Inventory Methods for Bears

Standards for Components of British Columbia's Biodiversity No. 21

Prepared by
Ministry of Environment, Lands and Parks
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Resources Inventory Committee

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Preface

This manual presents standard methods for inventory of bears 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 groups 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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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. The current version of this manual is the result of the hard work and expertise of Grant MacHutchon and John Boulanger. The background information and many protocols presented in this document were originally based on the unpublished government report, *Standardized Methodology for the Inventory of Biodiversity of British Columbia: Large Terrestrial Carnivores (Black Bear, Grizzly Bear, Gray Wolf, Cougar),* 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, and B. Spreadbury.

The Standards for 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

Grizzly bears (*Ursus arctos*) and black bears (*Ursus americanus*) have traditionally been given a high profile by wildlife managers and the public and are valued by hunters. As a result, considerable time, money and effort has gone into trying to inventory black bears and grizzly bears in North America. Numerous methods have been tried because of the range of habitats and densities that bear populations are found, the variability in inventory objectives (presence/not detected, relative abundance, absolute abundance), and the range of available resources. At normal population densities, presence/not detected information is relatively easy to determine, however, as population densities decrease the effort required to document presence increases. Relative and absolute abundance estimates require more expensive and labour intensive field procedures. There are few good techniques for deriving accurate, objective and repeatable estimates of population size and density for bears (Miller *et al.* 1987, 1997). A number of factors make it difficult to determine the relative or absolute abundance of bears, including:

- Behaviour, habitat use, and movements often make bears difficult to observe or capture.
- Bear sign is not easily distinguishable as grizzly or black bear where the two species occur together.
- Black bears and grizzly bears den for 5-7 months of the year, so sampling opportunities are restricted.
- Seasonal concentrations of bears where food density is high (e.g., salmon spawning areas, berry patches) can make them easier to count, but:
    - the attractiveness of these areas may vary annually according to the production and availability of different forage items.
    - the timing of peak attractiveness may vary each year.
    - some individuals or age/sex classes may not use these food concentrations or may have different spatial or temporal use of the area.
- Age/sex classes are difficult to determine without direct handling.
- Individual bears and different age/sex classes likely have different probabilities of capture or sightability.
- Bears generally occur at low densities and have large home ranges, low rates of harvest and inherent difficulties for capture or resighting, therefore, sample sizes available for population analyses are often small.

Methods for determining bear presence have focused on sign, sightings, or capture. Methods for quantifying relative abundance have included harvest assessment, habitat assessment, direct counts at seasonal concentrations, and various forms of catch per unit effort (CPUE), including sign counts, hunter effort, bait or scent stations, and remote cameras. Methods for determining absolute abundance or density have included counts of known bears in an area, total aerial census of an area, combinations of capture and intensive telemetry, and several forms of mark–recapture including aerial capture–mark–resight (CMR), hunter capture–mark–resight, camera capture–mark–resight, and DNA mark–recapture (Manning *et al.* 1994).

The objectives of this manual are to:

1. recommend the best methods for censusing populations of black bears and grizzly bears at stations throughout British Columbia; and
2. provide protocols for these survey methods at different levels of intensity (i.e., presence/not detected, relative abundance, absolute abundance).

2. Inventory Group

2.1 Black Bear (*Ursus americanus*) M-URAM

2.1.1 Distribution

Black bears are year-round residents in all terrestrial Ecoprovinces and almost all Biogeoclimatic zones of British Columbia. Nagorsen (1990) recognized five subspecies for the province, of which three are considered endemic. *Ursus americanus vancouveri* is found only on Vancouver Island, *U. americanus carlottae* is found only on the Queen Charlotte Islands, and *U. americanus kermodei* is found only in the north central part of the Coast and Mountains Ecoprovince. The two other subspecies are *U. americanus altifrontalis* found in the southern Coast and Mountains Ecoprovince and *U. americanus cinnamomum* found throughout the central and eastern part of the province. Another subspecies, *U. americanus emmonsii,* has not been verified for the province by specimens (Nagorsen 1990), however, it is on British Columbia's Blue list of mammals at risk (Harper 1996). *U. americanus emmonsii* is considered to be found in the extreme northwest of B.C. in the Northern Boreal Mountains Ecoprovince.

The five subspecies of black bear described for B.C. were distinguished based on morphology and skull and dental characteristics. There is some DNA evidence to suggest that these subspecies may be more closely related than first thought (T. Hamilton, BC MELP, Victoria, pers. comm.). The subspecies status of black bears in B.C. is likely to change when DNA data are more completely analyzed.

2.1.2 Status

Black bear populations of B.C. are considered to be stable with an estimated 120,000 animals (Wildlife Branch 1991). The black bear is currently on British Columbia's Yellow list of species, with the exception of *U. americanus emmonsii* which is Blue-listed (Harper 1996).

2.1.3 Home Range

Home ranges of black bears vary in size depending on the age and sex of the bear and where they live in the province. Male bears generally have larger home ranges than female bears and coastal black bears generally have smaller home ranges than interior black bears. In western Canada, male home ranges have been reported to be from 55 to 500 km^2 and female home ranges to be from 10 to 125 km^2 (MacHutchon and Smith 1990).

2.1.4 Diet and Habitat Use

After den emergence, black bears move to valley bottoms or south-facing slopes where snow melt is fastest. They will scavenge winter-killed and avalanche killed animals if available, but largely subsist on emerging green vegetation such as horsetail (*Equisetum* spp.), sedges (family Cyperaceae), grasses (family Poaceae) and forbs.

In spring, black bears will feed in wetlands, wet meadows, clearcuts, lake shores and river estuaries. Avalanche chutes and wet seepage areas on south-facing slopes are favoured feeding areas as snowmelt proceeds upslope. Open, south-facing slopes with mixed stands of deciduous and coniferous forest are well-used spring habitat in drier valleys. If emerging vegetation is not very abundant on dry slopes black bears will feed on overwintered berries such as bearberry (*Arctostaphylos uva-ursi*). In some areas, black bears prey on ungulate calves shortly after they are born in the spring. On the coast, intertidal areas are used for foraging on forbs as well as marine invertebrates.

In the summer, black bears find an abundance of forbs and ripening berries in forest openings, clearcuts and on avalanche chutes. In dry, less productive areas, there may be a period during which they primarily feed on insects, particularly ants, before berries ripen.

On the coast, black bears feed on spawning salmon when they become available in late summer. Prior to denning when the numbers of spawning salmon decline, black bears will feed on huckleberries (*Vaccinium* spp.) or forbs such as skunk cabbage (*Lysichiton americanum*). In the interior, black bears feed on berries from mid-summer until denning. In the fall, old burns and clearcuts are well-used feeding areas because of the abundance of fruit. As fruit ripens, some black bears move to higher elevations.

Black bears den in excavations under the roots of trees, in hollows under the roots of wind-thrown trees, in the trunks of large, standing or fallen dead trees, and in natural caves.

2.2 Grizzly Bear (*Ursus arctos*) M-URAR

2.2.1 Distribution

Grizzly bears inhabit most of the province except Vancouver Island, the Queen Charlotte Islands, smaller coastal islands, the lower mainland and portions of the south-central interior. Only one subspecies, *U. arctos horribilis*, is recognized for the province of British Columbia (Nagorsen 1990).

2.2.2 Status

Fourteen grizzly bear zones have been identified for Canada. Of these, all or a portion of nine zones are contained in B.C. (Fuhr and Demarchi 1990, Banci 1991). In a status review done for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Banci (1991) recommended that populations in the Hot Dry Plateau zone of south central B.C. be considered threatened, and populations in four other zones be considered vulnerable. The grizzly bear is currently on British Columbia’s Blue list of species (Harper 1996). Fuhr and Demarchi (1990) and Banci (1991) estimated approximately 13,000 grizzly bears for the province.

2.2.3 Home Range

Home ranges of grizzly bears vary in size depending on the age and sex of the bear and where they live in the province. Coastal bears tend to have smaller home ranges than interior bears and home ranges of males are generally larger than those of females. In western Canada, home ranges have been reported to be from 100 to 1300 km^2 for adult males, 20 to 430 km^2 for adult females, 30 to 1500 km^2 for subadult males, and 20 to 140 km^2 for subadult females (Banci 1991, MacHutchon *et al.* 1993).

2.2.4 Diet and Habitat Use

Grizzly bears are omnivorous and feed on a diversity of foods including, vegetation, berries, insects, small and large mammals, carrion, and fish.

Coastal grizzly bears feed on emerging green vegetation in the spring such as skunk cabbage and sedges found on estuaries and in wet areas. They follow the receding snow up avalanche chutes to feed on emerging vegetation and roots. In the summer, they move back to valley bottoms and sidehills where they feed on a number of berry species including: devil's club (*Oplopanax horridus*), salmonberry (*Rubus spectabilis*), elderberry (*Sambucus racemosa*), dogwood (*Cornus stolonifera*) and huckleberry. Coastal grizzly bears begin feeding on salmon in mid-summer and continue to do so until late fall. Once salmon availability declines, grizzly bears return to feeding on skunk cabbage and other vegetation.

Interior grizzly bears feed mainly on the roots of *Hedysarum* spp. and carrion, and opportunistically prey on winter-weakened ungulates in the spring. As green vegetation emerges, grizzly bears will graze on grasses, horsetails, rushes (family Cyperaceae) and sedges. Grizzly bears also prey on ungulate calves shortly after they are born in the early summer. In mid-summer when berries ripen, grizzly bears spend a great deal of time feeding on soapberries (*Shepherdia canadensis*), blueberries (*Vaccinium* spp.) and huckleberries. Berries remain important throughout the fall. As well, grizzly bears will return to digging *Hedysarum* spp. roots. In some parts of interior B.C., grizzly bears will prey on small mammals such as ground squirrels (*Spermophilus* spp.). Ground squirrels are most easily captured in late summer after they have aestivated. Both coastal and interior grizzly bears will feed on insects and insect larva when the opportunity arises.

Grizzly bears use a variety of habitats in B.C. from coastal estuaries to alpine meadows. Habitat use is primarily influenced by food distribution and abundance, and the presence of other bears. Grizzly bears must consume high quality food in relatively large quantities to meet their daily energy requirements, as well as to develop fat reserves for denning.

Dens are generally located at higher elevations in areas of deep snowfall and relatively slow snowmelt. Dens may be located in natural caves, hollows under the roots of trees, or they may be excavated under the roots of trees or dug into steep slopes.

3. PROTOCOL

Inventory methods for bears in British Columbia are usually appropriate for both grizzly bears and black bears. There are several differences between the species, however, that may affect the selection of an inventory method. Black bears usually occur at higher densities than grizzly bears, therefore sample sizes are often larger. Grizzly bears generally have larger home ranges than black bears, therefore the study area must also be larger to include the home ranges of all individuals in the population of interest. Because black bears are found in some areas of B.C. that grizzly bears are not, the problem of differentiating the two species is not always a concern.

If black bears are present in an area used by people their presence is generally known. It is often difficult, however, to know when grizzly bears are present in the same area if they occur at low densities. Many people do not distinguish between the two species easily. Consequently, some effort may be required to establish the presence or continuing presence of grizzly bears at the periphery of their range in B.C.

The objective of estimating absolute abundance on a study area will usually be to derive a density estimate. This density estimate, when extrapolated to a larger management area, is often used to estimate the size of the bear population in the management area. This population estimate is then used to derive harvest rates, to predict sustainable harvest levels or to assess the impact of development. If researchers or managers are planning to apply their inventory results in this way then they should address several important issues before proceeding with the inventory:

- The study areas should be physically and biologically representative of the larger management area and should include all habitats used or potentially used by bears.
- If study areas <u>only</u> include habitats which are used by bears then the density estimate is only applicable to that proportion of the management area that is used by bears. If this density estimate is applied over the entire management area, including habitats rarely or never used by bears, then it will over estimate the true population.
- Habitat use or selection may change as the mosaic of available habitat changes, therefore, application of habitat-specific densities beyond the study area may be inappropriate as the landscape context changes.
- The population of interest should be defined and the sample population should be representative of this population. For inventories at seasonal concentrations, this requires determining the overall range of the bears using the concentration.

3.1 Survey Standards

The following are guidelines for conducting inventories of bears 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 grizzly bears from black bears, particularly during aerial surveys. Observer ability should be tested and each person should receive training in bear identification. Furthermore, experienced personnel are required during track, scat, and sign surveys due to the difficulty associated with differentiating black bears and grizzly bears using these inventory methods. To maintain consistency and accuracy throughout the inventory sessions, it is recommended the same surveyors be present.

During inventory surveys involving capture and radio-marking, 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. 3, *Live animal capture and handling guidelines for wild mammals, birds, amphibians, and reptiles.*

3.1.2 Time of Year

To assess annual population trends (relative abundance), inventory surveys should be conducted under comparable conditions each year, although this is often difficult to achieve. Variability in the abundance and distribution of food between survey years can have a major impact on the timing of maximum concentrations at seasonal aggregations and can affect the attractiveness and placement of bait stations used in DNA hair capture surveys.

When bear surveys are conducted at seasonal berry or salmon concentrations, an independent measure of changes in berry/salmon abundance is essential. Sources such as the Department of Fisheries and Oceans stream inventory reports, fisheries officers, anglers and local residents can provide information on yearly changes in salmon numbers and the timing of peak spawning. At berry concentrations, a quantitative measure of the crop success should be made and berry development should be monitored so surveys can be timed to coincide with the maximum succulence of the berry crop. When collecting inventory data at seasonal aggregations (berry or salmon concentrations), a number of replicate surveys are necessary each year to maintain consistency between years.

To estimate population density (absolute abundance), capture–mark–resight surveys should be conducted in the early spring after all bears have left their dens, but before trees and shrubs have leafed out. This estimator requires capturing and marking bears >1 year prior to the density estimates. DNA mark–recapture surveys are recommended for the spring or summer when natural foods are scarce and bears are more likely to approach baited hair capture stations. On the coast, DNA mark-recapture surveys are likely best before berries are available in mid to late June. In the interior, surveys are likely best prior to the berry season in mid to late July. Bears are shedding their winter coats in the spring and summer, therefore there is a greater likelihood of obtaining hair follicles in samples during that time period.

3.1.3 Habitat Data Standards

- A minimum amount of habitat data should 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 terrestrial-based wildlife, the terrestrial Ecosystem Field

Form developed jointly by MOF and MELP (in 1995) should be used where appropriate. Under certain circumstances, the terrestrial Ecosystem Field Form may be inappropriate and other RIC-approved standards for ecosystem description may be used. For a description of approaches to habitat data collection in association with wildlife inventory, consult the manual *Species Inventory Fundamentals (No. 1).*

3.1.4 Considerations for DNA Based Techniques

Both mitochondrial DNA (mtDNA) and nuclear DNA (nDNA) can be extracted from blood, muscle tissue, hair follicles or tissue sloughed off in scats. Species identification is possible with mtDNA and sex determination, individual identification, and relatedness is possible with nDNA. Obtaining blood and muscle tissue samples usually requires physical restraint of the animal, however, hair and scat samples can be collected unobtrusively in the field. The ability to extract and analyze DNA from hair samples has led to the development of a DNA mark–recapture technique for bear population estimation. This technique was pioneered in B.C. by J. Woods (Parks Canada), B. McLellan (B.C. Ministry of Forests), D. Paetkau (University of Alberta), M. Proctor (University of Calgary), and C. Strobeck (University of Alberta) and is outlined in detail under DNA mark–recapture in section 3.6 Absolute Abundance. The procedure for extracting and analyzing DNA from scat samples has recently been developed and shows considerable promise but it is not yet as well established as the hair analysis technique (Wasser *et al.* 1997).

Analysis of DNA from hair samples (or scats) has great utility for all levels of bear inventory intensity, including presence/not detected, relative abundance, and absolute abundance. Mitochondrial DNA can be used to identify species in areas where grizzly bears and black bears overlap. Nuclear DNA can be used to identify different individuals of the same species within a population. Once a bear's genetic identity has been determined from a sample of its nDNA, that individual can be considered to be permanently "marked" for open or closed population mark–recapture studies.

Despite the utility of DNA analysis in inventory surveys, there are several considerations that people should be aware of when designing DNA based surveys:

- Sex determination is by polymerase chain reaction (PCR) amplification of the Y chromosome specific SRY gene in the nDNA, however, this test needs to be refined because it is susceptible to small amounts of contamination resulting in potentially false results (Woods and McLellan 1997).
- Microsatellite markers (a suite of variable Short Tandem Repeat (STR) sequences of DNA) are used to identify individuals (Paetkau and Strobeck 1994, Paetkau *et al.* 1995). The number of microsatellite markers required to get a high level of confidence in identifying individuals depends on the amount of genetic variation in the bear population. Generally, 6-8 microsatellite markers should give a high confidence in identifying individuals (D. Paetkau, University of Alberta, Edmonton, pers. comm.), however, the number of markers required may be higher if the population is found to have low genetic variability. Grizzly bears on Kodiak Island, Alaska have been found to have much lower levels of genetic variability than mainland grizzly bear populations and black bears on the island of Newfoundland have been found to have low levels of genetic variation compared to mainland populations (Paetkau and Strobeck 1994). The genetic variability of the bear population being studied should be evaluated prior to an intensive DNA based survey. Allele distributions at several microsatellite marker loci can be used

to generate probabilities of error for each population with a background sample of 30-50 different genotypes (Woods and McLellan 1997).

- Microsatellite marker loci that are highly variable in one bear population may not be as variable in another population. The initial analysis of population genetic variability described above should use as many microsatellite markers as possible to determine which markers are the most variable and, therefore, the most useful for individual identification. Following this initial analysis, a subset of the most variable markers can be used for subsequent identification of individuals, provided the population is found to have sufficient genetic variability. An initial analysis with a minimum of 8 different microsatellite markers is recommended.
- The techniques for analysis of DNA from bear hair samples were developed and refined at a research lab at the University of Alberta. These techniques have not been transferred to a commercial lab in western Canada without considerable start-up problems, initial expense, and time delays. As a result, there are currently few commercial labs available to analyze hair samples. In addition, microsatellite marker analysis of DNA extracted from hair can be relatively difficult to do and often requires a lot of time. Consequently, there can be a significant time lag between when hair samples are collected and when the DNA analysis is complete.
- Different labs can get different estimates of allele sizes at the same locus for the same individual. The allele size refers to the actual length of the DNA repeat, so theoretically the numbers should be exactly the same. The observed differences may be due to one or two reasons:

    1. Products of the Polymerase Chain Reaction (PCR) may run differently because of differences in the separation chemistry used in each lab (O. Bres, Northern Bioidentification Service Ltd., Winnipeg), and/or
    2. Each lab may have slightly different rules for assigning the amplification results at each loci to an allele size. Different alleles can be as little as 2 base pairs apart, so the correct categorization of the results is important.

    It is important to recognize these potential differences between results from different labs, particularly if projects are considering switching labs or if people are comparing results between projects that used different labs.
- A series of blind samples and known duplicates should be sent to labs for repeatability control and to ensure the lab is following strict protocols.
- Once samples have been analyzed, a permanent identification number should be assigned to each bear identified.

3.1.5 Survey Design Hierarchy

Bear 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 DNA mark-recapture survey for bears. A survey set up following this design will lend itself well to standard methods and RIC data forms.

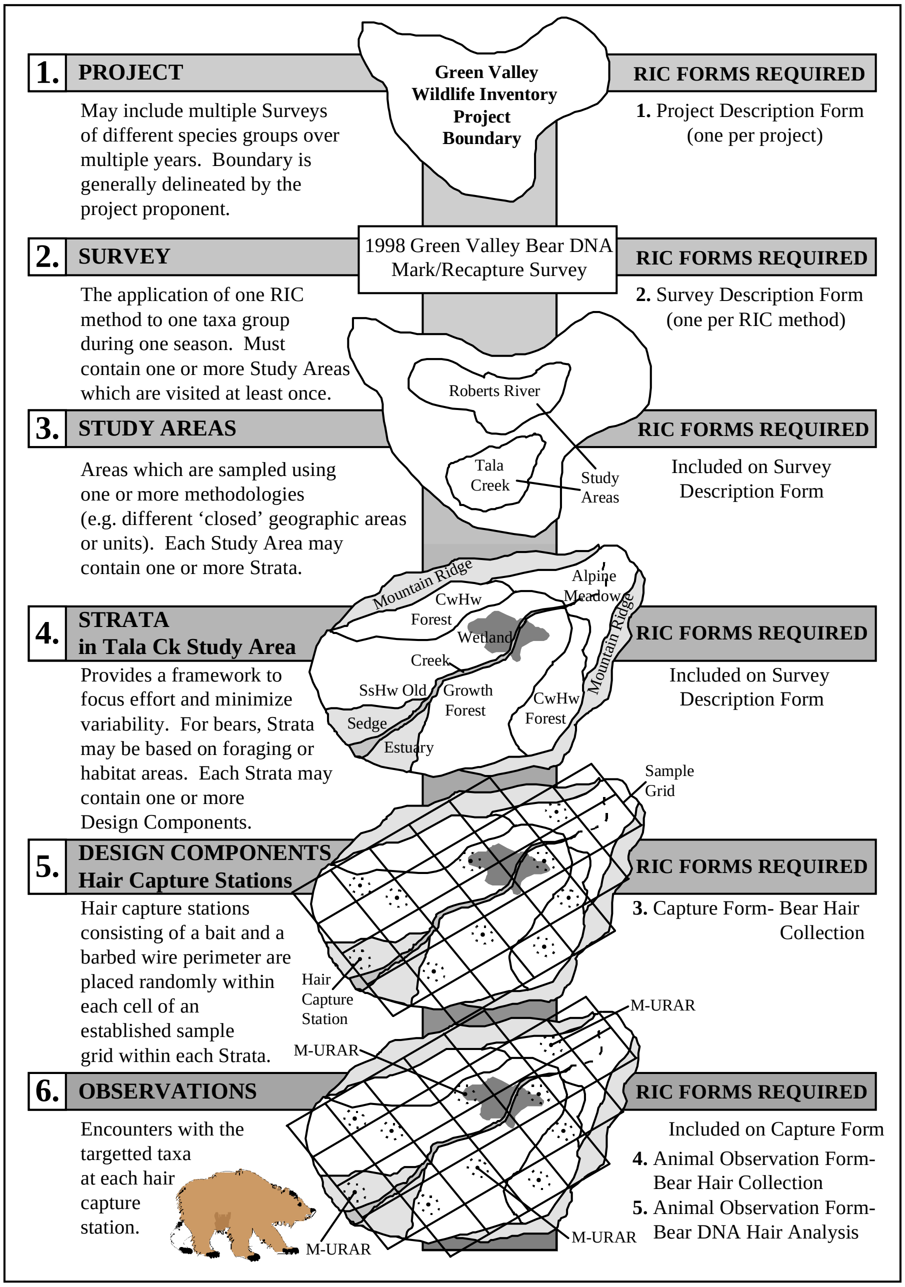


Figure 1. RIC species inventory survey design hierarchy with examples.

3.2 Preliminary Survey

Before conducting field inventories of bears, it is recommended that a preliminary survey be carried out. Preliminary surveys may take the form of personal interviews, mail-out questionnaires, or an evaluation of licensed hunting records. Questionnaires and hunting records are useful for obtaining cursory information on animal presence, distribution, as well as relative trends within or between areas over time. Population trend and distribution results gained from preliminary surveys are only applicable on a large geographic scale (i.e., national, provincial, or regional) 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. Additionally, hunter records may be inaccurate for determining relative abundance because the frequency of kills in various areas may reflect ease of access for hunters, rather than the relative abundance of bears. Thus, preliminary surveys should only be used as a source of supplemental data for determining large scale distribution patterns and relative abundance.

Office Procedures

- Review the introductory manual, *Species Inventory Fundamentals, No. 1*.
- Select a geographic area to be surveyed.
- Obtain relevant maps for the project area.
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area. This may be a useful way to stratify your questioning effort.
- Develop a list of people to include in the preliminary survey. Include biologists, foresters, conservation officers, park rangers, trappers, hunters, guide-outfitters, ranchers, farmers, and animal control personnel; the portion of the population who are most likely to encounter bears and to provide positive identification.
- Design a mail-out or interview questionnaire so that respondents provide data on: (1) location, dates, and numbers of bears involved for individual sightings, and (2) location and details of bear sign observed.
- For an examination of hunter records refer to Harris and Metzgar (1987a and 1987b), Garshelis (1990), Miller (1990a), and Miller and Miller (1990).
- Compulsory inspections and submission of harvest data are only required of successful grizzly bear hunters in B.C., so harvest data analysis is only appropriate for grizzly bear inventory.
- Consult with a statistician or quantitative ecologist who is familiar with the analysis of harvest, interview, and mail-out questionnaire data.
- Investigate historic harvest patterns, prior to compulsory inspection requirements, if it appears that it will provide some insight into current harvest patterns.
- Try to define the limitations and potential biases of the data obtained from preliminary surveys.

Sampling Design

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

Sampling Effort

- The amount of effort expended on a preliminary survey depends on the bear species of interest, the survey objectives and the level of survey intensity. For example, if the bear species is very difficult to detect, preliminary surveys may be extremely useful in identifying where to concentrate inventory efforts. For other situations, preliminary surveys may provide a coarse overview before delving into more intensive inventory techniques.
- The time required for harvest data analysis will depend on the complexity of the data, the number of confounding variables, and the questions being asked. If the required data can be easily extracted, then a review of temporal changes in the age and sex composition of the harvest may only take a few days.

Personnel

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

Equipment

- Maps of the project area
- Computer; data manipulation and analysis software

Field Procedures

- Map existing bear sightings to determine distribution.
- Compare presence/not detected and relative abundance at a regional or local scale using geographic boundaries or Biogeoclimatic zones.

Data Analysis

- Three main categories of harvest analysis are typically used by management agencies: total harvest, harvest sex ratio, and harvest age structure (Garshelis 1990). Many management agencies use total harvest as an indicator of population trend. Assuming harvest mortality rates are constant across years, trends in total harvest should reflect trends in population size. Meeting the assumption of constant harvest rate can be difficult, however. Harvest rate could change as a result of changes in hunter effort, the number of hunters, hunter access, and the vulnerability of bears (Garshelis 1990). Total harvest of black bears is currently used in B.C. to infer population changes, however, total harvest is estimated by dividing the number of hunters by their success rate and success rate is determined by hunter survey (Garshelis 1990).
- If data are used cautiously, the most useful harvest data analyses for assessing population trends are changes in both the sex and age composition of the harvest (Miller 1990a). Male bears are generally more vulnerable to harvest than female bears for a variety of reasons (Bunnell and Tait 1980). As a result, there are three general patterns of an overharvested population: a decreasing ratio of males to females with age, a decreasing average age of harvested males, and an increasing average age of harvested females. Unfortunately, none of these indicators alone or in combination necessarily indicates a population change. A number of confounding factors can affect how these variables change with harvest such as, differences in sex-specific non-harvest mortality, differences in the sex ratio of young bears prior to being harvested, changes in the

relative vulnerability of males and females, the natural age structure of the population is not stationary for some reason, changes in hunter effort and selectivity, changes in harvest regulations, and small sample sizes (Harris and Metzgar 1987a, 1987b; McLellan and Shackleton 1988; Garshelis 1990; Miller and Miller 1990). By observing changes in the age and sex composition of the harvest, most managers can detect a severe population decline, however, detecting bear population declines at their outset, particularly with low harvest rates, is very difficult (Harris and Metzgar 1987a, 1987b). Correctly interpreting changes in the sex and age composition of the harvest requires some understanding of the dynamics of the population in question and the hunters exploiting that population. With all the confounding factors potentially affecting changes in the harvest, cautious analysis and interpretation are necessary.

- Hunter effort analysis also has some merit as part of an overall examination of harvest trends, however, changes in hunter effort can be caused by many factors and, therefore, it is difficult to determine when they reflect real population changes. A change in hunter effort could be associated with a population change, however, it could also indicate changes in bear vulnerability, habitat, regulations, hunting season emphasis, the number of hunters, hunter ability, or methods of hunting (MacHutchon and Smith 1990). Data should be adjusted to correct for as many confounding variables as possible (Miller 1990a). Hunter effort is usually measured as the number of days hunted per bear killed. This information may come from compulsory submissions or hunter questionnaires. Increases in the number of bears killed under conditions where effort is constant may suggest an increasing bear population. The same increase in kill, where effort is also increasing, may suggest an increased exploitation rate and a declining bear population (Miller 1990a, Nagy and Gunson 1990). Hunter effort data are highly variable and statistical tests seldom reveal significant differences (Miller 1990a).

3.3 Inventory Surveys

Table 1 outlines the type of field surveys that are recommended for inventorying bears for various survey intensities. These survey methods have been recommended by wildlife biologists and approved by the Resources Inventory Committee (RIC). Grizzly bears and black bears are not differentiated in Table 1 or in the following discussion except where differences between the two species are considered particularly relevant.

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

Survey Type	Forms Needed	Intensity
Bear Sign & Sightings	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form-General • Animal Observation Form- Bear Sign & Sightings • Ecosystem Form	• PN
Bear (Aerial & Ground) Counts at Seasonal Concentrations	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form-General • Animal Observation Form- Bear Counts at Seasonal Concentrations • Ecosystem Field Form (for ground counts)	• RA
DNA Mark–Recapture for open (RA) or closed (AA) population models	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form-General • Capture Form - Bear Stations • Animal Observation Form - Bear Hair Collection • Animal Observation Form - Bear Hair DNA Analysis • Ecosystem Form • Animal Observation Form - Bear Relocation by Radio-telemetry (may be used for demographic closure check)	• RA • AA
Aerial Capture - Mark-Resight (CMR) or Capture–Telemetry	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form-General • Capture Form - Bear Stations • Animal Handling Form - Capture: Bear • Animal Observation Form - Bear Relocation by Radio-telemetry	• AA

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

3.4 Presence/Not Detected

Recommendation(s): Bear sign in combination with bear sightings could be used to determine bear presence and distribution throughout B.C.

The results from sign and sighting surveys should be substantiated by hair capture or scat collection and DNA analysis whenever possible. Both mitochondrial DNA (mtDNA) and nuclear DNA (nDNA) can be extracted from hair follicles or tissue sloughed off in scats. Species identification is possible with mtDNA and individual identification is possible with nDNA. The specific protocol for setting up hair capture stations and analyzing hair samples is outlined in section 3.6 Absolute Abundance. The procedure for extracting and analyzing DNA from scat samples has recently been developed and shows considerable promise but it is not yet as well established as the hair analysis technique (Wasser *et al.* 1997).

It is recommended that all presence/not detected surveys use methods that can be replicated to provide data of statistical value (Boulanger and Krebs 1997). Whenever possible presence/not detected surveys should use identical methods to relative abundance surveys so that the presence/not detected data can be used as preliminary data (i.e., for power analysis or sample size determination) for planning relative abundance surveys.

3.4.1 Bear Sign and Sightings

Bear sign has been used as an indicator of bear presence in two main ways. It has been used to help determine the existence of bears in areas where their current status was unknown (Trevino and Jonkel 1986) and it has been used to evaluate bear use of different habitats in areas already known to support bears (Hamer and Herrero 1983, Herrero *et al.* 1986, McCrory *et al.* 1986, McCrory and Mallam 1991).

Trevino and Jonkel (1986) used sign, sightings and a short-term attempt at capture to try and confirm whether grizzly bears were still present in northern Mexico. Their data led them to suspect grizzly bears were still present, but because black bears occurred in the same area, they could not be certain.

Herrero *et al.* (1986) and McCrory *et al.* (1986) used bear sign to subjectively rate bear habitat use. They used that rating in conjunction with a subjective rating of potential use, which was based on the presence and abundance of known bear foods, to derive a bear hazard rating. The hazard rating reflected the potential for bear – human conflict in a specific habitat or an area that contained several habitats. Bear sign and potential bear use were recorded along transects which were laid out to sample all the apparent habitats in an area (Herrero *et al.* 1986). The bear hazard evaluation method of Herrero *et al.* (1986) and McCrory *et al.* (1986) has been used by BC Parks and other government agencies for planning visitor facilities (McCrory and Mallam 1991). B.C. government biologists and technicians responsible for evaluating development referrals often have to rely on bear sign to judge bear presence and use of a habitat or watershed (T. Hamilton, BC MELP, Victoria, pers. comm.).

Using sign to determine presence can be simple and cost effective if bears occur at medium to high densities. However, there are some limitations to this method: 1) experienced personnel are required to differentiate sign from separate bear species where grizzly and black bears occur together, 2) a lack of bear sign or a lack of fresh bear sign may not indicate an absence of bears, but may be the result of low bear densities or only seasonal or periodic use of an area, and 3) some bear sign, such as mark trees, are persistent, therefore they may indicate past, but not necessarily current, use.

Sightings are a good way of documenting the presence of bears in an area. Obtaining sightings can be relatively simple and cost effective, however, where both grizzly bears and black bears occur many people find it difficult to distinguish between the two species therefore, the reliability of sightings has to be critically evaluated. In addition, people have been known to purposely mis-represent sightings to further a political cause.

Office Procedures

- Review the introductory manual, No. 1, *Species Inventory Fundamentals*.
- Obtain maps for project and study area(s) (*e.g.*, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- 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.
- Establish the intended use of the presence/not detected information and the probable density of bears (i.e., very low, low, medium, high) within the project area. These two

factors will determine the level of effort required and the specific survey protocol. Three expected scenarios are:

- *Scenario 1* – Only presence is required. Bears occur at moderate to high densities in surrounding areas and/or bears are suspected to occur at moderate to high densities within the project area.
- *Scenario 2* – Only presence is required. Bears occur at low or very low densities and/or may have been extirpated from the project area.
- *Scenario 3* – Occurrence and relative use by habitat is required. Bears are known to exist at moderate to high density in the project area.

- Evaluate historic occurrence of bears in the project area from explorer's journals, old government reports, newspapers, fur records, photographs, etc.
- Determine current bear occurrence and distribution by telephone or questionnaire interviews with biologists, foresters, conservation officers, park rangers, trappers, hunters, guide-outfitters, ranchers, farmers, and animal control personnel; the portion of the population who are most likely to encounter bears and to provide positive identification.
- Obtain habitat maps for the project area and rate habitats for their potential to support bears (*sensu* Fuhr and Demarchi 1990). Habitats may be rated based on the distribution and abundance of known foods and their proximity to water. Habitats should be stratified by their apparent value.
- 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 used in the Sampling Design then strata within the study areas should represent relevant strata in the larger project area.
- Review Herrero (1985), Jonkel (1993) and Rezendes (1993) for a discussion of the differences between grizzly bear and black bear sign, particularly tracks. See Figure 1 and 2 for an illustration of the differences between black bear and grizzly bear tracks.

Sampling Design

- All presence/not detected sign or sighting surveys should be systematic and replicated to provide data of statistical value (Boulanger and Krebs 1997).
- *Scenario 1* – Under this scenario, presence may be easily established, however, a systematic sampling design should still be used.
  - Small study areas should be searched completely using a systematic search pattern.
  - Larger study areas will require systematic surveys using transects; surveys stratified by habitat can make sampling more efficient.
  - The results from sign and sighting surveys could be substantiated through use of hair capture stations or scat collection with DNA analysis. The specific protocol for setting up hair capture stations and analyzing hair samples is outlined under section 3.6 Absolute Abundance.
- *Scenario 2* – Under this scenario a great deal of effort may be required to establish presence.
  - Small study areas should be searched completely using a systematic search pattern.
  - Larger study areas will require systematic surveys using transects; surveys stratified by habitat can make sampling more efficient.

  - The results from sign and sighting surveys should be substantiated through use of hair capture stations or scat collection with DNA analysis. The specific protocol for setting up hair capture stations and analyzing hair samples is outlined under section 3.6 Absolute Abundance. When using hair capture stations and DNA analysis to determine presence at low bear densities, use similar methods as for relative abundance estimates (see section 3.5 Relative Abundance) so that the data can potentially be used as preliminary data (i.e., for power analysis or sample size determination) for planning relative abundance surveys (Boulanger and Krebs 1997).
- *Scenario 3* – A well-designed systematic survey using transects should be used to standardize sampling across habitats. This scenario may also require more intensive sampling using relative abundance survey techniques to provide data of statistical value for comparisons among habitats (see section 3.5 Relative Abundance for a discussion of hair capture and DNA analysis techniques).
- Boulanger and Krebs (1997) provide a simple method to estimate probabilities of detection to provide a more quantitative framework for presence/not detected surveys. The primary objective of the negative binomial fitting technique is to allow some determination of sample sizes that might be needed to detect a population given assumptions about mean abundance and dispersion. To establish an estimate of mean and dispersion it is necessary to have conducted relative abundance surveys in another area. Obtaining quality estimates of the mean and dispersion parameters of the negative binomial distribution requires many replicated transects.

Sampling Effort

- The time required will depend on the size of the study area(s), the intensity of sampling and the suspected density of bears in the area. Surveys may take one day to several years.

Personnel

- The survey team must be familiar with bear ecology and behaviour. Experience in identifying bear sign and differentiating species in areas potentially occupied by black bears and grizzly bears is also necessary.
- All members of survey team should be familiar with proper safety precautions for working in bear habitat.

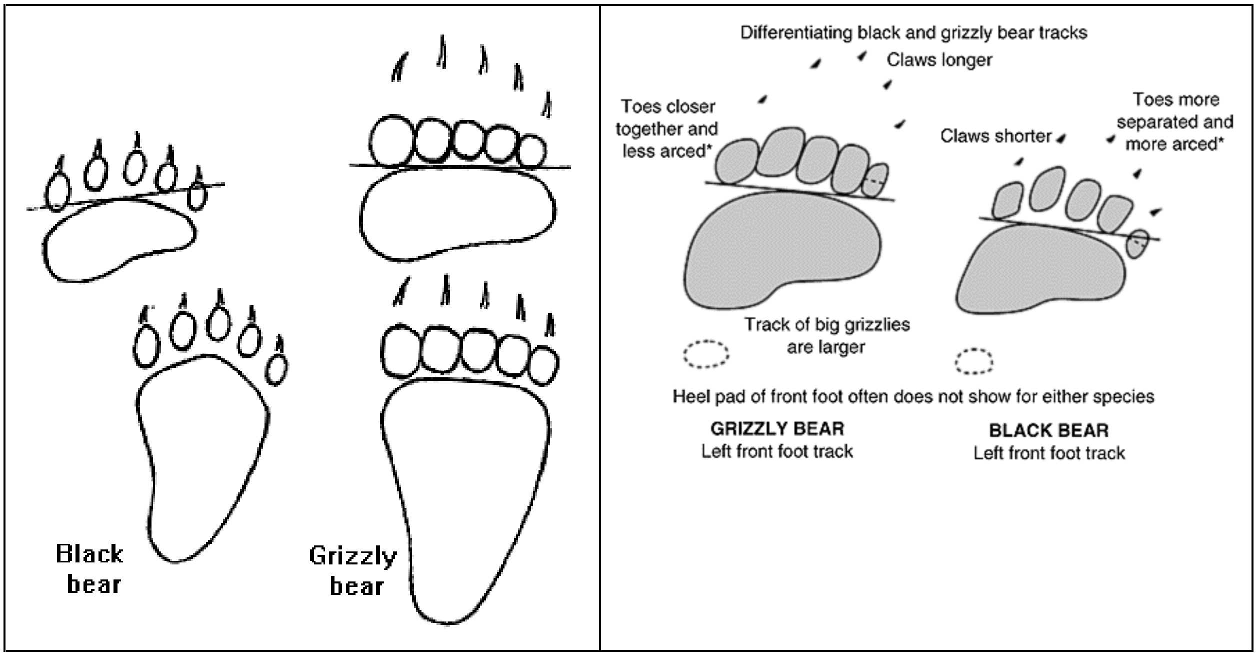
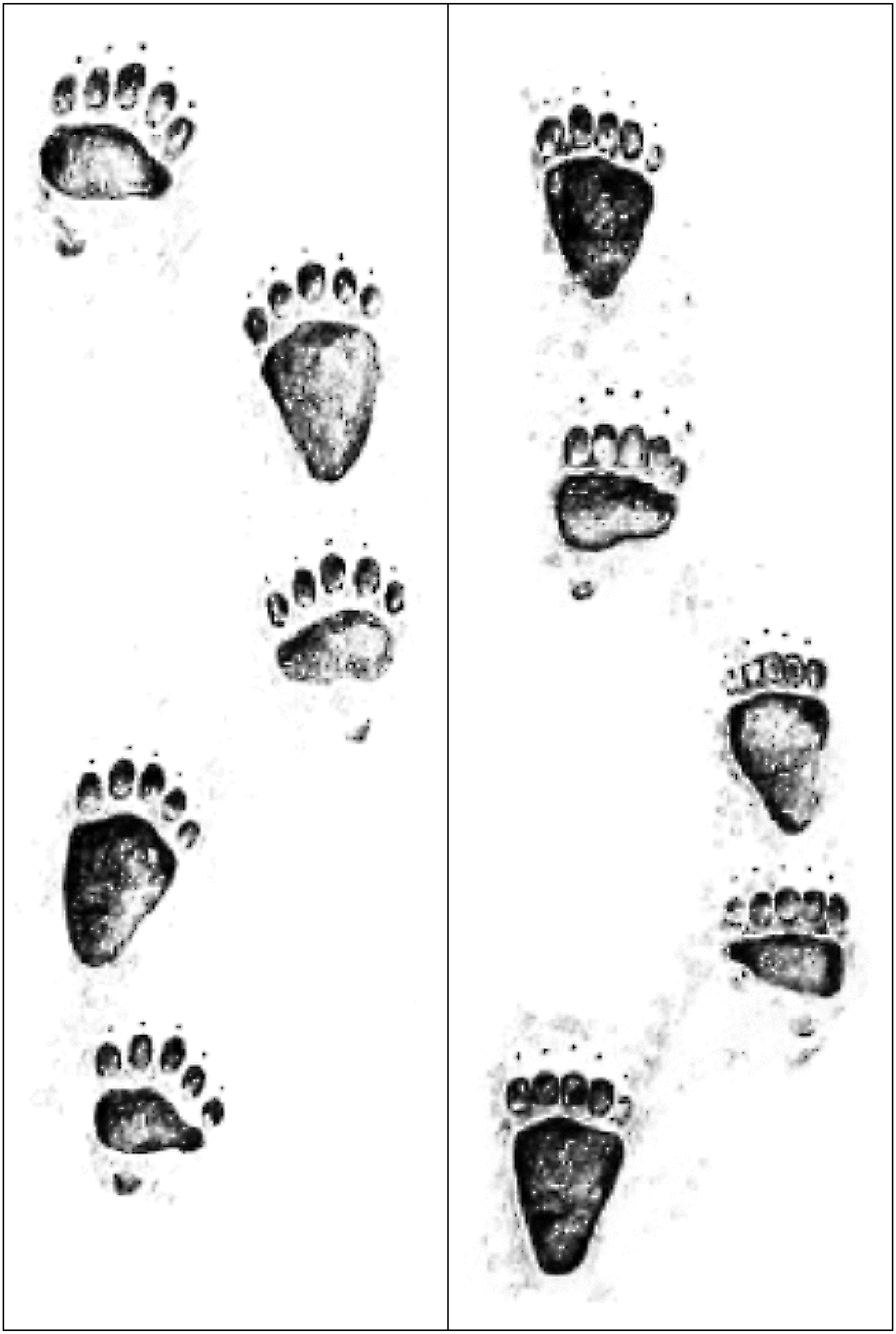


Figure 2. Two comparisons of black bear and grizzly bear foot-prints (Herrero 1985).

Note the long claws, closely spaced toes and relatively straight toe of the grizzly bear.

Following page:

Figure 3. Tracks and gait of black bear (left) and grizzly bear (right) (Herrero 1985).



Personnel

- The survey team must be familiar with bear ecology and behaviour. Experience in identifying bear sign and differentiating species in areas potentially occupied by black bears and grizzly bears is also necessary.
- All members of survey team should be familiar with proper safety precautions for working in bear habitat.

Equipment

- Maps and air photos
- Camera, possibly a video recorder
- Field notebook, data forms
- Plastic bags for collections
- Measuring tape
- Global Positioning System (GPS) receiver
- see the DNA Mark–Recapture in section 3.6 Absolute Abundance for an outline of equipment necessary for hair capture stations.

Field Procedures

- *General*
    - Both black and grizzly bears leave sign that is useful for identifying their presence, including hair, scats, tracks, beds, feeding sign, mark trees and mark trails. Although most bear sign may be easily distinguished from that of other animals, it requires considerably more experience to differentiate between bear species in areas where their ranges overlap (Herrero 1985).
    - Hair colour is not a good basis for identifying species because it may be tremendously variable for both grizzly and black bears. Similarly, although grizzlies tend to leave larger scats than black bears, this may not always be a reliable indicator of species depending on the area and the age/sex class of the bear. Both species of bears dig for underground plant parts or animals, however, black bears don't dig nearly as often as grizzly bears. Areas of extensive digging are usually from a grizzly bear. The best sign for differentiating bear species are tracks (Figures 1 and 2). See Herrero (1985), Jonkel (1993) and Rezendes (1993) for a discussion of track differences. Look for tracks in locations where clear prints are likely such as river banks, river bars, and mud flats. Clear tracks should be photographed or video-taped so species identity can be confirmed by other experts.
    - Whenever possible, hair or scats should be collected for mtDNA analysis to identify species.
    - Mark trees are generally associated with a distinct wildlife trail or trail system. The location of mark trees can usually be predicted; for example, near a potential feeding area, at the break of a slope, at a habitat type change, or at the intersection of two wildlife trails (MacHutchon *et al.* 1993).
- *Scenario 1* – Fixed-width transects or complete searches in the study area(s).
    - Conduct intensive, systematic ground searches throughout the entire study area if it is small or stratify by habitat and emphasize potentially high value habitats. Conduct a systematic transect-based survey if necessary (see Scenario 2).
    - Look for sign that indicates the presence of bears.

  - Use caution when differentiating between grizzly bears and black bears.
  - Survey the study area in each season if presence cannot be established in any one season.
  - Use hair capture stations or scat collection and DNA analysis to substantiate the results of the surveys, to help intensify the sampling effort (see section 3.5 Relative Abundance) or to help identify the bear species present in the area.
- *Scenario 2* – Fixed-width transects or complete searches in each habitat type.
  - Sample high value habitats disproportionately to their occurrence in the study area.
  - Search habitats completely or by using a transect method similar to Hatler (1991). An effective strip width of at least 4 m is recommended. As the purpose of the survey is to evaluate presence, all bear sign seen outside the transect line should be investigated as well.
  - Use sightings to confirm the results of sign surveys or to suggest areas to search. Obviously, confirmed sightings in the field by researchers are the best evidence of presence.
  - Extra care is required for differentiating species in areas potentially occupied by black and grizzly bears.
  - Use hair capture stations or scat collection and DNA analysis to substantiate the results of the surveys, to help intensify the sampling effort (see section 3.5 Relative Abundance) or to help identify the bear species present in the area.
- *Scenario 3* – Fixed-width transects in each habitat type.
  - Survey habitat types in proportion to their occurrence in the study area(s), but randomly select the habitat units to be surveyed.
  - Survey habitats in each season when bears are active, e.g., spring, summer and fall.
  - Survey habitats using transects with line intercept sampling similar to that outlined in Hatler (1991). An effective strip width of at least 4 m is recommended.
  - Record all bear sign seen along the transects.
  - Categorize bear sign (e.g., feeding sign, scats, mark trees) to accommodate the variability associated with differing detectability and permanence of sign.
  - Standardize search time and the distance searched per habitat.
  - Use sighting information to substantiate the seasonal distribution results of the sign surveys. Keep in mind that sightings will be biased toward open habitats.
  - Try to standardize the collection of sighting information. As an example, use sources such as Dept. of Fisheries and Oceans (DFO) Fisheries Officers who walk the same streams every year at approximately the same time of year. Provide them with data collection or sighting forms that list species identification criteria.
  - Use hair capture stations or scat collection and DNA analysis to substantiate the results of the surveys, to help intensify the sampling effort or to help identify the bear species present. This scenario may require more intensive sampling using relative abundance survey techniques to provide data of statistical value for comparisons among habitats (see section 3.5 Relative Abundance).

Data Analysis

- Verify sign or sightings with several experts and against provincial museum collections.
- Critically evaluate the reliability of a sighting when it is used to determine grizzly bear presence in an area that is also occupied by black bears. Particular attention should be paid to the criteria that observers have used for determining species. Any sighting which uses fur colour alone should be suspect.
- Whenever possible, hair or scats should be used for mtDNA extraction and analysis to identify species.

3.5 Relative Abundance

Recommendation(s): Aerial or ground counts at seasonal concentrations can be used to determine changes in relative abundance over time, particularly when investigators are interested in long-term trends in a population. It is important to note that large changes in the population may be necessary before trends can be detected. Aerial counts at seasonal concentrations are suggested for berry concentrations in the Spruce-Willow-Birch (SWB) Biogeoclimatic zone (part of the Northern Boreal Mountains Ecoprovince), and open, high elevation areas in the Engelmann Spruce - Subalpine Fir (ESSF) Biogeoclimatic zone (part of the Southern Interior Mountains and Sub-Boreal Interior Ecoprovinces). Ground counts, including foot and boat surveys, can be used to monitor relative abundance of bears at salmon concentrations on the coast (Coastal Western Hemlock (CWH) Biogeoclimatic zone, Coast and Mountains Ecoprovince).

Hair capture stations with DNA analysis can be used to determine relative abundance among areas at the same time or changes in relative abundance over time in all Ecoprovinces and Biogeoclimatic zones of B.C. Relative abundance estimates from hair capture stations (e.g., set out along a transect) can make use of open mark-recapture models to estimate relative survival. Open mark-recapture models do not make the restrictive assumption of population closure and therefore sampling can occur on a yearly basis. **The use of open population models is far superior to the use of counts for population monitoring estimates.** An inherent assumption with count data is that capture probabilities will be equal each time the population is sampled. Open population models estimate capture probability and therefore account for this potential bias.

Aerial capture–mark–resight or camera capture–mark–resight (see section 3.6 Absolute Abundance) can be used to detect temporal changes in relative abundance or to compare abundance among areas, however, both these techniques require intensive live capture and marking of bears (e.g., radio-marking).

3.5.1 Aerial and Ground Counts at Seasonal Concentrations

Changes in the number of bears at seasonal concentrations of preferred foods have frequently been used as an index to trends in the population at large (LeFranc *et al.* 1987). Direct counts of bears are done from the air or ground at seasonal concentrations such as garbage dumps, berry fields or salmon spawning areas.

An advantage of direct counts at seasonal concentrations is that they are relatively quick and easy to conduct, however, there are a number of disadvantages. There can be large year to year variation in the timing and amount of food available at the site, and consequently the timing and size of the maximum concentration of bears. Counts at seasonal concentrations do not provide any information about the size of the area from which the bears were drawn. As well, aerial counts at seasonal concentrations are subject to the same visibility biases as total count surveys (Caughley 1974) including, observer skill and experience, aircraft type, time of day, weather, lighting, search rate, food availability, vegetation cover and cover type, and animal behaviour and distribution. The visibility bias in bear aerial surveys is greater than for ungulate surveys because bears tend to be more secretive and are not active in the winter when visibility is best. Ground counts are often more effective for seeing bears than aerial surveys and therefore are preferable in forested areas (Erickson and Siniff 1963).

Boulanger and Krebs (1997) outlined 3 critical assumptions of count data used to estimate relative abundance:

1. Environmental, biological, and sampling factors are kept as constant as possible to minimize differences in survey bias and precision between surveys. It is essential that the proportion of a population observed is, on average, constant across surveys. For transect or quadrat counts, this means that on average the same proportion of the population is counted, or observed in replicate surveys. This may be possible in some systems, however, studies should be designed to accommodate this assumption in every possible way. As mentioned earlier, methods such as open population mark-recapture are superior to counts in that difference in sightability or catchability are accounted for.
2. Identical or statistically comparable methods are used for comparison between areas or for monitoring trends in one area over time.
3. Surveys are independent; one survey does not influence another.

Office Procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for project and study area(s) (*e.g.,* 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- Outline the project area on a medium to large scale map (1:100,000 – 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 used in the Sampling Design then strata within the study areas should represent relevant strata in the larger project area.
- Study area(s) should be defined so that they consist of one food concentration area. Try to use natural barriers to define the boundaries of the study area(s).

- Review all background information that may indicate important and consistent seasonal concentrations of bears:
  - DFO stream inventory reports provide information on yearly changes in salmon numbers and the timing of peak spawning. Some reports outline major salmon spawning areas, otherwise fisheries officers, anglers and other local people can often provide information on spawning areas.
  - Develop a method for monitoring berry development so that surveys can be timed to coincide with the same phase of bear aggregation each year.
  - Develop a method for carrying out yearly measurements of berry abundance. These measurements should be done every year, including the years between surveys.
  - Develop procedures for assessing the relative availability of berries or salmon during survey years. Assessments that should be considered include changes in distribution and availability of food as a result of such things as water level and water turbidity for salmon and late spring freezing for berries. Data on weather and stream hydrology are relevant to these assessments.
- Consult with a statistician or quantitative ecologist who is familiar with the design of population trend analysis. The results of any analysis will be dependent on how well the monitoring program was designed and implemented. There are many computer analysis packages that help design monitoring studies by considering sample error, autocorrelation of sample points, and trend modelling when determining optimal sample sizes and survey periods (see Thomas and Krebs 1996, Boulanger and Krebs 1997 for reviews). Boulanger and Krebs (1997) recommend the program MONITOR (J.P. Gibbs, Dept. Of Earth & Environmental Sciences, Columbia University, New York; ftp://ftp:im.nbs.gov/pub/software/monitor) for population trend analysis, but there are many other software packages available.

Sampling Design

- The following issues should be addressed when designing a long-term monitoring program for bears (Boulanger and Krebs 1997):
  1. Monitoring time frame – Use a trend analysis program to determine the number of years of monitoring, the monitoring interval, and the sample size needed to detect the desired level or rate of population change.
  2. Count data distribution – The collection of pilot or preliminary survey data or the analysis of data from similar studies will help determine if the assumption of normality can be met. If the assumption of normality cannot be met then alternative procedures as discussed in Boulanger and Krebs (1997) and Thomas (1996) should be considered for data analysis.
- If seasonal concentration counts are to be effective in detecting population trends, survey methodology has to be standardized and consistent between years. In addition, there should be some measurement of the natural fluctuations in food abundance over time. Surveys need to be synchronized with the same phase of the aggregation each year, preferably when maximum concentration of bears occurs. Numerous replicate surveys should be done each year and as many variables as possible held constant among replicates (LeFranc *et al.* 1987).
- Ground counts require a measure of yearly changes in salmon abundance and availability. Salmon numbers can fluctuate yearly and availability can be affected by

changes in water level and clarity. DFO stream inventory reports provide information on yearly changes in salmon numbers and the timing of peak spawning.

Sampling Effort

- Requires consistent and devoted effort over a number of years. Counts within a year will require several days.
- Use a trend analysis program to determine the number of years of monitoring, the monitoring interval, and the sample size needed to detect the desired level or rate of population trend.

Personnel

- One biologist familiar with bear biology and data analysis.
- Two or more biologists or technicians that are proficient at spotting bears from the air or the ground. Every observer should receive training in spotting bears and be tested as this is critical to the success of counts, particularly when done from the air. Observer bias should be standardized by using the same individuals each survey and each survey year and by ensuring that all observers are equally proficient at spotting bears.
- One statistician or quantitative ecologist.
- One or more skilled pilots for aerial counts.

Equipment

- Binoculars
- Tape recorders
- Field notebooks, data forms
- Measuring instruments relevant to assessing the abundance, distribution and timing of foods
- One or two aircraft or boats.

Field Procedures

For each study area (food concentration area):

- Monitor berry development or salmon movements so that surveys can be timed to coincide with the same period of the aggregation each year.
- Measure or estimate the relative abundance distribution of food (i.e. berries or salmon) and factors that may reduce their availability (e.g. water flow changes, water turbidity, late spring frost).
- Conduct aerial or ground surveys under optimal viewing conditions.
- Replicate surveys at least three times during the concentration within a given year.
- Maintain consistency in variables that can affect visibility such as observers, weather, time of day, aircraft and search rate.
- Record the number of bears observed in their appropriate sex/age category (cubs of the year (COY), young >1 year old, and adult bears), and the location of the observation. RIC data forms allow observations to be grouped into meaningful units, such as suspected families.

Data Analysis

- Test how changes in observers or search rate affect sightability.
- Summarize the number of bears observed in each age category and the total number observed.
- Determine the mean and standard error for the number of bears seen during the 3 surveys conducted within a year.
- See Boulanger and Krebs (1997) for a review of statistical methods for the analysis of trend data. If monitoring efforts are designed properly then simpler types of trend analysis may be used with the data. If trends are complex or data are non-normal, then more advanced procedures may be used to produce unbiased and precise trend estimates (Boulanger and Krebs 1997). Consult with a statistician or quantitative ecologist who is familiar with the analysis of trend data as many of the new methods for trend analysis require the use of statistically-complex, model fitting methods.
- When evaluating long-term data for potential trends there should be an estimate of the statistical power of the analysis, particularly when the null hypothesis is not rejected. There are many appropriate power analysis software packages available which are reviewed in Thomas and Krebs (1996) and Boulanger and Krebs (1997).

3.5.2 Hair Capture Stations with DNA Analysis

Analysis of DNA from bear hair samples has led to the development of a DNA mark–recapture technique for bear population estimation which is outlined in detail under DNA mark–recapture in section 3.6 Absolute Abundance.

A rigid, often expensive and logistically difficult sampling design is required to estimate population density using DNA mark–recapture. Hair capture stations and DNA analysis could, however, be set up with a less rigid protocol and be used to monitor temporal trends in population size or to compare population sizes among areas at the same time. Unfortunately, little empirical or theoretical work has been done yet to evaluate the effectiveness of hair capture and DNA analysis for estimating relative abundance.

One method which holds promise for relative abundance estimation is the use of open mark-recapture models to estimate relative survival with data from a transect or grid of hair capture stations. Relative survival is simply the survival rate of the population between sampling periods. This should not be confused with the biological survival rate of individuals which is usually obtained using radio-telemetry data. Bears have long life spans and therefore their biological survival rate is high. However, local effects such as hunting may reduce relative survival of the population which may in turn be reflected in the relative survival rate.

Open mark–recapture models, such as Jolly-Seber, allow the assumption that a population is demographically closed to be relaxed and therefore sampling can occur on a yearly basis. Population estimates using the Jolly-Seber model rely on similar assumptions to the Lincoln-Peterson model, except demographic closure, and are therefore susceptible to biases if the population is geographically open or has unequal capture probabilities. However, the survival rate estimate of the Jolly-Seber model is robust to most forms of capture probability variation and does not require geographic closure, therefore, it is a useful alternative for monitoring populations. In addition, many modifications to the Jolly-Seber are available which accommodate age-specific capture probabilities and survival rates, e.g., programs JOLLY and JOLLYAGE (Pollock *et al.* 1990) and POPAN (Arnason and Schwarz 1995). The Jolly-Seber approach to survival modelling has also been modified to allow the testing of a biological hypothesis using various model fitting procedures such as SURGE and MARK (see Boulanger and Krebs 1997). Programs SURGE and MARK only calculate survival rates whereas program POPAN will calculate an estimate of population size. All three programs provide greater precision in their estimates than a full Jolly-Seber model with no modification. Fundamental to the use of all models is an appropriate sampling design which allows adequate sample sizes and meets other model assumptions.

The use of open population models is superior to the use of counts for population monitoring. An inherent assumption when counts are used for estimating relative abundance is that capture probabilities will be equal each time the population is sampled. Open population models estimate capture probability and therefore account for this potential bias. Pollock *et al.* (1990) provides detailed discussion on the shortcomings of count based (minimum number alive) estimates of population. The only time that count based estimates should be used with DNA data is when recapture rates are too low to allow Jolly-Seber survival estimates. However, attention should be given to design studies to maximize recapture rates to avoid the use of minimum number alive estimators.

The following is a suggested protocol for relative abundance estimates using hair capture and DNA analysis. The method will be verified and updated as field tests and simulation work are conducted.

Office Procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Read DNA mark–recapture in section 3.6 Absolute Abundance for a review of hair capture and DNA analysis methods.
- Obtain maps for project and study area(s) (*e.g.*, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- 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 used in the Sampling Design then strata within the study areas should represent relevant strata in the larger project area.
- For this type of survey, the study area may be the same as the project area. Use natural barriers to define the boundaries of the study area to minimize movement in or out of the area during the survey.
- Consult with a statistician or quantitative ecologist who is familiar with the design of population monitoring surveys using open population models. The results of any analysis will depend on how well the monitoring program was designed and implemented. There are several computer analysis packages that help design open population monitoring studies. These programs are reviewed in Boulanger and Krebs (1997). For example, POPAN has a detailed simulation program that will aid in the formulation of optimal sampling strategies to obtain reliable estimates (Arnason and Schwarz 1995). It is important to ensure that adequate sample sizes are obtained for survival rate estimation using some of the newer models.

Sampling Design

The optimal hair capture station design is still being developed, however the following are some general guidelines:

- The primary goal of hair capture and DNA analysis to estimate relative abundance is to maximize the capture of bears in the study area and ensure the precision of the estimates among areas or over time. The precision or repeatability of population estimates will be a function of the number of bears in the sample and the mean capture probability of the population. It is also essential to maintain consistency in the sample design among study areas or over time to ensure precision of the estimates.
- A large grid set-up is not required when relative abundance and survival estimates are the primary objective of inventory efforts. However a **consistent, systematic** survey effort is still required.
- Hypothetically, a transect of hair capture stations might be optimal for coastal areas where there are incised drainages which confine bear movements. A grid with large cell sizes (e.g., 10x10 km) might be optimal for more open northern areas where bear movements are not confined by topography.

- A grid or transect should be set up in the study area to maximize encounter rates during the entire capture session. Unlike DNA absolute abundance design, the principal objective of DNA relative abundance estimates is to ensure that a bear encounters a station once during the entire sampling effort in a year as opposed to each individual session. As a result, bait stations can be checked fewer times but capture sessions should be lengthened.
- Hair capture stations should be set up in areas where bears will return on a yearly or seasonal basis to maximize yearly recapture rates.
- Maintain consistency between years (i.e., sampling conducted over the same time period, the same hair capture session length, the same number of hair capture stations, the same hair capture station placement, and the same hair capture station set-up and baits).
- Covariates that might influence survey effectiveness and bear survival should be recorded during each survey period. These covariates might be weather effects (e.g., severe weather), berry crop data, or any other factors that might influence bear survival. The influence of these factors can be tested in some of the newer analysis programs such as POPAN, SURGE and MARK.
- DNA-based relative abundance estimates are recommended for the spring or summer when natural foods are scarce and bears are more likely to approach baited hair capture stations. On the coast, DNA mark-recapture surveys are likely best before berries are available in mid to late June. In the interior, surveys are likely best prior to the berry season in mid to late July. Bears are shedding their winter coats in the spring and summer, therefore there is a greater likelihood of obtaining hair follicles in samples during that time period.

Sampling Effort

The optimal hair capture station sample effort is still being developed, however the following are some general guidelines:

- Whether the goal is to compare among areas or look at temporal trends, the sampling effort in each area or year should be consistent, i.e., sampling conducted over the same time period, the same hair capture session length, the same number of hair capture stations, the same hair capture station placement from year to year, and the same hair capture station set up and baits.
- The length of capture sessions can be extended when survival rate estimate is an objective because demographic closure is not assumed when open population models are used in the analysis. The capture session should, therefore, be determined by how long the bait remains attractive and how long the snagged hairs remain viable on the barbed wire. In general, less capture sessions will be required than with absolute abundance estimates; therefore, single session length should be maximized. It is recommended that a minimum of two capture sessions take place each year. This is especially important for studies which are unable to continue for 3 years as required for a Jolly-Seber model. Two sessions in a year will at least provide enough data to produce an annual Lincoln-Peterson estimate.
- The Jolly-Seber model requires at least 3 yearly capture sessions for survival rate estimates. As a result, whenever possible monitoring efforts should be planned to last at least three years and preferably longer. In reality, three years is a minimum to determine any biologically meaningful trend information regardless of the analysis method used. If

it is not possible to survey for three years, Lincoln-Peterson estimates can be used (see above).

Personnel

- One or two biologists familiar with bear biology and data collection and analysis.
- Two or four assistant biologists or technicians.
- One quantitative ecologist.
- One or more skilled helicopter pilots.

Equipment

- Maps and air photos.
- Field notebooks, data forms.
- Hair capture station set-up equipment, including:
    - barbed wire, fencing supplies and tools, leather gloves, climbing spurs or tree-steps, chainsaw, axe, machete, GPS, flagging tape.
- Hair capture station bait and equipment, including:
    - drums or pails, sacks, rope or twine.
- Hair collection equipment, including:
    - envelopes, tweezers, surgical gloves.
- Safety equipment, including:
    - radios, pepper spray, first-aid kit.
- One or more helicopters.
- Computer.

Field Procedures

- Read DNA Mark–Recapture in section 3.6 Absolute Abundance section for a summary of methods for hair capture station set-up, collection of hair samples and data management.

Data Analysis

- Read DNA Mark–Recapture in section 3.6 Absolute Abundance section for a summary of hair analysis techniques and data management.
- See Boulanger and Krebs (1997) for a review of statistical methods for the analysis of open population model data. Pollock *et al.* (1990) discuss in detail the use of the Jolly-Seber model.
- When evaluating long-term data for potential trends there should be an estimate of the statistical power of the analysis, particularly when the null hypothesis is not rejected. There are many power analysis software packages available which are reviewed in Thomas and Krebs (1996) and Boulanger and Krebs (1997).

3.6 Absolute Abundance

Recommendation(s): The terms mark–recapture or mark–resight refer to techniques that investigate the properties of a population by examining the properties of a marked sample of that population (Caughley 1977). Mark–recapture methods have been used for a long time in population ecology and there is extensive literature on the statistics of mark–recapture sampling models. Some thorough reviews include Otis *et al.* (1978), Begon (1979), Seber (1982, 1986), White *et al.* (1982), and Pollock *et al.* (1990).

Mark–recapture using analysis of DNA from hair samples (DNA mark–recapture) should be used for estimating absolute abundance of bears in forested areas of B.C.

The aerial capture–mark–resight (CMR) technique described by Miller *et al.* (1987, 1997) could be used for estimating bear population size and density in relatively open areas of B.C. such as the Boreal White and Black Spruce, Spruce–Willow–Birch and Alpine Tundra Biogeoclimatic zones of the Northern Boreal Mountains, Taiga Plains and Boreal Plains Ecoprovinces. The CMR method also could be used to estimate population size at seasonal concentrations in the Coastal Western Hemlock, Interior Cedar-Hemlock, Montane Spruce, and Sub-Boreal Spruce Biogeoclimatic zones of B.C.

Capture–telemetry should only be used on long-term and intensive research projects requiring a large sample of radio-collared bears. If capture–telemetry methods are used, then an independent estimator of population density such as capture–mark–resight or DNA mark–recapture should be used as well.

Capture and radio-marking (e.g., radio collaring) are important precursors to capture–mark–resight and capture–telemetry population estimators. Capture and marking should only be used in a well-designed inventory or research project. Bears in forested habitats are captured with Aldrich foot snares or barrel traps. Bears in open habitats are usually darted from a helicopter. Jonkel (1993) summarized methods for capturing, immobilizing and handling grizzly bears and black bears.

A capture–mark–resight (CMR) technique in which resightings of marked and unmarked bears were obtained using automatically triggered cameras set at bait stations was used for density estimates of grizzly bear populations in closed canopy forests of Montana (Mace *et al.* 1994). The remote camera CMR technique was originally recommended as the best method for determining bear density in forested areas of B.C. (Manning *et al.* 1994). Recently developed DNA mark–recapture techniques have fewer limitations than the remote camera CMR technique, therefore, the remote camera CMR technique is no longer recommended as the preferred absolute abundance technique for forested areas.

3.6.1 DNA Mark–Recapture

The DNA mark–recapture technique for bear population estimation was pioneered in B.C. by J. Woods (Parks Canada), B. McLellan (B.C. Ministry of Forests), D. Paetkau (University of Alberta), M. Proctor (University of Calgary), C. Strobeck (University of Alberta) and others (Woods *et al.* 1996a, 1996b). Individual bears are identified by ‘capturing’ some of their hair and then extracting and analyzing the hair follicle’s nuclear DNA.

The main benefits of the DNA mark–recapture technique are 1) bears do not have to be captured to be marked, therefore, the bears are not handled or disturbed, 2) marks cannot be lost, 3) relatively large sample sizes can be obtained, and 4) there is a low probability of mis-identification provided there is a reasonable level of genetic variation in the population (Woods *et al.* 1996a, 1996b).

The estimation of density and population size of bears using DNA mark–recapture techniques has only recently been developed and little theoretical work has been undertaken to investigate optimal methods of field sampling populations and estimating population parameters from mark–recapture data. There are many plausible sources of sampling bias when DNA mark–recapture methods are applied to bear populations, including differential home range sizes, habitat specific densities and age/sex differences in capture probabilities. Given the complexity of data, biologists have used estimation models with uncertain assumptions and subsequent unknown biases of parameter estimates.

An individual-based spatial Monte Carlo simulation model, originally developed by Zarnoch (1976), Wilson (1983), and Boulanger and Krebs (1996), has been adapted to aid in the grid design and spacing of hair capture stations for bear DNA mark–recapture. The simulation model has been used to explore the relationship between grid size, hair capture station spacing and possible biases in the estimate of population size and density of bears (MacHutchon 1997, Boulanger in prep.) and the model also could be used to determine the optimal estimation model(s) for mark–recapture data.

Office Procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for project and study area(s) (*e.g.*, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- 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 used in the Sampling Design then strata within the study areas should represent relevant strata in the larger project area.
- For this type of survey, the study area may be the same as the project area. Use natural barriers to define the boundaries of the study area(s) to help ensure the population is geographically closed during the DNA mark-recapture sampling. The assumption of population closure applies if density is to be estimated from the data and the closed models of program CAPTURE (Otis *et al.* 1978) are to be used. The assumption of closure is that no animals can enter or leave (geographic closure) or die or be born (demographic closure) during the time an area is sampled. The most probable cause of

lack of geographic closure in bear populations is animals living on the edge of capture grids leaving or entering the capture area during the capture session. This inflates the effective area of the capture grid (called “edge effects”) and can result in positively biased density estimates and increased heterogeneity of capture probabilities (White *et al.* 1982). Demographic closure is more easily ensured for bears by avoiding the recruitment period (January-February) and having sample periods that are brief relative to the species annual mortality rates (Woods and McLellan 1997).

- Design the DNA mark-recapture inventory using the sequential steps outlined below under *Sample Design*.
- Consult a quantitative ecologist or conduct simulation studies to determine the best sample design for the bear species and geographic area of interest (see *Sample Design* below).

Sampling Design

- Grid cell placement within the mark–recapture study area is determined by overlaying a grid of appropriately sized cells on a map covering the study area. This can be done on paper maps or using a Geographic Information System (GIS). The grid should be fit to the study area to maximize the number of cells that are within its boundaries.
- Hair capture stations should be placed randomly within each grid cell. Realistically, stations should be placed as close to a random point as access will allow.
- The primary goal of DNA mark–recapture study design is to meet the assumptions of the estimation models being used. Meeting the assumption of geographic closure is critical when closed population models are used. In addition, the maximal number of animals should be “caught” given the logistical constraints imposed on field efforts. If geographic closure and high rate of capture are both achieved then the simplest estimation model can be used for population estimates, which should yield the most precise results.
- The main components of study design, and associated problems are:

I. *Meeting the assumption of geographic and demographic closure*: If the closed models of program CAPTURE (Otis *et al.* 1978) are to be used and if density is to be estimated then it is assumed that the population is closed or “no animals leave, enter, die or are born during the sampling process”. Examples of causes of closure violation in bear populations are:

A. Males with large home range sizes move in and out of hair capture grids during capture sessions. This inflates the “effective area” of the grid and creates a bias towards higher density estimates.

B. This bias is increased further by the need to keep hair capture stations active for long periods of time in order to obtain adequate sample sizes.

II. *Capture probability variation*: Bears probably show unequal probabilities of capture which can lead to biased population estimates. There are three principle causes of variation in capture probability:

A. *Inherent heterogeneity*: Animals each have a unique probability of capture that is constant throughout the study. Some reasons for inherent heterogeneity in the susceptibility of bears to capture are:

1. Females with small home ranges encounter hair capture stations less than males with large home ranges, therefore, they are caught less resulting in a lower probability of capture.
2. Females with cubs tend to investigate capture station less than males.

B. *Behavioural adaptation*: Individual animals have an initial capture probability which changes after they are first captured. Some possible causes of behavioural adaptation are:

1. Bears become less interested in hair capture stations after not receiving a reward during initial visitation and therefore their capture probabilities decrease.
2. If bears are inadvertently rewarded during initial visits to capture stations, their subsequent interest in the stations may increase capture probabilities.

C. *Time*: Capture probability changes uniformly across the population each time hair capture stations are set out. An example of how timing will influence capture probability is:

1. Bear movements and interest in capture stations changes between spring and berry seasons as well as during salmon runs.

III. *Sample size*: The precision or repeatability of estimates will always be a function of the number of the animals in the sample. The main difficulty in obtaining an adequate sample size for a bear population is:

A. Grizzly bears have low population densities and therefore bears should be sampled for a long duration using large grid sizes to obtain adequate sample sizes.

IV. *Budget*: Prohibitively large budgets would be needed to mitigate all of the problems with DNA mark–recapture study design. Therefore, an optimal design is needed which mitigates the most substantive factors while maintaining a reasonable budget.

- The precision or repeatability of population estimates will be a function of the number of bears in the sample population and the mean capture probability of the population. In general, higher mean capture probabilities are needed for smaller populations to obtain adequate population estimates. White *et al.*(1982) recommend that if the models of program CAPTURE (Otis *et al.* 1978) are to be used for population estimation then the mean population capture probabilities should be at least 0.3, especially if the population is suspected to be less than 100 individuals. The main effect of sample sizes below this level are low estimates of precision, low power of the program CAPTURE model selection routine to diagnose capture probability variation in the data, and possible undetermined bias in estimates. The mean capture probability needed to obtain adequate estimates is dependent on the population size suspected to be on the hair capture grid. Figure 3 illustrates simulation results for different population sizes and different mean capture probabilities. It was assumed that bears had equal capture probabilities, and the jack-knife estimator (M_h) of program CAPTURE was used for estimates. In addition, five sequential hair capture periods were used for estimates. To evaluate estimator precision, the coefficient of variation was used which is the standard deviation of estimates divided by the mean estimate. Pollock *et al.* (1990) recommends that the coefficient of variation should be below 0.2 if estimates are to be used for monitoring and management. The graph demonstrates that a capture probability of 0.3 is needed for populations of size 50, and a mean capture probability above 0.3 is needed for populations below 50.

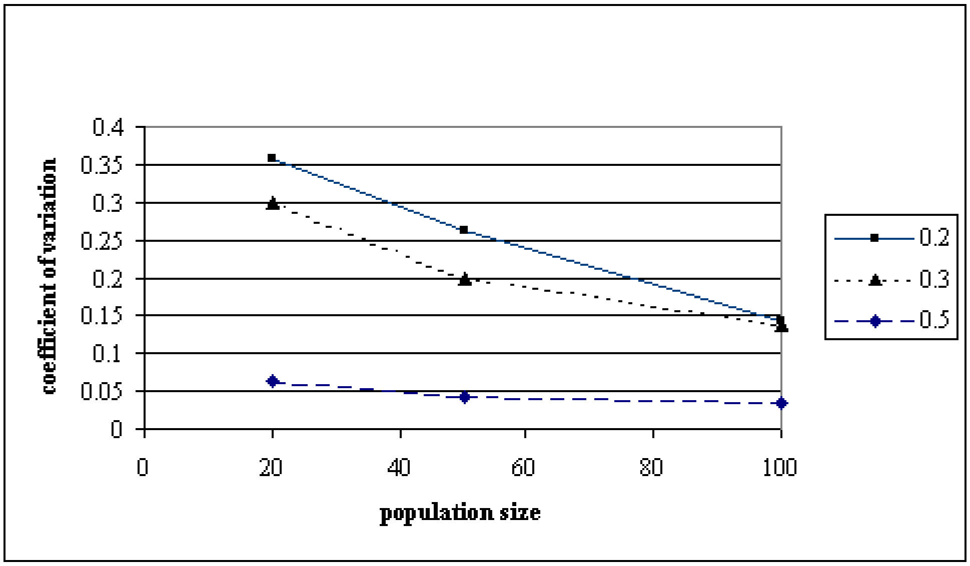


Figure 4. Coefficient of variation of model M_h (jack-knife) as it relates to population size at three levels of mean capture probability.

- A trade-off exists between the large overall grid size required to mitigate overestimation of densities and the grid cell size required to minimize capture probability variation. Three sub-issues to this are:
  1. If only a fixed number of hair capture stations are available during a study then larger individual cell sizes are needed to accommodate larger overall grid sizes. However, large spacing between capture stations may create unequal probabilities of capture because bears with small home ranges (e.g., females with cubs in spring) may never encounter capture stations.
  2. By minimizing edge areas (with larger overall grids) heterogeneity in capture probabilities is also minimized due to a lower proportion of animals which live at the edge of the grid. Edge animals introduce heterogeneity by only occasionally encountering capture stations in comparison with resident grid animals.
  3. As overall grid size is increased, edge effects are decreased therefore minimizing density bias created by large males moving on and off the grids.

  These three issues are not mutually exclusive; overall grid size and cell size will interact to cause capture probability variation. In particular, as overall grid size is increased, it is expected that heterogeneity in capture probability will increase due to lower capture station densities, but also decrease due to lessened edge effects (Boulanger in prep., MacHutchon 1997). Recent simulation findings (Boulanger in prep) suggest that moving traps between sessions will partially mitigate heterogeneity due to variation in trap encounter rates between sex classes. DNA mark–recapture sample designs should incorporate the trade-offs associated with optimizing grid cell size and grid size.
- Table 3 summarizes some of the sample design issues for DNA mark–recapture methods. The arrows represent how sampling methods can be adjusted to accommodate individual design issues. Of particular note is the difficulty in meeting all design issues given typical budget constraints. As a result, compromises must be made in the sample design to minimize violation of model assumptions while accommodating budgetary and logistical constraints.

Table 2. Bear DNA mark-recapture design issues and sample methods (Boulanger in prep.)

Arrows indicate how components of the sample design (e.g. Grid size) can be adjusted to accommodate different design issues (e.g. Inherent heterogeneity).

Design Issue	Overall grid size	Grid cell size	Number of hair capture stations	Number of capture sessions	Capture session duration
1) Capture Probability Variation					
a) Inherent heterogeneity	↑	↓	↑	↑	↑
b) Behavioural adaptation					
c) Time				↓	↓
2) Meet the assumption of closure	↑		↑	↓	↓
3) Maximize sample size	↑	↓	↑	↑	↑
4) Budget constraints	↓	↑	↓	↓	↓

- **The following are sequential steps that can be followed when designing a DNA mark-recapture inventory:**

I. Optimal sampling design should be determined on a case-specific basis. Designing a bear inventory project is best accomplished by a team of both a bear biologist and a biometrician working together to determine what sample design (i.e., grid cell size and overall grid size) will mitigate the most important design problems for their bear species and geographic area of interest. It is recommended that simulation studies be conducted using the model developed by Boulanger and Krebs (1996) and J. Boulanger (Integrated Ecological Research, Squamish) to determine the best sample design (for examples see MacHutchon 1997 and Boulanger in prep.). Theoretical and empirical work is currently underway to determine the best sample designs for bear populations in B.C. It will be difficult to generalize too much, however, because sample grids should be designed to accommodate the likely sampling bias prominent in each geographic area. For example, edge effects may be the prominent bias in areas where populations are less geographically closed, therefore, a larger grid and larger grid cells may be best. In contrast, variability in capture station encounter rates may be the prominent bias in coastal areas where home ranges are constricted, but populations are more geographically closed.

II. Calculate the approximate grid size needed to sample at least 50 bears, over the entire sample period, given plausible assumptions of expected bear densities on the study area. If it is not possible to sample a grid size large enough to include 50 bears, then the sampling protocol should be structured so that capture probabilities are maximized. Capture probabilities could be increased by decreasing the grid cell size and increasing the number of hair capture stations.

III. Given the calculated grid size, choose a study area with a high probability of geographic closure. This could be an area bordered by large lakes, mountain ranges, or other barriers to short-term movement. Edge effects will never be completely eliminated so placing a sample grid in a geographically closed location is important. **The importance of geographic closure can not be overemphasized.** Recent simulation work shows that highly biased estimates will result if the assumption of closure is ignored. For this reason, meeting the assumption of closure is critical if closed models are to be used (Boulanger in prep.). Recent simulation work also suggests that if closure violation is minimized and adequate sample sizes are attained (i.e., >100 bears) then capture probability variation will have comparatively little effect on estimates when the robust models of program CAPTURE are used. It is highly recommended that biologists contact statisticians who are familiar with mark-recapture estimation models to help determine the appropriate sample design, especially if the issue of geographic closure is outstanding.

IV. Preference should be given to study areas where there are radio-collared bears that can be tracked during sampling to allow empirical estimation of edge effects using the methods of Garshelis (1992). In addition, hair capture stations that are not part of the mark–recapture sample could be established on the perimeter of sample grids, at the mouth of watersheds or at passes into adjacent watersheds to help assess the closure of the grid.

V. *Grizzly Bears* — Simulation methods were used to evaluate sample design issues around DNA mark–recapture estimates of grizzly bear populations (Boulanger in prep.). Simulations were conducted using movement data from the Flathead Valley (McLellan and Hovey unpubl. data), West Slopes (Woods *et al.* unpubl. data), Tweedsmuir/Atnarko (Himmer and Gallagher unpubl. data), and Khutzeymateen Valley (MacHutchon *et al.* 1993) grizzly bear studies. DNA mark–recapture data from the West Slopes project during 1996 (Woods *et al.* 1997) was the main empirical data on bear hair capture used in the simulations. As a result, the following are <u>preliminary results</u> that will be verified and updated as more field data are analyzed and more simulation work is conducted.

A. Optimal grid cell size will be dependent on the density of bears within the study area. For populations that are less than 100, a maximum grid cell size of 7x7 km (49 km^2) would be suitable to ensure adequate encounter rates for adult female grizzly bears. For populations greater than 100, a grid cell size of 8x8 km (64 km^2) appears to be optimal to ensure adequate encounter rates. The optimal grid cell size will vary, however, with assumptions of bear home range size (during sampling), proportions of different sex/age classes in the study area, and the number and duration of capture sessions. The above recommendations are primarily based on the home ranges of grizzly bears in the Flathead Valley, at least four 10 day sample periods (capture sessions), and a population that is geographically closed.

B. Having suggested the above grid cell sizes, it is important to balance the issue of grid cell size with the issue of geographic closure. If the number of hair capture stations available is fixed due to budgetary constraints, then the only way to catch the majority of bears with small home ranges is to reduce grid cell size which requires reducing grid size. This will increase potential density biases and heterogeneity due to edge effects. Cell size adjustments should try and take into account the relative proportion of bears in the sampled population that will have 60 day home range sizes of less than 20 km^2 as these are best sampled using smaller cell sizes. The West Slopes and Flathead Valley movement data suggested that approximately 25% of females had 60 day home range sizes of less than 20 km^2. In contrast, coastal populations in the Khutzeymateen Valley had a higher percentage of bears with home range sizes below this threshold. This conclusion was based on fewer locations of radio-collared bears, however, and thus may be negatively biased. Nonetheless, if the majority of bears within a study area have 60 day home ranges larger than 20 km^2, it is best to use larger grid cell sizes to expand the overall grid size and minimize edge effects. Ultimately, the best grid cell size must also include some consideration of geographic closure. If a geographically-closed grid area is not available, then a larger 8x8 km grid cell size should be chosen. Conversely, if geographic closure can be assumed, then smaller grid cell sizes such as 6x6 km (36 km^2) should be considered to ensure adequate sampling of female bears with small home range sizes (Boulanger in prep.).

VI. *Coastal Black Bears* — Simulation methods were used to evaluate sample design issues around DNA mark–recapture estimates of black bear populations in Clayoquot Sound, B.C. (MacHutchon 1997). Simulations were conducted using movement data from the Nimpkish Valley (Hamilton *et al.* in prep). The following are preliminary results that will be verified and updated as field data are analyzed and more simulation work is conducted.

A. Simulation studies indicated that to compensate for edge effects, when it was assumed that the effective population used an area four times the size of the hair capture grid, a grid size of 24x24 km (576 km^2) was necessary to minimize overestimation of density (MacHutchon 1997). However, watersheds on the coast of B.C. are often steep-sided and have numerous physical barriers that minimize movement between them. It may be possible to minimize edge effects associated with smaller grid sizes by sampling entire watersheds or series of watersheds. Edge effects are likely to be specific to individual study areas, therefore, simulation and empirical methods should be used to estimate edge areas for individual studies.

B. A 2x2 km (4 km^2) grid cell size appeared to be best for coastal black bear population estimates. Although black bear males and females were not caught equally with this grid cell size, in the majority of the simulations, the results were a random sample of the population. In addition, if a mark–recapture population estimator is used which is robust to variation from inherent heterogeneity (i.e., the jack-knife estimator in program CAPTURE of Otis *et al.* 1978) then the amount of bias associated with sex differences in capture probabilities will likely be minimal. In contrast, cell sizes greater than 2x2 km had greater differences in the probabilities of capture of males and females and most samples were non-random (MacHutchon 1997). The recommendation of a 2x2 km grid cell will be further tested once field data are available from an ongoing black bear inventory project.

VII. In review, the following are suggested for the sampling design:

A. A statistician or quantitative ecologist should be consulted to determine what sample design (i.e., grid cell size and overall grid size) will mitigate the most important design problems for the bear species and geographic area of interest.

B. Hair capture grids should be large enough to encompass at least 50, preferably 100 bears.

C. Grids should be located in a geographically closed area. If this is not possible, grid size should be maximized given budget constraints and a quantitative ecologist should be consulted to determine the best sample design and data analysis approach.

D. Grid cell sizes of 7x7 to 8x8 km appear to be best for grizzly bears. The actual grid cell size will depend on the constraints in points b) and c), the expected population size of bears in the area, and the relative percentage of grizzly bears with home range sizes less than 20 km^2. Grid cell sizes of 2x2 km appear to be best for coastal black bears.

- DNA mark–recapture surveys are recommended for the spring or summer when natural foods are scarce and bears are more likely to approach baited hair capture stations. On the coast, DNA mark-recapture surveys are likely best before berries are available in mid to late June. In the interior, surveys are likely best prior to the berry season in mid to late July. Bears are shedding their winter coats in the spring and summer, therefore there is a greater likelihood of having hair follicles in samples during that time period.
- Several researchers believe that moving hair capture stations between capture sessions minimizes behavioural variation in capture probabilities, as well as allows field personnel to target optimal habitat types which may change over the duration of the inventory. Simulation results (Boulanger in prep) suggest that moving stations is advantageous in terms of minimizing bias due to trap encounter when grid cell size is greater than 6x6 km.

Sampling Effort

- Choosing an appropriate capture session (may also be known as sample session) length requires a trade-off between meeting the assumption of geographic closure and maximizing capture probabilities. Reducing capture session length is one strategy for mitigating the overestimation of density due to lack of grid closure. The amount that capture session length could be reduced is determined by the sampling rate of hair capture stations. Estimation of this requires a detailed analysis of mark–recapture data and experiments specific to different sampling. Capture session lengths of 8-15 days have been chosen for most DNA mark–recapture studies to date. The effectiveness of these sampling intervals needs to be empirically tested as well as theoretically explored. Preliminary simulation results suggest that a capture session (sample period) of no more than 10 days is optimal, especially if violation of closure is an issue (Boulanger in prep.).
- Bear populations likely will have some type of inherent heterogeneity in capture probability. In addition, behavioural adaptations and time may result in further variation in capture probability. As an example, bears may habituate to hair capture stations in later capture sessions and, therefore, will have a behavioural response to capture. As a result, the sampling protocol outlined here is designed to accommodate the use of

program CAPTURE (Otis *et al.* 1978) to estimate this variability. Program CAPTURE works best with at least five sequential capture sessions for each mark–recapture study. If possible, more than five capture sessions should be considered within each year of the study. The precision and quality of estimates as well as the power of the model selection routine will increase with higher numbers of capture sessions. If violation of closure is an issue, the overall length of the project should be considered when adding extra capture sessions. If additional capture sessions are added it may be best to reduce the length of each capture session.

Personnel

- One or two biologists familiar with bear biology and data collection and analysis.
- Two or four assistant biologists or technicians.
- One quantitative ecologist.
- One or more skilled helicopter pilots.

Equipment

- Maps and air photos.
- Hair capture station set-up equipment, including:
    - barbed wire, fencing supplies and tools, leather gloves, climbing spurs or tree-steps, chainsaw, axe, machete, GPS, flagging tape.
- Hair capture station bait and equipment, including:
    - drums or pails, sacks, rope or twine.
- Hair collection equipment, including:
    - envelopes, tweezers, surgical gloves.
- Safety equipment, including:
    - radios, pepper spray, first-aid kit.
- One or more helicopters.
- Computer.

Field Procedures

- Practice setting up hair capture stations before starting the capture sessions and ensure field crews understand the protocol. Prepare equipment for the hair capture stations before going in the field, e.g., pre-cut barbed wire, pre-bag bait.
- Ideally, hair capture stations should be placed randomly within each grid cell. Realistically, stations should be placed as close to a random point as access will allow. If there is no access possible in any one grid cell, then a hair capture station should be set-up as close as possible in an adjacent grid cell. If some grid cells can not be sampled then it will likely increase the variation in capture probability due to inherent heterogeneity. It is important to ensure that there is adequate distribution of hair capture stations throughout the study area to obtain equal probability of capture among bears.
- Human scent at hair capture stations and on station equipment should be kept to a minimum. Barbed wire should be used to capture hair samples at each station. The wire should be tightly stretched and stapled to the outside of trees so that it forms a perimeter approximately 5 m away from a central scent. The barbed wire should be strung approximately 50 cm off the ground and all dips, holes and low spots filled in.

- A bait should be hung between 2 trees such that it is centred in the barb wire perimeter. The bait can be hung in burlap sacks approximately 5-6 m off the ground and at least 5 m from each tree (Woods *et al.* 1996b, Gibeau and Herrero 1996). Bait should be positioned so that bears cannot access it.
- The Universal Transverse Mercator (UTM) co-ordinates, slope, aspect, elevation, habitat type, cell number and date of set-up of each hair capture station should be recorded. In addition, the UTM co-ordinates of the helicopter access point should be recorded.
- At the end of each capture session, each hair capture station should be revisited to collect the hair samples and rebait the station. If there are alternative access points in a grid cell then hair capture stations could be moved between capture sessions. Alternatively, different baits may be used in successive capture sessions. Moving stations or using different baits are measures intended to ensure bears do not lose interest in or habituate to hair capture stations thereby introducing behavioural adaptation to capture probabilities.
- Barbed wire should be checked carefully to ensure that all hairs are collected. A sheet of white reflective plastic can be run under the wire so that the hairs are more visible. Each hair sample (i.e., all the hair from one barb) should be placed in a separate envelope which should be marked with the station sample number. All hair sample envelopes from the station should be put in a large envelope. Station sample details should be recorded in a log book. Hair samples and envelopes can be dried and stored in a freezer (Woods *et al.* 1996b, Gibeau and Herrero 1996) or dried and stored in a cool, dry place.
- A standard field form with non-duplicated field labels should be used for samples to avoid confusion at laboratories and during data analysis (Woods and McLellan 1997).
- During sampling, any bears that are radio-collared should be tracked to determine approximate movements during the sampling process. In addition, the approximate "population boundary" should be calculated given likely home range movements of bears in the course of the study and possible barriers to movement such as lakes and mountain ranges. The population boundary should pertain to the time in which the study was conducted, as opposed to yearly movements and home range areas. This information can be used for future simulation efforts to estimate edge areas.

Data Analysis

- Species identification based on analysis of DNA from hair samples should be done by a lab (see Appendix A). To minimize lab costs in grizzly bear projects, glossy black hairs can be assumed to be from black bears; however, any hairs that are questionable should be analyzed. Bear species identification in the lab is done using a mitochondrial DNA marker.
- Microsatellite markers (also referred to as Short Tandem Repeat (STR) markers) are used to identify individuals (Paetkau and Strobeck 1994, Paetkau *et al.* 1995).
- The number of microsatellite markers required depends on the amount of genetic variation in the bear population and the level of confidence required. Likely, 6-8 microsatellite markers would give a high confidence in identifying individuals (D. Paetkau, University of Alberta, Edmonton, pers. comm.).
- The number of microsatellite markers required may be higher if the population is found to have low heterozygosity or genetic variability. Grizzly bears on Kodiak Island, Alaska have been found to have much lower levels of genetic variability than mainland grizzly bear populations (D. Paetkau, University of Alberta, Edmonton, pers. comm.) and black

bears on the island of Newfoundland have been found to have low levels of genetic variation compared to mainland populations (Paetkau and Strobeck 1994). The genetic variability of the bear population being studied should be evaluated prior to an intensive DNA mark–recapture population estimate. Allele distributions at several microsatellite loci can be used to generate probabilities of error for each population with a background sample of approximately 30-50 genotypes (Woods and McLellan 1997).

- Sex of the bear is determined by polymerase chain reaction (PCR) amplification of the Y chromosome specific SRY gene. This test needs to be refined because it is susceptible to small amounts of contamination resulting in potentially false results (Woods and McLellan 1997).
- A series of blind samples and known duplicates should be sent to labs for quality control and to ensure the lab is following strict protocols.
- Once samples have been analyzed, a permanent identification number should be assigned to each bear identified (Woods and McLellan 1997).
- One or more of the population estimation models of program CAPTURE (Otis *et al.* 1978) should be used to analyze the field data. In addition, statistical tests within program CAPTURE should be used to determine the dominant types of capture probability variation within the data set. Bear populations could exhibit heterogeneity, behaviour and time variation in capture probability. As a result, it will be important to determine which of these factors most affects the capture results and use a population estimation model that is robust to these biases. The model selection routine in program CAPTURE has been demonstrated to exhibit low power to choose appropriate models when samples sizes are low (Menkins and Anderson 1988, Boulanger and Krebs 1996), therefore, results of this routine should be interpreted cautiously. The simulation model of J. Boulanger (Integrated Ecological Research, Squamish) can be used in an adaptive fashion to help determine the optimal population estimation model(s).

The following are outstanding issues and concerns with the DNA mark–recapture population estimator that need to be addressed through empirical tests and further simulation work:

- *Capture probabilities of bear populations at different grid cell densities and bear densities.* The simulation results that were used to make recommendations for this report are largely based on one DNA mark–recapture data set (i.e., West Slopes 1996, Woods *et al.* 1997). These recommendations will be re-assessed in the summer of 1998 when five data sets from 1997 studies are expected.
- *Evidence of behavioural response to hair capture stations.* Analysis of mark–recapture field data will help determine if bears are habituating to capture stations.
- *The effect of seasonal changes in natural food availability on capture probabilities (i.e., time variation).*
- *The sampling rate of capture stations.* This could be determined by checking a subset of hair capture stations in an intensive fashion to determine how often capture stations are visited and whether the rate of new bears visiting the stations asymptotes after the station have been left out for a few days.
- *Determination of the robustness and precision of population estimators to lower sample sizes and probable heterogeneity variation in mark–recapture data.*
- *The availability of a black bear DNA mark–recapture data set to further refine simulation model recommendations.*

- *More exact data pertaining to movement patterns of black bears.* Refinement of the classification of movement rates and home range areas for different sex classes of grizzly bears.

3.6.2 Aerial Capture–Mark–Resight (CMR)

Miller *et al.* (1987) developed a capture–mark–resight (CMR) technique to estimate grizzly bear and black bear densities in Alaska. The method has since been used throughout Alaska in a wide variety of conditions (Reynolds *et al.* 1987; Schoen and Beier 1990; Ballard *et al.* 1990; Miller 1990b; Smith and Van Daele 1991; Miller and Ballard 1992; Miller and Sellers 1992; Reynolds 1993). By late 1996, the technique had been used 19 times for grizzly bears and three times for black bears in Alaska (Miller *et al.* 1997). All cited studies used similar survey methods as Miller *et al.* (1987). The CMR technique was thoroughly described and reviewed by Miller *et al.* (1997).

The CMR technique involves applying radio transmitters to bears for ≥1 year prior to the density estimate and then establishing a project area containing representative habitats used by bears throughout a year. The number and identity of radio-marked bears present in the project area during each replication is determined. A series of independent visual searches (replications) are conducted using fixed-wing aircraft to determine the number of marked bears in the population of bears observed on the project area. These data are used to derive density estimates (Miller *et al.* 1997).

The use of radio-telemetry to document the movements of marked bears across search-area boundaries eliminates the necessity to correct for edge effects in calculating density using the CMR technique (Miller *et al.* 1997). The CMR technique assumes geographic closure on each day of resight but permits marked and unmarked bears to move in or out on different days. The assumption that bears do not lose their marks during the experiment can be met because loss of radio transmitters (marks) can be detected daily (Ballard *et al.* 1990). The assumption that all marks are correctly noted and recorded can be met since radio-telemetry can be used to determine if an observed bear is marked or not (Ballard *et al.* 1990).

At low bear densities the capture–mark–resight method has a number of biases and sample size problems (Reynolds *et al.* 1987, Miller 1990b). In addition, the method is only appropriate where there is sufficient probability of seeing bears (i.e., >20%) such that an adequate sample of marked and unmarked bears can be obtained.

There was wide variation in effort, search variables and results for 18 CMR inventories done in Alaska. Premarking effort varied from 1 to 15 years, the proportion of the population marked varied from 8% to 69%, project-area size (search-area size) varied from 34 to 2,228 km^2, number of fixed-wing aircraft used ranged from 1 to 6, number of search replications flown varied from 2 to 9, search effort varied from 0.6 to 4.7 minutes/km^2, independent bears seen per hour varied from 0.2 to 15.5, sightability of marked bears varied from 11 to 65%, and percent of time marked bears were in the project area (geographic closure) varied from 46 to 100% (Miller *et al.* 1997). Costs of the Alaska density estimates were directly correlated with distance of the project area from facilities, size of the project area, number of replications and flying conditions. Cost estimates for grizzly bear density estimates in Alaska ranged from \$3 US/ km^2 to \$135 US/ km^2 and for black bear density estimates it ranged from \$15 to \$31 US/ km^2. The cost of premarking bears was usually not included in the density estimate cost unless the primary motive for the study was obtaining a density estimate. Radio-marking an adequate sample of bears can be expensive, but the actual amount will depend on the location of the project area and the ease of access (Miller *et al.* 1997).

Office Procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Read Miller *et al.* (1987, 1997) and White (1996).
- Obtain available planning and analysis software. Program NOREMARK is available on the World Wide Web (http://www.cnr.colostate.edu/~gwhite/software.html) or by sending a blank high-density formatted disk to G.C. White (Colorado State University, Fort Collins, CO). NOREMARK has a user friendly simulation program that can be used to determine optimal sampling strategies for desired precision of the population estimate. NOREMARK will calculate immigration–emigration joint-hypergeometric maximum-likelihood estimates (IEJH) and confidence intervals for user specified α and will simulate the CMR methods as an aid in designing efficient CMR density estimates (White 1996). Software for calculating estimates and confidence intervals for bear-days (based on LOTUS (Lotus Development Co., Cambridge, Mass.)) as well as simulation software for these estimators (requires FOXPRO (Microsoft Corp., Redmond, Wash.)) are available from S.D. Miller (National Wildlife Federation, Missoula, MT) by sending a blank high-density formatted disk.
- Consult closely with a statistician or quantitative ecologist who is familiar with mark–recapture planning and analysis.
- Evaluate the effectiveness of alternative study designs by simulating CMR results before conducting field inventories. Simulations can provide important guidelines for the necessary project-area size, number of marked animals, number of replicates, search intensity (sighting probability) and the implications of trade-offs between these design elements and the precision of the estimate (Miller *et al.* 1997).
- Obtain maps for project and study area(s) (*e.g.*, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- Outline the project area on a small to medium scale map (1:250,000 – 1:50,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area from maps.
- Define all habitats used by bears in the project area using telemetry data from premarked (radio-marked) bears.
- Delineate a study area(s) within the larger project area that encompasses representative proportions of the different habitats that bears use throughout the year. Try to use natural barriers to define the boundaries of the study area to reduce movements across these boundaries during a replication.
- 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 used in the Sampling Design then strata within the study areas should represent relevant strata in the larger project area.
- A study area is subjectively selected to represent the project area or larger surrounding areas (Miller *et al.* 1997). Random selection of study areas would permit extrapolation of estimates to larger areas (i.e. to the project area) to derive statistically valid estimates of population size in the project area (*sensu* Samuel and Garton 1994). However, the costs and logistic constraints involved in doing enough density estimates in randomly chosen study areas to allow statistically valid extrapolations would be prohibitive (Miller *et al.* 1997).

- The study area(s) should be selected to ensure complete search coverage each survey day.
- Before estimating density, provide persons knowledgeable about bear populations in the project area with reference density data from other areas and ask them to guess the density in the project area. These guesses can permit evaluation of the accuracy of density extrapolations from the project area to other areas of management interest (Miller *et al.* 1997).
- In study areas where >1 fixed-wing aircraft is used for searching, divide the study area into identifiable blocks (also called quadrats). Use natural landmarks such as streams and ridges to delineate block boundaries. If blocks are drawn to encompass different habitat types within the study area, then bear density within blocks or groups of blocks can be estimated (Miller *et al.* 1997).

Sampling Design

- Preferably >45% of the estimated population of bears are radio-marked during initial capture in the project area.
  - Premarking bears one or more years prior to the density estimate is an important component of the CMR technique and serves a number of purposes (Miller *et al.* 1997):
    1. Premarking bears helps to minimize any marking bias based on reproductive status. Females can be marked at a time when their reproductive status is different then during the density estimate and when they are more vulnerable to capture.
    2. Premarking bears can also help reduce the marking bias associated with individual behaviour or habitat use. Unmarked bears can be captured with helicopter darting when they are found accompanying previously marked adults during the breeding season. These may be bears that otherwise have relatively low probabilities of capture.
    3. Unmarked bears do not have to be captured during the density estimates if an adequate sample is previously radio-marked (Miller *et al.* 1987).
  - Bears should be captured and marked on a project area that is larger than the study area used during the density estimate. This provides the potential for augmenting the proportion of marks on the study area if some of these bears move on to the study area during the search period (Miller *et al.* 1997).
  - All bears encountered should be captured and marked to avoid bias in comparisons of population sex and age structure.
  - The confidence intervals around the population estimate can be reduced by increasing the proportion of marked bears in the population (Miller *et al.* 1987, Ballard *et al.* 1990).
- Study areas that are representative of the project area are searched for bears each day during the survey.
- Try to use different techniques or combinations of techniques for initial capture and radio-marking of bears than are used to obtain resightings. This increases the likelihood that the population of marked bears is representative of the population observed during surveys. If different techniques are not feasible, then exploit other opportunities to ensure an unbiased distribution of marks such as capturing unmarked associates of marked bears during the breeding season, capturing bears on ungulate kill stations,

capturing bears by following tracks across snowfields, or capturing bears at den sites (Miller *et al.* 1997).

- Confidence intervals around the population estimate can also be reduced by increasing the number of survey replications, with increased survey intensity during any one replication, or by increasing the study area in low-density areas (Miller *et al.* 1987, Ballard *et al.* 1990, Miller *et al.* 1997).

Sampling Effort

- Capture–mark–resight population estimates should be done as part of a multi-year bear study to justify capturing and radio-marking a large sample of bears. Once an adequate sample of bears are radio-marked, however, surveys can be conducted in 5-10 days.

Personnel

- At least one biologist familiar with bear biology and data analysis.
- At least one biologist or technician competent in aerial telemetry.
- Two or more biologists or technicians that are proficient at spotting bears from the air.
- Two or more skilled pilots.
- One statistician or quantitative ecologist.

Equipment

- Maps and air photos
- Field notebooks, data forms
- Capture equipment
- Telemetry equipment
- Data recording equipment
- Several fixed-wing aircraft or helicopters
- Computer

Field Procedures

Capture and Marking

- Attempt to radio-mark >45% of the estimated population during initial capture. It is preferable to radio-mark an adequate sample of bears prior to the resight surveys so bears do not have to be captured during the surveys (Miller *et al.* 1987).
- Monitor radio-marked bears for at least a year prior to surveys to estimate home ranges and habitats used. If capture occurs in the spring, then resight surveys should not be done until at least the following spring.

Resight

- Conduct CMR surveys after all bears have left their dens, but before trees and shrubs have leafed out. There is significantly reduced bear sightability after leaf emergence (Miller *et al.* 1997).
- The number and identity of radio-marked bears present in the study area (search area) during each replication (M_i) should be determined with a radio-tracking aircraft. Flights to determine M_i are referred to as closure flights (Miller *et al.* 1997). It is important that no information on bear locations be obtained by pilots and observer teams during closure

flights that could bias later search efforts. Marked bears should only be verified as in or out of a study area (search area) rather than specifically located. In some cases, marked bears close to study area boundaries may have to be precisely located. In these instances, another pilot and observer team should subsequently search that block (Miller *et al.* 1997).

- On a daily basis, assess whether any bears have dropped their radio collars (loss of marks).
- *Visual searches:*
  - Conduct visual searches using fixed-wing aircraft to determine the number of marks (m_i = bears with radio transmitters) in the population of bears observed on the study area.
  - Search the entire study area each day (replication) to minimize the possibility that unmarked bears are counted more than once.
  - Use two or more aircraft for searches depending on the size of the study area. Pilots and observer teams should rotate among search blocks on different replications to minimize the potential impact of previous experience within a block and because of differences in pilot and observer skill (Miller *et al.* 1997).
  - Search rate will depend to a large extent on vegetation cover on the study area. Use survey flight patterns that are designed to maximize the likelihood of seeing bears, but that will ensure that no individual bear is counted more than once per replication. The flight patterns used by Miller *et al.* (1997) usually consisted of flying in large circles in forested or tall shrub habitats, linear flight lines in open tundra or low shrub habitats, and flight lines along elevation contours in steep terrain or narrow drainages.
  - When bears are observed, turn on radio-telemetry equipment to determine if the bear is radio-marked or unmarked.
  - Plot the location and characteristics, such as group composition, colour, size, movement direction, time, etc., of all bears observed during searches on maps. These locations can be used to eliminate potential duplicate observations of bears seen by different observers near the borders between search blocks (Miller *et al.* 1997).

Data Analysis

- Monitor changes in the confidence intervals around the population estimate as successive surveys are done. If need be, the confidence intervals can be tightened with more replicates (survey days) or with greater survey intensity during any one replicate.
- Use the Immigration–Emigration Joint-hypergeometric Estimator (IEJH) to determine population sizes. Software for using the IEJH estimator is in program NOREMARK which is described in White (1996). Use of the IEJH estimator for population estimates of bears is described in Miller *et al.* (1997). The IEJH estimator is an extension of a joint-hypergeometric maximum likelihood estimator (JHE) and allows for movement of marked and unmarked bears in or out of the study area between replications. Confidence intervals are determined with the profile likelihood method (Miller *et al.* 1997).
- White (1993 in Miller *et al.* 1997) used Monte Carlo simulations to show that the IEJH estimator and CI performed well with relatively small populations (67-667), with capture probability of 0.3 and sighting probabilities of 0.5 and 0.7, with number of sighting replications of 5 and 10, and with probability of being on the search area of 0.75.
- Subsequent to the work of Miller *et al.*(1987), Eberhardt (1990) evaluated several estimators that used simulated CMR data and concluded that a bias corrected mean of

daily Lincoln-Petersen estimates was preferable to the ’bear-days’ estimator of Miller*et al.* (1987), particularly at low sighting probabilities (i.e., probability of being observed of 0.2). Eberhardt (1990) corrected for biases that resulted from low sample size and a low number of resighted marks. He suggested that the bear-days estimator yielded a consistent, but slight, overestimate. Miller *et al.* (1997) reported that the IEJH estimator provided point estimates and CI’s that were similar to those calculated using the bear-days estimator of Miller *et al.* (1987). The IEJH also produced point estimates that were similar to the mean Lincoln-Petersen estimator of Eberhardt (1990), however, the mean Lincoln-Petersen estimator was more sensitive to outlier replications and had larger CI’s. The low sample-size bias correction factor (Eberhardt 1990) resulted in little change to the point estimates (Miller *et al.* 1997).

- Important assumptions of the IEJH estimator are that all animals in the population have the same sighting probability for a particular replication (i.e., no heterogeneity of sighting probability across individuals) and that animal sightings are independent. Both assumptions are probably violated to some extent, however, the IEJH estimator should be fairly robust to moderate violations of these assumptions. Miller *et al.* (1997) felt that violations of these assumptions decreased confidence interval (CI) coverage, but had negligible effect on bias.
- Miller *et al.* (1997) felt that they were more likely to have violated the assumption of equal sightability than other assumptions. Violation of this assumption can cause density estimation biases or underestimates of the CI’s. Unequal sightability will occur if some bears or classes of bears are less likely to be captured and resighted than others, including: 1) individuals with personal experiences that tend to make them hide from aircraft or that live in habitats that restrict observations from the air and 2) classes of bears, such as females with new-born cubs, that may move less, be more secretive, or inhabit terrain where sighting from aircraft is more difficult. Based on their data, Miller *et al.* (1997) concluded that individual heterogeneity of sighting probabilities within reproductive and sex classes existed more so than differences in sighting probabilities among the classes. Individual heterogeneity of sighting probabilities can be minimized by applying radio-marks in a manner independent of that used to obtain resightings.
- Observations of each bear are not independent events when bears are associated in groups such as females with dependent offspring and breeding pairs. Miller *et al.* (1997) described simulations using the IEJH estimator and the bear-days estimator that demonstrated that variance is reduced and CI coverage is underestimated when members of groups are treated as independent sightings. This problem can best be overcome by selecting classification categories that eliminate (e.g., independent bears) or minimize the degree to which the assumption is violated (e.g., bears ≥2 years old). Violation of the independent observation assumption will occur when management needs require estimates of total population and, therefore, the true variance will be underestimated (Miller *et al.* 1997).
- Miller *et al.* (1997) derived density estimates for three age/sex classification categories of bears: bears of all ages, grizzly bears ≥2 years old (black bears ≥1 year old), and independent bears. For the “bears of all ages” category, they counted all bears encountered, including offspring accompanying females, and tallied them as marked or unmarked depending on whether the mother was marked or unmarked. For the category of “bears ≥2 years old”, offspring with their mothers were counted only if these offspring were known (in the case of marked bears) or estimated (for bears not captured) to be ≥2 years old. This was not necessary for the “independent bear” category, as offspring

accompanying a female were not counted regardless of age. Each individual in adult or sibling groups was counted as an independent observation; these groups would sometimes contain both marked and unmarked individuals.

- CMR population estimates can be converted directly to a density estimate using the size of the search (study) area without the need to correct for density or edge effects (Miller *et al.* 1997).

3.6.3 Capture–Telemetry

McLellan (1989a) proposed two methods for estimating bear density in areas where capture and telemetry have been used intensively. Variations of McLellan’s (1989a) approach have been used elsewhere (Garshelis 1990, Miller 1990a).

Bears were intensively captured over a number of years in a trapping area and an attempt was made to capture all bears using the trapping area (referred to as "saturation" trapping) (McLellan 1989a). The boundaries of the trapping area were later determined as the minimum convex polygon which enclosed all successful trap locations over the entire study period. All captured bears were radio-collared and tracked for several years. Bears were located from the air or the ground as often as possible, but at least one day apart. Two methods were used to estimate density:

1. Each radio-collared bear’s 97.5% minimum multi-annual home range convex polygon was plotted and the bear’s contribution to the density estimate was the proportion of its home range within the trapping area. McLellan (1989a) considered that an average of 2.5% of locations were outliers. Removing outliers reduced bias in two ways. For bears whose main area of activity was the trapping area, it reduced the proportion of their home range that might have been considered outside the trapping area, therefore reducing the chance of underestimating density. At the same time, it reduced the bias of not catching and therefore not counting bears whose high use areas were elsewhere and only entered the trapping area occasionally (McLellan 1989a).
2. The second method used the proportion of time each bear spent in the trapping area. This proportion was assumed to equal the proportion of a bear’s aerial locations within the trapping area. Aerial locations were used to eliminate any bias associated with differential access for ground tracking (McLellan 1989a).

A major assumption of McLellan’s (1989a) capture–telemetry method is that all bears having at least part of their 97.5% home ranges within the trapping area are captured. In addition, both estimators rely on a continuous sample of radio-collared bears. It is unlikely that all bears will be captured or all bears will carry collars for the duration of the study so population size may be under-estimated.

Garshelis (1992) used a similar approach to McLellan (1989a), but instead of assuming that all bears had been caught and marked, they calculated a marked:unmarked ratio and the contribution of each marked and previously unmarked bear was equal to the proportion of their telemetry locations in the trapping area. As an example, the total number of bears captured during the period of population estimation was equal to the number of previously captured bears that were recaptured, weighted by the proportion of their time in the trapping area, plus the number of new bears (previously unmarked) that were captured, weighted by the proportion of time they subsequently spent in the trapping area.

Capture–telemetry population estimators are more accurate than commonly used techniques such as counts of known bears. In addition, more accurate estimates of density may be achieved with capture–telemetry than mark–recapture methods when the size of the area occupied by the estimated population is uncertain (Miller 1990a). An accurate estimate of annual density allows an estimation of population rate of increase which can be related to the impacts of human activities, provided there is some measure of natural population changes

(McLellan 1989b, 1989c). However, capture–telemetry methods require intensive capture and radio-telemetry over a number of years, therefore, they are time consuming and expensive. The cost of capture–telemetry often precludes doing it over a large study area so extrapolating the density estimate to areas outside the trapping area can be difficult.

Capture–telemetry population estimates can contain subjective elements that make them difficult to replicate (Miller 1990a). McLellan's (1989a) first estimator in particular is tied to subjective decisions about what home range method to use and what percent of the home range to include. Different methods of estimating home range should be used to test their effect on the population estimate. In addition, McLellan's (1989a) capture–telemetry estimator does not include an estimate of variance (Miller 1990a). It has been suggested that standard errors of the estimate could be derived from bootstrap techniques which would remove the problem of underestimates to some degree (A. Derocher, pers. comm.). Garshelis (1992) discusses some of the issues associated with trying to estimate variance for these type of estimators.

Capture–telemetry should only be used on long-term and/or intensive research studies. In addition to evaluating population parameters, saturation trapping and intensive radio-telemetry can provide valuable and relevant information about habitat use. Because of this, both population and habitat questions should be addressed in studies that use capture–telemetry methods. Limits to time and money will often be major constraints to the application of capture–telemetry in B.C.

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.

ALLELE: One of the alternative forms of a gene. In an animal cell there are usually two alleles of any one gene (one from each parent), which occupy the same relative position (locus) on chromosomes.

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.

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.

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

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.

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

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.

GENE: A unit of heredity composed of DNA.

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

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

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

HETEROGENEOUS: (heterogeneity) Diverse in character; being of different kinds.

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

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.

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

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

MARK TREE: A tree scratched, bitten and rubbed on by bears as a form of social communication.

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

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

MITOCHONDRIAL DNA: (mtDNA) A circular ring of DNA found in mitochondria.

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

NUCLEAR DNA: (nDNA) DNA found within the chromosomes of the cell nucleus.

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.

POLYMERASE CHAIN REACTION: (PCR) A technique used to replicate a fragment of DNA so as to produce many copies of a particular DNA sequence.

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).

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.

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.

REPLICATES: Repeated surveys of the same survey area in order to increase the precision of estimates and to provide a measure of survey variability.

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: Animal faeces

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.

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.

TRANSECT: A survey route run along a straight line.

UNGULATE: A member of a family of large hoofed mammals including moose, deer, elk, sheep, mountain goat, caribou, and bison.

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

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Appendix

Appendix A. Laboratories that can or have conducted analysis of DNA from bears.

Contact	Location
1) Commercial Labs:	
Odd Bres	Northern Bioidentification Service Ltd. 403 - 63 Albert Street Winnipeg, Manitoba R3B 1G4 Telephone: 204-947-0742; Fax: 204-943-5711 E-mail: northern@mts.net Web site: http://www.mts.net/~northern
John Nelson	Seastar Biotech Inc. P.O. Box 32056 3749 Shelbourne Street Victoria, B.C. V8P 5S2 Telephone: 250-472-4076; Lab phone: 250-472-4072; Cell Phone: 250-812-6941; Fax: 250-472-4075 E-mail: jnelson@seqlab.ceh.uvic.ca Web site: http://seqlab.ceh.uvic.ca/seastar
Samuel Wasser Christine Clarke	Centre for Wildlife Conservation 5500 Phinney Avenue North Seattle, Washington 98103 Telephone (S.W.): 206-684-4810; Telephone (C.C.): 206-616-9124 E-mail: wassers@u.washington.edu E-mail: clarkec@u.washington.edu
Melanie Watt	Genetics Lab Inc. 140 Benchlands Terrace Canmore, Alberta T1W 1G2 Telephone / Fax: 403-678-5747 E-mail: mwatt@banff.net
2) University Research Labs – Information Only:	
Kermit Ritland	Department of Forest Sciences University of British Columbia 2357 Main Mall Vancouver, B.C. V6T 1Z4 Telephone: 604-822-8101; Fax: 604-822-9102 E-mail: kermit.ritland@ubc.ca Web site: http://forgen.forestry.ubc.ca/ritland
Curtis Strobeck	Biological Sciences Building University of Alberta Edmonton, Alberta T6G 2E9 Telephone: 403-492-3515; Fax: 403-492-9234 E-mail: curtis.strobeck@ualberta.ca
3) DNA Extraction:	
Kelly Stalker	Abacus Wildlife Consultants P.O. Box 2271 Revelstoke, B.C. V0E 2S0 Telephone: 250-837-4743 E-mail: arkades@junction.net