Conservation Strategies for North American Badgers in the Thompson & Okanagan Regions

Final Report for the Thompson-Okanagan Badger Project
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Executive Summary

From 1999 to 2003, we examined the distribution and ecology of North American badgers (*Taxidea taxus*) in the Thompson and Okanagan regions of British Columbia with the broad objective of developing conservation strategies for the species. The project had 4 specific objectives: to determine where badgers occur in the region, increase public awareness and understanding about badgers and grassland ecology, collect ecological information about badgers by conducting a radiotelemetry research study, and synthesise this information into effective conservation strategies for the species.

We solicited recent records of badgers in British Columbia from the general public, industry, and government employees from 1999 to 2003. We collected 566 records of badgers that helped refine the target areas for implementation of the conservation strategies. Despite badgers being considered primarily a grassland species, 38% of records occurred in forested biogeoclimatic units, followed by 33% in open forest units, and 29% in grassland units. The extent of occurrence of badgers within the Thompson and Okanagan regions was approximately 41,000 km², although the area of occupancy was likely substantially less, especially in the Okanagan valley. This result is significant because the Okanagan was probably the historic connectivity corridor between the Thompson and Cariboo population of badgers and the Great Basin population.

We captured, radio-tagged, and monitored 13 badgers (11 male, 2 female) between 1999 and 2002. The mean home range size (95% fixed kernel estimate) of adult males was 32.7 km² (SD = 11.6, n = 7), whereas the female with kit that we had tagged in 2000 had a summer home range of 15.6 km². Five of the 8 radio-tagged badgers had a few widely dispersed core areas in which they focused their activities. Badgers moved more during the summer than the winter, moved up to 14 km in 4 hours, and during summer tended to move at least 500 m within a day. Transportation corridors were the primary source of mortality for badgers in the Thompson region; 7 of 13 radio-tagged study animals died on highways or railways and an additional 13 untagged badgers were killed on roads in the region during the study.

Badgers appeared to make the majority of their habitat decisions on the basis of soil features and prey availability, although the male-bias of our data may have affected this conclusion. We detected the strongest selection for burrowing and foraging resources at relatively fine spatial scales. Badgers tended to select patches within ecosystem units that were characterized by silty soils with low coarse fragment contents and high concentrations of prey sign. Conservation of patches and ecosystem units with these features is expected to be important for the continued persistence of badgers in the Thompson and Okanagan regions.

We used a wide variety of forums and media to educate the general public, as well as specific target groups, about badger ecology and conservation in the Thompson and Okanagan regions. We gave 24 targeted presentations, released 33 newspaper and 6 television news articles, produced 3 project information posters, and developed a badger web site to help with public education. We also printed and distributed a series of 1,000 brochures about badgers in the Thompson and Okanagan regions. Because of these efforts, members of the public and ranching industry are more aware of the existence, general ecology, and conservation needs of badgers in British Columbia.

Conservation strategies for badgers in the Thompson and Okanagan regions focus primarily on reducing mortality within the population, providing for foraging and burrowing habitats at a variety of spatial scales, and establishing translocation protocols for badgers that are at risk of being destroyed by private landowners.

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Section 1 – Introduction & Objectives

North American badgers (*Taxidea taxus*) are large-sized members of the weasel (Mustelidae) family that occur throughout the grassland regions of North America (Messick 1987). Although badgers are relatively common in Alberta, Saskatchewan, and Manitoba, badger populations in Ontario and British Columbia are very small. In British Columbia, badgers are limited to the dry interior grasslands and open forests of the Thompson, Okanagan, Cariboo, and East Kootenay areas (Rahme et al. 1995). The current estimate of badger population size in British Columbia ranges from 250 to 600 individuals (Newhouse and Kinley 2000a), but recent research has suggested that populations are at the lower end of this estimate. These findings have led the Committee on the Status of Endangered Wildlife in Canada to place the subspecies of badgers found in British Columbia (*T. t. jeffersonii*) on the endangered species list (Committee on the Status of Endangered Wildlife in Canada 2000).

Badgers fulfill a variety of important roles in grassland ecosystems. As the only true fossorial carnivore in Canada, badgers help regulate grassland populations of fossorial and semi-fossorial rodents (Messick 1987). Badgers have several adaptations that allow them to be successful at digging for prey, such as powerful forearms and long claws (Messick 1987), and they also use these adaptations to dig burrows for thermal and reproductive cover. The soil exposed by badgers while foraging is an important source of new growing substrate that can affect the ecology and distribution of plant species (Weis 1982). The nesting ecology of the endangered burrowing owl (*Athene cunicularia*) is strongly linked to the denning and foraging burrows of badgers; owls use abandoned badgers excavations for nesting sites (Green and Anthony 1989). Other threatened grassland species, such as western rattlesnakes (*Crotalus oreganus*) and gopher snakes (*Pituophis catenifer*) also use vacant badger burrows for thermal cover (K. Larsen, University College of the Cariboo, personal communication).

Although much of the landscape of the Thompson and Okanagan valleys likely supported viable populations of badgers in the past, several human activities have probably negatively affected badger populations. First, badgers utilize grassland habitats, which are one of the most rare and threatened landscapes in the province. Loss of grassland habitats may be the major contributing factor to the current conservation concern facing badgers (Rahme et al. 1995). Urban encroachment into grasslands, fire suppression, and increased intensity of agriculture in grasslands may have also shifted the ecology of these habitats away from the setting in which badgers have evolved and probably need to survive. Second, badgers and their prey have long been considered pest species by farmers and ranchers and were systematically exterminated by hunting, trapping, and poisoning since European settlers first occupied grasslands. Third, collisions with vehicles on roadways may be a substantial source of mortality within badger populations.

Effective conservation efforts had been difficult to develop because very limited information was available about the ecology of this species in British Columbia, even though a conservation need had been clearly identified (Rahme et al. 1995). A study on badger ecology conducted in the East Kootenay region (Newhouse and Kinley 2000b), in a limited grassland setting, produced concerning results that suggested that more information specific to British Columbia was needed to develop appropriate management recommendations. The goal of our program was to effectively deal with each of these issues and provide practical solutions to ensure the persistence of badger populations in the Thompson and Okanagan regions of British Columbia.

OBJECTIVES

The specific objectives of our program were the following:

1) Collect and compile existing information on the distribution and occurrences of badgers in the Thompson, Nicola, and Okanagan areas. Develop distribution maps based on known occurrence data and a regional species account,
2) Create public awareness regarding the status and issues surrounding badgers and other grassland species in the Southern Interior Region through education programs,
3) Identify habitats required by badgers by examining habitat selectivity at a variety of spatial scales,
4) Create habitat management guidelines for habitats that are critical or important to badgers,
5) Develop realistic management guidelines for ranchers and farmers so that they can reduce their effects on badger populations without substantial decreases in the productivity of their operations,
6) Identify population factors, land use issues, habitat suitability issues, and prey base issues that may affect the conservation of badgers in the region,
7) Develop a translocation policy for "problem" badgers, so that these individuals are not removed from dwindling populations, and
8) Create conservation strategies based on scientific data for the species.

DOCUMENT ORGANIZATION

This document is arranged in several relatively discrete segments. In Section 2, we outline the current extent of occurrence of badgers in the Thompson and Okanagan regions based on recent records of badgers collected during this project. Section 3 details the ecological relationships of badgers that we determined from the radiotelemetry study of badgers - the data from which forms the basis of the conservation strategies. This section examines the space use and movements, habitat relationships, and population factors which affect the ability of the species to persist in the current landscape. The segments within this section are loosely prepared as manuscripts for publication, so some repetition occurs within the text. **Many of these sections are currently under review for publication in peer-reviewed journals, so please do not cite this report when considering the results and conclusions in these sections.** In Section 4, we summarize emergency conservation efforts that we undertook for badgers in the Thompson region. Section 5 describes the public education and extension programs that we implemented to increase the awareness of the existence, general ecology, and conservation needs of badgers in British Columbia. In Section 6, we summarize and assess the conservation issues facing badgers, present conservation recommendations, and develop a prioritized conservation action plan for the species. Finally, Sections 7 and 8 detail the project partners and literature cited in this report. Note that the Habitat Conservation Guidelines and Badger-Human Conflict recommendations, which are important components of the conservation strategy, can be found in the Appendix.

LOCATION

Badger Distribution and Public Education Area

The area over which we collected sightings to determine the distribution of badgers was generally the Thompson (Kamloops) and Okanagan (Penticton) Regions of the Ministry of Water, Land and Air Protection (Figure 1). This area included the major centres of Kamloops, Merritt, Vernon, Kelowna, Penticton, and Princeton and the Okanagan, Kettle, Similkameen, Thompson, and Nicola River drainages. The public education portion of the project was intended specifically for this area, which was also the target area for implementation of the conservation strategies.

Radiotelemetry Research Study Area

The location of the research study was in the vicinity of Kamloops, British Columbia (50° 40' N, 120° 20'W) and covered approximately 4,390 km^2 (Figure 2). The area was within the Southern Interior ecoprovince, Thompson-Okanagan Plateau ecoregion, and the Thompson Basin and Southern Thompson Upland ecosections. The study area was bounded to the west by the Tranquille River drainage, to the south by Stump Lake and Monte Lake, to the east by Chase Creek, and to the north by the community of Clearwater. This area included the Bunchgrass (BG), Ponderosa Pine (PP), Interior Douglas-Fir (IDF), Montane Spruce (MS), and Engelmann Spruce – Subalpine Fir (ESSF) biogeoclimatic zones. The study area was comprised of 810 km^2 of grassland (BGxh2, BGxw1, IDFxh1a, and IDFxh2a biogeoclimatic units), 1,410 km^2 of open forest (PPxh2, IDFxh1, and IDFxh2 biogeoclimatic units), and 2,170 km^2 of heavy forest (IDFdk1, IDFdk2, IDFmw2, MSdm2, MSxk, and ESSFdc2 biogeoclimatic units). The climates of the BG, PP, and IDF zones were characterized by warm to hot, dry summers and cool to cold winters with relatively little snowfall. Summer droughts were typical and prolonged. Much of the moisture available for plant growth in these zones was derived from winter snowfall.

Vegetation in the study area varied among biogeoclimatic zones (Lloyd et al. 1990). In the BG zone, climax sites were dominated by widely spaced bunches of bluebunch wheatgrass (*Pseudoroegneria spicata*), a well-developed lichen crust, and big sagebrush (*Artemisia tridentata*) at lower elevations. In the PP zone, open parkland forests of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) dominated the landscape, with an understory of bluebunch wheatgrass and fescues (*Festuca* spp.). The IDF zone was dominated by stands of Douglas-fir, occasionally mixed with ponderosa pine or lodgepole pine (*Pinus contorta*). Open forests of ponderosa pine often occurred at lower, hotter elevations. The understory of the IDF zone was often dominated by bluebunch wheatgrass, pinegrass (*Calamagrostis rubescens*), or birch-leaved spirea (*Spiraea betulifolia*). Grassland phases of the IDF zone lacked consistent tree cover and differed from the BG zone by occurring at higher elevations and including silky lupine (*Lupinus sericeus*).

Disturbance in the study area was widespread. Agriculture, both intensive (e.g., cultivation) and extensive (e.g., livestock grazing), occurred throughout most of the grassland areas since settlement by Europeans during the mid-1800s. Urban development also occurred extensively in the BG biogeoclimatic zones. Forest harvesting in the forested subzones occurred since the early 1900s. Natural disturbance in the study area was primarily through

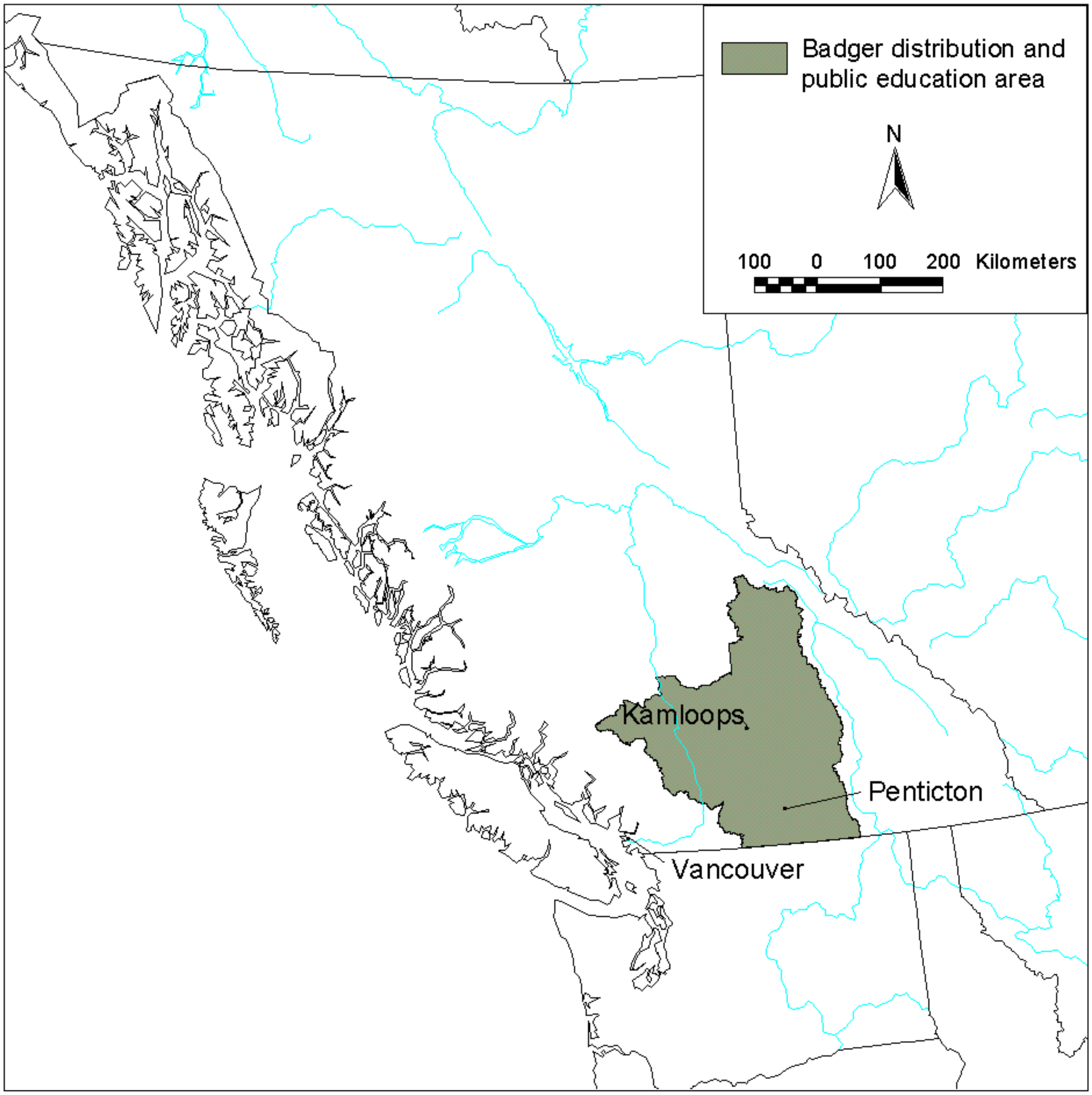

Figure 1. Area from which badger records were collected and public education was targeted in the Thompson and Okanagan regions (shaded in grey), Thompson-Okanagan Badger Project.

wildfires, with low-intensity surface fires occurring every 5-50 years (British Columbia Ministry of Forests and British Columbia Ministry of Environment, Lands and Parks 1995). Fire suppression in the study area led to forest encroachment into many grassland ecosystems (Bawtree et al. 1998). Extensive lowland areas within the forested biogeoclimatic zones were cleared for agricultural purposes.

The study area encompassed a variety of land use practices. Roughly 154 km² of the area was within a protected area (Lac du Bois Grasslands Provincial Park) in which moderate cattle grazing occurred. The Kamloops Indian Band controlled approximately 310 km² as both Indian Reserve lands and active ranches with some intensive agricultural development.

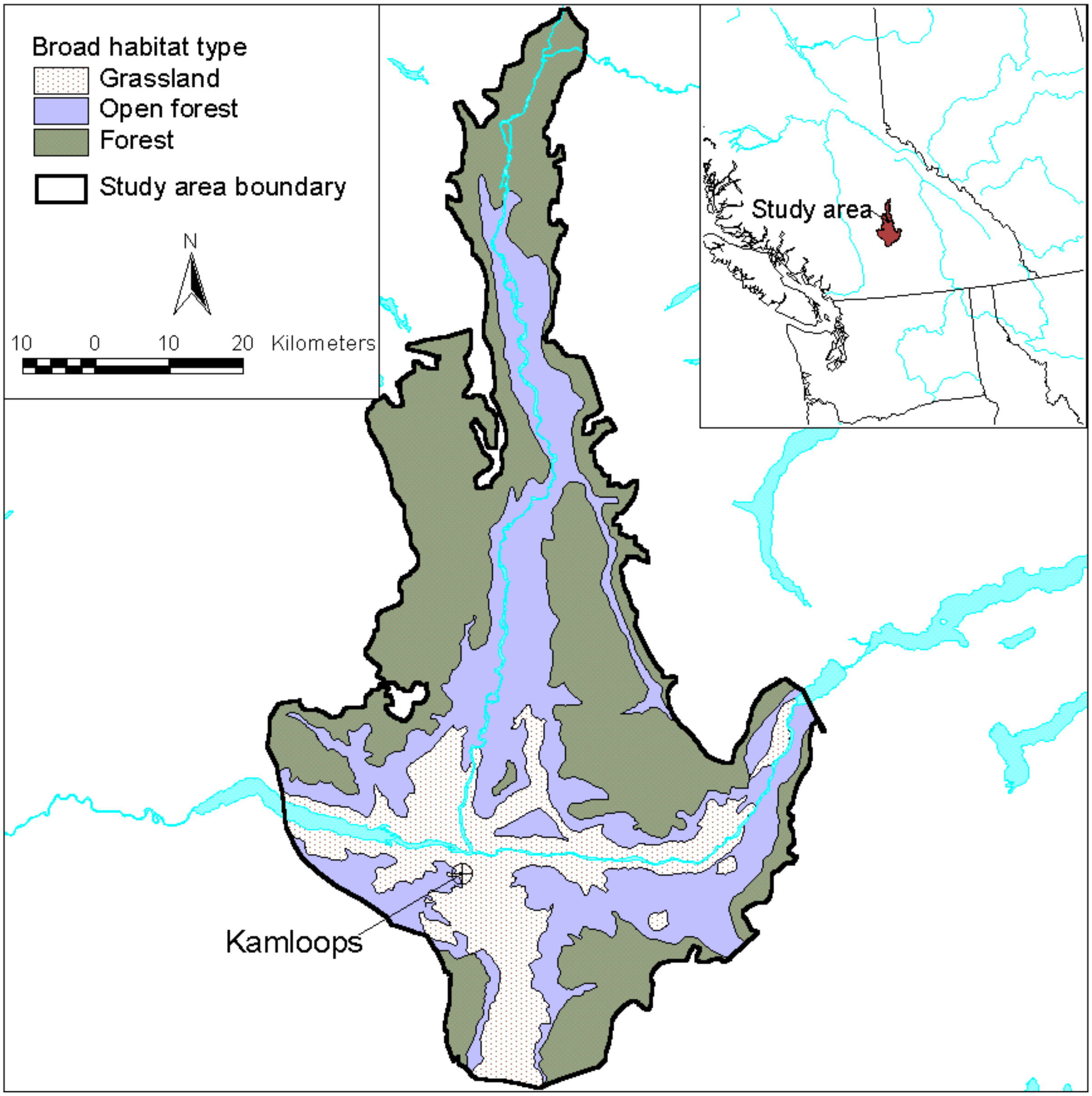

Figure 2. Location and broad habitats of the radiotelemetry research study area, Thompson-Okanagan Badger Project.

Most of the valley bottom areas surrounding the North and South Thompson Rivers were used for intensive agriculture or were converted to urban areas. Very little unmodified grasslands existed within the boundary of the study area. Forested crown land within the study area was exposed to cattle grazing through grazing permits issued by the Ministry of Forests.

Four major transportation corridors passed through the study area: both main lines of the Canadian Pacific and the Canadian National Railways, the TransCanada Highway, and the Yellowhead Highway (#5). During the peak traffic month of August, traffic averaged 18,000 vehicles/day on the TransCanada Highway and 6,400 vehicles/day on the Yellowhead Highway (B. Persello, Ministry of Transportation and Highways, personal communication).

Section 2 - Badger Distribution and Occurrence[1]

North American badgers (*Taxidea taxus*) are fossorial predators that occur in the arid tree-less continental regions of North America (Messick 1987). Four subspecies of North American badgers are currently recognized (Figure 3) and the *jeffersonii* subspecies is the only that occurs regularly in British Columbia (Rahme et al. 1995). The *jeffersonii* subspecies of North American badger is currently listed as endangered in Canada (Committee on the Status of Endangered Wildlife in Canada 2000) and, although endangered status does not afford legal protection for the species within British Columbia, trapping and hunting of badgers was discontinued in the province in 1967.

Historically, badgers occurred throughout the grasslands and dry forests of British Columbia (Rahme et al. 1995). Evidence suggests that populations of badgers in the province were considerable in these areas prior to European settlement; badger pelts traded in British Columbia reached a peak of over 300 pelts/year in the 1920s (Adams et al. 2003). It is believed that populations of badgers in British Columbia have diminished since then due to persecution of prey, habitat loss, and human-caused mortality (Rahme et al. 1995). However, the range of the species within the province is not believed to have changed significantly (Newhouse and Kinley 2000a).

The purpose of our research was to document the extent of occurrence and area of occupancy of North American badgers in the Thompson and Okanagan regions of British Columbia and to identify factors that may affect the distribution of the species at broad spatial scales. The Committee on the Status of Endangered Wildlife in Canada (2001) defines the extent of occurrence as the area contained within the shortest continuous imaginary boundary that can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy. Conversely, the area of occupancy is the area within its 'extent of occurrence' that is occupied by a taxon, excluding cases of vagrancy (Committee on the Status of Endangered Wildlife In Canada 2001). These delineations are useful for identifying areas in which badger populations probably occur, will help focus conservation efforts, and determine areas where the range of the species has changed.

METHODS

We solicited recent reports of badger sightings, carcasses, or burrows from the general public, conservation organizations, and private landowners through public speaking engagements and displays, newspaper articles, the World Wide Web, and direct contact. We also requested reports from government employees (primarily Ministry of Forests, Ministry of Water, Land and Air Protection [MWLAP], and Ministry of Transportation and Highways) through contacts with interested individuals and broadcast email notices. We also conducted an aerial survey for burrows of approximately 50 km² of grassland and open forest habitat in the northwest portion of the study area during January 2003.

We screened each report on the basis of supporting evidence to verify its authenticity. We used a 4-rank system similar to Aubry and Houston (1992) to gauge the reliability of each report: (1) physical evidence, such as a specimen or photograph, (2) detailed sightings

[1] Portions of this section are in preparation for publication in peer-reviewed journals. Please contact the report authors for the correct citation of results and conclusions presented in this section.

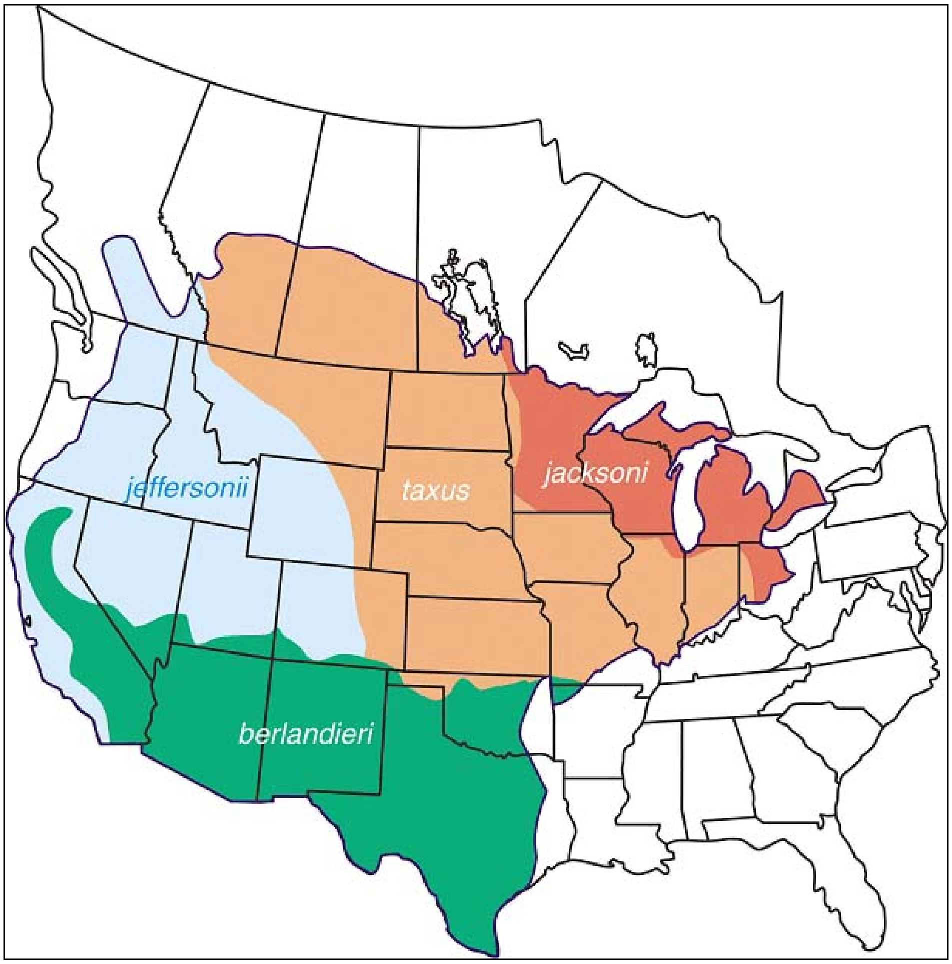

Figure 3. Distribution throughout North America of 4 subspecies of North American badger (from Newhouse and Kinley 2000a).

by experienced observers, (3) sightings by observers with no obvious natural history background but who provided an accurate description of features that differentiate badgers from other similar animals, and (4) questionable records where observers failed to identify distinguishing characteristics of badgers. We also included an assessment of the spatial precision of each record because exact geo-referenced coordinates were not always available. We used all records with reliability ranks between 1 and 3 that occurred between 1999 and 2003 for our determination of the current distribution of badgers in the region. Our delineation of the extent of occurrence was based on the spatial distribution of records supplemented by ecosection and biogeoclimatic boundaries.

We assessed the effects of several spatial and habitat variables on the distribution of records of badgers throughout the region. We documented the biogeoclimatic unit (Meidinger and Pojar 1991), broad ecosystem unit (Resources Inventory Committee 1998a), elevation, and proximity to roadways and waterways of each record. We only considered carcass or sighting records that were reliable and precise (i.e., records with reliability rank between 1 and 3 and precision ≤1 km) for our spatial and habitat analysis. We excluded burrow records for this analysis because the detectability of these observations was substantially different than that for carcass and sighting records.

RESULTS

We collected 566 records of badger burrows, carcasses, or sightings during the 4 years of surveys. Of these, 351 records were "reliable" (i.e., reliability code 1, 2, or 3) and occurred between 1999 and 2003. The majority of reliable records occurred in the Thompson region (236 records), but numerous records were also reported in the Okanagan (101 records) and Cariboo (14 records) MWLAP regions.

We estimated the extent of occurrence of badgers in the Thompson and Okanagan MWLAP regions to be approximately 41,007 km², which represented 46.9% of the region (Figure 4). However, the area of occupancy within this extent of occurrence appeared to be patchy, with many large areas from which we did not receive records of badgers.

We chronicled carcass and sighting records of badgers in many different ecosystems throughout the Thompson, Okanagan, and Cariboo regions. We documented badgers in 29 biogeoclimatic units (Figure 5), with records occurring most frequently in the very dry-hot Thompson variant of the Ponderosa Pine biogeoclimatic zone (PPxh2). Somewhat surprisingly, 88 (38%) of records occurred in forested biogeoclimatic units, followed by 77 (33%) in open forest units, and 69 (29%) in grassland units. The majority of the records occurred during summer (126 of 248 records), but records were also collected during spring (67 records), autumn (25 records), and winter (6 records).

We documented records of badgers in 23 broad ecosystem units (Table 1). The unit with the most badger records was Cultivated Field (24.3% of 234 records), followed by Douglas-fir – Lodgepole Pine (12.2%), Douglas-fir – Ponderosa Pine (10.4%), and Ponderosa Pine (10.0%) units. Only 15.1% of records of badgers occurred in natural grassland units (i.e., Big Sagebrush Shrub/Grassland or Bunchgrass Grassland).

Badgers were documented in relation to a variety of topographical features. The mean elevation of badger records was 822 m (range: 400 – 2,000 m, n = 250). Records were a median of 369 m from water (95% CI: 332 - 458 m, n = 250). The median distance to the nearest road was 88 m (95% CI: 67 - 108 m, n = 250), with 95% of all records occurring within 970 m of a road.

DISCUSSION

Through the collection of recent records of badgers, we refined the extent of occurrence of badgers in the Thompson and Okanagan regions of British Columbia. Whereas the extent of occurrence that was estimated from our data was not substantially different than that estimated by Rahme et al. (1995) and Newhouse and Kinley (2000a), our data more clearly delineated the boundaries of the distribution of badgers within the region. Additionally, we identified several areas where badgers had not been documented previously. It is difficult to determine if the changes in the extent of occurrence of badgers in British Columbia resulted from more or better data, or if an actual change in range has occurred. Because we collected more records, our determination of the extent of occurrence was probably more precise than that posed by Rahme et al. (1995).

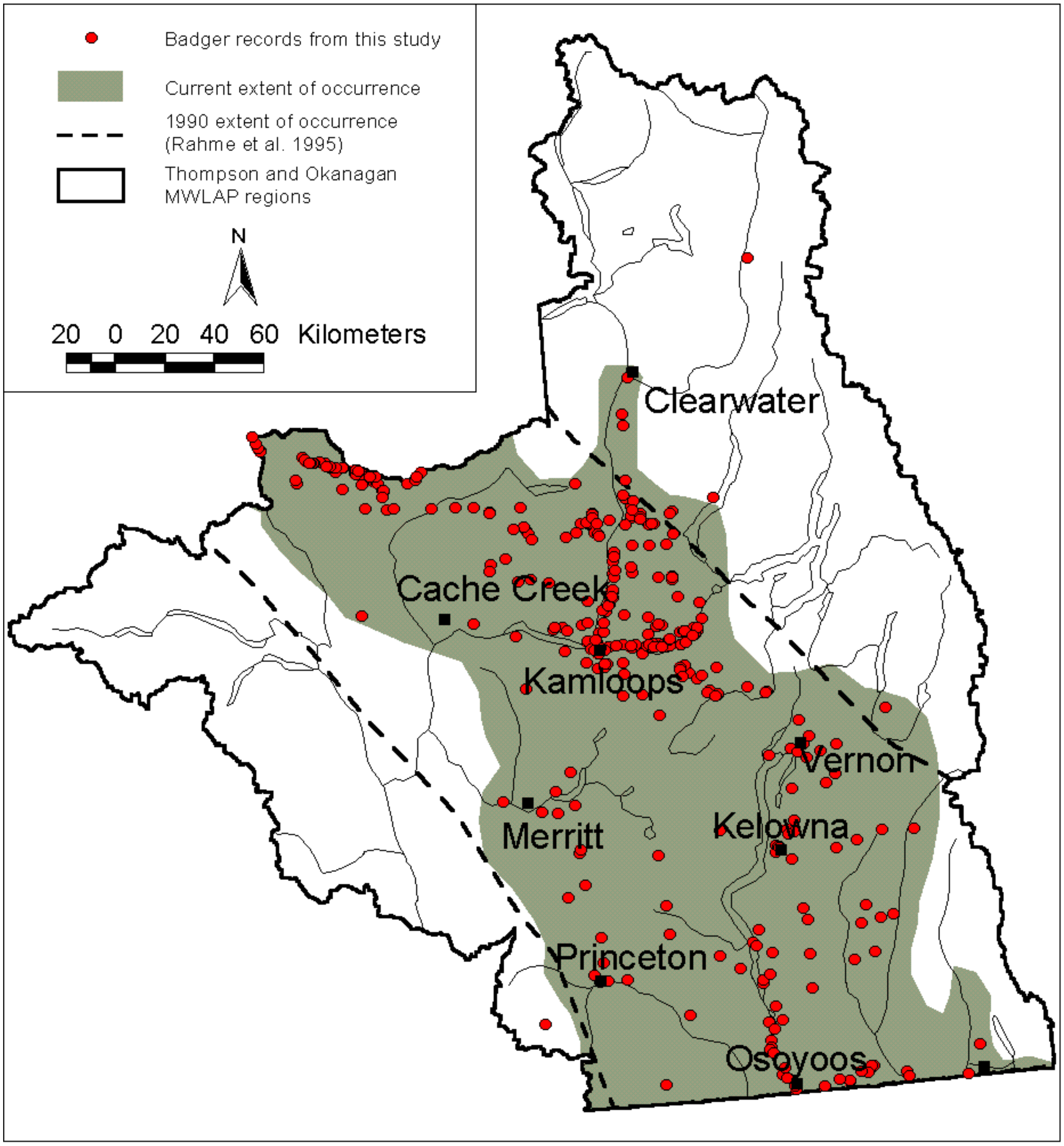

Figure 4. Extent of occurrence and distribution of reliable (ranks 1-3) and precise (≤1 km) records of badgers collected between 1999 and 2003 compared to the estimated distribution of Rahme et al. (1995) within the Thompson and Okanagan regions. Records were derived from sightings of animals, burrows, or carcasses.

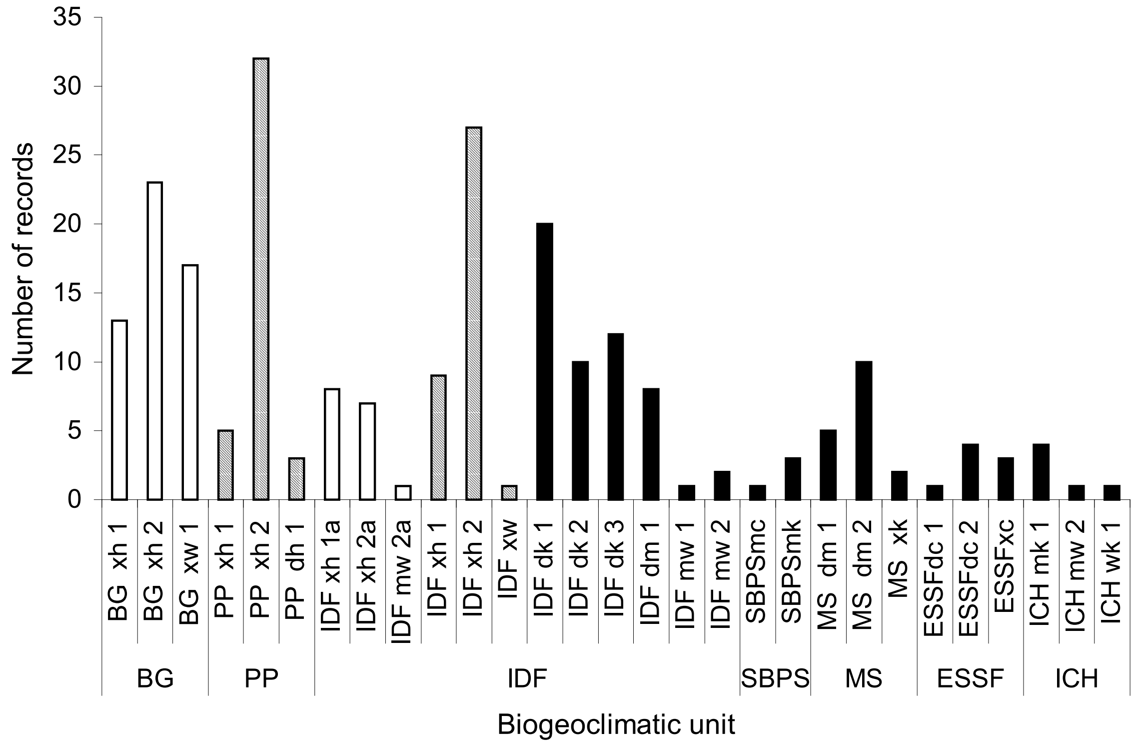

Figure 5. Biogeoclimatic units (Lloyd et al. 1990) of reliable (ranks 1-3) and precise (≤1 km) carcass and sighting records of badgers collected between 1999 and 2003 in the Thompson and Okanagan regions. Clear bars were records from grassland units, hatched bars were open forest records, and solid bars were forested records. *n* = 234 records.

A substantial change in the estimated extent of occurrence between our estimate and that of Rahme et al. (1995) occurred at the western edge of the Kootenay region. Although Rahme et al. (1995) suggested that populations of badgers in the Thompson and Okanagan region were contiguous with those in the East Kootenay region, our results suggests that subpopulations of badgers in the East Kootenay region may not be connected within British Columbia with those in the Thompson and Okanagan regions. Our estimate of the extent of occurrence supports the supposition by Kyle et al. (*in press*) that badger populations in British Columbia are divided into at least 2 sub-populations that are separated by considerable genetic distance.

Our results also suggest that the area of occupancy by badgers was not continuous throughout the extent of occurrence in the Thompson and Okanagan regions and it may have diminished considerably from historic levels. Although badger populations in the Thompson and southeast Cariboo regions appear to be relatively contiguous (i.e., individuals separated by <10 km), decreases in the areas of occupancy in other regions may have considerable implications for the conservation of the species in British Columbia.

Table 1. Broad ecosystem units (BEU) of reliable (ranks 1-3) and precise (≤1 km) carcass and sighting records of badgers collected between 1999 and 2003 in the Thompson and Okanagan regions. BEU mapping was typically comprised of complex polygons, so proportional assignments were made for each record, which resulted in totals occasionally not resulting in whole numbers. n = 234 records.

BEU[a] code	Broad Ecosystem Unit	Number of records	Total
CF	Cultivated Field	56.8	24.3%
DL	Douglas-fir - Lodgepole Pine	28.4	12.1%
DP	Douglas-fir - Ponderosa Pine	24.4	10.4%
PP	Ponderosa Pine	23.4	10.0%
SS	Big Sagebrush Shrub/Grassland	20	8.6%
BS	Bunchgrass Grassland	15.3	6.5%
SF	White Spruce - Subalpine Fir	14	6.0%
EF	Engelmann Spruce - Sub-alpine Fir Dry Forested	8	3.4%
RB	Western Redcedar - Paper Birch	7.6	3.3%
SD	Spruce - Douglas-fir	7.5	3.2%
DF	Interior Douglas-fir Forest	6.6	2.8%
UR	Urban	6.1	2.6%
SP	Slow Perennial Stream	4	1.7%
SL	Sub Boreal White Spruce - Lodgepole Pine	2.7	1.2%
WR	Hybrid White Spruce - Black Cottonwood Riparian	2.2	0.9%
WL	Wetland	1.8	0.8%
LP	Lodgepole Pine	1.2	0.5%
IH	Interior Western Hemlock - Douglas-fir	1	0.4%
IS	Interior Western Hemlock - White Spruce	1	0.4%
LL	Large Lake	1	0.4%
RO	Rock	0.7	0.3%
AB	Antelope-brush Shrub/Grassland	0.2	0.1%
ME	Meadow	0.1	0.1%

a broad ecosystem unit (Resources Inventory Committee 1998a)

The Okanagan region was a significantly large area within the estimated distribution of badgers from which we documented relatively few records, despite considerable attempts to collect records in this area. The records that we collected for the Okanagan region occurred predominately in mid-elevation forested areas outside of the valley bottoms. Of note, we collected very few records of badgers within the North Okanagan Basin and Central Okanagan Basin ecosections and those that we did collect were highly clumped. Urban and intensive agricultural development in these areas has excluded badgers from the arid valley bottom. Additionally, the large amount of vehicle traffic on transportation corridors that run the length of the valley expose resident and dispersing badgers to considerable mortality risk. The exception to this trend was the extreme southern portion of the South Okanagan Basin ecosection (i.e., south of Skaha Lake), which had several records of badgers. This area is different from the north and central Okanagan by having less urbanization and intensive agriculture and large Indian Reserves that were less developed than the surrounding landscape.

This gap in the area of occupancy through the Okanagan valley is significant for several reasons. First, the diminished population of badgers in this area may become more susceptible to stochastic events, jeopardizing the persistence of this important grassland predator. Second and most important, badgers in the Okanagan valley likely acted as a "genetic connection" for gene flow and dispersal between the badgers in the Thompson region and the much larger Great Basin population of badgers in Washington State.

Most of the gene flow among badger populations in the north-western portion of their range occurs in a north-south direction (Kyle et al. *in press*), so a decrease in the migration of animals among these populations may increase the genetic isolation of the Thompson and Cariboo regions. This increased isolation may make this population more susceptible to genetic drift and other deleterious genetic effects. Samples collected from badgers in the Thompson region show high levels of genetic structuring (C. J. Kyle, Ontario Ministry of Natural Resources, personal communication), which may be indicative of a genetically isolated population.

Despite the apparent lack of population connectivity through the grassland and dry forest habitat of the Okanagan valley, we documented records of badgers in several previously unidentified areas that may serve as alternative connectivity routes between regions. For example, the Salmon River valley may connect the Thompson with the north Okanagan, and the mid-elevation forests of the eastern Okanagan Highlands may serve to connect the central Okanagan with the Boundary region (i.e., Midway, Rock Creek, Grand Forks).

At the broad regional scale of our analysis, badgers did not appear to be limited to grassland ecosystems, but occurred in many open forest and forested biogeoclimatic zones. The occurrence of badgers in forested habitats may be an indirect result of forest harvesting and associated silvicultural activities, such as grass seeding and vegetation management. Newhouse and Kinley (2000a) suggested that forest harvesting might have prompted an elevational expansion of the range of badgers in British Columbia. The distribution of structural stages in forested biogeoclimatic zones has changed considerably over the past 3 decades from relatively contiguous mid- to late-successional forests to many widely dispersed early-successional stands (i.e., regenerating cutblocks). Colonies of Columbian ground squirrels (*Spermophilus columbianus*) became established in some, but not all, of these cutblocks. Subsequently, these regenerating cutblocks had sufficient prey to become suitable habitat for badgers. Thus, these areas may function as alternate connectivity corridors for the population as a whole.

It is unlikely that all logged areas form suitable habitat for badgers. In some areas, regenerating cutblocks do not have sufficient levels of forbs to feed colonies of Columbian ground squirrels. This is particularly true in areas that undergo intensive silviculture management, where the cutblock reaches "free-to-grow" status (i.e., trees >3 m tall, little competing vegetation) relatively quickly following harvest. Our field observations suggest that cutblocks that are not satisfactorily restocked (NSR) typically have abundant forb growth that increases the suitability of the site for establishing colonies of Columbian ground squirrels. Also, some newly harvested areas are not sufficiently close to a source population of Columbian ground squirrels to be colonized. In addition, the soils found in many harvested areas are not suitable for burrowing or supporting fossorial prey. Future research should be conducted to assess the relationship between silvicultural activities and the establishment of Columbian ground squirrel colonies. Understanding this relationship may help model habitat suitability of forested biogeoclimatic zones for badgers and allow land managers to enhance connectivity among populations of badgers in British Columbia.

It was difficult to assess the factors that affected the distribution of badger records because those that we collected may have been considerably biased. The probability of documenting records varied among areas and was likely related to the amount of human activity in addition to the suitability of the habitat for badgers. Areas that were heavily roaded and had substantial human activity were more probable to have records documented than those with poor access and little use by humans. Also, it is likely that badgers were more easily documented in areas with high sightability, such as on road surfaces, grasslands, or in recently cut hayfields. The effort that we expended collecting records was also not uniform; we spent far greater effort soliciting recent records in the Kamloops area because of our attempts to capture and tag badgers for the radiotelemetry study.

These biases were reflected in the distribution of records with respect to broad ecosystem units. Cultivated fields, which were the most commonly documented unit of records, probably had high rates of human visitation coupled with relatively little vegetative structure to obscure animals. It is unclear whether badgers were documented in this particular unit because it was highly suitable habitat (e.g., colonized by Columbian ground squirrels), had high rates of human visitation, or a combination of both factors.

Most sightings were reported during summer months, when badgers were most active. Male badgers travel widely looking for mates during this time (Messick and Hornocker 1981, Minta 1990) and are therefore more prone to encounter people. Increased day length during summer may also increase the likelihood of detecting badgers. Additionally, badger prey species are very active during the summer, which may decrease the foraging efficiency of badgers (Murie 1992, Michener 2000). This may force badgers to spend more time foraging above ground and thus be more likely to be detected by humans.

Apps et al. (2002) suggested that several landscape features dictated occupancy by badgers in the East Kootenay region. In their work, they identified soil parent material and texture, vegetation cover (i.e., forested versus non-forested), and topographical features as those environmental variables that most affected where badgers occurred throughout the landscape. To the extent to which we could examine the same variables, this trend appears to hold true in the Thompson and Okanagan regions. A more detailed analysis of the records, in combination with additional environmental data, would allow for stronger conclusions to be drawn regarding the factors that affected the area of occupancy within the region.

Section 3 - Ecological Relationships of Badgers

To provide the specific ecological information needed for badgers in the Thompson and Okanagan regions, we radio-tagged and monitored a sample of free-ranging badgers between 1999 and 2003. The following sections detail the methods used and ecological data that were collected during the radiotelemetry study.

CAPTURE AND IMMOBILIZATION

We used information from recent sightings that were reported during the distribution and occurrence portion of the project to identify areas with recent badger activity within the research study area. We attempted to capture adult badgers at active burrows in these areas. All captures and immobilizations were led by a person who had completed the provincial "Chemical Immobilization of Wildlife" course and followed the appropriate Resources Inventory Committee standards (Resources Inventory Committee 1998b). All methods of physical and chemical restraint adhered to the provincial guidelines for animal welfare. Protocols for handling and radio-tagging the badgers were approved by the University College of the Cariboo Research Ethics Committee (Animal Subjects), a committee recognized by the Canada Council on Animal Care.

We set livetraps at burrows using "den sets", which involved placing a trap at the mouth of active badger burrows (Baker and Dwyer 1987). We used off-set, padded "soft-catch" foot-hold traps (Victor 1½ coil spring) anchored with a 3 mm diameter cable to a flared anchor pounded 45 cm into the soil. We set each trap so that no more than 15 cm of cable was exposed above the soil surface. We scented nearby vegetation with commercial canine lure and occasionally baited burrow entrances with approximately 500g of road-killed deer or ground squirrels.

We set and monitored traps so that they were operational for a maximum of 14 hours each night. We set traps between 1800 and 2100 h and closed them between 0600 and 0900 h the following day. We released all non-target species immediately.

Upon capture of a badger, we estimated the body weight of each animal to determine the appropriate dosage of anaesthetic. Badgers were immobilized using a 1:1 mixture of tiletamine hydrochloride and zolazepam hydrochloride (Telazol®). We attempted to administer Telazol® at <5 mg/kg to induce light anaesthesia until further anaesthetizing for implant surgery. We restrained each badger using a handling pole prior to administering the anaesthetic with a jab-stick. Because of decreases in body temperature that we observed during immobilizations of other mustelids (e.g., fishers, Weir 2000), we placed the immobilized badgers in a sternal position over warm hot-water bottles. We then transported the immobilized badger to a veterinary clinic for implantation of a radiotransmitter.

We measured and monitored badgers while they were immobilized. Sex, body weight, and cranial and skeletal measurements were documented. We also collected hair and blood samples from each badger. We classified most badgers as adults or juveniles by examining sexual development and the level of occlusion of the canine teeth. Photographs were taken of the head, dorsal, and ventral regions. Respiration and cardiac rate, body temperature, and capillary refill time were also recorded at regular intervals while the badgers were immobilized.

Each badger that weighed >7 kg was surgically fitted with an intraperitoneal transmitter (ATS MOD17C or Telonics IMP400/L with high power option). Following the surgery, we wrapped each badger in a blanket to reduce the likelihood of hypothermia and placed it in a transfer container (modified plastic 200 l barrel) to recover from anaesthesia. We released each badger from the transfer container at their capture burrow when they had fully recovered from the anaesthetic.

RADIOTELEMETRY MONITORING

We attempted to locate radio-tagged badgers using standard ground and aerial telemetry procedures (Resources Inventory Committee 1998c). From the ground, we recorded directional bearings to badgers using a three-element, collapsible Yagi antenna. When badgers were inactive, we homed-in on their signal (White and Garrott 1990:42) whenever possible to identify the burrow that the animal was using. We occasionally triangulated radiolocations and estimated 95% error polygons from ground telemetry using LOAS software (Ecological Software Solutions 2000) when we were unable to home in on the signal source. We located badgers whenever possible from the ground.

RESULTS – CAPTURE AND MONITORING

We captured and radio-tagged 13 badgers (11 male, 2 female) between 14 July 1999 and 22 June 2001. All of the badgers responded well to the use of Telazol® and recovered easily from the surgery. The transmitter that we removed from B05 showed no signs of adhesions and did not seem to be causing him any difficulty. In fact, he had increased in body weight by 35% in the 450 days since placement of the original transmitter.

We encountered considerable difficulties in consistently radio-locating tagged badgers. During the first year of the research, we used ATS MOD17C transmitters, which generally prevented us from detecting signals from >1 km if the badger was underground. Consequently, the data we collected during the first year was limited. In subsequent years, we used Telonics IMP400/L transmitters with high or semi-high power options, which increased the distance over which we could detect signals. Despite the increased power of the Telonics transmitters, reliable detection of signals was generally limited to ≤4 km, so data collection capabilities were still somewhat restricted, especially for wide-ranging animals such as badgers. With both transmitter set-ups, we encountered considerable electromagnetic interference throughout the study area, due to the several high-voltage transmission lines that ran through the study area.

The short distances over which we were able to locate badgers may have resulted in some bias in the areas that we were capable of sampling. Unfortunately, aerial telemetry surveys, which would have reduced this bias, were too costly for locating radio-tagged badgers and did not alleviate the difficulties with electromagnetic interference.

We collected 494 radiolocations of 13 badgers between July 1999 and October 2002, during 4,791 radio·days of monitoring (1 radio·day: 1 transmitter operational for 1 day). We collected 8 aerial telemetry radiolocations, 26 ground triangulation radiolocations, and 460 "homing-in" radiolocations. Monitoring lasted between 10 and 1,025 days ($\bar{x}$ = 369 days, SD = 299, n = 13) for each radio-tagged badger. Of these radiolocations, 464 were suitably precise for home range scale analyses, 392 were suitable for within-home range scale analyses, and 367 were suitable for patch scale analyses. We identified the burrow or exact site that was used by the radio-tagged badger on 354 occasions. Not all of the radiolocations that we collected were spatially or temporally independent; 194 of the 494 radiolocations were either at the same burrow as previous radiolocations (94 radiolocations), not separated by >16 hours from previous radiolocations (37 radiolocations), or both (63 radiolocations). We radio-located badgers throughout the year, but most radiolocations were collected during summer. We collected 397 radiolocations during the summer (1 April – 31 August), 45 during autumn (1 September – 14 November), and 52 during winter (15 November – 31 March).

3.1 Spatial Organization[2]

Within Canada, the *jeffersonii* subspecies of North American badger is restricted to a small area of British Columbia and considered endangered within Canada (Committee on the Status of Endangered Wildlife in Canada 2000). The ecology of these animals is poorly understood, although loss of grassland habitat generally is considered a leading cause in the decline of populations (Rahme et al. 1995). Habitat conservation for these animals lacks direction because their use of the landscape, including critical habitats, remains unknown. Research in the United States has shown that home range size varies throughout badger distribution and is correlated with prey density, female availability, and habitat attributes (Lindzey 1978, Messick and Hornocker 1981, Minta 1993).

Portions of a home range that are used more intensively than others by an animal suggest that these areas are important relative to other areas (Hayne 1949). Home ranges generally encompass the resources that animals need for feeding, mating, and rearing offspring. However, animals that maintain home ranges do not use them uniformly because of the heterogeneous distribution of resources. For example, denning or nesting sites, patches of dependable food resources, and mating grounds are focal features within a home range that may be frequented (Litvaitis et al. 1986, Samuel and Green 1988, Pechacek et al. 2000). These areas within home ranges have been described as "core areas" (Powell 2000). By identifying core areas within a home range, researchers may be able to identify resources that are important for an animal, and delineate these areas as priorities for conservation.

The objective of our research was to assess the patterns of space use among badgers in the Thompson region of British Columbia. Understanding the spatial requirements of badgers, and the factors that affect space use, are critical for conservation planning for the species. Knowledge about the movements and spatial organization of badgers will allow land managers to better plan resource developments to minimize or mitigate negative effects on dwindling populations of this important grassland carnivore.

METHODS

Home range

We estimated the size and location of the home range of each radio-tagged resident badger using two estimators. For badgers with 25 or more radiolocations, we estimated home ranges using the 95% isopleth of the utilisation distribution (UD) generated from the fixed kernel method with the smoothing parameter selected by least-squares cross-validation and ad hoc adjustment (Worton 1989). Because many of the radiolocations were collected at the same location (e.g., same burrow), fixed kernel estimates with no smoothing adjustments produced disjunct polygons in areas where telemetry points were densest. Therefore, to create a smoother estimate (i.e., a more continuous home range), we adjusted the smoothing parameters used in the home range analysis with ad hoc adjustments of 4 or 5. To allow comparison with other studies, we also calculated annual home ranges using the minimum convex polygon (MCP) created from 100% of the radiolocations obtained for each badger.

[2] Portions of this section are in preparation for publication in peer-reviewed journals. Please contact the report authors for the correct citation of results and conclusions presented in this section.

We used Home Ranger software (Hovey 1999) for kernel home range calculations and the Animal Movement extension for ArcView (Hooge and Eichenlaub 1999) for MCP calculations.

To assess whether badgers used core areas, we compared an index of aggregation (Krebs 1989:126) of radiolocations to that generated from a random walk pattern. We then used Monte Carlo modelling to estimate the probabilities of observing as, or more, extreme observations than we documented. We delineated boundaries of the core areas for those badgers that exhibited aggregated use of areas (i.e., probabilities < 0.10).

We determined a biologically relevant boundary to the core areas by plotting each isopleth of the UD (0-95%) against its proportion of the home range area (95% FK; Powell 2000). If the distribution of radiolocations within the 95% isopleth were perfectly uniform, the area within each isopleth would accrue evenly with its volume. That is, the relationship between isopleth volume and area would be linear with the slope equal to 1 and the origin at 0. If the plotted relationship sagged below this reference line, then isopleth area accrued disproportionately to volume. The line would sag to the extent that locations were concentrated because area would accumulate less rapidly than expected under uniformity. Core areas for each animal were defined as the UD isopleth (%) where the slope of the tangent to the sagging line was 1.

Movements

We conducted focal sessions to continually monitor individuals during both day and night hours. During each session, we noted the activity and location for the animal every 30-45 minutes for 12-15 hours. We used triangulation to locate the animal when it was not visible.

We estimated the distance between consecutive radiolocations to determine minimum distance travelled per day during the summer and winter seasons. We considered the summer season from April 1 to August 31, which included the period when fossorial prey were active and badgers mated, and the winter season from September 1 to March 31, when fossorial prey were hibernating.

We assessed the likelihood of radio-tagged badgers moving at least 500 m by examining the support by the data for 2 different models: 1) a model with time between successive radiolocations as the only variable, and 2) a model with no variables (i.e., a constant null model). We used logistic regression of consecutive radiolocations collected within a 2-week period to construct maximum likelihood parameterizations of the 2 models. We calculated the AIC_c score (Burnham and Anderson 2001) for each model and ranked the relative support for each by comparing the scores between the 2 models. For each model, we calculated the log likelihood (log $\mathcal{L}$), number of estimated parameters (K), second-order Akaike information criterion (AIC_c, Burnham and Anderson 1998), difference between AIC_c score and the minimum AIC_c score for the candidate set (Δ_{AICc}), and Akaike weight (strength of evidence, w_i; Burnham and Anderson 1998). We then identified the model that best explained the probability of movement at least 500 m from the candidate set by selecting the model with the lowest AIC_c score.

RESULTS

Home range

We captured, radio-tagged, and radio-tracked 13 badgers (11 M, 2 F) from July 1999 to October 2002. We included 8 animals (7 males, 1 female) with ≥25 temporally independent radiolocations in the fixed kernel home range analysis.

Ninety-five percent fixed kernel areas for 8 badgers varied between 15.6 km^2 and 53.7 km^2 (Table 2). The mean size of male home ranges was 32.7 km^2 (SD = 11.6, n = 7), whereas the summer home range of the one female we had radio-tagged was 15.6 km^2. MCP areas ranged between 5.3 km^2 and 258.4 km^2 ($\bar{x}_{Male}$ = 78.8 km^2, SD = 88.1, n = 9; $\bar{x}_{Female}$ = 8.5 km^2, SD = 2.8, n = 2). Home ranges of 3 male badgers overlapped (B05, B09, B14; Fig. 6).

Core Areas

All animals, except B08, showed some degree of aggregation across their home ranges (Table 3). However, we concluded that only 5 of 8 badgers (B03, B05, B10, B12, and B14) used core areas ($P < 0.10$). These animals maintained between 2 and 5 core areas each that were delineated by 59% - 68% isopleths of their respective UD (Fig. 7, Table 4). Core areas accounted for 21% - 33% of the home range areas (95% FK) and encompassed an average of 72% of the radiolocations for each animal. Winter radiolocations were also confined within core areas.

Table 2. Home ranges of radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia. Minimum convex polygons (MCP), and 95% fixed kernel estimates (95% FK) were calculated from temporally independent radiolocations.

Badger ID	Age class	Sex	*n*	MCP (km^2)	95% FK (km^2)
B01	Ad	M	7	258.4	—
B02	Ad	M	5	5.3	—
B03	Ad	M	47	197.0	53.7
B04	Juv	M	2	—	—
B05	Ad	M	96	63.1	34.7
B06	Ad	F	49	10.5	15.6
B07[a]	Juv	F	8	6.5	—
B08	Juv	M	25	17.0	18.1
B09	Ad	M	45	45.0	37.3
B10	Ad	M	34	23.7	21.5
B12	Ad	M	31	32.5	30.5
B13	Juv	M	2	—	—
B14	Ad	M	56	66.8	33.4

a offspring of B06

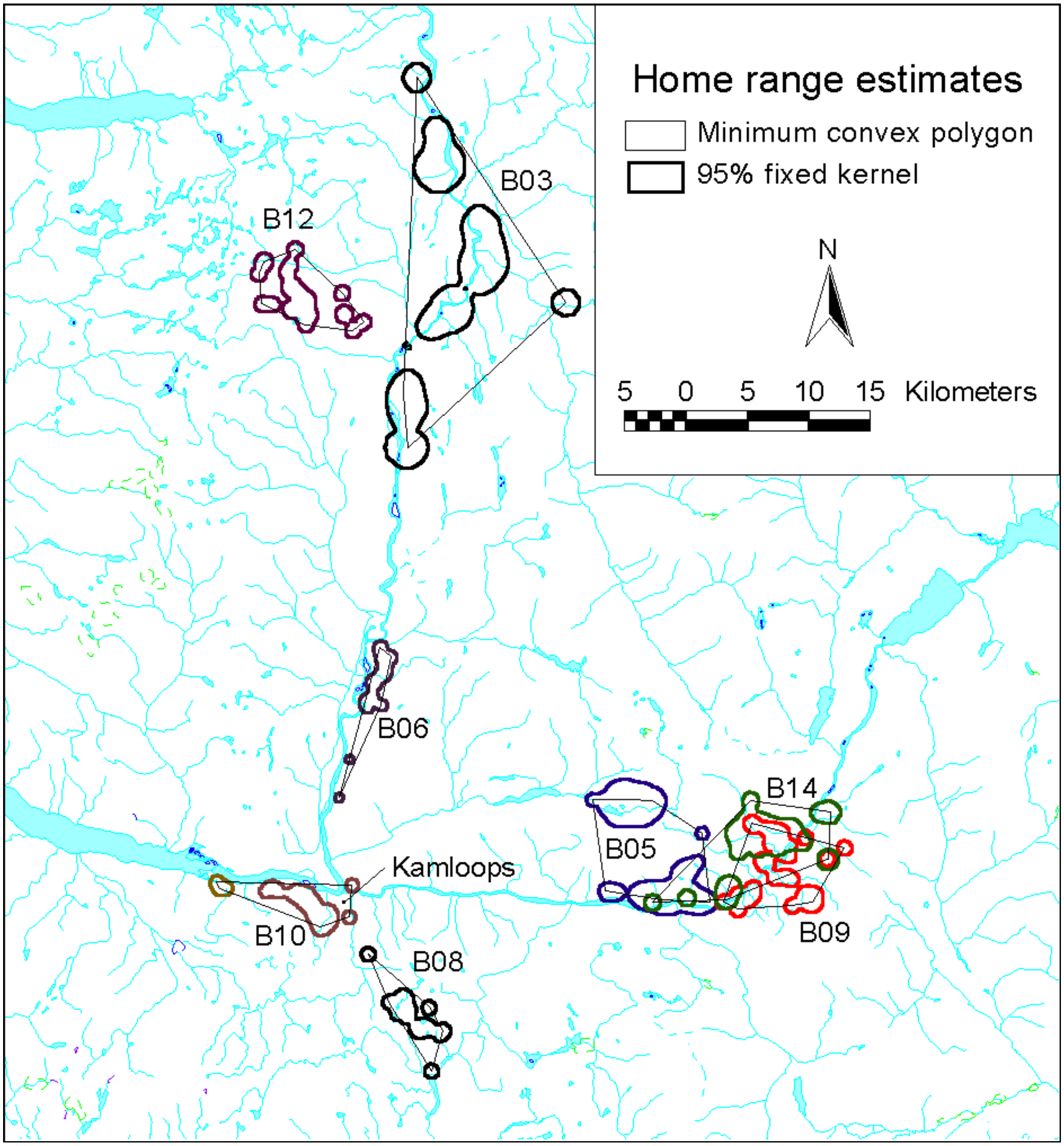

Figure 6. Home range estimates for 8 radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia. All badgers had multiple disjunct portions of their respective home ranges.

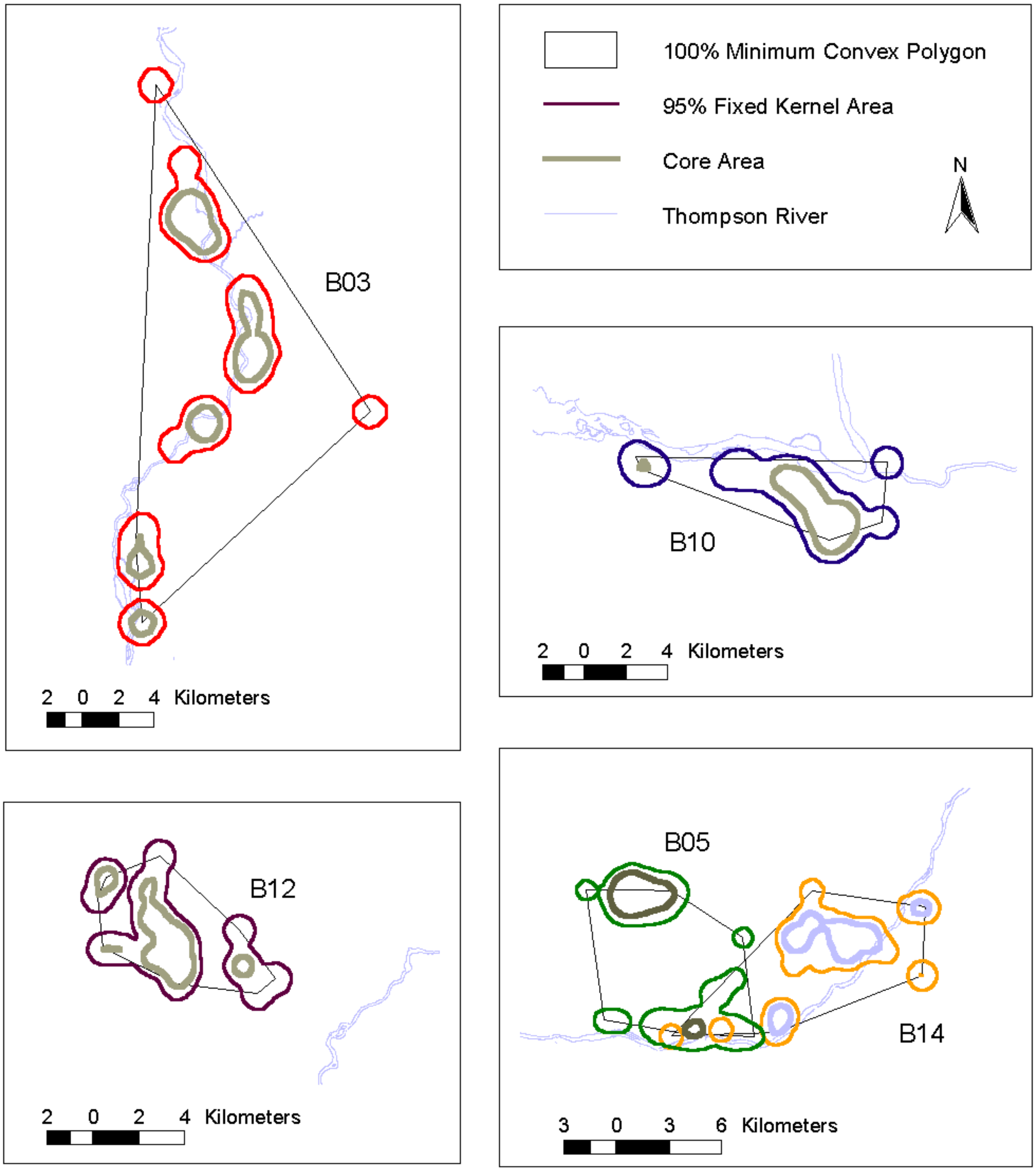

Figure 7. Spatial distribution of core areas within home ranges (MCP, 95% FK) of 5 radio-tagged male badgers monitored between 1999 and 2002 in the Thompson region of British Columbia.

Table 3. Indices of aggregation for radiolocations of radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia. The index value (R) indicates the degree of aggregation of radiolocations collected. P represents the probability of a modeled dataset being more aggregated than the observed value; if P was <0.10, we concluded the animal used core areas. The index value for B06 was calculated from summer radiolocations only.

Badger ID	Age class	Sex	*n*	Index value (R)	P
B03	Ad	M	51	0.44	0.014
B05	Ad	M	96	0.38	0.003
B06	Ad	M	49	0.68	0.995
B08	Juv	M	25	1.16	0.975
B09	Ad	M	45	0.81	0.604
B10	Ad	F	34	0.65	0.006
B12	Ad	F	31	0.73	0.061
B14	Ad	M	56	0.50	0.002

Table 4. Summary of core areas used by radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia. The number and size of core areas, the isopleths (% UD volume) that delineated core area boundaries, and the percent of each home range (95% FK) that core areas covered are reported.

ID	# of Core Areas	Area (km^2)	UD isopleth (%)	Proportion of home range area (%)
B03	5	18.0	68	33.5
B05	2	7.4	67	21.3
B10	2	6.9	63	32.0
B12	4	9.0	59	29.4
B14	3	10.1	64	30.3

Movements

We collected 328 radiolocations of 8 radio-tagged badgers during summer and 81 radiolocations during winter. During summer, the average time and distance between consecutive radiolocations of each animal was 9.8 days (SD = 5.4) and 2.8 km (SD = 1.0), respectively. During winter, the average time and distance between consecutive radiolocations of each animal was 20.0 days (SD = 15.6) and 0.8 km (SD = 0.7).

Badgers moved more during summer than winter. Average movement rates were 964 m/day (SD = 353) during summer, and 217 m/day (SD = 286) during winter. Long-distance movements started in mid-April, peaked in July, and continued until the end of September. This corresponded to the breeding season of badgers and periods of high prey activity.

We attempted focal monitoring on 6 occasions during the summers of 2000 and 2001. During most of the monitoring periods, badgers remained in or very near their burrows. In fact, B05, B06, and B10 did not stray substantially from their original radiolocations during their respective 12-hour monitoring periods. B09, however, swam across the South Thompson River on 3 occasions during 12 hours of monitoring. The female (B06) travelled over 6 km in 12 hours on 2 occasions during July 2000. One male (B03) that we monitored in July 2000 travelled 14 km in 4 h after spending at least 12 h in a burrow.

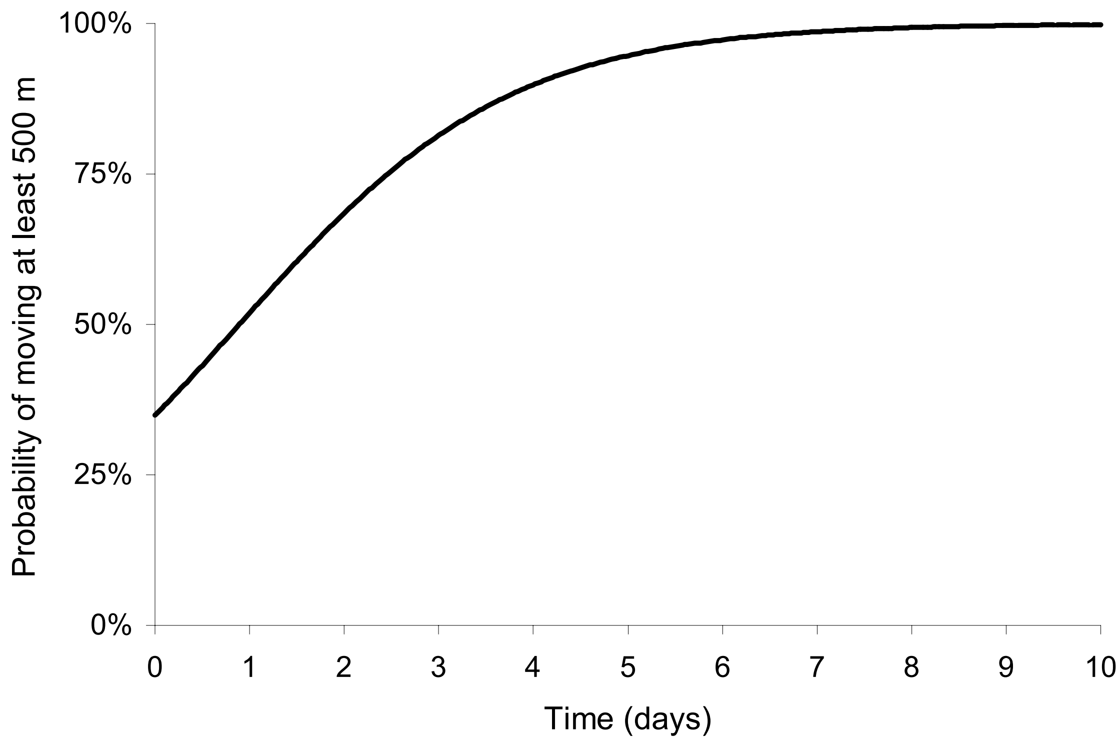

Figure 8. Probability of a radio-tagged badger moving at least 500m during summer as determined from maximum likelihood logistic regression modelling in the Thompson region of British Columbia. Badgers were more probable to have moved ≥500 m within 1 day than to have stayed in the same general area.

We collected 251 consecutive radiolocations, separated by between 25 minutes and 13.9 days, of 10 radio-tagged badgers during the summers of 1999 to 2002. The model that included time between radiolocations was the best model to describe the probability of movement ≥500 m (log $\mathcal{L}$ = -158.04, K = 2, AIC_c = 322.16, $w_i \approx 1.0$), when compared to the null model (log $\mathcal{L}$ = -203.51, K = 1, AIC_c = 411.06, $w_i = 4.98 \times 10^{-20}$). The parameterization of the best model suggested that, during summer, badgers were more likely to leave an occupied burrow and move ≥500 m away in the span of 1 day (odds ratio = 2.01, 95% CI = 1.61 - 2.52, Figure 8) than to remain within 500 m.

DISCUSSION

Badgers are not commonly considered to be a wide-ranging species or one that requires particular conservation initiatives throughout much of its range in North America (Long and Killingley 1983). By describing the patterns of spatial use of radio-tagged badgers in the Thompson region of British Columbia, our research has a number of implications for badger conservation. Radio-tagged badgers that we monitored occupied large home ranges that appeared to be widely dispersed across the landscape. Badgers had high movement rates that exposed them to many sources of mortality. Also, some individuals maintained core areas within their ranges where resources may have been concentrated.

Spatial organization

Badgers in our study used larger home ranges compared to those reported in other studies. In the Thompson region, MCP estimates of home ranges of male badgers averaged 87 km^2, which is twice that of the largest home range reported in the United States (95% MCP, 44 km^2; Warner and Ver Steeg 1995). In the East Kootenay region of British Columbia, home ranges of male badgers were even larger than those that we documented (MCP, 307.7 km^2; Newhouse and Kinley 2003). The home ranges of male badgers reported in the USA were much smaller than we documented (e.g., 12.0 km^2, 95% FK, Wyoming, Goodrich and Buskirk 1998; 2.4 km^2, MCP, Idaho, Messick and Hornocker 1981).

The large home range sizes we observed were likely related to long distance movements that male badgers made during the summer. These movements may be the result of males seeking few, widely dispersed breeding females in the population. For male badgers, potential mates are the limiting resource and home range size is determined by access to breeding females (Minta 1993). Although the lack of females in our study limits the conclusions we can make, the large home ranges of males may have been partially influenced by low female density. As a result, males probably had to travel longer distances than males in other, higher density populations, and therefore, used larger home ranges (Minta 1993).

The large home range areas may have also been influenced by the availability of food resources. For female badgers, home range size and orientation is influenced by food dispersion (Minta 1993). Reduced food availability is thought to increase the size of home ranges of badgers (Lindzey 1982, Minta 1993) and geographical differences in space use among badger populations are probably due to differences in the distribution and abundance of food (Goodrich and Buskirk 1998).

Relationships between home range size and food availability have been widely reported in the literature for other mammalian carnivores (Ward and Krebs 1985, Litvaitis et al. 1986). Prey biomass was linked to home range size of bobcats (*Lynx rufus*), whereby animals expanded their home ranges in response to land-use patterns that caused declines in prey populations (Litvaitis et al. 1986, Rolley 1987, Knick 1990). Gray foxes (*Urocyon cinereoargenteus*) also expanded their home ranges during mating season due, in part, to increased movements and decreased abundance of prey (Chamberlain and Leopold 2000). Because a correlation may exist between the size of home ranges for badgers and the availability of resources (Minta 1993), there also may be a correlation between dispersion of resources and use of core areas within the home range. Because the study area was large and spanned a diverse array of natural and human-altered habitats, variability in badger spatial ecology probably reflected the variability of the resources available to each badger.

Badgers may have been focusing on core areas within their home ranges where resources were concentrated. For example, use of core areas may have been related to burrowing sites, mate proximity, or areas of concentrated prey. Badgers specialize in hunting fossorial prey such as ground squirrels (*Spermophilus* spp.) and marmots (*Marmota* spp.; Messick 1987). Both species live in colonies that would be dependable patches of food for badgers that may be returned to often. Knick (1990) found that extra-territorial forays and patch use by bobcats were more pronounced during winters when they fed on lagomorphs that occurred in clumped distributions. This contrasted with the summers, when bobcats foraged on mice that were more uniformly distributed. We did not detect the use of core areas for several badgers, which suggested that the landscape, and perhaps distribution of prey resources, were different among badgers. Uniform use of home ranges may indicate more evenly dispersed prey resources such as voles, mice and arthropods. Although there is evidence to suggest badger spatial ecology is dependent upon prey dispersion, this relationship needs to be tested more rigorously before definitive conclusions can be drawn.

Gender also may have influenced the spatial ecology of badgers; however, we were not able to fully explore these differences. The lone adult female of our sample (B06) did not use core areas during the breeding season. She had two kits during the months she was monitored and we expected that her movements would be restricted to the vicinity of maternal burrows. However, she had the highest movement rates of all the study animals during the breeding season. After her 1 radio-tagged kit started to move independently of her in mid-July, she made two long-distance movements in 24 hours from one end of her home range to the other. She may have been searching for males, or she may have been moving to more productive hunting grounds (Lampe and Sovada 1981). The relatively short duration of monitoring of this female may have precluded us from detecting use of core areas around maternal burrows.

Movements

Use within home ranges varied seasonally, which is consistent with other studies of badger ecology (Sargeant and Warner 1972, Messick and Hornocker 1981). Badgers in this study reduced their movements during the winter and used smaller ranges that were confined to core areas. As badgers decrease their movements in the autumn, they increase food consumption and fat levels for the winter months (Harlow 1981, Michener 2000). Therefore, there should be some correlation between prey availability and over-wintering locations of badgers, and these sites would be particularly critical to incorporate into habitat conservation plans.

It is unclear as to the reason for the low activity of these badgers during winter. Other researchers have noted that the activity of badgers decreases substantially during winter and have attributed this behaviour to the conservation of resources through torpor (Messick and Hornocker 1981). Both B05 and B09 appeared to enter torpor during their extended stays in their winter burrow; on several occasions, the mortality switch on their transmitters indicated that each badger had not moved for at least 8 hours.

Conclusions

Home ranges of badgers in the Thompson region of British Columbia were large and widely dispersed across the landscape, which has likely contributed to the conservation crisis facing the species. The primary cause of death for badgers within this population is road mortality (Section 3.3). Large home ranges that overlap major transportation corridors, such as highways and railways, result in increased mortality risk for those animals. Furthermore, the high rate of movement during the summer months, whether for breeding or foraging, coincides with peak traffic volumes on highways (B. Persello, British Columbia Ministry of Transportation and Highways, personal communication). Additionally, peak traffic volumes also coincide with dissolution of family groups and exploratory movements by juvenile badgers (Messick 1987), which may further jeopardize the survival of dispersing offspring.

Our results suggested that identifying core areas and sites that are important to badgers that use large home ranges could strengthen conservation plans. For badgers, core areas may be colonies of ground squirrels, fields amidst an urban landscape, or established areas such as maternal burrows that have been used historically. Core areas can also identify important over-wintering sites that should also be targeted in conservation plans. Animals maintain cognitive maps of the landscape, and they use these maps to remember where resources are located (Stamps 1995). Therefore, core areas may be used for many years as long as resources are available. Thus, preservation of these areas is justified. Understanding the scale at which animals operate on the landscape will enable conservation initiatives to be set relative to the needs of the animals, resulting in more effective long-term management plans.

3.2 Habitat Relationships[3]

North American badgers (*Taxidea taxus*) are large-sized members of the weasel (Mustelidae) family that occur throughout the grassland regions of North America (Messick 1987). Badgers in British Columbia are at the northern periphery of the range of the species and are considered endangered (Committee on the Status of Endangered Wildlife in Canada 2000). The primary factors limiting badger populations in British Columbia are believed to be related to habitat and prey constraints (Newhouse and Kinley 2000a), although the exact effects of modification, alienation, and loss of habitat on badger populations in the province are largely unknown. Individual badgers likely need habitats with suitable densities of prey for foraging and appropriate substrates in which to dig burrows (Rahme et al. 1995).

Foraging habitat for badgers has often been linked to the ecology of colonial fossorial rodents (Messick and Hornocker 1981, Long and Killingley 1983) and populations of badgers seem to do well in areas where these prey occur (Messick 1987). In Wyoming, badgers are common predators in Uinta ground squirrel (*Spermophilus armatus*) or white-tailed prairie dog (*Cynomys leucurus*) colonies (Minta 1990, Goodrich and Buskirk 1998). Badgers have been associated with Belding ground squirrels (*S. beldingi*) and Townsend ground squirrels (*S. townsendi*) in Idaho (Todd 1980, Messick and Hornocker 1981), whereas in Alberta, badgers prey heavily on Richardson's ground squirrels (*S. richardsonii*; Michener 2000). The occurrence of suitable densities of colonial fossorial prey may be the most important factor that dictates the distribution and abundance of badgers in North America (Long and Killingley 1983). Subsequent to these observations, one would expect that the selection of habitat by badgers would be largely dictated by the availability of prey within it.

Badgers are relatively unusual among carnivores in that they lead a semi-fossorial lifestyle and have substantial adaptations for life underground. Badgers have a well-developed pectoral girdle with powerful forearms and long front claws to aid in digging through soil, both in pursuit of prey and in the excavation of burrows that are used as thermal, reproductive, and security cover (Long and Killingley 1983).

Despite their fossorial lifestyle, few investigators have characterized habitats used by badgers for burrowing or examined the effects of soil and terrain properties on site selection. Soil friability, which is the ease with which soil can be excavated, probably affects site selection by badgers (Rahme et al. 1995). Badgers in Ontario were frequently associated with sandy and sandy loam soils (Lintack and Voigt 1983), but this may have been related to the occurrence of a woodchuck population (Bartlett 1955). More recently, however, Apps et al. (2002) examined the habitat associations of radio-tagged North American badgers in the East Kootenay region of British Columbia. They examined the effects of a suite of environmental variables on selection at broad (28.3 km^2) and moderate (0.14 km^2) spatial scales and determined that most of the selection for habitat variables was expressed at broad scales, with fewer variables being important at the moderate scale. Their research highlighted that badgers in that area selected sites within their home ranges (i.e., 0.14 km^2 scale) on the basis of soil parent material, soil texture, soil drainage, and site productivity.

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[3] Portions of this section are in preparation for publication in peer-reviewed journals. Please contact the report authors for the correct citation of results and conclusions presented in this section.

The primary goal of our research was to determine the spatial scales at which badgers fulfill various resource requirements. The objective of our research was to examine the effect of prey and soil resources on selection of sites by radio-tagged badgers both within their home ranges and within various ecosystem units. We expect that badgers modify their selection of sites to respond to both food and soil factors. Additionally, we describe the soil and site characteristics of badger burrows to help with the identification of sites used by this endangered species.

METHODS

Animals make decisions regarding resource selection at several spatial scales (Johnson 1980). These scales are nested and range from fine scale (element) to coarse scale (landscape) (Figure 9). Selection for elements (e.g., the roots of a tree) occurs within patches of habitat, selection of patches occurs within ecosystem units, selection of ecosystem units occurs within home ranges, and selection of home ranges occurs within the landscape. Thus, when examining the factors that affect resource selection by animals, researchers need to consider selection as a process that occurs across these multiple spatial scales.

We limited our analyses of resource selection to the two middle spatial scales: selection of ecosystem units within home ranges (within-home range selection), and selection of patches within ecosystem units (patch selection). We were unable to assess the selection of home ranges within the landscape because our live-trapping efforts were not randomly located throughout the landscape (Section 3) and selection for measurable elements within patches was sufficiently rare that it did not warrant analyses.

Depending on its level of precision, we considered the suitability of each radiolocation for inclusion in habitat analyses at the patch and within-home range spatial scales. We included precise radiolocations in analyses at both spatial scales (i.e., patch and within-home range scale), while less precise radiolocations were only suitable for coarser-scale analyses (i.e., within-home range scale). For example, the radiolocation of a badger in a burrow was used for habitat analyses at both spatial scales. In this case, because we identified which patch within the ecosystem unit the badger used, we also knew which ecosystem unit was used. However, with less precise radiolocations, such as triangulated radiolocations with error polygons of 1.5 ha, we could only reliably identify which ecosystem unit was used by the badger. Thus, more precise radiolocations were appropriate for habitat analyses at both spatial scales, whereas imprecise radiolocations were precluded from use in analyses at the within-home range scale. We considered radiolocations with ≤10 m error (i.e., error polygon ≤0.314 ha) as suitable for patch scale analyses and those with ≤70 m error (i.e., error polygon ≤1.5 ha) as suitable for within-home range analyses.

Within-home range selection

We estimated the home ranges that radio-tagged badgers used between 1999 and 2002 to determine areas that were available to each individual (Section 3.2).

We used several sources of spatial data to assess habitat within the home ranges of each badger (Appendix 1). Ecosystem units for the study area were delineated on the basis of relatively homogenous site position, vegetation composition, vegetation cover, and structural

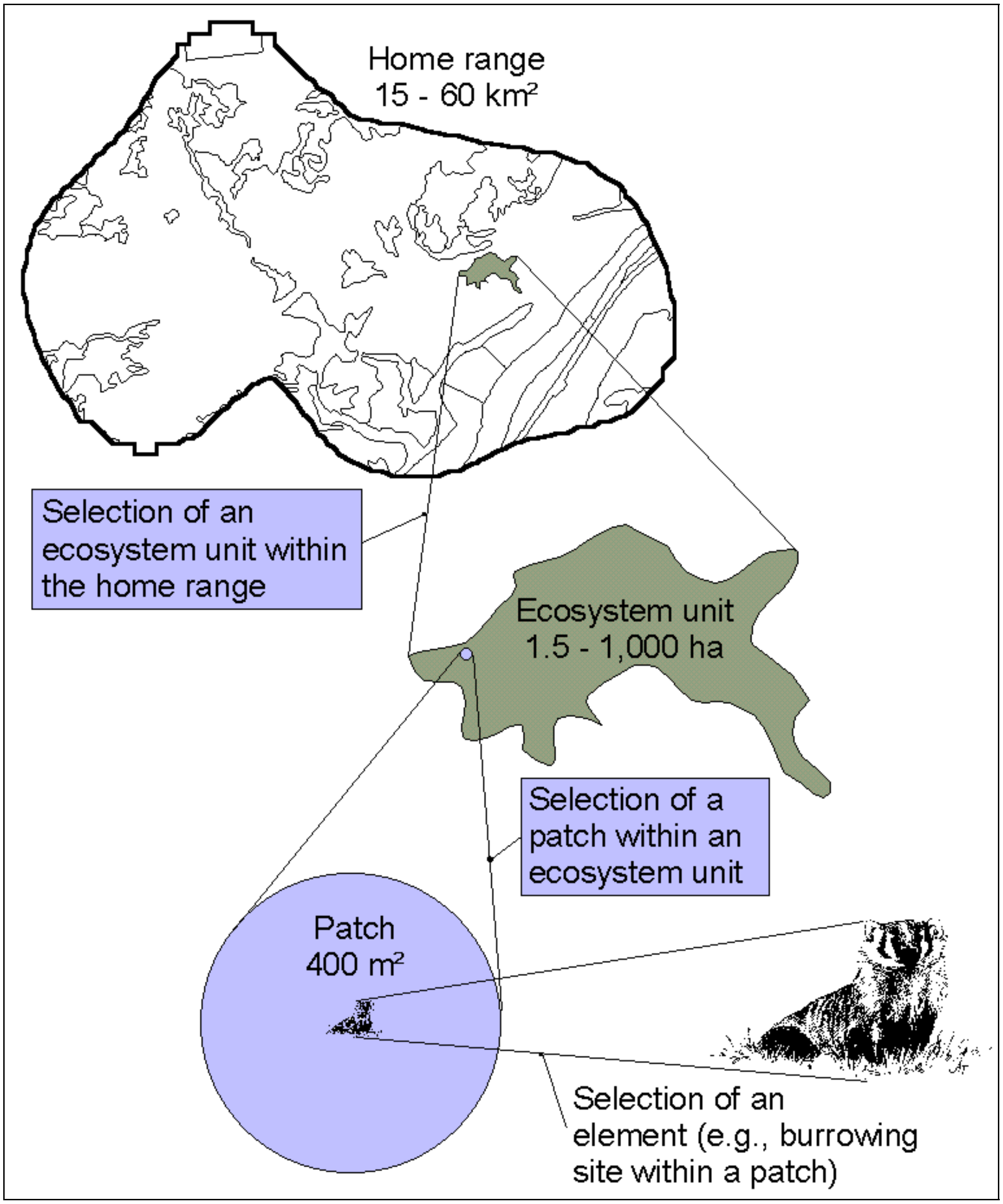

Figure 9. The hierarchical nature of scale. Animals can make decisions regarding resource selection at each scale. We examined the selection of 1) ecosystem units within the home range, and 2) patches within ecosystem units (shaded boxes).

stage using vegetation resources inventory (VRI; Resources Inventory Committee 2001) or forest inventory planning (FIP; Weyerhaeuser Company Limited 2001) data. We used digital soils and terrain data (Kowall 1986, Gough 1988, Young et al. 1992) to determine the soil texture and drainage, surficial material, and coarse fragment content of polygons within the home ranges. We used Terrain Resources Inventory Management (TRIM) topographical data to determine the elevation, proximity to water, and proximity to various road types for each point. We also estimated whether each point fell within the rights-of-way of transportation corridors by determining if each point was within 20 m of the centre-line of paved roads or 10 m of the centre-line of gravel roads and rail lines. The scales of these spatial data were 1:20,000 for the TRIM, VRI, and FIP data and 1:50,000 for the soils and terrain data.

Patch selection

We collected habitat information (Appendix 2) at 2 types of plots within the ecosystem units of the study area: at radiolocations and ecosystem description plots. Ecosystem description plots were centred on randomly located points within the various ecosystem units of the study area. Both of these plots reflected the values of a 400-m² patch that occurred at (or around) points used by badgers or random points within each ecosystem unit. We used these patch-scale data for 2 purposes: to quantify the structural and site characteristics of patches used by badgers and to provide estimates of normal (i.e., expected) values of these variables for each type of ecosystem unit. We used the units identified during the within-home range assessments to delineate the ecosystem units that were used by the radio-tagged badgers.

The techniques that we used to assess habitat were identical among plots at radiolocations and at ecosystem description plots. At each site, we completed site descriptions and collected soil and vegetation data following terrestrial ecosystem mapping standards for ground inspection plots (Resources Inventory Committee 1998d). We also assessed the grazing intensity at the site using a 5-scale rating system (Table 5) and determined the presence of prey (Columbian ground squirrels, yellow-bellied marmot [*Marmota flaviventris*], mice/voles, northern pocket gophers [*Thomomys talpoides*]) by tallying holes/dirt mounds on 4 – 25 m transects (as per Newhouse and Kinley 2000b).

Data analysis

We used a 2-tier approach to assess the spatial factors that affected the selection of sites by badgers within home ranges and within ecosystems. First, we developed a set of a priori candidate models to explain selection at each spatial scale based on published literature and suspected ecological relationships. The sets of candidate a priori models that we generated were composed of the global model, which included of all the variables of interest, as well as various reduced models that incorporated subsets of the global model variables. We then used an information-theoretic approach (Burnham and Anderson 1998) to determine which model was best supported by the data for each individual badger. Consequently, we ended up with 8 sets of best models. We assessed multicollinearity among the variables in each model with ordinary least squares regression. In cases of high correlation ($r^2 \geq 0.4$), we excluded 1 set of the correlated variables on the basis of a priori understanding.

Candidate models

We developed 2 sets of candidate models that represented several different possible combinations of variables that we expected to affect site selection at each spatial scale. These models were based on published results from studies conducted in other areas as well as on hypothesised relationships specific to our study area. Each of these models included variables that were expected to influence the quality of a site for its prey habitat suitability, suitability for burrowing, or security (i.e., proximity to other features). Each candidate model was slightly different in the hypothesised role that the variables played in affecting prey

Table 5. Utilization codes used to describe grazing pressure at habitat assessments conducted during 2001 and 2002 in the Thompson region of British Columbia.

Class range (% utilized)	Utilization description
None (0%)	The plants show no evidence of use.
Low (1 to 35%)	The plants show very little evidence of use and have the appearance of very slight grazing. Key forage plants may be topped or slightly used. Current seed stalks and young plants of key species show little disturbance. Low-value plants are ungrazed and 60 to 80% of current leafage of key plants remain intact.
Medium (36 to 65%)	The plants appear rather uniformly grazed. Fifteen to 25% of the number of current leafage of key species remain intact. No more than 10% of the number of low-value forage plants are used. Applied to a use zone, the area is entirely covered as uniformly as natural features or livestock facilities will allow.
High (66 to 80%)	Key species are almost entirely used, with <10% of the current leafage remaining. More than 30% of the low-value plants have been utilized. Applied to a use zone, the area has the appearance of complete search. Some trampling damage may be evident.
Very high (>80%)	Key species that are carrying the grazing load are closely cropped. There is no evidence of reproduction or current seed stalks of key species. Applied to a use zone, the area has a mown appearance, and there are indications of repeated coverage. Trampling and trailing is evident.

habitat suitability, burrowing suitability, or security available at specific sites. We developed a set of candidate models that predicted the relationship between its constituent variables and the probability of use of sites 1) within the home range of each radio-tagged badger (i.e., ecosystem units within the home range), and 2) within ecosystems used by badgers (i.e., patches within ecosystems). Because relatively few researchers have considered habitat relationships of badgers and only 1 team of researchers has addressed habitat selectivity, our use of complex models was limited.

We constructed models for the within-home range analysis based on published accounts of badger habitat relationships and suspected relationships (Table 6). Both Rahme et al. (1995) and Newhouse and Kinley (2000a) suggested that friable soil (i.e., loamy or silty soil with low coarse fragments) and prey were important habitat components for badgers. Apps et al. (2002) determined that badgers selected sites at moderate (14.5 km^2) spatial scales on the basis of colluvial parent material, canopy closure, well-drained soils, forest age classes, site index, elevation, glaciofluvial parent material, fine sandy loam soils, and open range. In the Thompson and Okanagan regions of British Columbia, badgers have been reported to consume primarily Columbian ground squirrels, yellow-bellied marmots, and northern pocket gophers (Hoodicoff 2003). Subsequently, we considered several models that were derived from speculated relationships between habitat variables and distribution of these prey species. Other models were derived from soil characteristics, topographic descriptions, and vegetation cover.

Similarly, we constructed models for the analysis of patch selection within ecosystem units on the basis of suspected ecological relationships between badgers, soils, vegetation cover, and prey (Table 7). Yellow-bellied marmots were not encountered at any of the 63 random plots that we conducted in the various ecosystem types, so this variable was not included in the within-ecosystem analysis.

Model parameterization

We employed maximum likelihood estimation using 1-1 matched logistic regression methods (Hosmer and Lemeshow 2000:226) to parameterize the candidate models for each badger. Parameterization involved the estimation of the "best" coefficient for each variable included in each model in the candidate set, on a model-by-model basis.

For the within-home range selection, model parameterization involved the 1-1 comparison of a site used by a radio-tagged badger (i.e., the case) to a simultaneously unused site that was randomly located within its home range (i.e., a random paired point; the control). Thus, for each radiolocation, we had a comparison between a site that was selected to one that was not selected at a specific instant in time. We used this conditional 1-1 matched pair approach because it allowed us to incorporate linear spatial variables (e.g., proximity to roads) into our analyses, which are difficult to model using standard resource selection functions (e.g., Manly et al. 1993).

Similarly, for the within-ecosystem examination of site selection, model parameterization involved 1-1 matched pair logistic regression methods, but with this approach, the assignment of the control value varied among variables. For soil variables, we set the control value as that identified on soil maps by the polygon in which the case occurred. For prey density, vegetation, and site variables, we set the control to the mean value for the ecosystem in which the case occurred. This resulted in some dependence of the case value (i.e., the site selected by the badger) on the type of ecosystem in which that radiolocation occurred. However, the conditional dependence between the case and control is accounted for in matched-pair logistic regression (Hosmer and Lemeshow 2000:223).

We modified or transformed some of the variables that we examined for a variety of reasons. Because logistic regression estimation requires either binary or continuous data (Hosmer and Lemeshow 2000:57), we created binary design variables for 10 categorical variables for the within-home range (Appendix 1) and 3 categorical variables for the within-ecosystem analyses (Appendix 2), with the reference value for each binary design variable set to the most frequently observed category. Some variables did not have logistic relationships (i.e., S-curves) with the probability of use, which is a requirement for the use of maximum likelihood logistic regression procedures (Hosmer and Lemeshow 2000:6). In these cases, we transformed the values of the offending variable to fit this criterion. We also included interactions in our models when we believed that the effect of one variable on the probability of use was affected by the value of another variable. We excluded some variables from models because of the lack of independence with other variables in the model (i.e., multicollinearity).

At the within-home range spatial scale, we assessed 28 models for fit, given the data (Table 6). Of these 28 models, 5 included variables that were related to prey habitat suitability, 8 were comprised of soil and surficial material variables, 3 were topographical, 6 models were based on "habitat" categories, and 5 included combinations of prey habitat

Table 6. Candidate set of models used to examine site selection by radio-tagged badgers within the home range between 1999 and 2002 in the Thompson region of British Columbia. See Appendix 1 for definitions of variables. Model components that estimated habitat suitability for prey species list the variables used for each species. THTA = northern pocket gopher (*Thomomys talpoides*); SPCO = Columbian ground squirrel (*Spermophilus columbianus*); MAFL = yellow-bellied marmot (*Marmota flaviventris*).

Model type	Model ID	Variables	Model components
Prey	P1	GRASS*FRIABLE_SOIL + DIST_H2O + T_AGE*SURF_SORT + GRASS*SURF_C_M + HAB_UV_G	THTA: [grassland*friable soils] + SPCO:[streamside+stand age*FG, LG, F parent material] + MAFL:[(colluvium*grassland) + unvegetated]
Prey	P2	DIST_H2O + T_AGE*SURF_SORT + GRASS*SURF_C_M + HAB_UV_G	SPCO:[streamside+stand age*FG, LG, F parent material] + MAFL:[(colluvium*grassland) + unvegetated]
Prey	P3	OPENING*SURF_SORT	SPCO:[% open*FG, LG, F parent material]
Prey	P4	DIST_H2O + T_AGE*SURF_SORT	SPCO:[streamside+stand age*FG, LG, F parent material]
Prey	P5	GRASS*FRIABLE_SOIL + DIST_H2O + T_AGE*SURF_SORT*PREY_ACTIVITY + GRASS*SURF_C_M*PREY_ACTIVITY + HAB_UV_G*PREY_ACTIVITY	same as P1, but with seasonal component for SPCO and MAFL
Habitat	H1	HAB_CF_G + HAB_DF_G + HAB_GW_G + HAB_MF_G + HAB_OF_G + HAB_S_G + HAB_UV_G + HAB_W_G	each BCLC habitat category
Habitat	H2	FC_A_FD + FC_D_FD + FC_E_FD + FC_NP_FD + FC_P_FD + FC_OC_FD + FC_UR_FD + FC_W_FD	forest cover category
Habitat	H3	HAB2_FOR_G + HAB2_WET_G + HAB2_UNV_G + HAB2_SHR_G + HAB2_UNK_G	reduced BCLC habitat categories
Habitat	H4	T_AGE	stand age
Habitat	H5	OPENING	% open
Habitat	H6	GRASS	in grassland unit
Soils	S1	SOIL_S_L + SOIL_Z + L + SOIL_C_L + SOIL_O_L	soil texture
Soils	S2	DRAIN_R_M + DRAIN_W_M + DRAIN_VP_M	soil drainage

Model type	Model ID	Variables	Model components
Soils	S3	SURF_C_M + SURF_F_M + SURF_FG_M + SURF_LG_M + SURF_O_M + SURF_RO_M	parent material
Soils	S4	COARSE_H_M + COARSE_L_M	coarse fragment content
Soils	S5	SLOPE_G_M + SLOPE_S_M + SLOPE_V_S	slope of unit
Soils	S6	SURF_SORT	parent material is sorted during deposition
Soils	S7	SOIL_S_L + SOIL_Z + L + SOIL_C_L + SOIL_O_L + COARSE_H_M + COARSE_L_M	soil texture and coarse fragment content
Soils	S8	FRIABLE_SOIL	friable soil
Topography	T1	ELEV + DIST_H2O + DIST_PAVE + SITE_C_M + SITE_U_M + SITE_L_M + SITE_T_M + SITE_D_M + SITE_F_M + SITE_K_M	elevation, distance to water, distance to pavement, slope position
Topography	T2	SITE_C_M + SITE_U_M + SITE_L_M + SITE_T_M + SITE_F_M + SITE_K_M	slope position
Topography	T3	DIST_H2O*PREY_ACTIVITY	distance to water in relation to season
Soils + Habitat	C1	SOIL_S_L*OPENING + SOIL_Z_L*OPENING + SOIL_C_L*OPENING + SOIL_O_L*OPENING	soil texture in relation to opening
Habitat + Topography	C2	ROW*CROWN_CLOSURE + OPENING	in road right-of-way in relation to crown closure, and opening
Soils + Activity	C3	PREV_LOCATION*PREY_ACTIVITY + FRIABLE_SOIL	previous radiolocation in relation to season, friable soil
Combination	C4	FRIABLE_SOIL + GRASS*FRIABLE_SOIL + DIST_H2O + T_AGE*SURF_SORT + GRASS*SURF_C_M + HAB_UV_G	Rahme et al. (1995): friable soil (loamy or silty soil with low coarse fragments) and prey
Combination	C5	SURF_C_M + CAN_CLOSE + DRAIN_W_M + T_AGE + SITE_INDEX + ELEV + SURF_FG_M + LOAMY + FC_NP_FD	Apps et al. (2002): colluvium, canopy closure, well-drained soils, forest age (surrogate for age classes), site index, elevation, glaciofluvial parent material, loamy soils (surrogate for FSL), non-productive (surrogate for open range)
Global	Global	ELEV + DIST_H2O + DIST_PAVE + SITE_C_M + SITE_U_M + SITE_L_M + SITE_T_M + SITE_D_M + SITE_F_M + SITE_K_M + GRASS*FRIABLE_SOIL + DIST_H2O + T_AGE*SURF_SORT*PREY_ACTIVITY + GRASS*SURF_C_M*PREY_ACTIVITY + HAB_UV_G*PREY_ACTIVITY	All non-multicollinear variables

Table 7. Candidate set of models used in the examination of patch selection within ecosystems by radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia. See Appendix 1 for definitions of variables.

Model type	Model ID	Variables	Model components
Prey	P-P4	MV_DENSITY + SPCO_DENSITY+ THTA_DENSITY	Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign
Prey	P-P3	SPCO_DENSITY	Density of Columbian ground squirrel sign
Soils	P-S1	SOIL_S_L + SOIL_Z_L + SOIL_C_L + COARSE_L_M + COARSE_H_M	Soil texture and coarse fragment content
Soils	P-S2	SOIL_S_L + SOIL_Z_L + SOIL_C_L	Soil texture
Soils	P-S3	COARSE_L_M + COARSE_H_M	Coarse fragment content
Site	P-SF1	SITE_SLOPE	Slope
Vegetation	P-V1	TREE_COVER + SHRUB_COVER + HERB_COVER	Tree, shrub, and herb cover
Vegetation	P-V2	TREE_COVER + SHRUB_COVER + GRAZE_H_M + GRAZE_VH_M	Tree and shrub cover, high levels of grazing
Vegetation	P-V3	GRAZE_N_M + GRAZE_L_M + GRAZE_H_M + GRAZE_VH_M	Grazing pressure
Prey + Soils	P-C1	MV_DENSITY + SPCO_DENSITY+ THTA_DENSITY + SOIL_S_L + SOIL_Z_L + SOIL_C_L	Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign and soil texture
Prey + Soils	P-C2	MV_DENSITY + SPCO_DENSITY+ THTA_DENSITY + COARSE_L_M + COARSE_H_M	Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign and coarse fragment content
Global	P-Global	TREE_COVER + SHRUB_COVER + HERB_COVER + SOIL_S_L + SOIL_Z_L + SOIL_C_L + COARSE_L_M + COARSE_H_M + MV_DENSITY + SPCO_DENSITY + THTA_DENSITY + SITE_SLOPE + SITE_ASPECT + GRAZE_N_M + GRAZE_L_M + GRAZE_H_M + GRAZE_VH_M	Global model

suitability, soil and surficial material, and topographical variables. The global model included all variables, except for those that were multicollinear.

At the patch spatial scale, we assessed 12 models for fit, given the data (Table 7). Of these 12 models, 2 included variables that were related to density of prey sign, 2 were comprised of variables that characterized soil features, 1 was related to site factors, 3 models were based on vegetation, and 2 models included variables that related to prey sign and soil characteristics. The global model included all variables, except for those that were multicollinear.

Model selection

We calculated the AIC_c score (Burnham and Anderson 2001) for each model and ranked the relative support for each by comparing the scores among competing models for each badger. For each model in the candidate set, we calculated the log likelihood (log $\mathcal{L}$), number of estimated parameters (K), second-order Akaike information criterion (AIC_c, Burnham and Anderson 1998), difference between AIC_c score and the minimum AIC_c score for the candidate set (Δ_{AICc}), and Akaike weight (strength of evidence, w_i; Burnham and Anderson 1998). We then identified the best model for each animal from the candidate set by selecting the model with the lowest AIC_c score. We used Akaike weights (w_i) to quantify strength of evidence about model-selection uncertainty among the candidate set of models for each badger and constructed 95% confidence sets of models for each badger based on the Akaike weights. That is, we identified a set of models in which we were 95% confident that the true best model occurred. We used multi-model inference (Burnham and Anderson 1998) to estimate model-averaged parameters and unconditional 95% confidence intervals in the production of a best predictive model for each individual. We also calculated the renormalized predictor weight ($w_{+(j)}$); Burnham and Anderson 1998:327) of each variable to assess the relative importance of each variable in affecting site selection among radio-tagged badgers. We considered the best model to be "definitive" when its Akaike weight was at least 3 times greater than the next best model.

RESULTS

We collected sufficient data to examine habitat relationships for 8 radio-tagged badgers between 1999 and 2002. Radio-tagged badgers occurred in 10 biogeoclimatic units (Table 8) and all of the badgers, except B12, had some grassland or open forest biogeoclimatic units within their home ranges.

Within-home range selection

We collected sufficient radiolocations to examine the factors that affected selection of sites within the home range for 8 radio-tagged badgers (7 M, 1 F). We collected between 23 and 83 radiolocations that were suitable for this analysis (i.e., those with error polygons less than 1.5 ha) for each badger ($\bar{x}$ = 40 radiolocations, SD = 19, n = 8).

The model selection process identified 7 different best models for the 8 radio-tagged badgers (Table 9). Two of the best models were those that attempted to capture habitat suitability for Columbian ground squirrels; this model was based on an interaction between percent opening and sorted parent materials (i.e., fluvial, glaciofluvial, and glaciolacustrine deposits). All of the best models included some component of soil characteristic, except for

Table 8. Proportions of home ranges in each biogeoclimatic unit for 8 radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia. Grassland units: BGxh2, BGxw1, IDFxh2a; open forest units: PPxh2, IDFxh2; forested units: IDFdk1, IDFdk2, IDFmw2, MSdm2, ESSFdc2.

Badger	Biogeoclimatic unit[a] (proportion of home range)									
ID	BGxh2	BGxw1	IDFxh2a	PPxh2	IDFxh2	IDFdk1	IDFdk2	IDFmw2	MSdm2	ESSFdc2
B03				0.19	0.71		0.06	0.05		
B05	0.29	0.20			0.09	0.43				
B06		0.07		0.91	0.02					
B08		0.96	0.04							
B09	0.21	0.43		0.09	0.27					
B10	0.67	0.29		0.04						
B12									0.82	0.18
B14	0.15	0.58		0.13	0.13					

a from Lloyd et al. (1990)

B12. The 95% confidence set of best models for each radio-tagged badger included between 1 and 18 models ($\bar{x}$ = 13, SD = 7, *n* = 8; Appendix 7). The number of models in the 95% confidence set was somewhat related to the number of radiolocations used in the analysis (r^2 = 0.42).

Model-averaged parameterization of the best models for each badger (Table 10) illustrated considerable variability. Only 3 of 25 of the parameterized variables in the best models had 95% confidence intervals that did not include an odds ratio of 1. That is, only 3 of the 25 variables had consistently positive or negative associations with probability of use.

For all badgers combined, the predictor weight of the variables indicated that friable soil, distance from water, and percent opening most affected site selection among badgers within their home ranges (Table 11). However, the parameterization of these variables was considerably variable both within and among badgers.

Patch selection

We collected habitat information at 167 radiolocations of 8 radio-tagged badgers ($\bar{x}$ = 21 radiolocations, range: 13 - 27, *n* = 8). The model selection process identified 6 different best models among the 8 badgers (Table 12). Variables accounting for soil characteristics (i.e., soil texture or coarse fragment content) comprised 4 of the best models, whereas models that included measures of prey sign were identified as the best model for 2 badgers. Models that included slope or vegetation cover (i.e., tree, shrub, and herb cover) variables were identified as the best model for 1 badger each.

Between 2 and 8 models were identified within the 95% confidence set of best models for each badger ($\bar{x}$ = 4, SD = 2, *n* = 8; Table 12). The best model was definitive for 6 of the 8 badgers; in these cases it was at least 3 times more probable to be the actual best model as the second-best model. For the other 2 badgers (B08, B12), between 3 and 4 models were similarly likely to be the best model. Of the 28 models that comprised the 95% confidence sets for the 8 badgers, 14 were based on soil attributes, 5 were based on prey and soil

Table 9. Best models explaining site selection within the home range of each radio-tagged badger monitored between 1999 and 2002 in the Thompson region of British Columbia.

Badger ID	Sex	Model ID	Model	Model components	log($\mathcal{L}$)	K	AIC_c	Δ_i	Competing models[a]
B03	M	C5	SURF_C_M + CROWN_CLOSURE + T_AGE + SITE_INDEX + ELEV + SURF_FG_M + LOAMY + FC_NP_FD	Apps et al. (2002): colluvium, canopy closure, well-drained soils, forest age (surrogate for forest age classes), site index, elevation, glaciofluvial parent material, loamy soils (surrogate for FSL), non-productive sites (surrogate for open range)	-2.77	8	26.19	1.00	0
B05	M	C4	FRIABLE_SOIL + GRASS*FRIABLE_SOIL + DIST_H2O + T_AGE*SURF_SORT + GRASS*SURF_C_M + HAB_UV_G	Rahme et al. (1995): friable soil (loamy or silty soil with low coarse fragments) and prey	-19.92	6	52.95	0.74	1
B06	F	P3	OPENING*SURF_SORT	SPCO:[% open*FG, LG, F parent material]	-22.51	1	47.13	0.42	13
B08	M	S1	SOIL_S_L	soil texture	-15.94	1	34.07	0.09	17
B09	M	S2	DRAIN_R_W + DRAIN_M_W	soil drainage	-16.65	2	37.68	0.29	15
B10	M	P3	OPENING*SURF_SORT	SPCO:[% open*FG, LG, F parent material]	-18.83	1	39.81	0.16	16
B12	M	C2	ROW*CROWN_CLOSURE + OPENING	in road right-of-way in relation to crown closure, opening	-12.15	2	28.89	0.33	14
B14	M	C3	DIST_PREV*PREY_ACTIVITY + FRIABLE_SOIL	previous radiolocation in relation to season, friable soil	-27.48	2	59.23	0.35	7

a Number of other models in the 95% confidence set of best models for each badger.

Table 10. Model-averaged parameterization of the best model explaining site selection within home ranges for each radio-tagged badger that was monitored between 1999 and 2002 in the Thompson region of British Columbia.

Badger ID	Parameter	Model-averaged parameter estimate	Unconditional SE	Odds ratio[a]	Odds ratio 95% CI Lower	Odds ratio 95% CI Upper
B03	FC_NP_FD	232.52	43,102.21	>1000	0.00	>1000
	SURF_C_M	126.71	61,538.71	>1000	0.00	>1000
	SURF_FG_M	14.88	1,701.38	>1000	0.00	>1000
	T_AGE	-38.22	63,241.48	0.00	0.00	>1000
	ELEV	-1.34	109.37	0.00	0.00	>1000
	SITE_INDEX	7.51	645.42	>1000	0.00	>1000
	CROWN_CLOSURE	-4.23	376.73	0.00	0.00	>1000
	LOAMY	-62.23	29,265.72	0.00	0.00	>1000
B05	DIST_H2O	-0.01	239.40	0.77	0.00	>1000
	FRIABLE_SOIL*GRASS	2.22	1.17	9.22	0.92	92.17
	SURF_SORT*T_AGE	11.49	0.33	>1000	>1000	>1000
	HAB_UV_G	-7.83	0.02	0.00	0.00	0.00
	GRASS*SURF_C_M	-8.76	0.70	0.00	0.00	0.00
	FRIABLE_SOIL	1.40	1.43	4.07	0.25	66.60
B06	OPENING*SURF_SORT	0.08	0.04	1.48	1.00	2.19
B08	SOIL_S_L	-17.56	670.79	0.00	0.00	>1000
B09	DRAIN_M_W	-16.08	0.83	0.00	0.00	0.00
	DRAIN_R_W	-29.45	0.01	0.00	0.00	0.00
B10	OPENING*SURF_SORT	-0.18	0.27	0.41	0.03	5.72
B12	OPENING	0.02	35.88	1.10	0.00	>1000
	CROWN_CLOSURE*ROW	0.75	0.40	43.19	0.90	>1000
B14	FRIABLE_SOIL	-1.52	1.23	0.22	0.02	2.45
	DIST_PREV*PREY_ACTIVITY	0.00	0.01	0.99	0.72	1.37

a Change in likelihood of use with 1-unit increase in value of parameter, except for CROWN_CLOSURE, OPENING, OPENING*SURF_SORT, and CROWN_CLOSURE*ROW (5-unit increase), DIST_H2O and DIST_PREV*PREY_ACTIVITY (25-unit increase), and ELEV (100 m increase).

Table 11. Relative importance of the 10 most influential variables that affected site selection within home ranges by 8 radio-tagged badgers between 1999 and 2002 in the Thompson region of British Columbia. Variables with higher predictor weight had greater influence on site selection.

Variable	Variable description	Renormalized predictor weight (w+(j))
FRIABLE_SOIL	loamy or silty soil and low coarse fragments (<20%)	0.083
DIST_H2O	distance from any water feature identified in TRIM (m)	0.068
OPENING	% of sky not obstructed by trees (100 - CROWN_CLOSURE)	0.057
T_AGE	1 if stand age <=5, decreasing at 0.036/year until age 30, then constant at 0.1	0.044
HAB_UV_G	BC land cover habitat category was unvegetated, with reference to grassland units	0.043
FC_NP_FD	forest cover label was non-productive, with reference to Douglas-fir units	0.042
DIST_PREV* PREY_ACTIVITY	distance from previous radiolocation in relation to activity of prey	0.036
SURF_FG_M	parent materials were glaciofluvial, with reference to morainal materials	0.035
SURF_C_M	colluvial parent materials colluvial, with reference to morainal materials	0.035
SURF_SORT* T_AGE	parent material was FG, LG, F, or E in relation to transformed stand age	0.034

Table 12. 95% confidence set of best models explaining selection of patches within ecosystem units by radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia. Best model for each badger is identified by bold font.

Badger ID	Sex	Model ID	Model components	log($\mathcal{L}$)	K	AIC$_c$	Δ_i	w_i
B03	**M**	**P-S2**	**Soil texture**	**-1.40**	**3**	**10.97**	**0**	**0.726**
		P-P3	Density of Columbian ground squirrel sign	-6.05	1	14.40	3.43	0.131
		P-S1	Soil texture and coarse fragment content	-1.39	4	14.78	3.81	0.108
B05	**M**	**P-P4**	**Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign**	**-1.65**	**3**	**10.45**	**0**	**0.738**
		P-C2	Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign and coarse fragment content	-1.32	4	12.64	2.19	0.247
B06	**F**	**P-S3**	**Coarse fragment content**	**-2.77**	**1**	**7.81**	**0**	**0.894**
		P-S1	Soil texture and coarse fragment content	-1.39	4	14.11	6.30	0.038
		P-S2	Soil texture	-3.20	3	14.24	6.42	0.036
B08	**M**	**P-SF1**	**Slope**	**-5.70**	**1**	**13.77**	**0**	**0.289**
		P-S2	Soil texture	-2.77	3	14.21	0.44	0.232
		P-S1	Soil texture and coarse fragment content	-0.70	4	14.40	0.63	0.211
		P-S3	Coarse fragment content	-7.03	1	16.42	2.65	0.077
		P-C2	Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign and coarse fragment content	-3.90	3	16.47	2.70	0.075
		P-V1	Tree, shrub, and herb cover	-5.95	2	17.11	3.34	0.054
		P-V2	Tree and shrub cover, high levels of grazing	-6.02	2	17.23	3.46	0.051
B09	**M**	**P-V1**	**Tree, shrub, and herb cover**	**-5.48**	**3**	**18.05**	**0**	**0.799**
		P-V2	Tree and shrub cover, high levels of grazing	-5.59	4	21.09	3.04	0.175
B10	**M**	**P-S2**	**Soil texture**	**-5.55**	**2**	**15.62**	**0**	**0.647**
		P-S1	Soil texture and coarse fragment content	-5.45	3	17.99	2.37	0.198

Badger ID	Sex	Model ID	Model components	log($\mathcal{L}$)	K	AIC$_c$	Δ_i	w_i
		P-C1	Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign and soil texture	-2.76	5	18.52	2.89	0.153
B12	**M**	**P-S1**	**Soil texture and coarse fragment content**	**-3.47**	**3**	**14.66**	**0**	**0.398**
		P-S3	Coarse fragment content	-6.24	1	14.73	0.07	0.384
		P-C2	Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign and coarse fragment content	-2.78	4	16.63	1.97	0.148
		P-S2	Soil texture	-6.93	2	18.66	4.01	0.054
B14	**M**	**P-P4**	**Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign**	**-2.21**	**3**	**11.55**	**0**	**0.681**
		P-C2	Density of mice/vole, Columbian ground squirrel, and northern pocket gopher sign and coarse fragment content	-2.13	4	14.27	2.71	0.176
		P-S2	Soil texture	-4.16	3	15.47	3.91	0.096

attributes, 4 were based on vegetation attributes, 3 were based on prey attributes, and 1 was based on site factors.

The model-averaged parameterizations of the best models for each badger illustrated some consistencies in the effects of several variables on selection for patches within ecosystems for all badgers (Table 13). Both of the badgers for which COARSE_L_M was in their best model (B06, B12) showed extremely strong positive responses with this variable, indicating that these badgers selected strongly for sites with less than 20% coarse fragments when they used ecosystems that were typified by coarse fragment contents >20%. All 3 badgers for which SOIL_Z_L was in their best model (B03, B10, B12) also showed extreme positive selection for sites with silty soil, relative to loamy soils.

However, we noted several differences among badgers in the effect of several variables on patch selection. The 2 badgers for which SOIL_C_L was in their best model had different responses to clayey sites; B10 strongly avoided sites within ecosystems that were clayey relative to loamy, whereas B03 showed a very strong positive selection for sites that were more clayey than expected. This same dichotomy occurred with the SOIL_S_L variable, whereby B12 selected sites that were sandy more than expected and B03 selected sandy sites less than expected.

Although models that included density of sign of different prey species were selected as the best for 2 badgers (B05, B14), the variability about the parameter estimates for these models was sufficiently large that we could not definitively determine the effect of these variables on site selection. The same trend held true for the best model selection for B09 (vegetation cover) and B08 (slope gradient).

Soil characteristics played the most substantial role in the selection of sites within ecosystems among the radio-tagged badgers (Table 14). Coarse fragment content (COARSE_L_M) and soil texture (SOIL_Z_L, SOIL_C_L, SOIL_S_L) were the most important variables affecting selection of patches within ecosystem units. Variables that reflected the density of prey sign (MV_DENSITY, THTA_DENSITY, SPCO_DENSITY) were the second-most important group of variables, whereas grazing intensity variables (GRAZE_N_M, GRAZE_L_M, GRAZE_H_M, GRAZE_VH_M) were the least important. We did not consider COARSE_H_M because soils with high coarse fragment content did not occur for many of the badgers and was thus under-represented in the modelling process.

Burrow descriptions

We identified 172 burrows used by 10 radio-tagged badgers and collected information on between 1 and 28 burrows for each badger ($\bar{x}$ = 17, SD = 10, n = 172). The entrances to the burrows were, on average, 24.3 cm in width (SD = 5.8 cm, n = 108) and 19.6 cm in height (SD = 4.9 cm, n = 108). The soil texture at burrows (Fig. 10a) was primarily silty (83 of 166 burrows), followed by loamy (43 burrows), clayey (28 burrows) and sandy (13 burrows). Coarse fragment content at burrows (Fig. 10b) was typically low (<20% coarse fragments, 123 of 163 burrows), although some burrows had coarse fragment contents that were moderate (20 – 50% coarse fragments, 34 of 163) or high (>50% coarse fragments; 6 of 163 burrows). The soil moisture regimes (Resources Inventory Committee 1998d) of burrow sites (Fig. 10c) were predominately submesic (53 of 143 burrows) and mesic (47 burrows),

Table 13. Model-averaged parameterization of best models to explain selection of patches within ecosystem units for each radio-tagged badger monitored between 1999 and 2002 in the Thompson region of British Columbia.

Badger ID	Parameter	Model-averaged parameter estimate	Unconditional SE	Odds ratio[a]	Odds ratio 95% CI Lower	Odds ratio 95% CI Upper
B03	SOIL_C_L	14.10	1.31	>10,000	>10,000	>10,000
	SOIL_S_L	-7.70	0.10	0.00	0.00	0.00
	SOIL_Z_L	5.92	1.33	373.70	27.58	5063.13
B05	SPCO_DENSITY	0.87	1.00	78.20	0.00	>10,000
	MV_DENSITY	0.05	3.80	1.69	0.00	>10,000
	THTA_DENSITY	-1.18	2.12	0.00	0.00	>10,000
B06	COARSE_L_M	14.95	0.49	>10,000	>10,000	>10,000
B08	SITE_SLOPE	-0.25	0.13	0.28	0.08	1.01
B09	TREE_COVER	-1.37	2.90	0.00	0.00	>10,000
	SHRUB_COVER	0.21	8.37	2.82	0.00	>10,000
	HERB_COVER	-0.01	45.98	0.94	0.00	>10,000
B10	SOIL_C_L	-8.91	0.54	0.00	0.00	0.00
	SOIL_Z_L	8.89	0.11	7292.50	5883.49	9038.95
B12	COARSE_L_M	11.52	3.04	>10,000	261.27	>10,000
	SOIL_S_L	8.83	1.51	6838.20	354.29	>10,000
	SOIL_Z_L	9.39	1.38	>10,000	807.91	>10,000
B14	SPCO_DENSITY	-0.31	2.32	0.22	0.00	>10,000
	MV_DENSITY	0.38	6.76	43.89	0.00	>10,000
	THTA_DENSITY	-0.35	8.65	0.03	0.00	>10,000

a Change in likelihood of use with 1-unit increase in value of parameter, except for SPCO_DENSITY, SITE_SLOPE, TREE_COVER, SHRUB_COVER, and HERB_COVER (5-unit increase), and MV_DENSITY and THTA_DENSITY (10-unit increase).

Table 14. Relative importance of variables that most affected selection of patches within ecosystem units by 8 radio-tagged badgers between 1999 and 2002 in the Thompson region of British Columbia. Variables with higher predictor weight had greater influence on site selection.

Parameter		Renormalized predictor weight ($w_+(j)$)
COARSE_L_M	coarse fragment was low (<20%), with reference to moderate levels (20-50%) of coarse fragments	0.158
SOIL_Z_L	soils were silty, with reference to loamy soils	0.156
SOIL_C_L	soils were clayey, with reference to loamy soils	0.124
SOIL_S_L	soils were sandy, with reference to loamy soils	0.113
MV_DENSITY	density of mice or vole burrows on 4 1-m wide transects emanating from used burrow	0.096
THTA_DENSITY	density of northern pocket gopher burrows on 4 1-m wide transects emanating from used burrow	0.096
SPCO_DENSITY	density of Columbian ground squirrel burrows on 4 1-m wide transects emanating from used burrow	0.094
SHRUB_COVER	% cover of shrubs in the B layer	0.045
TREE_COVER	% cover of shrubs in the A layer	0.035
HERB_COVER	% cover of shrubs in the C layer	0.033
SITE_SLOPE	slope gradient of patch surrounding burrow (%)	0.029
GRAZE_H_M	grazing pressure was high (66-80% utilization), with reference to medium pressure (36-65% utilization)	0.012
GRAZE_VH_M	grazing pressure was very high (>80% utilization), with reference to medium pressure (36-65% utilization)	0.006
GRAZE_N_M	grazing pressure was nil (0% utilization), with reference to medium pressure (36-65% utilization)	0.001
GRAZE_L_M	grazing pressure was low (16-35% utilization), with reference to medium pressure (36-65% utilization)	0.001

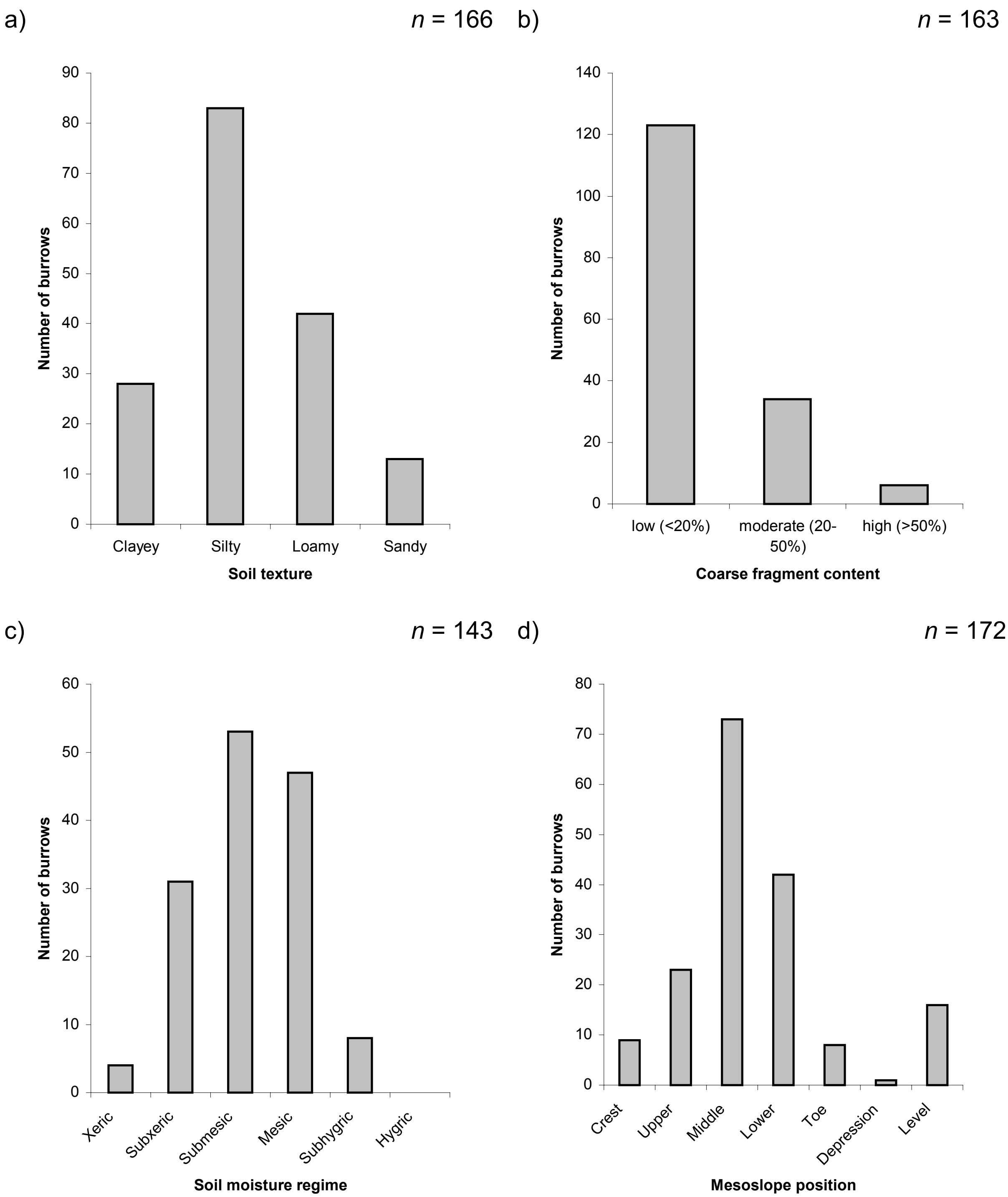

Figure 10. Use of sites for burrowing by radio-tagged badgers by a) soil texture, b) coarse fragment content, c) relative soil moisture regime, and d) mesoslope position between 1999 and 2002 in the Thompson region of British Columbia. Sample sizes varied because not all data could be collected for each burrow.

followed by subxeric (31 burrows), subhygric (8 burrows), and xeric (4 burrows). Sites used by badgers for burrowing ranged from flat (0% slope) to 116% slope ($\bar{x}$ = 29%, SD = 25%, n = 166) and occurred primarily at middle (73 of 172 burrows) and lower (42 burrows) mesoslope positions (Fig. 10d). The aspect of the burrows was generally southerly ($\bar{x}$ = 170°), however variability about this average was large (circular SD = 139°, n = 166). Burrows were associated with, on average, 42% herbaceous cover (SD = 25%, n = 158), 14% shrub cover (SD = 15%, n = 157), and 4% tree cover (SD = 8%, n = 153).

We excavated the natal burrow of a female badger that was struck and killed on the TransCanada Highway in May 2001. The single entrance to the burrow was through a tunnel dug into silty soil at an angle of decline of 19°. The tunnel began as an elliptical shape with a major axis of 30 cm and slightly widened in size to 35 cm after 160 cm, after which it opened up into a main chamber. The main chamber was approximately 125 cm in width, 62 cm in depth, and 40 cm in height and was excavated around a small (15 cm diameter) gas pipeline. From this main chamber, 5 narrower chambers led off. Three of these side chambers (each about 25 cm diameter) were short blind cavities, which had depths of 25 cm, 42 cm, and 60 cm, respectively. The 2 larger chambers were dug parallel and adjacent to the gas pipeline. The smaller chamber was comprised of loosely packed soil containing a few scats. This chamber extended approximately 100 cm and may have been used as a latrine. The largest side chamber was very extensively filled with loose soil and scats. It extended at least 354 cm along the gas pipeline and likely much farther. The height and width of this chamber were somewhat larger than the other chambers (about 50 cm diameter).

Re-use of sites

All of the radio-tagged badgers for which we collected >25 temporally independent radiolocations (i.e., separated by > 9 hours) exhibited some re-use of sites (i.e., same burrow or burrow complex with multiple entrances). We documented radio-tagged badgers using most sites only once (82%, 229 of 280 sites, n = 371 radiolocations). Conversely, at least 18% of sites were re-used at some point; we documented badgers re-using sites once (29 sites), twice (12 sites), 3 times (7 sites), and 4, 5, and 7 times (1 site each). Not surprisingly, the number of re-uses of each site appeared to be related to the number of radiolocations that we collected for each badger (r^2 = 0.58, slope of line = 0.22, n = 8). This relationship suggests that, on average, radio-tagged badgers re-used their burrows about 22% of the time during the duration of this study.

DISCUSSION

Radio-tagged badgers in our study showed varying degrees of selection for foraging and burrowing habitat at the 2 spatial scales that we examined. We detected best models that were definitive for more badgers at the patch spatial scale than we did at the within-home range spatial scale (Table 15). Thus, our data suggested that badgers selected primarily for atypical patches within ecosystem units, although some selection was evident for ecosystem units within home ranges for some badgers. The model selection processes indicated that soil characteristics were the most important variables affecting site selection at both spatial scales. Our descriptions of burrows used by badgers indicated that the selection of burrowing sites may be strongly affected by soil characteristics.

Table 15. Summary of scale-dependent habitat selection by radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia. Definitive best models were those for which the identified best model was >3 times as likely to be the actual best model as the next best model.

	Best model	
Badger ID	Patch scale	Stand scale
B03	Soil	Soil + prey + site factors
B05	Prey	Soil + prey
B06	Soil	Prey[a]
B08	Site factor[a]	Soil[a]
B09	Vegetation	Soil[a]
B10	Soil	Prey[a]
B12	Soil[a]	Generic[a]
B14	Prey	Soil + other[a]

a non-definitive best model

Within-home range selection

The badgers that we radio-tagged showed considerable variability in the factors that affected their selection of sites within their home ranges. Many different best models were identified among individuals as describing within-home range selection. However, none of the models were particularly useful as a predictive tool because the parameterizations of the variables had 95% confidence intervals that included 1 (i.e., no consistent effect).

Interestingly, the best models for 2 of the badgers were those predicted by other researchers. The definitive best model for B03 was that suggested by Apps et al. (2002), which included many soil, terrain, topographic, and vegetation parameters. The definitive best model for B05 was that suggested by Rahme et al. (1995), which included friable soil and prey habitat suitability. This indicates that, for these badgers, patterns of selection that we observed were similar to badgers elsewhere.

The complexity of the best model that was selected for each badger appeared to be related to the number of radiolocations that was used in the analysis. It appeared that more data allowed for the selection of a more complex model, a trend that was noted by Burnham and Anderson (1998:115). Also, because this was an exploratory analysis of habitat selection by badgers, our candidate set of models included many, slightly different models. Such a large candidate set may have diminished our abilities to definitively identify a single best model (i.e., best model >3 times more likely than next best model).

Our failure to detect substantial and consistent selectivity for sites within the home range by radio-tagged badgers may have resulted from several factors. Badgers in the Thompson region of British Columbia may not express selectivity for burrowing and foraging resources at the scale of their home range. In this situation, the selection of sites and ecosystems within the home range may be dictated by social factors, such as the presence of conspecifics (e.g., intruders or mating opportunities) or territorial movements. Male and female badgers may select habitat based on different resources. Badgers may have selected sites within their home ranges based on other habitat features that we did not measure. The VRI, FIP, TRIM, and terrain maps may not have accurately captured the variables that we used in the analysis.

Finally, our modelling of prey suitability may not have translated into actual prey on the ground, perhaps because prey abundance was not predictable from mapped variables.

Patch scale selection

We observed much stronger and consistent selection for foraging and burrowing resources at the patch spatial scale than within the home range. At the patch scale, soil characteristics appeared to be the most important variables dictating site selection for several badgers. The radio-tagged badgers that we followed often selected atypical patches within ecosystem units in which to dig burrows and forage for prey. Perhaps this is the scale at which badgers select burrows as well as the scale at which they select foraging areas.

Because badgers may rest in the same burrows that they excavate in pursuit of prey, it was difficult to discern the exact causal process that dictated selection. We detected considerable patch-scale selection for sites with abundant prey. In Idaho, badger burrows were more highly correlated with prey holes (Todd 1980). Indeed, Minta (1993) observed that badgers in Wyoming were associated with deep silty soils, a relationship that he attributed to the abundance of prey in these areas, but which may have been partially attributable to the badgers selecting for soil characteristics.

The lack of effect of grazing intensity on site selection within ecosystems suggests that this is not a substantial factor that affects selection at this scale. In Idaho, Todd (1980) also looked at the effects of grazing intensity on badger burrowing and prey and failed to detect a relationship. However, lack of an effect at the within-ecosystem scale does not imply that grazing does not affect habitat use by badgers; a relationship may be expressed under different conditions, or at another scale.

The selection among soil textures is probably related to the physical properties of the different soil textures. Each general type of soil texture has specific properties that affect its ability to remain cohesive and provide an amenable microenvironment for subterranean living (B. Chapman, British Columbia Ministry of Forests, personal communication). Because of the low surface area to volume ratio of the particles, sandy soils do not likely have sufficient cohesive strength, except when wet, to support burrows. Conversely, clayey soils have such high surface area to volume ratios that separating soil particles is difficult. Silts, however, have moderate surface area to volume ratios, which results in soils having strong cohesive strength, but not so strong that particles cannot be easily separated. Additionally, the hydraulic conductivity of silt is much higher than either sandy or silty soils. This means that silts are able to wick away the moisture produced by a respiring animal, whereas the humidity levels in sands and clays may quickly approach saturation. Thus, the selection of suitable soil textures may have profound implications for the energetic costs of digging, the structural stability of the excavated burrow, and the energetic costs of life underground.

Conclusions

Habitat for North American badgers has been loosely defined by several authors as areas that support sufficient fossorial prey (e.g., Messick 1987, Todd 1980), and badgers have been widely expected to select areas on the basis of food availability (Messick 1987). Todd (1980) documented an association between Belding ground squirrels (*Spermophilus beldingi*) and badger burrows, and he postulated that this relationship occurred because badgers select areas with abundant ground squirrels as prey. Our results, however, suggest that the suitability of soils for digging plays a role in the selection of sites within the home range and for atypical patches within ecosystem units.

We detected less selectivity at the within-home range spatial scale than at the patch spatial scale. In the East Kootenay region of British Columbia, researchers have also noted that selectivity at the within-home range scale was less than that at other spatial scales (Apps et al. 2002). This result may have occurred because important resource selections occur at either finer or coarser spatial scales. For instance, it is reasonable that badgers may establish their home ranges, at least partially, based on the abundance of prey. In this situation, prey may be distributed throughout a home range in a manner such that selecting one ecosystem unit over another is not necessary because all ecosystem units contain prey.

Our results suggest that badgers in the Thompson region of British Columbia make the majority of their selection decisions for foraging or burrowing at small spatial scales. Generally, more consistent and predictable selectivity for these resources appeared to occur at finer spatial scales. We also noted that badgers appeared to have some specific habitat requirements for sites in which they burrowed, although some flexibility was evident among site features.

Selection for foraging and burrowing resources by radio-tagged badgers in the Thompson region may be compensatory. That is, individual badgers tended to select for burrowing resources at one spatial scale and foraging resources at another (Table 15). For example, the best model to describe selection within the home range for B05 was based on soil friability and predicted prey habitat suitability. However, at the patch spatial scale, this badger showed strong selectivity for the abundance of prey; soil features were not a consistent factor that affected site selection at this scale.

The scale at which badgers exhibited selectivity for each resource is likely dependent upon the distribution of that resource at larger spatial scales. This observation re-enforces the point put forth by Garshelis (2000:129): the factors that affect selectivity by an animal are not only the result of the process of resource selection, but also of the composition of the landscape, home range, or ecosystem unit that is available to the individual. This scale-based limitation affects the applicability of the results to other areas because the selection pattern for one individual may not be relevant to another individual that is exposed to a different distribution of resources. In our study area, the distribution and abundance of foraging and burrowing resources was probably different among the home ranges of the radio-tagged badgers, particularly those occurring in different biogeoclimatic zones. These differences in availability may explain the variability in the best models that we identified at each spatial scale for each badger.

Badgers likely made resource decisions across several spatial scales simultaneously (i.e., elements, patches, ecosystem units, and landscapes), rather than based solely on the distribution of resources at one spatial scale alone. A limitation of our analysis was that we could not examine site selection at multiple spatial scales in the same model. A more effective sampling program would have enabled us to examine selection as a simultaneous multi-scale process, thereby addressing the scale context of Garshelis' (2000) paradox and increasing the applicability of the resultant best models.

The effect of the sex-bias in our sample of radio-tagged badgers on our conclusions is unclear. Patterns of resource selection by females may be more consistent than for males, because females are expected to select areas on the basis of food resources, whereas males are predicted to select areas on the basis of access to females, and less so on food resources (Minta 1990). Thus, the inconsistent selectivity for resources may be due, in part, to our primarily male sample of radio-tagged badgers.

As an exploratory analysis of the habitat factors that affected site selection, our results suggest several relationships that should be examined further. We were unable to assess the factors that affected the selection of home ranges within the landscape. Examining this would have allowed us to determine the factors that affect landscape occupancy, which is particularly relevant to conservation planning for this species. We did not have the entire badger population radio-tagged and our sample of badgers was limited to those areas in which badgers had been previously spotted. Thus, our sample of animals, and their respective home ranges, was biased to these areas. Also, our study involved a threatened and presumably declining population of badgers, so individuals may have been forced to be less selective because only sub-optimal concentrations of resources were available to them.

Management Implications

Land management activities have great potential to impact habitats that badgers use in British Columbia. Changes to undeveloped grasslands, urban development, agricultural crops, and harvesting of forested sites all affect the supply of burrowing and foraging resources for badgers. Because badgers select resources at several spatial scales, knowledge of which habitat requirements can be fulfilled at each scale allows for more effective and flexible management of their habitats.

Badgers rely upon features of ecosystem units, patches, and elements provided by many different types of habitats, particularly those that provide suitable soils for burrowing and adequate prey for foraging. Management that affects soil suitability and prey abundance at these scales will thus affect the quality of badger habitat.

Selectivity by badgers for resources appeared to be compensatory across spatial scales. That is, when using sub-marginal habitats at large spatial scales, badgers appeared to be able to select habitat at smaller spatial scales within the otherwise unsuitable habitat, and thus meet their resource needs. For example, when badgers used ecosystems that generally had poor soils for digging (e.g., a sandy glaciofluvial soil) they used patches with more fine-textured soil within this otherwise poor matrix.

In British Columbia, much of the land on which badgers occur is privately owned and management of badger habitat, at many scales, requires participation by private landowners. Using a scale-based approach, landowners and other land managers may be able to partially compensate for habitat alteration at coarse spatial scales by maintaining habitat at finer scales. That is, if a suitable ecosystem unit is to be developed or otherwise modified, some value can be maintained by retaining patches of suitable habitat within the ecosystem unit.

This multi-scaled approach to habitat management, although flexible, must be applied prudently. Caution should be used with this approach because adequate habitat cannot be maintained solely at small spatial scales. It is unlikely that the cumulative degradation of larger scale habitats (e.g., landscapes, ecosystem units) can be totally compensated at increasingly smaller scales. This scale-based approach may be compensatory to a point because there are 1) increased energetic costs for moving between smaller suitable patches and avoiding a matrix of dangerous habitats, and 2) the life requisites that are met at coarse scales may not always be met at fine scales. Also, forcing badgers to rely on increasingly fewer suitable patches may force them to wander more widely through areas with high mortality risk and further jeopardize the population. The best management practices for badger habitat involves conservation at broader spatial scales because this approach automatically preserves habitats that are required at finer scales. Land management that incorporates the conservation of foraging and burrowing habitat in regional management plans, individual landowner habitat stewardship programs, and urban developments will help ensure the persistence of this endangered carnivore in the province.

3.3 Population Factors

Throughout much of their range, badger populations are considered to be relatively stable or increasing (Messick 1987). However, in the Thompson and Okanagan regions of British Columbia, populations of badgers appear to be in decline, which may be a result of low survival within the population (Rahme et al. 1995). The objective of our research was to identify causes of mortality within a representative population of badgers in the Thompson region. By identifying mortality sources, conservation measures can be developed to reduce the rate of mortality and help expedite recovery of critically endangered populations.

METHODS

We radio-tagged and monitored 13 badgers as outlined in Section 3. When the radiotransmitters began emitting signals at the "mortality" rate, we attempted to collect the carcass for necropsy as soon as possible to determine the cause of death.

RESULTS AND DISCUSSION

Reproduction

The one adult female (B06) that we radio-tagged produced a litter of at least 2 kits. We first observed the 2 kits with B06 on 13 June 2000, 12 days following radio-tagging. The kits stayed with her until at least 7 July, when we caught one of the two kits (B07, female). Both the female and the one kit that we radio-tagged were eventually killed in collisions with vehicles on Highway 5. The fate of the other kit is unknown, although we documented 1 road mortality in 2001 and received several sightings in 2001 and 2002 of a badger in the same area.

Mortalities

We observed a very high rate of mortality among the badgers that we radio-tagged. Six of the 13 badgers died while being monitored and 1 other tagged badger died after the completion of the monitoring (Figure 11). Six of the 7 mortalities of study animals that we documented were the result of collisions with vehicles on highways (5) or trains (1). We observed 1 mortality that may have been the result of predation, but the remains that we discovered were insufficient to determine the cause of death.

Transportation corridors were clearly a major source of mortality for badgers in the Thompson region (Figure 12). Seven of 13 radio-tagged resident badgers that we monitored were killed on roads or railways, as well as at least 13 other untagged badgers between 1999 and 2003. Seven tagged and untagged badgers were killed in a 21 km stretch of the TransCanada Highway between Lafarge and Pritchard in 4 years. Of the 20 badger mortalities that we documented throughout the Thompson and Okanagan regions in the 4 years, 6 were females, 11 were males, and 3 were unidentified. Both adult (7) and juvenile (3) badgers were killed on roads. Most of the mortalities occurred during July (10), followed by May (4), August (3), June (1), and October (1).

We also documented and received many reports of badgers crossing Highway 5, occasionally narrowly missing collisions. We received several reports of a female with 2 kits (presumably B06, B07, and the other untagged kit) crossing the highway and causing

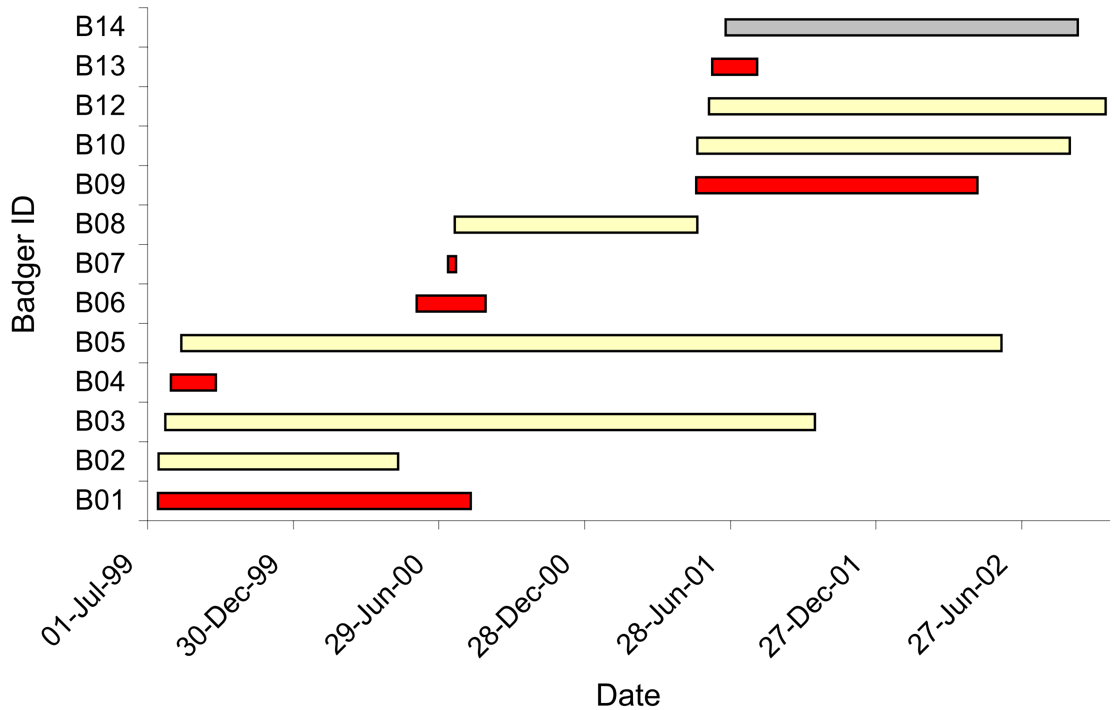

Figure 11. Monitoring history of 13 radio-tagged badgers in the Thompson region of British Columbia. Red bars indicate mortalities that occurred during the study, grey bar indicates mortality after monitoring ended, and clear bars indicate unknown fates. Six of the 7 confirmed mortalities were the result of collisions with vehicles or trains. B06 and B07 were both females; all other badgers were male.

traffic to stop during the summer of 2000. This female had established burrows on either side of Highway 5 at this site, and was located here 10 of 86 (12%) days that she was monitored. Both the female and her female kit were killed attempting to cross Highway 5.

Age did not seem to be a factor that affected susceptibility of badgers to collisions with vehicle traffic in our study. B01 was an adult male that had been tagged for more than 1 year before he was struck on the road in 2000. B03 (another adult male) was observed crossing the highway repeatedly, including one instance where he narrowly avoided being killed. Dispersing badgers, however, may be at greater risk to road mortality because of their inexperience with traffic and wide-ranging movements while transient.

The survival of badgers in the Thompson region may be related to the density of paved roads within their respective home ranges (Table 16) and, more specifically, the type of roads passing through their home ranges. B10 had a small portion of the TransCanada Highway passing through his home range, but most of the paved roads were municipal roads that had speed limits of 50 km/h. Other badgers had either the TransCanada Highway or Highway 5 running through their home ranges, both of which have peak traffic volumes during the summer months (B. Persello, British Columbia Ministry of Transportation and Highways, personal communication).

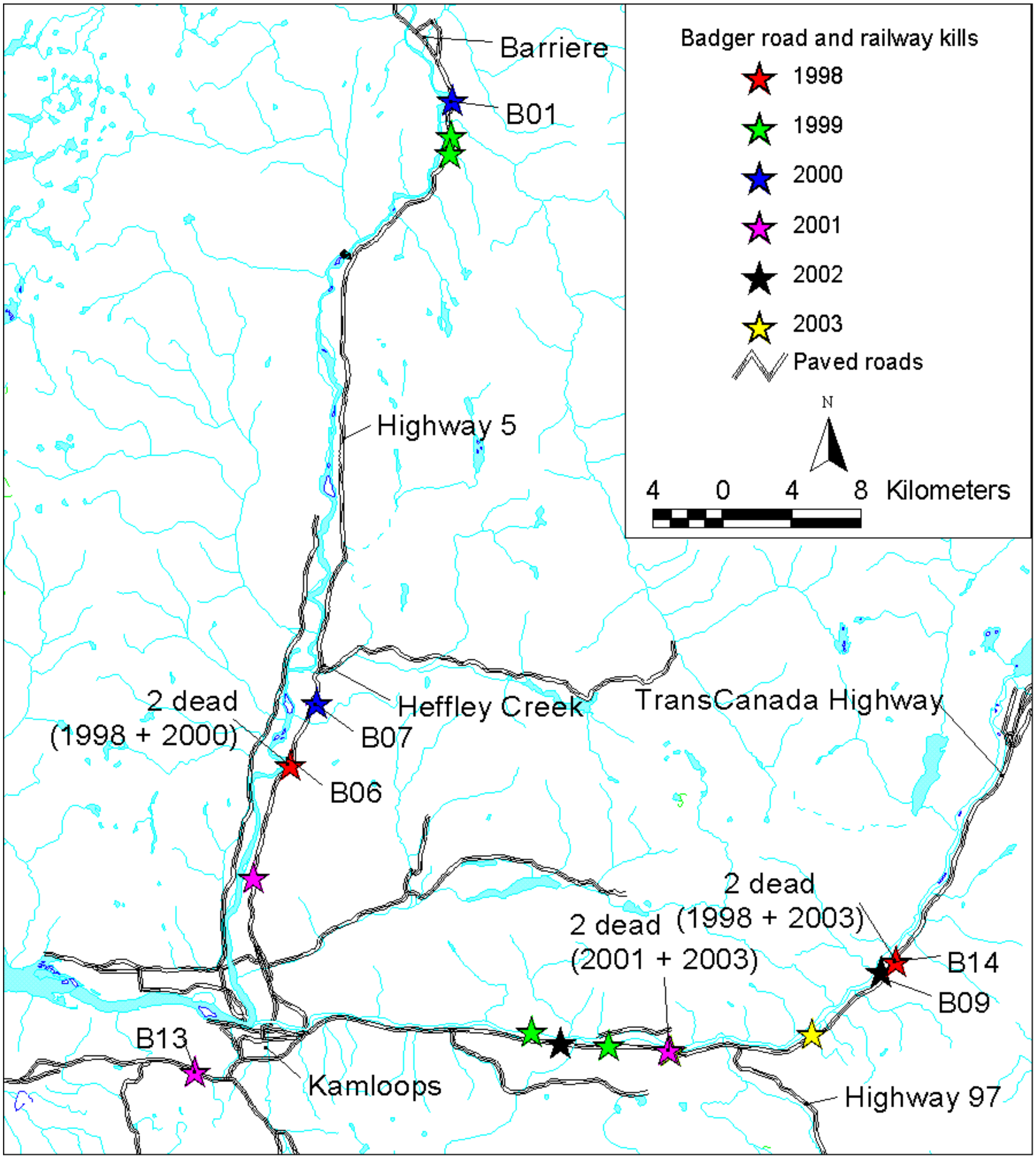

Figure 12. Spatial and temporal distribution of documented kills of 17 badgers that occurred on roads and railways in the Thompson region between 1998 and 2003. Several sites had multiple kills. Kills of radio-tagged badgers are identified by badger ID (e.g., B01).

Table 16. Effects of road density and road crossing frequency on mortality among radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia. All badgers were male, except for B06 and B07.

Badger ID	Monitoring period (radio·days)	Radio-locations	Minimum crossings of paved road	Home range size[a] (km^2)	Paved roads within home range (km)	Density of paved roads (km/km^2)	Fate[b]
B01	391	8	3	—	—	—	Road-kill
B02	299	5	0	—	—	—	Unknown
B03	812	76	26	53.7	57.6	1.07	Alive
B04	56	2	0	—	—	—	Unknown mortality
B05	1025	110	0	34.7	9.1	0.26	Alive
B06	86	62	15	15.6	24.2	1.55	Road-kill
B07	10	13	1	—	—	—	Road-kill
B08	303	33	3	18.1	1.9	0.10	Unknown
B09	352	47	17	37.3	14.4	0.39	Road-kill
B10	465	46	4	21.5	11.1	0.52	Alive
B12	496	33	0	30.5	0	0	Alive
B13	56	2	1	—	—	—	Road-kill
B14	440	56	4	33.4	13.8	0.41	Train-kill

a 95% fixed kernel estimate
b as of last radiolocation

The frequency with which the animals crossed the roads appeared to affect the survivorship of each badger. The TransCanada Highway passed through the home ranges of B09 and B14 and they both crossed it repeatedly. B06 was recorded crossing Highway 5 at least 15 times before she was struck and killed. However, B03 was documented successfully crossing Highway 5 at least 26 times. Perhaps the stretch of highway that he crossed had more safe crossing structures, or he repeatedly used a safe crossing point.

Concrete roadside barriers may be an unexpected hazard for badgers when crossing highways. We received several reports of badgers running up and down the roadside, attempting to get around these barriers. Six of the 20 badgers that we documented were killed in areas with continuous roadside barriers that occurred on only one side of the highway.

Section 4 – Applied Conservation Efforts

We were involved in a direct conservation intervention during 2001, when we attempted to rehabilitate an orphaned badger kit. In May, a reproductive female was struck and killed on the TransCanada Highway near Kamloops, leaving a male kit in her natal burrow. A decision was made to try to capture, hand-rear, and release the kit into the wild.

Immediately following the capture of the kit, we transferred the male kit to a temporary facility at the Kamloops Wildlife Park. The kit was provided with a makeshift burrow in a small enclosure in the rehabilitation centre. Here, he was provided with food and water *ad libidum* for 3 weeks, during which time his body mass doubled. His diet during this time began with Nebraska K9 dog feed supplemented with canned feed. As he grew, we began to feed him raw eggs and dead feeder mice and chicks.

It was recommended to us that housing the badger in a cement enclosure was inadequate because of the lack of opportunities to dig (C. Smeeton, Cochrane Ecological Institute, personal communication). Therefore, the kit was housed at the wildlife park while we built a 400-m^2 fenced enclosure on private property in Pritchard. We partially buried 2.4 m-tall chain link fencing 75 cm into the ground and backfilled with soil so that the kit could not easily dig his way out. We also dug an artificial burrow for the kit prior to his release into the pen. We kept several of the trees in the enclosure for security cover.

We moved the badger kit from the Kamloops Wildlife Park to the enclosure on June 15. He made many exploratory diggings within the first 24 hours in the enclosure and was digging burrows within the first week of release into the enclosure. We initially began feeding dead yellow-bellied marmots and Columbian ground squirrels to the badger. As the weeks progressed and the badger kit became more adept at burrowing and moving around, we began feeding the kit live prey.

After 1 month in its enclosure, the badger kit appeared to be ready for release into the wild. We spent several days finding an appropriate release site and preparing an artificial burrow. We selected the northern corner of Lac Du Bois Grasslands Provincial Park as the release site because it was a relatively natural grassland setting and reasonably far away from roads and people. We radio-tagged him prior to release so that we could monitor his fate.

The badger kit did not appear to hunt or travel widely following release. We provided the badger kit with food every 2-3 days, but he did not appear to come out of his burrow to actively hunt for prey. On the few opportunities that we had to observe him, he searched intensively in the area around his burrow but dug very few holes in pursuit of prey. Despite considerable monitoring effort, we did not document the badger kit wandering farther than 200 metres from his release burrow in the several weeks following release and he appeared to have only dug 3 new burrows during this time.

Although he was healthy prior to release in Lac du Bois Grasslands Provincial Park, a predator killed the badger kit 3 weeks following release, on August 9. Although a great-horned owl was feeding on the carcass, a post-mortem examination suggested that a coyote had killed the badger. The post-mortem revealed that the badger was in excellent physical condition prior to his death. He had considerable subcutaneous and mesenteric fat deposits, which indicated that he was getting sufficient food. Therefore, we know that the diet with which it was provided while it was under our care provided it with enough energy to grow and put on weight.

Although our attempts to successfully re-introduce the badger kit to the wild were unsuccessful, valuable experience was obtained in husbandry techniques for these animals. We learned how to care for and feed a young growing badger. We also discovered that inexperienced badgers need to learn how to hunt effectively and avoid predation. More importantly, we now have a network in place that will help us with any future rehabilitation or captive breeding that may occur, including a facility that will provide a temporary holding area for badgers.

Section 5 - Public Education and Extension

We used a wide variety of forums and media to inform members of the general public, as well as specific target groups, about badger ecology and the conservation of badgers in the Thompson and Okanagan regions. Our education program was met with enthusiasm and a desire to learn about badgers and their conservation challenges.

Critical to the success of the sightings collection was the implementation of the "Badger Hotline", a toll-free telephone number from which we fielded over 600 calls during the course of this project. People called to report badger sightings, enquire about the project, and notify us about recent badger activity in their area. We often received multiple calls from interested individuals.

Public reaction to the project was extremely favourable. We received overwhelming support and interest in the project from the general public, government employees, and many ranchers. Most people who support grassland conservation expressed concern about the plight of the badger in the Thompson and Okanagan areas. The limited amount of negative reaction that we have received for this project has come from some members of the ranching community. Badgers are occasionally considered pests by some landowners because badger burrows are viewed as hazards to livestock (Minta and Marsh 1988). Also, some large cattle operations have expressed concern regarding the implications of an endangered species being discovered using their land. The concern is based on the perception that federal endangered species legislation will limit the ability of their operations to function at current levels if this legislation is implemented.

NEWSPRINT MEDIA

During the project, many different newspapers published articles about badgers and the Thompson-Okanagan Badger Project. Articles about the project were printed in the following newspapers and newsletters:

- Kamloops This Week (5 articles),
- Kamloops Daily News (6 articles),
- North Thompson Star/Journal (Barriere; 2 articles),
- Summerland Review,
- Capital News (Kelowna; 2 articles),
- 100 Mile Free Press (3 articles),
- Morning Star (Vernon)
- Williams Lake Tribune,
- Merritt Herald,
- Knutsford and Pritchard community newsletters,
- Several notes in the BC Naturalist, with articles in newsletters for the following Naturalists' Clubs:
  - Central Okanagan
  - Kamloops
  - North Okanagan
  - Oliver-Osoyoos
  - South Okanagan
  - Vermillion Forks

- Full-feature article on badgers appeared in the Vancouver Sun in 2001.
- BC Grasslands
- NaturescapeNews

OTHER MEDIA

Other media were used to help disseminate information about badger conservation and the Thompson-Okanagan Badger Project during the past 4 years:

- 5 stories were broadcast about badgers and our project on local TV news throughout the Thompson and Okanagan regions.
- We assisted with the revision of the Provincial government's "Species at Risk" brochure on badgers.
- We had a short plug for the project broadcast on CBC Radio's "Daybreak" morning show (broadcast to southern British Columbia).
- We helped several private companies that have badgers on their property promote the conservation of them through interpretive signs (e.g., Sun Peaks ski resort).
- We created a World Wide Web site that features badgers in BC (www.artemiswildlife.com/artwc/badgers.htm). The web site features general badger ecology, the reason for the conservation concern, information about the Thompson/Okanagan Badger Project, project publications and updates, and a page for reporting badger sightings. In 2003, we undertook creating a website about badgers for the Badger Recovery Team, which is found at www.badgers.bc.ca.
- We posted hundreds of "Have You Seen a Badger" posters at many post boxes, corner stores, and in rural areas throughout the radiotelemetry study area. This poster included the Badger Hotline and the internet web site address.
- We developed and distributed 1,000 brochures ("Badgers in your Backyard") on the general ecology and conservation of badgers in the Thompson and Okanagan areas. We distributed these brochures widely as part of the research program, at public talks, to naturalist clubs, to nature centres, and through government agencies.
- Students of Karl Larsen, of the University College of the Cariboo, distributed 4,765 pamphlets requesting sightings of rare snakes and badgers to schools and homes in the Kamloops area during the summer of 1999.

PRESENTATIONS

We targeted education materials for different audiences and distribution forums.

- We developed two posters that we displayed at public forums. One gave details on badgers and the research project while the other was an interactive question-and-answer poster designed for the general public.
- We developed several slide shows that were specific for each audience's knowledge and interests.
- To attract the attention of children to our display, we had a badger hide tanned and had a stamp made of a badger track.

We gave many presentations about the Thompson-Okanagan Badger Project from 1999 through 2003. We gave presentations or had our poster displayed at the following events/centres:

- Osoyoos Desert Centre (3 presentations),

- Kenna Cartwright Park (Kamloops),
- Mayor's Environmental Expo (Kelowna),
- Kamloops and District Woodlot Association,
- Endangered Wildlife Festival (Kelowna) (3 times),
- Sustaining Healthy Grasslands Symposium (put on by the Grassland Conservation Council of British Columbia),
- Society of Northwest Vertebrate Biologist meeting,
- Rancher’s Day in the Grasslands (4 times),
- Meadowlark Festival,
- British Columbia Trapper’s Association AGM,
- Joint meeting of the BC Grasslands Conservation Council and the Society for Range Management (Northwest section),
- North Okanagan (Vernon), Kamloops, and Vermillion Forks (Princeton) naturalist clubs,
- The Society for Conservation Biology meeting in Canterbury, England
- Antelope Brush Symposium and Society for Ecological Restoration meeting, and
- Government agencies: Okanagan region of BC Parks, MWLAP Kamloops, MWLAP Penticton.
- We presented a poster on the conservation challenges facing badgers in the Thompson and Okanagan at the Carnivores 2002 conference in Monterrey, California.

We also organized and chaired the inaugural meeting of the Badger Working Group at the Carnivore 2002 conference.

From 2000 until present, our project information poster has been integrated into an interpretive program on grasslands put on by the Kamloops Wildlife Park. It is estimated that approximately 103,000 people viewed this exhibit each year. Also, the Wildlife Park included our badger information in an outreach and education program for 8,500 students/year in the Kamloops area. The project poster was prominently displayed at the Kamloops Wildlife Park for BC Hydro’s “Wild Lights” program during Christmas 1999. A total of 40,000 visitors were estimated to have viewed the project poster during that time.

We have consistently distributed project annual reports and updates on the project to regional Wildlife Branch staff in both the Kamloops and Penticton offices, as well as with government biologists, planners, and managers working in the Ministry of Forests, Ministry of Water, Land, and Air Protection, and BC Parks. In February and May 2002, we also gave a lunch-hour presentation on badgers to staff at the Ministry of Water, Land and Air Protection in Kamloops and Penticton. We plan on giving more talks to government staff in 2003 on the final results of the project.

LANDOWNER COOPERATION

Our success in building landowner cooperation can be measured in the few number of times we have needed to capture and translocate "problem" badgers (i.e., once). We have often fielded “problem badger” calls for the Conservation Officer service. In virtually all cases, we convinced the landowners that having badgers use their property was beneficial, particularly once we explained the conservation situation and general ecology of badgers.

Through our research, we have determined that badgers generally only spend a few days in one spot and then move on to another part of their large home ranges. When we explain that the badger likely has a home range of at least 30 km^2 and that it will probably be on their property for only 1-2 days, the landowners generally become more willing to leave the badger alone. Fear of aggressive attack is often a concern, but appears to be a very minimal risk.

AWARENESS

Because of the media coverage we have generated, members of public and the ranching industry are more aware of the existence, general ecology, and conservation needs of badgers in British Columbia. In fact, public awareness of badgers and the badger project is so high that we typically received 3-6 reports within an hour of a badger being struck on highways in the Kamloops region. During the study we retrieved 10 dead badgers in the Kamloops region, whereas the highways maintenance company did not collect any from roads during this same time period. In addition, we often receive multiple calls on individual badgers throughout the sightings collection area, further signifying the level of awareness regarding badgers and the badger hotline.

BADGER RECOVERY TEAM: EXTENSION AND COMMUNICATIONS RAG

We have been deeply involved in the Badger Recovery Team's Extension and Communications Recovery Action Group (RAG). We participated in the brainstorming session that created a logic model that provides us with prioritized activities to achieve desired outcomes to meet our extension planning goals. This logic model has also served as a model for other Recovery Teams. We are currently in the process of applying this logic model as part of the Badger Conservation Implementation program.

Section 6 - Conservation Strategies for Badgers

The conservation strategies outlined in this section are based largely on the hard work of the *jeffersonii* Badger Recovery Team in the development of a conservation logic model (Adams et al. 2003). The logic model process breaks out planning into overall goals, methods to attain each goal, long-term objectives, medium-term objectives, short-term objectives, and specific conservation outcomes.

IDENTIFIED CONSERVATION ISSUES

The following conservation issues were those identified during the sightings collection and research portions of the project in addition to those identified by the *jeffersonii* Badger Recovery Team in the creation of the Conservation Logic Model. The model components are summarized and listed below in order of descending importance for conservation planning for badgers in the Thompson and Okanagan regions. Not all of the conservation actions identified in the logic model are presented below; some of the actions in the logic model are beyond the scope of this document.

The overall goal of the conservation strategies is to ensure a self-sustaining meta-population of badgers throughout their historic range in the Thompson and Okanagan regions. This can be achieved by addressing the following conservation issues and reaching each associated conservation objective (ranked in descending order of importance):

1. **Low survival within the population of badgers**. Increasing survival within the population can be achieved through:
    a. Decreased road mortality
    b. Decreased extermination and poisoning of badgers
    c. Decreased railway mortality
    d. Improved survival of injured/orphaned badgers
2. **Low recruitment within the population of badgers**. Increasing recruitment within the population can be met through:
    a. Increased births
    b. Increased immigration
    c. Increased juvenile survivorship
3. **Insufficient or limited suitable habitat for badgers across the landscape**. Ensuring suitable habitat for badgers can be accomplished through:
    a. Protecting existing habitats
    b. Restoring and enhancing degraded habitats
    c. Decreasing the extermination and persecution of prey
4. **Increasing genetic variability** (beyond the scope of this document)

CONSERVATION STRATEGIES

We have identified ***long-term objectives*** (bold-italic font) and *medium-term objectives* (italic font) for each conservation issue. Short-term objectives and specific tactics should be determined by specific conservation programs during their respective planning processes and are beyond the scope of these conservation strategies. We have listed the conservation actions in descending order of priority.

1. Increasing survival within the population

1a. Decreasing road mortality

Decreasing road mortality of badgers can be achieved by pursuing 3 long-term objectives (in descending priority):

i) ***Increase the likelihood of badgers safely crossing roads***.

This will reduce the number of badgers killed on roads and thereby increase survival amongst badgers living in areas with high traffic volumes. Badgers have large home ranges and they move widely throughout their home ranges during the peak traffic months of May - August. Unfortunately, badgers do not appear to cross roads at predictable points, which increases the difficulty of managing crossing points.

- *Increase the number of crossings structures incorporated into new and existing highway developments*.

  This can involve strategically placing culverts, wildlife/cattle underpasses, or other crossing structures to facilitate successful movement under roadways, away from traffic. Research conducted in Montana and Banff National Park has examined the efficacy of several different crossing structures for a variety of wildlife and badgers have been documented using culverts to cross under highways in the East Kootenay region (N. Newhouse, Sylvan Consulting Ltd., personal communication). The results of these research projects may be appropriate for use in the Thompson and Okanagan regions. Contact Bill Ruediger (Ecology Program Leader for Highways, US Forest Service, bruediger@fs.fed.us) or Tony Clevenger (Warden Service, Banff National Park, tony_clevenger@pch.gc.ca) for more information.

- *Decrease the use of concrete roadside barriers (CRB) along only one side of road or the central meridian.*

  Having CRB on only one side of the road allows animals to get onto the road surface, but stops them from exiting quickly. At least 3 of the badgers that were killed in the Thompson region during the research study were killed in areas in which CRB occurred along only one side of the road. We documented numerous other records of badgers being "trapped" on the road surface, searching for an escape route. A solution to this problem may be to reduce the incidence of CRB on one side of the road, either through the removal of the lone wall of CRB or ensuring that CRB is placed along both sides of the roadway.

- *Increase the use of drainage CRB where appropriate to allow animals to exit the road surface safely.*

  When badgers feel vulnerable, such as when caught on the road surface and facing a concrete wall, their first instinct is to dig. This suggests that badgers would instinctively look for an escape route at ground level and be unlikely to climb up over the CRB. Providing the opportunity for badgers to exit the road surface through the hole in the drainage CRB may be a solution to this predicament. Unfortunately, one possible outcome of this option is that it may allow passage onto the road for some animals.

- *Facilitate the use of safe crossing structures by badgers.*

  In high-risk areas, such as those with recent badger activity or areas with repeated vehicle-badger collisions, the use of drift fences to channel badgers to safe crossing structures may be useful in reducing the likelihood of badgers crossing the road surface. Drift fences, like those used to direct snakes and control silt flow into waterways, could be constructed along these areas to stop badgers from accessing the road surface. Although badgers may occasionally dig underneath the fence, it will probably deflect a large proportion of the animals that attempt to cross the road. Possible difficulties associated with this approach may be increased difficulty in right-of-way maintenance, maintenance of the drift fence, and negative effects on the normal movement patterns of badgers (e.g., disruption of breeding movements).

Research is currently underway in the Thompson region to determine the influence of possible crossing structures (e.g., culverts, cattle underpasses) and concrete roadside barriers (CRB) on road kills on the TransCanada Highway. The research will be examining the effects of replacing solid CRB with drainage CRB on collisions between vehicles and wildlife. Results from this study will hopefully provide better guidance into the factors that affect road mortality in the region.

ii) ***Decrease traffic speeds***.

Many of the collisions between vehicles and badgers occur because drivers are unable to see badgers (which are low to the ground and dark-coloured) sufficiently far away to avoid hitting them. Decreasing the speed of vehicles in areas within high-risk zones and during high-risk times of year (i.e., May – August when badgers make long distance movements and traffic volumes are high) may provide drivers with sufficient time to avoid collisions with badgers which are crossing roads.

- *Increase the use of wildlife detection systems to alert drivers to wildlife on roads.*

  A pilot project is currently underway in the East Kootenay region to develop an effective wildlife detection system that provides drivers with advance notice of wildlife near or on the road surface.

- *Alert drivers to be prepared for badgers possibly crossing the road surface.*

  Signage in high-risk areas could be useful for increasing the awareness of drivers about badgers potentially crossing the roadway. An educational program, either from a short-distance radio broadcast (e.g., Endangered Species Radio) or repeated public service announcements may be an option for helping drivers become aware of badgers attempting to cross roads.

iii) ***Change habitat suitability near roads***.

The rights-of-way along most major roads in the Thompson and Okanagan region are maintained in an early seral (i.e., grass) structural stage, usually through vegetation management. Unfortunately, this increases the suitability of the rights-of-way for many prey species, which may in turn attract badgers to these areas (Meunier et al. 1999).

- *Change the vegetation management of rights-of-way on major transportation corridors to make them less attractive to Columbian ground squirrels, yellow-bellied marmots, and other rodents.*

  This may involve changing seed mixtures that are planted in disturbed areas to less palatable species (e.g., herbs rather than forbs). Also, using different means of vegetation management, other than mowing, may promote the establishment of woody species, thereby reducing the suitability for prey species.

1b. Decreasing extermination and poisoning of badgers

Although we did not document landowners killing radio-tagged badgers during this project, we occasionally encountered landowners that stated unequivocally that they would eradicate any badger that they encountered on their property.

i) ***Increase the appreciation of badgers and understanding about badger ecology among landowners***.

Addressing this conservation issue deals primarily with the education of landowners about the benefits of badgers, the effects of eradicating badgers, and allaying fears about the aggressive nature of badgers.

- *Increase the understanding about the benefits of badgers among landowners, and alternatively, the negative effects of eradicating the species*.

  Occasionally, landowners simply see badgers as a vermin that needs to be destroyed (Minta and Marsh 1988), without understanding the intricate and important role that badgers play in the health of the ecosystem of which the landowners are stewards. Landowners often perceive badgers as a larger pest than other small mammals or are not aware that badgers are carnivores that prey on rodents. Badgers need to consume approximately 2 ground squirrels per day to provide enough energy for survival (Lampe

1976). Thus, because badgers eat Columbian ground squirrels, yellow-bellied marmots, and northern pocket gophers (Hoodicoff 2003), badgers are extremely effective control agents for many pests that landowners spend considerable effort and money attempting to control. Conversely, if a landowner destroys a badger that is controlling burrowing rodents on their property, pest damage to their fields may increase exorbitantly.

- *Dispel the myth about livestock damage resulting from badger burrows.*

  The concern about the possible negative effects of badger burrows on livestock is usually identified as the primary reason that landowners do not want to have a badger on their property. However, we have not encountered a single landowner, in more than 200 contacts, that has had an animal injured from a badger burrow.

  A survey is currently underway to document the rate of occurrence of livestock injury attributable to badger burrows. These data will be useful to illustrate to landowners how low this risk actually is.

- *Increase understanding about the ecology and behaviour of badgers among landowners.*

  Landowners are usually concerned that if a badger is seen on their property, it has set up residence and will remain on their land indefinitely. This is a highly improbable scenario, unless it is a female badger that has established a natal burrow in the area. Results from our telemetry data suggest that, during summer, badgers are more likely to have moved at least 500 m away during the course of a day than to remain within the immediate vicinity.

  Some landowners express concern about the perceived aggressive nature of badgers. A badger, however, is a generally secretive animal that only becomes aggressive when it is either startled or does not have a burrow nearby into which it can escape. Landowners are also afraid that children may be at risk if a badger is nearby. Once again, badgers tend not to attack unless provoked, although any person who encounters fresh badger burrows is advised to avoid these areas.

ii) ***Increase tax incentives for landowners that maintain badgers on their lands***.

Much of the suitable habitat for badgers in the Thompson and Okanagan regions occurs on private lands. Unfortunately, no tax incentives currently exist for landowners that embrace badgers on their property. Considerable lobbying likely needs to be expended for this to become a reality.

iii) ***Develop an effective translocation methodology that can be used in cases where the badger is an actual threat and will be otherwise destroyed***.

Although translocation is not the preferred method of dealing with badgers on private land, a translocation methodology has been developed (Appendix 8) based on the live-capture and handling portion of the research project. It specifically lists criteria that should be met before translocation becomes necessary.

1c. Decreasing railway mortality

Although railway mortality does not appear to be as large of a source of mortality as roadways, we still documented railway kills of 1 radio-tagged badger as well as a female with 2 kits. Reducing the number of badgers on railways will likely involve many of the same long-term and medium term objectives as those needed to decrease road mortality.

i) ***Increase the likelihood of safe crossings of railways by badgers***.

The methods to address this are similar to the action items addressed in bullet *1a. Decreasing road mortality*.

- *Increase the number of crossings structures incorporated into new railway developments*.
- *Facilitate the use of safe crossing structures by badgers.*

ii) ***Remove attractants from railroad surfaces***.

Both of the main lines of the Canadian Pacific and Canadian National railways run through the Thompson region. These are the primary transportation routes to ports for grain crops from the Prairie provinces. Grain occasionally spills from container cars and likely attracts granivorous animals to the tracks. Badgers may forage along the tracks for these animals and, as a result, be at increased risk for collisions with trains.

Also, the rights-of-way along both railways in the Thompson and Okanagan region are maintained in an early seral (i.e., grass) structural stage, usually through vegetation management. Unfortunately, this may increase the suitability of the rights-of-way for many prey species, which may in turn attract badgers to these areas.

- *Reduce the spillage of grains during transport*.
- *Change the vegetation management of rights-of-way on major rail lines to make them less attractive to Columbian ground squirrels, yellow-bellied marmots, and other rodents.*

2. Increasing recruitment within the population

2a. Increasing births

Unfortunately, we only had 1 adult female badger radio-tagged during our research study, so our ability to examine the factors that affected reproductive success was limited.

i) ***Increase the number of successful breedings within the badger population***.

- *Increase density of adults*.

  Badgers may be induced ovulators (Wright 1963), so females may need repeated copulation, possibly with multiple males, before successful fertilization occurs. If the availability of males is low during the females' brief oestrus period, females may not successfully breed each year. Large home ranges, such as those that we documented in the Thompson region and were reported in the East Kootenays, may contribute to the low probability of males finding oestrus females (i.e., Allee effect).

Increasing the density of adult badgers may be achieved by increasing the survivorship within the population (see above) or by decreasing the home range sizes (see below on ensuring adequate prey).

2b. Increasing immigration

i) ***Increase dispersal among populations in British Columbia through improved connectivity of habitat***.

The methods to address this conservation issue are similar to those addressed in bullet *3. Ensuring suitable habitat for badgers*.

- *Increase permeability of landscape for dispersing badgers*.
- *Increase habitat suitability of matrix*.

ii) ***Increase source populations of badgers in adjacent jurisdictions***.

- *Increase knowledge among Washington State biologists regarding the importance of Washington badger populations to conservation in British Columbia*.

Badgers have not been a priority for the Washington Department of Fish and Wildlife (WDFW) in the past. However, with the recent decline of the steppe ecosystems and declines in the harvest of badgers within the state, wildlife managers have become aware of the need to consider badger conservation. We have had several constructive meetings with biologists from WDFW regarding badger conservation and plan to continue to develop a cooperative relationship with their conservation program.

Since 2002, 15 badgers have been translocated from north-western Montana into the East Kootenay region. This program appears to have been successful, with high survivorship of translocated individuals (only 1 mortality, likely predation) and successful reproduction among some of the translocated females (N. Newhouse, Sylvan Consulting Ltd., personal communication).

iii) ***Augment populations with new animals***.

- *Examine the feasibility of population augmentation using animals from genetically similar and healthy populations in adjacent jurisdictions*.

An assessment of possible enhancement options for badger populations in the Thompson-Okanagan is currently underway. This assessment will involve determining the feasibility and risks associated with population enhancement opportunities. The process involves an explicit assessment of current and future mortality risks, population limitations, and habitat limitations and includes genetic analysis to help identify a suitable source metapopulation for possible future translocations. If the assessment shows that the likelihood of a successful enhancement is high, the feasibility assessment will develop an enhancement protocol following IUCN translocation policies that will be reviewed and approved by the provincial wildlife veterinarian and an Animal Care Committee.

2c. Increasing juvenile survivorship

We did not develop specific strategies for this conservation action because juvenile survivorship will increase concomitantly with increases in the general rate of survival within the population, as outlined in the above sections.

3. Ensuring suitable habitat for badgers

3a. Protecting existing habitats

Our habitat analysis identified several habitat features whose conservation will be an important part of the overall conservation plan for badgers in British Columbia.

i) Increase voluntary protection of badger habitats by private landowners.

- *Help landowners identify badger habitat on their property by providing them with "Stewardship Support Manuals" that provides a pictorial guide to habitat identification.*
- *Provide landowners with simple tools to conserve badger habitat on their property.*

  These tools will likely take the form of a flow-chart for determining suitable approaches for habitat conservation and should be based on the Habitat Conservation Strategies outlined in Appendix 9 and with other badger research initiatives. These tools are currently under development for application within the next year.
- *Increase number of contacts between innovative landowners (i.e., those who embrace badger habitat conservation) and other landowners.*

  This may be facilitated by organizations such as the BC Cattleman's Association, the Grassland Conservation Council of BC, the Real Estate Board of BC, and other bodies.

ii) Increase the consideration given to badger habitat conservation at land-use planning tables.

- *Increase discussion about badger habitat needs at planning tables*

  This can be achieved by increased participation by badger advocates at planning tables. It will involve creating tools and making them available to table participants to help guide decision-making processes.

iii) Promote the use of covenants, easements, and tax incentives by private landowners.

- *Increase knowledge about how conservation easements and covenants work among interested landowners*

- *Facilitating the purchase of conservation covenants by non-governmental organizations*

iv) Minimize the negative effects of developments on badger habitat.

- *Increase the application of habitat conservation guidelines by real estate developers*

  This would involve retaining "interstitial" habitats within the developed matrix. See Appendix 9 for more details.

3b. Restoring and enhancing degraded habitats

i) Increase badger-friendly grassland restoration & open forest restoration projects

- *Increase the number of badger-friendly decisions being made by project managers in grassland and open forest restoration projects*

  This can be achieved by increasing knowledge about badger habitat requirements by project managers, via the application of the habitat conservation guidelines. Support prescribed burns in areas that support badger prey.

- *Stakeholders participate in voluntary restoration more often.*

ii) Increased badger-friendly land management activities (i.e., agriculture, range, forest management)

- *Promote the application of habitat conservation guidelines among ranchers, developers, and forest managers.*

  This can be achieved by increasing knowledge about badger habitat requirements to these groups, via the application of the habitat conservation guidelines.

3c. Decreasing the extermination and persecution of prey

i) Decrease shooting of prey

- *Decrease shooting of prey by landowners*

  This can be achieved by increasing knowledge about the negative effects of prey eradication on badger populations. This needs to be coupled with an effective strategy to help landowners control damage by burrowing rodents.

- *Decrease target shooting of prey by hunters*

  This can be achieved by increasing knowledge about the negative consequences that harvesting prey populations can have on carnivores, most likely through hunter education courses.

ii) Decrease poisoning of prey

- *Increase use of alternative population control measures by landowners*

  This can be achieved by increasing knowledge about the options for population control available to landowners as well as the strong negative consequences of using poisons on non-target wildlife.

- *Improve legislation around the use of poisons*

  This can be achieved by increasing the support by voters and politicians for change to the Pesticide Control Act. The most effective route to meet this goal is through increased awareness about the effects of poisons on rodent species and carnivores.

IMPLEMENTATION

These conservation strategies are currently in the process of being implemented by members of the various recovery implementation groups (RIGs) of the *jeffersonii* Badger Recovery Team. It should be noted that these conservation strategies are those that were developed as a result of the research conducted herein and may not be appropriate for badger conservation throughout British Columbia. The conservation strategies listed above are expected to evolve as more data becomes available and additional research is conducted.

Section 7 – Project Partners

Funding for this project was provided by the Habitat Conservation Trust Fund (HCTF), Tolko Industries Ltd. (Louis Creek Division), Natural Sciences and Engineering Research Council undergraduate awards, the Endangered Species Recovery Fund (ESRF), Student Summer Works grants, and Weyerhaeuser Company Ltd. The HCTF was created by an act of legislature in British Columbia to preserve, restore, and enhance key areas of habitat for fish and wildlife throughout British Columbia. Anglers, hunters, trappers, and guides contribute to the projects of the Trust Fund through license surcharges. The ESRF is a partnership between the Canadian Wildlife Service and World Wildlife Fund - Canada.

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The conservation strategies outlined in Section 7 were largely based on the hard work of the *jeffersonii* Badger Recovery Team in the development of the Badger Conservation Logic Model. The recovery team is lead by Ian Adams and includes Ted Antifeau, Mike Badry, Larry Campbell, Alan Dibb, Orville Dyer, Wayne Erickson, Larry Ingham, Agnes Jackson, Karl Larsen, Thomas Munson, Nancy Newhouse, Brent Persello, Julie Steciw, and John Surgenor. Special thanks to Karyn Sutherland for promoting and facilitating the development of a logic model for badger conservation in British Columbia. This quality of this report benefited greatly from reviews by Karl Larsen and Nancy Newhouse.

Many thanks go out to the numerous private landowners who took an interest in badgers and provided access for us to their land. Without landowners such as these - promoting the species on their property - the situation facing badgers in the Thompson and Okanagan regions would be much more dire.

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Appendices

Appendix 1. Definitions of variables used in the assessment of factors affecting site selection within home ranges by radio-tagged badgers between 1999 and 2002 in the Thompson region of British Columbia. Reference values (Hosmer and Lemeshow 2000:59) were those values of the categorical variable from which change was examined.

Variable name	Variable type	Variable definition	Reference value
SOIL_S_L	Binary	1 if fine soil texture was sandy, 0 if not	If all 4 variables scored 0, then soil was loamy
SOIL_Z_L	Binary	1 if fine soil texture was silty, 0 if not	
SOIL_C_L	Binary	1 if fine soil texture was clayey, 0 if not	
SOIL_O_L	Binary	1 if fine soil texture was organic, 0 if not	
SURF_C_M	Binary	1 if parent materials were colluvial, 0 if not	If all 6 variables scored 0, then parent material was morainal
SURF_F_M	Binary	1 if parent materials were fluvial or eolian, 0 if not	
SURF_FG_M	Binary	1 if parent materials were glaciofluvial, 0 if not	
SURF_LG_M	Binary	1 if parent materials were glaciolacustrine or lacustrine, 0 if not	
SURF_O_M	Binary	1 if parent materials were organic, 0 if not	
SURF_RO_M	Binary	1 if parent materials were rock outcrop, 0 if not	
SLOPE_G_M	Binary	1 if slope category was level, nearly level, or very gentle (<=5%), 0 if not	if all 3 variables scored 0, slope was moderate (gentle, moderate, or strong [6-30%])
SLOPE_S_M	Binary	1 if slope category was very strong or extreme (31-70%), 0 if not	
SLOPE_VS_M	Binary	1 if slope category was steep or very steep (>70%), 0 if not	
DRAIN_R_W	Binary	1 if drainage was rapid, 0 if not	if all 3 variables scored 0, site was well-drained
DRAIN_M_W	Binary	1 if drainage was moderate, 0 if not	
DRAIN_VP_W	Binary	1 if drainage was imperfect, poor or very poor, 0 if not	
COARSE_H_M	Binary	1 if coarse fragment was high (>50%), 0 if not	if both variables scored 0, coarse fragment content was moderate (20-50%)
COARSE_L_M	Binary	1 if coarse fragment was low (<20%), 0 if not	

Appendix 1 (cont.).

Variable name	Variable type	Variable definition	Reference value
SITE_C_M	Binary	1 if slope position was crest, 0 if not	if all 6 variables scored 0, then slope position was middle slope
SITE_U_M	Binary	1 if slope position was upper slope, 0 if not	
SITE_L_M	Binary	1 if slope position was lower slope, 0 if not	
SITE_T_M	Binary	1 if slope position was toe, 0 if not	
SITE_F_M	Binary	1 if slope position was depression or flat, 0 if not	
SITE_K_M	Binary	1 if slope position was unknown or not identified, 0 if not	
SNR_A_C	Binary	1 if soil nutrient regime was very poor, 0 if not	if all 4 variables scored 0, soil nutrient regime was moderate
SNR_B_C	Binary	1 if soil nutrient regime was poor, 0 if not	
SNR_DE_C	Binary	1 if soil nutrient regime was rich or very rich, 0 if not	
SNR_U_C	Binary	1 if soil nutrient regime was not identified or unknown, 0 if not	
FC_A_FD	Binary	1 if forest cover label was agriculture, 0 if not	if all 8 variables scored 0, then forest cover label was Douglas-fir
FC_D_FD	Binary	1 if leading tree species was deciduous (At, Act, Ep), 0 if not	
FC_E_FD	Binary	1 if forest cover label was exposed soil, 0 if not	
FC_NP_FD	Binary	1 if forest cover label was non-productive, 0 if not	
FC_P_FD	Binary	1 if leading tree species was ponderosa pine, 0 if not	
FC_OC_FD	Binary	1 if leading tree species was other conifer (Bl, Cw, Pl, Se, Sx), 0 if not	
FC_UR_FD	Binary	1 if forest cover label was urban, 0 if not	
FC_W_FD	Binary	1 if forest cover label was water or wetland, 0 if not	
HAB_CF_G	Binary	1 if BCLC[a] habitat category was coniferous forest, 0 if not	if all 8 variables scored 0, then habitat category was grasses and forbs
HAB_DF_G	Binary	1 if BCLC habitat category was deciduous forest, 0 if not	
HAB_GW_G	Binary	1 if BCLC habitat category was grass wetland, 0 if not	
HAB_MF_G	Binary	1 if BCLC habitat category was mixed forest, 0 if not	
HAB_OF_G	Binary	1 if BCLC habitat category was open forest, 0 if not	
HAB_S_G	Binary	1 if BCLC habitat category was shrub, 0 if not	
HAB_UV_G	Binary	1 if BCLC habitat category was unvegetated, 0 if not	
HAB_W_G	Binary	1 if BCLC habitat category was water or shrub wetland, 0 if not	

Appendix 1 (cont.).

Variable name	Variable type	Variable definition	Reference value
HAB2_FOR_G	Binary	1 if BCLC habitat category was coniferous, deciduous, or mixed forest, 0 if not	if all 4 variables scored 0, habitat category was grass and forbs
HAB2_WET_G	Binary	1 if BCLC habitat category was grass wetland, shrub wetland, or water, 0 if not	
HAB2_SHR_G	Binary	1 if BCLC habitat category was shrubs, 0 if not	
HAB2_UNK_G	Binary	1 if BCLC habitat category was unknown, 0 if not	
ELEV	Continuous	elevation above sea level (m)	
DIST_H2O	Continuous	distance from any water feature identified in TRIM (m)	
DIST_ROAD	Continuous	distance from any transportation feature identified in TRIM (m)	
DIST_PAVE	Continuous	distance from any paved road identified in TRIM (m)	
CROWN_CLOSURE	Continuous	total crown closure (%)	
SITE_INDEX	Continuous	site index	
STAND_AGE	Continuous	age of forest stand (years)	
DIST_PREV	Continuous	distance moved from previous radiolocation	
DIST_GRASS	Continuous	distance from upland grass and forb units (m)	
GRASS	Binary	1 if point was in grassland (as identified in BCLC), 0 if not	not grassland units
SURF_SORT	Binary	1 if parent material was FG, LG, F, or E, 0 if not	not sorted parent materials
FRIABLE_SOIL	Binary	1 if soil was loamy or silty and low coarse fragments (<20%), 0 if not	not friable soil
LOAMY	Binary	1 if soils were loamy, 0 if not	not loamy soil
ROW	Binary	1 if in road right-of-way, 0 if not	not in road right-of-way
OPENING	Continuous	% of sky not obstructed by trees (100 - CROWN_CLOSURE)	
T_AGE	Continuous	1 if <=5, decreasing at 0.036/year until age 30, then constant at 0.1	

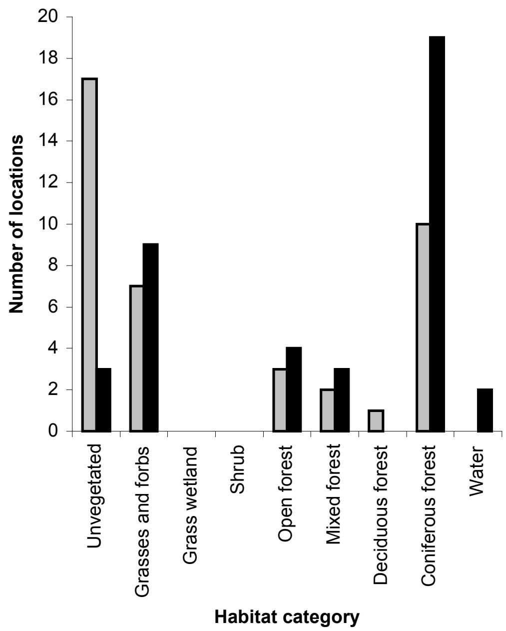
a BCLC: British Columbia Land Classification system

Appendix 2. Variables used in the examination of factors affecting selection of patches within ecosystems by radio-tagged badgers monitored between 1999 and 2002 in the Thompson region of British Columbia.

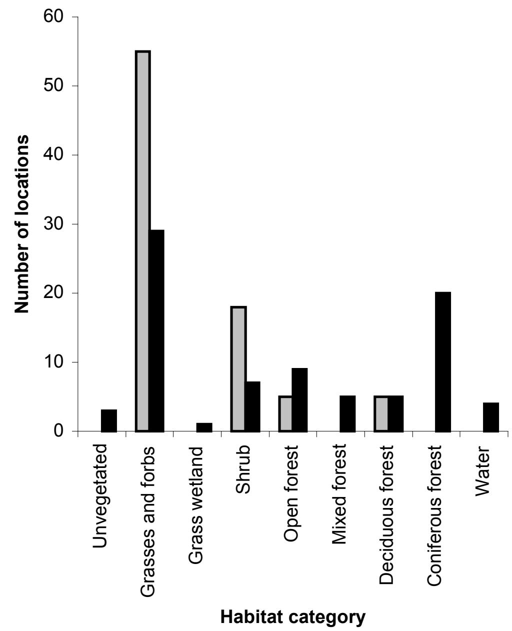
Variable name	Variable type	Variable definition	Reference value
SOIL_S_L	Binary	1 if fine soil texture was sandy, 0 if not	If all 3 variables scored 0, then soil was loamy
SOIL_Z_L	Binary	1 if fine soil texture was silty, 0 if not	
SOIL_C_L	Binary	1 if fine soil texture was clayey, 0 if not	
COARSE_H_M	Binary	1 if coarse fragment was high (>50%), 0 if not	if both variables scored 0, coarse fragment was moderate (20-50%)
COARSE_L_M	Binary	1 if coarse fragment was low (<20%), 0 if not	
GRAZE_N_M	Binary	1 if grazing pressure was nil (0% utilization), 0 if not	if all 4 variables scored 0, then grazing pressure was moderate (36-65% utilization)
GRAZE_L_M	Binary	1 if grazing pressure was slight or light (1-35% utilization), 0 if not	
GRAZE_H_M	Binary	1 if grazing pressure was high (66-80% utilization), 0 if not	
GRAZE_VH_M	Binary	1 if grazing pressure was very high (>80% utilization), 0 if not	
SITE_SLOPE	Continuous	slope gradient of patch surrounding burrow (%)	
MV_DENSITY	Continuous	density of mice or vole burrows on 4 1-m wide transects emanating from used burrow (burrows/100m)	
SPCO_DENSITY	Continuous	density of Columbian ground squirrel burrows on 4 1-m wide transects emanating from used burrow (burrows/100m)	
THTA_DENSITY	Continuous	density of northern pocket gopher burrows on 4 1-m wide transects emanating from used burrow (burrows/100m)	
TREE_COVER	Continuous	% cover of trees in the A layer	
SHRUB_COVER	Continuous	% cover of shrubs in the B layer	
HERB_COVER	Continuous	% cover of herbs and forbs in the C layer	

Appendix 3. Habitat categories used by radio-tagged badgers between 1999 and 2002 compared to random sites within home ranges in the Thompson region of British Columbia. Grey bars represent badger radiolocations; black bars represent random sites within home ranges.

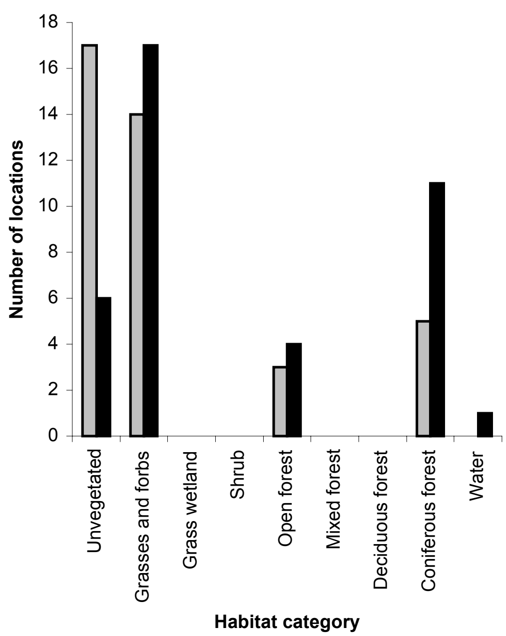
B03 *n* = 40



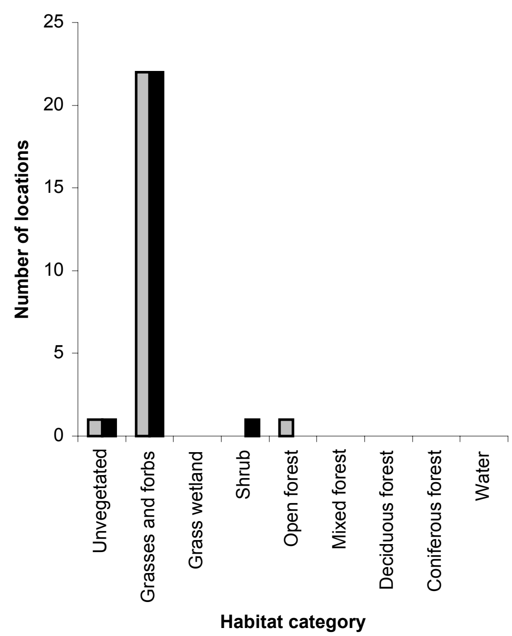
B05 *n* = 83



B06 *n* = 39

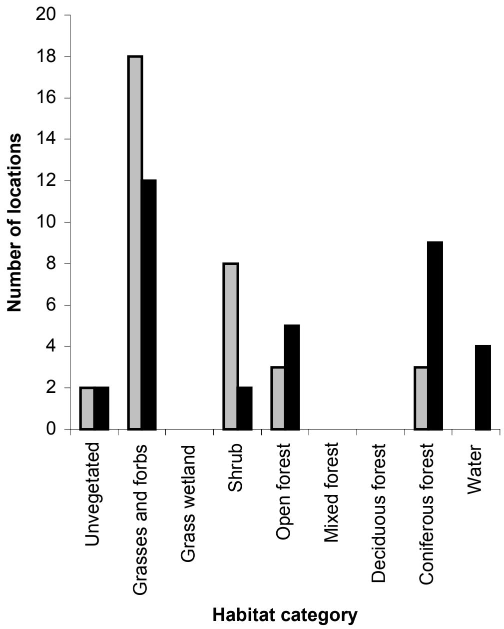


B08 *n* = 24

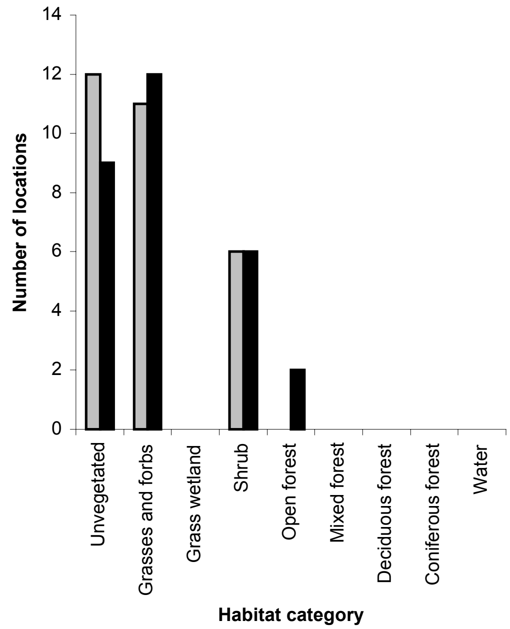


Appendix 3 (cont.).

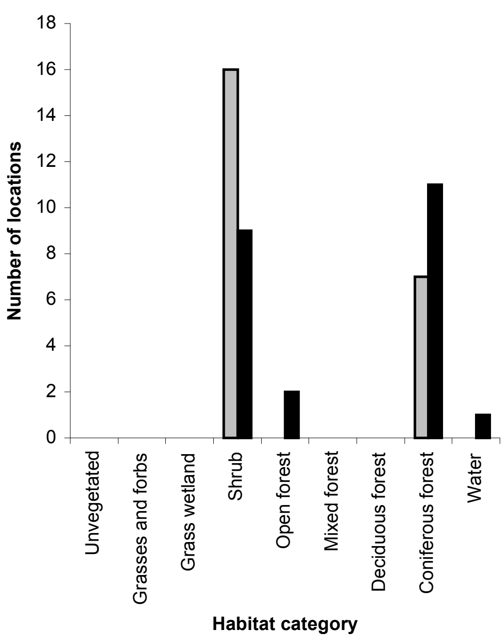
B09 *n* = 34



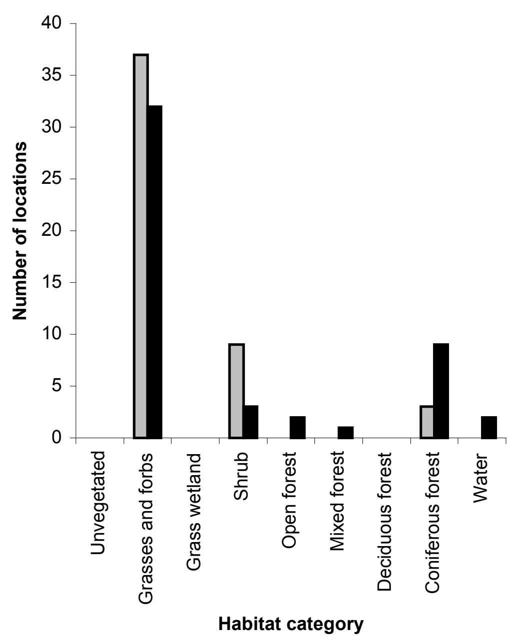
B10 *n* = 29



B12 *n* = 23

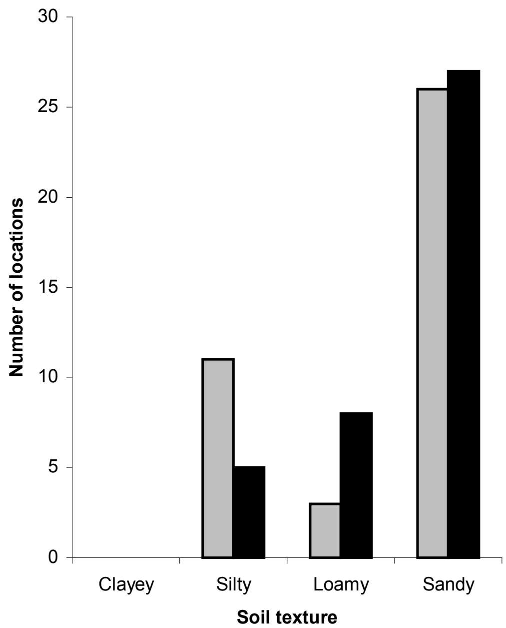


B14 *n* = 49

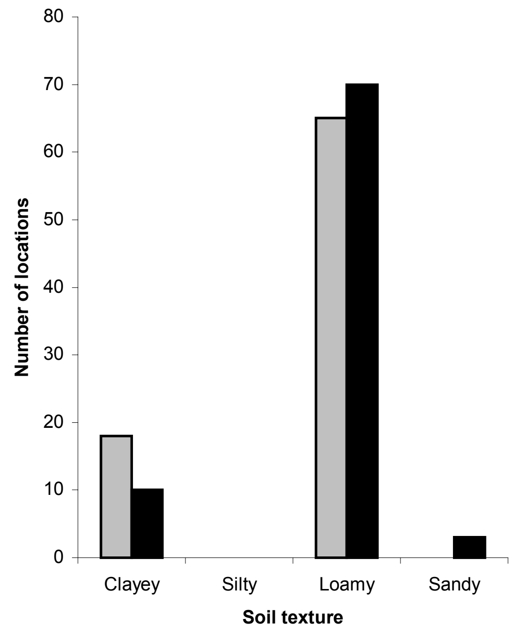


Appendix 4. Soil texture of terrain polygons used by radio-tagged badgers between 1999 and 2002 compared to random sites within home ranges in the Thompson region of British Columbia. Grey bars represent badger radiolocations; black bars represent random sites within home ranges.

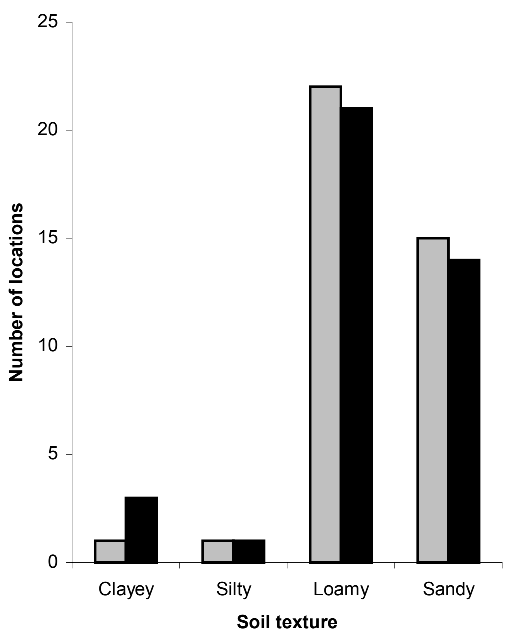
B03 *n* = 40



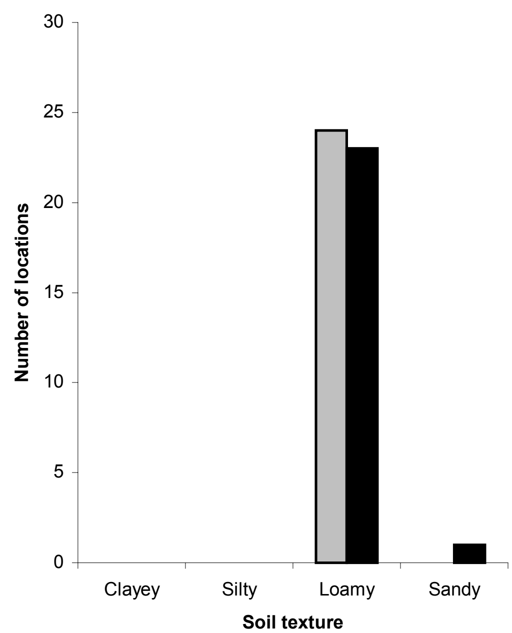
B05 *n* = 83



B06 *n* = 39

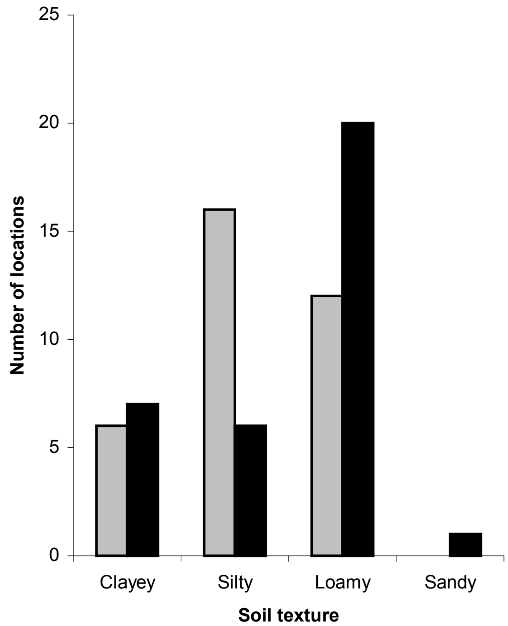


B08 *n* = 24

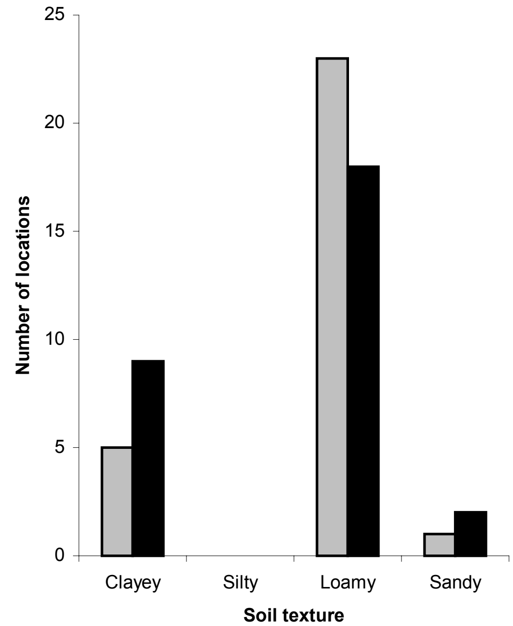


Appendix 4 (cont.).

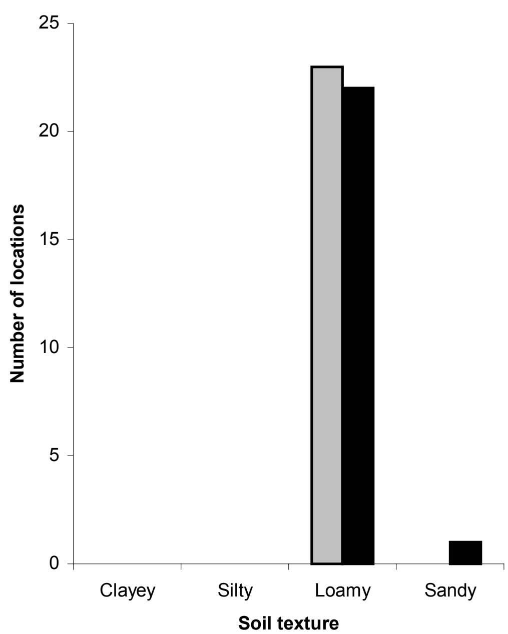
B09 *n* = 34



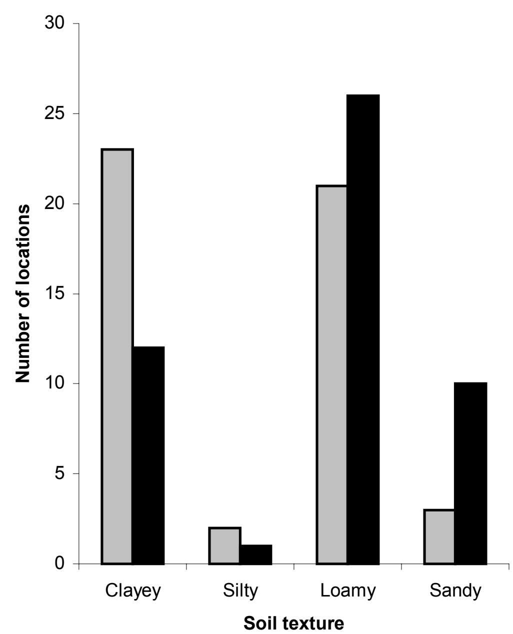
B10 *n* = 29



B12 *n* = 23

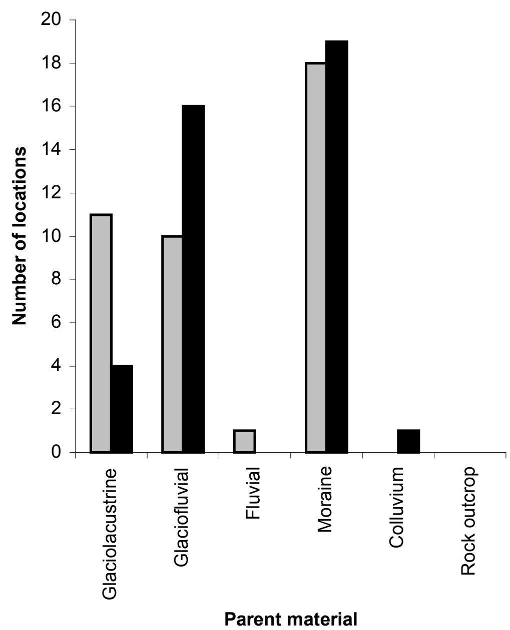


B14 *n* = 49

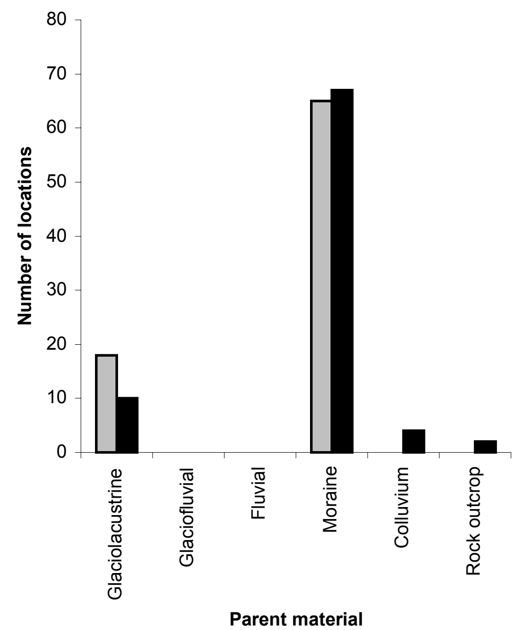


Appendix 5. Parent material of terrain polygons used by radio-tagged badgers between 1999 and 2002 compared to random sites within home ranges in the Thompson region of British Columbia. Grey bars represent badger radiolocations; black bars represent random sites within home ranges.

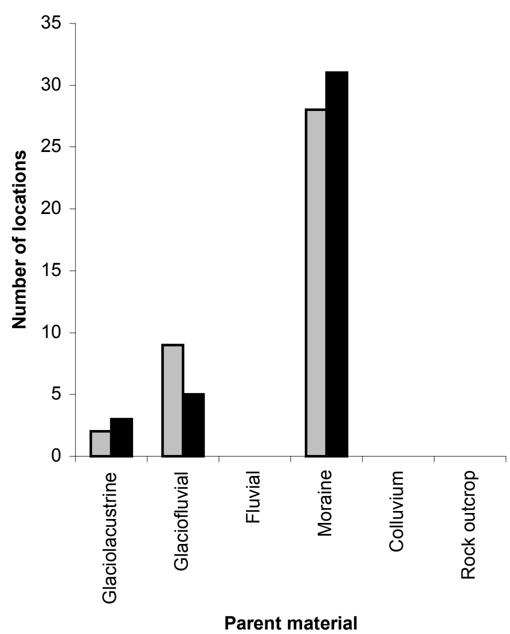
B03 *n* = 40



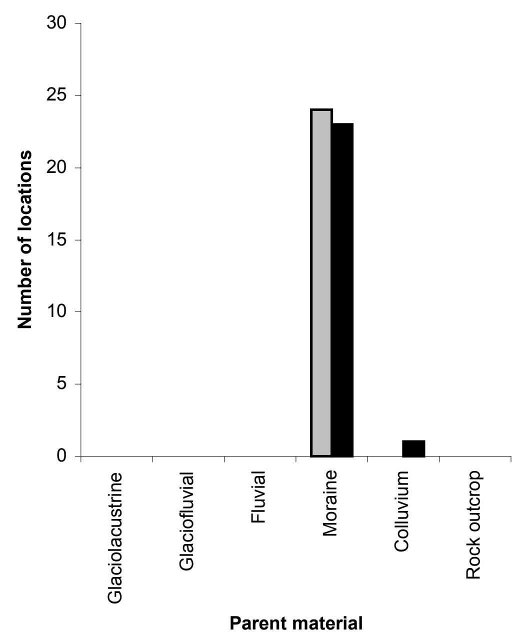
B05 *n* = 83



B06 *n* = 39

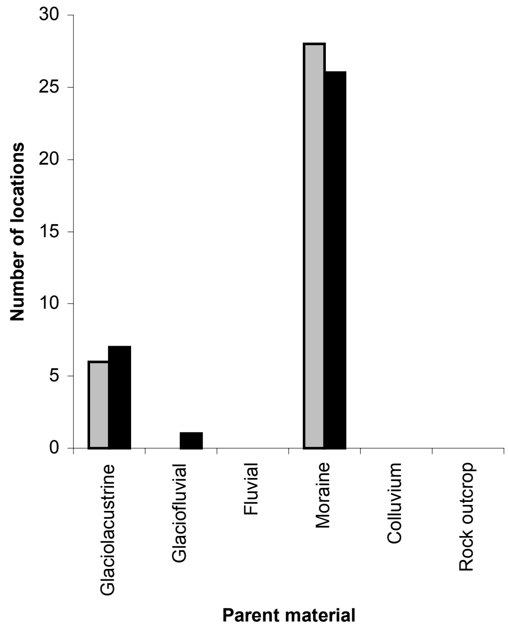


B08 *n* = 24

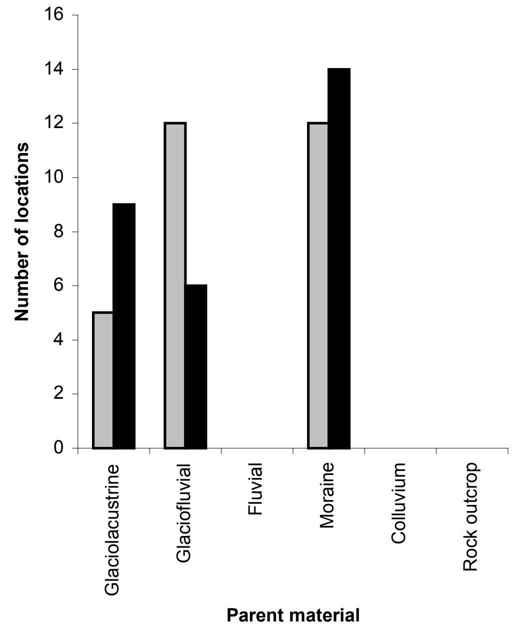


Appendix 5 (cont.).

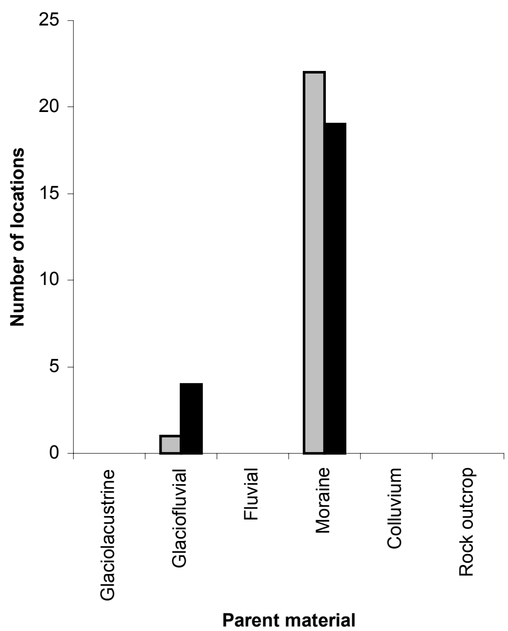
B09 *n* = 34



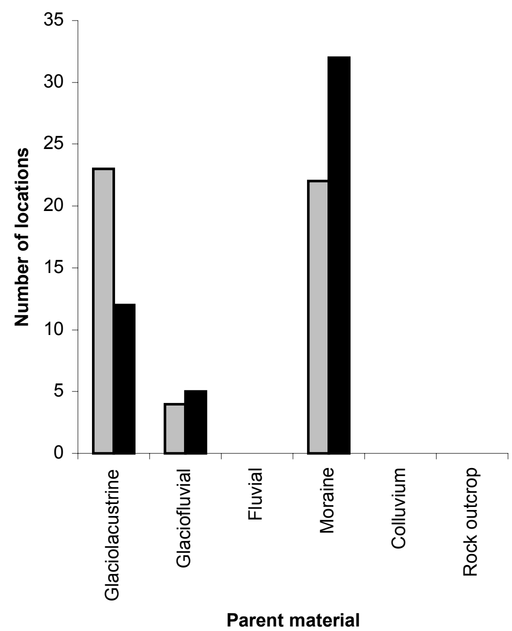
B10 *n* = 29



B12 *n* = 23

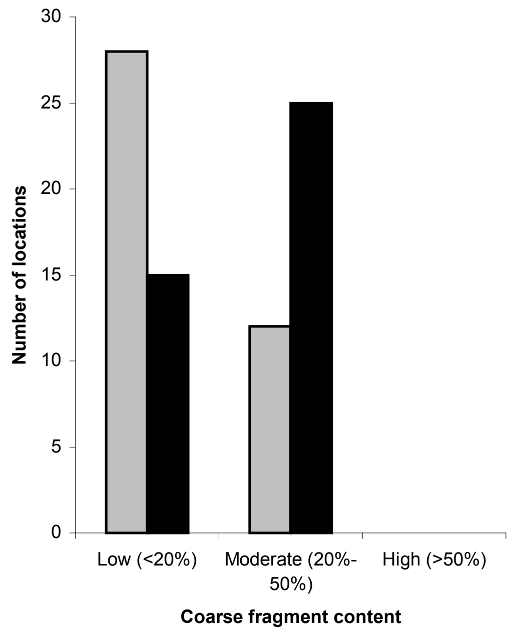


B14 *n* = 49

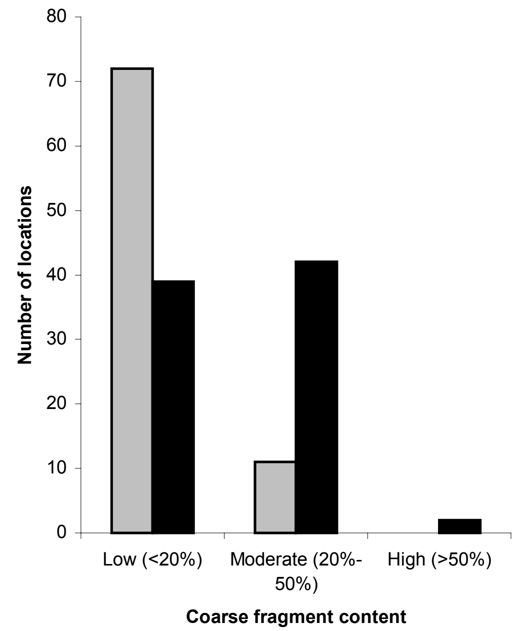


Appendix 6. Coarse fragment content of terrain polygons used by radio-tagged badgers between 1999 and 2002 compared to random sites within home ranges in the Thompson region of British Columbia. Grey bars represent badger radiolocations; black bars represent random sites within home ranges.

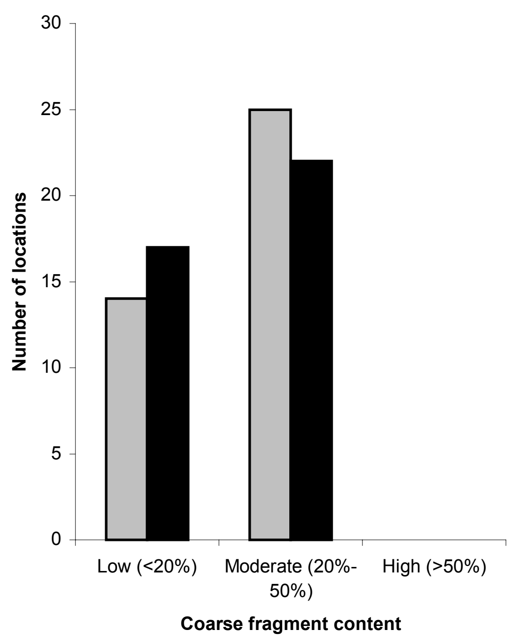
B03 *n* = 40



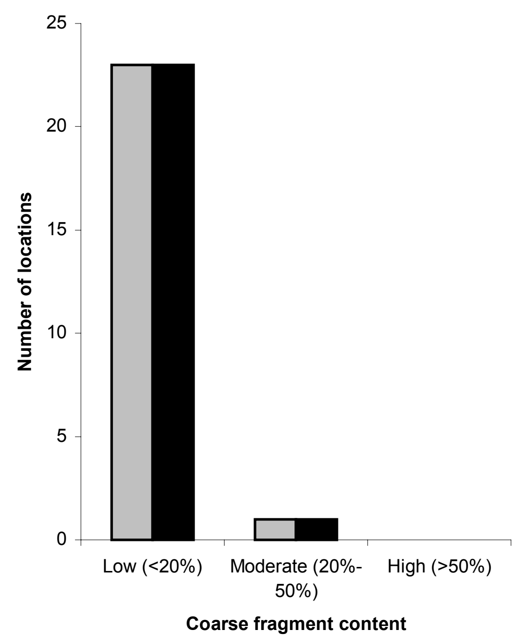
B05 *n* = 83



B06 *n* = 39

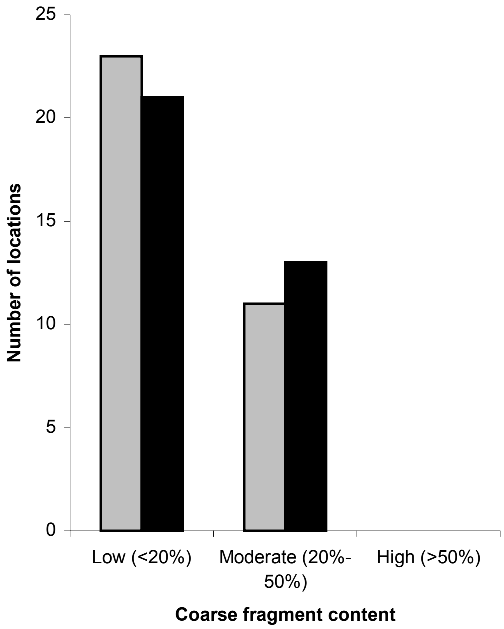


B08 *n* = 24

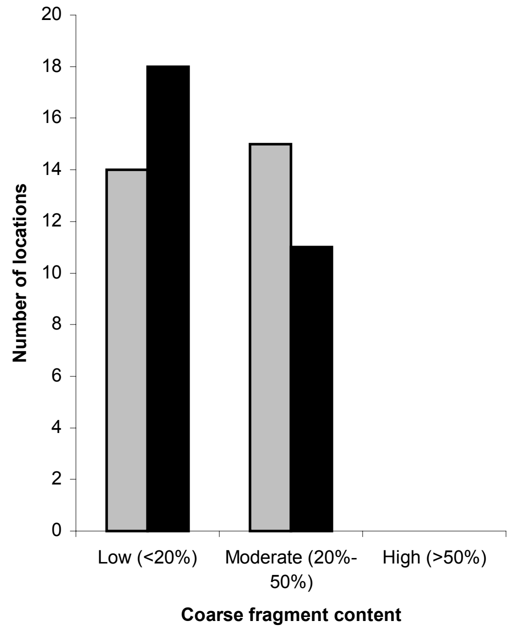


Appendix 6 (cont.).

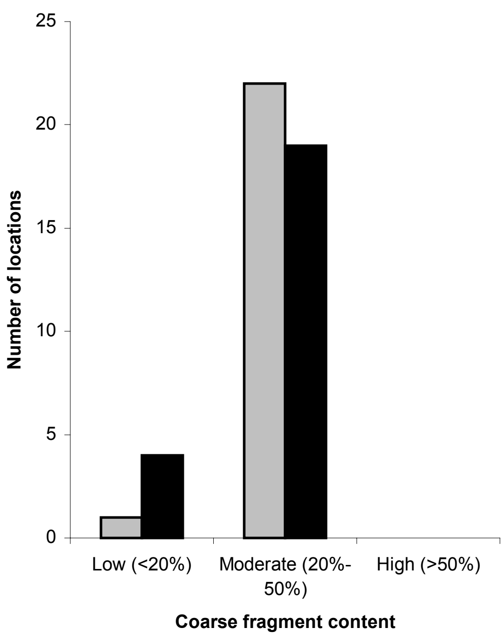
B09 *n* = 34



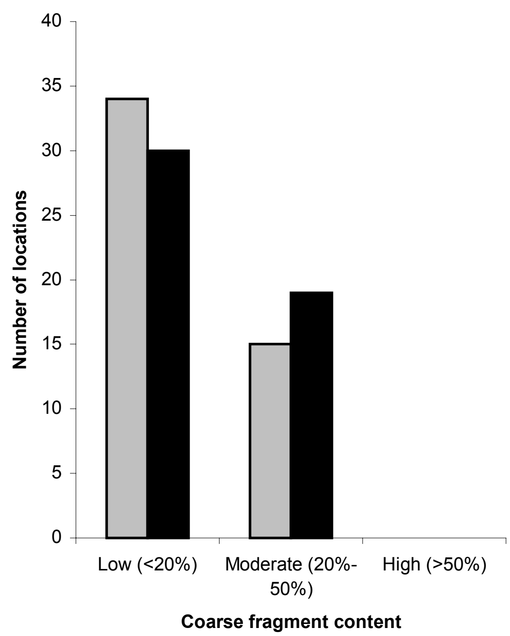
B10 *n* = 29



B12 *n* = 23



B14 *n* = 49



Appendix 7. 95% confidence set of best models explaining site selection within the home range of each radio-tagged badger monitored between 1999 and 2002 in the Thompson region of British Columbia.

Badger ID	Model ID	Model components	log($\mathcal{L}$)	K	AIC$_c$	Δ_i	w_i	Rank
B03	**C5**	**Apps et al. (2002): colluvium, canopy closure, well-drained soils, forest age (surrogate for forest age classes), site index, elevation, glaciofluvial parent material, loamy soils (surrogate for FSL), non-productive sites (surrogate for open range)**	**-2.77**	**8**	**26.19**	**0.00**	**1.000**	**1**
B05	**C4**	**Rahme et al. (1995): friable soil (loamy or silty soil with low coarse fragments) and prey**	**-19.92**	**6**	**52.95**	**0.00**	**0.741**	**1**
	P1	THTA: [grassland*friable soils] + SPCO:[streamside+stand age*FG, LG, F parent material] + MAFL:[(colluvium*grassland) + unvegetated]	-22.17	5	55.12	2.17	0.250	2
B06	**P3**	**SPCO:[% open*FG, LG, F parent material]**	**-22.51**	**1**	**47.13**	**0.00**	**0.418**	**1**
	P2	SPCO:[streamside+stand age*FG, LG, F parent material] + MAFL:[(colluvium*grassland) + unvegetated]	-19.92	4	49.02	1.89	0.163	2
	H1	each BCLC habitat category	-19.61	5	51.04	3.90	0.059	3
	H3	reduced BCLC habitat categories	-22.21	3	51.10	3.96	0.058	4
	P1	THTA: [grassland*friable soils] + SPCO:[streamside+stand age*FG, LG, F parent material] + MAFL:[(colluvium*grassland) + unvegetated]	-19.84	5	51.49	4.36	0.047	5
	H5	% open	-24.75	1	51.60	4.47	0.045	6
	P5	same as P1, but with seasonal component for SPCO and MAFL	-20.04	5	51.90	4.76	0.039	7
	C5	Apps et al. (2002): colluvium, canopy closure, well-drained soils, forest age (surrogate for forest age classes), site index, elevation, glaciofluvial parent material, loamy soils (surrogate for FSL), non-productive sites (surrogate for open range)	-15.85	8	52.50	5.36	0.029	8
	H2	forest cover category	-20.64	5	53.09	5.96	0.021	9
	H4	stand age	-25.54	1	53.20	6.06	0.020	10
	C2	in road right-of-way in relation to crown closure, opening	-24.47	2	53.27	6.14	0.019	11

Appendix 7 (cont.).

Badger ID	Model ID	Model components	log($\mathcal{L}$)	K	AIC$_c$	Δ_i	w_i	Rank
B06	C4	Rahme et al. (1995): friable soil (loamy or silty soil with low coarse fragments) and prey	-19.72	6	54.07	6.93	0.013	12
	P4	SPCO:[streamside+stand age*FG, LG, F parent material]	-24.94	2	54.22	7.09	0.012	13
	T3	distance to water in relation to season	-26.49	1	55.08	7.95	0.008	14
B08	**S1**	**soil texture**	**-15.94**	**1**	**34.07**	**0.00**	**0.093**	**1**
	C1	soil texture and opening	-15.94	1	34.07	0.00	0.093	2
	H4	stand age	-16.11	1	34.41	0.34	0.078	3
	T3	distance to water in relation to season	-16.26	1	34.70	0.63	0.068	4
	P4	SPCO:[streamside+stand age*FG, LG, F parent material]	-16.35	1	34.89	0.82	0.061	5
	H5	% open	-16.38	1	34.93	0.87	0.060	6
	S7	soil texture and coarse fragment content	-15.25	2	35.07	1.00	0.056	7
	S3	parent material	-15.25	2	35.07	1.00	0.056	8
	P5	same as P1, but with seasonal component for SPCO and MAFL	-15.27	2	35.11	1.04	0.055	9
	C3	previous radiolocation in relation to season, friable soil	-15.35	2	35.26	1.20	0.051	10
	S8	friable soil	-16.64	1	35.45	1.39	0.046	11
	S5	slope of unit	-16.64	1	35.45	1.39	0.046	12
	S4	coarse fragment content	-16.64	1	35.45	1.39	0.046	13
	H6	in grassland unit	-16.64	1	35.45	1.39	0.046	14
	S2	soil drainage	-16.64	1	35.45	1.39	0.046	15
	T2	slope position	-15.94	2	36.46	2.39	0.028	16
	P1	THTA: [grassland*friable soils] + SPCO:[streamside+stand age*FG, LG, F parent material] + MAFL:[(colluvium*grassland) + unvegetated]	-16.33	2	37.23	3.16	0.019	17
	P2	SPCO:[streamside+stand age*FG, LG, F parent material] + MAFL:[(colluvium*grassland) + unvegetated]	-16.33	2	37.23	3.16	0.019	18
B09	**S2**	**soil drainage**	**-16.65**	**2**	**37.68**	**0.00**	**0.287**	**1**
	S8	friable soil	-18.02	1	38.17	0.49	0.224	2
	C3	previous radiolocation in relation to season, friable soil	-17.58	2	39.55	1.87	0.113	3

Appendix 7 (cont.).

Badger ID	Model ID	Model components	log($\mathcal{L}$)	K	AIC$_c$	Δ_i	w_i	Rank
B09	C5	Apps et al. (2002): colluvium, canopy closure, well-drained soils, forest age (surrogate for forest age classes), site index, elevation, glaciofluvial parent material, loamy soils (surrogate for FSL), non-productive sites (surrogate for open range)	-7.28	9	40.07	2.39	0.087	4
	S3	parent material	-16.10	4	41.58	3.90	0.041	5
	H5	% open	-19.79	1	41.71	4.04	0.038	6
	C4	Rahme et al. (1995): friable soil (loamy or silty soil with low coarse fragments) and prey	-13.50	6	42.11	4.43	0.031	7
	T2	slope position	-17.83	3	42.46	4.78	0.026	8
	C2	in road right-of-way in relation to crown closure, opening	-19.13	2	42.64	4.96	0.024	9
	H3	reduced BCLC habitat categories	-16.69	4	42.76	5.08	0.023	10
	H4	stand age	-20.68	1	43.48	5.80	0.016	11
	H2	forest cover category	-17.11	4	43.60	5.92	0.015	12
	T1	elevation, distance to water, distance to pavement, slope position	-14.38	6	43.87	6.19	0.013	13
	S6	parent material is sorted during deposition	-21.06	1	44.24	6.56	0.011	14
	S7	soil texture and coarse fragment content	-17.56	4	44.49	6.81	0.010	15
	S5	slope of unit	-20.11	2	44.60	6.92	0.009	16
B10	**P3**	**SPCO:[% open*FG, LG, F parent material]**	**-18.83**	**1**	**39.81**	**0.00**	**0.159**	**1**
	H5	% open	-18.92	1	39.98	0.17	0.146	2
	S2	soil drainage	-19.50	1	41.14	1.33	0.082	3
	H2	forest cover category	-18.37	2	41.19	1.38	0.080	4
	S4	coarse fragment content	-19.71	1	41.56	1.75	0.066	5
	T3	distance to water in relation to season	-19.97	1	42.09	2.28	0.051	6
	H6	in grassland unit	-20.07	1	42.28	2.47	0.046	7
	S6	parent material is sorted during deposition	-20.07	1	42.29	2.48	0.046	8
	C2	in road right-of-way in relation to crown closure, opening	-18.92	2	42.30	2.49	0.046	9
	H4	stand age	-20.10	1	42.35	2.54	0.045	10
	S8	friable soil	-20.10	1	42.35	2.54	0.045	11

Appendix 7 (cont.).

Badger ID	Model ID	Model components	log($\mathcal{L}$)	K	AIC$_c$	Δ_i	w_i	Rank
B10	T2	slope position	-19.12	2	42.70	2.89	0.037	12
	S1	soil texture	-19.33	2	43.11	3.30	0.030	13
	H1	each BCLC habitat category	-18.30	3	43.56	3.75	0.024	14
	H3	reduced BCLC habitat categories	-18.30	3	43.56	3.75	0.024	15
	S5	slope of unit	-19.68	2	43.82	4.01	0.021	16
	P4	SPCO:[streamside+stand age*FG, LG, F parent material]	-19.89	2	44.24	4.43	0.017	17
B12	**C2**	**in road right-of-way in relation to crown closure, opening**	**-12.15**	**2**	**28.89**	**0.00**	**0.327**	**1**
	C3	previous radiolocation in relation to season, friable soil	-13.15	2	30.91	2.02	0.119	2
	P5	same as P1, but with seasonal component for SPCO and MAFL	-13.39	2	31.39	2.50	0.094	3
	T3	distance to water in relation to season	-14.97	1	32.12	3.23	0.065	4
	S8	friable soil	-14.98	1	32.15	3.26	0.064	5
	S6	parent material is sorted during deposition	-14.98	1	32.15	3.26	0.064	6
	S4	coarse fragment content	-15.13	1	32.46	3.57	0.055	7
	S2	soil drainage	-15.77	1	33.74	4.84	0.029	8
	P3	SPCO:[% open*FG, LG, F parent material]	-15.81	1	33.82	4.93	0.028	9
	H4	stand age	-15.83	1	33.84	4.95	0.028	10
	H5	% open	-15.94	1	34.07	5.18	0.025	11
	C4	Rahme et al. (1995): friable soil (loamy or silty soil with low coarse fragments) and prey	-13.65	3	34.57	5.67	0.019	12
	S1	soil texture	-15.08	2	34.76	5.87	0.017	13
	P4	SPCO:[streamside+stand age*FG, LG, F parent material]	-15.13	2	34.86	5.97	0.017	14
B14	**C3**	**previous radiolocation in relation to season, friable soil**	**-27.48**	**2**	**59.23**	**0.00**	**0.346**	**1**
	H2	forest cover category	-26.69	3	59.92	0.69	0.245	2
	H5	% open	-29.57	1	61.22	2.00	0.128	3
	H4	stand age	-30.06	1	62.21	2.99	0.078	4
	S3	parent material	-25.88	5	63.16	3.94	0.048	5
	H3	reduced BCLC habitat categories	-28.41	3	63.36	4.13	0.044	6

Appendix 7 (cont.).

Badger ID	Model ID	Model components	log($\mathcal{L}$)	K	AIC$_c$	Δ_i	w_i	Rank
B14	C2	in road right-of-way in relation to crown closure, opening	-29.56	2	63.38	4.16	0.043	7
	S8	friable soil	-31.43	1	64.95	5.72	0.020	8

Appendix 8. Translocation methodology developed from live-capture and handling portion of the research project.

Badger-Human Conflict Resolution

Populations of badgers in British Columbia are critically endangered and it is estimated that fewer than 300 animals occur in the province today. Because badgers are critical to the functioning of healthy grassland and dry forest ecosystems, ensuring the persistence of these carnivores is very important. Badgers occur at very low densities, have large space requirements, and have poor survival - all of which contribute to the current conservation crisis facing the species. This crisis has reached such a critical stage that every single badger is an important member of the population. The purpose of this document is to provide information on why conflict can occur between humans and badgers, information on possible resolutions other than translocation, a checklist for determining when it is appropriate to translocate badgers, and a methodology for capturing, transporting, and releasing animals.

Translocating animals is very risky. Animals that are unfamiliar with their release area may be more vulnerable to predation, unable to find sufficient food, or more susceptible to additional conflict with humans. Because of this, translocation should only be considered as a last resort when all other avenues for resolution have been attempted. Badgers should only be moved when there is a direct threat to their lives (e.g., a landowner threatening to shoot it or it is found in a location with a high mortality risk). Once most landowners learn more about the ecology and behaviour of badgers, they usually understand that the risk to humans, livestock, or property from badgers is very low.

Behaviour of Badgers – *Why do badgers end up in conflict with people?*

Badgers normally reside in grassland and open forest ecosystems. However, with increasing human development in these types of habitats, human-modified habitats that support high concentrations of prey can attract badgers, especially in areas where normal badger habitat has become degraded or disappeared altogether. Thus, badgers sometimes show up in some unlikely habitats, such as in urban areas, in parks and green-spaces, and along roadsides. Unfortunately, badgers are usually more tolerant of humans than vice versa, and because of preconceived notions that badgers are pests, landowners occasionally destroy badgers.

A primary contributing factor to the conflict between badgers and humans is that many of the habitats that badgers prefer are also desirable to humans. Conflict ensues when this overlap is combined with the creation of attractive habitats, such as those with abundant prey. The effects of human settlement on badgers are then twofold: badgers are both displaced from their natural habitats by community expansion and development and drawn into human-modified areas by abundant prey resources.

The types of human-modified habitats that often attract badgers include areas with short grass or abundant green herbaceous vegetation, such as over-grazed fields and golf courses, which provide quality habitat for Columbian ground squirrels. Rodent populations within these habitats typically multiply rapidly and are often considered pests by landowners. Landowners who do not recognize the pest-control benefits of badgers often consider the badger to be another pest that has invaded their property.

It is useful to understand several facets of the ecology of badgers to better assess the likelihood of a badger causing chronic conflict with a landowner. The average size of the home range over which badgers in the Thompson region roam is about 35 km² (3,500 ha or 8,750 ac) for males and 15 km² (1,500 ha or 3,750 ac) for females. Badgers typically move from burrow to burrow throughout their home range, especially during summer months, moving an average of 2.8 km per day. Occasionally, badgers return to existing burrows and re-use them, but research in the Kamloops area showed that radio-tagged badgers were more likely to move at least 0.5 km within 1 day than to stay in the same area (Figure A1). Thus, because of their wide-ranging movements and wandering lifestyle, badgers are very unlikely to establish themselves permanently on a single landowner's property.

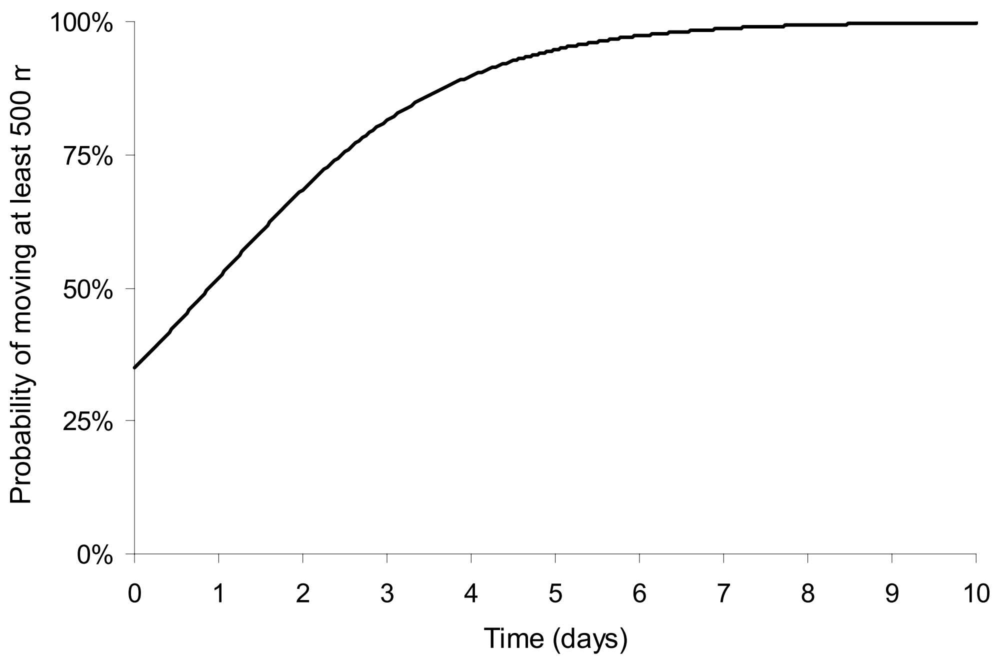


Figure A1. Badgers tend to move quite frequently during the summer and spend very little time in one place. This graph, based on radiotelemetry data, shows that a badger is more likely to have moved at least 500 m within 24 hours than to stay in the same area.

When badgers use habitats near livestock and houses they are often perceived to be a nuisance. Landowners may perceive badgers burrows to be a threat to livestock. However, the threat of livestock becoming injured by stepping in burrows appears to be overestimated and rarely occurs. Badgers are also perceived to be a risk to pets, and indeed they may sometimes prey on house-cats. Dogs may also be at risk, but large domestic dogs also kill badgers. The threat to humans appears to be low, despite their aggressive reputation. Badgers will occasionally put on aggressive displays when cornered, but they are unlikely to attack a person unless highly provoked.

Translocation criteria – *When is it appropriate to translocate a badger?*

The most appropriate action to take when a complaint is received is to provide the landowner with information about the movement patterns of badgers and to advise them to not disturb the animal. Once the movement patterns of badgers are explained to landowners, they are generally more accepting of the animal's presence and are willing to wait until the badger moves to another portion of its home range.

The needs of female badgers with young require particular sensitivity and understanding from landowners. Females with young may spend up to 2 months at their natal burrow, which they will use repeatedly. In fact, the only time that badgers spend a lot of time in the late spring/early summer at one burrow is if there is young. Capturing a female and all its young is a very risky and difficult undertaking and should be avoided, except in the most extreme cases. Female with young may be protective of their young and act aggressively towards people that approach the natal burrow or young. It is best to leave the animals alone and allow them to move on their own.

Release criteria – *Which badgers are good candidates for translocation?*

While the chances of having to translocate badgers (either from live-trapping a problem animal or after rearing a juvenile) are extremely low, the following criteria need to be considered before capture:

1. the animal must be in good physical health and not showing signs of disease
2. sex: females are critical to the population and should always be released
3. age: very young badgers whose mother has died may not be good candidates for immediate release because they are not capable of hunting successfully or avoiding predators on their own. These animals may need to be reared at a zoo or other approved facility prior to release into the wild.

Capture procedures

If the situation cannot be resolved with the landowner and a badger has to be captured, it should be done under the supervision of one of the badger projects currently underway in the province (East Kootenay Badger project, Nancy Newhouse (250) 342-3205; Thompson-Okanagan Badger Project, Richard Weir (888) 223-4376). Most conservation officers do not have the equipment necessary for capturing badgers, and these biologists have the expertise and equipment to complete the live-capture. The live-capture procedure is as follows:

Set livetraps at burrows using "den sets", which involves placing a trap at the mouth of an active badger burrow (Baker and Dwyer 1987). Do not attempt to immobilize free-ranging badgers using a dart gun or blowgun because the animal may disappear underground, become immobilized in an unsafe position, and possibly suffocate.

Use padded "soft-catch" foot-hold traps anchored by attaching the trap with a 3 mm diameter cable to a flared anchor pounded 45 cm into the soil. Use Victor 1½ coil spring traps - **do not use #2, #3, or #4 spring traps** because they may severely damage the badger's foot. Set each trap so that no more than 15 cm of cable is exposed above the soil surface. It may be effective to scent nearby vegetation with commercial canine lure.

Set and monitor traps so that they are operational for a maximum of 14 hours each night. Set traps between 1800 and 2100 h and close them between 0600 and 0900 h the following day. Release all non-target species immediately.

Upon capture of a badger, estimate the body weight to determine the appropriate dosage of anaesthetic. Restrain the badger using a handling pole prior to administering the anaesthetic with a jab-stick. Immobilize badgers using a 1:1 mixture of tiletamine hydrochloride and zolazepam hydrochloride (Telazol®). Attempt to administer Telazol® at <5 mg/kg to induce light anaesthesia for brief handling. Because of decreases in body temperature, place the immobilized badger in a sternal position over warm hot-water bottles.

Measure and monitor badgers while they are immobilized. Record the sex, body weight, and cranial and skeletal measurements. Collect hair and blood samples from each badger for genetic analysis. Take photographs of the head, dorsal, and ventral regions. Respiration and cardiac rate, body temperature, and capillary refill time should also be recorded at regular intervals while the badger is immobilized. Place the immobilized badger in transport container (modified 45 gallon plastic container), secure container in vehicle, and transport to release site.

Release sites– *Where is the best area to release a translocated badger?*

Since the intent of this protocol is to ensure the survival of badgers that are in conflict with humans, it is best to translocate an animal to another point within its home range. This way, the translocated animal is familiar with its surroundings, knows the location of resources, and is thus more likely to survive. The home ranges of females are approximately 15 km^2, whereas males have larger home ranges of around 35 km^2. Thus, if females are released in suitable habitat within 2 km and males are released within 3.5 km of their capture sites, the translocated animal will likely be within its home range.

However, if the likelihood of the badger returning to the same property is relatively high, a release site outside of the home range may be warranted. There are many unoccupied areas of suitable habitat currently available for badgers in the province, partly because population densities are so low. Grasslands or dry forests with large populations of prey (i.e., Columbian ground squirrels, yellow-bellied marmots, northern pocket gophers) and little human activity are probably the best candidates. Prey species tend to live in patches, so picking an area with many patches of prey nearby is preferable. Because the main source of mortality for badgers is from collisions with vehicles while crossing roads, release sites should be far-removed from busy roads.

To increase the likelihood of successful translocation, animals should be released directly into a previously dug burrow. For animals being released within its home range, finding a suitable burrow may take some reconnaissance of suitable habitats within a prospective home range radius. In areas not occupied by a resident badger, a small burrow may need to be pre-excavated prior to release.

Biologists involved in badger conservation should be contacted when considering potential release sites. During the course of their research, they have likely identified candidate areas for translocation and may also suggest atypical habitats where badgers have been successful, such as ski hills and clearcuts.

Appendix 9. Guidelines to maintain burrowing and foraging habitat for badgers.

Habitat Conservation Guidelines for Badgers

Badgers rely on habitat to provide them with 1) food, and 2) places to burrow for shelter. Private landowners can help conserve badger habitat by leaving some room for badgers to exist within their property. The benefits of badgers include free effective control of burrowing rodents and increased soil productivity. Every landowner, no matter how much land they have, can play an important role in maintaining badger habitat.

Two primary factors dictate the habitat conservation measures that are appropriate for specific situations: general soil and terrain characteristics, and land use and biogeoclimatic zone. Each of these factors plays an important role in determining which conservation or enhancement options are suitable. Soils and terrain characteristics can affect the ability of badgers to find suitable sites for burrowing, biogeoclimatic zones affect the prey community that badgers forage upon, and the extent of area under management affects how to best apply habitat conservation guidelines.

Soil and terrain characteristics:

Different soil types can be ranked for their suitability as burrowing habitat for badgers (Table A9). Most landowners are very familiar with the soil types that occur on their property.

Soil texture identification:

- Sandy soils – not sticky or slippery when wet, relatively grainy
- Silty soils –dusty when dry, slippery when wet
- Clayey soils – very sticky when wet, very fine when dry
- Loamy soils –slight features of sandy, silty, and clayey soils

Generally, silty and loamy soils are the best for badgers to excavate their burrows. Badgers will sometimes use clayey or sandy soils, but burrows in these types of soils are difficult to dig or collapse easily.

Coarse fragment content (stoniness):

Coarse fragments, those soil particles that are >2 mm diameter, greatly affect the utility of soil for burrowing. Soils with high coarse fragment contents (that is, >20% of the total soil volume) are not suitable for burrowing. Generally, soils that have visible stones that would seriously handicap cultivation (that is, >5% of the land covered, stones <10 m apart) are not suitable sites for burrowing.

If possible, conserve pockets of silty or loamy soils with low coarse fragment content. This can be achieved in areas that have poor operability, such as hummocky terrain, or along slopes (for example, >15% slope gradient). Attempt to keep the size of these areas >10% of the total land area and >400 m^2.

Table A9. Suitability of various soils for conservation of burrowing habitat for badgers. +++: high suitability, --- poor suitability. Coarse fragment content is the percentage of the soil occupied by particles >2 mm diameter.

	Coarse fragment content		
Soil texture	Low (<20%)	Moderate (20 – 50%)	High (>50%)
Sand	-	--	---
Silt	+++	++	---
Clay[a]	+		
Loam	++	+	---

a clay soils do not form in association with moderate or high coarse fragment materials

Biogeoclimatic zones

The different biogeoclimatic zones that badgers occur in have considerable effect on the type of habitat conservation that the landowner should use depending on the predominant land use. This is because the foraging ecology of badgers appears to be fairly different among the different zones. Landowners should consult Lloyd et al. (1990) or contact their local Ministry of Forests range officer to determine which biogeoclimatic zone applies to their area. For the purpose of these guidelines, biogeoclimatic zones can be lumped into 3 dominant groups: grassland, open forest, and forested zones.

Permanent developments

Applies in: ***Grassland zones:*** BG zones, PPxh1a, PPxh2a, IDFxh1a, IDFxh2a, IDFdk1a, IDFdk2a
Open forest zones: PPxh1, PPxh2, IDFxh1, IDFxh2

Permanent developments (e.g., housing, industrial, golf course) can reduce their impact on badger habitat primarily by maintaining green-space corridors. Objectives for green-space within developed areas include:

- Retain native grassland composition.
- Create corridors >30 m wide.
- Connect corridors with underpasses/culverts under roads to link to natural grassland areas.
- Assure safe passage through developments using fencing to prevent wildlife from accessing developed areas along corridors.

Intensive agriculture

Apply in: ***Grassland zones:*** BG zones, PPxh1a, PPxh2a, IDFxh1a, IDFxh2a, IDFdk1a, IDFdk2a
Open forest zones: PPxh1, PPxh2, IDFxh1, IDFxh2

Intensive agriculture, particularly for those crops that involve irrigation, can contribute substantially to the conservation of foraging habitat for badgers by providing prey. Fortunately, badgers do not tend to burrow in irrigated areas, so the likelihood of badgers damaging crops through burrowing is quite low. If anything, badgers will help reduce burrowing by rodents in crops by control the rodent population around the fields. Thus, badgers can be an effective method of control of burrowing rodents for agriculturists.

The primary method for conserving badger habitat in this type of setting is to preserve areas of natural grassland habitat on the sides of crop fields in which badgers can burrow.

- Retain native grassland composition along the edges of fields >5m wide, likely in areas with low operability, such as areas with steep slopes.
- Leave corridors >30 m wide between sections of native grasslands to allow connective routes between grasslands.
    - Minimize disturbance in these areas to avoid destruction of burrows.

<u>Grazing</u>

Apply in: ***Grassland zones:*** BG zones, PPxh1a, PPxh2a, IDFxh1a, IDFxh2a, IDFdk1a, IDFdk2a

Most grazing that occurs in grassland zones is compatible with habitat conservation for badgers, providing that landowners do not exterminate resident animals. Very high grazing levels may diminish prey populations, but grazing has not been shown to be a factor that strongly affects the habitats of badgers.

- Conserve some grassland areas for burrowing habitat, such as those with hummocky terrain or steep slopes that are not suitable for grazing.
- Do not exterminate populations of Columbian ground squirrels, yellow-bellied marmots, and northern pocket gophers unless absolutely necessary. If extermination is the only option, do not use poison.

Apply in: ***Open forest zones:*** PPxh1, PPxh2, IDFxh1, IDFxh2
Forested zones: IDFdk1, IDFdk2

- Conserve some open forest areas for burrowing habitat, such as those with hummocky terrain or steep slopes that are not suitable for grazing.
- Do not exterminate populations of Columbian ground squirrels, yellow-bellied marmots, and northern pocket gophers unless absolutely necessary. If extermination is the only option, do not use poison.

<u>Dry-land hay production</u>

Apply in: ***Forested zones:*** IDFdk1, IDFdk2, IDFdm, IDFmw, MS zones, ESSF zones

The primary method for conserving badger habitat in this type of setting is to preserve areas of natural grassland habitat or cleared areas for dry-land hay production on the sides of crop fields in which badgers can burrow.

- Retain native grassland composition along the edges of fields >5m wide, likely in areas with low operability, such as areas with steep slopes.
- Leave corridors >30 m wide between sections of native grasslands to allow connective routes between grasslands.
    - Minimize disturbance in these areas to avoid destruction of burrows.
- Conserve some grassland areas for burrowing habitat, such as those with hummocky terrain or steep slopes that are not suitable for grazing
- Do not exterminate populations of Columbian ground squirrels, yellow-bellied marmots, and northern pocket gophers unless absolutely necessary. If extermination is the only option, do not use poison.

Forest harvesting/clearing

Apply in: ***Open forest zones:*** PPxh1, PPxh2, IDFxh1, IDFxh2
Forested zones: IDFdk1, IDFdk2, IDFdm, IDFmw, MS zones, ESSF zones

Generally, forest harvesting or land clearing in these areas may enhance foraging habitat for badgers, providing that the cleared areas support sufficient prey species and are suitable for digging. Landowners can enhance habitat for badgers by:

- Maintain cleared or logged area in a low-disturbance grass/forb/shrub stage.
- Promote colonization by burrowing prey.
    - Yellow-bellied marmot and Columbian ground squirrel colonies may be enhanced by creating rock or log piles in the middle of cleared areas
    - Columbian ground squirrels will invade grassy/shrubby areas that have sufficient production of herbaceous plants
- Connect cleared areas with corridors >10 m wide to other openings to allow connective routes.
- Minimize use of heavy machinery in areas with suitable soils for burrowing (see section on soil and terrain characteristics).
    - Badgers that occur in areas with predominately morainal deposits (e.g., ESSF, MS forests) may be limited to using disturbed soils (e.g., overburden, road fill) or small glaciofluvial sites.