	- - -	o	8
	2	- - -	- - -	-	o	-	-	- - -	-	o	-	o	-	9
SPP_FD	1	+++	+++	o	o	- - -	+++	+++	+	+++	-	o	-	3
	2	- - -	o	- -	o	-	o	-	-	o	o	o	- -	6
SPP_P	1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	-	- - -	-	+++	-	10
	2	- - -	+	- -	-	- -	- -	o	o	o	o	+	- -	4

Table 2. Continued.

Variable	Level	F/01	F/03	F/05	F/07	F/14	M/02	M/04	M/06	M/09	M/11	M/12	M/15	Cons.[a]
SPP_PY	1	-	o	+++	+++	- - -	o	++	++	+++	o	-	o	2
	2	o	o	+	-	o	o	o	o	o	+	o	o	1
SPP_L	1	- - -	-	-	- - -	- - -	- - -	o	-	- - -	o	-	+	8
	2	o	o	-	o	- -	o	-	o	o	o	o	-	4
SPP_MESC	1	- - -	- - -	- - -	- - -	o	- - -	- - -	o	-	-	o	-	9
	2	- - -	- - -	-	-	- -	o	o	o	o	o	++	o	4
SPP_DEC	1	- - -	++	+++	-	+++	o	o	+	o	o	+++	o	3
	2	+	o	o	-	o	o	o	o	o	-	o	o	1
ALPINE	1	- - -	- - -	-	- - -	o	- - -	- - -	o	o	- -	- - -	o	8
	2	o	o	o	o	o	o	o	o	o	o	-	o	1
MARSH	1	+++	+++	o	+++	- - -	+++	+	o	o	o	-	o	3
	2	- - -	- - -	o	o	o	-	+	o	o	o	o	o	2
OPENRAN	1	+++	+++	+++	+++	+++	+++	+	++	++	+++	o	o	10
	2	+++	o	+++	+	+++	++	o	+	o	++	o	o	7
CULTIVAT	1	+++	+++	+	+++	+++	+++	++	+	+++	+++	-	o	9
	2	+++	o	o	+++	o	+++	+	o	o	o	o	o	4
CANOPY	1	- - -	- - -	- - -	- - -	- - -	- - -	- -	- - -	- - -	- - -	- - -	- - -	12
	2	- - -	- - -	- - -	- - -	- - -	- -	- - -	- - -	- - -	- -	o	- - -	11
COVER	1	- - -	- - -	- - -	- - -	- - -	- - -	++	-	o	o	+++	- -	6
	2	- - -	o	- - -	- - -	-	- -	-	-	o	o	++	- - -	7
SITE	1	- - -	- - -	- - -	- - -	- - -	- - -	++	o	- - -	-	+++	-	7
	2	- - -	-	- - -	- - -	-	- - -	o	o	o	-	+	- -	7
URBAN	1	+++	+++	o	o	-	++	+	+	o	o	o	+++	5
	2	o	+++	o	o	o	o	o	o	o	o	o	+++	2

Table 2. Continued.

Variable	Level	F/01	F/03	F/05	F/07	F/14	M/02	M/04	M/06	M/09	M/11	M/12	M/15	Cons.[a]
HIGHWAY	1	+++	+++	+++	+++	- - -	+++	++	o	o	+++	+++	-	6
	2	++	+++	-	o	o	o	++	o	o	o	+	o	3
LINEAR	1	+++	+++	+	+++	- - -	+++	+++	+++	+++	++	+++	+++	10
	2	o	+++	o	o	o	++	+++	o	o	++	+++	o	5
WATER	1	- - -	+++	o	+	+++	o	- - -	o	-	o	o	+++	1
	2	- - -	- - -	o	o	o	- - -	++	o	o	o	o	o	2
BT_ALP	1	- - -	- - -	-	- - -	o	- - -	- - -	o	-	-	- - -	o	9
	2	o	-	o	o	o	o	o	+	o	o	o	o	0
BT_AVAL	1	- - -	- - -	o	- - -	-	- - -	- - -	o	- -	- - -	- - -	o	9
	2	o	o	o	o	o	o	o	o	o	o	-	o	1
BT_FO	1	- - -	- - -	- - -	- - -	- - -	- - -	-	o	- -	- - -	- - -	-	11
	2	- - -	-	o	o	o	o	- - -	-	o	o	o	o	4
BT_FY	1	++	- - -	- - -	- -	- - -	-	o	- -	o	o	- - -	- - -	7
	2	- - -	- - -	- -	- - -	- - -	-	- - -	o	o	-	-	- -	10
BT_LOG	1	- - -	+++	o	- - -	- - -	- - -	++	+	+	o	+++	+++	2
	2	o	+++	o	o	o	-	o	-	o	o	+++	o	0
BT_RANGE	1	o	+++	+++	+++	+++	+++	o	+	o	+	o	o	7
	2	- -	o	+	o	+++	-	o	o	o	o	o	o	0
BT_AGRI	1	+++	+++	o	+++	+++	+++	+	++	+++	+++	- -	o	8
	2	+++	+	o	+++	- - -	+++	+++	+++	o	o	o	o	5
GVI	1	- - -	- - -	- - -	- - -	- - -	- - -	o	- -	- -	+	++	o	6
	2	- - -	- -	- -	+++	- -	-	o	o	-	o	o	o	5
WVI	1	- - -	- - -	- - -	- - -	- - -	- - -	o	- -	- - -	- - -	- - -	o	10
	2	- - -	- - -	- - -	-	- - -	- - -	- - -	- - -	- - -	- -	o	o	10

Table 2. Continued.

Variable	Level	F/01	F/03	F/05	F/07	F/14	M/02	M/04	M/06	M/09	M/11	M/12	M/15	Cons.[a]
ELEV	1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -	- - -	- - -	- -	-	12
	2	- - -	- - -	o	o	o	- - -	- - -	o	o	o	- - -	-	6
SLOPE	1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -	-	12
	2	- - -	- - -	o	o	- -	- - -	- - -	o	+++	o	- - -	o	5
SOUTH	1	+++	+++	+	o	+++	+++	+	o	-	- - -	o	+	5
	2	+++	+++	+	o	o	+	++	o	o	o	o	++	6
WEST	1	+++	+++	- - -	+++	+++	+++	+	- - -	- -	- - -	- - -	+	2
	2	+++	+++	- -	+	++	++	o	o	- -	o	+	o	4
TERRAIN	1	- - -	- - -	- -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -	o	11
	2	- - -	- - -	o	-	-	-	- - -	o	o	o	-	o	7
CURVA	1	- -	- - -	o	-	+	-	- - -	o	+++	o	- - -	o	4
	2	+	+	-	o	o	o	o	+	o	o	o	o	2

[a] Consistency of habitat selection among badgers is defined as the absolute difference between the number of badgers exhibiting at least marginal ($P < 0.1$) preference vs. avoidance. Selection is considered consistent among animals if this value ≥ 6.

Table 3. Multiple logistic regression model parameters of badger habitat selection ($P < 0.001$) in southeast British Columbia, 1996-2000.

Variable	Level	β	SE	*R*
ELEV	1	0.013	0.001	0.154
SOI_LUVI	1	-0.062	0.007	-0.117
PAR_GLFL	1	0.037	0.004	0.115
TEX_FSL	1	-0.046	0.005	-0.115
CANOPY	1	-0.119	0.014	-0.111
GVI	1	0.173	0.023	0.102
BT_ALP	1	-0.319	0.042	-0.101
BT_RANGE	1	-0.045	0.007	-0.093
OPENRANG	1	0.080	0.013	0.085
SOI_BRUN	1	-0.026	0.005	-0.069
SLOPE	1	-0.071	0.014	-0.068
AGE_7-9	1	0.045	0.009	0.067
LINEAR	1	0.097	0.019	0.066
BT_FO	1	-0.048	0.010	-0.066
BT_AGRI	1	0.026	0.007	0.049
SPP_FD	1	0.020	0.005	0.049
PAR_GLLA	1	0.017	0.005	0.039
SPP_L	1	0.036	0.012	0.035
WVI	1	0.060	0.021	0.034
SPP_MESC	1	0.041	0.015	0.033
HIGHWAY	1	0.099	0.044	0.024

Table 3. Continued.

Variable	Level	β	SE	*R*
ELEV	2	-0.010	0.001	-0.169
CANOPY	2	-0.079	0.007	-0.147
SOI_REGO	2	-0.025	0.003	-0.103
BT_ALP	2	0.076	0.011	0.095
WVI	2	-0.045	0.007	-0.091
AGE_2-6	2	0.013	0.003	0.066
SOI_CHER	2	-0.018	0.004	-0.056
MARSH	2	-0.035	0.009	-0.049
AGE_7-9	2	0.013	0.004	0.047
OPENRANG	2	0.008	0.002	0.041
COVER	2	0.007	0.002	0.035
DRAINAGE	2	-0.029	0.010	-0.033
Constant		-1.209	1.071	0.000

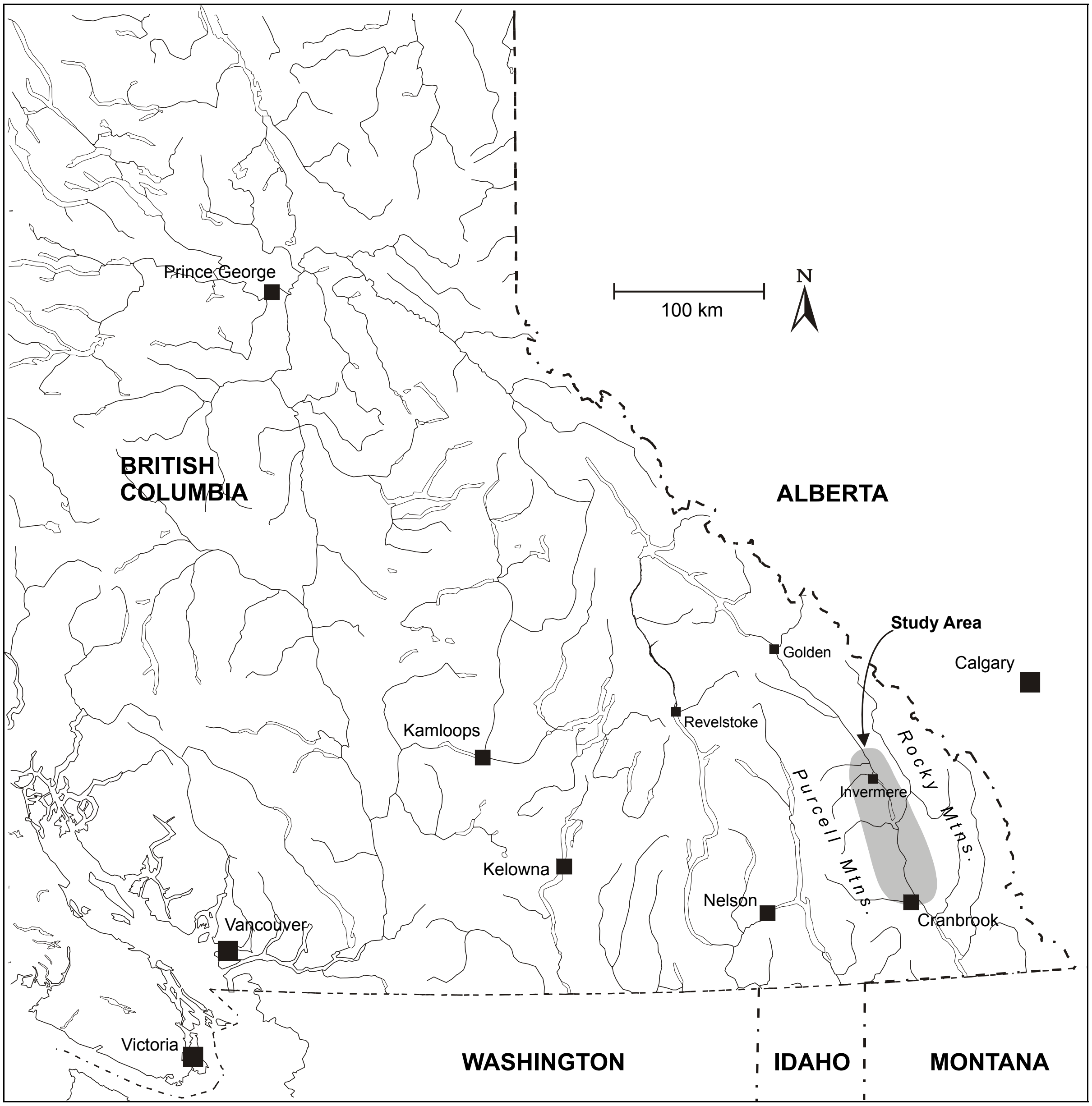


Figure 1. East Kootenay badger study area in southeast British Columbia.

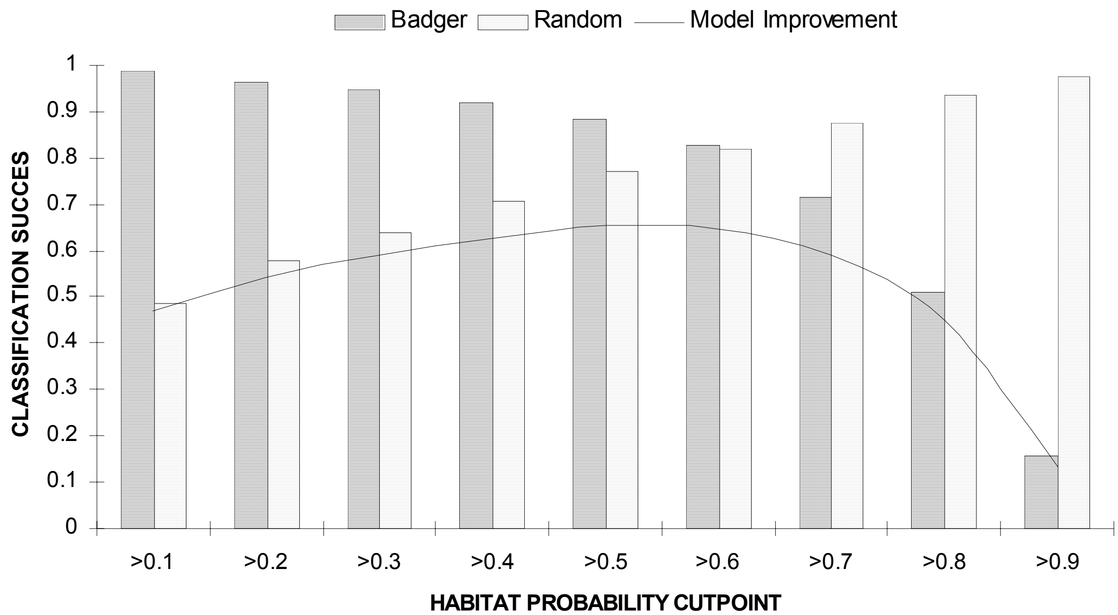
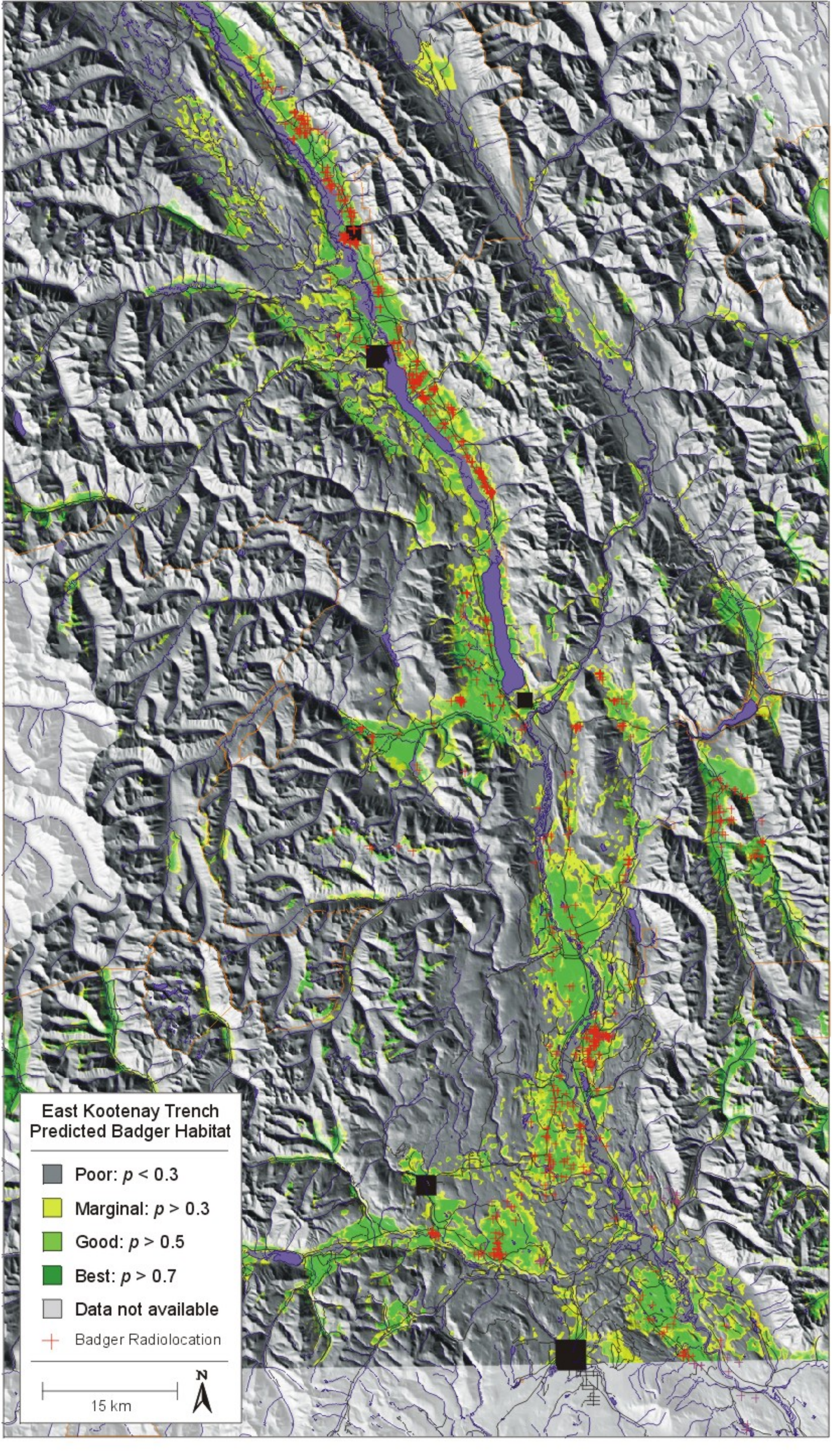


Figure 2. Predictive efficiency of badger habitat model across cutpoint probability levels in southeast British Columbia. Model improvement (correctly classified badger minus incorrectly classified random) indicates the optimum cutpoint in discriminating badger habitat from non-habitat.



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