
Inventory Methods for Medium-sized Territorial Carnivores: Badger

Standards for Components of British
Columbia's Biodiversity No. 25a

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Preface

This manual presents standard methods for inventory of Badgers as an addendum to the *Medium-sized Territorial Carnivores in British Columbia (No. 25)* manual. Methods are described at three levels of inventory intensity: presence/not detected (possible), relative abundance, and absolute abundance. The manual was compiled by the Ecosystems Branch of the Ministry of Environment, under the auspices of the Resources Information Standards Committee (RISC). The objectives are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series that present standard protocols designed specifically for a group of species with similar inventory requirements. The series includes an introductory manual (*Species Inventory Fundamentals No. 1*) that describes the history and objectives of RISC and outlines the general process of conducting a species inventory according to RISC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The *Species Inventory Fundamentals* manual provides important background information and should be thoroughly reviewed before starting with a RISC species inventory. RISC standards for vertebrate taxonomy are maintained by the BC Conservation Data Centre and are available at www.env.gov.bc.ca/atrisk/toolintro.html. For standards on animal capture and handling RISC follows the guidelines of Canadian Council on Animal Care at www.ccac.ca/en/CCAC_Programs/Guidelines_Policies/GDLINES/Guidelis.htm. RISC standards for radio-telemetry are written in CBCB series No. 5. Field personnel should be thoroughly familiar with these standards before engaging in inventories which involve any of these activities.

The data collection structure is provided in Appendix B. Custom data forms can be made for the specific needs of a project using the Wildlife Species Inventory (WSI) data capture template available from the website (www.env.gov.bc.ca/wildlife/wsi/wsi_xt/index.htm). The template is also used to enter data into the WSI database. For more information about WSI and data forms, visit the Wildlife Species Inventory Homepage at www.env.gov.bc.ca/wildlife/wsi/index.htm.

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve over time. Field testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded to the Ministry of Environment:

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The RISC evolved from the Resources Inventory Committee (RIC), which received funding from the Canada-British Columbia Partnership Agreement of Forest Resource Development (FRDA II), the Corporate Resource Inventory Initiative (CRII), and Forest Renewal BC (FRBC), and addressed concerns of the 1991 Forest Resources Commission.

For further information about the RISC, please access its website at <http://ilmbwww.gov.bc.ca/risc/>.

All decisions regarding protocols and standards are the responsibility of the Resources Information Standards Committee. The current version of this manual was the result of the hard work and expertise of Corinna Hoodicoff (Summit Environmental Consultants Ltd.) and Simone Runyan (Summit Environmental Consultants Ltd.) with valuable comments from Nancy Newhouse (Sylvan Consulting Ltd.), Bill Harrower (University of Victoria), Eric Lofroth (Ministry of Environment), Diana Demarchi (Ministry of Environment), Calvin Tolcamp (Ministry of Environment), and Mike Panian (Ministry of Environment).

Some of the background information and protocols presented in this document are based on Version 2.0 of this manual, *Inventory Methods for Medium-sized Territorial Carnivores: Coyote, Red Fox, Lynx, Bobcat, Wolverine, Fisher & Badger*, prepared by Vivian Banci with comments from Nancy Newhouse (Sylvan Consulting Ltd.), Trevor Kinley (Sylvan Consulting Ltd.), Richard Weir (Artemis Wildlife Consultants), John Boulanger (Integrated Ecological Research), Mike Badry (Ministry of Environment, Lands & Parks), Eric Lofroth (Ministry of Environment, Lands & Parks) and Dr. Charles Krebs (University of British Columbia).

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1. INTRODUCTION

The mammalian carnivores of British Columbia are an ecologically diverse group that includes members of the Canidae, Felidae, and Mustelidae families. Many of the species in this group are stealthy and secretive in nature, and occur at low densities and range over wide areas in comparison to herbivores of equivalent body sizes. These characteristics make this group one of the most difficult to study and to inventory.

Previously, inventory protocols for seven of these species were outlined in a single report for “medium-sized territorial carnivores” (RIC 1999). This group included the Coyote (*Canis latrans*), Red Fox (*Vulpes vulpes*), Lynx (*Lynx canadensis*), Bobcat (*Lynx rufus*), Fisher (*Martes pennanti*), Wolverine (*Gulo gulo*), and Badger (*Taxidea taxus*). All but the Badger are designated as furbearers and are trapped and, to a lesser extent, hunted. Trapping of Badgers has been banned since 1967 because of population declines (*jeffersonii* Badger Recovery Team 2005).

Badgers are distinct among the medium-sized carnivores because they are a grassland-dwelling species that digs and lives in burrows. The unique ecological characteristics of the Badger, and recent applications of new inventory methods, have led to this supplementary document outlining inventory protocols for Badgers separately from the other medium-sized territorial carnivores.

2. BIOLOGICAL CONSIDERATIONS

Badger, *Taxidea taxus* (M-TATA)

Assessing the presence or abundance of animals requires an understanding of the spatial and temporal patterns in which they occur. Sections 2.1 through 2.5 provide a general discussion of the distribution and life history of Badgers as they pertain to inventory methods for the species (Section 3).

2.1 General Ecology

The North American Badger is generally associated with mid-continental treeless areas such as prairie, plains, parklands, and cold deserts. Soils suitable for burrowing and available prey are the key habitat requirements for Badgers in the province (Rahme et al. 1995; Apps et al. 2002; Weir et al. 2003). Suitable soils include silts with low coarse fragment content (Weir et al. 2003).

Badgers are mostly solitary except for breeding pairs and family groups. Breeding occurs in the summer (July or August) following delayed implantation and an approximately eight-week gestation. One to four young (average two) are born the following March or April (Messick 1987). The young disperse by fall, so that maternal family groups exist in summer only. Although Badgers are largely nocturnal, they are frequently active for brief periods during the day when they may be observed traveling, hunting, or resting at their burrows.

The Badger is considered the rarest of all the medium-sized carnivores in British Columbia. Historical and current threats to the British Columbia Badger population include highway mortality, habitat loss and degradation, trapping, persecution, and loss of prey species (*jeffersonii* Badger Recovery Team 2005). Relatively little is known about the nature or extent of natural mortality in the species, but probable predation by Cougars and Bobcats was reported in the east Kootenays (Newhouse and Kinley 2006). The oldest Badger reported in the east Kootenay region was a female that was 13.6 years (Newhouse and Kinley 2006).

It is worth noting that discussion of the European Badger (*Meles meles*) in the literature may not necessarily be relevant to its North American namesake. Like the American Badger, the European Badger also has conspicuous dens and fossorial habits; however, it also tends to be more social rather than solitary and is largely dependent upon earthworms for prey rather than vertebrates. Inventory techniques developed for the European Badger should not necessarily be applicable to North American Badgers.

2.2 Distribution

The distribution of Badgers in British Columbia is the most restricted among the medium-sized territorial carnivores, with documented occurrence only in portions of the Southern Interior, Southern Interior Mountains, and Central Interior ecoprovinces (Adams and Kinley 2004). Within this broad range, Badger habitat is concentrated in grassland and open forest communities, particularly the Interior Douglas-fir (IDF), Ponderosa Pine (PP), and

Bunchgrass (BG) biogeoclimatic zones. However, Badgers also have been documented from valley bottoms to mountain tops in the Montane Spruce (MS), Interior Cedar–Hemlock (ICH), Sub-boreal Pine–Spruce (SBPS), Sub-boreal Spruce (SBS), Engelmann Spruce–Subalpine Fir (ESSF), and Alpine Tundra (AT) zones (Adams and Kinley 2004).

Detailed inventories of Badgers have been conducted in conjunction with research projects in the East Kootenay (Newhouse and Kinley 2006), Thompson–Okanagan (Hoodicoff 2003; Weir et al. 2003), and Cariboo (Packham and Hoodicoff 2006) regions of British Columbia. Observations of Badgers and Badger burrows in the province have been compiled into databases managed by the Wildlife Species Inventory (WSI) program and the BC Conservation Data Centre (CDC), and can be accessed at www.env.gov.bc.ca/wildlife/wsi/access.htm. Report the location and date of any recent sightings to WSI either by e-mail (SPI_Mail@Victoria1.gov.bc.ca) or the Incidental Sighting Form in the *Data Contributions* option on the WSI homepage (address above) so that records may be continually updated. All data submissions to WSI are accessible to the CDC.

Additional Badger and burrow inventory data may be obtained through other initiatives. For example, inventory of sensitive species, such as Badgers, may be conducted as part of grassland ecosystem restoration programs. Also, effectiveness evaluations conducted in Wildlife Habitat Areas (WHAs) established for Badgers include inventory measures (e.g., burrow searches, collection of DNA, etc) (e.g., Newhouse et al. 2007). Contact the Ministry of Forests and Range for more information on the Forest & Range Evaluation Program (www.for.gov.bc.ca/hfp/frep/values/wildlife.htm).

2.3 Status

The Badger is a protected species in British Columbia, and the status is included on the provincial tracking list maintained by the BC Conservation Data Centre (www.env.gov.bc.ca/atrisk/toolintro.html). The BC Species and Ecosystems Explorer also references the federal tracking list maintained by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; Newhouse and Kinley 2000).

2.4 Home Range and Movements

Badgers are not territorial, in that they do not defend home range boundaries. Rather, Badgers maintain solitary home ranges, but overlap occurs between neighbouring animals (Messick and Hornocker 1981; Minta 1993). The ranges of adult males generally are larger than those of females, and home ranges are larger in the breeding season than in the winter (Lindzey 1978; Lampe and Sovada 1981). The size and orientation of home ranges are determined by the availability of food and burrowing sites for female Badgers, and the availability of mates during the breeding season for male Badgers (Minta 1993).

In British Columbia, Badgers maintain large home range¹ areas. In the east Kootenay, home range areas averaged 301 km² for males ($n = 9$; SE = 98.4) and 35 km² for females ($n = 7$; SE = 12.1) (Newhouse and Kinley 2006). In the Thompson, home range areas averaged 79 km² for males ($n = 7$; SD = 88.1) and 11 km² for one female over a summer (Weir et al. 2003). In

¹ Home ranges cited here were estimated using 100% minimum convex polygon areas from radio-telemetry locations.

the Cariboo, home range areas averaged 171 km² for males ($n = 12$) and 35 km² for females ($n = 4$) (Packham and Hoodicoff 2006). In comparison, home range areas of Badgers in Illinois are reported as 44 km² for males ($n = 5$) and 13 km² for females ($n = 7$) (Warner and Ver Steeg 1995). Large home ranges observed in British Columbia have been attributed to the dispersed prey base in many regions (*jeffersonii* Badger Recovery Team 2005) and to the long distances moved to find mates (Weir et al. 2003).

Badgers do not appear to use their home ranges uniformly and there is considerable variation in the patterns of use between individuals. Sites with important resources, such as burrow sites, localized patches of soils suitable for burrowing, or colonies of ground squirrels, may be visited more often by an individual than other sites within a home range (Hoodicoff 2003). Season also plays a factor in patterns of use within a home range. Badgers remain fairly active during winter when the fresh diggings and tracks can be quite visible; however, most Badgers enter a state of underground inactivity for days, weeks, or months between December and March (Messick and Hornocker 1981).

The size, shape, and orientation of individual home ranges have implications for inventory of Badgers. For example, to sample populations in low-density areas, a larger area must be sampled to attain a particular level of precision. These variables will also govern sampling design and grid cell size and layout and are discussed further in Section 3.1.5.

2.5 Sign Characteristics

Badgers are difficult to observe directly in a consistent and predictable manner, so monitoring abundance or frequency of local use relies heavily on recognizing Badger sign, such as burrows, tracks, or scats. Badgers are often below ground, and leave much of their sign including a proportion of fecal deposits (or scat) in underground burrows. Badger scats deposited above-ground may be difficult to distinguish from scats of other carnivores, and should be confirmed with DNA screening. The tracks of Badgers, when intact, are distinctively turned in and their long claw marks are obvious. However, because of their low stature and stiff, bristle-like hair, tracks are often swept away as the Badger walks.

Badger burrows (or dens²) are the most conspicuous indication of Badger presence and activity. Burrows may be used for shelter, foraging, birthing, and raising young. Burrows used by Badgers may be difficult to differentiate from dens of other animals (e.g., Marmots, Foxes, and Coyotes), especially when other species occupy an abandoned Badger burrow. Dens dug by canids tend to be larger and triangular in shape, with narrow, vertical claw marks. A comprehensive field guide to the identification of Badger burrows is included in Appendix A, but key characteristics of Badger burrows include:

- Entrance that is typically oval-shaped or round (25–30 cm wide and 15–20 cm high);
- Horizontal claw marks (approximately 3 cm apart) on the sides of the burrow;
- A large mound or plume of dirt in front of the entrance that is loose if recently excavated; and,
- Shed guard hairs that are approximately 7 cm long and distinctively tri-coloured (from tip: white, light brown, dark brown, light brown, white) may be found at the entrance in the soil berm. If using this as a sign to confirm Badger presence, examination of other diagnostic characteristics should be undertaken.

² The terms ‘burrow’ and ‘den’ are used interchangeably in the literature; however, in this document, ‘burrow’ will refer to badger burrows, and ‘den’ will refer to dens of other species.

It is possible to identify some hair using colour, length, and texture, and examining the hair's morphological structure under a microscope (Foran et al. 1997b). Species are identified by comparing the cuticular pattern of the guard hair to that of a known specimen. An impression of the hair is made on coloured acetate (generally green or blue). The hair and acetate are sandwiched between two microscope slides and heated (e.g., in an oven or over a Bunsen burner). The cuticular impression left on the acetate is viewed under a compound microscope with phase contrast. Keys to hair identification guides include Day (1966), Moore et al. (1974), Adjoran and Kolenosky (1980), and Titus (1980). Alternatively, a key can be developed from known specimens.

Freshly excavated soil and shed guard hairs on the soil berm may indicate recent use by Badgers, but the lack of these does not necessarily confirm their absence. Also, the presence or evidence of kits is the only reliable way of differentiating a maternal burrow from a burrow used for foraging or shelter.

Useful references for interpreting sign and tracking include Murie (1954), Halfpenny and Biesiot (1986), and the *jeffersonii* Badger Recovery Team website (www.badgers.bc.ca).

3. PROTOCOLS

The first step before initiating an inventory survey is to decide the biological question to be answered. This may include 1) Do Badgers occur in the area? 2) How does the relative density of Badgers change in the area over time? or 3) How many Badgers occur in the area? Once a biological question is identified, you may determine the appropriate level of inventory required (Section 3.3). Presence/not detected surveys are used to determine a species occurrence in an area (Section 3.4). Relative abundance surveys provide indices of population size over time (e.g., catch per unit effort) (Section 3.5). These inventories are used to answer questions about species distribution, monitoring changes in species richness, environmental assessments, and recording patterns of animal activity (Southwood and Henderson 2000). Finally, absolute abundance surveys provide an estimate of the total number or density of species in an area (Section 3.6) with accompanying estimates of uncertainty.

The objectives of the following protocols are to outline the survey standards (Section 3.1) and preliminary information resources (Section 3.2), to ensure that the appropriate level of inventory is undertaken, and to ensure that the inventory is conducted by consistent methods.

3.1 Survey Standards

The following are guidelines for conducting inventories of Badgers in the province. Adherence to these guidelines will permit the collection of reliable data that should satisfy individual and corporate inventory needs, as well as contribute to biodiversity monitoring at local, regional, and provincial scales.

3.1.1 Personnel

Personnel familiar with identifying Badger sign are essential during the inventory of Badgers. Badger inventory relies heavily on indirect observations of burrows and other sign. Misidentification can render incorrect results. Personnel should be trained to ensure that methods are consistent. Specialized laboratories are necessary for genetic analyses.

During inventory surveys involving animal capture and radio-marking, biologists must be well trained in radio-telemetry procedures, emergency first-aid, handling of potentially dangerous wildlife, and care of immobilized animals, and must be able to accurately estimate the weight of animals to be drugged. Biologists should consult the relevant manuals and guidelines listed in the Preface of this document. Personnel immobilizing and handling animals are required to have completed a certified course on immobilization techniques.

3.1.2 Wildlife Species Inventory Data Standards

The Wildlife Species Inventory (WSI) program was developed to obtain, secure, and provide access to information about wildlife species inventory in British Columbia. Wildlife information is stored in several locations within the province's data systems, and can be searched to obtain wildlife inventory and monitoring reports, original data, ecosystem maps and wildlife habitat modeling, wildlife management papers, research papers and literature reviews, and spatial data. The WSI program includes standards for formatting and data capture as well as standards for inventory methods that must be followed when submitting inventory data to the provincial government.

The WSI data system was designed to help to facilitate the storage and access of inventory results for wildlife species observations. Using the Microsoft Excel data capture template (available at www.env.gov.bc.ca/wildlife/wsi/wsi_xt/index.htm), and the associated fields and codes that are applicable for Badgers (described in Appendix B), will ensure that your wildlife inventory data meets RISC standards and can be imported into the WSI database.

3.1.3 Time of Year

Time of year is an important determinant of the success of inventories. Burrow searches can be conducted during any season, but the probability of detection is highest in early spring when snow has melted and vegetation has not grown to obscure the burrow. Also, there is a higher potential of observing a Badger when they are more active during non-winter months. Surveys for maternal burrows should occur between April and June for highest probability of observing a female with her kits.

Inventory surveys designed for the assessment of annual population trends (relative abundance) should be conducted under comparable conditions each year, although this is sometimes difficult to achieve. Movement patterns of Badgers vary during different times of the year. For example, Badgers increase the distances and frequencies of their movements considerably in the spring and summer months (Weir et al. 2003). The variability in the abundance and distribution of food (e.g., natural population fluctuations of ground squirrel colonies) between survey years may influence the presence and local detectability of Badgers, and should be taken into consideration when designing inventories.

The most appropriate season to snag hair is from mid-spring to late summer when Badgers shed their winter hair and their movements between burrows are more frequent. Collecting shed and snagged hair during wet weather appears to negatively affect the quality of genetic data (Packham and Hoodicoff 2006).

Live-trapping may be conducted during any season, but extra precautions should be taken with maintaining and monitoring body temperatures of captured animals during cooler weather (refer to the RISC standards related to animal capture and handling listed in the Preface of this document).

3.1.4 Considerations for DNA-based Techniques

The DNA in cells collected from animals can be used to positively identify species, sex, individuals, relatedness between individuals, and the genetic structure of populations (Piggott and Taylor 2003). DNA can be collected and used for inventory of Badgers at all survey levels, including presence/not detected, relative abundance, and absolute abundance. However, there are several considerations to be aware of when designing a DNA-based survey.

DNA Collection and Preservation

DNA can be collected from blood, bones, tissue, hair follicles, and from cells sloughed off and deposited in scats. The method used to collect DNA also can influence the quality of DNA. Highest quality DNA may come from tissue samples collected directly from an animal, but this requires access to carcasses or adequate resources for live-trapping, and may disturb or harm the animal. Other sources include shed hairs found at the burrow, or hair snagged from an animal entering or exiting a burrow. The appropriate methods to preserve samples

will depend on the DNA source. Hairs can be preserved dry (e.g., in paper envelopes) at room temperature (Packham and Hoodicoff 2006); however, the laboratory conducting the analysis should be contacted before sample collection to determine the appropriate collection, preservation, and delivery methods.

Remote collection of hair is becoming widely used to obtain DNA from target species. The presence of a Badger may be confirmed with a relatively simple test to identify a shed hair collected at a burrow. According to Packham and Hoodicoff (2006), viability of shed hair samples was moderate (29% of 189 samples collected over three years were attributed to individual Badgers), and was considered a suitable method since it is cost-effective (approximately \$40 per sample using eight markers) and can be easily collected by non-experts in the field. However, hair snagged from Badgers consistently provided DNA with higher viability (i.e., greater chance of providing an identity) than shed hair collected at burrows. This was attributed to more genetic material (multiple hair follicles) from a snagged hair sample compared to a single shed hair that likely was exposed to unfavorable weather conditions. The method used to snag hair from Badgers also influenced viability of DNA (See Section 3.4.2 for further discussion of hair collection and identification).

Although DNA collected from scat samples has been successfully extracted and used to inventory some species (e.g., Palomares et al. 2002), no methods for Badgers have been developed in the province.

DNA Quality

DNA quality may be affected by the age of the sample and exposure to heat, ultra-violet light, and moisture (Foran et al. 1997b). DNA quality can be ensured by collecting samples that have not been exposed to extreme weather conditions. Frantz et al. (2004) also suggested extracting DNA from samples immediately after collection using a 5% Chelex-100 protocol that can be used in the field to ensure DNA quality.

Poor DNA sample quality can be dealt with in the laboratory, where multiple hairs can be pooled to increase the amount of viable material to minimize genotyping errors (Alpers et al. 2003). However, this procedure has an inherent risk of pooling samples from multiple individuals, resulting in no confirmed identification. Laboratory techniques have been improved so that small samples (i.e., one hair follicle) can be used to identify an individual (Taberlet et al. 1996; Vigilant 1999). Ideally, the DNA from a single hair should be extracted separately and compared to the rest of the pooled hair sample to verify the identification of the pooled sample (Frantz et al. 2004).

Variability of Microsatellite Markers

Microsatellites are polymorphic loci, or markers, that can be used to distinguish individuals of a species. The markers used to identify individuals must have enough variability to produce unique values (genotypes) for each individual that is sampled. If the microsatellite markers being used lack variability, there may be too few individuals identified. Paetkau (2003) recommends that for small projects ($n < 100$), individual identity should ideally be based on a minimum five-locus marker system when the expected heterozygosity (H_E) of those markers is at least 0.78 (or $H_E \geq 0.69$ for a six-locus marker system). For large projects ($n < 200$), individual identity should be based on a minimum five-locus marker system where $H_E \geq 0.83$ (or $H_E \geq 0.75$ for a six-locus marker system).

If the population being sampled is found to have low genetic variability, then additional markers may need to be developed and tested. In addition, variability of microsatellite

markers may not be the same between populations and further laboratory analysis to develop higher power markers may be required.

Quality Control and Error Prevention

Paetkau (2003) recommends a number of procedures to ensure quality control and prevent genotyping errors of DNA samples. For example, remote collection of DNA samples may result in poor-quality samples that originated from non-target species, more than one animal, or have poor DNA quality. Paetkau recommends a preliminary screening with a species-specific marker, or a very robust marker that performs consistently for the target species, to eliminate all poor-quality samples before more costly laboratory analysis.

Inconsistent genotyping of different samples from the same individual will create pairs of genotypes that are highly similar and may result in the recognition of more individuals than were actually sampled. Paetkau (2003) developed protocols to examine and re-analyze pairs of samples whose genotypes are highly similar though not identical (i.e., had fewer than three mismatched pairs of microsatellite marker values). By re-examining these close genotypes on a case-by-case basis, he is able to detect possible errors in genotypes and interpret incomplete genotypes more accurately.

Few laboratories have developed techniques for wildlife DNA analysis, and it is important to recognize the potential procedural differences between laboratories when interpreting DNA results. Switching laboratories during an inventory project is not recommended. If this is unavoidable, a series of blind samples and known duplicates can be sent to each laboratory to assess consistency and ensure quality of results.

3.1.5 Sample Units and Survey Design

Badger inventory surveys follow a sample design hierarchy that is structured similarly to the RISC standards for other medium-sized territorial carnivore inventories, the *Species Inventory Fundamentals* manual, and follow many of the recommendations of Zielinski and Kucera (1995). Figure 1 illustrates the appropriate conceptual framework for a survey using sample stations for Badgers, and clarifies certain terminology used within this manual (also found in the Glossary). A survey set up following this design will lend itself well to standard methods and associated WSI data standards. These standards may be modified to accommodate alternative sampling strategies and limitations of the study area, access, and resource availability.

The first step to initiate an inventory survey is to delineate the Project Area and one or more Study Areas based on geographic constraints or general habitat (e.g., biogeoclimatic zone). The Study Area may be equivalent to the Project Area, and can be sampled using one or more inventory methods, and stratified based on habitat types to focus effort and minimize variability in inventory results.

A Grid Cell is used as the statistical sampling unit, helping investigators to randomly sample or further stratify the Study Area. Ideally, a Grid Cell should encompass the entire home range of the target species to minimize animal cross-over. A Grid Cell generally corresponds to the home range of a female because these tend to be smaller than those of males (Zielinski and Kucera 1995). As home range size varies depending on ecological conditions, appropriate Grid Cell size may be determined from telemetry conducted in the local area. Grid Cells should be superimposed over the Study Area and oriented so that the maximum number of cells is included in the Study Area. Partial cell areas can be appended to adjoining cells. Where it is logistically difficult or beyond the available budget to sample every Grid

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Cell, it may be suitable to sample every other cell (like a checkerboard) or a random selection of cells (e.g., Mowat and Strobeck 2000).

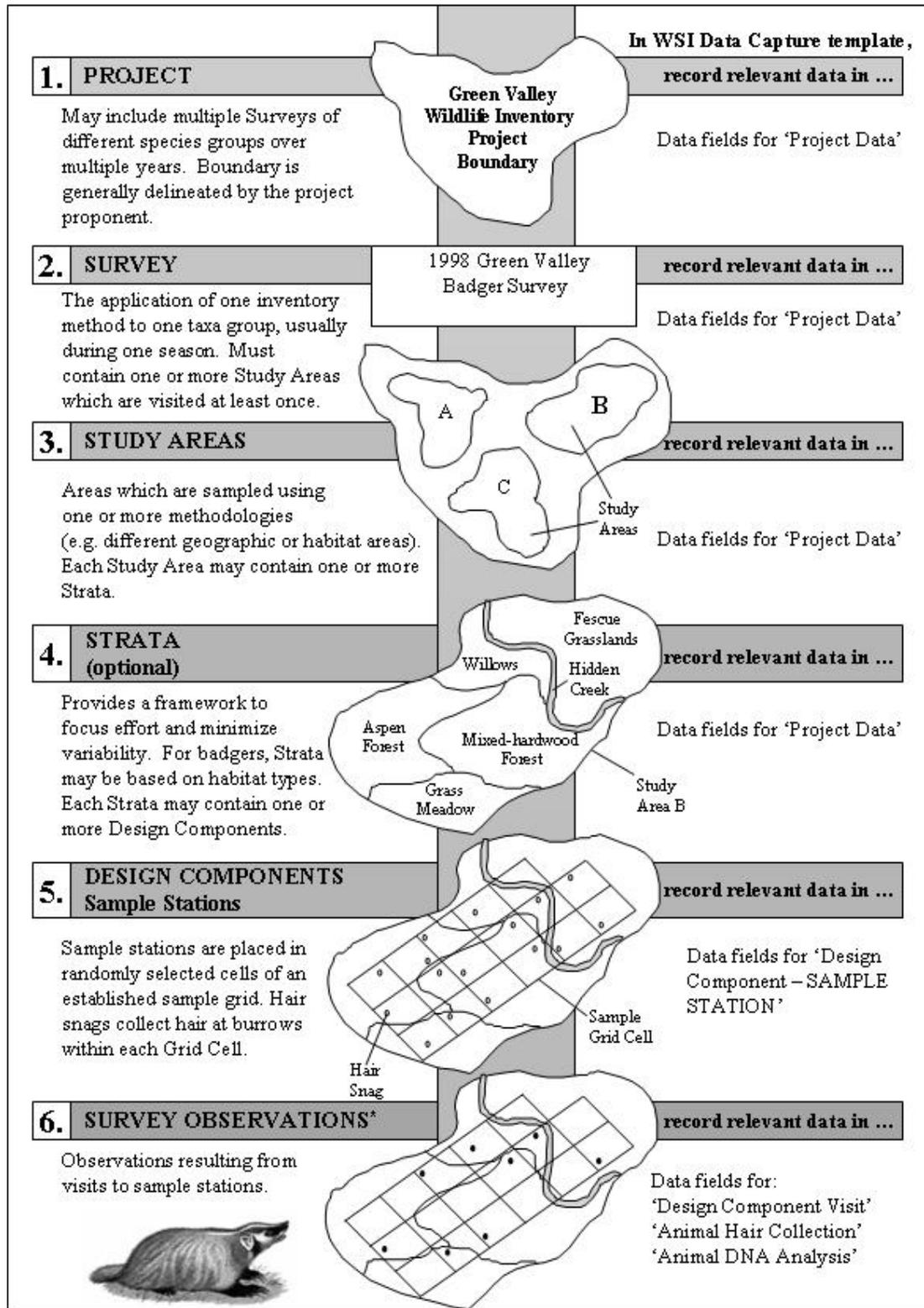


Figure 1. RISC species inventory survey design hierarchy for Badgers.

3.2 Preliminary Surveys

Preliminary surveys, the first step in any inventory, refer to the gathering of existing information, either in Ministry of Environment data banks or as public knowledge. For rare species that are difficult to document using field procedures, these surveys can be a critical source of information. In some cases, field-based inventory surveys may not be required if preliminary surveys meet the objectives of the project, especially for determination of presence/not detected.

Information Sources

Obtaining existing information should be the first course of action in an inventory project for Badgers in any area. Ministry of Environment biologists and other specialists (e.g., universities, consultants, First Nations, naturalists) should be consulted before initiating an inventory survey. The *jeffersonii* Badger Recovery Team has a website with links to research conducted in the province, reports, and other information (www.badgers.bc.ca). The B.C. Conservation Data Centre (www.env.gov.bc.ca/atrisk/toolintro.html) provides a list of rare wildlife and known occurrences in an area. Also, the WSI data system manages information and data from previous inventories in the province (www.env.gov.bc.ca/wildlife/wsi/index.htm). Although Badgers have not been commercially trapped since 1967, historical Badger harvest records may also provide additional information on historical occurrence.

Questionnaires and Public Appeals

Where more detailed localized information is required, questionnaires and interviews targeted to specific interest groups can provide important information on Badger occurrence and abundance. Report any recent sightings collected as a result of these efforts as outlined in Section 2.2.

Mail questionnaires are generally a practical approach because of the relatively low administrative involvement and the ability to canvass a large area from a central location. Mail questionnaires have been used to detect or assess populations of Red Fox (Lemke and Thompson 1960), European Badger (Aaris-Sorensen 1987), Lynx (Brand and Keith 1979), a combination of Coyote, Bobcat, Gray and Red Fox (Hatcher and Shaw 1981), and Wolverine (Groves 1988). However, measures of accuracy and precision are unattainable because the data collected are usually on a nominal scale. Bias is present due to variable response rates and non-response bias (differences between respondents and non-respondents). Those problems can be ameliorated somewhat by pre-survey contacts, use of “user-friendly” format and content, and mail follow-ups (Filion 1978). It is strongly recommended that a professional specializing in survey design (i.e., a social scientist) is consulted to determine the appropriate questions and their wording to obtain accurate results.

An extensive media campaign, including posters, radio, and newspaper advertisements, was successfully used to obtain data on sightings of Badgers and their burrows before and during research projects in the East Kootenays (Newhouse and Kinley 2006), Thompson-Okanagan (Weir et al. 2003), and Cariboo regions (Packham and Hoodicoff 2006). In these examples, a “Badger sightings hotline” was established so the public could call and report an observation by either talking to a researcher directly or leaving a detailed message. Also, the *jeffersonii* Badger Recovery Team have established a website where the public can report a Badger

sighting (www.badgers.bc.ca/HYSAB.htm). The website also provides photos and characteristics of Badgers and their burrows to ensure accurate identification.

Traditional ecological knowledge (TEK) held by the elders and other members of First Nations can also provide a wealth of historical information. Although TEK and local use information may be difficult to obtain, the value of this knowledge should not be discounted, especially where other information is absent or where historical information on occurrence, distribution, or relative abundance is required. Partnering with First Nations on inventory projects has been successful in the Cariboo, where a local First Nations inventory team conducted surveys for Badgers and their burrows, collected hair for DNA fingerprinting, and interviewed community members in remote areas. Their activities resulted in identifying the occurrence of Badgers in their traditional territories, raising local awareness of Badgers and their habitats, developing management objectives to maintain Badger habitat, and implementing restoration activities to improve Badger habitat and create local employment.

It is important to confirm that each reported observation is actually a Badger, and not another animal misidentified as a Badger. If dead Badgers are reported (e.g., roadkill or accidental captures), efforts should be taken to obtain the carcass, or at least a tissue or hair sample, so that species is confirmed and further studies can be conducted (discussed further in Section 3.3).

Office Procedures

- Select a geographic area to be surveyed.
- Obtain relevant maps for survey area (topographic, ecoregion). For trapline level information, 1:250 000 scale maps are appropriate.
- Develop a list of people and interest groups to include in the survey. Include biologists, foresters, hunters, recreational groups, guide-outfitters, ranchers, farmers, animal control personnel, and trappers. Focus on the group most likely to encounter Badgers and to provide positive identification.
- Consult with a professional who specializes in survey design to determine the appropriate questions and their wording for the audience so that you receive accurate results.

For surveys of First Nations people:

- The traditional knowledge held by First Nations people is proprietary and permission is required from the Chief and Council before you contact individuals. Even a fairly simple survey can require interpreters. The First Nations community may also request that they conduct their own surveys of their people. If investigators wish to embark upon a TEK survey, it is strongly recommended that an experienced professional be employed before any inquires of First Nations people.
- Determine if any historical harvest surveys have been completed by Regional Wildlife Branch offices. Regional staff may also direct you to staff within the Ministry of Aboriginal Relations and Reconciliation for assistance.

For all other surveys:

- Design a mail-out or interview questionnaire so that respondents provide data on the following: 1) location, dates, and numbers of animals sighted, and 2) location and details of sign observed. Consider generating questions so that an evaluation of the reliability and accuracy of the sighting can be assessed. These may be based on the diagnostic characteristics of Badger burrows identified in Appendix A.
- If appropriate, use other media such as posters, radio, and newspaper, and television advertisements.

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- Create an appropriate mechanism for public reports to be collected, or use existing channels (e.g., regional “Badger sightings hotline” phone numbers, or sighting report formats on-line).
- Define the limitations and potential biases of the data obtained from these preliminary surveys.
- Consult with a biometrician or quantitative ecologist who is familiar with the analysis of harvest, interview, and mail-out questionnaire data.

Sampling Design

- Consult a specialist in formulating, administering, and analyzing questionnaire results to design the sampling regime.

Sampling Effort

- The amount of effort expended on a preliminary survey depends on the survey objectives, survey audience, and the level of survey intensity.
- Sampling effort is a function of the questions being asked, the number of people being interviewed, and the time that is allowed between follow-up requests.

Personnel

- One person familiar with the biology of the species, scientific design, and computer statistical analyses is needed for preliminary surveys. If the person is not familiar with statistics or computer modeling, he or she should work closely with a biometrician or quantitative ecologist.

Equipment

- Maps of the Project Area.
- Computer and statistical software.

3.3 Inventory Surveys

As stated earlier, there are three levels of inventory surveys presented in this document: presence/not detected, relative abundance, and absolute abundance. These are discussed further in the next sections. Table 1 outlines the types of inventory surveys recommended for inventorying Badgers at various survey intensities, and the appropriate WSI data fields used to capture resulting data (see Appendix B for more information about capturing data).

Few attempts have been made to compare methods, or to compare census results against “known” populations, or even against each other. The recommended methods in this manual are based on current information and on the opinion of species specialists who considered logistics, accuracy, precision, and applicability. Recommendations may change with time as more information is collected.

Table 1. Types of inventory surveys, the level of intensity of the survey, and the WSI data fields used to capture resulting data.

Inventory Survey	Intensity*	WSI Data Field Grouping
1. Preliminary Surveys	• PN	• Animal Observation and Sign

(e.g., hotline reports)		
2. Burrow Search (e.g., aerial and ground surveys)	<ul style="list-style-type: none"> • PN • 	<ul style="list-style-type: none"> • Animal Observation and Sign
3. Sample Stations (e.g., hair, cameras and scats)	<ul style="list-style-type: none"> • PN • RA 	<ul style="list-style-type: none"> • Animal Hair Collection • Animal DNA Analysis
4. DNA Mark-Recapture (e.g. using hair snags)	<ul style="list-style-type: none"> • RA • AA 	<ul style="list-style-type: none"> • Animal Hair Collection • Animal DNA Analysis
5. Live-Capture/ Telemetry	<ul style="list-style-type: none"> • AA 	<ul style="list-style-type: none"> • Animal Capture and Handling: Medium to Large Mammals

*PN = presence/not detected (possible); RA = relative abundance; AA = absolute abundance.

3.4 Presence/Not Detected

Recommended method(s)

Incidental observations of live or dead animals, as reported during preliminary surveys (Section 3.2), and burrow searches from the air or ground can be used to confirm the presence and distribution of Badgers. Also, the detection of Badger activity at burrows using remote cameras, hair snags, tracks, and scat will confirm the presence of Badgers.

Presence/not detected surveys are used to determine if a species occurs in an area. As discussed in Section 3.2.2, questionnaires and public appeals have proven effective in collecting incidental observations of live and dead Badgers in an area, and may also lead to the location of burrows. Burrow searches also can be used to target large areas of suitable habitats (Section 3.4.1), although it is important to note that the occurrence of Badger burrows does not confirm current occupation of an area. Evidence of recent activity that can be attributed to Badgers must be used to confirm presence. Burrows also are used as sample stations to monitor for Badger activity (Section 3.4.2). Badger detection surveys can be used as preliminary data for power analysis or sample size determination in advance of relative abundance surveys. Therefore, these surveys should use methods that can be replicated to provide data of statistical value (Boulanger and Krebs 1997).

The most economical means to survey large areas is to terminate surveys once the target species has been detected, or is still undetected after a reasonable amount of effort has been expended (Zielinski and Kucera 1995). Failure to detect presence does not necessarily confirm absence. The credibility of data on absence relates to 1) expectations based on known, broad geographic ranges and seasonal habitat selection, 2) the distinctness of sign in the season and habitat(s) surveyed, and 3) the intensity of the search. Multi-year surveys may be required to increase confidence that the species is not present in an area.

3.4.1 Burrow Search

Burrow searches can be used to determine the occurrence of Badgers in areas where there is potential habitat but the extent of their range is unknown, and to identify active burrowing habitats where there are historical records but little is known about their current status. Since

one Badger may dig and maintain a number of burrows within its range, the density of burrows is not considered an indication of the relative density of Badgers.

Badger burrows can be identified from their shape and the distinctive soil berm in front of a single entrance, or multiple entrances that may lead to a single tunnel or complex of tunnels (Appendix A). Burrows may be used by a single Badger, multiple Badgers at different times, or by a family group (maternal burrows) at the same time. Most burrows can be classified as having been occupied during the current year (versus previous years). Actively used burrows may be identified by loose, excavated soil, fresh tracks in the soil or snow, trampling, and degree of plant growth. Burrow searches may occur during any time of the year, although vegetation growth may limit the sightability of burrows. Also, Badgers become less active between December and March and this may not be an optimal time to determine actively used areas.

The most efficient method of searching large areas for Badger burrows is by airplane or helicopter. Burrows may be more obvious from the air in the late fall after a light snowfall, or in early spring when most of the snow has melted off exposed hillsides but before vegetation has obscured the burrow. Ground searches are also effective. In some areas, it may be more efficient to search by horseback rather than walking to allow access into more remote areas. Road-side searches from a vehicle are also effective, but result in bias of burrow locations near roads. Smaller, discrete areas may be surveyed on foot along transects.

Ideally, once a burrow is identified, it would be investigated for sign to confirm it is used by a Badger, and if it has been used recently. In addition to fresh diggings and tracks, Badger use can be readily confirmed by an observation of a live animal, or the presence of loose guard hairs. Remote cameras and/or hair snags may be used to confirm Badger presence. Scat samples collected could also be used, although this likely would require DNA analysis to confirm their origin as Badger scat.

Office Procedures

- Review the introductory manual, *Species Inventory Fundamentals (No. 1)*.
- Conduct a preliminary survey (Section 3.2) that includes soliciting reports of Badgers and their burrows, conducting interviews, and consulting local experts to determine current available knowledge of Badger occurrence and historical occurrence records.
- Identify objectives, delineate the Project Area, and select appropriately sized Study Area(s) within the Project Area in which you will actually sample. An overlay of biogeoclimatic zones may help to identify a Study Area within suitable habitat.

Sampling Design

Aerial Surveys:

- On a map or air photo of appropriate scale for the Study Area (1:20 000 or 1:50 000 recommended), draw and label Grid Cells that will be used as transect flight lines. The distance between transects (flight lines) will be a function of the terrain, and should be determined based on a Study Area.
- In some cases it may be more appropriate to target the most suitable habitats (e.g., south-facing grassland slopes) for directed searches. These areas should be identified on a map before the flight.

Ground searches over large areas:

- Overlay Grid Cells onto the Study Area to use as sample units. The size of Grid Cells will be a function of the terrain and should be based on the characteristics of the Study Area.
- Randomly select Grid Cells to survey for burrows if the whole Study Area is considered suitable habitat. If conducting surveys from horseback, it may be more suitable to use the grid to establish transects.
- If information suggests that burrowing areas are concentrated in suitable habitats within the Study Area, consider stratifying surveyed Grid Cells by biogeoclimatic zone or other appropriate variable. The number of Grid Cells will depend on the access and resources available for the survey.

Ground searches over small areas:

- Using a Geographic Information System (GIS), overlay a 100 × 100 m grid on the search area, and label transects. Lay out transects so that the maximum area per transect is surveyed. Depending on resources and time availability, it may be appropriate to identify certain lengths of transects for the searches (e.g., 50 m lengths).

Sampling Effort

- Sampling effort will be a function of the number of Grid Cells or transects (sample units) that must be searched, animal abundance, and search method.
- Aerial searches may be completed in a few hours, whereas ground searches may be intensive and take days depending on access and the number of burrows found.
- Additional sample units should be searched if initial efforts yield no results.

Personnel

- Personnel familiar with identifying Badger burrows and their sign is required.

Equipment

- Maps or air-photos at 1:20 000 or 1:50 000.
- Global Positioning System (GPS) receiver (for establishing location of burrows).
- Transportation (e.g., airplane, helicopter, truck, all terrain vehicle, horse).
- Compass.
- Binoculars.
- Computer and statistical analysis software.

Field Procedure

Aerial Surveys:

- Referring to the map of the Study Area with the flight lines or habitats to be surveyed, fly the appropriate areas searching for burrows.
- The altitude of the aircraft should be at least 1000 feet above ground level.
- Use a GPS unit (hand-held or in the aircraft) to record the locations of burrows identified.
- Where possible, follow up aerial surveys with ground assessment to confirm that it is a Badger burrow and record an accurate location using a hand-held GPS. Also, determine whether the burrow is recent (i.e., used within the current year) or older (i.e., not used within the current year). Make a special note of possible maternal dens, which often have large piles of soil, show signs of longer-term use (i.e., multiple tracks, trampling), and often have multiple entrances.

Ground searches over large areas:

- Referring to the map of the Study Area with the Grid Cells or transect, conduct the search for burrows. Use a hand-held GPS to determine the start point of each transect segment. If searching transects from horseback, identify burrows restricted to within 10 m of the transect (as visibility allows).
- Use a hand-held GPS unit to record the locations of burrows identified and mark location on the map.
- Record whether the burrow is recent (i.e., used within the current year) or old (i.e., not used within the current year). Make a special note of possible maternal dens, which often have large piles of soil, show signs of longer-term use (i.e., multiple tracks, trampling), and often have multiple entrances.
- Avoid motorized vehicles during the period when Badgers are having their kits (March–April). Conducting surveys on horseback or on foot is recommended during this time.

Ground searches over small areas:

- Use a hand-held GPS to determine the start point of each transect segment. Use a compass to walk along the transect. With a hand-held GPS, record all Badger burrows on both sides of the transect within 5 m perpendicular to the transect, and mark the locations on the map.
- Record whether the burrow is recent (i.e., used within the current year) or old (i.e., not used within the current year). Make a special note of possible maternal dens, which often have large piles of soil, show signs of longer term use (i.e., multiple tracks, trampling), and often have multiple entrances.

Data Analysis

- Produce maps of Grid Cells searched and transects used during the searches and records of confirmed burrows, including UTM locations and Badger activity notes.
- Record latency to detection, the number of search days required for detection (search effort), the total area searched to detect a burrow.
- Calculate burrow density in the Study Area.

3.4.2 Sample Stations

This method is a form of trapping in which evidence of an animal's visit, rather than the animal itself, is captured. Such evidence may consist of a photograph, hair, tracks, or scat.

Because Badger densities are typically low and individuals are wide ranging, intensive efforts may be required to detect individuals in most areas. The use of bait and scent is often used to lure most territorial carnivores to sample stations; however, this approach is not recommended for Badgers as it attracts non-target animals and disrupts sampling. Instead, it is recommended that most sampling occurs at Badger burrows where there is some certainty of Badger occurrence and non-target species are relatively excluded.

The following methods may be used to detect the presence of Badgers in an area. These methods also may be used to determine estimates of relative abundance (Section 3.5) and absolute abundance (Section 3.6).

Remote Cameras

Remote cameras can be used to detect Badger presence or in co-ordination with other detection methods, especially at suspected maternal burrows that may be more sensitive to disturbance. The most effective system used for Badgers is a camera triggered by an infrared sensor (single-sensor) or by microwave action and a passive infrared heat sensor (dual-sensor). The camera can be mounted on a nearby tree or other stable mount. In some areas, security of the system may be required to prevent theft or sabotage. Otherwise, the camera can be left unchecked for a period of time, depending on film capacity and battery power. Frequent visits by Badgers or non-target animals can result in many pictures being taken of the same animal, and quickly filling up a film roll. Digital cameras can be set to take still photos or short video, but may use extra battery power.

Hair Capture

Badger guard hairs can be found loose in the soil berm at a burrow, or snagged from an animal entering or exiting a burrow. Badger guard hairs can be readily identified by their distinctive tri-coloured appearance, but the morphological structure of hair is unique to species and can provide further confirmation. Although more complex than examining physical characteristics of hair, DNA in follicles of shed or snagged hair can also be used to indicate species and sex (discussed in Section 3.1.4). Snags tend to collect multiple hairs with follicles so there is a higher potential for extracting viable genetic material than from a single sample.

Generally, hair snag stations are baited and configured so that as a target animal approaches, it is forced to come into contact with the collection device and deposit a hair sample. Several different devices have been used to pull hair from territorial carnivores. Raphael (1994) described a number of earlier studies that used barbed wire in a variety of configurations, or PVC (polyvinylchloride) tubes baited with sticky material, all of which obtained some hair of *Martes* species. Foran et al. (1997b) describe using glue-boards (3 × 3 cm made from commercial glue traps for rodents) attached to tree trunks to snag hairs of Marten. For Lynx, Weaver (1993) used a piece of scented carpet 10-cm square studded with tacks affixed to a tree, and attracted animals with a visual attractant, such as a dangling feather or aluminum pie plate. Krebs and Lewis (1998) and Lofroth et al. (2000) also conducted similar trials of hair-snaring for Wolverine that included barbed wire, different configurations of glue-boards situated on running poles, inside and outside of wooden cubbies, with varying levels of success.

For Badgers, investigators are encouraged to experiment with different hair snagging media. Various methods have been tried that include barbed wire, Velcro, and pinned-knaplock in sets erected around a perimeter and inside of burrows (Packham and Hoodicoff 2006). Barbed wire snags were the least effective at snagging hair, and yielded moderate DNA viability (52% of 50 samples were assigned to individual Badgers). Velcro snags were effective at collecting hair and simple to manufacture and install into burrows, but the viability of DNA was lowest of all methods (23% of 69 samples were assigned to individual Badgers). Since most of these snags were set in early spring when Badgers are shedding their winter coats, Velcro combed loose hair from an animal and it was speculated that the follicles may have been exposed to weather or other factors that would have reduced the quality of DNA.

Snags using pinned-knaplock were the most successful method of consistently collecting hair with follicles, and resulted in the highest DNA viability (75% of 189 samples were assigned to individual Badgers). One or more snags were placed in the burrow so that an animal

moving into or out of the burrow would brush along the pinned-knaplock and deposit a hair sample. DNA quality was retained by setting snags well inside of the burrows, reducing exposure, and collecting samples promptly after they have been snagged. A perimeter snagging device was successfully used around a number of burrow openings where a family group was observed. The structure increased the potential for collecting hair and was checked regularly to maximize the probability that each hair sample was collected from a single individual before another animal passed under the same location and contaminated the hair sample (Packham and Hoodicoff 2006). Directions for construction of these snags and photographs are included in Appendix C.

Scat

As noted earlier, Badger scat may be deposited above ground or inside of burrows. The classification of scat according to species by morphology is subjective and can be confounded by a number of factors. DNA analysis may be used to confirm a Badger source and to identify individuals in the population. However, because Badger scat may contain DNA from numerous prey species, this may increase the complexity of laboratory work.

Foran et al. (1997a) report that they were successful in obtaining DNA from the scats of 14 species of North American carnivores, including Badger. They note that differences among areas do occur and caution that the local population under study should always be analyzed using appropriate reference samples. Palomares et al. (2002) also recommend using fecal genetic analysis to determine the presence and distribution of rare and elusive carnivores. However, attempts to determine species from scats using pH or bile acids (Quinn and Jackman 1994) have proved ineffective. Before attempting this approach, contact a laboratory with experience extracting DNA from scats to ensure feasibility of the study.

Tracks

Tracks may be recognized at the entrance of a burrow or along trails between nearby burrows. Because Badger tracks are often erased because their long hair sweeps the ground, tracks may not be a reliable method to detect presence. Other sign, such as hairs or photographs, should be collected to corroborate track evidence.

In most cases, soil or snow will be a suitable medium for registering the tracks of animal visitors. Moist sand may be placed at a burrow and raked into a 1 m circular plot at the entrance to record Badger tracks (Conner et al. 1983). Sooted aluminum plates also were considered to record Badger tracks, but are time-intensive and finicky, and not considered effective for this application.

Office Procedures

- Review the introductory manual, *Species Inventory Fundamentals (No. 1)*.
- Conduct a preliminary survey (Section 3.2) that includes soliciting reports of Badgers and their burrows, conducting interviews, and consulting with local experts to determine current Badger locations and other historical occurrence records. Consult with researchers on the behaviour of the target species within the Study Area and on methods of detection.
- Identify objectives, delineate the Project Area, and select appropriately sized Study Area(s) within the Project Area in which you will actually sample. An overlay of biogeoclimatic zones may help to identify a Study Area within suitable habitat.
- It is strongly recommended that a burrow search (Section 3.4.1) be conducted before setting up the sample stations.

- Select one or more methods of detection, as described above. Hair snags and/or remote cameras are recommended.
- If relying on DNA fingerprinting, contact a laboratory before collecting samples to confirm their availability, recommended storage procedures, and other specific questions.

Sampling Design

- A consistent, systematic survey effort is recommended (although may not be necessary) to determine presence/not detected (Boulanger and Krebs 1997). This may include overlaying Grid Cells over the Study Area, and randomly selecting Grid Cells to sample.
- The size of Grid Cells, or sample units, should be based on presumed Badger home range size, and may be a function of the terrain in the Study Area. Ideally, sample stations would be set at burrows in randomly selected Grid Cells. Overlay the sampling grid onto the Study Area using GIS or printed maps.
- Sampling design may be altered to accommodate regional differences in animal density and operational feasibility.

Sampling Effort

Jones and Raphael (1993) observe that “a relation probably exists between the spacing of the stations and detection success, but it is currently not known,” and “optimal spacing and length of running time need to be researched in different areas for different target species.” The number, spacing, and monitoring schedule for sample stations may vary with study objectives, detection methods, and time/expense limitations. The following are general guidelines, and operational trials are recommended to further refine effort.

- The number of Grid Cells sampled will at least partially depend on access and resources available for the survey. In areas with low burrow density, all identified burrows within a Study Area may be surveyed. It is recommended that a trial survey be conducted, and that a power analysis be completed to determine the appropriate sampling effort for the comprehensive assessment.
- Sample stations should be set for 4 to 10 nights, and checked every other day to ensure that the sample stations are operating. In remote areas, stations may be set for longer periods of time and checked infrequently. Statistical estimates will have to take this into account.
- Detection of Badgers is recommended for the spring or early summer when Badgers are making long-distance movements searching for mates, and are readily losing hair.

Personnel

- Individuals monitoring sample stations (burrows) must be familiar with identification of Badger sign.

Equipment

- Maps or air photos (1:20 000 or 1:50 000).
- Paper envelopes for collecting hair.
- Bags for collecting scat, and labeling markers.
- Gloves.
- Field notebook or data forms.
- Detection Media:

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- Remote cameras: Detailed information on appropriate camera systems should be obtained from the manufacturer as systems will change with time.
- Hair snags: A number of snags should be constructed before starting surveys. Instructions for construction of pinned-knaplock snags are included in Appendix C.
- Sand: Moist, sifted sand (enough for a circular plot of 1 m radius at each burrow); sand sifter and rake.
- Computer and statistical analysis software.

Field Procedure

- Establish sampling units (e.g., Grid Cells) and location of burrows to be sampled on a map. Record the location, UTM coordinate, and burrow ID number for each burrow sampled. Record the method, time, date, and number of snags set at each site.
- Handle all equipment with gloves and refrain from leaving human scent at the station, if possible.
- Monitor sample stations as per study design. Data are recorded as “visits” (e.g., hair, scat, tracks, or photographs). Record the date, time, sign of Badger activity and other relevant information.

Remote Cameras:

- Follow manufacturers’ directions when setting up the remote system. Position the sensor to detect movement across the opening of the burrow. Take into consideration snow and vegetation that may trigger the system.
- Affix the camera to a tree (or other suitable stand) focusing on the burrow entrance. Have an assistant simulate the target animal to ensure that the system is working properly. If using print film, the first roll should be a test photo to ensure the camera is working properly, noting the location, date, and time to allow for interpretation after photos are developed. Setting the camera date/time stamp also helps to organize photos after they are developed.
- Ensure completed rolls are labeled with the date in/out, the station name and the location.

Hair Snags:

- Place hair snag (one or more) inside the entrance of the burrow within reach. Use the nails to anchor the snag into the soil. Additional anchors (e.g., lengths of wire) may be required if the soil is unsuitable or the animal dislodges the device.
- Remove snagged hairs and place in paper envelopes labeled with the location, date, time, and surveyor. Cross-contamination of the hair sample with human DNA is not a concern since the genetic fingerprinting procedures are specific to genus (D. Paetkau, pers. comm. 2007).
- If possible, retain hairs for future DNA analysis, even if it is not an objective of the current study. However, hairs that will be analyzed for DNA require more careful treatment than those collected for physical inspection.
- Check hair snags frequently to avoid DNA degradation and to reduce the chance of multiple captures.
- Store hair samples in the paper envelopes in a dark, dry location. Consult with the laboratory for storage protocols of samples that will be kept for long periods of time.

Scats:

- Because DNA degrades over time, the condition of the scat is important and samples need to be collected as fresh as possible and preserved quickly.
- Contact the DNA laboratory for appropriate methods to store scat samples.

Tracks:

- Record any tracks by taking detailed notes, and photographs with a scale marker are recommended. Note that individual tracks are not counted independently.
- Between monitoring visits, rake the soil, snow, or sand to obliterate existing tracks.

Data Analysis

- Produce maps of Grid Cells searched and transects used during the searches.
- One animal visit is represented by one or more detection (tracks, hair, scat, photograph) of a species at one station in one day.
- Delete inoperative station nights, i.e., where evidence of an animal visit is absent and believed to be the result of extraneous factors, such as the snag being removed by an animal, or obliteration of sign by wind or rain.
- Calculate latency to detection (LTD) as the number of station-days required to achieve a detection in a Grid Cell (similar to expressing trapping success as number of trap-nights per successful capture). Report the Grid Cell size.
- If DNA fingerprinting was used, identify the number and sex of each animal, and the location where each was identified.

3.5 Relative Abundance

Recommended method(s)

DNA fingerprinting of genetic material collected from hair, scat, or tissue can be used to conduct a mark-recapture survey and estimate the relative abundance of Badgers. Badgers are not easily observed, are wide-ranging and occur at low densities. Therefore, direct observation and snow tracking, although used for other territorial carnivores, are not considered feasible methods for estimating relative abundance of Badgers.

Relative abundance inventories provide indices of population size over time, and usually are based on some measure of effort. This level of inventory is used to answer questions about species distributions, monitor changes in species richness, conduct environmental assessments, and record patterns of animal activity (Southwood and Henderson 2000). The simplest measures of relative abundance include minimum number alive (MNA) and catch per unit effort (e.g., # Badgers detected per month or per year). Mark-recapture estimates generally require a sampling design that is resource-intensive to meet assumptions, but a less rigid approach may be used to measure relative abundance for monitoring trends in population size over time or between study areas.

Measuring the relative abundance of Badgers can be accomplished with a burrow survey and sample stations with a systematic survey design, where the MNA and catch per unit effort is reported (discussed in Section 3.4.2). A more robust approach would include a systematic survey to collect genetic material (e.g., hair) for DNA fingerprinting, and use of open population mark-recapture estimators to determine population size that can be compared over time. The following is a suggested protocol for relative abundance estimates using DNA

analysis and mark-recapture modeling. As this is a new application for Badgers, techniques may be refined as more research is completed.

3.5.1 DNA Mark-Recapture

The ability to identify individuals using DNA fingerprinting has led to the development of DNA mark-recapture techniques, where a “marked” individual can be recognized between sampling sessions to determine relative and absolute abundance. This approach was first used to inventory bears (Woods et al. 1999), and since has been applied as a provincial inventory standard for the species (see manual no. 21, *Inventory Methods for Bears*).

Although collection of some sources of DNA requires trapping and handling animals, hair and scat can be collected using non-invasive methods as described in Section 3.4.2. In particular, collection of shed and snagged hair at burrows has been successfully used to estimate relative abundance for Badgers in the Cariboo region (Packham and Hoodicoff 2006).

Mark-recapture models require certain assumptions to be met. These include demographic and geographic population closure, random sampling where every individual has the same probability of being marked (i.e., equal catchability), every individual has the same probability of survival, no marks are lost between sampling periods, and sampling time is negligible in relation to intervals between samples (Krebs 1999). Open mark-recapture models (e.g., Jolly-Seber) allow for relaxing demographic (i.e., births, deaths) and geographic (i.e., movement into and out of the Study Area) assumptions; it can therefore be used to estimate relative survival between sampling periods when animals are not geographically restricted (RIC 1998).

As identified in the *Inventory Methods for Bears*, the main benefits of the DNA mark-recapture technique are: 1) animals do not have to be captured to be marked, and therefore are not handled or disturbed, 2) marks cannot be lost, 3) large sample sizes can be obtained with a relatively low cost (compared to live-trapping methods), and 4) individuals can be identified with little error. However, several sampling biases could violate the assumptions of mark-recapture, including difference in home range areas, habitat-specific densities, and age and sex differences in capture probabilities (Boulanger and McLellan 2001). Unequal catchability may also result from the behaviour of individuals near the trap, learning by animals (i.e., trap-happy or trap-shy), and unequal opportunity to be caught because of trap positions (Krebs 1999). For Badgers, sampling is generally conducted at burrows located within the home range of one or several individuals. Therefore, this is not truly random sampling, and tests of equal catchability may be conducted to determine whether every individual has the same probability of being detected.

Several statistical programs may be used for mark-recapture calculations and tests of assumptions. Some of these are summarized in Table 2. The procedures described below are largely taken from the *Inventory Methods for Bears* and the methods used by Packham and Hoodicoff (2006), and may be refined as techniques are further developed and tested.

Table 2. Example of software available for mark-recapture calculations.

Program	Author(s)	Description
CAPTURE	Gary White	Computes estimates of capture probability and population size for “closed” population capture-recapture data.
JOLLY	James E. Hines	Computes estimates of survival and capture probability for 1-age class open population capture-recapture models.
JOLLYAGE	James E. Hines	Computes estimates of survival and capture probability for 2-age class open population capture-recapture models.
MARK	James P. Gibbs	Provides parameter estimates from marked animals when they are re-encountered at a later time.
POPAN	Neil Arnason and Carl Schwarz	Provides for estimation of population size and recruitment with the Jolly-Seber model.
RELEASE	Gary White	Computes estimates of survival and capture probability for capture-recapture experiments on open animal populations.
SURGE	Evan Cooch, Roger Pradel and Nadav Nur	Provides parameter estimates from marked animals when they are re-encountered at a later time.
SURVIV	Gary White	Computes estimates of survival (or any model parameter) with multinomially distributed data.

Office Procedures

- Review the introductory manual, *Species Inventory Fundamentals (No. 1)*.
- Read Section 3.1.4 “Considerations for DNA-Based Techniques,” Section 3.4.2 “Sample Stations,” and the sections reviewing collection methods for hair capture and scat in particular, and relevant literature (some are cited in this manual) to understand the process for DNA studies.
- Obtain maps for project and study area(s) (e.g., 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- Identify objectives, delineate the Project Area, and select appropriately sized Study Area(s) within the Project Area in which you will actually sample. An overlay of biogeoclimatic zones may help to identify a Study Area within suitable habitat. The Study Area may be situated in areas of suitable habitat where there is a high probability of geographic closure. Use natural barriers to define the boundaries of the Study Area to minimize movement in or out of the area during the survey.
- When using closed population models, geographic closure will be a challenging assumption to meet for Badgers, especially for those animals living on the edge of the study area, and wide-ranging males who may leave or enter the study area during the capture session.
- Conduct a preliminary survey (Section 3.2) that includes soliciting reports of Badgers and their burrows, conducting interviews and consulting with local experts to determine

current Badger locations and other historical occurrence records. This should also include setting up a reporting hotline for the public to call and report sightings. Consult with researchers on the behaviour of the target species within the Study Area and on methods of detection.

- It is strongly recommended that a burrow search (Section 3.4.1) be conducted before initiating a survey for relative abundance.
- Consult with a statistician or quantitative ecologist who is familiar with the design of population monitoring surveys using open population models. The results of any analysis will depend on how well the monitoring program was designed and implemented. There are several computer analysis packages that help design open population monitoring studies (see Table 2 for examples). Many of these programs are reviewed in Boulanger and Krebs (1997).
- Contact a laboratory specializing in DNA fingerprinting before collecting samples to confirm their availability, recommended storage procedures, and other specific questions.

Sampling Design

- The primary goal of hair capture and DNA analysis to estimate relative abundance is to maximize the collection of Badger DNA in the study area and ensure precision of the estimates among areas or over time. The precision of population estimates will be a function of the number of Badgers in the sample and the mean capture probability of the population. It is also essential to maintain consistency in the sample design among study areas or over time to ensure precision of the estimates.
- A large grid setup is not required when relative abundance and survival estimates are the primary objective of inventory efforts. However a consistent, systematic survey effort is still required. This may include overlaying Grid Cells over the Study Area, and randomly selecting Grid Cells to sample. The size of Grid Cells, or sample units, will be a function of a Badger's home range, and the terrain of the Study Area. Ideally, sample stations would be set in randomly selected Grid Cells.
- Sampling of Grid Cells should target areas to maximize encounter rates during the entire capture session. Unlike mark-recapture design to estimate absolute abundance (Section 3.6.1), the principal objective of relative abundance estimates is to ensure that a Badger encounters a sample station (e.g., hair snag set at burrow) once during the entire sampling effort in a year as opposed to each individual session. As a result, sample stations can be checked fewer times but capture sessions should be lengthened.
- Hair capture stations should be set up in areas where Badgers will return on a yearly or seasonal basis to maximize yearly recapture rates, such as frequently used burrows.
- Covariates that might influence survey effectiveness and Badger survival should be recorded during each survey period. These covariates might be weather effects (e.g., severe weather), loss of any occupied habitats (e.g., to development), or any other factors that might influence Badger survival. The influence of these factors can be tested in some of the analysis programs such as POPAN, SURGE, and MARK (Table 2).

Sampling Effort

- The number of Grid Cells sampled will depend on access and resources available for the survey. In areas with low burrow density, all identified burrows within a Study Area should be surveyed. It is recommended that a trial survey be conducted, and that a power

analysis be completed to determine the appropriate sampling effort for the comprehensive assessment.

- Maintain consistency between years by sampling over the same time period, maintaining the same hair capture session length, the same number of hair capture stations, the same hair capture station placement, and the same hair capture station setup and baits.
- The length of capture sessions can be extended when survival rate is an objective because demographic closure is not assumed when open population models are used in the analysis. The capture session length can be determined by how long a burrow appears active and how long the snagged hairs remain viable. In general, fewer capture sessions will be required than with absolute abundance estimates; therefore, single session length should be maximized.
- Monitoring efforts should be planned to last at least three years and preferably longer. In particular, the Jolly-Seber model requires at least three capture sessions for survival rate estimates. If it is not possible to survey for three years, more sampling sessions may be conducted within a year so that Lincoln-Peterson estimates can be used.
- DNA-based relative abundance estimates are recommended for the spring or early summer when Badgers are making long-distance movements searching for mates, and are readily losing hair.

Personnel

- One or two biologists who are familiar with Badger biology and data collection and analysis.
- One or more assistant biologists or technicians who are able to recognize Badger burrows and activity. The number of assistants required will depend on the size of the Study Area, sampling strategy, and access.
- A statistician or quantitative ecologist who is familiar with the design of population monitoring and computer software used to complete mark-recapture analysis is beneficial.

Equipment

- Maps and air photos.
- Field notebooks, data forms.
- Hair capture station equipment, including:
 - 2-cm wide metal strapping (the type used to wrap lumber); ~30 cm for each snag
 - 3-inch nails; 2 per snag
 - Rivets
 - Pinned-knaplock (used to anchor carpet in doorways)
 - Rubber mallet
 - Leather gloves
- GPS, flagging tape and/or wooden stakes to mark burrow #
- Paper envelopes and labeling marker.
- Computer.

Field Procedures

- Before the survey session, manufacture enough hair-snagging devices to complete the survey, following the construction directions provided in Appendix C.

- Follow Field Procedures for hair snags provided in Section 3.4.2 “Sample Stations.”
- Set hair snags at one (or several) burrow(s) within each Grid Cell that was identified for sampling. It is important to ensure that there is adequate distribution of hair capture stations throughout the Study Area to obtain equal catchability among Badgers. Record the location, UTM coordinate and burrow ID number for each burrow sampled. Also, record the time, date, and number of snags set at each site.

Data Analysis

- DNA fingerprinting of hair samples should be completed by a laboratory experienced in such analyses. Section 3.1.4 provides some relevant considerations for DNA-based techniques.
- Once samples have been analyzed, a permanent identification number should be assigned to each Badger identified.
- One or more of the population estimation models should be used to analyze the field data to determine population size (and density if appropriate). Boulanger and Krebs (1997) provide a review of statistical methods for the analysis of open population model data. The minimum number alive (MNA) should be calculated.
- Other analyses to conduct include an estimate of the statistical power of the analysis, tests of covariates that may have influenced survey effectiveness and survival, and tests of equal catchability to determine whether every individual has the same probability of being detected.

3.6 Absolute Abundance

Recommended method(s)

DNA fingerprinting of genetic material collected from hair, scat, or tissue can be used to conduct a mark-recapture survey and is the recommended method to estimate the absolute abundance of Badgers. Live-trapping and radio-telemetry can also be used for estimates of absolute abundance.

Absolute abundance surveys provide an estimate of the total number or density of species in an area with accompanying estimates of uncertainty. DNA mark-recapture may be the most efficient means to inventory Badgers because it is cost-effective, can be conducted remotely over large areas, and does not require handling animals. Measuring the absolute abundance of Badgers can be accomplished by initiating a burrow survey and setting sample stations using a systematic survey design that ensures capture of a large portion of the population. Although untested for Badgers, methods to address these issues have been developed during various bear inventory programs conducted in the province, and are briefly discussed below.

An alternative approach includes an actual count of animals within the Study Area using live-trapping with radio-telemetry. This approach requires a less rigid sampling protocol than mark-recapture efforts, but can be resource-intensive and expensive; however, it can ultimately provide more ecological information for the species.

3.6.1 DNA Mark–Recapture

A similar application of the DNA mark-recapture procedures to estimate relative abundance of Badgers, described in Section 3.5.1, can be applied to estimate absolute abundance. Estimates of absolute abundance require a more rigid protocol that achieves a high detection rate and meets the assumptions of the mark-recapture estimator. These include minimizing the heterogeneity of capture probabilities, and sampling from a closed population if using this type of estimator (Boulanger et al. 2004).

Heterogeneity Bias

Biological differences can contribute to unequal catchability between individuals within the population (e.g., home range size, site fidelity, concentrations of resources). Although some estimators are robust to unequal catchability probabilities (Otis et al. 1978), simpler estimators (i.e., closed population models) provide more precise estimations of population size, but do not provide a mechanism to explore biological bias of capture probabilities. To address this, Boulanger et al. (2004) describe their use of the program MARK to analyze the biological causes of capture probability variation. They suggest that heterogeneity bias can be modeled using covariates with the Huggins model assuming that all main forms of heterogeneity are identifiable. Other models, such as the Chao heterogeneity estimator (Chao 1989), jackknife estimator (Burnham and Overton 1979), or mixture models of Pledger (2000), can be used. Finally, Boulanger et al. (2004) suggest that heterogeneity models require large sample sizes (marked and detected animals), where at least four sessions and grid cell sizes approximating the home range size of adult females (which, for bears, are the smallest home ranges maintained by adult residents) are recommended.

Closure Violation

Violation of population closure assumptions can result in an overestimate of population size because, as animals move in and out of the mark-recapture grid, the number of marked animals is inflated and negatively biases the capture-probability estimates (White et al. 1982). Tests for closure violation are influenced by heterogeneity bias (discussed above) and do not provide explanations for biological causes of closure violation (Otis et al. 1978; Stanley and Burnham 1998). Boulanger and McLellan (2001) use the program MARK to explore the effects of closure violation for DNA mark-recapture methods using Pradel models to explore closure violation based on survival, recruitment, and recapture rates as a function of the location of sample stations relative to the sampling grid edge. Once an appropriate distance was established to reduce bias from sampling grid edge-effect and closure violation, then they used the Huggins closed model estimator to estimate the bear population within their study area. The authors stress that radio-telemetry of animals should be used to explicitly estimate average populations and their movements across sampling grid boundaries.

The following is a suggested protocol for absolute abundance estimates using DNA analysis and mark-recapture modeling that is largely taken from the *Inventory Methods for Bears*. DNA sampling for Badgers has been tested in the field (e.g., hair capture, Packham and Hoodicoff 2006), but the sampling design outlined here has not been implemented in the field and should be refined as more research is completed.

Office Procedures

- Review the introductory manual, *Species Inventory Fundamentals (No. 1)*.

- Read Section 3.1.4 “Considerations for DNA-Based Techniques,” Section 3.4.2 “Sample Stations,” and the sections reviewing collection methods for hair capture and scat in particular, and other relevant literature to understand the process for DNA studies.
- Obtain maps for project and study area(s) (e.g., 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- Identify objectives, delineate the Project Area, and select appropriately sized Study Area(s) within the Project Area to sample. An overlay of biogeoclimatic zones may help to identify a Study Area within suitable habitat. The Study Area may be situated in areas of suitable habitat where there is a high probability of geographic closure. Use natural barriers to define the boundaries of the Study Area to minimize movement in or out of the area during the survey.
- Conduct a preliminary survey (Section 3.2) that includes soliciting reports of Badgers and their burrows, conducting interviews and consulting with local experts to determine current Badger locations and other historical occurrence records. This should also include setting up a reporting hotline for the public to call and report sightings. Consult with researchers on the behaviour of the target species within the Study Area and on methods of detection.
- It is strongly recommended that a burrow search (Section 3.4.1) be conducted before initiating a survey for absolute abundance.
- Consult with a statistician or quantitative ecologist who is familiar with the design of population monitoring surveys using closed population models. The results of any analysis will depend on how well the monitoring program was designed and implemented. Several computer analysis packages are available to help design closed population monitoring studies (see Table 2 for examples). Many of these programs are reviewed in Boulanger and Krebs (1997).
- When using closed population models, geographic closure will be a challenging assumption to meet for Badgers, especially for those animals living on the edge of the study area, and wide-ranging males who may leave or enter the study area during the capture session. If geographic closure and high rate of capture are achieved, then the simplest estimation model should yield the most precise population estimates.
- Contact a laboratory specializing in DNA fingerprinting before collecting samples to confirm their availability, recommended storage procedures, and other specific questions.

Sampling Design

- High mean capture probabilities are required to provide adequate population estimates for small populations, in particular. Therefore, the sampling protocol should be structured so that capture probabilities are maximized.
- Determine an appropriate sampling strategy, including Grid Cell size. For bears, a grid size that would sample at least 50 animals over the sampling period is recommended (RIC 1998); however, because Badgers occur at low densities, this may be impossible to complete with available resources. Higher capture probabilities may be ensured by decreasing the grid size and increasing the number of sample stations (i.e., burrows) sampled.
- Sample grids should be designed to accommodate the likely sampling bias prominent in each geographic area. For example, a larger grid and larger Grid Cells may be appropriate to reduce edge effects where populations are less geographically closed (RIC 1998). Also, moving traps between sessions is expected to partially mitigate heterogeneity due to variation in trap encounter rates between sex classes (Boulanger et al. 2004). Several

models could be used to determine the optimal grid design and spacing of sample stations, such as those discussed in the introduction of this section.

- The size of Grid Cells, or sample units, also may be a function of the terrain and should be determined based on characteristics of the Study Area.
- Overlay the sampling grid onto the Study Area using Geographic Information Systems (GIS) or printed maps.
- Select the Grid Cells to be sampled. Ideally, sample stations would be set at burrows in randomly selected Grid Cells.
- Covariates that might influence survey effectiveness and Badger survival should be recorded during each survey period. These covariates might be weather effects (e.g., severe weather), loss of any occupied habitats (e.g., to development), or any other factors that might influence Badger survival. The influence of these factors can be tested in some of the analysis programs such as POPAN, SURGE, and MARK (Table 2).
- Ideally, sampling for three years is a minimum to determine any biologically meaningful trend information regardless of the analysis method used.
- It is strongly recommended that a burrow search (Section 3.4.1) be conducted before setting up the sample stations.

Sampling Effort

- In areas with low burrow density, all identified burrows within a Study Area may be surveyed. The number of Grid Cells sampled will depend on access and resources available for the survey. In areas with low burrow density, all identified burrows within a Study Area should be surveyed. It is recommended that a trial survey be conducted, and that a power analysis be completed to determine the appropriate sampling effort for the comprehensive assessment.
- Choosing an appropriate length of capture session (may also be known as sample session) requires a trade-off between meeting the assumption of geographic closure and maximizing capture probabilities. Reducing capture session length is one strategy for mitigating the overestimation of density due to lack of grid closure. The amount that capture session length could be reduced is determined by the sampling rate of hair capture stations. Estimation of this requires a detailed analysis of mark–recapture data and experiments specific to different sampling. For example, capture session lengths of 8 to 15 days have been chosen for most DNA mark–recapture studies of bears (RIC 1998). The effectiveness of these sampling intervals needs to be empirically tested as well as theoretically explored.
- Sample stations should be set for 4 to 10 nights, and checked every other day to ensure that the sample stations are operating. In remote areas, stations may be set for longer periods of time and checked infrequently. Statistical estimates will have to take this into account.
- To maximize detection, DNA-based relative abundance estimates are recommended for the spring or early summer when Badgers are making long-distance movements searching for mates, and are readily losing hair.
- Maintain consistency between years by sampling over the same time period, maintaining the same hair capture session length, the same number of hair capture stations, the same hair capture station placement, and the same hair capture station setup and baits.

Personnel

- One or two biologists who are familiar with Badger biology and data collection and analysis.
- One or more assistant biologists or technicians who are able to recognize Badger burrows and activity. The number of assistants required will depend on the size of the Study Area, sampling strategy, and access.
- A statistician or quantitative ecologist who is familiar with the design of population monitoring and computer software used to complete mark-recapture analysis is beneficial.

Equipment

- Maps and air photos.
- Field notebooks, data forms.
- Hair capture station equipment, including:
 - 2-cm wide metal strapping (the type used to wrap lumber); ~30 cm for each snag
 - 3-inch nails; 2 per snag
 - Rivets
 - Pinned-knaplock (used to anchor carpet in doorways)
 - Rubber mallet
 - Leather gloves
- GPS, flagging tape and/or wooden stakes to mark burrow #
- Paper envelopes and labeling marker
- Computer.

Field Procedures

- Before the survey session, manufacture enough hair snags to complete the survey following the procedure provided in Appendix C.
- Set hair snags at one (or several) burrow(s) within each Grid Cell that was identified for sampling. It is important to ensure that there is adequate distribution of hair capture stations throughout the Study Area to obtain equal catchability among Badgers. Record the location, UTM coordinate and burrow ID number for each burrow sampled. Also, record the time, date and number of snags set at each site.
- Follow Field Procedures for hair snags provided in Section 3.4.2 “Sample Stations.”

Data Analysis

- DNA fingerprinting of hair samples and sex analysis should be completed by a laboratory experienced in such analyses. Section 3.1.4 provides some relevant considerations for DNA-based techniques.
- Once samples have been analyzed, a permanent identification number should be assigned to each Badger identified.
- One or more of the population estimation models should be used to analyze the field data to determine population size (and density if appropriate). Boulanger and Krebs (1997) provide a review of statistical methods for the analysis of open population model data.

- Other analyses to conduct include an estimate of the statistical power of the analysis, tests of covariates that may have influenced survey effectiveness and survival, and tests of equal catchability to determine whether every individual has the same probability of being detected.

3.6.2 Live Capture / Telemetry

Estimates of absolute abundance for species in this inventory group have been determined from studies that attempt to capture all the animals within a given area, follow them intensively using radio-telemetry, and determine home range size. Often the overall objective is to know how many animals are present in a much larger area, such as a region or province. However, studies on low-density species must be interpreted cautiously because low sample sizes are common, despite the expense and effort invested to study terrestrial carnivores. As a result, such intensive studies are few.

Limits to time and money are major constraints in applying capture / telemetry of medium carnivores in British Columbia. Due to the difficulty in studying these species, the lack of information on habitat relationships and life-history, and the effort involved in trapping and collaring animals, both population and habitat questions should be addressed in studies that use capture–telemetry methods. Determining absolute abundance will rarely be the primary justification for conducting such studies.

Ethical methods and proper animal care are major considerations in a live-capture study (consult the manuals listed in the Preface of this document).

Instead of the more conventional radio collars, Badgers are typically equipped with an intraperitoneal transmitter that can be inserted only by a qualified veterinarian. These implants do not hinder Badger movements inside of burrows and cannot be removed by the animal. Other technologies, such as satellite and GPS, may replace the use of VHF signals as battery sizes decrease and signal strength improves. For both technologies, locations are automatically recorded when the animal is in the open and a tracking satellite passes overhead.

Office Procedures

- Review the introductory manual, *Species Inventory Fundamentals (No. 1)*.
- Obtain maps for project and study area(s) (e.g., 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- Identify objectives, delineate the Project Area, and select appropriately sized Study Area(s) within the Project Area in which you will actually sample. An overlay of known burrows and biogeoclimatic zones may help to identify a Study Area within suitable habitat. Use natural barriers to define the boundaries of the Study Area to minimize movement in or out of the area during the survey.
- Conduct a preliminary survey (Section 3.2) that includes soliciting reports of Badgers and their burrows, conducting interviews and consulting with local experts to determine current Badger locations and other historical occurrence records. This should also include setting up a reporting hotline for the public to call and report sightings. Consult with researchers on the behaviour of the target species within the Study Area and on methods of detection.
- It is strongly recommended that a burrow search (Section 3.4.1) be conducted before initiating a live-capture program.

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- If using DNA fingerprinting in co-ordination with live-trapping, contact a laboratory specializing in genetic analysis before collecting samples to confirm their availability, recommended storage procedures, and other specific questions.

Sampling Design

- Because Badgers are relatively rare, the objective should be to capture all residents present in the Study Area to reach a sufficient sample size. Although this is possible, it is unlikely. Extremely trap-shy animals are very difficult to trap and the study population may be underestimated. This effect may be minimized by conducting a hair snagging survey with DNA analysis to further identify untrapped animals. Remote cameras may also be set at burrows to help determine trap effectiveness.
- Although attempts should be made to cover the Study Area during trapping without any large gaps, traps should be biased to the most suitable habitats and at burrows where there is recent activity. Scent and bait may be used, although there is no real evidence that this attracts Badgers and may just lead to non-target animals, such as Foxes and Skunks, being trapped. The presence of human activity does not appear to be a significant factor.
- Consult the Ministry of Environment and other appropriate agencies to obtain trapping and animal care permits.

Sampling Effort

- Expect low trapping success for low-density populations. Maximize the number of traps and their distribution in the landscape, and expect to trap for a minimum of three years (generally spring-fall) to accumulate a reasonable sample size.
- Plan to track animals for several years, or as long as transmitters are functioning. At least two years of complete data (minimum of 30 independent locations are recommended per individual) are needed to determine home range size, to account for seasonal and annual differences. Animals should be re-located as often as possible, but at least once a week, if possible.

Personnel

- Personnel should be trained in the trapping and care of immobilized animals, and in radio-telemetry procedures. The provincial immobilization course is obligatory.
- A veterinarian is required if implants are being used. Not all veterinarians are qualified to work with wildlife species.

Equipment

- Off-set, padded “soft-catch” foot-hold traps (Victor 1½ coil spring) anchored with a 3 mm diameter cable (45 cm long) attached to a flared anchor that is driven into the ground. Other trap types (e.g., box traps) may be used in areas where it is unsafe or inappropriate to use modified foot-hold traps.
- Leather gloves, pliers, trowel, soil sieve, wax paper (to cover foot plate)
- Commercial lure and/or bait is optional
- Badger transportation container (modified plastic 200-litre barrel)
- Appropriate drugs and immobilizing equipment, including jab stick and rabies pole

- Radio-telemetry equipment and implants
- Ear-tags.
- Cameras and hair snags, if these are to be deployed at trap sites (Section 3.4.2)
- Truck or aircraft charter for relocations
- GPS receiver, for recording locations
- Computer and statistical analysis software.

Field Procedures

- Survey access within the study area and determine sites to trap based on recent activity and proximity to other traps (important to minimize process and transportation time if more than one animal is trapped overnight).
- Set each trap at the burrow entrance. Pound the anchor into the soil so that no more than 15 cm of cable is exposed above the soil surface. Scent nearby vegetation with commercial lure and/or bait burrow entrances with approximately 500 g of carrion (optional).
- Set each trap between 1800 and 2100 h, and close between 0600 and 0900 h the following day. In the Thompson region (Weir et al. 2003), traps were set and monitored for a maximum of 14 hours each night. It is generally a good idea not to trap if temperatures are extreme (hot or cold) for animal safety and comfort.
- Consult researchers who have live-trapped the target species and with local trappers in your area. Be prepared to change trapping methods and sampling design if these are not successful.
- Cameras and hair snags can be useful because they may indicate if an animal is in the area but too wary to enter the trap.
- Handle live-trapped animals quickly and quietly to minimize stress, as indicated in the standards about live animal and capture listed in the Preface of this manual. Release non-target species immediately.
- Locate the animal for the next two successive days to ensure it has recovered from the tagging process and that the transmitter is functional. Subsequently, locate animals preferably once a week (as resources allow), and at least biweekly.
- Animals may be re-located by vehicle, on foot or horseback. For most of these species, especially where access is difficult, aircraft may be the most efficient means of obtaining locations.

Data Analysis

- The boundaries of the Study Area are usually larger than the area trapped; the Study Area boundary encompasses the area used by resident Badgers, and may be larger than the area trapped. Territorial carnivores occasionally leave their home ranges on excursions that are temporary and outside of their usual range. These are excluded in calculations of density. For species with stable home ranges, the density estimate is an absolute reflection of the number of animals the area can support.
- Calculate the absolute density of the Study Area as number of square kilometres per resident adult (include both males and females). Densities should be calculated for the

fall period, after juvenile dispersal but before winter mortality. If information on juvenile and transient animals are available, a density estimate including these segments of the population should also be calculated. How these estimates were derived should be explicitly stated.

- Report the average home range size (\pm 95% confidence level) for adult males and adult females. If sufficient information on juveniles and transients is available to calculate home ranges, these should also be reported. However, the density estimate is based on those resident adults that maintain stable territories.
- A variety of techniques and software are available to evaluate home range sizes. Minimum convex polygon (MCP) home ranges are a standard statistic computed by most researchers and allow comparison between areas. However, when all points are included, the MCP does not indicate how intensively different parts of the home range are used, although smaller polygons (i.e., 90%, 75%, 50% MCPs) can be calculated.
- Two other common methods of calculating home ranges, adaptive and fixed kernel (ADK, FK) and harmonic mean (HM) estimators (Boulanger and White 1990), allow determination of more than one centre of activity or core-activity area (Dixon and Chapman 1980; Harris et al. 1990; Worton 1995). These are generally superior to MCP as long as there are criteria established for the selection of level of home range to be used. The harmonic mean estimator has often been criticized as being too strongly dependent on grid spacing and scale (Worton 1995, and others). Lawson and Rodgers (1997) reviewed home range programs and reported that widely varying results could be produced, largely dependent on the results of user decisions with respect to calculations of estimators and various parameters. It is recommended that project biologists calculate both MCP and ADK home ranges, reporting not only the estimator and home-range program used, but also the values of input parameters and user-selected options (Lawson and Rodgers 1997).

Glossary

ABSOLUTE ABUNDANCE: The total number of organisms in an area. Usually reported as absolute density – the number of organisms per unit area or volume.

ACCURACY: A measure of how close a measurement is to the true value.

BIOGEOCLIMATIC ZONE: A large geographic area with a broadly homogeneous macroclimate, having a characteristic web of energy flow, nutrient cycling, and typical, major species of trees, shrubs, herbs, and/or mosses, as well as characteristic soil-forming processes (e.g., Coastal Western Hemlock).

BIODIVERSITY: Jargon for biological diversity: the variety of life forms, the ecological roles they perform, and the genetic diversity they contain (Wilcox 1984 cited in Murphy 1988).

CHROMOSOME: A threadlike structure, several to many of which are found in the nucleus of plant and animal cells. They carry genes in a linear sequence.

CUTICULAR PATTERN: The pattern that the overlapping scales or cuticles made by the external surface of a guard hair. This pattern is species-specific.

DNA: Deoxyribonucleic acid. The genetic material of most living organisms that is a major constituent of the chromosomes within the cell nucleus (nuclear DNA) and plays a central role in determining hereditary characteristics by controlling protein synthesis in cells. It is also found in organelles other than the nucleus, such as the mitochondria (mitochondrial DNA).

GENE: A unit of heredity composed of DNA.

GENETIC VARIATION: Differences between individuals due to differences in genetic constitution. The most important sources of genetic variation are mutation, recombination, and outbreeding. Wide genetic variation improves the ability of a species to survive in a changing environment, since the chances that some individuals will tolerate a particular change are increased.

GENOTYPE: The genetic composition of an organism, i.e., the combination of alleles it possesses.

GPS: Global Positioning System.

GRID CELL: A rectangular cell, generally occurring within a larger, rectangular, multi-celled grid. Grid Cells provide a basis for distributing sampling devices, such as scent/bait stations, cameras, and/or transects, across the landscape. They are also the primary sample unit for many surveys.

HETEROZYGOUS: (heterozygosity) Describes an organism in which the alleles at a given locus on chromosomes with the same structural features are different.

LOCUS: The position of a gene on a chromosome or within a DNA molecule.

LATENCY TO DETECTION (LTD): The time required to achieve detection in a surveyed area.

MICROSATELLITE: A gene marker used in genetic (DNA) analyses.

MINIMUM CONVEX POLYGON (MCP): Approximates the home range of an animal by depicting the smallest area around that encompasses all known or estimated locations for an animal (Hayne 1949).

PRESENCE/NOT DETECTED (POSSIBLE): A survey intensity that verifies that a species is present in an area or states that it was not detected (thus not likely to be in the area, but still a possibility).

PROJECT AREA: An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventory. Sampling generally takes place within smaller Study Areas within this Project Area.

RADIO-TELEMETRY: A monitoring technique for tracking free-ranging animals using radio-collars and radio-receivers.

RANDOM SAMPLE: A sample that has been selected by a random process, generally by reference to a table of random numbers.

RESIDENT: Among territorial carnivores, an individual animal that occupies and remains on a more or less exclusive home range (territory) for more than one season.

RELATIVE ABUNDANCE: The number of organisms at one location or time relative to the number of organisms at another location or time. Generally reported as an index of abundance.

SCAT: A single deposit of feces.

STRATIFICATION: The separation of a sample population into non-overlapping groups based on a habitat or population characteristic that can be divided into multiple levels. Groups are homogeneous within, but distinct from, other strata.

STUDY AREA: A discrete area within a project boundary in which sampling actually takes place. Study Areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

SURVEY: The application of one inventory method to one taxonomic group, usually for one season.

SYSTEMATIC SAMPLE: A sample obtained by randomly selecting a point to start, and then repeating sampling at a set distance or time thereafter.

TRANSIENT: Among territorial carnivores, an individual that does not occupy or reside on an exclusive home range or territory (“of no fixed address”).

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Personal Communications

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Appendix A. Badger Sign Identification

An example of a Badger burrow ID card that was developed by Sylvan Consulting Ltd. (Newhouse and Kinley 2006) is available at www.badgers.bc.ca/pubs/Badger_burrow_ID.pdf. A copy of this ID card and other information to help identify Badger sign can also be accessed at www.badgers.bc.ca/publications.htm%20w.

Appendix B. WSI Data Collection and Reporting

You must use the Wildlife Species Inventory (WSI) data capture template to record and capture data from Badger inventories. The template, with the associated predefined data fields and codes, and groupings of data fields, facilitates loading the data into the WSI database. Both the template and data submission information are available from the WSI home page (www.env.gov.bc.ca/wildlife/wsi/index.htm) by following the “Data Contributions” link.

Table B1. Organization And Description Of WSI Data Capture Template Worksheets And Data Fields.

Worksheet Name	Description
Project Data	Consists of a group of data fields for capturing project-level data such as Project Name, Project Agency, Project Start Date, Study Area Name(s), Surveys, etc.
Design Component Information	Used to capture data relevant to a Sample Station (e.g., burrows used for detection) Design Component. A list of all data fields relevant to a sample station is available in the group of data fields named ‘Design Component - Sample Station’.
Survey Observations (Four groupings of data fields – See below)	You must create one worksheet for each grouping of Survey Observation data fields. Each grouping of survey observation fields must include one or more data fields (e.g. ‘DC Visit Date’ must be included) from the ‘Design Component Visit’ data-field grouping. A list of all data fields relevant to a Design Component Visit is available in the group of data fields named ‘Design Component Visit’.
1. Animal Observations and Sign 2. Animal Hair Collection 3. Animal DNA Analysis 4. Animal Capture and Handling: Medium to Large Mammals	For compilation and capture of data from the Preliminary and Burrow Search surveys. For recording information regarding collection of animal hair by using hair snares or other methods. For recording information regarding DNA samples taken from animals and sent to a lab to determine species, individuals, and or gender. For recording morphometric measurements of captured badgers. Often used to record the initial capture information for telemetry and GPS tracking.

Appendix C. Badger Hair Snags and Construction

Pinned-knaplock snags were made from 30 cm of 2-cm wide metal strapping, the type used to wrap lumber, formed into a 'D' (Photo 1). 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. Two squares (approximately 2 cm by 2 cm) of pinned-knaplock (used to anchor carpet in doorways) were riveted to the curved edge of the metal strapping. Finally, a rubber mallet was used to bend the teeth of the knaplock down to prevent injury to any animal. Lengths of wire attached to the snags were forced through the soil to the surface and fastened to further anchor the snags at the burrow.

A similar snag device can be set around the perimeter of a number of burrows where multiple Badgers may have been observed (e.g., a family group). Lengths of 1" × 2" lumber with pinned-knaplock secured to the undersides were erected approximately 30 cm off the ground surface around every burrow opening (Photos 2 and 3). Again, the teeth of the knaplock were bent down to prevent injury to any animal.



Photo: Philippe Verkerk

Photo 1. Pinned-knaplock hair snag set in Badger burrow with hair sample.



Photo 2. Perimeter snag set at a maternal burrow with Badger moving under the pinned-knaplock.



Photo 3. Pinned-knaplock lining underside of perimeter snag with hair sample.