Inventory Methods for Wolf and Cougar

Standards for Components of British Columbia's Biodiversity No. 34

Prepared by
Ministry of Environment, Lands and Parks
Resources Inventory Branch
for the Terrestrial Ecosystems Task Force
Resources Inventory Committee

June 15, 1998

Version 2.0

Published by the
Resources Inventory Committee

Canadian Cataloguing in Publication Data

Main entry under title:

Inventory methods for wolf and cougar [computer file]

(Standards for components of British Columbia's biodiversity ; no. 34)

Available through the Internet.
Issued also in printed format on demand.
Includes bibliographical references: p.
ISBN 0-7726-3564-1

1. Wolves - British Columbia - Inventories - Handbooks, manuals, etc. 2. Pumas - British Columbia - Inventories - Handbooks, manuals, etc. 3. Ecological surveys - British Columbia - Handbooks, manuals, etc. I. BC Environment. Resources Inventory Branch. II. Resources Inventory Committee (Canada). Terrestrial Ecosystems Task Force. III. Series.

QL737.C2I58 1998 599.709711 C98-960138-2

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Preface

This manual presents standard methods for inventory of wolves and cougars in British Columbia at three levels of inventory intensity: presence/not detected (possible), relative abundance, and absolute abundance. The manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group 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 which present standard protocols designed specifically for group of species with similar inventory requirements. The series includes an introductory manual (Species Inventory Fundamentals No. 1) which describes the history and objectives of RIC, and outlines the general process of conducting a wildlife inventory according to RIC 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 commencing with a RIC wildlife inventory. RIC standards are also available for vertebrate taxonomy (No. 2), animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in inventories which involve either of these activities.

Standard data forms are required for all RIC wildlife inventory. Survey-specific data forms accompany most manuals while general wildlife inventory forms are available in the Species Inventory Fundamentals No. 1 [Forms] (previously referred to as the Dataform Appendix). This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory Datasystem (SPI). For more information about SPI and data forms, visit the Species Inventory Homepage at: http://www.env.gov.bc.ca/wld/spi/ric_manuals/

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve very quickly over their initial years of use. Field testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded to the Elements Working Group by contacting:

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Acknowledgements

Funding of the Resources Inventory Committee work, including the preparation of this document, is provided by the Corporate Resource Inventory Initiative (CRII) and by Forest Renewal BC (FRBC). Preliminary work of the Resources Inventory Committee was funded by the Canada-British Columbia Partnership Agreement of Forest Resource Development FRDA II.

The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report "The Future of our Forests".

For further information about the Resources Inventory Committee and its various Task Forces, please contact:

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Terrestrial Ecosystems Task Force

All decisions regarding protocols and standards are the responsibility of the Resources Inventory Committee. Background information and protocols presented are based on the unpublished draft manual, *A Methodology for Surveying Bears, Wolves and Cougars in British Columbia*, prepared by E. Todd Manning, A. Grant MacHutchon and John M. Cooper of Branta Educational Consultants, with assistance from A. Hamilton, A. Derocher, D. Janz, L. Carbyn, K. Atkinson, R. Hayes, R. Stephenson, P. Clarkson, M. Jalkotzy, J. Gunson, F. Hovey, K. Goh, B. Webster and B. Spreadbury.

The Components of British Columbia's Biodiversity series is currently edited by James Quayle with data form development by Leah Westereng.

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1. INTRODUCTION

Large carnivores, including wolves (*Canis lupus*), and cougars (*Puma concolor*), have traditionally been given a "high profile" by both wildlife managers and the public because of their intimidating size and predatory behaviour. Cougars are a valued big game species for many hunters, but also possess a charisma for many British Columbians not involved in sport hunting. Similarly, wolves have become very popular in the global media, taking on a symbolic value as a survivor from a history of global persecution. In British Columbia, wolves have traditionally been trapped as furbearers and, in past, their numbers have been periodically controlled in an effort to reduce predation on ungulate populations. Public controversy over past wolf control programs has served to heighten public interest in the management of large carnivores in general. This has added emphasis to the need to collect inventory data about these creatures.

Numerous studies have been conducted on the ecology and population dynamics of both cougars and wolves in North America (e.g. Fritts and Mech 1981; Peterson *et al.* 1984; Lindzey *et al.* 1988; Ross and Jalkotzy 1992). However, because of their highly mobile nature and generally large home range sizes, obtaining accurate and precise population estimates for any large carnivore can be difficult. This is influenced by the level of inventory intensity desired by the researcher. At normal population densities, presence is relatively easy to determine, however, as population densities decrease the effort required to document presence increases. Relative and absolute abundance estimates usually require more labour intensive field procedures, such as aerial and/or ground surveys as well as capture and radio-telemetry. Indices such as the Jolly-Seber Method and modified Lincoln Index (Caughley 1977) are regularly used to estimate populations from capture-recapture data. However, these indices have basic assumptions which must be met and consequently there are limitations to their use. Other researchers have described additional field techniques for inventorying large carnivore populations (e.g. Van Dyke *et al.* 1986a and 1986b; Hayes *et al.* 1991). These include methods for quantifying animal presence and relative abundance such as direct visual sightings, use of remote cameras, track counts, presence of scats or other animal sign such as scent marks and habitat assessment techniques (carrying capacity estimates).

The objectives of this manual are to:

1. Recommend established methods for censusing populations of wolves and cougars at sites throughout British Columbia; and

2. Provide protocols for these census methods at different levels of intensity (presence/not detected, relative abundance, absolute abundance).

2. INVENTORY GROUP

2.1 Gray Wolf (*Canis lupus*) M-CALU

2.1.1 Distribution

The wolf has one of the broadest distributions of any mammal. In British Columbia it is a year-round resident occurring in all forested regions of the province (found in all ecoprovinces and biogeoclimatic zones), including Vancouver Island and some adjacent islands. However, it is not found on the Queen Charlotte Islands and is only occasionally present in areas along the Canada/USA boundary. In recent years, wolf sightings have become more common in the east Kootenay region of southeastern B.C., suggesting that wolves may be recolonizing this area from the northern Rocky Mountains.

2.1.2 Status

Population numbers of wolves in B.C. are variable, at an estimated 7500 animals. Wolf numbers fluctuate with prey populations. In areas close to human settlement or agricultural operations, numbers are expected to decline over the long term. Moderate to high wolf populations occur in the north and central interior and in coastal areas, while low populations occur at higher elevations and within the southern parts of its range (Tompa 1983). The wolf is on the provincial Yellow list.

Formerly, Nagorsen (1990) recognized three subspecies of *Canus lupus* in the province. However, following a re-evaluation of wolf taxonomy by Nowak (1995), two subspecies are currently recognized in B.C.: *C. lupus nubilus* and *C. lupus occidentalis* (Nagorsen, 1998). Currently, the distributions of these subspecies can best be described in general terms. *C. lupus nubilus* is found on both Vancouver Island and coastal B.C. while *C. lupus occidentalis* occurs throughout the interior.

2.1.3 Territory Size and Population Densities

Wolves travel extensively in their search for food. Territory size and movement patterns are highly variable depending on pack size, availability of prey species, physiography, and seasonality (Fritts and Mech 1981, Ballard *et al.* 1987). In northwestern Minnesota, Fritts and Mech (1981) found territory sizes ranging from 195 to 555 km^2 (a density of 7 to 30 wolves/1000 km^2); in south to central Alaska, Ballard *et al.* (1987) found territory sizes from 943 to 2541 km^2 (a density of 2.6 to 10.3 wolves/1000 km^2); in the southern Yukon, Hayes (1992) found territory sizes of 583 to 794 km^2 (a density of 10 to 12 wolves/1000 km^2); in the Kenai Peninsula, Alaska, Peterson *et al.* (1984) found average territory sizes of 638 km^2 (with a density of 18 wolves/1000 km^2); in northwestern B.C., Bergerud and Elliot (1986) found wolf densities of 5 to 11 wolves/1000 km^2; and in coastal forests of northern Vancouver Island, Atkinson and Janz (1994) found territory sizes from 100 to 400 km^2 (a density of 4 to 43 wolves/1000 km^2).

Lone wolves and dispersing animals can travel great distances and have accordingly large territory sizes. Peterson *et al.* (1984) found that recolonizing wolf pairs on the Kenai Peninsula, Alaska had 3 to 4 times larger areas per wolf than members of larger packs. Straight-line dispersal distances can be in the hundreds of kilometres. Ballard *et al.* (1987) described a pack of 3 non-denning males which traversed an area of 3077 km^2, and Hayes *et al.* (1991) found the average linear distance that wolves dispersed was 90 km (range 10 to 140 km).

2.1.4 Diet and Habitat Use

Wolves are carnivores, preying mainly on adult ungulates, ungulate calves and fawns, and beaver (Scott and Shackleton 1980, Peterson *et al.* 1984, Hatter 1988, Hayes *et al.* 1991). To a lesser extent, they will also eat hares, small rodents such as mice and voles, and occasionally birds. Habitat utilization is primarily influenced by availability of prey species and physiography (Fritts and Mech 1981, Ballard *et al.* 1987).

In summer a pack's affinity for a particular denning area also influences habitat use. Dens can be excavated in banks or shallow hillsides, or can be among the roots of large trees, in hollow logs, or in rock crevices. Maternity dens are often used by the same pack year after year, and summer homesites where pups are raised are usually within a few kilometres from the den. Thereafter, pup activities center around a succession of homesites, progressively farther from the den as mother and pups eventually rendezvous with the pack (Van Ballenberghe *et al.* 1975, Peterson 1977, Peterson *et al.* 1984, Ballard *et al.* 1987).

In winter, wolves tend to be found in areas associated with ungulate winter ranges (Fritts and Mech 1981), and often use frozen waterways as travel corridors where snow accumulation can be less. Intensity of use patterns within territories is greatly influenced by physiography. Areas such as treeless marshes or homogeneous coniferous cover tend to be used less by wolves (Fritts and Mech 1981). Wolves routinely patrol their territories, scent-marking the peripheries by urinating and defecating (Peters and Mech 1975). Extraterritorial movements and dispersal by pack members can occur throughout the year, but are common in February and early March (coinciding with the breeding season), and during the summer (coinciding with whelping).

2.2 Cougar (*Puma concolor*) M-PUCO

Synonym: Felis concolor

2.2.2 Distribution

The cougar is a year-round resident, found in most forested areas of British Columbia. Documented records from the Northern Boreal Mountains and Taiga Plains ecoprovinces are lacking but it is thought that cougars occur there at very low densities (K. Atkinson pers. comm. 1994). This conclusion is reasonable considering that cougars are resident in the southern Yukon (Anderson 1983).

2.2.3 Status

Populations of cougar in B.C. are generally considered to be stable to increasing, with an estimated population of 3000 animals (B.C. Wildlife Branch 1991). Populations are expected to fluctuate primarily with available deer numbers. The cougar is on the provincial Yellow list, reflecting its stable population and management as a game species.

A global re-evaluation of mammal taxonomy has resulted in the cougar being classified in the genus *Puma* (Wilson and Reeder 1993), and this change is recognized in British Columbia (Nagorsen 1998). Three subspecies of *Puma concolor* are recognized in British Columbia. *P. c. oregonensis* is found in the Cascades and southern Coast Mountains as far north as Jervis Inlet. *P. c. missoulensis* occupies the southern and central interior and the central coast from Jervis Inlet to the Skeena River. *P. c. missoulensis* precise boundaries with *P. c. oregonensis* in B.C. are unknown (Cowan and Giguet 1965). *P. c. vancouverensis* is restricted to Vancouver Island and larger adjacent islands (Nagorsen 1990).

2.2.4 Home Range Size and Population Densities

Home range sizes and population densities are variable, depending on abundance of prey species. In southeastern B.C., mean home ranges were 55 km^2 for females and 151 km^2 for males. Winter population densities were estimated at 3.5 to 3.7 cougars/100 km^2 (Spreadbury 1989). In southwestern Alberta, Ross and Jalkotzy (1992) found mean annual home ranges for female cougars of 140 km^2 (range from 62 to 318 km^2), while males had larger ranges of 334 km^2 (range from 221 to 438 km^2). Population densities from this study varied from 2.7 to 4.7 cougars/100 km^2. Adult females with kittens typically have the smallest home ranges. Juvenile animals disperse from the maternal home range once they reach independence (usually within 21 months of age). Dispersal distances for juveniles ranged from 31 to 163 km in southeastern B.C. (Spreadbury 1989) and from 30 to 155 km in southwestern Alberta (Ross and Jalkotzy 1992), although juvenile females often establish home ranges adjacent to and occasionally overlapping their mothers' home range.

Male cougars are the most territorial. Territories are well scent-marked and are defended against conspecifics, although cougars usually try to avoid each other temporally thereby reducing direct conflicts (Ross and Jalkotzy 1992). In general, cougars are solitary animals, except for mother and kittens and during mating periods.

2.2.5 Diet and Habitat Use

Cougars prey primarily on adult ungulates and ungulate calves and fawns (Spalding and Lesowski 1971, Toweill 1977, Ackerman *et al.* 1984, Spreadbury 1989, Harrison 1990, Alberta Fish and Wildlife Division 1992, Ross and Jalkotzy 1992). Beavers, rabbits and hares, porcupines, domestic stock, and raccoons are also preyed upon.

Cougars can be found in most forested habitats which support ungulate populations. They often prefer areas with rock ledges or outcrops which can be used as vantage points for hunting, for resting, and to escape wolves or dogs. Maternity dens can be located in dense thickets and brush piles, in rock crevices, or under large fallen trees (Anderson 1983).

3. PROTOCOL - General

3.1 Sampling Standards

The following are guidelines for conducting inventory studies on wolves and cougars in the province. Close 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

It is essential that qualified and experienced personnel are present during inventory surveys. This will ensure the correct visual identification of wolves from coyotes (*Canis latrans*) or domestic dogs (*Canis familiaris*). Observer ability should be tested and each person should receive training in animal identification. The correct identification of the animal of interest is critical to the success of counts, particularly during aerial surveys. For example, Stephenson (1978) found that experienced observers counted three times more wolves during aerial surveys than inexperienced observers.

During inventory surveys involving capture and radio-telemetry, biologists must be well trained in: radio-telemetry procedures, handling of firearms, emergency first-aid, handling of potentially dangerous wildlife, care of immobilized animals and must be able to accurately estimate the weight of animals to be drugged. Personnel handling animals are required to have completed a provincially certified course on immobilization techniques and should be familiar with manual No. 5, *Live animal capture and handling guidelines for wild mammals, birds, amphibians, and reptiles*. When capturing cougars, an experienced dog-handler with trained cougar hounds is required to track and tree cougars.

To maintain consistency and accuracy, it is recommended the same surveyors be present throughout the inventory sessions.

3.1.2 Weather

Weather conditions are important when conducting inventory surveys for wolves or cougars that rely upon track detections. Snow-tracking requires a fresh snowfall of at least 5-10 cm, to enable accurate track interpretation. Tracking should begin within 2 to 3 days after snowfall. For aerial surveys, good light conditions (preferably bright sunshine) are necessary to enhance track definition and detection. When conducting track surveys on roads, the surface should be soft enough to retain clearly defined track imprints.

3.1.3 Time of Year

To assess annual population trends, inventory surveys must be conducted under comparable conditions each year, although this is often difficult to achieve.

Most wolf inventory methods (except radio-telemetry and scat transects) are limited to winter months (late October to March) so that tracks and scat can be seen in the snow. However, surveys should be conducted prior to the mating season (which usually begins in late February), because pack cohesiveness starts to break down during this period.

Cougar surveys are not limited to any particular time of year (unless snow-tracking), although it is recommended that the timing of surveys between inventory years be consistent to prevent seasonal factors such as food supply and weather conditions from dominating survey results.

3.1.4 Habitat Data Standards

A minimum amount of habitat data must be collected for each survey type. The type and amount of data collected will depend on the scale of the survey, the nature of the focal species, and the objectives of the inventory. As most, provincially-funded wildlife inventory projects deal with terrestrially-based wildlife, the terrestrial Ecosystem Field Form developed jointly by MOF and MELP (1995) will be used. However, under certain circumstances, this may be inappropriate and other RIC-approved standards for ecosystem description may be used. For a generic but useful description of approaches to habitat data collection in association with wildlife inventory, consult the introductory manual *Species Inventory Fundamentals (No. 1).*

3.1.5 Survey Design Hierarchy

Wolf and cougar surveys follow a sample design hierarchy which is structured similarly to all RIC standards for species inventory. Figure 1 clarifies certain terminology used within this manual (also found in the glossary), and illustrates the appropriate conceptual framework for a snow-tracking survey for wolves. A survey set up following this design will lend itself well to standard methods and RIC data forms.

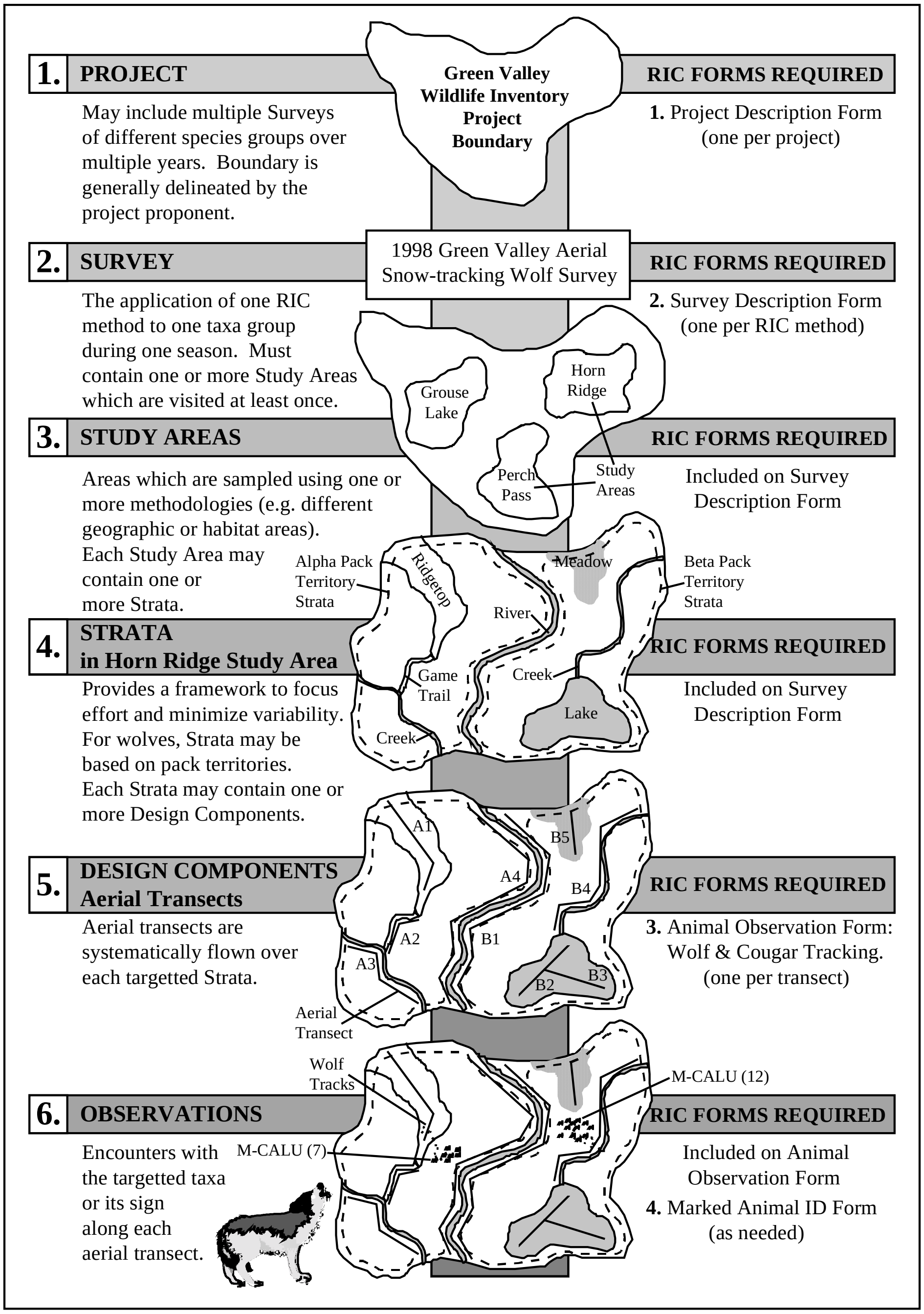

Figure 1. RIC species inventory survey design hierarchy with examples.

3.2 Preliminary Survey

Before conducting inventory studies on wolves and cougars, it is recommended that a preliminary survey be carried out. Questionnaires have been used to obtain data on relative use of different areas by wolves (Jones and Mason 1983). They have also be utilized several times to learn about the distribution of cougars in the United States (Cahalane 1964; Sitton 1973; Berg 1981; Berg *et al.* 1983).

Preliminary surveys may take the form of personal interviews, mail-out questionnaires, or licensed hunting and trapping records, depending on the species of interest. Questionnaires and hunting/trapping records are useful for obtaining cursory information on animal presence/not detected, distribution, as well as relative population trends within or between areas over time (e.g. there seem to be more wolves in Area X now than 20 years ago). Population trend and distribution results gained from preliminary surveys are only applicable on a large geographic scale (i.e. national, regional, or provincial) because of the coarseness of the results and should therefore be treated with caution. For example, results from mail-out questionnaire surveys may not provide an adequate sample of information depending on the survey respondents.

The compulsory inspection program for cougars provides useful preliminary survey data. All cougars taken by hunters must be presented to wildlife officers for compulsory inspection shortly after being killed. Data on sex, age, and location are collected for each cougar in some MELP regions. These data are useful in helping to determine the geographic range of cougars in each region because it provides definitive proof of occurrence. However, they are not necessarily indicative of relative abundance because the frequency of kills in various areas may reflect ease of access for hunters rather than the relative or actual abundance of cougars. Harvest data are considered to be poor indicators of population trends (Lindzey 1987).

In addition to the compulsory inspection program, a sub-set of people who have purchased deer hunting licenses are sampled each year for wolf and cougar sightings (Region 1 - Vancouver Island and adjacent central mainland coast). A Hunter Sighting Index is then calculated and used to track trends on a regional and management unit basis (see Hebert *et al.* 1982).

Preliminary surveys should only be used as a source of supplemental data for determining large scale distribution.

3.2.1 Office procedures

- Review the section, Conducting a Wildlife, in the introductory manual *Species Inventory Fundamentals (No. 1).*
- Select a geographic area to be surveyed.
- Obtain relevant maps for project area (e.g. 1:5,000 air photo maps, 1:20,000 forest cover maps, 1:20,000 TRIM maps, 1:50,000 NTS topographic maps)
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area. These may provide a basis for pre-stratifying the survey.
- Develop a list of people to survey for a preliminary survey. Include biologists, foresters, hunters, guide-outfitters, ranchers, farmers, animal control personnel and trappers: the portion of the population who are most likely to have positive identification and to encounter cougars and wolves.

- Design mail-out or interview questionnaire so that respondents provide data on: (1) location, dates, and numbers of animals involved for individual sightings, and (2) location and details of animal sign observed.
- For hunter/trapper records refer to Harris and Metzgar (1987a and 1987b).
- Consult with a statistician who is familiar with the analysis of harvest, interview, and mail-out questionnaire data.
- Try to define the limitations and potential biases of the data obtained from preliminary surveys.
- Investigate historic harvest patterns if it appears that it will provide some insight into current patterns.

3.2.2 Sampling Design

- It is not necessary to follow a strict sampling design for preliminary surveys as these surveys are used to gather supplementary information.

3.2.3 Sampling Effort

- The amount of effort expended on a preliminary survey depends on the animal of interest, the survey objectives and the level of survey intensity. For example, if the animal is very difficult to detect, preliminary surveys may be extremely useful in identifying where main inventory surveys should be concentrated. For other animals, preliminary surveys may be used just as a coarse overview before delving into more intensive inventory techniques.

3.2.4 Personnel

- One person familiar with the biology of the animal of interest, scientific design, and computer statistical analyses is needed for a preliminary survey. If the person is not familiar with statistics or computer modeling, he/she should work closely with a statistician or computer modeler.

3.2.5 Equipment

- Maps of the project area.
- Computer, data manipulation, and analysis software such as SAS (SAS Institute Inc., Cary, NC).

3.2.6 Procedures

- Map cougar/wolf sightings or sign to determine distribution (Figure 1, Berg *et al.* 1983).
- Compare presence/not detected and relative abundance at a regional or local scale using geographic boundaries or biogeoclimatic zones.

3.2.7 Data Analysis

- The most useful harvest data analyses for assessing population trends are changes in both the sex and age composition of the harvest, however, these data must be used cautiously.
- Control for factors that could confound the existing harvest data, such as differences in sex-specific non-harvest mortality, changes in the relative vulnerability of males and females, differences in the natural age structure of the population, changes in hunter effort and selectivity, changes in regulations, and small sample sizes.

- The Hunter Sighting Index is calculated by:

$$\frac{\text{\# cougar/wolf sighted while hunting deer}}{\text{number of days spent hunting deer}}$$

3.3 Inventory Surveys

The table below outlines the type of surveys that are used for inventorying wolves and cougars for the various survey intensities. These survey methods have been recommended by wildlife biologists and approved by the Resources Inventory Committee.

Table 1. Types of inventory surveys, the data forms needed, and the level of intensity of the survey.

Survey Type	Forms Needed	Intensity
Wolf Scat and Track Surveys	• Wildlife Inventory Project Description Form • Wildlife Survey Description Form - General • Animal Observation Form: Wolf Sign Transect	• PN • RA
Wolf Aerial Snow Tracking	• Wildlife Inventory Project Description Form • Wildlife Survey Survey Description Form - General • Animal Observation Form - Wolf & Cougar Tracking	• RA • AA
Wolf Radio-telemetry	• Wildlife Inventory Project Description Form • Wildlife Survey Description Form - General • Capture Form - Wolf Stations • Animal Handling Form - Wolf & Cougar Capture • Animal Observation Form- Wolf & Cougar Relocation by Radio-telemetry	• AA
Cougar Aerial Snow-tracking and Road Track Counts	• Wildlife Inventory Project Description Form • Wildlife Survey Description Form - General • Animal Observation Form: Wolf & Cougar Tracking	• PN
Cougar Probability Sampling	• Wildlife Inventory Project Description Form • Wildlife Survey Description Form - General • Animal Observation Form: Wolf & Cougar Tracking	• AA
Cougar Radio-telemetry	• Wildlife Inventory Project Description Form • Wildlife Survey Description Form - General • Animal Handling Form - Wolf & Cougar Capture • Animal Observation Form- Wolf & Cougar Relocation by Radio-telemetry	• AA • AA

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

4. PROTOCOL - Wolves

Because of their wide-ranging behaviour, low densities, and occurrence in rugged, forested areas, wolves can be difficult to inventory. Depending on the study objectives and desired level of inventory intensity, this can be compounded by difficulties associated with adverse weather conditions and the cost of aerial survey and radio-telemetry techniques. Nevertheless, because wolves leave behind conspicuous sign such as tracks, scats and kills, wolf inventory can be relatively successful.

Various techniques for surveying wolves and estimating abundance have been developed, but most are non-statistical since they do not employ sampling (Hayes *et al.* 1991). This disallows any probabilistic modeling, standardized replication, or establishment of confidence intervals about a mean (Fuller and Snow 1988). Some procedures used elsewhere (Alaska, Yukon Territory) such as the line-intersect track sampling method (Becker 1991), have not been tested in British Columbia. The best estimates of population sizes have come from the total count method (using aerial snow-tracking surveys) described by Stephenson (1978) and Ballard *et al.* (1995). However, this method cannot be used in areas of dense, homogeneous forest cover (e.g. in coastal areas of B.C.). In these areas, characterized by dense forest or vegetation, radio-telemetry is useful for determining absolute abundance. Thus, the selection of an appropriate inventory technique in British Columbia requires a biologist to consider both objectives (level of intensity) and circumstance.

When conducting a survey for wolves it is essential that any study (i.e. search) area be large enough to minimize the chance of resident wolves occurring outside of it, and to eliminate extrapolation errors resulting from concentrations of prey and wolves in particular habitats (Simpson *et al.* 1993). In Alaska and the Yukon the minimum recommended study area is 4000-5000 km^2, concentrating on entire drainages or discrete portions of large drainages to facilitate navigation (Simpson *et al.* 1993, R. Hayes pers. comm. 1994). Surveying of this area should be completed in 1-2 days.

4.1 Presence/Not detected- Wolves

Recommended Method(s): Scat and track surveys by foot or vehicle are recommended in dense, rugged forested areas where visibility is poor and aerial survey techniques are not practical. This includes coastal forests, and mountainous areas in the central interior and southern parts of B.C.

Aerial snow-tracking for wolf tracks can be useful in relatively open habitat such as in northern B.C. (Northern Boreal Mountains, Boreal, and Taiga Plains ecoprovinces; Sub-Boreal Spruce, Boreal White and Black Spruce, and Spruce-Willow-Birch biogeoclimatic zones). However, because of the expense involved, aerial surveys are not recommended to determine the presence of wolves. Surveyors wishing to use this method should follow procedures outlined in the Relative Abundance section.

4.1.1 Scat and Track Surveys - Wolves

Scat and track surveys are relatively quick, easy, and inexpensive methods for determining presence of wolves. In areas with few roads or trails where it may be difficult to establish and monitor scat and track transects, this inventory technique may be more difficult to employ.

In general, transects are established along forest roads and trails through the area of interest and wolf scats are identified, counted, and collected (or removed) when encountered. Track surveys are limited to the winter months (late October to March) and to days when fresh snowfall allows for track detection and identification (Figure 3). This requirement may cause track surveys to be less effective in areas that receive low snowfall or during poor snow years. It is also possible to conduct wolf scat surveys and track counts concurrently.

Office Procedures

- Review the section, Conducting a Wildlife Inventory, in the introductory manual *Species Inventory Fundamentals (No. 1).*
- Obtain relevant maps for the project area, and use these as the basis for selecting study areas (if deemed appropriate) in which sampling will actually take place.
- Obtain relevant maps of each study area (e.g. 1:5,000 air photo maps, 1:20,000 forest cover maps, 1:20,000 TRIM maps, 1:50,000 NTS topographic maps).
- Based on the maps and other knowledge of the study areas (previous reports, local resource specialists), identify strata which are of most interest for surveying.
- Identify transects along forest roads or trails within strata on map sheets.
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for transects.

Sampling Design

- For presence/not detected surveys it is not required that a strict sampling design be followed. However, it is useful to distribute survey effort to maximize the chance of encounter. A practical way to accomplish this is to stratify each study area based on habitat and establish transects along roads or trails within strata. Both strata and transects should be delineated on a map.

Sampling Effort

- As presence surveys are intended to detect wolves, surveyors should focus effort so as to maximize the possibility of encountering wolf sign. Although the distribution of effort may differ from that applied in a relative abundance survey, surveyors should follow similar diligence tracking both the temporal and spatial distribution of survey effort within the study area. In this way, presence surveys may form the precursor to later, more intensive surveys to assess wolf abundance.
- Snowfall may limit the frequency of surveys which are possible. In such cases, it may be wisest to conduct track surveys after each fresh snowfall.

Personnel

- The crew leader should be a qualified biologist with experience in wolf scat and track identification.

Equipment

- Maps of study area(s)
- Compass
- Data forms
- Truck (preferably four-wheel drive) or ATV
- Rubber gloves and sealable bags to collect scat

Field Procedures

- Drive slowly (< 20 kph) along transects, looking for scats and tracks (if snow present). Some transects may be inaccessible to motorized vehicle and observers will have to walk.
- It is a good idea to repeat each transect twice to ensure that no scats or tracks are missed.
- Collect or remove scats from transect when encountered. Each scat should be classified as to age:
  - very fresh (recently deposited; usually less than a day old);
  - fresh (moist; one to several days old);
  - medium (dried; 1 day to several weeks old);
  - leached (mostly hair remaining; probably > 1 month old);
  - and amorphous or crumbly and flat (probably several months to a year old).

  Scats can be frozen and later analyzed for dietary content and parasite load. Anyone handling wolf scats should be aware of the potential for transmission of wolf parasites to humans, and exercise due caution.

- Record observations and other information on standard data forms.
- Wolf scat and/or track surveys may be conducted simultaneously while censusing prey species along the same transects (e.g. deer pellet group counts, D. Janz, Nanaimo, pers. comm. 1994).
- Depending on the location of the study area, scats from cougars (*Puma concolor*), coyotes (*Canis latrans*), or domestic dogs (*Canis familiaris*) may be encountered and are sometime difficult to distinguish from wolf scats. Specimens and photographs may be used to verify species, when observers are unsure of tracks or scat.

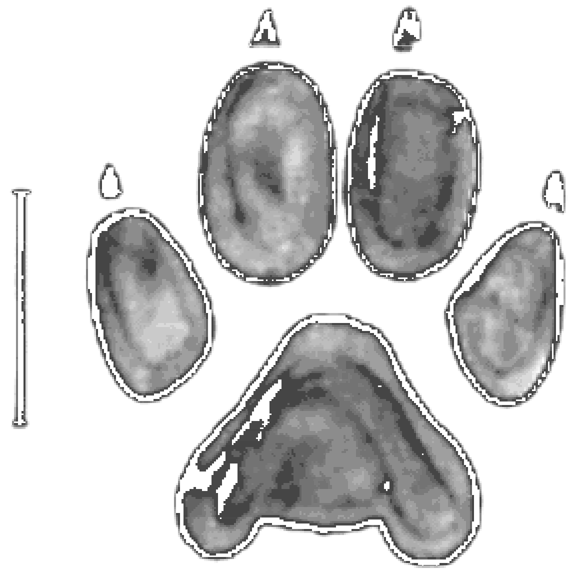

Figure 2. The front paw of a wolf (Halfpenny and Biesiot 1986). Scale is 2.5 cm.

4.2 Relative Abundance- Wolves

Recommended method(s): Scat and track surveys by foot or vehicle are recommended in dense, rugged forested areas where visibility is poor and aerial survey techniques are not practical. This includes coastal forests, and mountainous areas in the central interior and southern parts of B.C.

Aerial snow-tracking for wolves is recommended in relatively open habitat such as in northern B.C. (Northern Boreal Mountains, Boreal, and Taiga Plains ecoprovinces; Sub-Boreal Spruce, Boreal White and Black Spruce, and Spruce-Willow-Birch biogeoclimatic zones).

4.2.1 Scat and Track Surveys - Wolves

Scat and track surveys are relatively quick, easy, and inexpensive methods for determining relative abundance of wolves. In areas with few roads or trails where it may be difficult to establish and monitor scat and track transects, this inventory technique may be more difficult to employ.

In general, transects are established along forest roads and trails through the area of interest and scats are identified as wolf, counted, and collected when encountered. Hatter (1988) performed monthly scat surveys to evaluate wolf distribution, recording scat densities as number of scats per km of transect per month. Track surveys are limited to the winter months (late October to March) and to days when fresh snowfall allows for track detection and identification (Figure 3). This requirement may cause track surveys to be less effective in areas that receive low snowfall or during poor snow years. It is possible to conduct wolf scat surveys and track counts concurrently.

If comparable transects are established in two or more study areas, then this method can be used to estimate relative abundance between these areas (Crête and Messier 1987). An effort should be made to control for variability in factors such as frequency, length, and location of transects between habitat types or study areas, to increase the reliability of relative abundance estimates. Researchers should be aware that sample size requirements may be quite demanding to evaluate relative abundance with reasonable confidence.

This technique is also used for presence/not detected surveys. Only differences from the presence/not detected survey are listed here. For details on how to conduct this type of survey see section 4.1.1

Office Procedures

- Review the section, Conducting a Wildlife Inventory, in the introductory manual *Species Inventory Fundamentals (No. 1).*
- Obtain relevant maps for the project area, and use these as the basis for selecting study areas (if deemed appropriate) in which sampling will actually take place.
- Obtain relevant maps for each of the study areas (e.g. 1:5,000 air photo maps, 1:20,000 forest cover maps, 1:20,000 TRIM maps, 1:50,000 NTS topographic maps).

Sampling Design

- A stratified random sampling design is recommended to determine relative abundance using scat and track surveys.
- Stratify study areas according to the inventory objective. Stratification may be based on expected densities (low, medium or high) or on wolf pack home range boundaries (e.g. 50%, 50-90%, 90-100%; Hatter 1988) if these are known.
- Randomly select transect routes within strata and mark these on the map sheets or air photos. These should follow forest roads or trails greater than 0.5 km in length. Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for transects.

Sampling Effort

- Sampling effort is structured so that most effort is planned for the strata expected to contain highest wolf densities where variance is usually greatest (to minimize variance).
- As scat and tracks can be difficult to see, it is useful to survey each transect twice to be sure not to miss anything (Hatter 1988).
- Several studies have conducted sampling on a monthly basis (Hatter 1988; Fuller 1989; Atkinson and Janz 1994) and this is generally recommended.
- Hatter (1988) sampled 98.5 km of transect per month to evaluate wolf distribution in a 530 km^2 study area of coastal forest on Vancouver Island with considerable success. Monthly scat densities appeared to be representative of pack home ranges and movements as verified through radio-telemetry.
- Crete and Messier (1987) sampled a 48 km circuit of 4 to 10 km scat transects weekly for 6 to 8 times per year in an effort to evaluate relative abundance between two 3000 km^2 areas of hardwood-conifer forest in Quebec. Although their results showed a strong relationship (r^2=0.90) to abundance as verified through radio-tracking of packs, scat survey results were subject to considerable variability. Sample size calculations revealed that 70-80 sample weeks would be required to assess abundance within a 20% confidence interval. The authors suggest that variance could have been reduced by increasing the total length of transects which were surveyed.
- If snowfall does not allow for resurveying transects at least once a month, transects should be surveyed for tracks after each fresh snowfall

Data Analysis

- Comparison of mean scats or tracks/km/sampling interval (generally week or month) between different areas, strata or over time.

4.2.2 Aerial Snow-tracking - Wolves

This is the most common technique for censusing wolf populations in northern B.C., Alaska and the Yukon. It has been described in detail by Stephenson (1978), Gasaway *et al.* (1983), and Ballard *et al.* (1995). Flight routes should follow terrain on which tracks are visible and over which wolves are likely to travel such as ridge tops, knolls, promontories, lakes, rivers and trails (Stephenson 1978).

Aerial snow-tracking provides a relative abundance estimate for winter wolf populations reported as the number of wolves/ km of linear transect surveyed. Individual packs can be recognized by site fidelity to their specific territories (Stephenson 1975).

This technique does not work well in heavily forested or homogeneous habitats with few openings or watercourses.

In B.C., this technique is most useful in the northern interior ecoprovinces during early winter months when pack cohesiveness is greatest (November to February recommended).

Office Procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant 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).
- Outline the project area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area from maps.
- Delineate one to many study areas within this project area. Study areas should be representative of the project area if conclusions are to be made about the project area. For example, this means if a system of stratification is employed in the Sampling Design then strata within the study areas should represent relevant strata in the larger project area.
- Study areas should include areas in which tracks are visible and over which wolves are likely to travel.

Sampling Design

- To determine relative abundance of wolves using aerial track surveys, a stratified random sampling design should be used. Sampling design generally follows that described by Stephenson (1978).
- Attempt to stratify study areas according to the inventory objectives. For example, stratification may be based on expected densities (low, medium or high) or wolf home range boundaries if these are known (50%, 50-90%, 90-100%; Hatter 1988). Stratification can be project-specific and will be based on a presumption that the project biologist can distinguish between habitats of different quality based on knowledge of the relationship between the species and its habitat. Stratification may be used to focus effort in order to maximize the probability of detecting wolves, or it may be used to distribute effort to ensure representative coverage of an area.
- Select transect routes within strata and mark these on the map sheets or air photos. These should follow terrain on which tracks are visible and over which wolves are likely to travel such as ridge tops, knolls, promontories, lakes, rivers and trails.

- Determine Broad Ecosystem Units for transects.
- In study areas where habitat is generally homogeneous, it may better to fly parallel transects 10 km apart. In more densely forested terrain, transects should be wider apart (10-15 km).
- Small packs which are stationary on a kill for a few days may be missed if they occur between transects lines and outside the observer's field of vision (R. Stephenson, pers. comm.).

Sampling Effort

- Sampling effort is structured so that most effort is planned for the strata expected to contain highest wolf densities where variance is usually greatest (to minimize variance).
- Aerial searches over moderate to dense forest canopies require more search effort as tracking conditions may be poor (both for track and animals). Under heavy timber conditions, Hayes (1987) covered about 140 km^2/hr.
- Where wolf distribution gaps occur, areas suspected of having wolves should be searched again until packs or their trails are seen, or until observers are confident that wolves are not present.

Personnel

- The fixed-wing airplane or helicopter pilot should be an experienced observer.
- Each passenger involved in the project should be a qualified biologist with prior experience in aerial wolf surveys and wolf track identification. Stephenson (1978) found that experienced wolf observers counted three times more wolves from the air than inexperienced ones.

Equipment

- Light fixed-wing aircraft (Piper PA-18 Supercub, Cessna 180 or 172, or Maule M5 or M7), or Bell 206B helicopter because of their maneuverability, stability, and low stall speeds
- Binoculars (7X or 8X magnification; wide angle field of view)
- Maps of project area
- Expandable file folders for map storage and data forms
- Data forms
- Clipboards
- Coloured pencils, number 2 lead pencils, and large eraser
- Intercom and headsets (and spare batteries for intercoms)

Field Procedures

- Conduct surveys within 2-3 days following a fresh snowfall of at least 5-10 cm, since fresh snow permits accurate track interpretation.
- Whenever possible, surveys should be conducted in good light conditions.
- Fly transects along drainages and take deviations to view lakes, trails, forest openings, ridges, knolls and promontories.
- When wolf tracks are seen, record the direction of travel and follow them as long as possible or until the wolves are located.
- Tracks with their direction of travel, the number of wolves and their locations should be plotted on maps of the study area.

- When wolves are located, the aircraft should circle widely at about 150 m altitude until a count and description of animals can be obtained (colour, relative size or social status).
- To guard against duplicate sightings, and to provide a basis for comparisons in replicate surveys, wolves should always be categorized by colour and, when possible, by relative size (Peterson and Page 1988, Simpson *et al.* 1993). However, it is often only possible to distinguish pups of the year based on relative body size. Colour is usually covered by white, grey, black, or brown, although truly white wolves are rare in B.C. (Simpson *et al.* 1993).
- If wolves cannot be located, the number of wolves should be determined by counting the number of distinguishable trails. Do this by landing at a place where pack members have diverged briefly. Hayes (1987) found this to be especially successful on river and creek ice where pack members tended to spread out.
- When there is a possibility of duplication in the enumeration of wolves based on the occurrence of tracks they should be followed and/or intervening areas should be searched.
- For small study areas (<50 km^2) of homogeneous habitat which are bordered by streams or openings, it can be useful to fly the perimeter since wolves will rarely remain in dense cover for long periods of time when snow is heavy.
- To maintain consistency and accuracy when conducting aerial track surveys, it is best if the same observers conduct the aerial searches over the duration of the study period (Hayes *et al.* 1987).

Data Analysis

- Comparison of mean number of wolves/km surveyed within each stratum.
- Comparison of changes in mean number of wolves/km surveyed within a stratum over time.

4.3 Absolute Abundance - Wolves

Recommended method(s): **Aerial snow-tracking** for wolf tracks are recommended in relatively open habitat such as in northern B.C. (Northern Boreal Mountains, Boreal, and Taiga Plains ecoprovinces; Sub-Boreal Spruce, Boreal White and Black Spruce, and Spruce-Willow-Birch biogeoclimatic zones).

Radio-telemetry should be used to obtain absolute abundance data in dense, rugged forested areas where visibility is poor and aerial survey techniques are not practical. This includes coastal forests, and mountainous areas in the central interior and southern parts of British Columbia.

A combination of both methods provides the most accurate absolute abundance estimate.

4.3.1 Aerial Snow-tracking - Wolves

Aerial snow-tracking provides a count-based estimate of the minimum numbers or minimum density of wolves in the study area, thereby providing an estimate of winter wolf population size (Stephenson 1978, Hayes *et al.* 1991). Researchers have confirmed its accuracy by comparing population estimates from snow tracking with those obtained from radio-telemetry studies (Hayes *et al.* 1991).

Sampling Design Considerations

Procedures for aerial snow-tracking are outlined under “Relative Abundance”. The following should be considered when using this methodology to obtain Absolute Abundance estimates:

- Survey results should be expressed as number of wolves per 1000 km^2 (based on a range of minimum and maximum numbers of wolves in each pack).

- Total counts and therefore estimates of absolute abundance can be inaccurate if the entire area is not searched or if animals are missed or counted twice (Norton-Griffiths 1975).

- Late winter (or spring) population size is the sum of observed wolves and wolf tracks thought to represent different individuals, minus any known winter mortality and emigration, plus a compensatory factor of 10% to account for the proportion of lone wolves in the population (Mech 1973, Gasaway *et al.* 1983, Carbyn 1987, Hayes *et al.* 1991).

- Fuller (1989) found that lone wolves may represent as much as 30% of a high density, saturated wolf population in Minnesota, and that lone wolves formed pairs during September to December.

- If the ability to survey large study areas in a short period is restricted by low snow accumulations, poor light, windy conditions, or the availability of suitable aircraft, then censuses may be restricted to smaller areas (500 - 3000 km^2). This may skew population estimates accordingly.

- If winter surveys are conducted too near the breeding season, packs may split into smaller sub-units which may then be missed in the count (L. Carbyn pers. comm. 1994).

4.3.2 Radio-telemetry - Wolves

Live capture and subsequent radio-telemetry of wolves is a technique which has been used routinely by numerous researchers over the years to inventory and monitor wolf populations (Fritts and Mech 1981, Gasaway *et al.* 1983, Peterson *et al.* 1984, Ballard *et al.* 1987, Hatter 1988, Hayes *et al.* 1991). With advances in radio-telemetry technology over the past 10-15 years, this technique provides a reliable method for monitoring wolf movements (territory sizes), determining prey selection and predation rates, and evaluating population dynamics (immigration/emigration, natality/mortality).

Population density estimates can be made by extrapolating known numbers of wolves within radio-marked packs to other areas with similar habitat (and presumably prey species potential) where observations are limited (Ballard *et al.* 1987).

Wolf Capture Methods

Wolves can be live-captured by helicopter darting, snaring, or with leg-hold traps (Fritts and Mech 1981, Peterson *et al.* 1984, Hatter 1988, Hayes *et al.* 1991). Due to the cost of aircraft time, helicopter darting is expensive but is a relatively quick and efficient method of capturing wolves, especially in winter when wolves frequent frozen watercourses, ridges, and other open areas where snow accumulations are less, and when packs are generally most cohesive (Peterson *et al.* 1984). Wolf pups can often be selected for aerial darting because they are less elusive, remain in a pack for at least one year, and are seldom live-trapped in summer (Peterson *et al.* 1984).

Trapping is also an effective way to catch wolves. Steel traps, and neck and foot snares have been used with varying success (Carbyn 1987). Leg-hold trapping (using offset steel traps with rubber padded jaws) is an efficient technique. However, this type of trapping should be limited to the period from May through October because leg-hold traps will impede circulation of a captured limb, commonly resulting in freezing the caught foot (Peterson *et al.* 1984). Wolves often struggle to get out of leg-hold traps but are not generally known to chew their legs to escape (Carbyn 1987). However, damage to legs can include skin lacerations and broken metacarpals, and in severe cases, broken long bones. Wolves left in traps for long periods can break teeth. Studies in Manitoba (Carbyn 1987) showed that pups sustained fewer injuries than adults during trapping and that no animals were lost as a result of broken long bones.

Snares are most commonly used in winter, when snaring can be more efficient (Van Ballenberghe 1984), and when colder temperatures minimize hyperthermia in captured wolves. Large numbers of snares can be set out in an area, and it is generally wisest to focus trapping effort on travel routes which are known to be used by wolves. Galvanized cable (3.2 mm) neck snares with limited closure (350-375 mm diameter) should be used. Because snares can be lethal to captured wolves, neck circumference of local wolves should be determined prior to constructing and setting snares. Even using properly set snares, wolves can easily be injured (although it may not be readily apparent) depending on a number of factors including the animal’s age, the length of time it is in the trap, the extent to which it struggles, and the skill with which it is immobilized (R.D. Hayes, Yukon Fish and Wildlife Branch, pers. comm.). Foot snares are similar to the Aldridge foot snare used for capturing bears (Manning 1985). However, foot snares are less commonly used than neck snares because they are generally difficult to conceal and are thought to be inefficient at capturing trap-shy wolves. Many wolf researchers are not satisfied with the use of snares as a live-capture technique. P. Pacquet (pers. comm) described 3-5% mortality rates of wolves in some studies which used snares.

Traps and snares should be set along forest roads or trails where tracks or other wolf sign have been located, or near centers of wolf activity (e.g. along a territory boundary or near a kill site, Fritts and Mech 1981, Carbyn 1987). To increase capture success, wolves can be drawn to traps or snares with scent posts (use of scats, urine, or both as attractants), with bait (e.g. deer or beaver carcasses, although the use of baits can result in the capture of non-target species such as eagles, ravens, foxes or weasels), or set along suspected "travel" trails (Hatter 1988).

Traps and snares should be checked every 24 hours (or twice daily during warm summer weather). Captured wolves are anaesthetized with intramuscular injections of drugs (administered via a jab stick or dart gun), and fitted with radio-transmitter collars with individual frequencies which can be monitored from the ground or air. Animals are classified by age and sex, and are usually eartagged and weighed. Other measurements such as body length and canine teeth should also be taken. Any captured wolves which sustain foot injuries from the trap can be injected with antibiotics (e.g. 1,200,000 units of bicillin) or given vitamin injections (Fritts and Mech 1981).

Radio-telemetry Methods

Radio-transmitter collars consist of a hermetically sealed transmitter and battery attached to a two layered machine-belt collar. The antenna is located between the belt layers. Most transmitters have a dual mode where a faster pulse rate (e.g. X2) occurs whenever the unit has remained motionless for a long period of time (e.g. 4 hr). This usually indicates that the animal is dead or has lost its collar. Transmitter/battery failure is usually low. Transmitter life varies from 1-4 years. Peterson *et al.* (1984) reported transmitters functioning for up to 27 months.

Peterson *et al.* (1984) reported that failure to obtain the signal from a transmitter could indicate: 1) the transmitter had failed; 2) the wolf had moved out of tracking range; or 3) the wolf had been killed and its transmitter damaged. Thiel and Fritts (1983) documented the loss of collars on Gray wolves in Wisconsin due to chewing removal by other wolves. This trend appears to be somewhat unusual, however, as a survey of 11 wolf biologists reported only 7/378 (1.9%) of machine-belt collars placed on wolves were chewed off (Thiel and Fritts 1983).

Radio-collared wolves can be monitored from the ground using a hand-held, 3-element Yagi antenna, from a vehicle with a truck-mounted whip antenna, or from the air (fixed-wing aircraft or helicopters can be used; a 3- or 4-element antenna should be mounted horizontally on the wing strut of the plane or on the helicopter skids).

Depending on study objectives (e.g. pack movements and structure, predator-prey relationships), time of year, accessibility to the wolves, and human-power and budget, relocation frequency of radio-collared wolves will be variable. Desired minimum total number of relocations also depends on pack territory size. In Manitoba, in a population with relatively small territories (178-268 km^2), Carbyn (1983) showed that a minimum of 30 locations are required to completely describe wolf territories. In Alaska, in a population with large territory sizes (average 1645 km^2), Ballard *et al.* (1987) found 60 locations was the minimum number required. Relocations should be attempted in early morning as much as possible because wolves are more active and more likely to be seen at this time of day (Mech 1970). However, activity levels can vary throughout the year, and during mid-winter under cold weather conditions, wolves are often active and visible during mid-afternoon (L. Carbyn pers. comm. 1994).

Movements and territory sizes of radio-collared wolves can be calculated from radio-telemetry data collected during wolf inventory. Computer programs which calculate a pack's home range sizes are available (Harestad 1981, Ackerman *et al.* 1989). Harestad's (1981) program allows home range size calculation at a 100%, 90%, or 50% level (100% home range includes all radio locations and is considered synonymous with the pack's territory; 90% home range is often used to exclude "outlying" individuals; 50% home range includes only the closest 50% of known locations and is identified as the core area of use). If only one wolf is collared from a pack, its home range can be assumed to represent the pack's home range, unless scat transects or some other information indicates otherwise (Hatter 1988).

For a more detailed description of general radio-telemetry protocol refer to manual No. 5, *Wildlife Radio-telemetry*. Also, refer to manual No. 3, *Live Animal Capture and Handling for Wild Mammals, Bird, Amphibians and Reptiles* for general information on capturing and handling of animals.

Office Procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant 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).
- Outline the project area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area from maps.
- Delineate one to many study areas within this project area (this may help to organize trapping and relocations).

Sampling Design

- After the study area is identified, it may be useful to stratify based on expected densities (low, medium or high) or wolf home range boundaries if these are known (50%, 50-90%, 90-100%; Hatter 1988). This may provide a framework to guide trapping efforts or a useful context for relocations.
- There is no strict sampling design for animal capture. When using ground-based techniques, place traps or snares near scats, scent posts, territory boundaries, or along trails, but away from human activity such as hiking trails or campsites. If results of tracking radio-collared wolves are to be extrapolated to other wolves in the project area, then traps should be equally accessible to all animals in the project area so that captures will represent a random sample of wolves.
- For information on relocating animals using radio-telemetry, see manual No. 5, *Wildlife Radio-telemetry*.

Sampling Effort

- Relocations every two to four days is considered adequate. Less frequent locations are necessary during winter months. The desired minimum total number of relocations also depends on pack territory size with more frequent relocations required for larger territories. A minimum of 30 relocations are required to determine wolf (and pack) territory size.

Personnel

- When using helicopter darting for capturing wolves, an experienced helicopter pilot and qualified biologist capable of immobilizing running wolves with a dart gun, are required.
- If traps/snares are used to capture wolves, qualified biologists that are experienced in trapping/snaring will be necessary.
- Biologists must also be experienced in animal handling, affixing radio transmitters and ear tags, tattooing, and taking standard body measurements.
- For aerial radio-telemetry relocations, an experienced pilot and biologist must be present. For ground telemetry relocations, a biologist with previous radio-telemetry experience is required.

Equipment

Capture:

- Bell 206 or Hughes 500 helicopter for aerial capture
- Four-wheel drive vehicle for checking traps/snares
- Wide-angle field of view binoculars (7X or 8X magnification)
- Traps and Snares: [if using steel leg-hold traps, choose #14 Newhouse with offset jaws which are wrapped with rubber for padding. A modified #14 Newhouse with 1.1 cm offset jaws seems to produce the fewest injuries in captured wolves (Kuehn *et al.* 1986). Braun Wolf Traps (Wayne's Tool Innovations, Inc., Campbell River, B.C.) are also used routinely as leg-hold traps by researchers in Alaska, the Northwest Territories, and British Columbia. These traps are stronger and heavier than a #14 Newhouse.]
- Immobilization equipment and drugs:
  - Combination of Ketamine Hydrochloride (Parke-Davis, Brockville, Ont.) and Xylazine (Rompun, Cutter Lab., Mississauga, Ont.) for trapped and snared animals
  - Telazol (Amhurst Pharmaceutical, Montreal) for helicopter darting or for trapped and snared animals
  - 2-cc syringes
  - Cap-Chur rifle
  - Jab stick
- Maps of study area
- Compass
- Data forms
- Ear tags and tattoo equipment
- Equipment for taking standard body measurements

Radio-telemetry:

- Piper PA-18 Supercub or Cessna 180 or 172 for aerial radio-telemetry
- Wide-angle field of view binoculars (7X or 8X magnification)
- Four-wheel drive vehicle for ground based telemetry
- Radio receiver and headphones (Telonics recommended)
- 3- or 4-element Yagi antenna

- Collars manufactured by Telonics (Mesa, Ariz.), AVM Instrument Co. (Champaign, Ill.), Holohil Systems (Ottawa, Ont.), Lotek (Aurora, Ont.), or Austec (Edmonton, Alta.) are recommended. Transmitter frequency is usually in the 150-160 MHz range, and those with motion detector pulse modes (mortality sensors) are preferable. Collar prices range between $300-$750.
- Some radio collars can be ordered with a built-in recapture system. These collars allow serial recaptures of animals by controlling the firing of anaesthetic darts attached to the radio collar (Wildlink System, Brooklyn Park, Minnesota). These collars are more expensive than regular radio collars (>$1000/collar), but are designed to: (i) transmit during preset time periods, thereby saving battery life; (ii) detect and store intervals of activity data and transmit them upon remote command; (iii) remotely change the resolution of recorded activity data; (iv) remotely control signal pulse width, rate, and transmission periods; (v) measure battery voltage; and (vi) remotely release the collar from the animal.
- Maps of study area
- Data forms
- Compass

Field Procedures

Capture

- Place traps or snares near scats, scent posts, territory boundaries, or along trails, but away from human activity such as hiking trails or campsites.
- Leg-hold traps should be attached by trap chains (about 2-2.4 m in length) to drags or grapple hooks rather than staked in place. This allows the wolf to escape a short distance from the trap site, often reducing its initial fear and tendency to fight the trap, and thereby reducing injury. Retaining chains should be centered below the trap pan to reduce torque on the foot when the animal struggles to get away (Carbyn 1987). The trap should be set where there is adequate standing timber and brush for the drag to tangle near the trapsite.
- Many researchers construct their own cable neck snares. Snares should be about 3 m long, using 3.2 mm galvanized steel cable. Various swivels and locks can be added as a means of securing the cable and for controlling the sliding, closing, and twisting movements of the snare loop and anchor.
- Because snaring is very non-selective, it is important to position the snare loop at the proper height (at estimated wolf shoulder height) to avoid catching non-target species.
- Traps and snares must be checked every 24 hours to minimize the risk of injury to captured animals (traps should be checked twice daily in hot weather to prevent hyperthermia).
- Captured animals can be darted with a Cap-Chur gun, or hand injected with a jab stick.
- Immobilize trapped/snared wolves with a mixture of Ketamine Hydrochloride (Parke-Davis, Brockville, Ont.) and Xylazine (Rompun, Cutter Lab., Mississauga, Ont.) or with Telazol. If using a Ketamine:Rompun mixture, ratios range from 5:1 to 2:1 Ketamine:Rompun. Mixture ratios closer to 2:1 will bring animals down quickly since the relative concentration and effects of Rompun (a muscle relaxant) are increased. Estimate body weight of captured animal. Most wolves receive dosages of 10-15 mg Ketamine/kg body weight. If Telazol is used as an immobilization drug, a 1 ml injection of a concentration of approximately 166 mg/ml (or 2.5 ml distilled H_2O: 500 mg Telazol) works well (animals are usually down in 2-4 minutes and stay immobilized for about 30 minutes, P. Clarkson pers. comm. 1994).

- For wolves darted from helicopters, Telazol (Amhurst Pharmaceutical, Montreal) has proven to be an effective drug. Recommended dosage concentration is approximately 166 mg/ml (or 2.5 ml distilled H_2O: 500 mg Telazol). Ideally, drugs should be delivered at close range with 2-cc syringes fired from a Cap-Chur rifle (P. Clarkson pers. comm. 1994).
- After immobilization, attach eartags and tattoo (usually in ear or lip, if desired) to the captured animal and record standard body measurements (sex, est. age, weight, canine length) on data forms.
- Attach a radio-transmitter collar to the wolf and ensure signal is transmitting.

Radio-telemetry:

- Monitor radio-collared wolves on a regular basis (from ground or air, generally relocating collared animals every 2-4 days)
- Plot wolf locations on topographic maps in the field and later as metric grid coordinates (Universal Transverse Mercator grid - to nearest km).
- Home range/territory sizes can be determined by connecting the outermost observations (minimum convex polygon) excluding extraterritorial forays and obvious dispersals (Mohr 1947), or with home range software (e.g. Harestad 1981).

Data Analysis

- Wolf movements, home range sizes and population estimates can be determined with software described by Harestad (1981) and Ackerman *et al.* (1989).
- Determine minimum population densities from home range sizes and known number of animals.
- Statistical differences in means (e.g. kill frequencies) and differences in ratio data (e.g. pack cohesion indices or the probability of pairs of radio-marked pack members being together) can be tested with *t* tests and chi-square analyses, respectively (Snedecor and Cochran 1973). Correlations such as the relation between observability and snow depth can be determined using linear and multiple regression techniques (Fuller 1989). Samples of unpaired, non-normal measurements (e.g. dispersal distances, small pack sizes) can be compared using Mann-Whitney *U* tests (Snedecor and Cochran 1973).
- Statistical tests should generally be conducted at the 0.05 level of significance.

4.3.3 Combination of Aerial Snow-tracking and Radio-telemetry - Wolves

Radio-telemetry can be used to verify population estimates obtained from other survey techniques such as aerial snow-tracking. Gassaway *et al.* (1990) and Hayes *et al.* (1991) employed both aerial snow-tracking and capture/radio-telemetry techniques to obtain accurate minimum counts of wolves. By using both techniques, Hayes *et al.* (1991) were confident in the accuracy of the population estimates they determined through snow-tracking for the following reasons:

1. in areas where territorial packs are spatially separated most of the time, all packs could be located and counted by frequently searching all habitats and elevation zones;
2. the probability of locating wolves increased as sampling frequency increased. All areas were searched until wolves or their sign were found, or observers were confident wolves did not use the areas;
3. because wolves frequently travel long distances during winter, it was probable that experienced observers would intercept a trail and follow it until the pack was found or an estimate of pack size was made from separate trail counts;
4. by knowing the whereabouts of radio-collared packs throughout the winter, observers were able to intensively search where non-instrumented packs were ranging. This increased the probability of encountering new packs and minimized the possibility of duplicating packs;
5. wolves and their trails were highly visible because most of the study area was above tree-line.

5. PROTOCOL - Cougars

Cougars are widely, but sparsely distributed across southern and central-northern British Columbia. As with most large terrestrial carnivores, they are extremely secretive and are most active during nocturnal periods. Because of their secretive behaviour, high mobility, general solitary nature, and preference for habitat that is lightly traveled by humans, cougars are very difficult to survey. The best estimates of population sizes have come from long-term and costly studies (Hornocker 1970; Seidensticker *et al.* 1973; Ross and Jalkotzy 1992). Additional factors, such as differing harvest levels and differential detectability of sex and age classes (Barnhurst and Lindzey 1989), make applying density estimates in areas of similar habitats risky (Lindzey 1987).

5.1 Presence/Not detected and Relative Abundance - Cougars

Recommendations: Road or aerial track counts.

Questionnaires are likely the most inexpensive way to determine presence of cougars in an area. If this is not appropriate or effective, track count field surveys designed to locate tracks of cougars in bare dirt or snow are recommended for determining presence.

Counts are made along roads from a moving vehicle or, in snow, along transects from helicopters. A few studies on cougar populations have estimated abundance and monitored change over time from data on tracks alone, without knowledge of actual population sizes (Currier 1976; Koford 1978; Shaw 1979; Shaw *et al.* 1988). The reliability of population estimates in these studies were not evaluated. More recent research has evaluated the reliability of estimating populations by track counts from known populations (Van Dyke *et al.* 1986a; Van Sickle 1990; Van Sickle and Lindzey 1991). It is common for radio-telemetry studies to supplement relocation data with data from tracks found.

Aerial snow-tracking is particularly useful in interior areas with open forest cover. Biologists interested in utilizing this technique may also want to review the section on Relative Abundance, “Aerial track probability sampling”. Given the high cost of hiring an aircraft to survey for tracks, it may be more cost effective to undertake a probability sampling method which can more statistically-valid conclusions about the number of animals present.

Aerial tracking in general may be ineffective in coastal areas or in interior areas with heavy forest cover where visibility is limited. Aerial viewing of cougar tracks in coastal forests is impractical except in recently logged or agricultural areas, because of the heavy forest overstory obscuring views to the ground. In addition, cougars rarely use clearcut areas in coastal forests (K. Atkinson pers. comm. 1994). On the coast, snow conditions are rarely ideal for aerial tracking due to lack of snow, or the frequency of rain, which reduces track visibility even when snow is present.

Track counts along dirt roads might be more useful to determine occurrence than aerial surveys, especially were roads with good tracking condition are abundant. Road track counts involve driving along dirt roads in cougar habitat and searching for track imprints in dirt, dust, or snow (Figure 3). Areas characterized by extensive networks of dirt logging roads are ideal, such as certain roaded forests in southern British Columbia. Investigators should use caution when using road track counts as a measure of relative abundance as they have been shown to be poor indicators of overall cougar density when conditions are not ideal. However, road track surveys may provide better results, and be useful to estimate large-scale population changes under optimal conditions in areas where dirt road abundance and location allow a population to be sampled adequately (Van Sickle and Lindzey 1992). They have also been shown to be good estimators of abundance for resident females and kittens, when dirt-tracking conditions were optimal (Van Dyke *et. al*, 1986a).

As cougars tend to be secretive, the success of this type of field survey will be increased if crews are capable and inclined to record observations of all types of cougar sign, including prey kill sites, scats, scrapes, and mounds over scats.

5.1.1 Cougar Aerial Snow-tracking and Road Track Counts

Office Procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant 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).
- Outline the project area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area from maps.
- Delineate one to many study areas within this project area. Study areas should be representative of the project area if conclusions are to be made about the project area. For example, this means if a system of stratification is employed in the Sampling Design then strata within the study areas should represent relevant strata in the larger project area.
- Study areas should include areas in which tracks are visible and over which cougars are likely to travel.

Sampling Design

- Track surveys generally take place on a very broad scale. If estimates of relative abundance are desired, it may be useful to initially use a grid to divide the study area up into cells. Cells to be sampled may then be randomly selected. If a road survey is to be conducted, road coverage in the study area must be fairly extensive to facilitate this approach.

- If a grid is not appropriate, attempt to stratify study areas according to the inventory objectives. Stratification can be project-specific and will be based on a presumption that the project biologist can distinguish between habitats of different quality based on knowledge of the relationship between the species and its habitat. Stratification may be used to focus effort to maximize the probability of detecting a cougar, or it may be used to distribute effort to ensure representative coverage of an area.

Aerial Snow-tracking

- Select a reference line within each strata or grid cell. Sample each strata using transects which are systematically placed perpendicular to this reference line.
- Remember that cougars have a tendency to travel drainages and ridges (Hemker *et al.*1984) so orienting transects perpendicularly to these features may result in the greatest success.
- Determine Broad Ecosystem Units for transects.

Road Track Count

- Identify existing road networks and choose suitable roads (transects) for surveying within each grid cell/strata. Ideally roads must be soft enough to retain cougar track imprints and located to intercept home ranges of as many cougars as possible.
- Determine Broad Ecosystem Units for transects.
- For estimates of relative abundance, Van Sickle and Lindzey (1992) found a positive relationship between track finding frequency and the number of home ranges known to overlap survey roads (transects). As a result, they noted that sampling biases were a major

problem in assessing abundance where cougar home ranges are not uniformly distributed and roads are not located to cross cougar home ranges.

- Under ideal dirt-tracking conditions, Van Dyke *et al.* (1986a) found a positive relationship between track finding frequency and higher densities of resident females and kittens. Road Survey. Poorer estimates resulted from roads with hard surfaces and snow cover.

Sampling Effort

- Generally, effort should be focused on strata where cougars are expected to occur (and variability is highest).
- Road Surveys: Van Dyke *et al.* (1986a) estimated a maximum of 360 km road searched for every 500 km^2 habitat is required to locate any individual cougar in the eastern United States. This is only an estimate which will vary with the distribution of roads.

Personnel

- Driver / helicopter pilot should be an experienced observer.
- Each passenger involved in the project should be a qualified biologist with prior experience in aerial / road cougar surveys and cougar track identification.
- One member of the survey team will be required to delineate cougar tracks on a large scale map. This person should have a good sense of direction and be able to estimate distances on the ground.

Equipment

- Helicopter that has good maneuverability, stability, and low stall speed for aerial snow-tracking
- Reliable vehicle for road transects
- Binoculars (7X or 8X magnification; wide angle field of view)
- Maps of project area
- Expandable file folders for map storage
- Compass
- Data forms
- Clipboards
- Coloured pencils, large eraser, number 2 lead pencils
- Intercom and headsets, (and spare batteries for intercoms)

Field Procedures

Aerial Snow-tracking

- Conduct surveys within 2-3 days following a fresh snowfall of at least 5-10 cm. More snow is not necessarily better, as heavy snowfall may result in reduced movements by cougars (Van Sickle and Lindzey 1991).
- Whenever possible, survey during good light conditions.
- Fly transects in a helicopter, scanning the ground for cougar tracks.
- When cougar tracks are seen, record the direction and length of movements on maps of the study area. Follow tracks as long as possible or until each cougar is located.

- When cougars are located, the aircraft should circle widely at about 150 m altitude until a count and description of animals can be obtained. Plot cougar locations on maps of the study area.
- When there is a possibility of duplication in the enumeration of cougars based on the occurrence of tracks they should be followed and/or intervening areas should be searched.
- To maintain consistency and accuracy when conducting aerial track surveys, it is best if the same observers conduct the aerial searches over the duration of the study period (Hayes *et al*. 1987).

Road Track Counts

- Drive roads at approximately 20 kph, scanning for track imprints in dirt, dust, or snow.
- Roads surveyed must be soft enough to retain cougar track imprints.
- Conduct winter snow-tracking surveys within 2-3 days following a fresh snowfall of at least 5-10 cm. Sampling biases due to snow may result in poorer estimates of abundance in road-based tracking (Van Dyke *et al.* 1986a) and thus snow-tracking along roads may not be appropriate for estimating abundance.
- When cougar tracks are seen, record the direction of travel and number of cougar tracks on maps of the study area. Follow tracks as long as possible or until each cougar is located.
- When cougars are located, record the sex and age class of the animal(s) and plot cougar locations on maps of the study area.

Data Analysis

- Display locations, direction and extent of cougar tracks on a map.
- Differentiate observations by sex or maturity if animals were observed.
- If appropriate, summarize occurrence in different strata, Broad Ecosystem Units, or other habitat classes.
- Summary statistics for distance traveled or mean tracks per km/sampling interval (generally week or month) between different areas, strata or over time.

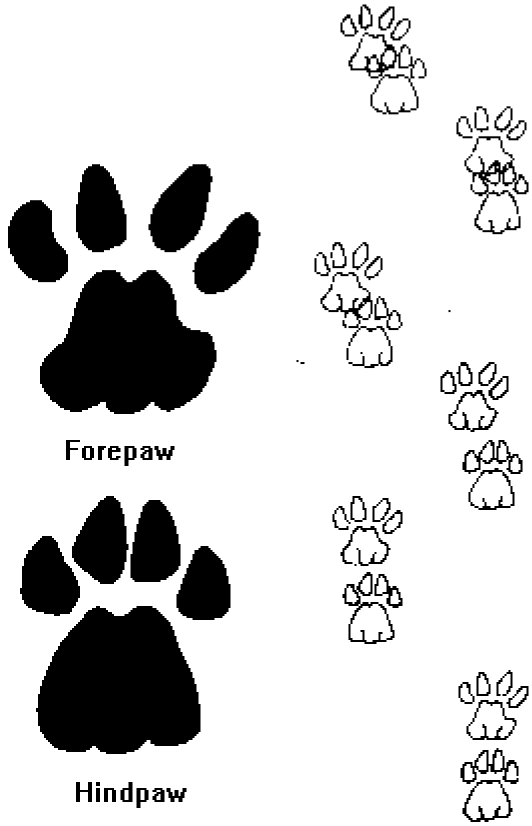

Figure 3. Illustration of cougar track characteristics (Source: Shaw 1979).

5.2 Absolute Abundance - Cougars

Recommendations: Aerial track probability sampling or Radio-telemetry

Aerial track surveys using probability sampling may be used in areas of interior British Columbia with predictably good sightability. Although somewhat experimental, aerial snow-tracking using a probability sampling design appears to provide a viable and relatively inexpensive means of estimating cougar numbers for an area (Van Sickle and Lindzey 1991). Success will be most likely where sufficient snowpack to cast tracks is present, and where airborne observers have a clear view to the ground. This technique is not appropriate for coastal areas or in interior areas with heavy forest cover where visibility is limited.

Radio-telemetry is also recommended, and will be the only option in parts of the province where forest cover limits visibility. Virtually all recent studies on population size and biology of cougars have used radio-telemetry techniques. Although it is very expensive, radio-telemetry is widely acknowledged as the best method for obtaining data on actual population sizes, as well as providing additional data on cougar biology (e.g. morphometric measurements).

5.2.1 Aerial Track Probability Sampling - Cougars

The basis for this technique is a study by Van Sickle and Lindzey (1991) following development of probability sampling methods by Kaiser (1983), Becker (1991) and Becker and Gardner (1992). The technique was tested for cougar in Utah on a 12km x 30km rectangular study area which was divided in the thirds widthwise. A reference transect, running parallel to the long axis of the study area was randomly placed within the first third and then two parallel transects were also established, each at similar positions within the remaining two thirds (Figure 4). The transects were then flown collectively within one to three days of a recent snowfall as part of one systematic sample. New transects were then selected and the whole process repeated after the next snowfall event. Van Sickle and Lindzey (1991) repeated four systematic samples.

During each flight, all adult cougar tracks encountered are noted and delineated on a map. The observers then follow the tracks to determine each cat’s current position as well as its position immediately after it stopped snowing. The success of this method relies on the assumptions that all tracks are identifiable, that all tracks which cross a transect line are counted, and that tracks can be followed to the cougar's present location. This technique does not require demographic closure, and so animals can move freely in and out of the study area.

A major advantage of this method is that presence can be determined with only a few days of field work. It is ideal to conduct surveys within 2 days of moderate snowfalls of 8-12 cm, as less snow may hinder tracking and greater snowfall may reduce cougar movement (Van Sickle and Lindzey 1991). Although this method has proven reliability under certain conditions, its application in British Columbia will be restricted to areas in the interior with relatively open forests, shrublands, and grasslands.

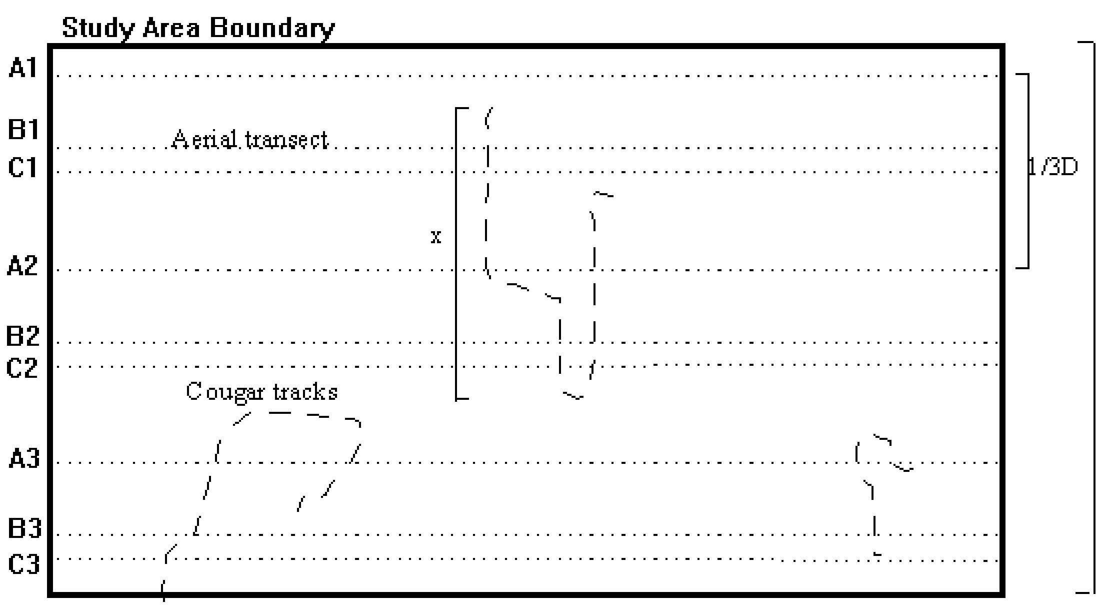

Figure 4. Systematic survey design to estimate numbers of animals in a study area using snow-tracking (after Becker 1991 and Van Sickle and Lindzey 1991).

Three systematic samples are denoted by the letters (A, B, C) and replicates in each third of the study area are denoted with numbers (1, 2, 3).

Aerial track probability sampling

Office Procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant 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).
- Outline the project area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area from maps.
- Delineate one to many study areas within this project area. Study areas should be representative of the project area if conclusions are to be made about the project area.
- Study areas should include areas in which tracks are visible and over which cougars are likely to travel.

Sampling Design

- Aerial track probability sampling does not require any form of stratification (it was originally developed in the absence of adequate information on which to stratify).
- A rectangular study area should be selected, and transects which run parallel to the long axis of the study area should be delineated. This is accomplished as follows:
    - The study area is divided in the thirds running lengthwise.
    - A start point for a transect, which will run parallel to the long axis, is randomly selected along the short axis of the first third. A second and third parallel transect are then placed 1/3D and 2/3D away from the initial one (Figure 4). These three transects are ONE systematic sample.
    - The process should be repeated until transects are delineated for three to four other systematic samples.
- With regard to study area delineation, precision of estimates apparently increases as transects become more perpendicular to major drainages. Cougars have a tendency to travel drainages and ridges (Hemker *et al.*1984).
- Determine Broad Ecosystem Units for transects.

Sampling Effort

- Each systematic sample of three transects must be flown on the same day.
- Van Sickle and Lindzey (1991) used four systematic samples to derive estimates of cougar abundance for a 360 km^2 rectangular study area with a width of 11.2 km.
- Becker (1991) used four systematic samples to derive estimates of abundance for wolverine over an 1871 km^2 study area.

Personnel

- Helicopter pilot should be an experienced observer.
- Each passenger involved in the project should be a qualified biologist with prior experience in aerial cougar surveys and cougar track identification.
- One member of the survey team will be required to delineate cougar tracks on a large scale map. This person should have a good sense of distances on the ground as lateral distance traveled by each cougar will be an input to density calculations.

Equipment

- Helicopter that has good maneuverability, stability, and low stall speed for aerial snow-tracking
- Binoculars (7X or 8X magnification; wide angle field of view)
- Maps of project area
- Expandable file folders for map storage
- Compass
- Data forms
- Clipboards
- Coloured pencils, large eraser, HB lead pencils
- Intercom and headsets, (and spare batteries for intercoms)

Field Procedures

- Conduct surveys within 2-3 days following a fresh snowfall of at least 5-10 cm. More snow is not necessarily better, as heavy snowfall may result in reduced movements by cougars.
- Whenever possible, try and survey during good light conditions.
- In a helicopter, fly the three transects which make up the systematic sample.
- When cougar tracks are seen, record the direction and length of movements on maps of the study area. It is also useful to estimate the distance traveled perpendicular to the transect. (This can also be taken from the maps after the flight, but it is useful to estimate distance in the field for comparison.) Follow tracks as long as possible or until each cougar is located.
- When cougars are located, the aircraft should circle widely at about 150 m altitude until a count and description of animals can be obtained. Plot cougar locations on maps of the study area.
- When there is a possibility of duplication in the enumeration of cougars based on the occurrence of tracks they should be followed and/or intervening areas should be searched.
- To maintain consistency and accuracy when conducting aerial track surveys, it is best if the same observers conduct the aerial searches over the duration of the study period (Hayes *et al.* 1987).

Data Analysis

Following the methodology for furbearers developed by Becker (1991), the number of animals occupying a study area may be estimated by calculating the probability of encountering a set of tracks as below:

$$p_u = x_u(D/q) \text{ for } x_u < D \text{ (otherwise } x_u = 1)$$

where p_u = the probability that the u*th* animal is contained in the sample

x_u = the distance perpendicular to the transect traversed by the u*th* animal

D = the width of the study area perpendicular to the transect

q = the number of transects used for each systematic sample

Then,

$$T_{yi} = \quad 1/\, p_u$$

where T_{yi} = population estimate for the i*th* systematic sample. This formula will need to be adjusted slightly for observations of tracks associated with a group of animals (see Becker 1991 for more detail).

For an animal to be counted as “in” the study area, at least half of its x-axis movement must be within the study area boundaries.

A population estimate for the entire study area may then be obtained by averaging replicate systematic samples as follows:

$$T_y = \quad T_{yi} \,/\, r$$

where r = the number of systematic samples that are conducted.

An estimate of the variance of T_y is:

$$Var(T_y) = [\quad (T_{yi} \,/\, r)^2]/[r(r-1)]$$

5.2.2 Radio-telemetry

Virtually all recent studies on population size and biology of cougars have used radio-telemetry techniques, because radio-telemetry is widely acknowledged as the best method for obtaining data on actual population sizes. Studies using this technique have been conducted in Alberta (Ross and Jalkotzy 1992), Idaho (Hornocker 1970), New Mexico (Sweanor 1990), California (Padley 1990; Beier 1993), Wyoming (Logan *et al.* 1986a; 1986b), Utah, Arizona (Ackerman *et al.* 1984; Hemker *et al.* 1984; Van Dyke *et al.*1986b; Lindzey *et al.* 1988, 1992), and Florida (Maehr *et al.* 1991). In British Columbia radio-telemetry has been the primary research technique for a study in the east Kootenay (Spreadbury 1989) and for an ongoing study on Vancouver Island (Knut Atkinson pers. comm.). This method should also be used when detailed data on cougar biology are required.

This technique involves the initial capture of cougars by pursuit with trained dogs and treeing or baying of cats, immobilization with drugs, fitting of a neck collar with a radio-transmitter to each individual, and relocating the individual on a regular basis for several years.

Advantages of this technique are that the data acquired allow for reliable estimates of home range sizes and densities of resident animals within the study area, provided that most individuals are captured and collared. Even if all animals in a study area are not captured and radio-collared, data from tracks, kills, and knowledge of known individuals can be used to refine population estimates. An additional advantage of radio-telemetry over a capture/recapture method, is that animals are not subjected to stress when repeatedly recaptured with the use of dogs (Harlow *et al.* 1992).

This technique is expensive because of the cost of associated equipment, cost of vehicles or aircraft to track collared animals, and the labour required to monitor movements on a regular basis over a long period of time. However, most studies of cougar populations that are based on field research would require large investments of labour and logistical support, in any case. This type of research project must be extremely well planned to be cost efficient.

Office Procedures

- Obtain relevant 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).
- Select a project area of appropriate size.
- Outline the project area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area from maps.
- Delineate one to many study areas within this project area (this may help you organize your searches).
- Obtain 1:50,000 or 1:20,000 NTS maps, or ordinal air photos so that each relocation of collared cougars can be marked on the maps.

Sampling Design

- It may be useful to stratify the study area according to the inventory objectives. Stratification can be project-specific and will be based on a presumption that the project biologist can distinguish between habitats of different quality based on knowledge of the relationship between the species and its habitat. Stratification may provide a framework to guide trapping efforts or a useful context for relocations.

- There is no strict sampling design for animal capture. If the results of tracking radio-collared cougars are to be extrapolated to other animals in the project area, then theoretically each cougar in the project area should have an equally opportunity of capture so that captures will represent a random sample.
- Systematically search study areas looking for cougar sign by driving along roads.
- Systematically search study areas from the air until a collared cougar is relocated.
- For more information on relocating animals using radio-telemetry, see the manual *Wildlife Radio-telemetry*.

Sampling Effort

- After initial capture of cougars, animals should be relocated on a regular basis (preferably once/week during the survey period) for several years.

Personnel

- A minimum of one biologist and one dog handler are needed to be in the field during capture sessions. Ideally, an additional dog handler and a veterinarian should be along as well (K. Atkinson pers. comm. 1994). Thorough site investigations require an additional biologist (K. Atkinson pers. comm.). Although one biologist can perform radio-telemetry tracking alone, a second person should accompany the biologist when work is conducted in remote areas or under adverse conditions.
- The biologists must be well trained in radio-telemetry procedures, handling of firearms, handling of potentially dangerous wildlife, emergency first-aid, care of immobilized animals, and able to accurately estimate the weight of cats to be drugged. Personnel handling cougars must have taken a provincially certified course on immobilization techniques.
- An experienced dog-handler with trained cougar hounds is required to track and tree cougars that are to be captured and collared.
- If fixed-wing aircraft are used for relocations an experienced bush pilot will be needed.

Equipment

- Four-wheel drive vehicle to access cougar habitat
- Fixed-wing aircraft (e.g. Cessna 172 or 182)
- VHF telephone or portable radio, and first-aid kit in case of personal injury in rugged terrain
- Cap-Chur rifle, dart syringes (use needles with brakes to minimize injury), immobilization equipment
- Ketamine hydrochloride (Vetelar, Ketaset) and xylazine hydrochloride (Rompun)
- Radio transmitters and receivers (Austec, Edmonton, Alberta; Telonics Inc., Mesa, Arizona; Lotek Engineering Inc., Aurora, Ontario; or AVM Instrument Co., Champaign, Illinois)
- Radio collars, ear tags, and tattoo equipment

Field Procedures

Capture

- Drive along roads looking for sign of recent cougar crossings.
- Send cougar hounds after a reasonably fresh cougar track and follow until the cougar is treed or bayed. Cougars bayed on the ground should not be tranquilized, but should be enticed to climb a tree (K. Atkinson pers. comm. 1994).
- Call off dogs and tie them up.
- Shoot the cougar with a dart rifle-fired syringe dart or jab stick containing Ketamine hydrochloride (KHCL) and xylazine hydrochloride (XHCL) mixed at a ratio of 1.0 KHCL:0.5 XHCL at 1 ml/10 kg of cougar body weight. Medetomidine is thought to be a superior drug to XHCL (K. Atkinson pers. comm. 1994).
- Secure the cougar after it becomes immobilized.
- Take standard field measurements (body measurements, and dental characteristics to determine age at capture), tattoo the inside of one ear with a unique number, pre-punch each ear for eartags to speed healing, affix external numbered rototags to both ears, and affix a radio-transmitter collar around the cat's neck.
- Test that the radio-transmitter is working.
- Administer antibiotics.
- Wait for the cougar to regain its motor skills and observe, from a safe distance, as it moves away from the capture site. Use an antagonist to speed recovery time of the immobilized cougar.
- Cougars can also be captured using Aldrich leg-hold snares and baits. This technique is not used as commonly as capture with hounds. The same immobilization and measurement procedures as described above should taken.

Relocation by Radio-telemetry

- Locate each collared animal on a regular basis, preferably about once/week using a fixed wing-aircraft or from the ground.
- Tracking flights can be scheduled 4 times/month and all collared cougars should be located.
- Ground locations can be made by one person using triangulation made from two or more points (three is preferable) less than 1 km from the animal.

Data Analysis

- Home areas are determined by connecting mapped outermost relocations or by the minimum convex polygon method (Mohr 1947). Assuming all resident cougars are accounted for, densities of resident animals can be calculated.
- Determine minimum population densities from home range sizes and known number of animals.
- Use supplemental data to account for transients and kittens in estimating total population.
- Statistical tests should generally be conducted at the 0.05 level of significance.

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.

BED: an impression left in vegetation or dirt when an animal lies down.

BIODIVERSITY: jargon for biological diversity: "the variety of life forms, the ecological roles they perform, and the genetic diversity they contain" (Wilcox, B.A. 1984 cited in Murphy, D.D. 1988. Challenges to biological diversity in urban areas. Pages 71 - 76 in Wilson, E.O. and F.M. Peter, Eds. 1988. Biodiversity. National Academy Press, Washington, D.C. 519 pp.).

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).

BLUE LIST: taxa listed as BLUE are sensitive or vulnerable; indigenous (native) species that are not immediately threatened but are particularly at risk for reasons including low or declining numbers, a restricted distribution, or occurrence at the fringe of their global range. Population viability is a concern as shown by significant current or predicted downward trends in abundance or habitat suitability.

CAP-CHUR RIFLE: a rifle designed to fire tranquilizer darts.

CARNIVORE: a flesh-eating animal.

CARRYING CAPACITY: number of individuals that a given geographic area can support.

CATCHABILITY: the probability that an individual will be equally likely to be observed/captured as any other individual.

CBCB (Components of B.C.'s Biodiversity) Manuals: wildlife species inventory manuals that have been/are under development for approximately 36 different taxonomic groups in British Columbia; in addition, six supporting manuals.

CREPUSCULAR: active at twilight

DART SYRINGE: syringe filled with immobilizing drug in a rifle-fired dart.

DARTING: shooting a dart syringe into an animal.

DEN: to seek a hibernation chamber in the ground or hollow tree.

DESIGN COMPONENTS: georeferenced units which are used as the basis for sampling, and may include geometric units, such as transects, quadrats or points, as well as ecological units, such as caves or colonies.

DISPERSAL: movement of non-resident individuals to new areas, usually young animals.

DISTRIBUTION: the range of occurrence of a species throughout a geographic area.

DIURNAL: active during the daytime.

DOG HANDLER: person that owns and controls a pack of dogs trained to pursue and tree cougars, and other animals.

ECOPROVINCE: areas of consistent climate or oceanography, and physiography. There are nine terrestrial and one marine ecoprovince in British Columbia (e.g. Southern Interior Mountains).

ECOREGION: areas with major physiographic, minor microclimatic or oceanographic differences within each ecoprovince. There are 43 ecoregions in British Columbia (e.g. Mackenzie Plains).

EWG (Elements Working Group): a group of individuals that are part of the Terrestrial Ecosystems Task Force (one of 7 under the auspices of RIC) which is specifically concerned with inventory of the province's wildlife species. The EWG is mandated to provide standard inventory methods to deliver reliable, comparable data on the living "elements" of BC's ecosystems. To meet this objective, the EWG is developing the CBCB series, a suite of manuals containing standard methods for wildlife inventory that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species populations.

EXTRATERRITORIAL MOVEMENT: movements of animals outside their normal territory.

GEOGRAPHIC CLOSURE: an assumption that individuals do not leave a study area, or new individuals enter a study area.

HARVEST: basic data on sex, age, and location of animals killed during a legal hunting season.

HOME RANGE: the total geographic area used by an individual.

INVENTORY: the process of gathering field data on wildlife distribution, numbers and/or composition. This includes traditional wildlife range determination and habitat association inventories. It also encompasses population monitoring which is the process of detecting a demographic (e.g. growth rate, recruitment and mortality rates) or distribution changes in a population from repeated inventories and relating these changes to either natural processes (e.g. winter severity, predation) or human-related activities (e.g. animal harvesting, mining, forestry, hydro-development, urban development, etc.). Population monitoring may include the development and use of population models that integrate existing demographic information (including harvest) on a species. Within the species manuals, inventory also includes, species statusing which is the process of compiling general (overview) information on the historical and current abundance and distribution of a species, its habitat requirements, rate of population change, and limiting factors. Species statusing enables prioritization of animal inventories and population monitoring. All of these activities are included under the term inventory.

KITTEN: a juvenile cougar dependent on its mother.

MARK TRAIL: trails with distinct bear foot impressions etched semi-permanently into the ground or vegetation.

MARK-RECAPTURE METHODS: Methods used for estimating abundance that involve capturing, marking, releasing, and then recapturing again one or more times.

MICROSITE: an extremely small-scale habitat used for particular purposes.

MINIMUM CONVEX POLYGON: the total area used by animals determined by connecting the outermost locations plotted on a map.

MONITOR: to follow a population (usually numbers of individuals) through time.

NOCTURNAL: active at night.

OBSERVATION: the detection of a species or sign of a species during an inventory survey. Observations are collected on visits to a design component on a specific date at a specific time. Each observation must be georeferenced, either in itself or simply by association with a specific, georeferenced design component. Each observation will also include numerous types of information, such as species, sex, age class, activity, and morphometric information.

PACK: a number of wolves that travel and associate together.

POPULATION DYNAMICS: underlying causes of population size (mortality, fecundity, immigration, emigration).

POPULATION: a group of organisms of the same species occupying a particular space at a particular time.

PRECISION: a measurement of how close repeated measures are to one another.

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).

PREY BIOMASS: the number of individual prey animals present in a specified geographic area, corrected for size differences between prey species.

PREY KILL SITES: sites where remains of prey killed by a predator are found.

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 for species generally takes place within smaller, representative study areas so that results can be extrapolated to the entire project area.

PROJECT: a species inventory project is the inventory of one or more species over one or more years. It has a georeferenced boundary location, to which other data, such as a project team, funding source, and start/end date are linked. Each project may also be composed of a number of surveys.

PUP: a juvenile wolf dependent on its mother.

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.

RED LIST: taxa listed as RED are candidates for designation as Endangered or Threatened. Endangered species are any indigenous (native) species threatened with imminent extinction or extirpation throughout all or a significant portion of their range in British Columbia. Threatened species are any indigenous taxa that are likely to become endangered in British Columbia, if factors affecting their vulnerability are not reversed.

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.

REPLICATE: repeated surveys of the same survey area.

RIC (Resources Inventory Committee): RIC was established in 1991, with the primary task of establishing data collection standards for effective land management. This process involves evaluating data collection methods at different levels of detail and making recommendations for standardized protocols based on cost-effectiveness, co-operative data collection, broad application of results and long term relevance. RIC is comprised of seven task forces: Terrestrial, Aquatic, Coastal/Marine, Land Use, Atmospheric, Earth Sciences, and Cultural. Each task force consists of representatives from various ministries and agencies of the Federal and BC governments and First Nations. The objective of RIC is to develop a common set of standards and procedures for the provincial resources inventories. [See http://www.for.gov.bc.ca/ric/]

SCAT: solid animal faeces

SCENT STATION: a baited or scented area designed to attract carnivores for the purpose of detecting their presence.

SCENT-MARK: urination or defecation to mark territory.

SCRAPES: areas of ground scratched and pawed to mark territory

SIGN: evidence of animal occurrence including scats, tracks, scrapes, kill sites, and hair.

SIGN COUNT: a survey technique that relates the amount of sign observed along a linear survey path.

SITE FIDELITY: faithfulness, over time, of an individual or group to a particular site or area.

SNARE: a trap designed to capture animals by encircling the neck with wire cable.

SPI: abbreviation for ‘Species Inventory’; generally used in reference to the Species Inventory Datasystem and its components.

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 RIC method to one taxonomic group for one season.

SURVIVORSHIP: the probability of a new-born individual surviving to a specified age.

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

TERRESTRIAL ECOSYSTEMS TASK FORCE: one of the 7 tasks forces under the auspices of the Resources Inventory Committee (RIC). Their goal is to develop a set of standards for inventory for the entire range of terrestrial species and ecosystems in British Columbia.

TERRITORY: a defended geographic area used for breeding or feeding.

TRACK: the imprint of an animals foot in dirt or snow.

TRACK COUNTS: a survey technique where animal tracks are found and quantified.

TRANSECTS: a survey technique where survey routes are run along series of straight lines and data are recorded from within preset distances from the transect line.

TRANSIENT: a non-resident animal moving through an area.

TRIANGULATION: the process of taking directional readings of one radio-collared animal from three different points, in order to determine precise location of an individual.

UNGULATE: large herbivorous hoofed mammals including moose, deer, elk, sheep, mountain goat, caribou, and bison.

WILDLIFE MANAGEMENT UNIT: a geographic unit designated by the B.C. Wildlife Branch for the purpose of managing wildlife

YELLOW-LIST: includes any native species which is not red- or blue-listed.

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