**FINAL REPORT**

# QUESTIONS AND INDICATORS FOR EVALUATING THE EFFECTIVENESS OF BADGER WILDLIFE HABITAT AREAS

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## EXECUTIVE SUMMARY

The purpose of this document is to develop a framework to evaluate the effectiveness, or function, of Wildlife Habitat Areas (WHAs) established for badgers. The goal of a badger WHA is to protect key habitats, such as concentrations of burrow sites, especially maternal dens, and concentrations of prey species or friable soil habitat. WHAs used to rear kits or are regularly used by family groups will be considered highly effective, with functioning habitat and sustainable management regimes. If a WHA is not used by badgers, it may signify naturally declining conditions such as regional badger population densities or prey cycles and not necessarily reflect management regimes. WHAs ranked as not effective may require further inquiry, and implementation of restoration or conservation initiatives that are outlined in recovery strategies or established regionally (e.g., Regional Implementation Groups). Nine indicators of habitat quality and badger populations have been selected to monitor the effectiveness of WHAs. A phased approach to monitoring effectiveness of badger WHAs is recommended, where a *Routine* assessment of *High* priority indicators is implemented first, and may identify the need to implement more *Intensive* evaluations. This effectiveness monitoring framework relies on detection of trends by assessing indicators over time and adapting management regimes to maintain effective WHAs.

## ACKNOWLEDGEMENTS

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# 1.0 INTRODUCTION

## 1.1 PROJECT BACKGROUND

One goal of the British Columbia *Forest and Range Practices Act* (FRPA) is to conserve biological diversity, including plant communities and wildlife habitat, from the impacts of forest and range activities. Under FRPA, the Ministry of Environment (MoE) is authorized to establish habitat management strategies for species designated within the Identified Wildlife Management Strategy (IWMS; MWLAP 2004). Designated species within the IWMS can be managed through the establishment of Wildlife Habitat Areas (WHAs) that are established around key habitats considered to be most limiting to a particular Identified Wildlife. The objectives and General Wildlife Measures outlined in the IWMS regulate activities within WHAs by describing management practices and potentially prohibiting certain activities or limiting them during sensitive periods, such as the breeding season. The IWMS applies to all Crown land regulated by FRPA, and to private land that is subject to a tree farm or woodlot license. Forest tenure holders are required to incorporate management strategies that are consistent with WHA objectives, and comply with these established measures during operations.

Badgers (*Taxidea taxus*) are designated as Identified Wildlife under FRPA, and are potentially affected by forest and range activities. The subspecies of badger (*T. t. jeffersonii*) that occurs in the province is considered "endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and is red-listed in the province. Badgers are fossorial carnivores that are found in grassland and open forest habitats, and their main habitat requirements include suitable soil for burrowing and sufficient prey resources. Currently, a number of WHAs are proposed across the province for protection of critical habitat for this species. This document provides guidelines for conducting effectiveness evaluations of badger WHAs established in British Columbia to determine whether management objectives are being achieved.

## 1.2 PROJECT OBJECTIVES AND APPROACH

The purpose of this document is to develop a framework to evaluate the effectiveness, or function, of WHAs established for badgers. Effectiveness monitoring evaluates the response of the habitat or badger population to the management practices within and adjacent to a WHA. The response then must be compared to adequate baseline information to reliably determine the difference between natural variation and the effects of WHA design, location or management practices.

The development of the evaluation framework follows the approach provided by the Wildlife Resource Value Team (Erickson, et al. 2005) and is consistent with the monitoring framework developed for Great Basin gopher snakes (*Pituophis catenifer deserticola*) in B.C. (Ovaska and Lennart 2004). First, objectives and questions that address the level of function of a WHA are established. Threats to badger habitat and populations are then identified, and indicators are selected that measure physical characteristics or population parameters that change as a result of threats. Candidate indicators are identified using a conceptual model, and screened based on cost and intensity of monitoring to select those that are most effective to address the monitoring questions. This process was supported by consultations with the *jeffersonii* Badger Recovery Team during a meeting on February 12, 2006, and with on-going dialogue.

This document includes the following components:

1. Overview of existing information on badger ecology and conservation issues;
2. Goals and general measures for WHAs as outlined in the IWMS account for badgers;
3. Monitoring objectives and key questions that relate to the overall goal of WHAs for badgers;
4. Conceptual model describing linkages between habitat and population threats and candidate indicators; and,
5. Description all potential indicators and the screening process to select most appropriate indicators to address the key questions;

6. Definition of effectiveness organized into four functional categories (e.g., *Highly Effective, Moderately Effective, Effective,* and *Not Effective*) and recommended targets and thresholds;
7. Description of each indicator selected for WHA effectiveness monitoring, including rationale for selection, methods, and criteria for action. Each indicator will be ranked according to intensity of the survey (*Routine, Extensive,* and *Intensive*), and priority (*High, Moderate,* and *Low*); and,
8. Strategy to implement effectiveness monitoring for badgers, and identification of potential challenges in meeting conservation and management targets.

The testing of monitoring protocols and any revisions identified during testing are outside of the scope of this project, and will be completed in the future.

# 2.0 OVERVIEW OF EXISTING INFORMATION

## 2.1 DISTRIBUTION AND HOME RANGE

Badgers (*Taxidea taxus*) are found mainly in grassland ecosystems across North America. In British Columbia, badgers are at the north-western limit of their range and the subspecies occurring in the province (*T. t. jeffersonii*) inhabits the dry southern interior within the East Kootenay, Boundary, Okanagan, Thompson and Cariboo regions (Figure 1). Biogeoclimatic zones that are mainly associated with badger habitat are the Bunchgrass (BG), Ponderosa Pine (PP) and Interior Douglas Fir (IDF). These habitats are generally limited to linear corridors in valley bottoms that are often fragmented by transportation corridors and urban developments. In addition to grasslands, badgers in B.C. have been observed living in a range of habitats including forested and alpine areas (Apps et al. 2002; Hoodicoff 2003; Weir et al. 2003; Hoodicoff 2004a).

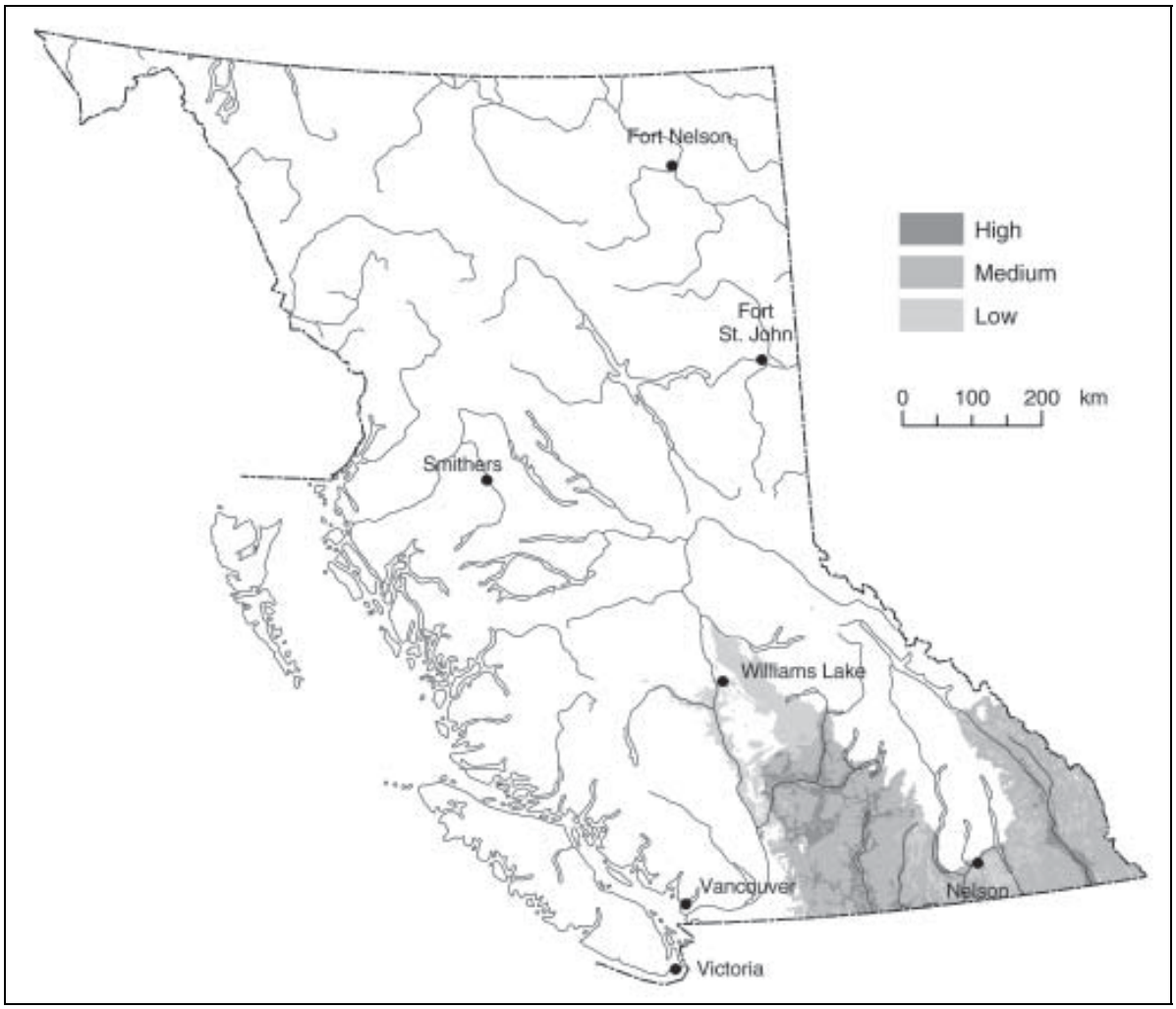


Figure 1. Potential distribution of *jeffersonii* badgers in British Columbia (Source: Adams and Kinley 2004).

Home ranges of badgers in British Columbia are large, and average 315 $km^2$ for males in the East Kootenay region ($n$ = 9; Newhouse and Kinley 2004) and 88 $km^2$ for males in the Thompson region ($n$ = 8; Weir, et al. 2003). Home ranges of female badgers are smaller, and average 34 $km^2$ in the East Kootenay region ($n$ = 7; Newhouse and Kinley 2004) and 11 $km^2$ in the Thompson region ($n$ = 1; Weir et al. 2003). Minta (1993) also determined that the availability of breeding females determines the home range area of male badgers, and food availability determines the size and orientation of female home ranges (Goodrich and Buskirk 1998; Minta 1993). Therefore, large home range sizes may result from expanded movements of badgers due to low prey densities and low (female) badger densities (*jeffersonii* Badger Recovery Team 2005).

## 2.2 DESCRIPTION OF HABITAT REQUIREMENTS

The main habitat requirements of badgers are suitable soils for burrowing and sufficient prey resources (Rahme, et al. 1995). The Recovery Strategy for *jeffersonii* badgers suggests that conservation of patches and ecosystem units with these features is important to maintain local populations.

### 2.2.1 Burrows and Soils

Badgers dig and maintain a number of burrows that are frequently re-used throughout their home ranges. Burrows are used by badgers for a number of purposes, including resting, foraging, and raising kits ("maternal burrows") (*jeffersonii* Badger Recovery Team 2005). Maternal burrows may be identified by larger than average burrows with large soil berms, signs of repeated use, or observations of family groups. However, maternal burrows are not always identified reliably without confirming the presence of a family group. A standard description of badger "residences" as defined under the federal *Species at Risk Act* (SARA) and provincial *Wildlife Amendment Act* is currently being drafted by the B.C. Ministry of Environment.

Soils that may be readily dug ("diggable"), provide structure, and appropriate thermal and moisture properties are considered suitable for badger burrows. Apps, et al. (2002) found

that badgers in the East Kootenay region select sites based on soil parent material, soil texture, soil drainage and site productivity. Weir et al. (2003) found that badgers in the Thompson region select patches with silty soils that were well-drained and had low coarse fragment content. Within the Cariboo region, Hoodicoff (2004a) identified burrows in mainly Aeolian deposits. These soils are typically well-sorted, mainly fine sand and coarse silt textures, with very low coarse fragment content and are atypical of the landscape (Chapman, per. comm. 2006). Hydroconductivity, the ability of a soil to wick moisture, may also be an important soil characteristic for badgers (Weir, pers. comm. 2006).

### 2.2.2 Prey

Badgers are opportunistic carnivores specialized to hunt fossorial or semi-fossorial prey, and are known to diversify their diet to take advantage of abundant prey resources (Lampe 1982; Messick 1987). As a result, badger diets are variable across the province. Columbian ground squirrels (*Spermophilus columbianus*) are widely dispersed across the province and commonly reported as a main component of badger diets in many regions (Rahme, et al. 1995; Newhouse and Kinley 2001; Hoodicoff 2003). Yellow-bellied marmots (*Marmota flaviventris*) also are common across the province, and were associated with up to 75% of badger sightings reported in the Thompson region (Rahme, et al. 1995). Pocket gophers (*Thomomys talpoides*) were identified in diets of badgers in the Thompson region (Hoodicoff 2003), and although pocket gophers are common in the southern interior, they do not occur north of the Thompson River (Johnstone 1954). In the Cariboo region, muskrats (*Ondatra zibethicus*) appear to be a primary source of prey for some badgers where ground squirrels are not abundant (Hoodicoff 2004b). Badgers also generally supplement their diets with many other small mammals, reptiles, amphibians, birds and eggs, and insects (Newhouse and Kinley 2001, Hoodicoff 2003).

This diversity of prey allows badgers to respond and adapt to many habitat conditions. Since ground squirrel and marmot colonies often are found in heavily grazed pastures, poor grassland condition does not necessarily indicate low food availability for badgers.

However, poor habitat condition does limit the diversity of prey species and the ability of badgers to adapt to changing conditions.

## 2.3 BADGER POPULATION TRENDS

Evidence suggests a long-term and continuing decline of badger populations in the province. Historic records report that badgers were trapped heavily in the mid-1920s, when more badgers were trapped than are currently estimated to live in the province. Pelt returns have remained low since the 1940s (*jeffersonii* Badger Recovery Team 2005). Landowners also are reporting less frequent badger sightings over the past 20 years. More recently, research conducted in the East Kootenay and Thompson regions report low juvenile and female badger capture rates (Newhouse and Kinley 2004; R. Weir unpublished data). Currently, the provincial population is estimated at 228 to 340 badgers, where 70% are thought to be breeding adults (*jeffersonii* Badger Recovery Team 2005).

Genetic analyses of badgers across the province suggest that there are at least two distinct metapopulations, located in the East Kootenay and Thompson/Okanagan regions (Kyle, et al. 2004). The East Kootenay metapopulation was genetically more similar to badgers in Montana than in the Thompson/Okanagan, which is separated by mountain ranges. The Thompson/Okanagan metapopulation has relatively little genetic exchange with other populations and relatively low levels of genetic variability, placing it at risk because of its insularity and susceptibility to stochastic events (*jeffersoni* Recovery Team 2005). Genetic material from badgers in the Cariboo region was not included in this study; however, it is likely that badgers in the region also have low genetic diversity because it is at the extreme northern periphery of the range of badgers, and is relatively geographically isolated from other badger populations (Lesica and Allendorf 1995). The Cariboo badgers may contribute to the Thompson/Okanagan metapopulation, or form a distinct third metapopulation on its own.

## 2.4 THREATS AND LIMITING FACTORS

### 2.4.1 Habitat Loss and Degradation

Habitat loss and degradation from human activity is identified as a threat to badger populations in British Columbia (*jeffersonii* Recovery Team 2005). While urban development is the main cause of habitat loss, habitat is also degraded from agricultural conversion and cultivation, poor range practices, highway construction, reservoir flooding. Fire suppression leading to forest in-growth and encroachment also plays a role in reducing grassland habitat for badgers as forest canopy closes in on naturally open grassland. Wildfires may have a negative effect in the short-term, but badgers may be capable of retreating from fire or seeking refuge in underground burrows.

Factors that reduce or contribute to a decline in habitat conditions affect badger habitat at the landscape scale. Grassland habitat in the province is generally restricted to arid valley-bottoms where development rates are high, habitat is fragmented, and opportunities for badger dispersal are limited. Because badgers are capable of using modified landscapes and can tolerate some level of human activity, pristine landscapes are not necessary to ensure the persistence of badger habitat. However, maintaining large tracts of relatively undeveloped land that provide burrowing and foraging resources is considered essential to the overall persistence of badger populations in the province (*jeffersonii* Recovery Team 2005).

### 2.4.2 Loss of Prey

Loss of prey at the home range spatial scale may result from local agricultural cultivation practices such as irrigation and tilling, pest management, and poor range practices. Alteration of suitable habitat conditions, such as soils, vegetative cover, and food resources leads to decreased diversity of prey. Some species, such as meadow voles, require tall grass and have more restrictive habitat requirement than others. Other species, such as ground squirrels, generally tolerate or recolonize relatively quickly after disturbance and may eventually increase in numbers to benefit badgers.

Because of their burrowing habits, badger prey species such as ground squirrels, marmots and pocket gophers are often viewed as pests on agricultural land and are the focus of extermination practices. While direct evidence of malnourished badgers is limited, the energetic demands of a wide-ranging carnivore are high. Badgers may expand their home ranges in search for food (Lindzey 1982), contributing to low density populations and decreased breeding opportunities (Minta 1993). This is especially significant for female badgers who may require multiple copulations to induce ovulation (Wright 1963). Female badgers also exhibit delayed implantation of embryos that may be linked to nutritional requirements of pregnancy and lactation (Long and Killingley 1983). Insufficient nutrition may eventually lead to aborted implantation.

### 2.4.3 Human-Caused Mortality

Human activity is the leading cause of badger mortality in B.C.[1] Historically, badgers were trapped for their fur, but this practice was stopped in British Columbia in 1967. Now, badgers are occasionally exterminated on some properties where they are perceived as threats to property and people. As urban interfaces and agricultural practices expand, badgers are exposed to human activity more frequently. Badgers must increase their movements within large home ranges and this may expose individuals to higher risk of mortality on highways (Weir, et al. 2003).

Transportation corridors are a significant source of badger mortality. Roads (or railways) accounted for 36% of the known mortalities of radio-tagged badgers in the East Kootenay ($n$ = 5; Newhouse and Kinley 2004), and 86% in the Thompson ($n$ = 6; Weir, et al. 2003). This has been attributed to the location of badger habitat in valley bottoms where most transportation corridors are constructed. Burrows often are found within close proximity to road rights-of-way since road cuts and fill-slopes provide suitable burrowing substrates (Newhouse and Kinley 2001). Also, vegetation treatments within road rights-of-way provide habitat for many small mammals that also attracts badgers (Adams and Geis 1983, Meunier

[1] Predation is considered relatively minor in comparison to human-caused mortalities.

et al. 1999, Underhill and Angold 2000). In addition, badgers make long-distance movements most frequently during the breeding season, which coincides with peak traffic volumes in the summer months.

## 2.5 BADGER WILDLIFE HABITAT AREAS

Badgers are wide-ranging carnivores that require substantial tracts of grassland habitat to maintain viable populations. However, preserving large tracts of land may not be necessary to ensure population viability since a badger is able to co-exist with some level of disturbance on the landscape. Rather, conserving habitats in which badgers can burrow and find prey will help to ensure that badgers persist throughout their range in the province.

The goal of a WHA is to conserve habitats considered most limiting to a given Identified Wildlife element (MWLAP 2004). According to the IWMS account for badgers (Adams and Kinley 2004), the goal of WHAs is to **"protect [key][2] habitat such as concentrations of burrow sites, especially maternal dens, and concentrations of prey species or [diggable][3] soil habitat."** Potential disturbances in WHAs are identified as forestry activities (clearcutting, silvicultural site preparation), intensive cattle grazing, recreation and gravel extraction (Adams and Kinley 2004). The purpose of General Wildlife Measures for badger WHAs is to maintain important habitat features, such as open- and non-forested landscapes, grasslands in a range of seral stages, friable soils, prey resources, vegetation structure and litter to provide hiding cover for badgers and their prey (Adams and Kinley 2004).

[2] The IWMS for badgers uses the term "critical habitat" to describe the goal of Wildlife Habitat Areas. Identification of "critical habitat" is a formal process under the *Species at Risk Act* that ultimately is the responsibility of the competent Minister. This is not the intended reference in the IWMS, so the word "critical" was exchanged with "key" habitat for the purposes of this document.

[3] The IWMS for badgers uses the term "friable" to describe soils that are easily dug by badgers. In this report, these soils are referred to as "diggable" soils.

To date, there are 22 wildlife habitat areas proposed in the province: 12 in the Cariboo, 7 in the East Kootenays, and 3 in the Thompson. WHAs are designed to encompass badger habitat with the following features:

- High densities of burrows with known badger use, often with evidence of long-term occupation or associated with important foraging sites;
- Maternal burrows and frequent observations of family groups;
- Key habitat features (i.e., burrows, prey colonies, soil deposit) that are far from other known badger burrows or similar habitat features; and,
- May be at risk due to development or other disturbance.

Badger burrows provide nesting and cover habitat for a number of other species, many of which also are Identified Wildlife under FRPA. These include the burrowing owl (*Athene cunicularia*) and the Great Basin gopher snake (*Pituophis catenifer deserticola*). Also, WHAs for badgers often incorporate key habitats of other listed species, such as the sharp-tailed grouse (*Tympanuchus phasianellus*), and the American avocet (*Recurvirostra americana*). Therefore, WHAs established for badgers also may be used as a sentinel, or key species, for grassland habitat as a whole.

## 3.0 EFFECTIVENESS EVALUATION FRAMEWORK

### 3.1 FRAMEWORK

The purpose of an effectiveness evaluation is to determine whether a WHA is achieving its goal to protect key habitat for badgers. The framework to evaluate WHA effectiveness first involves establishing monitoring objectives and questions that are related to WHA goals, and identifying candidate indicators to quantify threats to badger habitats and populations. Ultimately, a suite of indicators will be selected to evaluate the effectiveness of management. The components of the framework are described in Table 1.

Table 1. Framework used to evaluate effectiveness in Wildlife Habitat Areas (WHAs).

| COMPONENT | DESCRIPTION & PURPOSE | CATEGORIES |
|---|---|---|
| Monitoring Objectives and Questions | Used to determine whether a WHA is achieving its intended goal. | • WHA used for reproduction<br>• WHA used by badgers<br>• WHA suitable for badgers |
| WHA Effectiveness Targets | Targets used to evaluate the level of function of a WHA based on monitoring questions. | • Highly Effective<br>• Moderately Effective<br>• Effective<br>• Not Effective |
| Conceptual Model and Candidate Indicators | Links threats to effects on habitat or populations | • Habitat<br>• Population<br>• Threat |
| Screening Process | Process to select indicators that are most effective in answering monitoring questions, based on priority, cost and intensity of measurement. | |
| Selected Indicators | Measurable physical characteristics or population parameters that change as a result of threats. | • Spatial Scale (Local, Regional)<br>• Intensity (Routine, Extensive, Intensive)<br>• Priority (High, Moderate, Low) |

### 3.2 MONITORING OBJECTIVES AND QUESTIONS

The goal of wildlife habitat areas established for badgers is to protect key habitats. In particular, these are concentrations of burrows (especially maternal burrows), suitable soils, and concentrations of prey. WHAs should support badgers, or at least have the ability to do so, and ideally could be used for reproduction and rearing of young to support population recovery. Because WHAs alone are not large enough to support individual badgers, it is also important to consider habitat adjacent to WHAs in order to monitor effectiveness. Indicators used to determine effectiveness should also reflect the factors responsible for establishing the WHA, as identified in the WHA Data Form.

With these objectives in mind, effectiveness of badger WHAs can be evaluated based on a tiered approach. First, the habitat within a WHA should continue to be suitable for badgers. This can be accomplished by assessing habitat features existing within the WHA (e.g., suitable soils, abundant prey) and identifying potential threats (i.e. stressors) to these

features. Ecosystem restoration should be an option if habitat becomes less suitable for badgers. The second tier is to determine whether a WHA supports badgers, and finally, to identify whether the site is used for reproduction, or by females to rear kits.

Key monitoring goals, stated in the form of questions, to determine whether a WHA is providing key habitats for badgers include:

1. Is the habitat (burrows, suitable soils and prey) within the WHA suitable for badgers?
2. Are there activities within or adjacent to the WHA that may disturb badgers or their key habitats?
3. Are badgers using the WHA and how regularly?
4. Are badgers using the WHA to reproduce or rear kits?
5. Are travel corridors between and adjacent to WHAs safe for badgers?

### 3.3 EFFECTIVENESS TARGETS

The effectiveness targets provide guidelines to evaluate the level of function of a WHA and are based on the monitoring objectives outlined in Section 3.2. WHAs used to rear kits and those that are regularly used by family groups will be considered highly effective, with functioning habitat and sustainable management regimes. If a WHA is not used by badgers, it may signify naturally declining conditions such as regional badger population densities or prey cycles, and not necessarily reflect management regimes. WHAs ranked as not effective may require further inquiry, and implementation of restoration or conservation initiatives that are outlined in the Recovery Strategy or established regionally (e.g., Regional Implementation Groups).

Effectiveness of WHAs for badgers is broken down into four categories: 1) highly effective; 2) moderately effective; 3) effective; and, 4) not effective. Criteria for these categories are described below:

1. *Highly Effective* – This category is assigned to WHAs that provide suitable habitat and are used to rear kits and/or are regularly used by family groups. Populations and

habitat conditions appear to be stable within the WHA given current management regimes.

2. *Moderately Effective* – This category is assigned to WHAs that provide suitable habitat and are regularly used by badgers (e.g., monthly). Populations and habitat conditions appear to be stable within the WHA given current management regimes.

3. *Effective* – This category is assigned to a WHA that provides key features and suitable habitat conditions that are sustainable given current management regimes; however, may not receive regular use by badgers.

4. *Not Effective* – This category is assigned to a WHA where key habitat features and suitable conditions are not sustainable given current management levels, and may result in short-term declines of habitat conditions that will limit badger productivity. Intensive monitoring may be required to clearly determine threats to habitat and population declines. Implementation of conservation or restoration activities that are identified within the *jeffersonii* Badger Recovery Strategy should be considered.

### 3.4 CONCEPTUAL MODEL AND CANDIDATE INDICATORS

According to Lint, et al. (1999), components of an ecological monitoring program include identifying threats to habitats and the population, and developing a conceptual model linking threats and disturbances to relevant ecosystem components or processes. Ideally, the model should emphasize how resources (habitats) are affected by threats, and the anticipated response of the population to these threats. The threats and their quantifiable effects on habitat and populations can be used as indicators of effectiveness.

Indicators are physical characteristics or population parameters that can be used to answer monitoring questions. Indicators that measure physical characteristics, such as changes to vegetation or soils, are the most cost-efficient to assess. However, it is important to incorporate population parameters to guard against "erroneous conclusions resulting from inappropriate indicators" (Lint, et al. 1999).

I developed a conceptual model to identify the links between potential threats within WHAs and badger habitat and populations (Appendix A) that is similar to the one taken for the Great Basin gopher snake (Ovaska and Lennart 2004). The main threats identified to badgers include habitat loss and degradation, prey loss, and human-caused mortality (Section 2.4). These potentially affect badgers by causing an increase or decrease in certain habitat characteristics (e.g., productivity, prey abundance and diversity, road densities) or on badger populations (e.g., home range size, nutrition, mortality). Candidate indicators are stratified to reflect their application across local (within the WHA) and regional (between WHAs) spatial scales. The conceptual model helps to identify candidate habitat and population indicators for badgers.

### 3.5 SCREENING PROCESS AND INDICATOR SELECTION

The selection of suitable indicators to evaluate effectiveness is a critical component in developing a monitoring framework. The selection process may be particularly challenging for ecological systems that are not completely characterized, or where the system's response to various disturbances and threats are poorly understood (Lint, et al. 1999). Each indicator must have the ability to be measured accurately and precisely with high information content and a clear linkage to badger ecology (Lint, et al. 1999). The selection model of each candidate indicator will include an assessment of the input required to measure each indicator (intensity), the cost-efficiency to measure, and its relative priority.

The FRPA Resource Evaluation Program (Province of British Columbia 2004) uses a three-tiered approach to conducting effectiveness evaluations and these were used to rank each candidate. According to the Wildlife Resource Value Team, *Routine* or *Extensive* evaluations will be used to make an assessment of a WHA, and that together these indicators may signal the need for more *Intensive* evaluations (Erickson, et al. 2005).
The three tiers are defined as follows:

> *Routine* – Relatively low intensity or routine evaluations calling for typically inexpensive and rapid routine data collection;

*Extensive* – Moderate intensity evaluations that collect categorical data by visual estimates of specified indicators at randomly selected sites; and,

*Intensive* – Detailed evaluations that involve quantitative data collection and analysis with comparison to controls or benchmarks.

The nine indicators of effectiveness that were selected during screening are identified in Table 2, and are described in further detail in Section 4.0. Indicators were selected to identify threats, habitat and population changes for badgers. They are classified by spatial scale, where local indicators are measured within the WHA and regional indicators are measured within WHAs across a region, by intensity (*Routine, Intensive, Extensive*) and priority (*Low, Moderate and High*). Descriptions include the monitoring questions that each indicator addresses (Section 3.2). All of the candidate indicators that were eliminated during screening and the rationale for doing so are listed in Appendix B.

Table 2. Indicators of effectiveness for badger Wildlife Habitat Areas (WHAs).

| INDICATORS | DESCRIPTION | MONITORING QUESTIONS* | SPATIAL SCALE | INTENSITY /PRIORITY |
|---|---|---|---|---|
| ***Threat*** | | | | |
| 1. Area of suitable habitat lost | • Area of development/habitat conversion in and adjacent to WHA | 1,2 | Local, Regional | Routine / High |
| 2. Change in % canopy closure | • Baseline measure and monitored over time; identify candidates for restoration | 1,2 | Local | Routine / High |
| 3. Road density by road type | • Length of primary (hwy), paved, gravel roads in/adjacent to WHA (ha) | 2,5 | Local, Regional | Routine / High |
| ***Habitat*** | | | | |
| 4. Burrow density | • # burrows per WHA, per ha | 1,3 | Local | Extensive / High |
| 5. Condition of grassland | • Survey of grassland condition and grazing intensity | 1,2 | Local | Extensive / Moderate |
| ***Population*** | | | | |
| 6. Number of road mortalities | • Recorded within proximity of WHA | 2,5 | Local, Regional | Routine / High |
| 7. Frequency of burrow use | • Remote cameras<br>• Hair snagging for species screening | 1,3 | Local, Regional | Extensive / High |
| 8. Number of badgers using WHA | • Mark/Recapture using hair snagging and DNA fingerprinting | 1,3 | Local, Regional | Intensive / High |
| 9. Presence of female or family | • Sightings, anecdotal<br>• Remote cameras<br>• Hair snagging for DNA fingerprinting | 1,4 | Local | Extensive (Intensive)/ High |

*Key monitoring questions to determine whether a WHA is providing key habitats for badgers include (Section 3.2):

1. Is the habitat (burrows, suitable soils and prey) within the WHA suitable for badgers?
2. Are there activities within or adjacent to the WHA that may disturb badgers or their key habitats?
3. Are badgers using the WHA and how regularly?
4. Are badgers using the WHA to reproduce or rear kits?
5. Are travel corridors between and adjacent to WHAs safe for badgers?

## 4.0 SELECTED INDICATORS OF EFFECTIVENESS

Three indicators of threats, two indicators of habitat, and four indicators of population were selected to monitor effectiveness of badger WHAs (Table 2). All threat indicators selected are considered *Routine* to measure, as information is readily available (e.g., GIS coverages), and are considered a *High* priority. The habitat indicators require more *Extensive* evaluations with High to Moderate priority. Finally, the population indicators range between *Routine*, *Extensive* and *Intensive* evaluations and are considered *High* priority. Ideally, all three types of indicators will be used together to assess the effectiveness of badger WHAs.

### 4.1 AREA OF SUITABLE HABITAT LOST

*Rationale* – Suitable badger habitat is degraded or lost as urbanization and conversion to intensive agricultural crops increases in grasslands across the province (*jeffersonii* Recovery Team 2005). This also increases the risk of badger mortality with the exposure to humans and roads, and provides a measure of loss of burrowing and foraging opportunities.

This indicator addresses the following monitoring questions:

1. Is the habitat (burrows, suitable soils and prey) within the WHA suitable for badgers?
2. Are there activities within or adjacent to the WHA that may disturb badgers or their key habitats?

*Description and Methods* – The percentage of land base lost (e.g., urban development) or converted (e.g., intensive agriculture) from grassland and open forest will be calculated at the regional scale. This will help to provide a relative value of habitat within a WHA in the context of a changing landscape and is considered *High* priority. Areas can be assessed using GIS where this information is available, and therefore, is considered a *Routine* indicator that should be assessed every five years. The Grassland Conservation Council (2004) completed a risk assessment for development of grassland habitats in British Columbia by region.

*Criteria for Action* – This measure will indicate the trend in grassland habitat loss and degradation over time, and may identify the need and urgency to establish additional WHAs within a region, or to implement conservation actions that are identified within the *jeffersonii* Badger Recovery Strategy.

### 4.2 CHANGE IN PERCENT CANOPY CLOSURE

*Rationale* – Forest encroachment and in-growth resulting from fire suppression has substantially reduced grassland area in the province. This has a direct impact on habitat suitability for badgers that mainly rely on grassland and open-forest habitats and prey species.

This indicator addresses the following monitoring questions:

1. Is the habitat (burrows, suitable soils and prey) within the WHA suitable for badgers?
2. Are there activities within or adjacent to the WHA that may disturb badgers or their key habitats?

*Description and Methods* – The percentage of forest encroachment (forest establishing on grassland) and in-growth (open forest infilling with seedlings) will be measured by the change in canopy closure. This will help to provide a measure of habitat loss, and is considered *High* priority. Areas can be assessed using GIS where this information is available (e.g., forest cover mapping), and therefore, is considered a *Routine* indicator that should be assessed every five years. The Grassland Conservation Council (2004) also completed a risk assessment for forest encroachment and in-growth for grassland habitats in British Columbia by region.

*Criteria for Action* – This measure will indicate the trend in forest encroachment and in-growth over time, and may identify the need to implement ecosystem restoration within and outside of WHAs to mitigate the impacts to grassland habitat.

### 4.3 ROAD DENSITY BY ROAD TYPE

*Rationale* – A significant cause of mortality for badgers is collision with traffic on roads. Badgers are at risk as they make long-distant movements in valley bottoms where many roads are located. Roads may be located within close proximity to a WHA, posing a hazard to badgers travelling to and from the habitat. This indicator should also be compared to the number of road mortalities in proximity to the WHA (description Section 4.6).

This indicator addresses the following monitoring questions:

2. Are there activities within or adjacent to the WHA that may disturb badgers or their key habitats?
5. Are travel corridors between and adjacent to WHAs safe for badgers?

*Description and Methods* – By calculating the length of each type of road (highway, paved, gravel) in and adjacent to WHAs, an index of risk for badgers can be determined. The type of road will help to refine the level of threat due to traffic volumes and speed, where primary paved roads (highways) represent the highest threats due to high traffic volumes and speed, and gravel (forestry) roads will pose less of a threat assuming low traffic volumes and slower speeds. Because of the significant impact road mortality has on badger populations, this indicator is given a *High* priority, and a *Routine* ranking since road densities can be readily assessed using GIS. Road densities can be measured within the WHA, and in expanding radius (within 1 km, 3 km) and compared to average regional densities to give a relative measure of potential risk.

*Criteria for Action* – WHAs with local road densities (e.g., within 1 km radius of WHA) above the average regional density, or where any badger road mortality occurs within 3 km will be considered a high hazard. Mitigating measures, such as those recommended in the *jeffersonii* Badger Recovery Strategy (2005) including road signage, slower speeds, and dry culvert crossings, should be implemented.

### 4.4 BURROW DENSITY

*Rationale* – The density of burrows within a WHA will confirm the occurrence of suitable habitat, the presence of badgers (at least historically), and provides a preliminary surrogate for population indicators because it requires fewer resources. Also, regular surveys can help to indicate if and how regularly burrows are being used or maintained by badgers, and if there are any disturbances to habitat occurring within the WHA.

This indicator addresses the following monitoring questions:

1. Is the habitat (burrows, suitable soils and prey) within the WHA suitable for badgers?
3. Are badgers using the WHA and how regularly?

*Description and Methods* – To identify the presence of badgers, burrow surveys within each WHA can be conducted simply by visual observation in the field (RIC 1999). Some burrows also may be identified from air photos. Although this indicator requires field assessment, it is considered a *Routine* survey since it simple to conduct and involves relatively few resources. This indicator is a *High* priority and should be completed annually because it allows for a relatively simple surrogate for badger inventory, and can help to determine the general frequency of use of burrows if evidence of badger activity is recorded.

*Criteria for Action* – If burrows are damaged or if there is no evidence of badger activity within a WHA, this may suggest the need for increased assessment and implementation of conservation or recovery activities.

### 4.5 CONDITION OF GRASSLAND

*Rationale* – Grassland (or open forest) habitat that is in healthy condition offers diverse habitat structure that is suitable for a range of small mammals and other badger prey species (e.g., insects, nesting birds, reptiles). Disturbance, such as high grazing intensity, may favour some prey species but it reduces the overall species richness of a small mammal community (Rosenstock 1996). This limits the ability of badgers, and other grassland

carnivores, to respond to local declines of a particular prey population. Grassland condition is used here as an indicator of potential prey abundance and diversity.

This indicator addresses the following monitoring questions:

1. Is the habitat (burrows, suitable soils and prey) within the WHA suitable for badgers?
2. Are there activities within or adjacent to the WHA that may disturb badgers or their key habitats?

*Description and Methods* – The condition of grasslands is a complex concept and can be measured using many methodologies. The province of Alberta has developed a protocol to assess the health of grassland, forest and tame pastures (Adams, et al. 2003). This involves surveys to assess the local soils, vegetation, community structure, moisture and nutrient cycling. Also, the Grassland Conservation Council of British Columbia is preparing to develop a classification for grassland habitats that will include late- and early-seral stages (http://www.bcgrasslands.org/projects/conservation/classification.htm). Other assessments of grassland condition and its suitability for small mammals may include measures of visual obscurity (MacKenzie 2005). The measurement of this indicator is considered *Extensive* as it requires field surveys, and is assigned a *Moderate* priority rating since badgers are able to co-exist with many forms of minor disturbance.

*Criteria for Action* – A consistent decline in grassland condition may indicate the need to change the range management regime (e.g., lower grazing intensity, duration, or exclude livestock) to respond to changing conditions.

### 4.6 NUMBER OF ROAD MORTALITIES

*Rationale* – Because a significant cause of mortality for badgers is collision with traffic on roads, it is important to monitor the number of road mortalities within close proximity to a WHA. This indicator should also be compared to the density of roads in proximity to the WHA (description Section 4.3) to indicate risk levels.

This indicator addresses the following monitoring questions:

2. Are there activities within or adjacent to the WHA that may disturb badgers or their key habitats?
5. Are travel corridors between and adjacent to WHAs safe for badgers?

*Description and Methods* – There are established reporting lines that collect badger sightings, including mortalities on roads. Further information and contacts are available on the *jeffersonii* Badger Recovery website (www.badgers.bc.ca). The Ministry of Transportation also is required to report badger road mortalities when and where they are detected. The measurement of this indicator is considered *Routine* and is assigned a *High* priority rating.

*Criteria for Action* – Criteria for action will be consistent with suggestions made for road density by road type in Section 4.3.

### 4.7 FREQUENCY OF BURROW USE

*Rationale* – This indicator will provide a measure of the utility of a WHA by badgers. The frequency of use identifies that badgers are using the WHA, habitat is suitable, and they are not being disturbed.

This indicator addresses the following monitoring questions:

1. Is the habitat (burrows, suitable soils and prey) within the WHA suitable for badgers?
3. Are badgers using the WHA and how regularly?

*Description and Methods* – Different methods to identify use of burrows include the use of remote cameras, or snagging hair to screen for species (RIC 1999). Hair snagging protocols for badgers currently are being developed, but general methods in Appendix C provide some guidance (taken from Hoodicoff 2005). This indicator is relatively simple to measure but requires repeated visits to a site. Therefore, this is considered an *Extensive* survey with *High* priority because of the value of population information.

*Criteria for Action* – This indicator is a qualitative measure of the confirmed use of habitat by badgers, which increases the effectiveness rating of a WHA. If a burrow site is not used at least annually, it may indicate the need to implement more in-depth surveys to identify the reasons. However, the lack of use in a WHA may be a function of low population density in the region regardless of the habitat quality within the WHA.

### 4.8 NUMBER OF BADGERS USING WHAS

*Rationale* – This indicator will provide a measure of the utility of a WHA by badgers. Further to the frequency of use, identifying the number of badgers using a WHA provides a local and regional population estimate.

This indicator addresses the following monitoring questions:

1. Is the habitat (burrows, suitable soils and prey) within the WHA suitable for badgers?
3. Are badgers using the WHA and how regularly?

*Description and Methods* – Hair snagged while identifying the frequency of burrow use can be analyzed by a lab using DNA fingerprinting to identify the number of source individuals. Protocols for this are currently being developed, but the methods in Appendix C provide a brief synopsis (Hoodicoff 2005). Although this does not require additional effort in the field, it requires resources for the lab analysis. Therefore, this is considered an *Intensive* survey with *High* priority because of the value of population information.

*Criteria for Action* – The confirmed use of habitat by badgers (i.e. at least one badger identified) provides a quantitative measure of WHA effectiveness. If a burrow site is not used at least annually, it may indicate the need to implement more in-depth surveys to determine the reason for disuse. However, it is important to note that the absence of badgers within a WHA may be a function of low population density in the region, regardless of the habitat quality within the WHA.

### 4.9 PRESENCE OF FEMALE OR FAMILY

*Rationale* – This indicator will provide a measure of the utility of a WHA by female badgers to reproduce and raise kits, as well as provides an approximate local and regional (female) population estimate.

This indicator addresses the following monitoring questions:

1. Is the habitat (burrows, suitable soils and prey) within the WHA suitable for badgers?
4. Are badgers using the WHA to reproduce or rear kits?

*Description and Methods* – Identifying the presence of family groups at burrows can be accomplished by collecting sightings or setting up remote cameras to document multiple badgers. This method is considered an *Extensive* survey with *High* priority because of the value of population information. Also, hair snagged while identifying the frequency of burrow use can be screened by a lab to identify sex of source individuals (Appendix C). This method is more reliable and provides quantitative data; however, it requires additional resources for the lab analysis. Therefore, this method is considered an *Intensive* survey.

*Criteria for Action* – The confirmed use of a WHA by a female badger to rear kits, or family groups, increases the effectiveness rating to the highest level.

## 5.0 IMPLEMENTATION OF EFFECTIVENESS MONITORING

### 5.1 IMPLEMENTATION STRATEGY

A phased approach to monitoring badger WHAs is recommended, where a *Routine* assessment of High priority indicators is implemented first to determine effectiveness (Table 3). Identifying that the WHA is suitable for badgers (i.e. *Effective*) can be accomplished by assessing only the threat and habitat indicators. A survey of burrow density is strongly suggested during the *Routine* assessments, even though it is considered an *Extensive* evaluation. To determine if a WHA is regularly used by badgers (i.e. *Moderately Effective*),

more *Extensive* assessments of population indicators will be required. In this case, an assessment of the frequency of burrow use, by snagging hair at burrows, should be implemented to quantify badger use. To determine if a WHA is used to rear kits and/or are regularly used by family groups (i.e. *Highly Effective*), the presence of a female or family group and the number of badgers using a WHA can be assessed using the hair collected at a site with further funds for lab analysis. If key habitat features and suitable conditions are not sustainable given current management levels (i.e. *Not Effective*), then more *Extensive* or *Intensive* monitoring may be required to more clearly determine the source of threats to habitat and their effect on populations (identified as *Criteria for Action* in Section 4.0). For example, condition of grassland should be assessed where other habitat indicators identify considerable declines in habitat quality. Conservation and ecosystem restoration activities, in this case, may be considered to improve WHA effectiveness.

Table 3. The minimum indicators required (dots) and recommended (shaded) to evaluate WHA effectiveness.

| | EFFECTIVENESS EVALUATION TARGET | | |
|---|---|---|---|
| INDICATORS | Effective/ Not Effective | Moderately Effective | Highly Effective |
| ***Threat*** | | | |
| 10.Area of suitable habitat lost | ● | ● | ● |
| 11.Change in % canopy closure | ● | ● | ● |
| 12.Road density by road type | ● | ● | ● |
| ***Habitat*** | | | |
| 13.Burrow density | ● | ● | ● |
| 14.Condition of grassland | | | |
| ***Population*** | | | |
| 15.Number of road mortalities | | | |
| 16.Frequency of burrow use | | ● | ● |
| 17.Number of badgers using WHA | | | |
| 18. Presence of female or family | | | ● |

Ultimately, the effectiveness or function of a WHA is determined by the regular presence of badgers and the contribution it makes to support a sustainable, reproducing population. This requires an evaluation of each WHA (local scale) in context of threats and habitat characteristics important to badgers populations in WHAs across the region (regional scale). A multi-scale approach helps to determine the influences from land use practices or management outside of the WHA.

## 5.2 POTENTIAL CHALLENGES AND INFORMATION GAPS

The regional differences in badger behaviour and habitat selection, and the lack of information regarding population density and composition make it particularly difficult to establish a provincial standard for monitoring these indicators. Rather, this effectiveness monitoring framework relies on detections of trends by assessing indicators over time and adapting management regimes to maintain effective WHAs. It is recommended that the monitoring protocols for each indicator be tested, and appropriate revisions made before this effectiveness monitoring framework is fully implemented. Intensive research (e.g., radio-telemetry monitoring) may be required to fill information gaps, especially in regions where there has been no previous research.

While it is agreed that there is a strong association between badgers and their prey, this relationship is poorly understood in British Columbia. Diets of badgers vary regionally, and there are a range of habitat requirements for each species. The response of prey to disturbance types and intensities vary with species. An appropriate method to index or measure abundance of prey available to badgers is needed. Local information collected during WHA monitoring could be used as benchmarks for prey species, and to improve management of grassland and open ecosystems.

Also, relatively little is known about the site characteristics that determine maternal burrow selection, and the habitat requirements of pregnant females. The relationship between food resources and pregnancy success may affect local population densities, and also influences effectiveness thresholds. The relative fitness of the population should be studied including the number of successfully breeding females and juvenile survivorship.

Finally, protocols to collect hair for DNA fingerprinting have not been fully developed, but it is anticipated to play a key role in effectiveness monitoring. A pilot project in the Cariboo region was established to develop a standard method of hair collection, identify viable genetic markers for DNA fingerprinting of badgers, and to estimate the home range size and extent of movements of badgers (Hoodicoff 2005). Protocols and results of this study are anticipated in 2006. Eventually, this method can be used to inventory badgers across the province and to potentially answer other questions such as the level of inbreeding and relatedness of animals.

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## 7.0 LIST OF ACRONYMS

| | |
|---|---|
| COSEWIC | Committee on the Status of Endangered Wildlife in Canada |
| FRPA | *Forest and Range Practices Act* |
| IWMS | Identified Wildlife Management Strategy |
| MOE | Ministry of Environment (formerly Ministry of Water Land and Air Protection) |
| MOFR | Ministry of Forest and Range |
| MWLAP | Ministry of Water Land and Air Protection (now Ministry of Environment) |
| SARA | *Species at Risk Act* |
| WHA | Wildlife Habitat Area |

# Appendix A

## CONCEPTUAL MODEL

| THREATS | POTENTIAL EFFECTS ON BADGERS | | CANDIDATE INDICATORS | |
|---|---|---|---|---|
| | Habitat | Population | Habitat | Population |
| ***Habitat Loss and Degradation*** | | | | |
| Urban development & Intensive agriculture | • Decreases available grassland habitat<br>• Decreases potential burrowing area<br>• Increases fragmentation of habitat<br>• Destruction of burrows | • Displacement of badgers<br>• Increases disturbance from human activity | • Area of grassland habitat lost<br>• Area of "diggable" soil lost<br>• Index of fragmentation<br>• Burrow density | • Frequency of burrow use<br>• # badgers using WHA |
| Highway construction | • Increases road densities | • Increases potential for road mortality | • Road density | • # of road mortalities |
| Highway maintenance | • Increases attractants to road rights-of-way | • Increases potential for road mortality | • Measure of vegetation on rights-of-way | • # of road mortalities |
| Forest in-growth and encroachment | • Decreases suitable grassland habitat | • Displacement of badgers | • Change in % canopy closure<br>• Burrow density | • Frequency of burrow use<br>• # badgers using WHA |
| ***Prey Loss*** | | | | |
| Pest management | • Decreases prey abundance | • Increases energy required to find alternative prey resources | • Index of prey abundance | • Home range size |
| Poor range practices | • Decreases suitable habitat for prey<br>• Decreases prey diversity | • Decreases in breeding opportunities and ovulation potential<br>• Decreases in successful litters due to aborted implantation | • Index of prey abundance and diversity<br>• Condition of grassland<br>• Grazing intensity | • Presence of female or family<br>• # and size of successful litters |
| ***Human-Caused Mortality*** | | | | |
| Trapping and persecution | | • Increases badger mortality | | • # reported trapping mortalities |
| Traffic volumes and speed | • Decreases potential for safe crossing | • Increases badger mortality | • Road density (by road type) | • # of road mortalities |

# Appendix B

## INDICATORS ELIMINATED DURING SCREENING

The indicators that were eliminated during the screening process and the rationale are listed below:

- *Index of fragmentation* – WHAs represent a small proportion of habitat available to badgers across the landscape, and by their nature, may be considered fragments;

- *Area of "diggable" soil* – It is assumed that WHAs will be established where there are suitable soils for badgers and/or their prey. Any loss of burrowing potential in soils will be measured by the area of suitable habitat lost;

- *Measure of vegetation on rights-of-way* – Because roads are an identified hazard to badgers, WHAs are established in areas where roads are limited and right-of-way vegetation likely has little impact on the effectiveness of a WHA;

- *Index of prey abundance and diversity* – Prey species targeted by badgers varies regionally and seasonally, and prey abundance varies temporally and spatially. The *jeffersonii* Badger Recovery Team agreed that this was not the best measure of habitat suitability for badgers given their ability to travel long distances and take advantage of many prey sources. Rather, grassland condition was an appropriate surrogate to indicate the potential for prey abundance and diversity;

- *Home range size* – Home range size varies due to a number of variables that are influenced by factors outside of the WHA;

- *Number of successful litters compared to potential pregnancies* – Placental scarring to measure potential pregnancies can only be identified during necropsy and relies on availability and condition of female badger carcasses, which are not abundant; and,

- *Number of reported trapping mortalities* – Reports of incidental trapping are not reliable and happen too infrequently to accurately monitor effectiveness within discrete areas.

# Appendix C

**HAIR SNAGGING METHODS**

**(Hoodicoff 2005)**

The following is an excerpt taken from the Cariboo Region Badger Project Year End Report, Habitat Conservation Trust Fund Project #5-119(Hoodicoff, 2005). Prepared for Roger Packham, Ministry of Water, Land and Air Protection, 100 Mile House, B.C.

***Objectives***

We determined the local distribution and abundance of badgers and estimated the home range size and extent of movements of badgers in the Cariboo region using DNA fingerprinting. We remotely collected hair at active burrows, using non-invasive methods, as a source of genetic material. Remote hair collection has been used to inventory bears (Woods et al. 1999; Mowat and Strobeck 2000; Poole et al. 2001), and also has been successful with other species (Mowat and Paetkau 2002; Creel et al. 2003). Badgers were a likely candidate for this method to inventory the population because hair could be collected at burrows that are repeatedly used by individuals. Our objective was to execute a pilot project to establish a standard method of hair collection, identify viable genetic markers for DNA fingerprinting of badgers, and to estimate the home range size and extent of movements of badgers in the South Cariboo. Eventually, these methods can be used to inventory badgers across the province and potentially answer other questions such as the level of inbreeding and relatedness of animals.

Our secondary goal was to determine the efficacy of using DNA extracted from hair samples that were systematically snagged compared to shed hair opportunistically collected at burrows to identify badgers. Snagged samples generally are of better quality because they are collected quickly and more hair from an individual is harvested, but this method requires more resources. In contrast, collecting shed hairs is inexpensive but the quality of samples may be compromised due to weathering and time.

***Field Methods***

To estimate the minimum number of badgers and their ranges, we collected hair for DNA fingerprinting. We opportunistically collected badger guard hairs that were shed at burrow entrances, and we snagged badger hair at burrows. The hair snags were made from 30 cm of 2 cm wide metal strapping, the type used to wrap lumber, formed into a ‘D’ (Figure 2). Two

3 inch nails were inserted through holes drilled at the base of the 'D' and were used to secure the snag inside the burrow. Three rivets were placed at each edge and middle to secure the strapping in its shape. The 'hook' side of adhesive Velcro (2 cm wide) was placed along the arc to capture hair.

Figure 2. Velcro hair snag used to collect hair from badgers. Snags were placed inside the burrow entrance to comb animals entering and exiting burrows.

Badger hair was snagged at burrow entrances that had evidence of recent use, e.g., freshly excavated soil, foot prints, or an animal. The snags were placed inside each burrow, along the top of the entrance, where an animal entering or exiting would brush along the Velcro and deposit hair. Snags were handled with leather gloves to minimize human scent, and were checked at the burrows every 4 to 6 days for hair. All of the hair was collected from each snag with forceps and placed inside of a paper envelope and stored at room temperature. At the end of the field season, all samples were sent to Dr. David Paetkau at Wildlife Genetics International (Nelson, BC) for DNA fingerprinting.

***Lab Analysis***

Markers (microsatellite loci) used to assign hair samples to individual badgers were selected based on results from Davis and Strobeck (1998) and Kyle et al. (2004). To test for viability of the genetic material, all of the samples were pre-screened with 2 markers (*Tt-3* and *Tt-4*) that preformed well in preliminary marker tests. The samples that did not perform well in this pre-screening were either not badger hairs or were of poor quality and were discarded. Six of the most variable makers were used to assign hair samples to individuals (*Ma-1, Tt-1, Tt-2, Tt-3, Tt-4, Mvis072*). Marker variability was determined by the proportion of individuals identified that were heterozygous ($H_o$), that is, had two different alleles at each marker.

Inconsistent genotyping of different samples from the same individual is expected to create pairs of geonotypes that are highly similar, and will lead to the recognition of more individuals than actually were sampled. To ensure that samples were not mistakenly assigned to individuals, the samples were also subjected to a computerized comparison of all pairs of unique genotypes, and suspiciously similar pairs of genotypes that might be indicative of genotyping errors were flagged.

Gender was determined from each sample using a nuclear DNA analysis of the SRY locus on the Y-chromosome. Mustelid-specific primers were developed from sequences deposited in Genbank and were successfully tested on fisher, marten and wolverine samples (Paetkau, pers. comm. 2005).

We used the minimum number of badgers we detected with DNA fingerprinting to approximate the minimum density of badgers in the immediate area we surveyed, and to estimate movements made by individuals and preliminary home range areas using 100% minimum convex polygons.

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