Species Inventory Fundamentals

Standards for Components of British Columbia's Biodiversity No. 1

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

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Preface

This manual presents an introduction to the species inventory program in British Columbia. It 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 an introduction to the Standards for Components of British Columbia's Biodiversity (CBCB) series. It describes the history and objectives of RIC, and outlines the general process of conducting a species inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. This manual, *Species Inventory Fundamentals*, provides important background information and should be thoroughly reviewed before commencing with a RIC species 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 any of these activities. The rest of the manuals in the CBCB series present standard protocols designed specifically for a group of species with similar inventory requirements. Each of these manuals outlines inventory methods at three levels of intensity: presence/not detected (possible), relative abundance, and absolute abundance.

Standard dataforms are required for all RIC species inventory. Survey-specific dataforms accompany most manuals while general inventory forms are available in the corresponding 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 dataforms, 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:

Species Inventory Unit
Wildlife Inventory Section, Resources Inventory Branch
Ministry of Environment, Lands & Parks
P.O. Box 9344, Station Prov Govt
Victoria, BC V8W 9M1
Tel: (250) 387 9765

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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:

The Executive Secretariat
Resources Inventory Committee
840 Cormorant Street
Victoria, BC V8W 1R1

Tel: (250) 920-0661
Fax: (250) 384-1841

http://www.for.gov.bc.ca/ric

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 of James Quayle, Tom Ethier and Leah Westereng. Special thanks to John Boulanger and Dr. Charles Krebs who contributed a draft of the chapter on Data Analysis Methods, the appendix on Population Analysis Software, and portions of the discussion on Habitat Description. Helpful suggestions and reviews were provided by Dave Clark, Lynne Bonner, Andrew Harcombe, Ian Hatter, Eric Lofroth and Lorne McIntosh.

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1. INTRODUCTION

This manual provides an introduction to the 41 other manuals in the Components of British Columbia's Biodiversity (CBCB) series produced by the Resources Inventory Committee (RIC) of British Columbia. Each CBCB manual is written to provide relevant information and standard protocols for the collection of reliable inventory data for wildlife species in British Columbia. CBCB manuals are intended to act as the methodological standard for species inventory and assessment, including both operational and strategic-level field inventories of wildlife, population monitoring, and species statusing.

A brief discussion of terminology is helpful to define the scope of the CBCB series. The focus of the series is *inventory*, a term which is defined as 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 distributional change 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, 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 this manual, *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*.

In addition to providing background information about CBCB series, it is intended that this manual will outline the process of setting up a *species inventory* project, beginning with project design through to data collection, storage, and eventual analysis. It is not the intention to create a comprehensive review of wildlife inventory, but rather to highlight important considerations and issues which are generic to many inventory projects, and to clarify the broad expectations surrounding RIC standards for species inventory.

1.1 Species Inventory and Biodiversity Conservation

Human activities and escalating population growth resulting in habitat loss, habitat fragmentation, pollution, and the introduction of exotic species have contributed to a global decline in biological diversity and integrity (Wilson 1991, Angermeier and Karr 1994). While British Columbia contains Canada's greatest diversity of species and ecosystems, our province is not exempt from concerns over the conservation of many populations of species. For example, over 150 taxa of known mammals, birds, reptiles, and amphibians and over 600 vascular plants are listed for legal designation as threatened or endangered in British Columbia. The continuing loss of biological diversity will have a major impact on the health and functions of ecosystems and the quality of life in the province.

Historically, there has been a lack of data to allow resource managers to evaluate the state of our province's biodiversity, or to make scientifically-based land use decisions. Endeavours to catalogue the distribution and abundance of plant and animal taxa in British Columbia have been erratic. In only rare and exceptional cases have inventory and monitoring programs been designed to give statistically valid population estimates over time. Most of these programs have focused on game species such as ungulates and waterfowl; however, expanding human populations and increasingly efficient methods of resource extraction have made it imperative for scientists and land managers to develop a clear picture of the status and trends of a wide array of species. To better understand what and how much is at risk of being lost, resource managers require high quality data collected by well-documented, proven methods, as this will allow comparative analyses, examination of population trends, and insight into the impact of human activities on biodiversity.

From the perspective of maintaining the biodiversity, the importance of standardization can not be overemphasized, as province-wide consistency and reliability will facilitate comparison among and between different studies to reveal landscape-level changes in distribution and population trends. In contrast to this, the continuance of the historic approach of using project-specific data collection methods will make broad scale comparisons difficult, if not impossible. For example, we can not compare the composition of bird species in an area over time based upon mist netting in one year and audible detection techniques in the following year. Although annual differences in bird composition may reflect real differences in species, they are also likely the result of sampling biases, many of which are created by not controlling the sampling method. Standardization of methods within a study and between studies makes it possible to minimize biases due to changes in sampling technique and more accurately reflect ecological patterns. The desire to standardize inventory protocols province-wide has resulted in the establishment of the Resources Inventory Committee. This is one of several inventory initiatives by the British Columbia government working in partnership with the Federal government and First Nations.

1.2 The Resources Inventory Committee

The Resources Inventory Committee (RIC) was established in 1991, with the primary task of developing 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.

The Resources Inventory Committee 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 provincial resources inventories. The development of standards for inventory for the entire range of terrestrial species and ecosystems in British Columbia is the goal of the Terrestrial Ecosystem Task Force.

The Elements Working Group (EWG) is that part of the Terrestrial Ecosystem Task force which is specifically concerned with inventory of the province’s wildlife species. The EWG is mandated to provide standard inventory methods that will 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 standardized methods for species population inventory. Standardizing how inventory data are collected in British Columbia is intended to provide insight into:

- the distribution and habitat associations of species;
- relative abundance and population trends of species; and
- absolute abundance for populations, as required.

The goals, objectives, manuals and projects of the EWG have evolved in response to requirements of initiatives such as the Forest Practices Code and Forest Renewal British Columbia. Recognizing the difficulty of establishing workable standard methods for the diverse biota of British Columbia, the EWG has taken a consultative approach. This has involved drawing in biological expertise from universities, private consulting firms, and provincial and federal government agencies.

The process of manual development began in December 1992, when a group of species specialists met to discuss strategies for biodiversity inventory and to determine inventory groups. An inventory group was defined as a group of species, usually taxonomically connected, which can be surveyed by a common inventory method. Thirty-six inventory groups were designated (Table 1, CBCB manuals series no. 7-42), and currently, CBCB manuals are being prepared for the majority of these. Each manual follows a standardized format providing protocols for inventory to determine species presence, distribution, relative abundance, and absolute abundance. Additional components covered in each manual include factors to be considered when developing a survey program, sampling methods for collecting data, and statistical methods for developing population estimates, or estimating changes in population parameters. The majority of manuals are accompanied by a set of field dataforms and coding instructions.

It was recognized that other documents were needed to support the species-specific manuals and provide information about technical issues which are common to many species groups. These documents include standard taxonomic references, capture and handling protocols, a guide to radio-telemetry, a protocol for terrestrial vertebrate biodiversity surveys, and this introductory manual (Table 1, CBCB manuals series no. 1-6).

Table 1. Manuals in the Components of British Columbia's Biodiversity (CBCB) Series.

CBCB Series #	Manual	Accompanied by Dataforms?
Support Documents		
1	Species Inventory Fundamentals	Y
2	The Vertebrates of British Columbia: Scientific and English Names	N
3	Live Animal Capture and Handling Guidelines for Mammals, Birds, Reptiles, and Amphibians	N
4	Collection and Preparation of Voucher Specimens	N
5	Wildlife Radio-telemetry	Y
6	Initial Vertebrate Reconnaissance Inventory	Y
Birds		
7	Marsh Birds: Bitterns and Rails	Y
8	Colonial-nesting Freshwater Birds	Y
9	Nighthawks and Poorwills	Y
10	Marbled Murrelet	Y
11	Raptors	Y
12	Riverine Birds	Y
14	Shorebirds	Y
15	Forest and Grassland Songbirds	Y
16	Swallows and Swifts	Y
17	Upland Gamebirds	Y
18	Waterfowl	Y
19	Woodpeckers	Y
Mammals		
20	Bats	Y
21	Bears	Y
22	Beaver and Muskrat	Y
23	Hare and Cottontails	Y
24	Marten and Weasels	Y
25	Medium-sized Territorial Carnivores	Y
26	Moles and Pocket Gopher	Y
27	Mountain Beaver, Busy-tailed Woodrat and Porcupine	Y
29	Pikas and Sciurids	Y
31	Small Mammals	Y
32	Ungulates: Aerial Inventories	Y
33	Ungulates: Ground-based Inventories	Y
34	Wolf and Cougar	Y

CBCB Series #	Manual	Accompanied by Dataforms?
Herptiles		
36	Plethodontid Salamanders	Y
37	Pond-breeding Amphibians and Painted Turtle	Y
38	Snakes	Y
39	Tailed Frog and Pacific Giant Salamander	Y
Arthropods		
40	Terrestrial Arthropods	Y
Plants		
41	Macrofungi	N
42	Rare Vascular Plants, Lichens and Bryophytes	N

2. SURVEY DESIGN

"The most critical stage of implementing and completing an inventory or monitoring study is not data collection, presentation or interpretation, but rather design. Careful design will increase effectiveness, reduce costs and lead to improved interpretation" (Jones 1986).

As with any scientific endeavour, selecting an appropriate survey design is dependent on establishing clear objectives from the very beginning. In general terms, there tend to be three objectives which pertain to species inventory projects:

1. to obtain baseline data on the abundance and distribution of species,
2. to monitor changes in abundance, composition, and/or distribution, and
3. to measure the direction and extent of these changes.

Species inventory projects in British Columbia are limited to activities which address at least one of these objectives using one or more of the methods outlined in a CBCB manual.

This chapter outlines survey design concepts which should be standard to all species inventory surveys in British Columbia. These include selection of a level of intensity, adherence to the standard survey design hierarchy, and consideration of “Identified Wildlife” as defined by the Forest Practices Code. Discussion will also deal with a number of generic concepts that are important to every survey, such as bias, accuracy, precision, and sampling design.

2.1 Level of Intensity

RIC has identified three broad levels of intensity at which inventories can be conducted: presence/not detected (possible), relative abundance, and absolute abundance. The selection of a level of intensity will depend on the survey objectives.

2.1.1 Presence/not detected (possible)

Presence/not detected surveys are designed to determine a species' occurrence in an area. Presence/not detected is the simplest measurement of a population. Generally there are two goals of a presence/not detected inventory: to make a species list for a study and /or to determine species/habitat associations. The former can be used to determine species richness, while the latter helps to clarify the distribution and habitat association of a species. Both usually require sampling representative areas.

Adequate sampling effort is essential for presence/not detected surveying. The general presumption is that presence can be detected with some reliability given minimal effort. Techniques for determining how much effort is theoretically required to detect a certain species in a specific habitat are outlined in Section 5.2.4. However, mathematics are only part of a successful presence/not detected survey, and it is important to realize that there are many factors that can account for a species not being verified in an area (Cooperrider *et al.* 1986). These include poor sampling technique, animal rarity, unskilled observers, weather, seasonal absence of the species, and other sources of bias (see section 2.4.2). For these reasons, only presence of a species can confidently be determined. The potential risk of declaring a species absent when it may exist at very low density can not be over-emphasised. For example, a management activity may proceed on the assumption that an inventory found the species absent. If the species does exist at low levels, the decision to proceed with a potentially-detrimental management activity may result in its extirpation. Rarely can the goal of determining absence be accomplished, normally only failure to detect a species in an area can be reported.

2.1.2 Relative abundance

Relative abundance data provide indices of population sizes which usually can not be converted to an estimate of absolute abundance. However, providing survey bias is constant, the results can provide comparable estimates of abundance between localities and species, or within species over time. These indices are usually based on some measure of effort such as a unit of time or distance travelled. Typical relative abundance measures include (from Jones 1986):

- number of animals or their sign seen per unit of time (*e.g.*, deer/hour, also termed time-restraint)
- number of animals or their sign seen per linear distance (*e.g.*, raptors seen per kilometre of powerline)
- number of animals trapped per 24 hours (*e.g.*, mice)
- number of animal calls heard per hour (*e.g.*, frogs)

It is usually assumed that these measures are related linearly to the true population size (although other relationships are possible) and, consequently, the majority of ecological problems can be tackled through the use of indices of density rather than absolute estimates (Caughley 1977). Indices that are highly variable require multiple counts to achieve precision when used for trend monitoring. This necessitates either conducting replicate counts each year, and/or calculating trends only after a sufficiently long period of time (Harris 1986). Analysis of relative abundance is discussed in detail in Section 5.3.

2.1.3 Absolute abundance

Absolute abundance refers to total numbers or density of a species. Estimates of absolute abundance are often obtained in similar ways to relative abundance; however, the estimates are applied to a specified area. Absolute abundance is usually more costly and difficult to measure than relative abundance. Although most problems associated with population studies can be resolved by using indices of relative abundance, absolute abundance data are required for studies in which one attempts to relate population density to vital statistics, such as reproduction, survival, emigration or immigration (Caughley 1977, Krebs 1989). Absolute density is also required for analysis of harvest strategies.

Estimates of absolute abundance may be made directly from total counts or sampled counts; and indirectly by mark-recapture. Mark-recapture inventories on whole are generally considered as a techniques which will provide an estimate of absolute abundance, even though certain models (*e.g.*, Jolly-Seber) incorporate immigration and emigration into population estimates and thus do not provide a true estimate of density. It is important to consider the advantages and disadvantages of any method for deriving absolute abundance prior to commencing an inventory at this level (Table 2).

Table 2. Absolute abundance survey methods.

Survey Method	Advantages	Disadvantages
Total Counts	• not influenced by sampling errors if the assumption that all animals are counted is true.	• effective only for small areas and if animals are conspicuous and discretely distributed • should be considered ‘minimum counts’ as even conspicuous animals are often missed
Sampled Counts	• minimizes collection time • reduces the chance of double counting • causes less disturbance to the population • provide estimates of statistical precision if replicated and • allows optimization of effort	• subject to sampling errors • relies more on statistical assumptions (*e.g.*, randomness) than total counts
Distance methods	• uses similar methods to traditional point counts and strip transects, with little increase in effort to obtain estimates. • allows statistically rigorous estimates of population size and survey variance.	• requires larger samples sizes for estimates.
Mark-recapture Mark-resight	• provides data on a greater number of population parameters (*e.g.*, population health, productivity) • Mark-resight provides a cheaper alternative to mark-recapture for non-cryptic species.	• high costs and effort associated with capturing and recapturing animals • strong reliance on statistical assumptions (*e.g.*, closure, equal catchability) • stressful to focal population

2.1.4 General considerations

Whether a biologist chooses presence/not detected (possible), relative abundance, or absolute abundance as the level of intensity for a project will depend upon the specific goals of the inventory. Radio-telemetry provides a further option which may serve as the basis for an inventory or to enhance traditional methods. (This is discussed in detail in manual No. 5, *Wildlife Radio-telemetry*.) Careful consideration of what question the inventory is supposed to address will provide guidance as to the appropriate level of intensity. This can best be illustrated by example (Table 3).

Table 3. Examples of questions that can be addressed at each level of inventory intensity.

Presence/Not detected	Relative Abundance	Absolute Abundance
Determine the types of species occupying various habitats within a defined Study Area.	Detect a change in population size and composition over time.	Set optimal harvest rates for a hunted population.
Delineate the distribution of a species within a larger geographic area.	Rank Study Areas within a larger Project Area based on the abundance of a particular species.	Determine the relationship between reproduction and species density.
Detect an expansion* in the distribution of a population or species over time.	Determine population trend in managed and unmanaged Study Areas.	Monitor the recruitment of a red-listed species.

* Presence/Not Detected surveys can not detect range reduction as they do not have the statistical validity to conclude local extinction.

Generally, the level of intensity will decrease, as the geographic scale of the Study Area increases. In many cases, presence/not detected studies can be relatively inexpensive because crews with minimal training and experience can be used. However, this may not always be the case as compilation of a species list requires reliable identification skills. The reduced cost of presence/not detected surveys may facilitate coverage of a greater geographical area than more intensive methods. In contrast, collecting data to determine relative abundance requires higher levels of funding and expertise because of the demand for precision. As well, a sampling design and framework are required to collect relative abundance data to an adequate level of precision over a broad geographic area because time and funding are often limited. Similarly, costs and time tend to prohibit collecting data for absolute abundance of species on a large geographic scale.

2.2 Standard Survey Design Hierarchy

The task of standardizing how field data are collected for all of British Columbia's wildlife species is a daunting one. This is made doubly complicated when couched with a companion task of developing a computer system to hold all the information collected. What makes both of these complex tasks achievable is the understanding that there are certain components of a species inventory project which are common to all species, and which have a common relationship to one another regardless of focal taxa. Besides the survey itself, there are a collection of spatial phenomena - Project Area, Study Area, Design Components, and observations - that are a necessary part of a species inventory whether the objective is to survey moose from a helicopter or trap small mammals using grids on the ground.

The species survey design hierarchy (see Appendix C for examples) is fundamental to all RIC species inventory. It is the basis for all of the dataforms as well as the data system. Because of this, it is valuable for a project biologist to understand the hierarchy when designing a species inventory. Surveys which are set up following this model will lend themselves well to standardized methods and data collection. Knowledge of the hierarchy will greatly aid crew leaders in understanding how RIC dataforms are to be used, and how data will be entered into the data system. As well, biologists who work with a variety of species will find terminology in the hierarchy is used consistently throughout current manuals (less so in earlier versions), making it easier to learn new methods quickly.

Regardless of which species is being surveyed, the same elements in the design hierarchy are repeatedly used as focal points to which survey data are attached; they are the "hooks" from which all pieces of information are "hung".

2.2.1 Project

The project is fundamental to the organization of species inventories in British Columbia A project possesses a boundary which is generally delineated by a proponent based on some environmental concern. As a result, project boundaries are frequently more politically than ecologically relevant, acting as the area to which the results of an inventory are applied or extrapolated. Information about a project, such as a project team, funding source, and start/end date must be recorded on one Wildlife Inventory Project Description Form (see *Species Inventory Fundamentals No. 1* ***[Forms]***). Each project may occur over a period of years, and may be composed of a number of surveys, each with different focal taxa, objectives, start and end dates, systems of stratification and/or Study Areas. A project is simply a way of grouping together surveys which belong together because they may be repeated censuses of the same population (*e.g.*, Bulkley Valley Moose Project 1995 - 1998) or because they share a common geography (*e.g.*, Ainsley Creek Small Mammal and Amphibian Project 1996).

2.2.2 Survey

A survey is the application of one RIC-approved method to a group of species for a meaningful period of time. For example, an autumn small mammal index trap-line survey or a spring song bird point count survey. Although the length of a survey is up to the project biologist, it is probably most useful to think of the survey duration as the amount of time it takes to complete the census for a relevant period of time, such as one season or one year (*e.g.*, one day is generally too short and two years is generally too long). If appropriate, a survey may encompass numerous capture (trap) sessions which are to be used in a single mark-recapture calculation and may span numerous Study Areas. Information about a survey, such as survey type, objectives, crew members, Study Areas, sample session durations, and stratification scheme must be recorded on a Wildlife Inventory Survey Description Form (see *Species Inventory Fundamentals No. 1 [**Forms**]*). Only one of these forms is required for each survey.

2.2.3 Study Area

Study Areas are sites within the project boundary where sampling actually takes place to make conclusions about the larger Project Area. Generally, Study Areas should be representative of Project Areas if conclusions are to be extrapolated outward. This means that surveys which utilize stratification of Study Areas to place sample units should ensure that strata within Study Areas are representative of those within the Project Area (Stratification is discussed further under Section 4.4). Not every project will utilize smaller Study Areas within a project boundary, and consequently, certain projects will have only one Study Area which follows the project boundary. Study Areas may be shared between surveys within the same project. The name and UTM at the center of each Study Area is recorded on the Wildlife Inventory Survey Description form (see above).

2.2.4 Design Components

Design Components are 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. When first introduced to the concept, most people are quick to associate a Design Component with what is traditionally referred to as a statistical “sampling unit”. However, it is more correct to think of a “sampling unit” as a special class of Design Component, as the concept of the Design Components also includes the various nested pieces of geometry that are used in designing a survey, but are not necessarily relevant to statistical calculations. For example, a small mammal survey may utilize a grid as well as capture (trap) stations along that grid. Both of these are Design Components although only the former will likely be used in abundance calculations. The location and type of Design Components used for a survey are recorded on forms which accompany each species-specific CBCB manual. The locations of Design Components are important as they provide valuable information about where surveyors actually searched, as well, in many cases, the location of focal species is recorded only by reference to a Design Component.

Below are descriptions of the main Design Components which are utilized in the CBCB manuals and dataforms.

Stations as Design Components

Sampling using stations (also referred to as points) involves the collection of data at one point in space. Stations may be randomly located, but often they are placed systematically at points separated by standardized distances. Generally speaking, stations must be spaced so that no individual is counted twice. Interstation distance is generally dependent upon a species home range requirements with smaller distances used for smaller animals and larger distances for larger animals.

This method, when repeated at several stations, can provide a list of species present in an area. It can also be used to measure relative abundance if some assumptions are made about how the ability to observe varies over distance (*e.g.*, Reynolds *et al.* 1980). It is also possible to generate density estimates using collections of stations (*e.g.*, by placing small mammal trap stations in a grid pattern over an area). Data are recorded as the number of individuals/sign counted per station.

Station counts are often preferred to continuous transects in more fine-grained habitats if the identification of the habitat characteristics is an associated objective. This is because habitat data can be more easily collected at a point or station than along a continuous transect. An assortment of different stations are found in the CBCB manuals, including raptor call playback stations, amphibian calling stations, songbird and woodpecker point count stations, carnivore scent stations, and capture (trap) stations for a variety of species.

When using a point-based sampling method, it is important to remember that only animals which are encountered at the station during the appropriate time window are eligible for inclusion in final calculations. Animals or their sign are not included if they are encountered between stations.

Transects as Design Components

A transect is a linear sample unit, which may or may not have width. Transects can be conducted on either foot, boat, motor vehicle, or aircraft. They can follow predetermined straight lines, roads, contours or drainages. Species may be sampled continuously along the transect or at fixed points along it. Fuller and Mosher (1987) identify several different types of transects used in wildlife censusing. Transects are utilized in several ways within the CBCB manuals and dataforms.

An **encounter transect** is a survey area in the form of a long continuous line along which observed species are counted continuously or at fixed points, regardless of the distance from the line. These transects are usually used to provide species community composition and general distribution information. Encounter transects are generally used only for presence/not detected surveys because the lack of a measure of area surveyed makes it impossible to estimate population size. However, accurate mapping of the transect location will allow duplication of the survey and may enable calculation of relative abundance such as the number of animals observed per hour or kilometre. As well, encounter transects are useful as a basis for pre-stratification of a Study Area.

Surveyors travelling on a **fixed-width transect** (sometimes also referred to as strip transects) count all species within a fixed distance from the center line. The transect width is based on the type of habitat, behaviour of the animal(s) and type of transportation being used. Density is estimated as the number of individuals seen on the strip divided by the product of the strip width and transect length. A major problem with the fixed-width transect method is the assumption that all animals within the sample unit are actually counted. Among the many uses of fixed-width transects are aerial surveys for estimating relative abundance of ungulates. Caughley (1974) identified density, strip width, speed and altitude as potential biasing factors in such surveys.

For surveys along coastlines, rivers, roads and other continuous linear features, CBCB dataforms may provide spaces to divide a transect into **transect segments**. Breaking a long transect up into segments makes it easier to identify where an observation took place. Rather than recording the location of each animal observed, it is generally easier to map out the transects which form the basis for the survey and then associate each observation with a segment.

When using a **line transect**, only animals which are observed on the transect line are assumed to be completely counted. Although observed animals which do not occur on the transect are still counted, their numbers are estimated based on the assumption that the probability of animal detection decreases with increasing distance from the transect line. Proper analysis of line transect data requires the generation of a detection function using the number of individuals counted as the dependent variable and the distance from the transect line to the individuals as the independent variable. Data are recorded either as perpendicular distance to the sighted individual or radial distance to the sighted individual and the sighting angle. Although a major advantage of this method appears to be its accuracy for achieving density estimates (Laake 1978), a major difficulty is that at least 40 individuals must be observed during the transect to develop a reliable detection function (Krebs 1989). Buckland *et al*. (1993) provide an excellent discussion of line transect and other techniques.

Areas as Design Components

Several types of area-based samples are used in the CBCB inventory series. The term “**quadrat**” is used to describe relatively small, rectangular plots which are used for sampling sedentary organisms, such as terrestrial salamanders, or animal sign, such as pellet counts for hares and cottontails. **Sample blocks** are potentially-larger and more irregularly shaped than quadrats, although it can be beneficial if all the sample blocks used in a survey are of similar size. Sample blocks are more commonly used in aerial surveys of ungulates, in which they are used as a means to delineating separate "samples" of the available landscape. Generally they are used in the same manner throughout the CBCB series, to delineate an area which is completely surveyed. **Search areas** are a final type of area Design Component used in the CBCB series. These are used for less formal surveys, such as hand collection of snakes, to delineate a small area or feature of the landscape (*e.g.*, meadow, barn, pile of cobbles) that was searched for the focal species.

Although different types of areal Design Components may vary in size and shape, they share some common characteristics. Plant and animal counts which use quadrats or sample blocks are generally used to estimate abundance. There are two basic requirements for using this technique: (1) the area counted is known, and (2) the organisms are relatively immobile during the count or adequate vision and equipment still allow for accurate counts. The best polygon size and shape to use will depend on the species and location of the Study Area, and will represent a balance between statistical precision, resources and ecological factors (Krebs 1989).

When determining the shape of a polygonal sample unit, the edge effect must be considered as it can lead to counting errors. Edge effect arises because a decision must be made whether a plant or animal is to be counted every time it is positioned at the edge of a sample polygon (block) boundary. Edge effects can be reduced by using a sample polygon shape with a smaller edge/area ratio, such as a circle. However, one reason for not doing this, is habitat heterogeneity. Organisms are usually distributed somewhat patchily over an area and long thin sample blocks may allow more representative sampling as they cross more patches than circles.

Habitat Features as Design Components

In some cases, a habitat feature may be used as a Design Component. Some feature of habitat may be the most logical unit for the basis of sampling in certain cases. In such cases, surveyors are chiefly interested in surveying a known habitat feature, such as wildlife trees, bat hibernaculae or bird nests, in an effort to determine occupation or to count or estimate the number of individuals which use such a feature. Habitat types or large landscape features are not generally used as Design Components, as these are more appropriate as Study Areas or strata.

2.2.5 Observations

An observation is an encounter with the focal taxa or its sign. An observation is made when a surveyor makes a visit to a Design Component on a specific date at a specific time. Each observation may be georeferenced in itself or simply by association with a specific Design Component. Observations are recorded on the Animal Observation forms which accompany all CBCB species manuals, and may include information on species, sex, age class, activity, and/or measurements, depending on whether the animal is in-hand or roaming free.

Incidental Observations

It is fairly common for field workers to make *ad hoc* observations of wildlife species as a consequence of spending long hours in the outdoors. These incidental observations can have considerable value to provincial conservation programs, particularly when the observations involve red- or blue-listed species, or critical habitat features. If you should make an observation of a red or blue-listed species, it is very important to accurately record your location, in UTM coordinates referenced to NAD83.

A small, fairly simple form is currently available from the Resources Inventory Branch, in conjunction with the Conservation Data Center, that will allow people to record observations of species and habitat features which were not collected as part of a systematic survey (a sample is available in *Species Inventory Fundamentals No. 1 [**Forms**]*). It is recommended that all field personnel carry several copies of this form with them at all times in the event that they encounter noteworthy species. Copies of this form are available from the Wildlife Inventory Section, Resources Inventory Branch, MELP.

2.3 Sampling Design

At the core of all good inventory data sets is a good sample design. The main objective of any inventory is to make inferences about a population from information contained in the sample set. Typically in species inventory the inference will be in the form of a population estimate such as a mean, total, or proportion with a confidence interval on the estimation.

Because every additional sample costs more money, it is the responsibility of the project leader to design a survey which optimizes the information gained for each dollar spent. Collecting too little information precludes reliable estimates while collecting too much information is not cost effective.

The quantity and quality of information obtained in the sample depends on the sample size and on the amount of variation in the data. The amount of variation in a sample can be controlled by selecting an appropriate sample design. Typically field surveys make use of one or a combination of three sampling designs.

2.3.1 Simple random sampling

Simple random sampling occurs when all sample units in a population have an equal chance of being selected. For example, within a Study Area boundary, coordinates are randomly generated for the locations of carnivore capture (trap) stations. Each of randomly-placed capture station may act as a sample unit, and these may be collectively analyzed to determine population parameter estimates. Because this type of design does not attempt to reduce the effect of variability on estimates, a large sample size is typically needed to put reasonable bounds on the confidence interval. Thus, a completely random sampling design is rarely used in species inventory because it is often not cost-effective.

However, this is not to say that “randomization” is not part of a good species inventory survey design. Randomization is required to reduce bias and increase the accuracy of the estimated parameters, even if a design is not entirely random. Most statistical tests assume that the collection of observations is unbiased and independent (that is selection of one observation has no influence on the selection of others). Although this assumption is an ideal that generally can not be achieved in the natural word, statistically speaking, the probability of making an error (α) can not be accurately obtained if observations are not truly independent. It is therefore important, within any sample design, to make a sincere effort to avoid bias and collect samples from the population in a random fashion (Krebs 1989).

2.3.2 Systematic sampling

Systematic sampling is typically employed when the population of interest can be sampled from a list (*e.g.*, every fifth individual) or, of more relevance to species inventory, in a line. As an example, systematic sampling may be used when surveying forest and grassland songbirds with the point count method at stations distributed along a transect. A random starting point is selected from the line, and sampling is repeated at a set distance thereafter. Systematic sampling is very common because it produces good coverage of the Study Area while generally costing less than simple random or stratified sampling.

Systematic sampling also has the benefit of being relatively easy to do, and less subject to site selection errors by field workers. However, one concern with using this design centers around the periodic variation of environmental variables. There is a chance that samples will be selected at the same periodicity each time, producing a biased estimate. However, because most ecological patterns are highly clumped and irregular, this is generally disregarded in many studies. Because of cost savings and the ease of implementation, systematic methods remain popular ways of sampling.

2.3.3 Stratified sampling

Stratified sampling consists of separating the sample population into similar, non-overlapping groups, called strata, and then selecting either a simple random or systematic sample from each strata. In many types of ecological sampling, stratification is believed to increase the reliability of the data relative to unstratified studies of a similar cost. It is critical to the success of a stratified design that each strata is homogeneous within, but distinct from, others.

As an example, suppose an inventory of an owl species is planned for a forested valley which contains three distinct age-classes of forest in equal quantities. If the owl in question has a proven affinity for mature forest, it may be unnecessary and impractical to survey the entire valley with equal effort. A more successful study might begin by stratifying the forest by age class prior to sampling, and focusing more effort on to those strata where owl numbers are expected to be highest. Rather than spending large amounts of time and money recording null data for early age classes, a stratified sampling design allows surveyors to maximize the number of observations in areas where variability is highest.

Most ecological surveys have some degree of stratification incorporated into the design. A stratified sampling design can work as a framework for either a systematic or random design. There are three distinct advantages to a stratified sample design:

1. Stratification tends to produce a tighter confidence interval than that produced by a simple random sample of the same sample size. This is especially true if the measurements within the strata are homogeneous.
2. Cost per observation is normally reduced.
3. If estimates of population parameters are desired for subgroups of the population, separate estimates can be obtained for each.

Stratification is encouraged when doing species inventory in British Columbia. Surveyors filling out a mandatory Wildlife Inventory Survey Description form (see Species Inventory Fundamentals No. 1 [**Forms**]) will notice available spaces for describing the system of stratification which was employed for a species survey. Generally, stratification will be based on one of the following:

1. ***Habitat*** **-** Strata are delineated from landscape features indicative of habitat. These can be derived from existing maps, such as Site Series or Forest Cover polygons, or customized from aerial photos. The goal is to delineate habitat strata which are homogenous with regard to species abundance or distribution.

2. ***Expected Density*** - Strata are delineated based on expert opinion of where animals will occur or based on preliminary, reconnaissance-level surveys. Although this type of stratification may have a relationship to habitat, it may not necessarily be reflected by similarities in habitat between similar strata. Strata are usually labeled as High, Medium, Low, and Nil densities.

3. ***Home Range*** **-** Strata are delineated based on known/strongly suspected home range boundaries of animals or groups of animals. The basis for stratification is generally most meaningful for territorial mammals with large home ranges which are the focus of long-term monitoring.

2.4 Accuracy and Precision

There is a large body of literature devoted to sampling designs and statistical applications for estimating population parameters and their associated confidence levels (*e.g.*, Cochran 1977, Zar 1984, Krebs 1989). A major concern associated with these procedures is the accuracy and precision of the survey results. Accuracy refers to the magnitude of systematic errors or degree of bias associated with an estimation procedure. This affects how well the estimated value represents the true value. Systematic errors may or may not be measurable and can cause estimates to consistently under or over-estimate the true value. In contrast, precision refers to the variability in estimates. High precision means that random variation associated with the collection procedure is minimized. Generally larger numbers of samples provide greater precision than small numbers. Acceptable levels of accuracy and precision should be determined prior to conducting a survey.

2.4.1 Variability

In statistical terms, precision is evaluated using measures of variability, such as sample variance or standard deviation (SD) (which is the square root of the sample variance). These are measured as the difference between the sample average ($\bar{x}$) and the actual observed values that make up that average. Confidence limits are a derivative of these standard measures of variability. They delineate an upper and lower limit around an estimate and provide a probability that the true value is contained within this range. As variability increases, it widens the confidence intervals at a given probability and erodes the confidence with which population parameters may be estimated.

With specific regard to wildlife inventory, the greatest problem with sampling wildlife populations is the high degree of variation that can exist, even with repetitive sampling of the same population. When the variation between samples is high, the precision of the total estimated population parameter is low and consequently confidence limits are wide. Most statistical procedures require that certain assumptions are met during the sampling procedure. In the case of comparing changes in abundance between Study Areas, high variation makes it difficult to determine if there are statistically significant trends in the population. Therefore, it is important to carefully choose sampling techniques and develop sampling programs that both meet the necessary assumptions and minimize the variation between samples.

It is important that the sampling design be developed properly and consistently applied to minimize variation between Study Areas and/or sampling times. It is also important to give careful consideration to the species and age classes of concern prior to the start of any sampling, as these may produce variability within the population being sampled. This may be anticipated and mitigated by having a basic understanding of the life history, habitat requirements and behaviour of the species that is under survey. The variability in the number and composition of species enumerated between Study Areas or at the same Study Area but at different times can naturally be very high even when the total population in the Project Area remains constant. Because of this, it is very important that the sampling procedure be consistently applied for each census.

2.4.2 Bias

Effort should be made to ensure surveys are conducted during the optimal conditions for the sampling method being used and for the species being studied (see appropriate CBCB manual). The time of day, time of year and weather conditions should all be considered. Although sampling standards have been recommended in each manual to minimize sources of bias in the data collection, project biologists should be aware of bias when planning inventory studies. Biologists should also note that consistent bias (with optimal precision levels) is the main objective of relative abundance surveys whereas unbiased and precise estimates are the main objective of absolute abundance surveys.

Some common sources of bias are:

- *Effort bias:* The number of individuals detected will increase with sampling effort (*i.e.*, the size of the area sampled and the time spent sampling per unit of area). Effort should be standardized to improve accuracy so that data from different samples can be compared.
- *Habitat bias*: It is easier to detect individuals in some habitats than others. Different amounts of effort or different survey methods may be needed to sample different habitats.
- *Species/sex/age class bias:* Some species/sex/age classes are easier to detect than others because they are noisier, more conspicuous, breed earlier, or are easier to capture. Each species/sex/age classes may require different survey methods.
- *Density bias:* It is difficult to count some species and distinguish between species when they occur at high densities. In contrast, it may be difficult to detect some species at low densities. More effort or different survey methods may be needed to sample at high and low densities.
- *Activity bias:* The behaviour of some species (*e.g.*, flying, sleeping, incubating, hibernating) will alter visibility. Carry out counts when species are engaged in activities that make them most visible.
- *Seasonal bias:* Visibility of many species varies with the season. More accurate counts will be obtained in a particular season.
- *Time of day bias:* Activity patterns of animals vary with time of day. Standardized times are recommended when possible.
- *Tidal rhythm bias:* Activity patterns of some species vary with tidal height (*e.g.*, shorebirds). Surveys along coastal shorelines and estuaries should occur at a standardized tidal height.
- *Weather bias:* Weather can alter the activity of some species and the visual acuity of observers. Surveys should occur under standardized conditions and never in poor weather.

2.5 Sampling Effort

How many data are enough? Recommendations on the amount of sampling effort required attempt to balance the need to collect sufficient data to make valid statistical inferences with the need to minimize cost and time expenditures. The actual number of points, transects or quadrats etc. that should be sampled and the number of times each should be revisited during the field season will vary depending on the rarity of the species, variability of habitat and survey objectives.

Ideally, inventory objectives should dictate the scale, intensity, and accuracy and precision of the survey estimates. Once these are identified the resources required to accomplish the surveys can be estimated. However, because resources are often scarce, methods and specific objectives may have to be adjusted to what is affordable.

Inventories can be conducted on different geographic scales, depending on management needs, *e.g.*, inventories can be conducted on populations that occur in a discrete geographic area, in one habitat type, in several habitat types, and/or over a large area. The question of scale is particularly relevant for many species in British Columbia because management information needs vary over a range of geographic scales. Thus, there may be a need to monitor populations at a single site of concern, to investigate the response to a particular management activity, or to focus effort over a broader geographic area for migratory species or where impacts are extensive.

The cost of collecting data increases as the scale broadens, the focus intensifies, and/or the demand for accuracy and precision increases. For this reason, data collected on a broad scale are usually less accurate and less precise than data collected at specific Study Areas. There is also a trade-off between accuracy and precision. Time and energy devoted to getting an accurate count in a single area is subsequently unavailable to repeat counts and reduce the variance of an estimate and increase its precision.

Mathematical equations are available to estimate the number of samples required to produce a reliable estimate of a population parameter. Determining the optimum number of samples needed should be an initial step of every species inventory, regardless of whether it is to determine presence or abundance.

More sophisticated studies may not only attempt to estimate a parameter's size, but to detect changes in it over time or space. Statistical estimates of sampling effort required to detect changes or trends tend to focus on the concept of statistical power. The power of a test is the probability of rejecting a null hypothesis which is, indeed, false ($1-\beta$). In general, the power of a test is influenced by the probability of Type 1 error (α), the probability of Type 2 error (β), sample size (n), variability, and the strength of the trend (often r, rate of change). Additionally, the relationships between these parameters depends on the ecological process producing the trend and the techniques used to detect it. For this reason, the selection of an appropriate model to evaluate power is critical (Gerrodette 1987).

Power analysis is useful in two respects. First an *a priori* power analysis can provide guidance to ensure an adequate sample size. This exercise will help to prevent the implementation of a study which is too weak and unable to discriminate a meaningful difference. This is often due to a small sample size that is too small and/or high variability in the study population; the latter which may be corrected for with replication if identified early in the study (Harris 1986). Secondly, a retrospective power analysis is also useful in assisting interpretation of study results. For example, a study objective might be to detect a decline in a sensitive species in an area receiving a certain forest-cutting practice. Failure to reject the H_o provides evidence that forest-cutting is having no effect on this sensitive species. Justification of this interpretation requires an estimate of statistical power. This is especially important when the information resulting from the study will influence management recommendations.

Recently many free user-friendly software packages have become available for power analysis. For more information on power analysis see Section 5.0 or consult Krebs (1989).

2.6 Considerations for Identified Wildlife

Identified wildlife are those species and plant communities that have been approved by the chief forester and deputy Minister of Environment, Lands and Parks, or designate, as requiring special management under the Forest Practices Code Act of British Columbia. These include species from the province's red and blue-lists, as well as species which have been identified as being of regional management concern. Generally speaking, management of identified wildlife involves conserving known locations of key habitat features, such as nests, hibernaculae, or breeding habitat, which are critical to the success of species. Information on which species are "identified" and their special management requirements is available from Wildlife Branch, MELP or found in the *Identified Wildlife Management Strategy* (IWMS) documents (draft).

Surveys for identified wildlife will utilize the same CBCB manuals as surveys for other species; however, the emphasis of a survey which is implemented to satisfy the IWMS may focus less on locating and counting animals and more on finding the active habitat features which are required for their conservation. Several important issues are discussed below.

2.6.1 Finding habitat features

A central objective will be to locate key habitat features which are currently active, as these are the basis for much of the IWMS. As a result, surveys which focus on identified wildlife will likely place a greater emphasis on finding habitat features than will traditional population counts. Although both sorts of surveys will borrow methods from the same "toolbox" (the CBCB manuals), the specific objectives will vary.

This "shift" in objective may be straightforward for many species which will simply require the implementation of a presence or relative abundance level inventory to locate their key habitats. For example, tailed frogs as an identified wildlife species depend on the identification of known breeding locations in the upper reaches of mountains streams so that a Wildlife Habitat Areas can be established. The relative abundance of tailed frogs within different stream reaches can be investigated using the Hand Collection protocol described in manual No. 39, <u>Inventory Methods for Tailed Frog and Pacific Giant Salamander</u>.

However, locating key habitat features for identified wildlife may be more complicated when a habitat feature is more difficult to find. For example, standard methods for woodpeckers are designed to provide estimates of the relative abundance of birds but not necessarily to locate nests, whereas management prescriptions for certain "identified" woodpecker species (Lewis's Woodpecker, White-headed Woodpecker) are based on the location of nest trees. To properly survey for nesting sites of these woodpeckers, a crew would follow the usual standard protocol for woodpeckers, using Point Count Surveys (CBCB manual No. 19), and follow up on those "identified" woodpeckers in an effort to locate their nest trees. This approach of working with standard methods and then following detected animals will likely be a common occurrence for many identified wildlife species. The "follow-up" may require the capture and radio-tagging of the focal animal in some cases, such as finding snake hibernacula or locating the major roosts, maternity colonies and hibernacula of bats. In these cases, tracking animals will become a major component of the project.

See Chapter 4, "Habitat Description and Classification" for discussion of how to describe habitat and evaluating its quality.

2.6.2 Optimizing effort

In many cases, those species which are part of the IWMS are habitat specialists, included because their small numbers or discrete distribution has rendered them vulnerable to range and/or forest practices. Attempting to determine the presence of a rare species may require a slightly specialized approach in some cases. Rather than devoting large quantities of effort to recording the absence of a species throughout 70% of the Project Area, it may be more productive to focus survey efforts on those portions of the landscape which are most likely to provide available habitat. This may be accomplished by a well-researched pre-stratification of the project area into two strata (at minimum): one in which the species is unlikely to occur and a second in which the species is more likely to occur. Field surveys will then focus on the latter strata. If this approach is utilized it is important that the basis for stratification be properly recorded on the Survey Description Form (*Species Inventory Fundamentals [**Forms**])*.

If the project objective is to locate as many habitat features as possible for a rare species, a surveyor may choose to attempt to survey as much of the “likely” strata as possible, maximizing the amount of new habitat which is surveyed at the expense of repeat samples. This approach may work well in certain cases; however, it is largely dependent on the biologist’s confidence in the reliability of the survey method. There is always a danger that the end result will be a large amount of area surveyed, but none of it done intensively enough to yield any useful conclusions.

For more information on sample sizes required to detect presence, see Chapter 5 (Data Analysis) Section 5.2 (Presence/Not Detected).

3. PROJECT MANAGEMENT

A successful field season is preceded by thorough preparation. This is especially true as the time available for many types of species inventory is limited by biological cycles, seasonal weather, and economic constraints. To avoid unforeseen delays and make the most efficient use of time in the field, a project biologist should anticipate the demands of survey work prior to leaving the office. Although no one can anticipate every obstacle, thorough preparation can help to avoid many problems and inefficiencies, in addition to making unforeseen difficulties easier to manage.

All surveys must be conducted in a safe manner. Because of potential dangers while working in the outdoors, field crews should contain a minimum of two people, at least one of which possesses a current, WCB-endorsed first aid certificate. Proper survey planning; appropriate safety equipment and proper training in the use of field equipment; standards for weather and field conditions in which the survey may be conducted; and field workers that are in good physical condition, can aid in ensuring a safe and successful survey.

Once the objectives and methods of the inventory have been determined, the project leader should develop a time schedule which considers:

1. Preliminary information collation (section 3.1).
2. Hiring / contracting / training personnel (section 3.2).
3. Obtaining necessary equipment and supplies (section 3.1.2).
4. Doing preliminary field work.
5. Describing associated habitat (section 4.0).
6. Operational species inventory.

3.1 Collating Resources

Bringing together available resources is the first step when starting any project. Prior to beginning a field inventory, it is mandatory to collate existing information which may have relevance to the current project. There are numerous potential sources of useful geographic, ecological, and logistical information for most Study Areas in British Columbia. Information may come in four basic forms: maps, reports and articles, spoken word, and raw data. Following are some appropriate sources of information for planning most wildlife inventories.

3.1.1 Information

Map Products

1. **Base maps:** TRIM is preferred. Where this is not available, the best alternative is a current NTS map sheet registered to NAD 83.
2. **Small scale ecological mapping:** This includes mapping based on ecoregion and biogeoclimatic classification. Much of the province has been mapped as Broad Ecosystem Units at a scale of 1:250,000. Species-specific habitat capability and suitability interpretations exist for some of these.
3. **Large scale ecological mapping:** Terrestrial ecosystem mapping showing ecological site series may exist at scales of 1:20,000 to 1:50,000 for small areas of

the province. Species-specific habitat capability and suitability interpretations exist for some of these.

4. **Resource-based thematic maps:** In many cases, maps of key habitat attributes may have been created unintentionally by other resource sectors. These include maps of forest cover, soils, and bedrock geology.
5. **Aerial photographs:** Select photos of the appropriate scale, coverage and quality. Computerized “ortho” photos are also available. These are aerial photos which have been orthorectified to resolve distortion due to the curvature of the earth’s surface.
6. **Road maps:** Access is an important consideration when planning inventory work. Road maps, forest recreation maps, and logging road maps produced by forest licensees may all be useful.

Reports and Articles

1. **Field guides:** This may include district, provincial and/or continental guides to species identification and distribution.
2. **Scientific papers:** Even if they may not address local conditions, papers from peer-reviewed journals provide high quality information about general species ecology such as behaviour and habitat selection, and specialized technical matters, such as sampling design and data analysis.
3. **Status reports:** Of particular interest are status reports produced in British Columbia through the academic community or by MELP, and nationally by COSEWIC. Useful information about species ecology, current distribution, habitat associations, and limiting factors. They are also of great use when providing management recommendations.
4. **Conference proceedings:** These may provide a more pragmatic look at certain issues which may not be suitable for scientific journals.
5. **Government publications:** These are numerous, but may be very relevant, particularly in terms of assessing previous work in the Study Area.
6. **CBCB manuals:** The RIC inventory manual for each species group contains relevant information on the ecology of different species, as well as detailed descriptions of techniques for sampling them. In addition, each manual contains a bibliography of useful references.

Spoken Word

1. **Professional Biologists:** Government biologists who might be consulted include forest ecosystem specialists, habitat protection officers, regional wildlife biologists, wildlife and habitat inventory specialists, rare and endangered species specialists, and provincial species and inventory specialists. Private consultants, university professors, and graduate students may also share their knowledge.
2. **Local First Nations People:** Local indigenous people may possess valuable historical knowledge of the distribution and abundance of species within their traditional territory. Their current land use practices may also give them a familiarity with wildlife populations.
3. **Naturalists:** Particularly for inventories dealing with non-game species, such as songbirds, raptors, and herptiles, local naturalist clubs may be the greatest source of local information about species distribution.

4. **Sportsperson/Hunting Guides/Trappers:** Consumptive wildlife users have a strong interest in following the annual fluctuations in abundance and seasonal movements of games species and furbearers.
5. **Field Workers:** Timber cruisers, loggers, and other workers who work largely in the outdoors have useful observations of conspicuous species.

Data

1. **Conservation Data Center (CDC):** The CDC maintains an electronic database of occurrences of rare and endangered species and ecosystems in the province. This information is available free to the public, although a handling fee may be charged for large requests.
2. **Provincial Wildlife Harvest Data Systems:** Several datasystems containing wildlife harvest information are maintained by MELP. Specifically, the Summary Statistics Database contains information about hunters and harvest, and the Wildfur Harvest Database contains information about trapping of furbearers in the province.
3. **Provincial Species Inventory Data System (SPI):** Since 1995, all wildlife projects which are funded with provincial money are required to contribute their data to this centralized provincial datasystem. In addition, all existing wildlife data in possession of the provincial government will eventually be included in this system. Summary information and non-sensitive data will be available free to the public, although a handling fee may be charged for large requests.
4. **Other Sources:** Numerous programs for collection of wildlife data already exist (*e.g.*, Breeding Bird Survey) and provide data to interested people for a minimal cost. In addition, there are also a number of independent datasystems designed to centralize wildlife observations throughout the province.

3.1.2 Equipment

A checklist of the essential equipment for each survey method has been provided in each CBCB manual as part of the survey protocol. Due to their specialized nature, certain items of equipment can be very difficult to acquire (*e.g.*, Anabat detector for bat surveys). Availability of these items will need to be ensured well ahead of the field season to allow time for alternatives if required, and to provide lead time to allow crew members to become familiar with equipment prior to entering the field. All equipment should be checked to make sure it is in good working condition before going out in the field. Back-up equipment should be carried as appropriate (*i.e.*, spare batteries, an extra tape recorder and tape, etc.).

Global position system (GPS) equipment may be convenient for registering locations of sample units and species observations. Persons using GPS should be familiar with the document, British Columbia Standards, Specifications and Guidelines for Resource Surveys Using Global Positioning System (GPS) Technology, available at:

http://www.env.gov.bc.ca/gdbc/gsn/resspec_html/resspec.htm

However, satellite technology is not required, and georeferenced locations may also be obtained by recording them in UTM co-ordinates from maps registered to NAD 83 or latitude/longitude.

In addition to the items of equipment listed in the CBCB manuals, field crew should carry appropriate safety equipment to ensure that they are able to deal with the rigors of working outdoors as well as handle emergencies. A camera is also useful to have along, particularly for capturing pictures of significant or unidentifiable animals, plants, behaviours, landforms, etc. for later discussion.

3.2 Personnel

Skills, experience and motivation of observers can greatly influence the quality of data. Therefore, it is essential that the project managers, crew leaders, and field technicians have the appropriate levels of skill, knowledge, and experience. Qualifications for these positions are provided as suggested standards for resource inventories in British Columbia.

3.2.1 Project Manager

The project manager should have the following minimum qualifications:

- eligibility for status as a Registered Professional Biologist or equivalent, with a minimum of three years of related field experience and two years of project management skills;
- demonstrated data analysis and report writing skills; and
- experience in co-ordinating staff and controlling budgets.
- successful completion of "*Species Inventory Fundamentals*" training course, and possibly other courses, depending on the type of inventory.

Duties of the project manager may be divided between two or more people as long as details of the lines of communication are formalized. The project manager will be responsible for quality control and quality assurance of all project deliverables to the satisfaction of the contract monitor.

3.2.2 Crew Leader

The crew leader should have the following minimum qualifications:

- eligibility for status as a Registered Professional Biologist or equivalent, with a minimum of two years of appropriate field experience, or
- Technical Diploma Graduate in a relevant field, with three years of appropriate field experience, or
- Technician in a relevant field, with four years appropriate field experience
- a valid British Columbia Driver's license; and
- a valid, WCB endorsed first aid certificate.
- successful completion of "*Species Inventory Fundamentals*" training course, and possibly other courses, depending on the type of inventory.

Appropriate field work experience should include:

- knowledge and experience with animal inventory methods;
- knowledge and experience assessing animals and their habitat; and
- knowledge of the operation of relevant equipment.

The crew leader will be responsible for direct supervision of field technicians during project field activities.

3.2.3 Field Technician

The field technician(s) must have the following minimum qualifications:

- Basic knowledge of animal species identification and animal biology.
- At least one person with basic knowledge of plant species identification.

The following is also recommended:

- a valid British Columbia Driver's license; and
- a valid, WCB endorsed first aid certificate.

Training to meet these qualifications may be accomplished on-the-job, if appropriate to the complexity of the field work, provided the technician is under the direct supervision of a qualified crew leader so that the quality of data is not compromised. It is best to use the same field technicians throughout the project. Field technicians should be tested to ensure that a consistent data collection standard is met. The number of field technicians required will depend primarily on the size of the sampling area and study objectives.

3.2.4 Specialized RIC training

RIC is in the process of developing training courses based on several of the manuals being published for species inventory. These courses are targeted at people with biological backgrounds and are intended to ensure that inventory standards are applied consistently across the province. RIC has determined that proof of competency will be a requirement for certain inventories, and the current direction is that a course based on this manual (titled appropriately, *Species Inventory Fundamentals*) will be a mandatory requirement for project managers, crew leaders and any other persons who are independently collecting data on a provincially-funded species inventory project.

Other courses include:

- *Marbled Murrelets* - Intended for project managers, crew leaders, and any other persons who are independently collecting inventory data on marbled murrelets in terrestrial habitats. This course provides an excellent evaluation of observer skill for murrelet inventory, which in high demand and has potentially large economic implications.

- *Bats* - Intended for project managers, crew leaders, and any other persons who are independently collecting inventory data on bats. Bats are an unusual, challenging and sensitive species group to inventory. Certain species are difficult to sample and identify, even for experts. Misidentifying Red or Blue-listed species can have significant economic and/or conservation implications.

- *The Chemical Immobilization of Wildlife* - Required by any biologist who will be using chemical means to restrain wildlife. An existing course has been developed by the Canadian Association of Zoo and Wildlife Veterinarians. Current plans are to offer this course, with other species inventory courses, through the British Columbia Forestry Continuing Studies Network. This course will be only training component associated with the manual, *Live Animal Capture and Handling Guidelines for Wild Mammals, Birds, Amphibians, and Reptiles*.

- *Forest and Grassland Songbirds* - Intended for project managers, crew leaders, and any other persons who are independently collecting inventory data on songbirds. An excellent course for professional biologists and naturalists alike; this course shows how to set up and perform songbird point counts according to the provincial standard.

- *Raptors* - Intended for project managers, crew leaders, and any other persons who are independently collecting inventory data on raptors. This course outlines inventory techniques for diurnal and nocturnal raptors, as well as both conspicuous and inconspicuous species. For less experienced biologists, a day-long course devoted to species identification is also available.

- *Small Mammals* - Intended for project managers, crew leaders, and any other persons who are independently collecting inventory data on small mammals. This course is intended to demonstrate proper set up of a live trapping survey for mice, voles, rats and/or shrews. In addition, participants learn about safety issues as well as proper animal handling.

- *Plethodontid Salamanders*- Intended for project managers, crew leaders, and any other persons who are independently collecting inventory data on plethodontid salamanders. This course provides an excellent classroom introduction and field-based learning for techniques for finding and evaluating the abundance of Ensatina, Western Red-backed, Clouded, Coeur d'Alene salamanders.

All of these courses are strongly recommended, particularly for personnel lacking specialized experience. For certain projects or species groups, RIC courses may be considered mandatory for the project team.

Courses are also available which deal with landscape description, including biogeoclimatic classification, ecosystem field description, biophysical mapping, and wildlife habitat capability and suitability. These may be relevant for certain projects.

For more information about RIC training courses, contact the British Columbia Forestry Continuing Studies Network.

3.2.5 Final preparations for field staff

Before rigorous field surveys begin, all personnel should visit the Study Area to evaluate access, practice identification skills (if required), and familiarize themselves with the various ecosystem distributions and major land use practices. Crew leaders should be introduced to appropriate land and resource managers in the Study Area to avoid complications during active sampling. In certain situations it may be necessary to obtain permission from those with tenure over the land prior to commencing surveys. This is also an appropriate time to become familiar with the practicalities and logistics of the methods to be used, to sort out any problems and to refine techniques to suit site-specific conditions. As well, a review of the dataforms and their corresponding codes is essential before attempting to record actual observations in the field.

3.3 Data Management

Data management is one of the most crucial areas of project supervision. Historically, data have been misplaced, forgotten or left in a form that is unusable to resource managers and other data users. In an effort to improve data management, RIC requires project managers to take responsibility for the proper handling of data from the moment the first field observation is written down through to its analysis and final storage in the SPI data system. Data sheets must be handled with proper care and attention, and protected from field conditions which may damage, obscure, or destroy them. Ecological data are extremely expensive to acquire, and, in many cases, lost data can never be recovered. The utmost care must be taken to maximize their life expectancy.

Cooperrider *et al.* (1995) make an important distinction between the terms "data" and "information" to denote separate entities. "Data" are defined as raw, unedited, unanalysed observations in the form of numbers, pictures, locations, and so on. "Information" refers to data which have been analyzed, synthesized or summarized so that inferences or predictions can be made about natural patterns. For example, an observation of an animal in a location is one datum; many such observations are data. A map of the distribution of the species compiled from such data is information. Unlike the raw data from which it was derived, information tends to address specific questions. For example, from a distribution map, it is possible to predict where a species is likely to occur.

Typically, biologists collect data for inventory projects, make interpretations of the data, and present these interpretations in a report. The "information" contained in the report then circulates around the scientific/management community as a final product; however, the utility of this information may be confined to the specific objectives which the report was intended to address. It is the intention of RIC to alter this tradition and expand the scope of questions that each inventory may answer by placing an emphasis on raw data rather than project-specific information. The central objective of the RIC standards for species inventory is to ensure that raw data are collected to an acceptable standard in such a way that they may be included within a secure, accessible, central data repository. Although reports on inventory projects will still be required, one of the most important deliverables of any inventory project will be the set of raw data.

3.3.1 Dataforms

In the past the convention has been to record only those data which are specific to project objectives, and hypotheses to be tested. The decision of what and how data are recorded has been left to personal preferences which have frequently lead to difficulties in interpretation once the principle investigator has left the project. It is the vision of RIC that data will be collected in the same manner throughout the province, recorded on standard dataforms, and will ultimately become part of the provincial SPI datasystem. To achieve this vision, it is the responsibility of project biologists to ensure that dataforms are properly filled out. Quality assurance of this nature will greatly increase the life of the data. More importantly, when project data are added to the central repository, the SPI data system, they will become part of a powerful, growing data set which will permit scientists and resource managers to perform many and varied interpretations. Each new inventory project will add to this electronic knowledge base, providing a source of information which will inevitably outlive the written inventory report. Ultimately, this will promote better management decisions.

Each inventory project will be required to use a minimum of three types of dataforms (Table 4). At least two of these, the Wildlife Inventory Project Description form and Wildlife Inventory Survey Description form, are available in the package of generic species inventory forms which accompanies this manual *(Species Inventory Fundamentals No. 1 [Forms]* - previously referred to as the Dataform Appendix). The remaining dataforms are contained within each CBCB species-specific manual.

Table 4. Some of the dataforms used for RIC Species Inventory Projects (not including ecosystem/habitat description forms).

Dataform	**Required for**	**Type of information recorded**
Project Description	All projects	General data about inventory project (*e.g.*, location, start date).
Survey Description	All projects	Data about each survey (*e.g.*, Study Areas, stratification, team)
Animal Observation	All projects	Data about each animal observed on a survey (*e.g.*, species, sex, number)
Capture Station	Any project where animals or their evidence is captured at stations	Data about capture (trap) stations (*e.g.*, trap type, location). Includes hair snag, track plate, and other types of stations where evidence is captured.
Animal Handling	Any project involving chemical immobilization of a medium to large mammal or bird.	Data about medium to large mammals and birds (*e.g.*, sex, measurements, drugs) which are handled.
Survey Collection Label	Surveys involving voucher collection	Documents the collection of any wildlife specimen or artifact (*e.g.*, photograph) so that it can be linked to an observation.

Figure 1 depicts the relationships between the different types of forms used for species inventory. There are strong similarities between the structuring of the forms and the structuring of the Standard Survey Design Hierarchy (see Appendix C). Generally, each project requires the completion of one Wildlife Inventory Project Description form. Each project may involve numerous types of surveys (as depicted), in which a RIC method is used for a set period of time on a certain species group. Each survey requires the completion of one Wildlife Inventory Survey Description form. Each type of survey will then require a number of completed Animal Observation Forms. Depending on the nature of the survey, it may also require one or more Animal Handling, Capture Station, Survey Collection, or Habitat Description (*e.g.*, Nest Site Description) forms. Form requirements for each method will be outlined in a table within the species-specific manual. As a general rule, any form required for survey can be found in one of two places: the form package which accompanies the species manual, and/or the form package which accompanies this manual. The only deviations from this rule are for Habitat Description forms (see Chapter 4, “Habitat Description and Classification”), and forms for radio-telemetry studies. The latter may not always be in the species manual, but will be included in the forms which accompany manual No. 5, *Wildlife Radio-telemetry*.

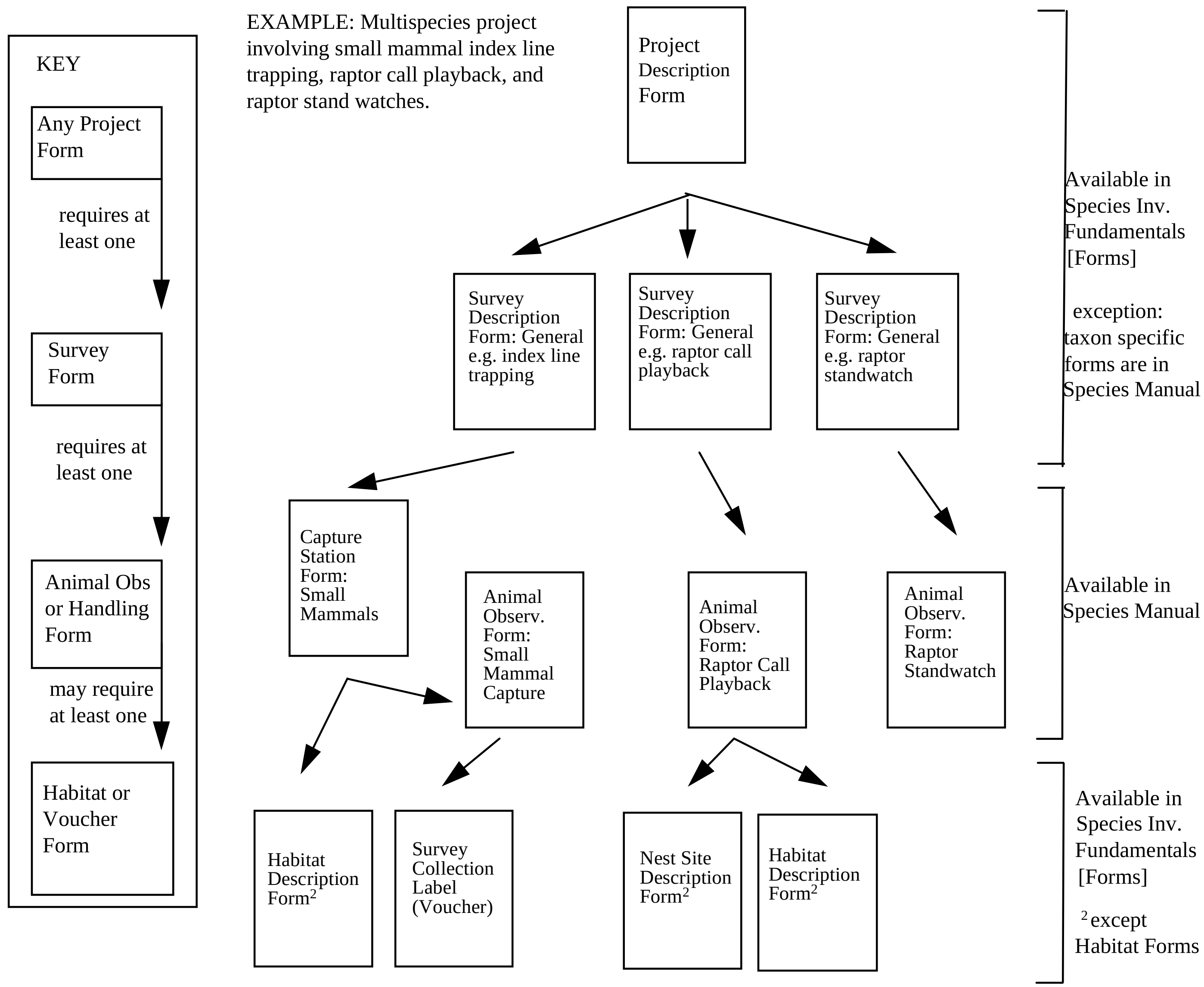

Figure 1. Diagram showing how to use RIC forms. "Key" on left depicts general rules for form use. Diagram in center shows example with three surveys. Notes on right tell where to get each form.

It is absolutely critical that RIC-approved dataforms be used for all data collection and that these be filled out properly, using standard codes (these are described in *Species Inventory Fundamentals No. 1 [Forms]*). Neglecting to do so will render portions of the data set incomprehensible to others, and, at worst, potentially disqualify project data from inclusion in the provincial SPI database. It is also essential that datasheets be accompanied by a set of survey maps showing the location of the project boundary, survey strata, sample units, critical habitat features, and, in some cases, observed animals. These maps must be neat, legible, and properly labeled with reference to the sample units and observations contained on the dataforms.

It is important to understand that the RIC dataform represents the <u>minimum</u> data to be collected. Under certain circumstances, such as when projects are integrated with research studies, research objectives may require the augmentation of the data set. In such cases, additional observations should be recorded on a separate dataform. If this is not possible (*i.e.*, it is impractical for field work), the project biologist has the prerogative to design a new form which combines the datasets to meet both inventory and research objectives. RIC only requires that it contain the required inventory fields, as laid out in the appropriate manual, and that data are collected and recorded according to RIC standards. Ideally, inventory information should be transferred onto a RIC-approved species inventory dataform or into the SPI data system at a later date.

3.3.2 Data storage

Ultimately, all species inventory data which are collected to RIC standards will be stored in the SPI data system, housed within the Resources Inventory Branch of MELP. To facilitate the transfer of new data into the SPI system, access to the data capture portion of the system (called SPI_DC) is available via the internet. Newly-entered data will be quality assured by regional Ministry staff before being downloaded into the SPI operational database (called SPI_OPD). In the case of multi-year projects, periodic downloading of project data into the SPI system will allow resource managers to begin to make use of new information even before a project is complete.

In terms of spatial information, SPI_DC will store exact locations of point features, such as call stations, animal observations, or habitat features, as well as start and end points of transects. However, for more complex shapes, such as Study Area boundaries or sample block locations, SPI_DC will accommodate spatial keys which have been linked to digital arc or polygon features. For more detail about proper storage of spatial data, consult *Digital Spatial Data Specifications for Species Inventory Mapping in GIS*, available at > http://www.env.gov.bc.ca/wld/spi/

All spatial objects must be mapped with reference to NAD 83.

3.4 Reporting

Although it may vary according to contract specification, every RIC species inventory project should produce, as a minimum:

1. A final report (for format, see Appendix B).

2. A complete set of raw data. This will include metadata about the project and surveys, as well as species observations and habitat/ecosystem descriptions.

3. A complete set of clearly-labelled, NAD83-based maps (preferably TRIM) showing the locations of the project boundary, Study Areas, strata, sample units, and, in some cases, animal observations.

4. HABITAT DESCRIPTION & CLASSIFICATION

In addition to locating and counting species populations in British Columbia, a secondary purpose of species inventory is to develop insight into species/habitat associations. As provincial management of wildlife involves conservation of their habitat, new information about the nature of the habitats utilized by a species is invaluable. Such information forms the basis for protected areas, management plans, prescriptions to mitigate environmental impacts, and further species inventory.

General techniques for ecosystem sampling, description, and mapping are well developed and standardized across British Columbia (Resources Inventory Branch, MELP 1998a, 1998b), as are rating schemes for habitat capability and suitability at different map scales for certain species (Resources Inventory Branch, MELP 1998c). These standard mapping and interpretation systems, in conjunction with species population inventory data, are intended to provide a basis for wildlife and habitat conservation in British Columbia To realize this objective, biologists conducting a species inventory are required to describe habitat in a manner which utilizes attributes and definitions borrowed from methods used in ecosystem mapping and interpretation. This will provide a common context for species and habitat inventory in the province, facilitating the integration of these two types of data and providing opportunities to refine and extrapolate habitat models.

In the sections that follow, discussion focuses on the collection and interpretation of habitat data which are obtained as part of a species inventory. The minimum requirements for collection of habitat data are outlined, and discussion touches on a number of topics, including provincial modeling schemes, habitat use and availability, interpretation, and stratification. Although this subject has considerably more depth than can explored within one chapter, it is hoped that the discussion will promote consistency in how habitat data are collected and provide guidance in the interpretation of species/habitat patterns.

4.1 Habitat Capability and Suitability Models in British Columbia

In British Columbia, wildlife managers and planners are responsible for protecting, managing and enhancing a remarkable diversity of species. Simple economic constraints prohibit conducting inventories of all of the province's animal populations, and, thus, one objective of species inventory is to aid in the development and testing of habitat capability and suitability models. Standard methods for capability and suitability in the province (Resources Inventory Branch, MELP 1998c) have been developed which utilize standard ecosystem mapping systems (*e.g.*, TEM) to extrapolate estimates of habitat quality across large areas.

Generally speaking, these models can be categorized into two classes.

Expert-driven models: A team of experts uses their combined knowledge to determine critical limiting habitat factors for a given species. The primary source of inference for these models is assumptions made by the experts as opposed to data collected in the field. These models are typically qualitative rather than quantitative.

Data-driven models: The results of a habitat selection study for a species are incorporated into a quantitative model which is used to prioritize management decisions as well as formulate assumptions regarding habitat specific species densities.

Currently, due to the limited amount of data available, provincial habitat suitability and capability models tend to be expert-driven. However, as more species population data are collected, there is some anticipation that habitat modeling will shift toward a data-driven approach. Using computer algorithms, species occurrence and density information will be "applied" to areas beyond the original point of collection. Data from areas in which species are well-inventoried will be extrapolated to estimate suitability in similar areas in which inventory surveys are less extensive.

For both expert- and data-driven models, habitat suitability is evaluated using spatial databases with standard mapping systems. The usefulness of each model is limited by the availability of mapped areas which include the habitat attributes upon which the model is based. Because of this, there is a strong emphasis within the species inventory program on being able to place Design Components and observations in the context of one of the standard systems of ecosystem classification as these are the basis for ecosystem mapping throughout the province.

4.2 Standard Habitat Attributes

The variety of ecological niches exploited by British Columbia's animals and plants is, simply put, overwhelming. The province's flora and fauna are extremely diverse (and in many cases, poorly researched). This makes it difficult and potentially impractical to define a unique suite of habitat attributes for each and every creature. However, recognizing that a major objective of collecting habitat data is the potential to use existing map schemes to model or predict species occurrences, a more practical approach is to limit habitat attributes to those that are used in existing ecological mapping systems. Table 5 outlines generic subsets (or suites) of habitat attributes which were selected from the comprehensive set of habitat attributes which are currently utilized and defined in existing mapping programs, such as Terrestrial Ecosystem Mapping, Broad Ecosystem Mapping, Forest Cover Mapping, and Wildlife Capability and Suitability Interpretation. Suite groupings are based on subject area (*e.g.*, soil attributes are grouped together) as well as the level of expertise required to describe them (*e.g.*, Describing Basic Veg attributes may not require as much botanical expertise as Detailed Veg attributes).

Table 5.Suites of standard habitat attributes used in species inventory.

Suite Name	Attributes included	Source of Attributes
Location	Geographic coordinates, Broad Ecosystem Unit, Ecosection, Biogeoclimatic Subzones (from map)	Geographic coordinates should be referenced to NAD83. Broad Ecosystem Units are outlined in the review draft, Standards for Broad Terrestrial Ecosystem Classification and Mapping for British Columbia: Classification and Correlation of the Broad Habitat Classes - electronic copies from ftp://wldux2.env.gov.bc.ca/pub/TEM/ (filename: beuapp3.doc)
Site Series	Site series as derived in field	Information on regional site identification is available in provincial Land Management Handbooks (Crown Publications).
Site Info	Elevation, Slope, Aspect, Mesoslope Position	Taken from FS882 - Site Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Topography	Surface Topography	Taken from FS882 - Site Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Structural Stage	Structural Stage	Taken from FS882 - Site Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Basic Veg	List of Dominant/ Indicator Vegetation Species (usually minimum 3/layer) & % Cover for Tree, Shrub, Forb and Moss/Lichen layers	Taken from FS882 - Vegetation Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Detailed Veg	Detailed % Cover of different vegetation species by vertical stratum	Taken from FS882 - Vegetation Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Wildlife Tree Plot	Abbreviated Tree Attributes for Wildlife (plot of trees) - Area, Min. DBH, No. of Trees, No. Alive/Dead, Avg. DBH, Avg. Length, Avg. Lichen Load Class	Taken from FS882 - Wildlife Habitat Assessment Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Individual Wildlife Tree	Attributes for an Individual Tree - Species, Stand/Fall, DBH, Estimated Length, Crown Class, Height to Live Crown, Crown Condition, Bark Retention, Wood Condition	Taken from FS882 - Tree Attributes for Wildlife Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/

Suite Name	Attributes included	Source of Attributes
Regime	Soil Nutrient Regime, Soil Moisture Regime	Taken from FS882 - Site Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Simple CWD	Simple Coarse Woody Debris	Taken from FS882 - Wildlife Habitat Assessment Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Surface Substrate	Surface Substrate	Taken from FS882 - Site Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Soil	Soil Drainage, Soil Texture, Coarse Fragments, Humus Form, Root Restricting Layer, Surficial Material, Geomorphic Process	Taken from FS882 - Soil Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Special Form	Specialized Habitat Form. Includes Nest Site Description form and/or any other form found within a CBCB manual.	Taken from CBCB manuals. Nest Site Description form is found in Species Inventory Fundamentals, No.1 [Forms].
Stream	Stream Site Card - Channel, Water, Cover, and Morphology sections	Taken from Reconnaissance Fish & Fish Habitat Inventory: Dataforms and User Notes available at: http://www.env.gov.bc.ca/fsh/ids/invent/

It will quickly become apparent after examining Table 5, that the majority of standard habitat attributes have been taken from terrestrial Ecosystem Field Form (also called the FS882). This form was developed jointly by MOF and MELP for description of terrestrial ecosystems, and is designed to accommodate site-level descriptions of topography, vegetation, soils, wildlife trees, and coarse woody debris. Although many attributes have been borrowed from FS882, the requirements for species inventory habitat description are not as intensive as those required to complete a full FS882 for an ecosystem mapping project. The scope of attributes selected reflects a condensed version of the FS882 called the Ground Inspection Form (GIF) which contains a subset of the site, vegetation and soil attributes available on the Ecosystem Field Form. Although descriptions of individual fields are contained in Appendix D, biologists will likely wish to obtain the *Field Manual for Describing Terrestrial Ecosystems* (Ministry of Environment and Ministry of Forests 1998) which is now available with detailed procedures for collecting individual habitat attributes. For more comprehensive procedures still, consult *Describing Ecosystems in the Field* (Luttmerding *et al.* 1990).

For species which utilize aquatic habitats, attributes have been borrowed from stream description forms which have been jointly developed by the Ministry of Fisheries and the Department of Fisheries and Oceans. These forms, which are used to collect data at a fairly coarse level, provide a useful, province-wide system for describing river and stream characteristics.

4.2.1 Minimum Requirements

Minimum requirements for habitat description are outlined in Appendix E. The matrix in this appendix lists each of the species groups for which there is a standard CBCB manual. Each of these groups is then further divided into the Design Components (see Section 2.2.4) which are required for each type of standard survey. The suites of habitat attributes required for each survey are then indicated with an “X” in the appropriate cell of the matrix. A series of superscript modifiers provide additional information as to the specific circumstance under which an attribute is compulsory.

Generally speaking, habitat description requirements are most rigorous for critical habitat features, such as nests or burrows, as the ability to model and anticipate the locations of these can be central to a species conservation. In contrast, requirements are generally smallest for large Design Components, such as aerial or marine transects, which are too extensive to warrant plot-level description. In such cases, surveyors are asked only for a minimum of contextual information, including a georeference, ecosection, biogeoclimatic subzone, and a Broad Ecosystem Unit (BEU). Many biologists may not be familiar with BEU’s. These are a high level method of ecosystem classification based on the old Broad Habitat Classes (BHC’s) used in 1:250 000 ecological mapping. A list of current codes are provided in Appendix F; however, to actually assign a BEU to a landscape, it will be necessary to review the descriptions of each Broad Ecosystem Unit contained in the review draft, *Standards for Broad Terrestrial Ecosystem Classification and Mapping for British Columbia: Classification and Correlation of the Broad Habitat Classes used in 1:250 000 Ecological Mapping*. Copies of this document (filename beuapp3.doc) are available through a Ministry FTP site > ftp://wldux2.env.gov.bc.ca/pub/TEM/.

4.2.2 How to Apply the Requirements

As a general rule, habitat descriptions are based on a 400 m^2 plot. Application of this approach is straightforward for Design Components which are stations or points from which the plot can extend out. However, for polygonal or linear Design Components, biologists will need to locate their plots in a more subjective manner, by establishing them in places which they feel represent the habitat being sampled. As a minimum, each Design Component in Appendix E requires the establishment of at least one habitat plot and the collection of the required attributes. Polygonal or linear Design Components may require establishing more than one plot each to adequately describe the sampled habitat. For example, a transect which follows an altitudinal gradient may require numerous, systematically-placed plots to adequately describe the habitat variation which it encompasses. Standardizing the intensity of habitat sampling required to represent every Design Component is not realistic, as it will vary from ecosystem to ecosystem and situation to situation. Because of this, the number of habitat plots used per Design Component will be at the discretion of the project biologist.

4.2.3 Specialized Habitat Description

It is understood that the list of attributes defined in Appendix D is not comprehensive. In some cases, habitat data which are not included may have strong relationships with the occurrence and/or abundance of a species. However, the requirements for each survey type are intended to be a minimum, a common core of data which are collected for all similar surveys across the province. This “common core” may not satisfy the requirements of certain projects which may be more specialized and warrant the collection of additional habitat data. Biologists are encouraged to increase the scope and detail of habitat description beyond provincial standards if this is necessary to satisfy regional objectives.

In some cases, the dataforms which accompany CBCB manuals include forms for the collection of habitat attributes. These forms are intended to capture species-specific information which is believed to be of particular relevance throughout an organism’s range. Perhaps the most relevant of these (due to its applicability to many species) is the generic Nest Site Description form. This form is used to record a description of a nest and its supporting structure, as well as to monitor the progress of the eggs/nestlings over a number of visits.

4.3 Habitat Use and Selection

Resource or habitat selection is defined as the likelihood that a habitat or resource will be chosen if offered on an equal basis with other habitat types. It is not possible to garner appropriate conclusions about habitat associations without an understanding of the difference between habitat use and habitat selection. Habitat use is simply a record of habitat types which are utilized by a species, possibly based on different life stages, whereas habitat selectivity is the result of comparing habitat use to actual habitat availability.

These concepts of use and availability can be illustrated with an example. A caribou is monitored over the duration of a winter using radio-telemetry. In the Study Area, three principal habitat types are identified. It is found that 50% of the telemetry locations lie in habitat type A, 30% lie in type B, and 20% lie in type C. From these results, it might be concluded that type A is the most important habitat type. However, after measuring the relative availability of habitat types, it is found that type A composes 80% of the Study Area, type B 4%, and type C 16%. Based on this additional information, it becomes apparent that type B is very important because the caribou spend 30% of their time in this habitat type, even though it comprises only 4% of the Study Area.

In addition to demonstrating the difference between use and selectivity, the example above is also a useful means of illustrating a second issue: the ease with which a researcher can bias a habitat study. The strength with which the caribou selects each habitat type is directly related to its availability; how that availability is measured is therefore critical to the conclusions of the study. The relative availability of habitat types A, B, and C in the example is directly influenced by where the researcher draws the boundary around the Study Area. To further the example, if the Study Area were altered to include a large patch of habitat type B, the results of the study might be very different, with the caribou selecting habitat C over habitat B. Although there is extensive literature on methods to address this problem (*e.g.*, Alldredge and Ratti 1986), the reason for including this example is to demonstrate the tremendous potential to inadvertently bias the results of habitat selection. To generalize this further, gleaning patterns of habitat use is a complicated business, and biologists should be cautious when doing so, particularly from species or population inventory data which may have inherent bias. In a well-designed habitat study, sampling should be based on a random sample of habitat variables within a Study Area, which should contain an appropriate suite of habitat types that are available to the animal for the time period or life history stage of interest (Manly *et al.* 1993). A RIC species inventory may not necessarily utilize a design which is unbiased for making habitat inferences, and biologists should be aware of this.

As a generic guideline, three study designs for measuring habitat selection and habitat use are briefly described below. Biologists who wish to pursue this topic further should consult Manly *et al.* (1993).

Design I: With this design all measurements are made at the population level and individual animals are not recognized. Used and unused resources are sampled for the entire Study Area with no regard to individuals. For example, fecal pellets are recorded as present or absent on a series of quadrats.

Design II: Individual animals are identified and the use of resources measured for each individual, but the availability of resources is measured at the population level for the entire study zone. For example, telemetry locations of individual caribou can be measured and compared with the habitat available on the Study Area.

Design III: Individual animals are measured as in Design II but in addition the resources available for each individual are measured. For example, habitat locations can be measured for a set of radio-collared caribou and these can be compared to the habitats available within the home range of each individual caribou.

Designs II and III are most desirable for research objectives, since they allow a measurement of resource preferences for each individual, but, more than likely, Design I is most practical for a RIC species inventory project. If the animals studied are a random sample of the population, we can infer the average preference of the entire population in Design I.

4.4 Making Habitat Inferences from Species Inventory

It is important to understand the differences between a study designed to investigate population characteristics versus one with the purpose to evaluate habitat selection. These differences will have a significant influence on the conclusions that the investigator can reasonably make.

In terms of experimental units, a true population study will have a primary sampling unit which is either a cluster sample device (*e.g.*, an aerial transect for elk) or in some cases the individual animal being studied. Classic population sampling is designed to provide a random sample of population units or individuals within the population. In contrast, habitat type is the experimental unit for habitat studies. Use and availability of habitat types is meant to be measured in a way that is not biased by observation of use. This may not necessarily be contingent with a species inventory where methods tend toward those used to study populations. These may focus effort on locations where animals are most likely to occur, driven by requirements for large sample sizes to calculate population parameters.

Despite the different approaches to population and habitat studies, there are opportunities to design a species inventory to learn about both a population and the habitats which it utilizes. Manly *et al*. (1993) detail various study designs for gaining habitat inference in which the sample units are a population, or an individual. Even if the sample unit is a population (Design I), it may often be appropriate to define it in terms of an area or habitat (*e.g.,* a pond). Similarly, population studies which involve individual animals that can be identified using radio-telemetry or visual markers may provide excellent opportunities to learn about habitat associations. This, of course, would require the forethought to define the population and associated Study Area with consideration for both temporal and spatial scale of the target species.

The amount which inventory design should be adjusted to accommodate habitat inference depends on the scale of habitat inference desired and the goals of the inventory project. It will not always be possible, nor desirable, to design a study which provides both population and habitat inference; whichever of these is to be emphasized will need to be decided based on the initial objectives of the inventory. It is useful to have some understanding of the limitations created and compromises required to integrate population and habitat studies:

- ***Use versus Selection:*** Population studies do not necessarily follow a study design which will allow effective habitat inference. Species population studies generally emphasize measurement of use as opposed to selection. This is because population inventory may require a large sample size to ensure precise calculations of population parameters. Given this requirement, many species inventories tend to focus on those places where animals are present, without sampling other possible habitats. In addition, available habitat units may not be measured adequately or are measured in a biased fashion. It can also be difficult for a biologist to document habitat variables adequately when the prime objective is to census populations. As a result, habitat inference is restricted to use as opposed to selection or preference.

- ***Time Scale:*** The time scale of population censuses may preclude adequate measurement of variation in habitat selection based on life history stage. Generally speaking, it is desirable for a census to capture a brief “snapshot” in the fluctuations of a population. Such surveys will occur over only a short period of time to meet assumptions of population estimators or due to the convenience of employing certain methods within a specific season or portion of the annual cycle. The resulting data will document the use over a specific and brief time period or environmental condition and will not represent overall habitat use. For example, most ungulate species have habitat requirements for each season of the year. These can not be well-represented by an annual population census.

Deriving habitat inferences from species inventory census data requires a consideration of the life history of a species and how it interfaces with sampling efforts. Generally speaking, manuals in the CBCB series tend to emphasize timing of surveys which coincide with critical stages in species life cycle. Such an approach provides information about distribution and abundance during those portions of a species' life history which are most critical for survival. Information about habitat collected at such times can be invaluable. Many species have several critical stages in their life cycle, and it will be necessary to make a decision as to when surveys should be done to best meet objectives. Many times population censuses occur in the springtime. If the primary determinant of survival of an animal such as woodland caribou or mountain goat is winter range, then population surveys may not identify critical habitat unless a census takes place in the critical season.

- ***Spatial Scale:*** The spatial scale of population censuses may preclude adequate measurement of variation in habitat selection. A population Study Area may be defined by the logistics of sampling (*e.g.*, live trapping grids) resulting in under-representation of key habitat units. Some species operate on a spatial scale that goes far beyond the boundaries of a population census area. For these species, habitat inference may be difficult because it is impossible to obtain an unbiased sample of habitat usage on a very large spatial scale. The critical questions to ask for any given species are:
    - Does habitat selection occur at the macro, meso or micro scale?
    - How do these scales interface with the dimensions of the population census area?
- In contrast, it might be possible to obtain habitat preferences for species which are sedentary or territorial during portions of their life cycle. For example, small mammals, songbirds, and amphibians may all have seasonal home range sizes that may be easily encompassed by the inventory Study Area. Estimates of the home range sizes of many species are available in the literature and can be used as guidelines for development of a sample design.
- ***Performance measures:*** The ultimate purpose of integrating species (population) and habitat inventories is to reach a conclusion as to the quality of different habitat types. At first consideration, such an approach appears to rely heavily on the assumption that species occurrence or abundance is correlated with habitat quality. This may not necessarily be the case for species which occupy marginal or "sink" habitats. Under such circumstances, productivity may be low and the continuance of populations may rely on immigration from neighboring populations. Similarly, different habitats may have varying effects on the ability of an observer to count species, resulting in inflated estimates of habitat quality in those communities where detectability is greatest.

  Although CBCB manuals are geared to methods which involve counting animals, the scope of the series is wide enough in many cases to allow evaluation of productivity and/or recruitment, a more reliable indicator of habitat quality in many cases. Methods for nest searches and monitoring are included for all bird species; reproductive status data are collected for all animals which are trapped; surveys may generally be timed to include reproductive periods; and, radio-telemetry methods are eligible for all species large enough to carry a transmitter.
- ***Data analysis:*** There are many statistical techniques available for analysis of habitat selection data (which are generally beyond the scope of this manual). Some of these techniques make restrictive assumptions and therefore will influence how data are collected in field efforts. As with abundance data, the power of these methods will be influenced by sample size (*i.e.*, number of plots) as well as the number of habitat variables measured. Therefore, the method to be used in analysis should be considered before data are collected. Power analysis packages are available to evaluate logistic regression and other techniques that are used for habitat data analysis. Manly *et al*. (1993) give a good overview of the analysis methods that are currently available for resource selection studies.

4.5 Habitat Stratification

Stratification of the landscape is generally recommended for species inventory projects (see also Section 2.3.3). Habitat will frequently form the basis for this stratification, the landscape being separated into discrete units so that survey effort can be distributed into a number of habitat types. From a statistical perspective, stratification is intended to improve estimates of species numbers; however, habitat stratification can also yield useful information about the use of different habitats by a species.

A good approach to habitat stratification is outlined below:

1. Delineate the Project Area boundary. This will generally be based on the objectives of the project proponent, and may have little to do with ecological realities.
2. Review the literature on the habitat requirements of the focal species. If enough relevant work has been done, it may be possible to gain some understanding of which habitat attributes relate to habitat quality. However, Morrison *et al.* (1992) caution against accepting all statements in the habitat use literature as authors tend to repeat the statements of previous authors, and many studies are most applicable to only one time and place.
3. Develop a system of habitat stratification that you expect will coincide with species habitat requirements. This must be documented on the Wildlife Inventory Survey Description Form (see *Species Inventory Fundamentals, No. 1 [**Forms**]*). Do not overestimate your ability to discern habitats of different quality. Simple is generally better.
4. Use maps and aerial photographs (see discussion below) to review the Project Area, and select Study Areas which are representative of the Project Area, in terms of the types of strata they contain. This may allow you to extrapolate your findings from the Study Area out to the entire Project Area. Once you have done preliminary species surveys in the various strata, it may be possible to refine your survey design and focus your effort on those strata with the greatest variability.
5. It will likely be useful to evaluate the availability of each of the habitat strata within the Study Area. Depending on survey design, this may provide some inference as to habitat selection (subject to the limitations discussed in Section 4.3).

In terms of species conservation, the most useful systems of habitat stratification for wildlife conservation are those which are based on existing mapping systems. Possible options include forest cover maps, biogeoclimatic maps, ecoregion maps, broad ecosystem unit maps, biophysical maps, and terrestrial ecosystem maps. All of these systems for classifying the landscape are commonly used across British Columbia, and thus when associations are formed between species and these mapped units, they may have relevance throughout the province. This may be particularly useful for statusing species, targeting conservation strategies, developing management plans, and directing future inventories.

In some cases where stratification is used as part of an inventory, the scale of available mapping may be inappropriate as a means of delineating strata for the focal species. For example, it would not be particularly useful to use 1:50,000 Ecosystem Units as the sole basis for stratifying for a survey of mice and voles. However, broad scale ecological units are still useful as a means of identifying coarse changes in the landscape. Air photos can be used to flesh out this existing ecosystem “skeleton” with finer scale units to suit the featured species. This approach retains some of the possibility for extrapolating broad scale species/habitat association to other portions of the province. If finer level strata, such as successional stage, can be “nested” within existing mapped units, it may make it possible to pool observations to investigate larger scale patterns later.

Broad scale habitat classification units, such as 1:250,000 Broad Ecosystem Units, can be used to stratify sampling for wide-ranging animal species. Alternatively, it might be useful to form broad scale units by aggregating fine scale polygons.

Ultimately, regardless of what approach is taken, habitat strata should emphasize existing mapped units and standard systems of landscape classification wherever possible. If this simple guideline is followed, the longevity and application of the data collected will be greatly enhanced.

5. DATA ANALYSIS

Statistics are a standard tool for the biologist working within the area of inventory or monitoring. Reliable data are necessary for managing natural resources and statistical inference allows a biologist to make informed decisions about a larger population based on a collection of representative samples. Despite the frequency of their use, many people forget that statistics are only a tool to manipulate data in an effort to tease out meaningful patterns. More specifically, it is not uncommon for educated people to adopt a statistical test result as the definitive answer to a question, without any consideration for the limitations and assumptions upon which this answer is based. Because of this, it is important that statistical analysis be well considered and appropriately applied to each project. Given the potentially misguided faith placed in statistical tests, a poor choice of test may produce an inappropriate management strategy.

The discussion which follows is meant to provide useful guidance for analysis of general species data at the presence/not detected, relative abundance, and absolute abundance levels of intensity. Species-specific data analysis will be discussed within species manuals. (Although initial versions of the CBCB species manuals focused more on data collection rather than analysis, data analysis is a high priority for subsequent versions.)

A small and final point: in the interest of maintaining a logical flow, the chapter on Data Analysis has been placed at the end this manual. However, although data analysis is performed after data are collected, the frameworks, assumptions, and constraints of various statistical tests must be considered well before this, during project planning.

5.1 Hypothesis Testing

When investigating population trends or comparing population estimates between areas, the traditional model for hypothesis testing should be followed:

1. Identify the parameters to be compared and the level of statistical significance.
2. Identify a null and alternative hypothesis(es).
3. Select an appropriate statistical procedure to test the null hypothesis.
4. Determine if the observed value of the statistic has a probability of occurrence less than a pre-chosen level of significance.
5. If it does, reject the null hypothesis.

This process results in a definitive decision as to whether to reject the null hypothesis. This decision carries with it the potential for two types of error. A Type I error occurs when the null hypothesis is rejected when it should not be. The probability of this occurring is designated alpha (α) which should normally be set at 0.10 (but may vary depending on objectives), thus ensuring that if the difference is not significant, the risk of a mistaken conclusion is no more than 10 %. The hazards associated with Type I error are generally well recognized and carefully controlled. A Type II error occurs when the null hypothesis is retained when it should be rejected; the probability of this occurring is designated beta (β). Traditionally β has been ignored, although the recent trend in ecological reporting is to give it much greater consideration. Typically β should be set at 0.20, but can also vary depending on objectives.

Generally, a conservative approach is recommended when setting the levels of α or β. Depending on how the hypothesis is worded, the risk of Type I or Type II error may be adjusted in an attempt to avoid irresponsible errors. For example, if a null hypothesis is stated:

H_o: There is no significant difference between the abundance of Species X in pristine and severely disturbed Study Areas.

The consequences of making a Type II error based on this type of hypothesis could result in potentially irresponsible management practices for Species X. It is very important that error be minimal when evaluating such a hypothesis. In such a case, a conservative approach would be to reduce the possibility of making such an error by reducing the level of β, possibly below 0.20 if this was appropriate. The intent is not to manipulate statistics to produce a specific result, but rather, to ensure that experiments are designed to minimize the risk of making errors with potentially damaging impacts. It is wise to test hypotheses in a manner which is conservative with regard to management implications, and ecological sense should always take precedence over statistical testing.

Finally, it is important when selecting the appropriate statistical procedure to determine whether parametric or non-parametric methods should be used. Parametric methods of statistical analysis assume that the population has a normal distribution. Ecological variables often have skewed distributions which violate this assumption. Traditionally, non-parametric methods of data analysis have often been used as these do not require the population distribution to be normal and are not subject to restrictions in terms of variance or form (Krebs 1989). However, non-parametric methods have recently been criticized for having lower power, and hidden restrictive assumptions regarding the distribution of data. For example most non-parametric methods still require a symmetrical distribution and are not necessarily robust to highly skewed data. Many times parametric methods are as robust to non-normal distributions as non-parametric techniques (as long as N is large enough), and also have significantly higher power (See Day and Quinn 1989). Currently, generalized linear models (poisson regression, logistic regression, White and Bennetts (1996) negative binomial test) are being used as a method to accommodate non-normal distributions.

5.2 Presence/Not detected (possible)

Data analysis depends primarily on the objectives of the presence/not detected survey. Some options for data analysis are:

- List of species present or a list of species expected based on literature reviews and discussions with knowledgeable people.
- Species richness (McIntosh 1967), expressed as the number of species present in a given habitat or season. However, since it is not often possible to enumerate all species in a community, other methods may be used. One of these methods is the Rarefaction method that standardizes samples to a common size so that they can be compared between communities or within the same community over time (Krebs 1989, p.330-336). Species richness can also be estimated using the Jackknife or Bootstrap approach (for nonparametric distributions) when sampling quadrats (Krebs 1989, p.336-341).
- Species diversity, calculated from indices such as the Shannon-Wiener index (Shannon and Wiener 1963). This index takes species rarity into account (Krebs 1989, p.361-362). If the population has a nonparametric distribution, then a Simpson's Index can be used that does not make assumptions about the shape of the species abundance curve (Krebs 1989, p.357-362).

5.2.1 Limitations of a presence/not detected survey

The general objective of presence/not detected surveys is to determine whether a species is present to document species geographic ranges or species diversity in an area. To determine species absence or local extinction in an area is more difficult. Some species, such as the spotted owl or a nesting marbled murrelet, may be very difficult to detect because they occur at very low densities, possess a cryptic nature, and/or show a great degree of spatial and temporal variability in geographical distribution. Therefore, the documentation of absence or local extinction can occur only after survey efforts are replicated both spatially and temporally for a longer time period. Given these constraints, the results of presence/not detected surveys should always be phrased "our study failed to detect species x" as opposed to species x is "absent" or "extinct".

Non-replicated presence/not detected surveys will not yield data of statistical value, and if possible, it may be wiser to "upgrade" surveys to employ methods used for relative abundance. This way the data can be used as preliminary data (for power analysis or sample size determination) for planning of relative abundance surveys. In many cases it may be more effective to use relative abundance methods to document changes in the geographical ranges of species.

It is useful to discuss some general guidelines for optimal sample sizes to use in presence surveys. In all cases the sample size for determination of presence will depend on assumptions that can be made regarding species density and distribution. These assumptions will probably vary markedly between Study Areas and habitat types. Therefore, the calculation of sample size *can not be generalized* to all other areas or all other studies. In addition, a preliminary survey using replicated relative or absolute abundance methods is needed to make the sample size calculations discussed below.

5.2.2 Cluster sampling

Cluster sampling is the process of surveying a population using quadrats, live traps, or other standardized survey methods. Each sample unit is composed of a "cluster" of one or many elements, such as quadrats or transects (as opposed to the individual animals in the population). In terms of the following discussion, a survey consists of several samples collected by the use of a cluster sampling device such as a quadrat or transect.

If environmental factors are held constant then the main factors that influence detection are the density of the target species, the number of quadrats or cluster sample devices counted, and the distribution of the target species within the Study Area. If a survey is stratified properly, it will sample areas of differing densities. Replicated surveys within strata can then be used to index sample efficiency and calculate sample sizes needed for the detection of individuals or groups of individuals at estimated densities. This technique requires that a preliminary abundance survey precede sampling for presence. There are several assumptions with this technique:

1. The distribution and density of animals, environmental factors, and size of area used in the preliminary relative abundance survey are all similar to those in the area to be surveyed for presence/not detected.
2. The distribution of animals in the study areas is best approximated by the negative binomial distribution for determination of optimal sample effort to detect individuals.
3. Surveys are composed of random samples.

5.2.3 Sample size for multi-species surveys in a particular habitat type

A very simple way to determine the samples required in a particular habitat type is to plot the cumulative number of species detected versus the total number of samples. Theoretically, this curve will plateau when the most detectable species have been found. This curve will change for different habitat types, and different seasons and therefore must be recalculated when survey parameters change. Fundamental to the applicability of this method is that a proper Study Area has been defined and the habitat types of interest have been surveyed in a thorough (stratified) fashion. In addition, the areas of habitat to be surveyed should be roughly equivalent in size. The results of this graphic approach are not necessarily statistical but they will provide a rough estimate of the number of samples needed.

Caution should be exercised in comparing the species richness of different areas especially if different amounts of area were surveyed or a different degree of effort was exercised in surveying. The relationship between species and area sampled has been explored extensively in ecology in the form of species richness indices and species/area relationships. Krebs (1989, p.330) provides a detailed discussion on the measurement of species richness. In addition, Hayek and Buzas (1997, p.310) provide discussions on analysis of species diversity and methods to standardize survey results to account for total area surveyed.

5.2.4 Sample sizes for individual species surveys

In general, clumped populations are more difficult to detect then randomly distributed populations. Therefore, any estimation of optimal sample sizes for detection should account for both of these factors. For this reason, it is generally suggested that the negative binomial distribution be used for sample size calculations.

The negative binomial distribution has two principal parameters; the mean (m) and dispersion factor (k). The mean of the negative binomial is simply the mean number of a species counted in replicated quadrats which will be proportional to the density of the species being sampled. The parameter k describes the dispersion of the data which will reflect the distribution of a population. If k is small, individuals in the population are clumped, and if k is large individuals are spaced randomly.

The negative binomial distribution is superior to the binomial (or Poisson) distributions for calculating detection probabilities because the natural clumping or randomness of populations is partially accounted for (by the dispersion parameter). Use of the binomial (or Poisson) distribution implies that individuals are dispersed randomly, which may lead to biased estimates if populations are clumped (Krebs 1989). See Section 5.2 for more discussion about the use of the negative binomial distribution.

Determination of optimal sample sizes for species detection involves fitting replicated count data from surveys to a negative binomial distribution. To obtain quality estimates of the mean and dispersion parameter requires many replicated quadrats. See Krebs (1989, p.189) for more details on optimal sample sizes needed to estimate negative binomial parameters. In addition, the goodness of fit of the negative binomial distribution to the data can be tested using the methods of Krebs (1989) and program NEGBINOM (see Appendix G).

Estimates of *m* and *k* can be obtained from survey data using NEGBINOM or NEGTEST software programs. Both of these programs are very easy to use (see Appendix G). Estimates of *m* and *k* can then be used to calculate the probability of no individuals appearing in a quadrat or similar sampling device. (Krebs 1989, p.82). The formula for the probability of zero individuals occurring in one quadrat is:

$$p(0) = \left(1 + \frac{m}{k}\right)^{-k}$$

(1)

The probability of n randomly sampled quadrats not detecting a species is:

P(n quadrats with no individuals) = $(p(0)^n)$

The probability of detecting at least one individual in n quadrats is:

P(≥1 individual in n quadrats)= $(1-(p(0)^n))$

Therefore, the number of quadrats needed to optimize the probability of detection can be calculated simply by taking the $(1-(p(0)^n))$ to successive powers. From these data, a sample curve can be constructed with the number of quadrats on the x-axis and probability of detecting at least one individual on the y-axis.

To illustrate the use of the negative binomial, hypothetical data sets are provided in which *m* and *k* are varied. These data sets are meant for illustrative purposes only, not for determination of recommended sample sizes.

In the first example (Figure 3), hypothetical data sets are generated in which different values of *m* (mean count per quadrat) are used with a constant dispersion parameter (*k*) of 1. This dispersion parameter represents a “loosely” clumped population.

It is obvious from this example that the abundance of a species (as reflected by the mean count) will determine the number of quadrats needed to allow detection of the species. In addition, with rarer species (*e.g.*, 0.02 species/quadrat in Figure 3), the increase in number of quadrats sampled does not produce an appreciable increase in the probability of detection.

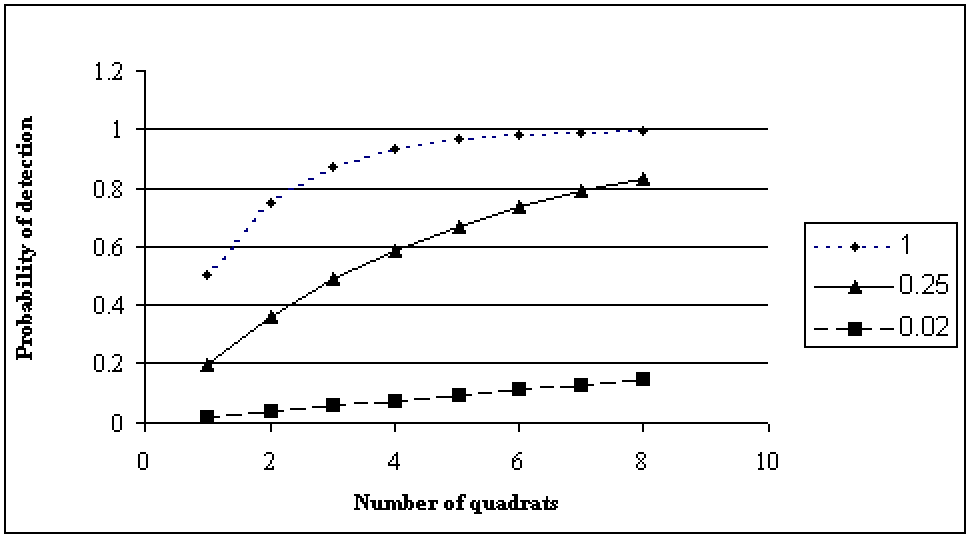

Figure 2. Probabilities of detection as a function of mean abundance with a constant negative binomial dispersion factor, k = 1.

However, as mentioned earlier, the distribution of populations will also influence detectability. The example given (Figure 4) is for hypothetical data sets in which different values of the dispersion parameter *k* are used with a constant mean (*m*) of 0.25 individuals / quadrat. A mean of 0.25 individuals / quadrat could be considered to represent an “infrequent” species. A value of $k = 0.2$ represents a fairly clumped population whereas a dispersion parameter (*k*) of 20 represents a less clumped population.

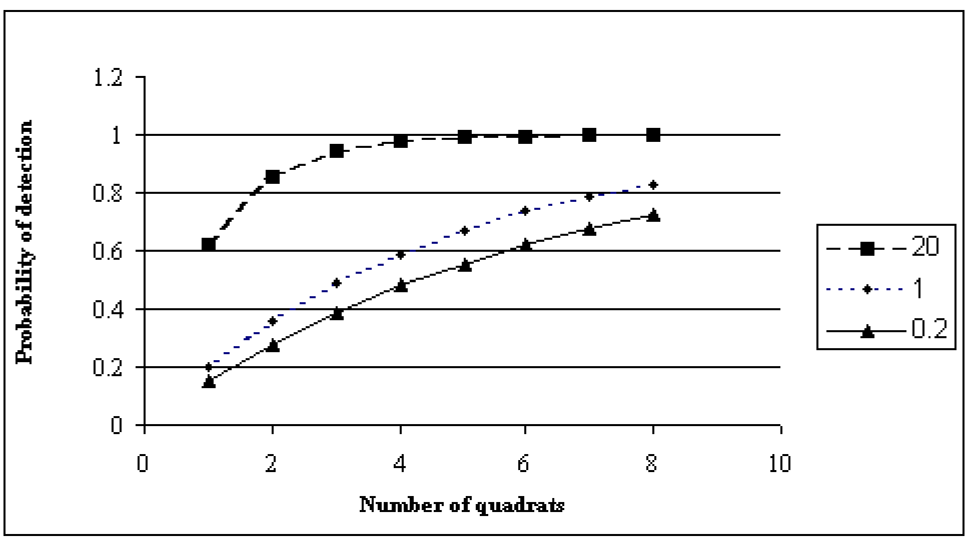

Figure 3. Probabilities of detection as a function of negative binomial dispersion factor (k) for data of mean = 0.25.

The most important point to note in Figure 4 is that the relative distribution of the population will greatly influence detection probabilities. This is why it is important to use the negative binomial as opposed to the Poisson for computing optimal sample sizes. Using the Poisson distribution implies that *k* is very large (or equivalently that individuals are randomly distributed). Therefore, using the Poisson distribution many times will lead to an optimistic interpretation of optimal sample sizes especially if individuals are clumped (and k is small).

These calculations *are very sensitive* to the assumption that the distribution (as estimated by k), and density of individuals (as estimated by m) are similar in all areas surveyed or to be surveyed. Therefore, the above calculations must be repeated for each habitat type (strata).

There will be error associated with the estimation of k and m, as with any statistical parameters. Programs NEGBINOM and NEGTEST give confidence limits for the mean value and variances for estimates of k. Using the value from the lower confidence interval will provide a more conservative (and possibly more realistic) mean (m) in equation (1). To provide a more conservative sample size estimate k for equation (1) subtract twice the square root of the variance of k from the estimate of k (as a rough approximation of the lower confidence limit for the data).

These calculations will provide rough estimates of sample size needed to ensure survey thoroughness. If the above calculations are used as a guide and an adequate number of samples are taken (*i.e.*, so probability is greater than 0.95) then an optimal level of sampling for a species can be reached. In addition, the relative effectiveness of surveys as a function of species density and distribution can be evaluated. If an optimal number of surveys are conducted and a species is not detected then the following conclusions can be made:

1. The populations being surveyed may have a lower abundance (m) or may exhibit a different distribution (as reflected by k) than the population that was used for the calculations. This hypothesis can be tested using program NEGTEST and the methods of White and Bennetts (1996) if sample sizes are adequate (see Appendix G).
2. The population being surveyed may not be as well represented by the negative binomial distribution as the preliminary data used for the initial calculations. This hypothesis can be tested by a goodness of fit test of the survey data to the negative binomial using the program NEGBINOM if sample sizes are adequate.
3. Like any statistical test, there is always a probability that the population was there at the levels of m and k, but simply was not detected. This is similar to the concept of power in statistical tests.

Given the possible contributions of any of these errors above as well as the natural variation in species distributions across space and time, absolute knowledge that a species is absent is difficult to obtain. Only through very rigorous replication through space and time can absolute absence be determined. Therefore, in general, *presence/not detected surveys can only determine presence. This is especially true for species at low densities*.

Despite these limitations, it is still useful to attempt to obtain an adequate sample size as this will increase the confidence with which resource decisions can be made. Easy to implement methods exist to calculate optimal sample sizes needed to detect species. These methods provide a useful tool for design of studies as well as a basis for quantitative comparison of surveys in different areas and over time.

5.3 Relative Abundance

Sampling designs that increase precision and reduce (or maintain constant) bias are used to collect relative abundance data. Precision can be further increased by (1) increasing the number of samples and (2) stratifying into areas that are likely to have similar abundance and distributions. Despite this, even large, stratified samples can result in large detection errors and low statistical power. Thus, trend estimation should generally be accompanied by power analysis, as sampling variation may mask trends in population change. Analysis of statistical power will not only indicate the reliability of the trend, but may also indicate a need to increase precision through the use of replicate samples, or by collecting data regularly over a long term (Harris 1986, Gerrodette 1987). In some cases it may be more practical to seek alternative methods for monitoring populations such as estimating annual survival rates.

Many relative abundance methods use counts or censuses of animals to compare populations, or calculate trends of populations. There are three very critical assumptions with relative abundance surveys:

1. Identical or statistically comparable methods are used when comparison between areas or monitoring trends in one area over time is an objective.
2. Environmental, biological, and sampling factors are kept as constant as possible to minimize differences in survey bias and precision between surveys.
3. Surveys are independent; one survey does not influence another.

The most important assumption is that survey bias, as reflected by the proportion of a population observed is, on average, constant across surveys. For trap based surveys, this means that the population on average shows a constant capture probability across time and space. For transects or quadrat counts, this means that on average the same proportion of the population is counted, or observed in replicate surveys. This may be not be entirely realistic in some systems; however, studies should be designed to accommodate this assumption in every possible way. Generally, absolute abundance methods such as mark-resight, or mark-recapture methods are more effective at accounting for differences in proportions of the population observed, but are also considerably more expensive. Distance methods (line transect, point counts) allow more rigorous estimates with minimal extra effort however sample size issues may sometimes limit the application of these techniques (See Section 5.4). Surveyors using relative abundance methods will need to make a concerted effort to minimize violation of this assumption.

The analysis of relative abundance data can be statistically complex because the data are rarely normally distributed, which is generally assumed for parametric analysis. In addition, many counts lack independence, due to pseudoreplication, or autocorrelation of census data, and this may further bias the results of parametric statistical tests. Many of the bias factors can also be eliminated by proper design of studies. Consult individual CBCB manuals for more details on appropriate study design.

5.3.1 Distributions of count data

If count data are collected using fixed-width (strip) transects, point counts, quadrat counts or other cluster sampling methods then they will usually follow a Poisson or negative binomial distribution. Table 6 describes each of these distributions.

Table 6. Common distributions of count data.

Distribution	Statistical parameters	Comments
Poisson	Mean (*m*)	• Var(x) =m • describes spatial randomness
Negative binomial	Mean (*m*) Dispersion factor (*k*)	• Variance always greater than the mean • as $k \rightarrow 0$, describes clumped population • as $k \rightarrow \infty$, describes random (Poisson) population

The Poisson and negative binomial distributions have been used traditionally to describe random and clumped patterns of population distributions (Krebs 1989, p.81). Real data will fall into either or a mixture of these distributions, and tests are available to determine the goodness of fit of data to each type of distribution (Krebs 1989, White and Bennetts 1996). Many times the variance of count data will be greater (overdispersed) or less then the mean (underdispersed) and therefore will not fit the Poisson distribution however it is possible to correct Poisson analyses for this problem (McCullough and Nelder 1989). Alternatively, count data can be modelled using the negative binomial distribution using the method of White and Bennets (1996) which are described later in this section.

Count data are technically not normally distributed because they are discrete (*i.e.*, integers) whereas the normal distribution is used for continuous data (*i.e.*, real numbers). However, it has been found that as the mean count increases the normal distribution can provide a good approximation of count data. The normal distribution does not work well for counts of rare species in which the most frequent count is zero, resulting in a frequency distribution of counts that is strongly skewed to the left. In addition, the variance of counts is usually related to the mean which violates the assumptions of most parametric tests (White and Bennetts 1996). Therefore, the challenge of data analysis for many counts is either to transform the data to resemble a normal distribution, or analyze the data using methods which model the Poisson or negative binomial as the assumed distributions. If data which fit a Poisson or negative binomial distribution are falsely assumed to be normal, and are blindly dumped into traditional parametric tests, then erroneous statistical results may occur. See the section “What to do if parametric assumptions are not met” for more information.

Count data are usually analyzed for two purposes; 1) to compare distribution over space and test the hypothesis of equal abundance in two or more areas, and 2) to analyze trends over time, and test the hypothesis that abundance is increasing or decreasing with time.

5.3.2 Comparisons between populations

If the assumptions of relative abundance surveys can be met (see above) then data can be analyzed to compare the relative abundance of the species in each area. Following is an outline of the assumptions of traditional parametric methods followed by a discussion of some alternatives when parametric assumptions can not be met.

Assumptions of parametric methods:

Traditional parametric ANOVA methods have three stringent assumptions regarding the data to be analyzed. These assumptions, and strategies to confront assumption violations are now described:

1. ***Normality:*** With any data set for counts, it is useful to first visually assess the data to determine the severity of any departures from normality. A plot of the cumulative frequency distribution on normal probability paper (Zar 1996, p.88) is a straight line for a normal distribution. A Kolmogorov-Smirnov

test (Zar 1996) is often used to test if the data are distributed normally but it has low statistical power. Zar (1996, p.89) presents a second goodness of fit test for the normal distribution suggested by D'Agostino that has more power. The D'Agostino test is implemented in some of the existing statistical packages like NCSS. If count data are not normally distributed, transformations may reduce departures from normality. See Krebs (1989), Zar (1996), and Sokal and Rohlf (1995) for a detailed discussion of transformation strategies. The D'Agostino test or the Kolmogorov-Smirnov test should be redone with the transformed data to determine if the data have been transformed adequately to meet the assumption of normality. Note that if count data for rare species have the most frequent count of zero, transformation to a normal distribution will not be possible. If the data can not be transformed to be approximately normal, alternatives are presented under "What to do if parametric assumptions aren't met".

2. ***Independence of observations:*** This is related to the design of the study. The most common violation of the assumption of independence is pseudoreplication of observations. Pseudoreplication occurs when the same subject is repeatedly sampled so that the samples are not independent. Repeated measures ANOVA designs (Hurlburt 1984), or randomization tests (Manly 1997) which are robust to this problem can be used if other parametric assumptions are met (see the heading below "What to do if parametric assumptions aren't met"). The key point is to clearly define the experimental unit in the study, and design the data collection so that the counts are independent of one another.

3. ***Variances between samples are equal:*** A variety of tests can be used to determine if variances between samples are equal (Zar 1996, p.204). However, these tests require that the data are distributed normally. If the assumption of normality is not met, an alternative is to compare the smallest sample with the mean of other variances at the 25% significance level, as described in Day and Quinn (1989). Potential bias due to unequal variances can be severe in a traditional ANOVA (see the heading below "What to do if parametric assumptions are not met" for details on how to confront this problem). Note that often (but not always) a transformation that makes counts more normally distributed will also tend to make the variances among the groups equal, so that the two assumptions can often be treated together.

What to do if parametric assumptions are not met

Robustness of parametric ANOVA: The parametric ANOVA has been shown to be robust to minor departures from normality if n (the sample size) is equal between samples, and n is large (> 20 in each sample) (Day and Quinn 1989, Zar 1996). White and Bennetts (1996) cite an unpublished thesis which demonstrated that ANOVA applied to negative binomial count data was quite robust to deviations from the assumptions given above. However, the parametric ANOVA is not robust to large variance heterogeneity especially if sample sizes are not equal (Day and Quinn 1989). Day and Quinn (1989) suggest alternatives to the parametric ANOVA if variances are not equal, but note that these tests are not robust to non-normal data and/or unequal sample sizes.

If the data are severely non-normal, and large differences in variances exist then no ANOVA test will give valid results (Day and Quinn, 1989). It may be fruitful to explore the methods of McCullough and Nelder (1989), and White and Bennetts (1996) (discussed below) for analysis of this type of data. On the other hand, if departures from normality are not severe (either for the original or transformed data), variances are nearly equal, and sample sizes are large and nearly equal in the different groups, then a parametric ANOVA should still provide statistically valid results. See Day and Quinn (1989) for a detailed discussion regarding ANOVA techniques.

A common technique is to use multiple comparison tests after an analysis of variance. A large number of statistical tests are available in most computer packages for this purpose. Unfortunately, these tests will give different results dependent on characteristics of the data, and other sample assumptions. It is strongly recommended that biologists read Day and Quinn (1989) to aid in the design of the sample program, as well as in analysis of the data.

Robust data-based model selection methods: Recently, procedures such as generalized linear models and likelihood theory have been used to allow ANOVA type tests to be performed in which the assumed distributions are a variety of statistical distributions (McCullough and Nelder 1989). The rationale behind these new methods is that count and other types of biological data are rarely normally distributed, so it is preferable to develop methods to accommodate the true distribution of the data rather than forcing it into parametric tests (Burnham and Anderson 1992, White and Bennetts 1996). These new methods are the “way of the future” for they are infinitely flexible to anomalies in the data, and provide parsimonious, and robust inference for a variety of statistical problems. Many of these approaches require advanced statistical knowledge. It is beyond the scope of this manual to detail all the potential uses of generalized linear models. We suggest biologists consult Hillborn and Mangel (1997), McCullough and Nelder (1989) and qualified statitisticians for more information on analysis stategies using generalized linear models.

One relatively simple application of generalized linear models is the fitting of the negative binomial distribution to count data for ANOVA type questions as discussed by White and Bennetts (1996). White and Bennetts utilize the fact that the negative binomial distribution can fit random or clumped distributions dependent on the value of *k*, the dispersion parameter (Table 6). Therefore, by determining the goodness of fit of a count data set to a negative binomial distribution, and estimating *m* and *k* from a count data set (using maximum likelihood theory), robust inferences can be gained about both the central tendency (or mean) of the data set as well as its dispersion. Furthermore, pairwise comparisons between data sets can be made to test hypotheses concerning the difference between population abundance (as reflected by counts) and dispersion of individuals within the populations (based on values of *k*).

This approach is “state of the art”, providing robust inference not possible with ANOVA techniques. As well, in Monte Carlo simulation tests, the traditional ANOVA performed in a comparable fashion to the negative binomial method for comparison of means if variances and sample sizes were equal (White and Bennetts 1996). Project biologists are advised to use the negative binomial tests outlined in White and Bennetts (1996) if possible. Techniques for fitting the negative binomial distribution are discussed extensively in Krebs (1989, p.81) and biologists should try to provide the negative binomial parameters for their data as outlined in White and Bennetts (1996).

A Windows-based program that will do White and Bennet’s (1996) calculations will be released in Fall 1998 as part of an updated package of Ecological Methods programs for Windows. This program will estimate *m* and *k* and will test for equality of *m* and *k* between groups. However, it will not do multiple comparison type tests (as discussed in White and Bennetts 1996). Some statistical packages are designed to allow multiple comparison tests using these methods (SAS PROC GENMOD) but they also require extensive programming to obtain results. See Appendix G for more details on NEGTEST and other programs.

Randomization tests and data resampling methods: Randomization tests have been proposed as an alternative to parametric methods. The philosophy behind randomization methods is that all the information needed for the analysis of data is contained within the data set to be analyzed and through random resampling of the data set, robust tests are possible with minimal assumptions. These tests are considered to be more robust to non-random sampling, non-normal data, and can account for statistical anomalies in the data set. In addition, bootstrap and jackknife methods provide more robust estimates of central tendency than traditional methods. However, results from randomization methods are hard to compare to other studies since each randomization test is based only on a given set of data, as opposed to a theoretical statistical distribution. There is no reason to use randomization tests if the assumptions of parametric tests are met for they will give the same results (Manly 1997). Many of these techniques are statistically complex. Manly (1997) provides a thorough discussion of randomization, bootstrap, and jackknife techniques, and has also produced RT, a DOS based software package for randomization analysis (see Appendix G). Randomization tests are not recommended if it is possible to use either parametric ANOVA or the robust White and Bennetts (1996) procedure.

Nonparametric methods: Nonparametric methods such as the Kruskal-Wallace test are widely used as alternatives to the parametric ANOVA when the assumptions for parametric tests can not be met. Although these methods make fewer assumptions regarding the distribution of data, they also have much lower power than parametric methods. In addition, they still require "similar" data distributions and are not robust to variance heterogeneity (Day and Quinn 1989, Fowler 1990, White and Bennetts 1996). Given these restrictions, they are not generally recommended.

Keys to good study design

In summary, many methods exist to compare relative abundance of populations. New data-based methods hold promise for more robust inference, and added inference about distribution as well as central tendency from relative abundance data. Parametric ANOVA methods are robust to departures in normality, if studies are designed properly. Some of the most important study design issues are:

1. ***Equal sample sizes:*** The robustness of the parametric ANOVA is greatly diminished if sample sizes are not equal (Day and Quinn 1989).
2. ***Proper stratification*****:** Sampling should be designed with proper stratification by expected densities, or habitat types when possible (Krebs 1989, p.212).
3. ***Observer effects:*** Proper observer training, and if needed, nested ANOVA designs should be used to minimize and test for observer effects (Krebs 1989, p.283).
4. ***Within-site variability:*** Replication of individual sites (when sight or call surveys are used) should be considered in some cases. The influence of within-site variability, and optimal design strategies is discussed in Link *et al.* (1994).

It is important in any monitoring study to do pilot studies to check on these statistical problems before extensive work is set in motion. Power analysis of statistical tests should always be used to determine optimal sample sizes for survey efforts.

5.3.3 Analysis of trend data

If counts are replicated at the same site on an annual or similar increment then a time series can be formulated to estimate trend. Thomas (1996) outlines four patterns that may possibly contribute to that which is observed in time series data. The objective of a statistical analysis is to separate trend from the three other factors that create noise in the data.

1. ***Trend:*** The prevailing tendency of the population to increase, decline, or remain stable as determined by birth, death and immigration rates. This is the quantity that researchers and biologists wish to determine. A trend can be constant (linear) or changing (non-linear) through time.
2. ***Interventions:*** Irregular environmental effects that influence the population independently of trends. Examples of this would be severe winters, or other density independent factors which may increase the rate of decline (or reduce it).

3. ***Autocorrelation of time series points:*** The state of the population in previous years will affect its state during the following years. Therefore, census points in a time series are not statistically independent. Examples of this would be a population taking many years to recover from losses sustained in a severe winter. The census numbers observed may be low in years following a severe winter as the population recovers.
4. ***Sampling error:*** All census data will have sampling error as determined by the methods used, sample precision, population density, and relative efficiency of surveys.

Linear regression

Traditionally, linear regression has been used to analyze count data in which counts or log transformed counts from a survey conducted in the same area are regressed against the year of survey. Most trend analysis assumes that population changes are multiplicative so that log-transformed counts are most appropriate for analysis. If surveys are replicated yearly in different areas (or routes) then a “route regression” approach would be used in which separate linear regression analyses are done for each route and then averaged for an overall trend estimate (Geissler and Sauer 1990). The underlying model of population trend when linear regression (with log-transformed counts) is used for analysis is:

$$E(C_y)=E(C_0)\beta^{y}$$

where $E(C_y)$ is the expected count in year y and β is the trend. This type of analysis is referred to as “linear-multiplicative models” (Thomas 1996).

This method has the following assumptions:

1. ***Transformed count data are distributed as log-normal:*** (for replicated counts in a survey period). The distribution of count data is rarely normal especially if individual counts are low. A biased estimate of β (and variance of β) will result if non-normal count data are used with linear regression.
2. ***Trend is constant (linear) throughout time:*** If the population trend changes through time due to interventions or biological factors then the assumed linear model of trend is false and β as an estimate of trend will be biased. Linear regression has been shown to be robust to interventions as long as they are random (Thomas 1996).
3. ***Survey precision is equal between years:*** If population change is minimal, and a monitoring program is properly designed then this assumption might be met. The log transformation also tends to homogenize variances. In extreme cases, surveys can be weighted by relative precision to minimize bias due to this factor.
4. ***Counts as well as survey units are independent:*** This assumption is violated due to the fact that yearly surveys are autocorrelated. However, if a trend is constant throughout time and interventions, stochastic effects, and density dependent effects are minimal, then bias due to this problem will be small. Linear regression has been shown to be fairly robust in terms of bias to autocorrelation in time series. However, estimates of variance will be negatively biased if autocorrelation exists in the data. Spatial replication of monitoring efforts and the use of route regression techniques will partially minimize potential variance bias due to autocorrelation (Thomas 1996).

The main problems that arise when linear regression models are applied to trend analysis are the assumptions of a constant trend (as estimated by β), and log-normal distributions of count data (Geissler and Link 1988). There has been much theoretical development of new methods for trend analysis as a response to the problems with linear regression analysis. Much of this work has been focused on the analysis of breeding bird surveys, and statistical ways to deal with unknown trend models, and poor survey data (James *et al.* 1996, Thomas 1996, Thomas and Martin, 1996).

Other types of regression

The general regression techniques used for trend data (each with various statistical routines) are described in Thomas (1996). Examples of potential methods include:

1. ***Polynomial-multiplicative model.*** This type of regression analysis allows trend to change over time. The challenge with this technique is determining the underlying trend model. This can be chosen *a priori* or using data based methods (see Burnham and Anderson 1992). Parametric polynomial regression is possible in most statistical packages. Generalized linear models allow count data to follow alternative distributions (such as Poisson, negative binomial etc.). Methods are available which can accommodate over or under dispersed Poisson distributed count data (ter Braak *et al.* 1994).
2. ***Additive models.*** With this method, no model of trend is chosen *a priori* and therefore there are minimal assumptions made about the trend. Instead sources of variation are removed statistically using filters such as locally-weighted regression. The main disadvantage of this technique is that the filters require the use of a smoothing parameter to remove variation from the data, which is chosen subjectively (see James *et al.*1996).
3. ***Rank models.*** This method estimates the tendency for counts to increase or decrease but does not calculate rate of increase or decrease (Titus *et al.* 1990). This method makes no assumptions regarding the distribution of counts, but also limits inference into population change given that no estimate of trend is given.

Many of these methods require the use of statistically complex model-fitting methods. Therefore, it is advisable that biologists consult a trained statistician for advice on their proper use. Proper selection of trend model, and analysis technique can not be overemphasized, for each of the above methods might give a different result when confronted with the same data set (Thomas 1996, Thomas and Martin 1996). Table 7 summarizes the most important assumptions of each method. See Thomas (1996) for a list of routines available under each method as well as simulation evaluation of specific routines.

Table 7. Regression models for trend analysis.

Method	Assumptions		Comments
	Trend model	Distribution of counts	
Parametric regression	Linear-multiplicative (*i.e.*, linear on a semilog plot) or polynomial	Log normal	• Restrictive assumptions regarding distribution of counts • Must select trend model (linear or polynomial) • Easy to calculate
Generalized linear models	Linear or Polynomial-multiplicative	Poisson, log-normal, and other distributions.	• Must select trend model (linear or polynomial). • Can accommodate non-normal count data
Additive models	Additive	None	• Subjective choice of data filter • Allows trend model to change over time
Rank models	Ranks	none	• Minimal assumptions regarding trend model or distribution of counts • No estimate of trend magnitude

[1]dependent on routine used

Experimental considerations

***Importance of length of monitoring effort*:** One very important factor is the time frame of the monitoring effort. Populations will go through periodic fluctuations due to demographic stochasticity and other factors. In addition, a population recovering from a perturbation may have an artificially high rate of increase for a few years which obscures long term population trends. Given this, a trend analysis should occur over a long time period to adequately determine population trends (Barker and Sauer 1992).

***Importance of appropriate study design*:** As with any statistical procedure, the results of the analysis will be very dependent on how well a monitoring effort was designed and implemented. It is important for inventory biologists to collect data to minimize the violation of assumptions for linear regression. For example, relative abundance studies should attempt to collect survey data with the largest counts possible. Also, censuses should be carried out at constant intervals (*e.g.*, same time each year) with continuity so that years are not missed. If possible, the same observers should be used each year, or a well documented training program should be undertaken to minimize variance among observers in precision of surveys. The degree of within-site variability should also be considered using the methods of Link *et al.* (1994). Most importantly, the critical assumption of relative abundance methods, that similar proportions of animals are sighted for each replicate survey, should be tested, and accommodated in design of surveys.

Program MONITOR and other analysis packages (as described in Appendix G) are helpful in the design of monitoring studies by considering sample error, autocorrelation of sample points, and trend model when determining optimal sample sizes and survey periods.

A general approach to trend analysis

The following questions should be asked prior to starting a monitoring effort, and analyzing the data.

1. What is the appropriate time frame for the monitoring effort? Use program MONITOR to determine the number of years of monitoring, and adequate sample size to detect hypothetical population trends. This step should be done before monitoring begins, and adaptively throughout the monitoring effort to determine optimal sample sizes.
2. What type of population trend is most likely with the target species? Search the literature to determine the likely type of population trend with the species to be studied. The knowledge of likely trend model will greatly help monitoring efforts. Obviously, if a species exhibits trends such as population cycles, a longer monitoring effort may be needed.
3. How are the count data distributed? The collection of pilot or preliminary survey data, and analysis of data from similar studies will help determine if the assumption of normality can be met. If data violate the assumption of normality, use the methods outlined above to account for potential sources of bias.

In summary, if monitoring efforts are designed properly then simpler types of trend analysis may be used with the resulting data. If trends are complex, or data are non-normal, then more advanced procedures do exist to still produce unbiased and precise trend estimates. User friendly computer packages are not currently available for these advanced models which generally require the assistance of a professional statistician.

5.4 Absolute Abundance

Absolute abundance methods provide population estimates which are expressed as number of individuals per unit area. There has been much theoretical development in these methods in the last twenty years, resulting in a variety of new robust analysis methods available as computer software. It is difficult to overemphasize the statistical advantage of these methods over relative abundance methods. Relative abundance methods will always be limited by the stringent assumptions in regard to similar bias of replicate estimates. In addition, some of the newer distance methods require little extra field effort when compared to fixed-width (strip) transects or similar relative abundance methods. An overview of methods is presented in this section. For more exact recommendations, review individual CBCB manuals.

5.4.1 Distance methods

There has been much recent development in distance methods for density estimation. The two principle distance methods are line transects and point counts. With each method, the actual distance of the animal from the line or center of point is measured. This allows an estimation of the detection probability of animals, as well as an estimate of density. Line transects and point counts have the following assumptions.

1. ***Objects on the line or point are detected with certainty.*** With line transects, an observer should record animals that are detected in front of the line, as well as to the sides. Having two observers will aid in this process. With point counts, the exact distance of the animal from the middle of the point should be recorded.
2. ***Objects are detected in their initial location.*** This assumption will generally be met as long as animals are not flushed during the search process. This assumption can be relaxed by modeling “fleeing behaviour” of animals when initially disturbed (Buckland *et al.* 1993).
3. ***Measurements are exact.*** This may be difficult to achieve, but new inexpensive laser rangefinders will aid in making measurements exact. These units allow exact measurement of distances using a “gun sight” monocular. They will give accurate estimates from non-reflective surfaces such as trees.

In some cases, these methods require about the same amount of effort as fixed-width (strip) transects or point counts used for relative abundance. However, a major constraint to this method is sample size. Buckland *et al.* (1993) states that at least 60 animals should be sighted for the use of distance models in program DISTANCE.

Program DISTANCE provides highly flexible methods of modeling detection probabilities. While the DISTANCE estimation methods can be complex, they also can be quite robust to anomalies in field data and provide superior results when compared to earlier estimation methods. We suggest that a statistician is consulted when planning distance surveys, and for the analysis of the field data. Buckland *et al.* (1993) provides a thorough discussion of this topic and the use of program DISTANCE.

5.4.2 Mark-recapture methods

Other inventory techniques may be capable of detecting a decline in population size but they often provide little additional information about the factors that may be responsible. In contrast, mark-recapture techniques provide an estimate of absolute abundance as well as other population parameters, including survivorship and movement rates. To illustrate this further, the Jolly-Seber mark-recapture method can be used to determine geographic patterns of distribution during migration, estimate population size and production, estimate survival and assess harvest pressure on different sex/age classes (Brownie *et al.* 1985, Bibby *et al.* 1992). Therefore, mark-recapture offers an advantage over other techniques in that it provides insight into mechanisms of population change when this is required.

The following questions should be evaluated before beginning a mark-recapture inventory (Bibby *et al*. 1992):

1. Will it be possible to catch enough individuals to obtain worthwhile results?
2. Will the mark harm the individual or affect its behaviour (*i.e.*, make it more vulnerable to predation, alter its place in any hierarchy, or interfere with pair bonding)?
3. If the individual must be handled again, can it be caught again? Are its chances of capture affected by the fact that it was caught in the first place?
4. If field observations will be made, are the marks properly distinguishable?

Despite the additional information they provide, mark-recapture techniques have some drawbacks. Population estimates obtained through mark-recapture are subject to restrictive assumptions which must be met to ensure accuracy. In addition, relative to other techniques, mark-recapture studies require large amounts of time, effort, and money. In compensation for this second shortcoming, it is necessary to determine the sample size needed to obtain a good estimate of abundance before beginning a mark-recapture study. Depending on the results of this type of sample size estimation and the availability of resources, it may be necessary to consider a less expensive option for gathering inventory information.

Mark-recapture models can be dichotomized into open and closed models. An open population is defined as having births, deaths, and movements on and off the Study Area during the census period. A closed population assumes that movements, births, and deaths, are insignificant during the census period. An open population is more commonly found in nature; however a population can be considered closed if capture and recaptures are spaced close together in time so that population change is negligible. The models of program CAPTURE and the Lincoln-Peterson estimator are the most common closed models. In general, closed models are used for estimates of density and population size. Open models (which do not assume population closure) are usually used for estimates of survival. The most common open model is the Jolly-Seber model.

Closed Models - The Lincoln-Peterson ratio estimator

The Petersen method is the simplest mark-recapture technique requiring only one marking period and one recapture. Animals are initially captured through a random sample of the population, all captured animals are marked and released, and then the population is randomly sampled a second time. The proportion of total population which was initially captured and marked is considered to represent the proportion of marked animals which were recaptured.

The Petersen Method relies on the assumptions that:

- the population is closed, so N is constant
- all animals have the same chance of getting caught in the first sample
- marking individuals does not affect their catchability
- animals do not lose marks between the two sampling periods
- all marks are reported on discovery in the second sample

The Petersen equation is:

$$N = \frac{(C + 1)(M + 1)}{R + 1} - 1$$

(2.0)

where: $\hat{N}$ = *Estimate of population size at time of marking*

M = *Number of individuals marked in first sample*

C = *Total individuals captured in second sample*

R = *Individuals in second sample that are marked*

This estimator is unbiased if $(M + C) \geq N$ and nearly unbiased if there are at least seven recaptures of marked animals ($R > 7$). This formula assumes that sampling is without replacement in the second sample, so individuals can only be counted once.

To determine the reliability of the estimate it is necessary to compute the confidence interval around the estimate (Section 5.2). Confidence intervals provide information on the precision of the estimate; a confidence interval of great width is considered imprecise, requiring more samples to narrow the confidence limits. There are a number of techniques available for computing confidence intervals and their application depends on the relationship between population size and the number of samples taken. Krebs (1989) gives the following guide:

1. If the fraction of marked animals (R/C) is less than 0.10, and

    a) the number of recaptures (R) is less than 50, use Poisson confidence intervals

    b) the number of recaptures (R) is above 50, use the normal approximation to obtain confidence intervals.

2. If the fraction of marked animals (R/C) is more than 0.10, use binomial confidence intervals.

Lincoln-Peterson estimates are easy to calculate, and the estimator has been shown to be robust to time variation in capture probabilities. However, there are important assumptions associated with this estimator such as equal probabilities of capture between animals, population closure, and no net loss of animal marks between samples. If absolute abundance is the objective of methods, and animals can be marked individually then it is more appropriate to use the estimators in program CAPTURE. These will generally give a better estimate.

Closed Models - Program CAPTURE

The Lincoln-Peterson estimator will produce a biased estimate if unequal probabilities of capture exist in the population being trapped. For this reason, robust models for closed populations have been developed which are available in program CAPTURE. Program CAPTURE has a variety of models to accommodate various types of capture probability variation. There are three principle issues to be considered with the use of program CAPTURE.

1. ***Obtaining adequate sample sizes*:** The population on the trapping grid, population capture probability, and the number of sample (capture) sessions all influence sample size. To use the program CAPTURE model selection routine at least 4 or 5 sample sessions should be conducted. The number of sample sessions may have to be increased if populations are small or capture probabilities are low. See White *et al*. (1982), Boulanger and Krebs (1996), Boulanger and Krebs (1994), and Menkins and Anderson (1988) for a discussion of sample size issues with program CAPTURE.

2. ***Meeting the assumption of closure*****:** Trapping should be conducted in a brief time interval. In addition, grids should be large enough so that edge areas are minimized. See White *et al.* (1982) for details on closure issues.
3. ***Minimize capture probability variation:*** Capture probability variation occurs in three ways
   a) *Heterogeneity*- This is the variation which occurs between different animals. Each animal has a unique but constant capture probability.
   b) *Behaviour*- This is the variation which occurs once an animal has encountered a trap. Each animal's probability of capture may change after it is trapped.
   c) *Time*- The capture probability for the population changes each time traps are set.

Trapping experiments should be designed to minimize heterogeneity, time, and behaviour bias, if this is logistically possible. However, program CAPTURE will produce valid estimates even if capture probability variation is present ***if*** sample design issues one and two are adequately met.

The overall size of the study grid should be considered if estimation of density is an objective of the inventory effort. The size of grid areas will determine sample sizes in the mark-recapture data but will also influence the degree of edge area in the grid. If a grid is small compared to the home range area of a target species, an edge effect will be created, and density estimates will be positively biased. Given this, grid areas should be large compared to small mammal home range areas. Program CAPTURE has a nested subgrid algorithm that estimates the degree of edge area possessed by each grid. However, this routine needs very large sample sizes to give reasonable results. If a subsample of animals is radio collared and monitored during trapping then a correction factor can be calculated using the methods of Eberhardt (1990). The general message is that most trapping grids in the past have been too small, and it is important to utilize as large a trapping grid as is required for the species involved.

Open populations - Jolly Seber (ratio) estimator

The Jolly-Seber method allows for gains and losses to the population, thus it may be a more realistic estimator than Petersen or Schnabel estimates in many cases. It requires at least three capture (trapping) sessions and marks that are session-specific because a surveyor must be able to tell which is the most recent session in which an animal was previously trapped. If animals are marked as individuals, this can be derived from capture histories.

The Jolly-Seber Method relies on the following assumptions:

- every individual has the same probability (α_t) of being caught in the *t* th sample, whether it is marked or unmarked
- every marked individual has the same probability (ϕ_t) of surviving from the *t* th to the (t + 1)st sample
- individuals do not lose their marks, and marks are not overlooked at capture
- sampling time is negligible in relation to intervals between samples

Formulas and example calculations can be found in Krebs (1989, p.37).

Because the population estimate of the Jolly Seber model has similar assumptions to the Lincoln Peterson (except population closure), it is also susceptible to biases if unequal capture probabilities are exhibited in the trapped population. However, the survival rate estimate of the Jolly Seber is robust to most forms of capture probability variation, and is therefore a useful alternative for monitoring populations. In addition, there are many modifications to the Jolly-Seber to accommodate age-specific capture probabilities and survival rates (programs JOLLY, JOLLYAGE and POPAN). A Jolly-Seber estimate requires at least three samples.

The Jolly Seber approach to survival modeling has been extended to allow the testing of biological hypotheses using generalized linear models and related methods as documented in MARK and POPAN. These methods are the "way of the future" for they allow unparalleled flexibility, and the use of sampling covariates (such as weather factors) to minimize bias of estimates. In addition, they allow testing of biological hypothesis with mark-recapture data in addition to actual survival estimates. It is strongly recommended that biologists consult a statistician about these models if population monitoring is an objective of inventory efforts. (These programs are discussed further in Appendix G). The price of statistical consultation for design and analysis of the data is usually quite small compared to the amount of money required for field efforts!

Combining Open and Closed Models for robust estimates

The "robust" study design of Pollock *et al.* (1990) is recommended if density estimates, survival, and/or other demographic rates are an objective of inventory efforts. With this design, a series of 5-day samples are conducted at equal intervals (*i.e.*, every month) during the time period of interest. The data from the 5 day sessions is used to estimate density using program CAPTURE. In addition, these data are pooled and used with the Jolly-Seber model to estimate survival and other demographic parameters. This design has the following advantages:

1. Theoretically robust estimates of population size and survival are possible.
2. Temporary emigration from the Study Area can be estimated from the data set allowing for further demographic inference, and less biased survival estimates if a subset of the population. A new program, RDSURVIV, has been designed for this purpose when the robust design is used (Appendix G).
3. The data should also allow further demographic inference and model fitting of survival rates using programs MARK, SURGE, and POPAN (Appendix G).

Sample sizes for Mark-recapture

There are methods available for biologists to determine needed sample sizes for the various mark-recapture estimators. The following sources are recommended for sample size calculations (Table 8).

Table 8. Sources for sample size calculation.

Estimator	**Source for optimal sample size calculation:**
Lincoln-Peterson estimator.	Krebs (1989, p.22)
Jolly Seber estimates	Pollock *et al.* (1990, p.72) Simulation: POPAN (See Appendix G)
CAPTURE	White *et al.* (1982) Simulation: CAPTURE (See Appendix G)

The above references include graphs, and discussions of needed sample sizes for estimators. The determination of optimal sample sizes for program CAPTURE is complex. An easy to use simulation module is available as part of program CAPTURE to allow biologists to explore sample size issues.

5.4.3 Mark-resight methods

Mark-resight methods involve an initial marking period of animals and then subsequent resighting periods. The design of a mark-resight study is similar to that of a mark-recapture study.

Recently, there has been a fair amount of development in flexible, robust models for mark-resight data. The most popular models are found in program NOREMARK. NOREMARK has a variety of models to select from, and also provides a user friendly simulation module, which is quite useful in the planning of studies (Neal *et al.* 1993, White 1993, 1996a, 1996b). Program NOREMARK contains estimators such as the joint hypergeometric estimator (JHE), that estimate immigration and emigration and therefore do not require population closure. However, the JHE estimator does require equal probability of sighting of individuals in the population. The Bowden and Minta-Mangel estimators do not require constant sighting probabilities but do require population closure. Obviously, it is imperative that the assumptions of NOREMARK estimators be considered when planning sampling efforts (White 1993, 1996a, 1996b).

Often the use of mark-resight estimators requires the use of radio collars so that the number of marked animals alive in the population can be conclusively determined. Arnanson *et al*. (1991) have produced an estimator in which the number of marked animals in the population alive during the survey can be unknown which negates the use of radio collars. This estimator still requires that each marked animal can be individually identified using resighting techniques and that the population is closed during the survey. This estimator has been applied to eagle populations as discussed in Arnanson *et al*. (1991).

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: The magnitude of systematic errors or degree of bias associated with an estimation procedure which effects how well the estimated value represents the true value.

ALPHA (α): The probability of making a Type I error (level of significance).

BETA (β): The probability of making a Type II error.

BIAS: The mean difference from the real value of a measure by estimators of that measure. The result of systematic error in data collection.

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, DC. 519 pp.).

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.

BROAD ECOSYSTEM UNIT: A permanent area of the landscape, meaningful to animal use, that supports a distinct kind of dominant vegetative cover, or distinct non-vegetated cover (such as lakes or rock outcrops). A Broad Ecosystem Unit is defined as including potential (climax) vegetation and any associated successional stages (for forests and grasslands).

COMPONENTS OF BC'S BIODIVERSITY SERIES (CBCB): A series of manuals designed to provide information and set standards for the collection of reliable biodiversity inventory data at the species level for British Columbia.

CONFIDENCE INTERVAL: A specified range of numbers that will contain the true value of the parameter with the probability of ($1-\alpha$).

DATA: Raw, unedited, unanalysed observations in the form of numbers, pictures, locations, etc.

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.

ECOSYSTEMS WORKING GROUP: That part of the Terrestrial Ecosystem Task Force which is responsible for the development of standard inventory methodologies to deliver reliable, comparable information on ecosystems.

ELEMENT: An object on which a measurement is taken

ELEMENTS WORKING GROUP: Part of the Terrestrial Ecosystem Task Force which is responsible for the development of standard inventory methodologies to deliver reliable, comparable information on species abundance, distribution and population trends, as well as habitat associations of species in British Columbia.

ESTIMATE: An approximate value given as close to the true value as possible, that is a function of observable random variables, and perhaps other known constants, used to estimate a parameter.

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 species inventory that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species populations.

EXTINCT: No longer exists anywhere.

EXTIRPATED: No longer exists locally (but exists elsewhere).

INFORMATION: Data which have been analysed, synthesized or summarized so that inferences or predictions can be made about natural patterns.

INVENTORY GROUP: A group of species, usually taxonomically connected, which can be surveyed by a common RIC inventory method.

LEVEL OF INTENSITY: The intensity and extent to which field data are collected. Three broad levels are used by RIC: presence/not detected (possible), relative abundance, and absolute abundance.

LINE TRANSECT: A sampling unit in the form of a long continuous strip in which only those individuals which are observed on the transect line are assumed to be completely counted. The probability of detection (measured from the survey) decreases with increasing distance from the transect line.

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

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

NOCTURNAL: Active at night

NONPARAMETRIC METHODS: Methods of statistical analysis that do not require the population distribution to be normal or have the same variance or form (usually specified in terms of parameters).

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.

PARAMETERS: Descriptive characteristics of a population, such as the mean, total, or variance.

PARAMETRIC METHODS: A method of statistical analysis that assumes that the population has a normal distribution.

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

PRECISION: A measurement of the repeatability of measurements.

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.

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

RANDOMIZATION: Impartial selection, choice is made by a chance mechanism that does not favour one particular selection over any other.

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.

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/]

SAMPLE: A collection of sampling units drawn from a population.

SAMPLE BLOCK: A small plot or sample unit of any shape and size

SAMPLE SET: A collection of samples used to make inferences about a population.

SAMPLING UNITS: Non-overlapping collections of elements which are intended to be representative of a population.

SIMPLE RANDOM SAMPLE: A sampling procedure where a sample of size n is drawn from a population of size N in such a way that every possible sample of size n has the same chance of being selected.

SITE SERIES: An ecosystem classification for land areas capable of supporting a specific climax plant association and reflecting a specified range of soil moisture and nutrient regimes within a subzone or variant.

SPECIES 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*.

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

STATISTICAL INFERENCE: The ability to draw conclusions about a population parameter from an analysis of the sample data.

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.

STRATIFIED RANDOM SAMPLE: A sample obtained by separating the sampling units into nonoverlapping groups (stratification), and then selecting a simple random sample from each stratum.

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 DESIGN: The method of selecting the sample.

SURVEY: The application of one RIC method to one taxonomic group for one season.

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

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

TERRESTRIAL ECOSYSTEMS TASK FORCE: One of the seven 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.

TYPE I ERROR: The null hypothesis is rejected even though it is true.

TYPE II ERROR: The null hypothesis is accepted even though it is false

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

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APPENDICES

Appendix A. List of Acronyms.

Acronyms	Term/Explanation
ANOVA	Analysis of Variance (statistical technique)
BEU	Broad Ecosystem Units (provincial habitat classification system)
BHC	Broad Habitat Classes (former provincial habitat classification system replaced by BEU)
CBCB	Components of BC's Biodiversity series (series of RIC manuals concerned with species inventory)
CDC	Conservation Data Center
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DFO	Department of Fisheries and Oceans
EWG	Elements Working Group
GPS	Global Positioning System (electronic device which uses satellites to determine its map coordinates)
IWMS	Identified Wildlife Management Strategy
MELP	Ministry of Environment, Lands and Parks
MOF	Ministry of Forests
NAD	North American Datum (basis for topographic mapping in North America. NAD 83 is the datum established in 1983)
NTS	National Topographic Series (national map series)
RIC	Resources Inventory Committee
SPI	Species Inventory Data System (data system which will hold all RIC species inventory data)
SD	Standard deviation (statistical measure of dispersion)
TEFF	Terrestrial Ecosystem Field Form (FS882)
TEM	Terrestrial Ecosystem Mapping (biophysical mapping; usually at 1:20,000 or 1:50,000 scale)
TRIM	Terrain Resource Inventory Mapping (provincial digital map series at 1:20,000 scale)
UTM	Universal Transverse Mercator (map projection)
WCB	Worker's Compensation Board

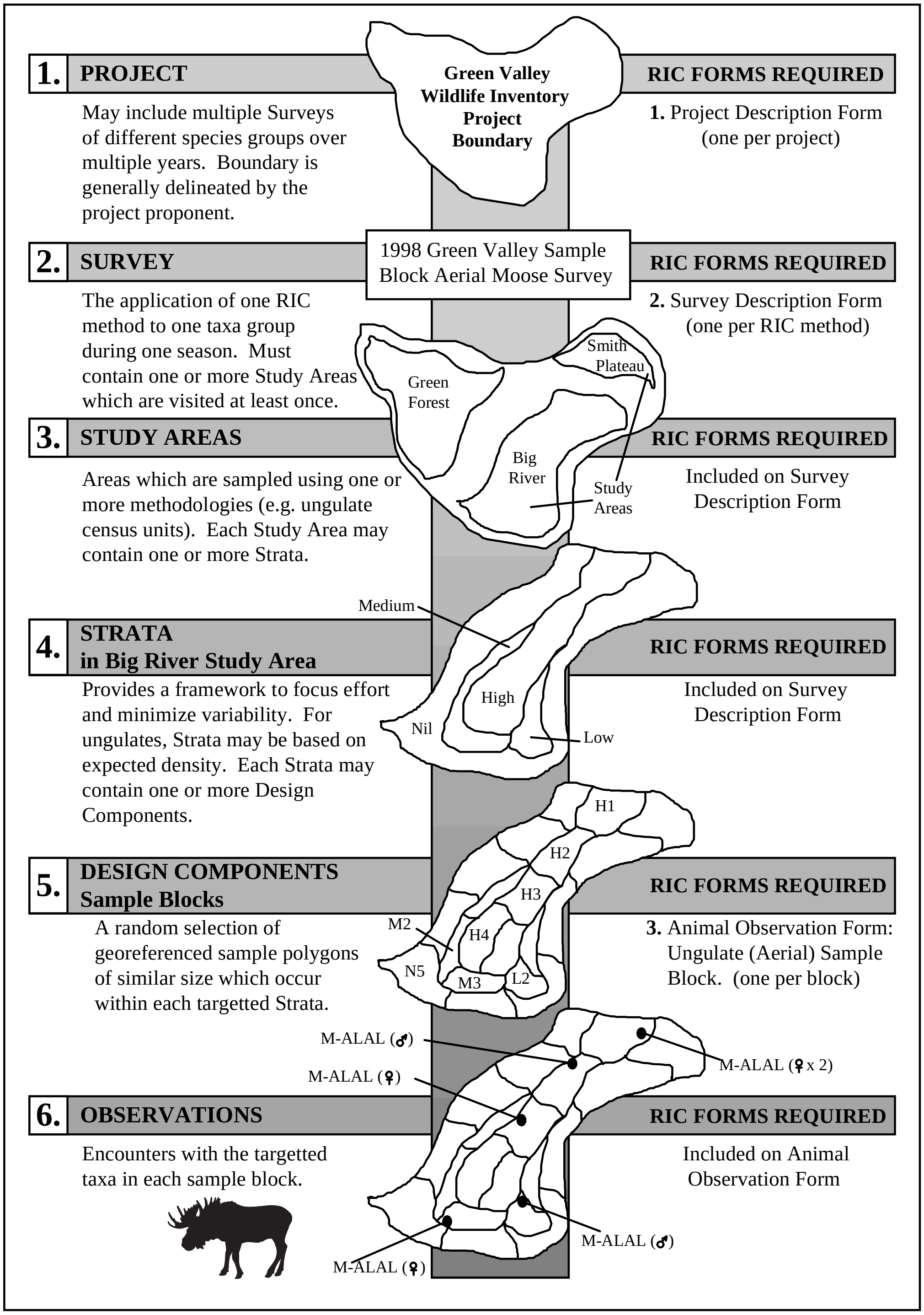
Appendix B. Format for Species Inventory Project Final Report.

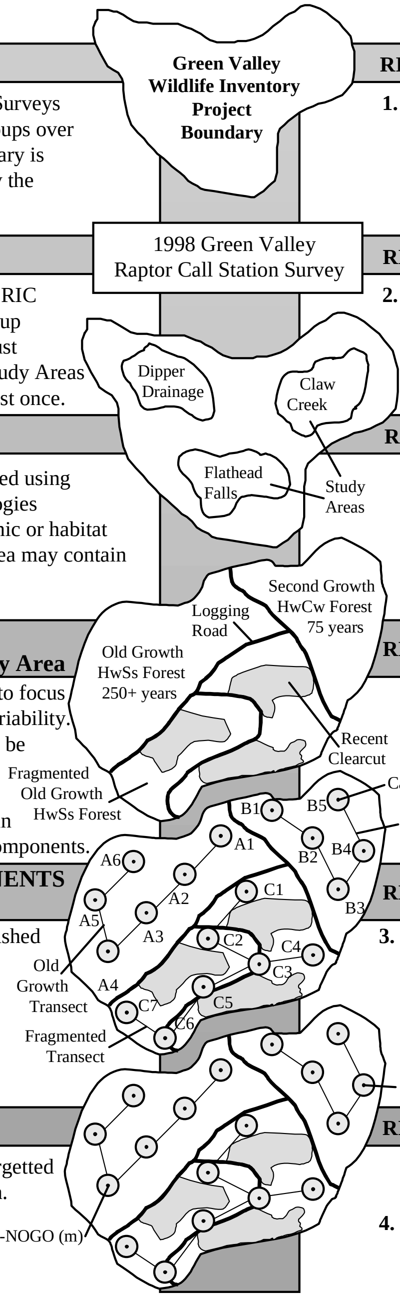
1. TITLE. Short, specific and informative. Preferably less than 10 words. Try to include species inventory groups, geographic location and subject matter.
2. EXECUTIVE SUMMARY or ABSTRACT. Must be complete and informative in scope, methods and results. Briefly indicate significance of findings. Avoid unnecessary descriptions.
3. TABLE OF CONTENTS. List primary and secondary headings. For longer documents include list of table, list of figures and list of appendices.
4. INTRODUCTION. States the objectives in simple point form. Reference any pertinent investigations which are related to the study. Provide background information on the abundance and distribution of the species inventoried. Include literature review here. Include acknowledgments as a final paragraph in this section.
5. PROJECT & STUDY AREAS. Describe the Project and Study Areas, their sizes, and include a map of their location. Indicate appropriate ecoprovinces, ecoregions and ecosections; and biogeoclimatic zones and subzones covered by the Project and Study Areas.
6. SUMMARY OF EXISTING INFORMATION. Include a review of existing information on the distribution, abundance, and habitat requirements of the species inventory groups examined within the Project Area.
7. METHODS. Describe the design and organization of the survey. Procedures used, including statistical analyses of data must be referenced. If RIC approved inventory methods were not yet available, provide justification for the choice of the inventory method, and describe the sampling procedures in sufficient detail to allow the reader to repeat them properly. Include the credentials of all inventory staff and their roles in the survey.
8. RESULTS. Summarize findings in tables, figures and charts. The text itself should be meaningful without reference to tables, figures or appendices. Figures, tables and appendices should be referenced in parentheses. There should be at least one table which summarizes a species occurrence list for the Project Area. Species designation (*e.g.*, red-, blue- or yellow-listed), and the ecosection, biogeoclimatic zone, subzone and broad ecosystem unit occupied should also be noted in the table. Summarize additional data in a clear and easy to read format. Only data necessary to support the text should be included in the body of the report. Provide statistical confidence intervals on the data, where appropriate (*e.g.*, population estimates). Presence/not detected surveys and measures of relative abundance need not necessarily provide a statistical measure of error but should include a qualitative assessment of reliability and identification of error in the process.
9. DISCUSSION. Present a basic interpretation of the data gathered. State the significance of the findings and their relation to previous or ongoing work, and literature reviews. Tabular comparison with other survey data can be included. Include any speculation and intuitive comments based upon experience. Address the issues of scale and level of error inherent in the data set. Specifically, provide warnings against inappropriate extrapolations or interpolations of data.
10. CRITIQUE OF INVENTORY PROTOCOLS. Provide an evaluation of the inventory methods used. If the survey revealed new information on survey methods, or species-specific aspects of surveying or particular problems which need to be addressed by the Elements Working Group, include them here.
11. MANAGEMENT RECOMMENDATIONS. Provide management recommendations. This may include recommendations for maintenance of wildlife diversity based on the inventory results, that relate to forest development planning or implementation of the Forest Practices Code (*e.g.*, Wildlife Habitat Areas); or statement of hypotheses regarding the effects of disturbance on distribution.
12. CONCLUSION. The highlights of the survey findings are summarized here in a simple format.

13. LITERATURE CITED. Reference all unpublished and published papers, reports, manuals and books used or referred to in the report.

Appendix C. Sample RIC Survey Design Hierarchy Diagrams.

Three examples follow, each showing the survey design hierarchy and dataforms required for a specific survey. Example one shows an aerial moose survey; example two shows a raptor call playback survey, and example three shows bat detection and capture surveys.


1. PROJECT
May include multiple Surveys of different species groups over multiple years. Boundary is generally delineated by the project proponent.
Green Valley Wildlife Inventory Project Boundary
RIC FORMS REQUIRED
1. Project Description Form (one per project)
2. SURVEY
The application of one RIC method to one taxa group during one season. Must contain one or more Study Areas which are visited at least once.
1998 Green Valley Sample Block Aerial Moose Survey
RIC FORMS REQUIRED
2. Survey Description Form (one per RIC method)
Green Forest
Smith Plateau
Big River
Study Areas
3. STUDY AREAS
Areas which are sampled using one or more methodologies (e.g. ungulate census units). Each Study Area may contain one or more Strata.
RIC FORMS REQUIRED
Included on Survey Description Form
Medium
High
Nil
Low
4. STRATA in Big River Study Area
Provides a framework to focus effort and minimize variability. For ungulates, Strata may be based on expected density. Each Strata may contain one or more Design Components.
RIC FORMS REQUIRED
Included on Survey Description Form
H1
H2
H3
H4
M2
M3
N5
L2
5. DESIGN COMPONENTS Sample Blocks
A random selection of georeferenced sample polygons of similar size which occur within each targetted Strata.
RIC FORMS REQUIRED
3. Animal Observation Form: Ungulate (Aerial) Sample Block. (one per block)
M-ALAL (♂)
M-ALAL (♀)
M-ALAL (♀ x 2)
M-ALAL (♂)
M-ALAL (♀)
6. OBSERVATIONS
Encounters with the targetted taxa in each sample block.
RIC FORMS REQUIRED
Included on Animal Observation Form



1. PROJECT

May include multiple Surveys of different species groups over multiple years. Boundary is generally delineated by the project proponent.

RIC FORMS REQUIRED

1. Project Description Form (one per project)

2. SURVEY

The application of one RIC method to one taxa group during one season. Must contain one or more Study Areas which are visited at least once.

RIC FORMS REQUIRED

2. Survey Description Form (one per RIC method)

3. STUDY AREAS

Areas which are sampled using one or more methodologies (e.g. different geographic or habitat areas). Each Study Area may contain one or more Strata.

RIC FORMS REQUIRED

Included on Survey Description Form

4. STRATA in Claw Creek Study Area

Provides a framework to focus effort and minimize variability. For raptors, Strata may be based on nesting or foraging habitat. Each Strata may contain one or more Design Components.

RIC FORMS REQUIRED

Included on Survey Description Form

5. DESIGN COMPONENTS Call Stations

Call stations are established systematically in each Strata.

RIC FORMS REQUIRED

3. Animal Observation Form: Raptor Call Station Survey. (one per call station)

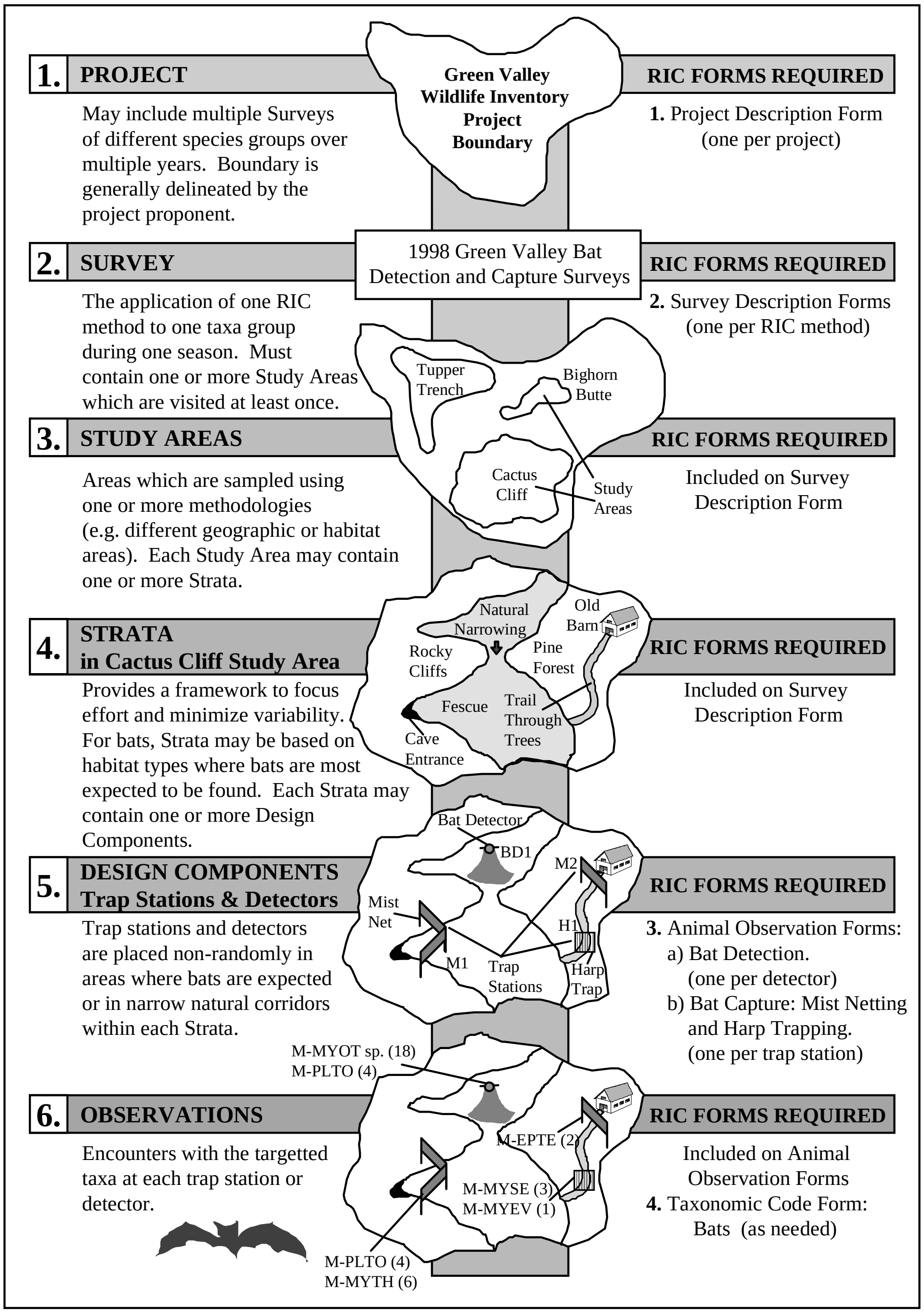
6. OBSERVATIONS

Encounters with the targetted taxa at each call station.

RIC FORMS REQUIRED

Included on Animal Observation Form

4. Nest Site Description Form (as needed)


1. PROJECT
May include multiple Surveys of different species groups over multiple years. Boundary is generally delineated by the project proponent.
Green Valley Wildlife Inventory Project Boundary
RIC FORMS REQUIRED
1. Project Description Form (one per project)
2. SURVEY
The application of one RIC method to one taxa group during one season. Must contain one or more Study Areas which are visited at least once.
1998 Green Valley Bat Detection and Capture Surveys
RIC FORMS REQUIRED
2. Survey Description Forms (one per RIC method)
Tupper Trench
Bighorn Butte
3. STUDY AREAS
Areas which are sampled using one or more methodologies (e.g. different geographic or habitat areas). Each Study Area may contain one or more Strata.
Cactus Cliff
Study Areas
RIC FORMS REQUIRED
Included on Survey Description Form
4. STRATA in Cactus Cliff Study Area
Provides a framework to focus effort and minimize variability. For bats, Strata may be based on habitat types where bats are most expected to be found. Each Strata may contain one or more Design Components.
Natural Narrowing
Old Barn
Rocky Cliffs
Pine Forest
Fescue
Trail Through Trees
Cave Entrance
RIC FORMS REQUIRED
Included on Survey Description Form
5. DESIGN COMPONENTS Trap Stations & Detectors
Trap stations and detectors are placed non-randomly in areas where bats are expected or in narrow natural corridors within each Strata.
Bat Detector
BD1
M2
Mist Net
H1
M1
Trap Stations
Harp Trap
RIC FORMS REQUIRED
3. Animal Observation Forms:
a) Bat Detection. (one per detector)
b) Bat Capture: Mist Netting and Harp Trapping. (one per trap station)
M-MYOT sp. (18)
M-PLTO (4)
6. OBSERVATIONS
Encounters with the targetted taxa at each trap station or detector.
M-EPTE (2)
M-MYSE (3)
M-MYEV (1)
M-PLTO (4)
M-MYTH (6)
RIC FORMS REQUIRED
Included on Animal Observation Forms
4. Taxonomic Code Form: Bats (as needed)

Appendix D. Sample Habitat Form, Attribute Definitions, and References

Sample habitat form for describing terrestrial ecosystems is included, as are descriptions and references for all terrestrial attributes. Page numbers and section references refer to:

Ministry of Environment, Lands and Parks and Ministry of Forests. 1998. *Field Manual for Describing Terrestrial Ecosystems.* Land Management Handbook 25. Victoria, BC.

Information on stream attributes can be obtained from *Reconnaissance Fish and Fish Habitat Inventory: Dataforms and User notes.*

SPI SAMPLE HABITAT FORM - Part A

Location	UTM Zone	East	North	Description
	BEU		BGC Unit	Ecosection

Site Series	Site Series	Site Modifiers

Site Info	Elevation _________ m	Slope ____________ %	Aspect ____________ °	Mesoslope Position ___________________

Structural Stage ___________

Topography

Regime
SMR
SNR

Simple Coarse Woody Debris					Sampled _____ m of 30 m transect						
Decay Class											
Diam. Class											
Decay Class											
Diam. Class											
Comments											

Substrate (%)			
Organic Matter		Rocks	
Decaying Wood		Mineral Soil	
Bedrock		Water	

Soil

Drainage - Mineral Soils	☐ Very rapidly ☐ Rapidly	☐ Well ☐ Moderately Well ☐ Imperfectly	☐ Poorly ☐ Very poorly
Mineral Soil Texture	☐ Sandy (LS, S) ☐ Loamy (SL, L, SCL, FSL)	☐ Silty (SiL, Si) ☐ Clayey (SiCL,CL, SC, SiC,C)	
Humus Form	☐ Mor ☐ Moder ☐ Mull	Root Restricting Layer Depth ________ cm	Type ___________
Coarse Fragment Content	☐ < 20% ☐ 20-35%	☐ 35-70%	☐ > 70%

Surficial Material
1
2

Geomorph Process
1
2

SPI SAMPLE HABITAT FORM - Part B

Basic / Detailed Veg	Plot Label ___________							
Stratum Coverage:	Tree (A)		Shrub (B)		Herb (C)		Moss + Lichen (D)	
L.	Species	Tot%	L.	Species	Tot%	L.	Species	Tot%
				Complete ☐	Partial ☐			

Wildlife Tree Plot		
BAF	Area	Min DBH
No. of trees	No. dead	No. live
Avg. DBH (cm)	Avg. length (m)	
Avg. lich load class	Comments	

Individual Wildlife Tree								
Spp	Stand / Fall	DBH	Est. Length	Crown Class	Ht. to live Cr.	Crown Cond.	Bark Reten.	Wood Cond.

Location - Georeferenced coordinates, Broad Ecosystem Unit, Ecosection, Biogeoclimatic Subzones (from map)

UTM - Enter the UTM zone indicated on the mapsheet (8–11 within BC), to indicate precise plot location. Record northing and easting (NAD 83 only), using the best available topographic base map or GPS (NAD 83).

BEU - Enter the code for the Broad Ecosystem Unit (BEU) in which the plot occurs. For current listing of codes see *Broad Ecosystem Units of British Columbia* available on the FTP site > ftp://wldux2.env.gov.bc.ca/pub/TEM/beu3app.doc

Biogeoclimatic Unit - Enter a code for the biogeoclimatic zone and subzone; include variant and phase where applicable. For current listing of codes see Site Description, Appendix 1.1 (p. 31).

- Transitional areas can be coded. In areas distinctly transitional between two recognized biogeoclimatic units, enter the code for the dominant unit here and mark with an asterisk (*). Identify other unit and explain under "Comments".

Ecosection - Enter a three-letter code for the ecosection. For current listing of codes see Site Description, Appendix 1.2 (p.38).

Site Series

Site Series [Site Description, p.8] - Enter a two-digit site series code and a letter code for site series phases, where recognized, from the appropriate MoF regional field guide for site identification and interpretation. (Letter codes and "typical" environmental conditions for all site series are provided in file 'map_code.xls' on the site: ftp://wldux2.env.gov.bc.ca/pub/ TEM). Note the following special cases:

- If two or more distinct site series are present, list in order of predominance, followed by the proportion of the plot represented by each in percent. For example: 01a (70%), 05 (30%).
- Where site characteristics are uniform but distinctly transitional between two recognized site series, indicate with a dash (*e.g.*, 01a-05).
- If the ecosystem does not resemble a recognized site series, leave this field blank, and explain under "Comments".

Site Modifiers - Record up to two site modifier codes (one letter each) to indicate atypical conditions relating to site series (Ground Inspection Form, Table 1.1, p.15). For example, if a site series is typically described as significant slope, warm aspect, with deep, medium textured soils but the site you are describing has a shallow soil, record an "s" to indicate this site modifier. Full descriptions of site modifiers are found in Appendix 1.1 (Ground Inspection Form, p.19). See Soil Description, Appendix 2.4 (p.59) for soil texture codes.

Site Info - Aspect, Elevation, Slope, Mesoslope Position (see FS882, GIF p.12)

Aspect - Record the orientation of the slope, measured by compass, in degrees (enter due north as 0°; level ground as "999").

Elevation - Record elevation, in metres, using an altimeter. Confirm by consulting a topographic map.

Slope - Record percent slope gradient, measured with a clinometer or similar instrument.

Meso Slope Position - Checkmark the appropriate box to indicate the position of the plot relative to the localized catchment area [see Site Description, Item 30 (p.25)].

Topography - Surface Topography (see FS882, HRE)

Surface Topography - Note the general surface shape and the size, frequency, and type of microtopographic features. Describe to the level that best represents what you see, separating coding with periods (*e.g.*, code a generally straight surface that is slightly mounded as ST.sl.mnd and a generally concave surface that is relatively flat as CC.smo). For codes see Site Description, Item 31 (p.26).

Structural stage (see FS882, GIF)

Structural Stage - Record structural stage. [see Site Description, Item 23 (p.16)]. Use numeric and lower case alphabetic codes unless otherwise directed. Modifiers for stand structure and stand composition are optional. Separate modifier codes from the structural stage code with a slash (*e.g.*, 7/mC; 3b/D).

Basic Veg - List of Dominant/ Indicator Vegetation Species (see FS882, GIF)

Dominant/Indicator Plant Species - List the dominant and indicator species (generally a minimum of three per layer). Use provincial plant species codes either by entering the names in full, or using the 4-3-1 (genus-species-subspecies or variety) code from *British Columbia Plant Species codes and Selected Attributes* (Meidinger *et al.* 1998), [see Vegetation, Species Lists (p.6)].
% Cover of Each Layer - Estimate percent cover of each layer of vegetation (tree, shrub, grass/forb, moss/lichen) as a portion of the plot.
Indicate that only a partial listing has been made, by checking the appropriate box (Partial) at the bottom of the form.

Detailed Veg - % Cover of different vegetation species by vertical stratum (number of stratum may vary; see FS882, GIF)

Species and Percent Cover (%) - List the dominant and indicator species and the percent cover for each species as a percentage of the sample area (plot). Use provincial plant species codes either by entering the names in full, or using the 4-3-1 (genus-species-subspecies or variety) code from *British Columbia Plant Species codes and Selected Attributes* (Meidinger *et al.* 1998), [see Vegetation, Species Lists (p.6)].
Indicate that whether a complete or a partial listing has been made, by checking the appropriate box at the bottom of the form.
Layer - Enter the layer codes for each of the plant species [see Vegetation, Vegetation Layers (p.5)].
Total Stratum Coverage (%) - Estimate the total percent cover for each layer indicated (A, B, C, D) as a percentage of the sample area (plot) [see Vegetation, Vegetation Layers (p.5)].

Abbreviated Tree Attributes for Wildlife (see Wildlife Habitat Assessment Form, p.23)

The purpose of this section of the form is to provide for a quick assessment of selected tree attributes for wildlife. The data recorded here is abbreviated and more qualitative than that collected using the detailed Tree Attributes for Wildlife Form (Section 6). Refer to Section 6 for information on selecting the sampling method. Once selected, the same sampling method should be used consistently throughout the project.
Also, refer to Section 6 for information on selecting the prism BAF or plot size, and minimum DBH. Once the prism or plot size is determined for the plot, complete appropriate sections of the Wildlife Habitat Assessment Form.
Field Procedures

- Establish plot center
- Stand at the plot center and estimate the number of trees in the plot as
- follows:
    1. For a variable radius plot do a prism sweep while counting the number of trees in the plot.
    2. For a fixed area plot stand at the plot center and while holding arms out at right angles to each other (Wildlife Habitat Assessment Form, p.24, Figure 5.1) estimate the area and number of trees in one quarter of the plot. Then turn 90 degrees and while holding arms out, repeat the estimate for the second quarter. Do this for all four quarters. Total the values to obtain the number of trees.
- Complete the Abbreviated Tree Attributes for Wildlife portion of the form based upon the trees selected in the step above.

Basal Area Factor - If a variable radius plot is used, enter the standard metric Basal Area Factor (BAF) in m^2/ha.
Area - If a fixed area plot is used, enter the area of the plot, in m^2.
Minimum DBH - Enter the minimum diameter at breast height (Min DBH) being used (in cm).
Number of Trees - Record the number of trees (No. of trees) in the variable radius or fixed area plot.
Number of Dead Trees - Record the number of dead trees (No. dead) in the variable radius or fixed area plot.
Number of Live Trees - Record the number of live trees (No. live) in the variable radius or fixed area plot.
Average DBH - Visually estimate, and record to the nearest cm, the average diameter at breast height (Avg. DBH) of the trees in the variable radius or fixed area plot.
Average Length - Visually estimate, and record to the nearest m, the average length (Avg. length) of the trees in the variable radius or fixed area plot. The estimate must be within 15% of the true average length. A quick and accurate method of estimating tree length is as follows:

- Mark a point 2 m in height from the base of the tree

- Move away from the tree so that the top of the tree is at an angle of 45°, or less.
- Tilt your head so that by rolling your eyes, and not moving your head, you can see the bottom and top of the tree.
- Hold a piece of twig or grass vertically between your thumb and index finger, and about 20 cm from your face. Adjust the length of the twig so that it spans the 2 m distance marked at the bottom of the tree.
- Move the twig upward vertically, and while rolling your eyes, count the number of twig-lengths that fit between the bottom of the tree and the top. When moving the twig upward it is important to keep the twig vertical and in the same plane, and your head still.
- Multiply the number of twig-lengths by two to obtain the length of the tree, in metres.

<u>Average Lichen Loading Class</u> - Visually estimate and record the average lichen loading class (Avg. Lich load class) of the wildlife trees in the plot. Assign a rating (0–5) based on comparison with photos in Estimating the Abundance of Arboreal Forage Lichens (Armleder *et al.* 1992).
<u>Comments</u> - Record observations on tree attributes deemed to be of importance to wildlife.

Individual Wildlife Tree - Species, Crown Class, Height to Live Crown, Crown Condition, Bark Retention, Wood Condition (see Tree Attributes for Wildlife, p.1)

<u>Species</u> - Identify tree species using the codes given in Appendix 6.1, Tree Attributes for Wildlife, p.13.
<u>Standing / Fallen</u> - Classify the tree as standing or fallen using the following codes and criteria: S Standing Trees or portions of trees with the root attached and self-supporting (*i.e.*, the tree would remain standing if all supporting materials were removed). F Fallen Trees or portions of trees with the root attached and not self-supporting, greater than 1.3 m in length.
<u>Diameter at Breast Height</u> - Measure the diameter at breast height (DBH), *i.e.*, 1.3 m, of all live, dead, standing, and fallen sample trees.

- On slopes, breast height is measured from the high side of the tree.
- Measure diameter to the nearest 0.1 cm.
- Hold the diameter tape tight, making no allowance for missing bark.
- If it is not possible to measure DBH accurately because of an obstruction or unsafe conditions, enter an estimate.

<u>Estimated Length</u> - If estimating length, enter to the nearest metre. Project objectives may allow for some lengths to be estimated in order to speed-up the field work. Use conventions as in Item 13. Note: If measuring length, the data entry program, VENUS, will calculate the length from the information in Item 13.
<u>Crown Class</u> - Assign a crown class designation to all standing live trees as follows:

- D = Dominant Trees with crown extending above the general level of the layer; somewhat taller than the codominant trees, and have well developed crowns, which may be somewhat crowded on the sides.
- C = Codominant Trees with crowns forming the general level of the crown canopy; crown is generally smaller than those of the dominant trees and usually more crowded on the sides.
- I = Intermediate Trees with crowns below, but extending into the general level of the crown canopy; crowns usually small and quite crowded on the sides.
- S = Suppressed Trees with crowns entirely below the general level of the crown canopy.

<u>Height to Live Crown</u> - For each live tree, measure height to live crown (effective portion of the live crown for growth) in metres. This is normally the height on the stem at which live branches occupy about three-quarters of the stem circumference. Enter negative one (-1) for trees with no “effective” crown (*e.g.*, only a few green branches).
<u>Crown condition (Crown)</u> - Using one of the classes in Table 6.1, of Tree Attributes for Wildlife, (p.9) rate the condition of the crown in relation to a normal live crown. Note: lower crown loss due to self-pruning is not counted as foliage or branch loss.
<u>Bark retention (Bark)</u> - Indicate the proportion of bark remaining on each tree, using the codes in Table 6.2, of Tree Attributes for Wildlife, (p.10).
<u>Wood condition (Wood)</u> - Classify the texture (soundness) of the wood for each tree, using the codes in Table 6.3, of Tree Attributes for Wildlife, (p.10).

Regime - Soil Nutrient Regime, Soil Moisture Regime (see FS882, GIF)

Soil Moisture Regime - Enter a code (0–8) for soil moisture regime (SMR) [see Site Description, Item 20 (p.9)].
Soil Nutrient Regime - Enter a code (A–F) for soil nutrient regime (SNR) [see Site Description, Item 21 (p.11)].

Simple CWD - Simple Coarse Woody Debris (see Wildlife Habitat Assessment Form, p.26)

The purpose of this section of the form is to provide for a quick assessment of total coarse woody debris volume and volume by decay classes following the methods developed by Taylor (1997). The detailed Coarse Woody Debris Form (Section 7) is used both to collect more quantitative data than that collected here and to collect more attributes. To complete this section of the form, set up a 30 m line transect as follows:
1. Determine plot center
2. Establish one 30 m (horizontal distance) line transect following a random azimuth from the plot center. It is important to measure the slope along the line and determine the slope distance required to produce a horizontal transect of 30 m. If significant slope changes occur along the line, more than one slope distance correction is required. 3. The slope distance factors in Table 4.1 can be used to calculate the required slope distance for a given slope. For example, if the slope is 35%, the slope distance factor is 0.944. The required slope distance is determined by dividing the horizontal distance by the slope distance factor, *i.e.*, 30 m / 0.944 = 31.78 m.
Sampled __ of 30 m Transect - Indicate the length of the line that was sampled. The form has room to record 22 pieces of CWD. If more than 22 pieces are encountered on a 30 m transect, discontinue the transect and record the number of metres that were sampled to reach 22 pieces. If the entire line was sampled, indicate that all 30 m were sampled.
Decay Class - Assign a decay class (1 to 5) based on the majority condition of each piece encountered along the transect. See Table 5.13, Wildlife Habitat Assessment, Item 31 (p.27) for descriptions of classes.
Diameter Class - Using the diameter class limits from Table 5.14, Wildlife Habitat Assessment, Item 32 (p.28) record the diameter class (Diam. class) at the point of intersection for each piece encountered along the transect.
Comments - Record observations of interest or importance to making wildlife interpretations.

Soil - Soil Drainage, Soil Texture, Coarse Fragments, Humus Form, Root Restricting Layer, Surficial Material, Geomorph Process (see FS882, GIF)

Drainage - Mineral Soils - Checkmark the box for the appropriate drainage class. Drainage describes the speed and extent at which water is removed from a mineral soil, in relation to supply [see Soil Description, Item 14 (p.21)].
Mineral Soil Texture - Determine soil texture in the rooting zone of the soil profile and tick the appropriate box [see Soil Description, Item 27 (p.40)].
Organic Soil Texture - If assessing an organic soil, determine the fabric of the surface tier (0-40 cm) and tick the appropriate box. Use the definitions of Of, Om, and Oh horizons to determine fibric, mesic and humic, respectively [see Soil Description, Item 16 (p.26)].
Humus Form - Examine the humus form profile and tick the appropriate box [see Soil Description, Item 7 (p.15), and Appendix 2.3 (p.57)].
Root Restricting Layer - Identify and record the type of root restricting layer, if present. Measure and record the depth in cm. from the ground surface (top of the upper-most soil horizon, including organic horizons) to this layer. Enter a letter code for type. [see Soil Description, Item 11 (p.20)].
Coarse Fragment Content - Estimate the percent coarse fragment (>2 mm diameter) volume in the rooting zone of the soil profile and tick the appropriate box for the range.
Surficial Material and Geomorphological Process - Two information fields are provided for recording surficial material and geomorphological process, respectively (Howes and Kenk 1997) (see [see Soil Description, Tables 2.5 (p.11) and 2.7 (p.13) and Figure 2.1 (p.10)). Up to three codes can be entered in each of these fields. Place qualifying descriptor codes (Table 2.8, p.14) in the appropriate field to the right of any other codes used in that field (superscript codes are no longer used). Code line 1 for the uppermost stratigraphic layer, and code line 2 for an underlying layer. For those wishing to use terrain subclasses and subtypes, refer to Howes and Kenk (1997).

Note:

Surveyors should place habitat plots to be representative of line/polygon features.
For gradient, minimum of one station at start of transect and one at endpoint.

Appendix E. Required Habitat Attributes by Taxon Group and Design Component.

Interpreting the Habitat Requirements Matrix - An Illustration

The following example is provided showing how to interpret the habitat requirements matrix.

A project team is planning to undertake a project surveying for bats using netting stations and they wish to find out how much habitat data they are required to collect at each net station. They consult Appendix E by looking under the Taxon Group, “Bats”, and the Design Component, “Net/Harp Station”. Reading across to the right, “X’s” are shown under each suite of habitat attributes that must be collected. For a net station, the required attributes are geographic coordinates, a broad ecosystem unit, ecosection, biogeoclimatic subzone, elevation, slope, aspect, mesoslope position, surface topography, structural stage, a list of dominant plant species, and estimates of the percent cover of tree, shrub, herb, and moss/lichen layers. If the station is in the forest, they have the additional requirement of having to complete an abbreviated wildlife tree plot.

If the same biologists, as part of their bat inventory discover a critical habitat feature, such as active hibernacula located in a tree, the level of habitat description required will increase. Describing a critical habitat feature for bats involves collecting the same data required for a netting station, plus a description of the Individual Wildlife Tree (for arboreal habitat features) and determination of both soil moisture and nutrient regime to correctly identify the Site Series. As well, depending on the objectives of the inventory, describing a critical habitat may also involve completing a detailed vegetation plot showing percent cover by species by vertical strata. Finally there may also be a specialized form as part of the CBCB bat manual, which is to be used for recording very specific information such the number of entrances and exits to the hibernacula and their dimensions. The need to complete this sort of form is indicated by the “X” under the “Spec Form” column.

Table E1. Key to Modifiers

Modifier	Restrictions
$\mathbf{X}^{A}$	Arboreal features only (*e.g.*, nest, cavity).
$\mathbf{X}^{E}$	Optional. Proper collection of these attributes will generally require specialized expertise (*e.g.*, a pedologist).
$\mathbf{X}^{F}$	Forested habitats only.
$\mathbf{X}^{O}$	Fossorial animals and features, and mineral licks only.
$\mathbf{X}^{R}$	Riparian habitats only.
$\mathbf{X}^{S}$	Selected species only.
$\mathbf{X}^{T}$	Non-lentic (terrestrial) habitats only.

Table E2. Key to Suites of Habitat Attributes.

Suite Name	Attributes included	Source of Attributes
Location	Geographic coordinates, Broad Ecosystem Unit, Ecosection, Biogeoclimatic Subzones (from map)	Geographic coordinates should be referenced to NAD83. Broad Ecosystem Units are outlined in the review draft, Standards for Broad Terrestrial Ecosystem Classification and Mapping for British Columbia: Classification and Correlation of the Broad Habitat Classes - electronic copies from ftp://wldux2.env.gov.bc.ca/pub/TEM/ (filename: beuapp3.doc)
Site Series	Site series as derived in field	Information on regional site identification is available in provincial Land Management Handbooks (Crown Publications).
Site Info	Elevation, Slope, Aspect, Mesoslope Position	Taken from FS882 - Site Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Topography	Surface Topography	Taken from FS882 - Site Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Structural Stage	Structural Stage	Taken from FS882 - Site Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Basic Veg	List of Dominant/ Indicator Vegetation Species (usually minimum 3/layer) and % Cover for Tree, Shrub, Forb and Moss/Lichen layers	Taken from FS882 - Vegetation Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Detailed Veg	Detailed % Cover of different vegetation species by vertical stratum	Taken from FS882 - Vegetation Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Wildlife Tree Plot	Abbreviated Tree Attributes for Wildlife (plot of trees) - Area, Min. DBH, No. of Trees, No. Alive/Dead, Avg. DBH, Avg. Length, Avg. Lichen Load Class	Taken from FS882 - Wildlife Habitat Assessment Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Individual Wildlife Tree	Attributes for an Individual Tree - Species, Stand/Fall, DBH, Estimated Length, Crown Class, Height to Live Crown, Crown Condition, Bark Retention, Wood Condition	Taken from FS882 - Tree Attributes for Wildlife Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Regime	Soil Nutrient Regime, Soil Moisture Regime	Taken from FS882 - Site Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Simple CWD	Simple Coarse Woody Debris	Taken from FS882 - Wildlife Habitat Assessment Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Surface Substrate	Surface Substrate	Taken from FS882 - Site Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/

Suite Name	Attributes included	Source of Attributes
Soil	Soil Drainage, Soil Texture, Coarse Fragments, Humus Form, Root Restricting Layer, Surficial Material, Geomorphic Process	Taken from FS882 - Soil Form; Ground Inspection Form - available from Crown Publications, Victoria (print); electronic copies from ftp://wldux2.env.gov.bc.ca/pub/deif/
Special Form	Specialized Habitat Form. Includes Nest Site Description form and/or any other form found within a CBCB manual.	Taken from CBCB manuals. Nest Site Description form is found in Species Inventory Fundamentals, No.1 [Forms].
Stream	Stream Site Card - Channel, Water, Cover, and Morphology sections	Taken from Reconnaissance Fish and Fish Habitat Inventory: Dataforms and User Notes available at: http://www.env.gov.bc.ca/fsh/ids/invent/

Table E3. Required Habitat Attributes for Species Inventory by Taxon and Design Component.

Taxon Group	**Design Component**	**Required Habitat Attributes**														
		Loc	Site Series	Site Info	Topo	Struct Stage	Basc Veg	Det Veg	Wild Tree Plot	Ind Wild Tree	Reg	Simpl CWD	Substr	Soil	Spec Form	Strm
BIRDS																
Bitterns & Rails	Call Playback Station	**X**		**X**	**X**	**X**	**X**									
	Fixed Width Transect	**X**		**X**	**X**	**X**	**X**									
	Nest	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]			**X**		**X**		**X**	
Colonial-Nesting Freshwater Birds	Aerial Survey	**X**														
	Study Area for Ground-based Survey	**X**					**X**									
	Boat Transect	**X**														
	Colony	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]		**X**		**X**			
	Nest within Described Colony									**X**[A]					**X**	
Nighthawks & Poorwills (Goatsuckers)	Point count	**X**		**X**	**X**	**X**	**X**									
	Nest	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]			**X**		**X**		**X**	

Taxon Group	**Design Component**	**Required Habitat Attributes**														
		Loc	Site Series	Site Info	Topo	Struct Stage	Basc Veg	Det Veg	Wild Tree Plot	Ind Wild Tree	Reg	Simpl CWD	Substr	Soil	Spec Form	Strm
Marbled Murrelet	Marine Aerial Fixed-width Transect	**X**														
	Marine Vessel Fixed-width Transect	**X**														
	Forest Survey Station	**X**	**X**	**X**		**X**	**X**								**X**	
	Nest	**X**	**X**	**X**		**X**	**X**	**X**[E]		**X**	**X**				**X**	
Raptors	Aerial Block	**X**														
	Encounter Transect	**X**														
	Call Playback Station	**X**		**X**	**X**	**X**	**X**		**X**[F]							
	Standwatch View	**X**		**X**		**X**										
	Nest	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**	**X**[F]			**X**	
Riverine Birds	Transect - Aerial or Marine Offshore Island	**X**														
	Transect - Land-based Marine Shoreline Survey	**X**														
	River Shoreline Transect	**X**														
	Transect - Territory Length Survey	**X**														
	Capture Location	**X**		**X**		**X**	**X**									
	Nest	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**		**X**		**X**	**X**[R]
Seabirds	Under development															

Taxon Group	**Design Component**	**Required Habitat Attributes**														
		Loc	Site Series	Site Info	Topo	Struct Stage	Basc Veg	Det Veg	Wild Tree Plot	Ind Wild Tree	Reg	Simpl CWD	Substr	Soil	Spec Form	Strm
Shorebirds	Boat Offshore Island Encounter Transect	**X**														
	Aerial Encounter Transect	**X**														
	Ground Count Station	**X**														
	At-Sea Transect	**X**														
	Transect Survey	**X**														
	Call Playback Station	**X**		**X**	**X**	**X**	**X**						**X**			
	Nest	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]		**X**[A]	**X**		**X**		**X**	
Songbirds	Encounter Transect	**X**														
	Point Count Station	**X**		**X**		**X**	**X**		**X**[F]							
	Spot Map	**X**	**X**[E]	**X**		**X**	**X**	**X**[E]	**X**[F]		**X**[E]					
	Nest	**X**	**X**	**X**		**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**		**X**		**X**	
Swallows & Swifts	Point Count Station	**X**		**X**		**X**	**X**		**X**[F]							
	Colony	**X**	**X**[E]	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]		**X**[E]		**X**[O]	X[EO]		
	Nest within Described Colony	**X**		**X**						**X**[A]					**X**	
	Nest (no colony)	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**		**X**[O]	X[EO]	**X**	
Upland Gamebirds	Point Count Station	**X**		**X**	**X**	**X**	**X**					**X**				
	Encounter Transect	**X**														
	Study Area/Grid - Territory Mapping	**X**	**X**[E]	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]		**X**[E]					
	Lek	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]		**X**					
	Nest	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]		**X**	**X**			**X**	
Waterfowl	Under development															

Taxon Group	**Design Component**	**Required Habitat Attributes**														
		Loc	Site Series	Site Info	Topo	Struct Stage	Basc Veg	Det Veg	Wild Tree Plot	Ind Wild Tree	Reg	Simpl CWD	Substr	Soil	Spec Form	Strm
Woodpeckers	Call Playback Station	**X**		**X**	**X**	**X**	**X**		**X**							
	Transect - Wildlife Tree/Sign Survey	**X**														
	Spot Mapping Area	**X**	**X**[E]	**X**	**X**	**X**	**X**	**X**[E]	**X**		**X**[E]					
	Nest	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**				**X**	
MAMMALS																
Bats	Net/Harp Station	**X**		**X**	**X**	**X**	**X**		**X**[F]							
	Detection Station	**X**		**X**	**X**	**X**	**X**		**X**[F]							
	Critical habitat feature (roost, hibernacula, etc)	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**				**X**	
Bears	Sign survey transect	**X**														
	Survey Area - Seasonal Concentration Survey	**X**														
	Hair snag station	**X**														
	Bear capture location	**X**														
	Telemetry location	**X**														
	Critical habitat features (den, etc.)	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**					
Beaver &	Ground transect	**X**														
Muskrat	Aerial transect	**X**														
	Critical habitat feature (colony, etc.)	**X**		**X**	**X**	**X**	**X**									**X**[R]
Hare &	Detection Transect	**X**														
Cottontails	Roadside Survey Route	**X**														
	Pellet Count Study Area	**X**		**X**	**X**	**X**	**X**	**X**[E]								
	Capture Grid/Station	**X**		**X**	**X**	**X**	**X**	**X**[E]								

Taxon Group	**Design Component**	**Required Habitat Attributes**														
		Loc	Site Series	Site Info	Topo	Struct Stage	Basc Veg	Det Veg	Wild Tree Plot	Ind Wild Tree	Reg	Simpl CWD	Substr	Soil	Spec Form	Strm
	Critical habitat feature (homesite, etc)	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]			**X**		**X**	**X**[EO]		
Marten & Weasels	Snow Tracking	**X**														
	Detection Station	**X**		**X**	**X**	**X**	**X**									
	Capture Station	**X**		**X**	**X**	**X**	**X**									
	Critical habitat feature (den, etc)	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**	**X**[F]				
Medium-Sized Territorial Carnivore	Snow Tracking transect	**X**														
	Detection Station	**X**		**X**	**X**	**X**	**X**									
	Hair Snag Station	**X**		**X**	**X**	**X**	**X**									
	Capture Station	**X**		**X**	**X**	**X**	**X**									
	Telemetry Location	**X**														
	Critical habitat feature (den, etc)	**X**	**X**	**X**	**X**	**X**[F]	**X**	**X**[E]	**X**[F]	**X**[A]	**X**	**X**[F]		**X**[E]		
Moles & Gopher	Study Area for Presence Survey	**X**														
	Capture Station/Line/Grid	**X**		**X**	**X**	**X**[F]	**X**									
	Critical habitat feature (encampment, etc)	**X**	**X**	**X**	**X**	**X**[F]	**X**				**X**		**X**	**X**[EO]		
Moutain Beaver, Woodrat & Porcupine	Physical Sign Search Area or Transect	**X**														
	Capture Station	**X**		**X**	**X**	**X**	**X**									
	Critical habitat feature (homesite)	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**	**X**[F]		X[EO]		
Otter & Mink	Under development															

Taxon Group	Design Component	Required Habitat Attributes														
		Loc	Site Series	Site Info	Topo	Struct Stage	Basc Veg	Det Veg	Wild Tree Plot	Ind Wild Tree	Reg	Simpl CWD	Substr	Soil	Spec Form	Strm
Pikas & Sciurids	Sign Search Area/Transect	**X**														
	Capture Grid/Transect/Station	**X**		**X**	**X**	**X**	**X**		**X**[F]				**X**			
	Critical habitat feature (colony, nest, etc.)	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]	**X**[A]	**X**	**X**[F]	**X**	X[EO]		
Raccoon, Opossum & Skunk	Under development															
Small Mammals	Capture Lines/Grids	**X**	**X**	**X**	**X**	**X**	**X**				**X**	**X**[F]	**X**			**X**[RS]
	[S] Water shrew surveys only															
Ungulates - Aerial Methods	Sample Units - All Surveys	**X**				**X**										
Ungulates - Ground Methods	Any transect/block	**X**														
	Pellet plot	**X**		**X**	**X**	**X**	**X**									
	Telemetry location	**X**														
	Total count area	**X**														
	Capture site	**X**														
	Critical habitat feature (critical range, etc)	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]	**X**[F]		**X**			X[EO]		
Wolf & Cougar	Any transect	**X**														
	Capture station	**X**		**X**		**X**										
	Capture site (no station)	**X**														
	Telemetry location	**X**														

Taxon Group	**Design Component**	**Required Habitat Attributes**														
		Loc	Site Series	Site Info	Topo	Struct Stage	Basc Veg	Det Veg	Wild Tree Plot	Ind Wild Tree	Reg	Simpl CWD	Substr	Soil	Spec Form	Strm
	Critical habitat feature (den, etc)	**X**	**X**	**X**	**X**	**X**	**X**	**X**^{E}			**X**			X^{EO}		
HERPTILES																
Lizards	Under development															
Plethodontid Salamanders	Time Constrained Search Unit	**X**		**X**	**X**	**X**	**X**					**X**	**X**			
	Study Area sampled with Quadrats			**X**	**X**	**X**	**X**					**X**	**X**			
	Transect	**X**		**X**	**X**	**X**	**X**					**X**	**X**			
	ACO / Pitfall Trapping Grid/Array/Station	**X**		**X**	**X**	**X**	**X**					**X**	**X**			
	Night driving Road Transect	**X**														
Pond Breeding Amphibians & Painted Turtle	Auditory Survey Station	**X**														
	Road Survey Transect	**X**														
	Time Constrained Search Area (adults or larvae)	**X**		**X**^{T}	**X**^{T}	**X**^{T}	**X**					**X**^{F}	**X**^{T}			
	Systematic Search Transect (adults or larvae)	**X**		**X**^{T}	**X**^{T}	**X**^{T}	**X**					**X**^{F}	**X**^{T}			
	Larval Dipnetting	**X**														
	Aquatic Trap Station	**X**														
	Terrestrial Trap Grid/Array/Station	**X**		**X**	**X**	**X**	**X**					**X**^{F}	**X**			
	Critical habitat feature (*e.g.*, permanent breeding site)	**X**	**X**	**X**^{T}	**X**^{T}	**X**^{T}	**X**				**X**		**X**			

Taxon Group	Design Component	Required Habitat Attributes														
		Loc	Site Series	Site Info	Topo	Struct Stage	Basc Veg	Det Veg	Wild Tree Plot	Ind Wild Tree	Reg	Simpl CWD	Substr	Soil	Spec Form	Strm
Snakes	Search Unit or Quadrat - Hand Collection	**X**		**X**	**X**	**X**	**X**					**X**[F]	**X**			
	Time Constrained Search Unit	**X**		**X**	**X**	**X**	**X**					**X**[F]	**X**			
	Search Transect	**X**		**X**	**X**	**X**	**X**					**X**[F]	**X**			
	Trap Grid/Station	**X**		**X**	**X**	**X**	**X**					**X**[F]	**X**			
	Road Survey Transect	**X**														
	Critical habitat feature (hibernacula, etc)	**X**	**X**	**X**	**X**	**X**	**X**	**X**[E]			**X**	**X**[F]	**X**		**X**	
Tailed frog &	Hand Collection Reach	**X**		**X**		**X**	**X**									**X**
Pacific Giant Salamander	Critical habitat feature (reach with active breeding)	**X**	**X**	**X**		**X**	**X**	**X**[E]			**X**					**X**
ARTHROPODS																
Terrestrial Arthropods	Habitat block in broad, reconnaissance-level survey	**X**	**X**[E]	**X**		**X**	**X**				**X**[E]					
	Habitat block in localized, intensive survey	**X**	**X**	**X**	**X**	**X**		**X**	**X**[F]	**X**[A]	**X**	**X**	**X**	**X**[EO]		
FUNGI																
Macrofungi	Study Area	**X**	**X**	**X**	**X**	**X**		**X**		**X**[A]	**X**			X[EO]		
PLANTS																
Rare Vascular Plant	Occurrence	**X**	**X**	**X**	**X**	**X**		**X**			**X**			X[EO]		

Appendix F. Current Listing of Broad Ecosystem Units for British Columbia (Spring 1998).

To actually assign a BEU to a landscape, it will be necessary to review the descriptions of each Broad Ecosystem Unit contained in the review draft, *Standards for Broad Terrestrial Ecosystem Classification and Mapping for British Columbia: Classification and Correlation of the Broad Habitat Classes used in 1:250 000 Ecological Mapping*. Copies of this document (filename beuapp3.doc) are available through a Ministry FTP site > ftp://wldux2.env.gov.bc.ca/pub/TEM/.

COASTAL FOREST ECOSYSTEMS
CD Coastal Douglas-fir
CG Coastal Western Redcedar - Grand Fir
CH Coastal Western Hemlock - Western Redcedar
CP Coastal Douglas-fir - Shore Pine
CS Coastal Western Hemlock - Subalpine Fir
CW Coastal Western Hemlock - Douglas-fir
DA Douglas-fir - Arbutus
FR Amabilis Fir - Western Hemlock
GO Garry Oak
HB Coastal Western Hemlock - Paper Birch
HL Coastal Western Hemlock - Lodgepole Pine
HS Western Hemlock - Sitka Spruce
MF Mountain Hemlock - Amabilis Fir
OA Garry Oak - Arbutus
YM Yellow-cedar - Mountain Hemlock Forest

SOUTHERN INTERIOR FOREST ECOSYSTEMS
AC Trembling Aspen Copse
DF Interior Douglas-fir Forest
DL Douglas-fir - Lodgepole Pine
DP Douglas-fir - Ponderosa Pine
EF Engelmann Spruce - Subalpine Fir Dry Forest
IG Interior Western Redcedar
IH Interior Western Hemlock - Douglas-fir
IS Interior Western Hemlock - White Spruce
PP Ponderosa Pine
RB Western Redcedar - Paper Birch
RD Western Redcedar - Douglas Fir
SD Spruce - Douglas-fir

CENTRAL AND NORTHERN FOREST ECOSYSTEMS
BA Boreal White Spruce - Trembling Aspen
BL Black Spruce - Lodgepole Pine
BP Boreal White Spruce - Lodgepole Pine
EW Subalpine fir - Mountain Hemlock Wet Forest
FB Subalpine Fir - Scrub Birch Forest
LP Lodgepole Pine
SA Subboreal White Spruce - Trembling Aspen
SB White Spruce - Paper Birch
SF White Spruce - Subalpine Fir
SL Subboreal White Spruce - Lodgepole Pine
TB Trembling Aspen - Balsam Poplar

FORESTED WETLAND AND RIPARIAN ECOSYSTEMS
BB Black Spruce Bog
CB Cedar - Shore Pine Bog
CR Black Cottonwood Riparian
ER Engelmann Spruce Riparian
PB Lodgepole/Shore Pine Bog
PR White Spruce - Balsam Poplar Riparian
RR Western Redcedar - Black Cottonwood Riparian
RS Western Redcedar Swamp
SK Spruce - Swamp
SR Sitka Spruce - Black Cottonwood Riparian
TF Tamarack Wetland
WG Hybrid White Spruce Bog Forest
WR White Spruce - Black Cottonwood Riparian
YB Yellow Cedar Bog Forest
YS Yellow-cedar Skunk Cabbage Swamp Forest

SUBALPINE PARKLAND AND KRUMMHOLZ ECOSYSTEMS
BK Subalpine Fir - Scrub Birch Krummholz
FP Engelmann Spruce - Subalpine Fir Parkland
HP Mountain Hemlock Parkland
WB Whitebark Pine Parkland
WP Subalpine fir - Mountain Hemlock Wet Parkland

SHRUB AND HERB DOMINATED ECOSYSTEMS
AB Antelope-brush Shrub / Grassland
AD Sitka Alder - Devil's Club Shrub
AV Avalanche Track
BS Bunchgrass Grassland
MS Montane Shrub / Grassland
SS Big Sagebrush Shrub / Grassland

NON-FORESTED WETLAND AND AQUATIC ECOSYSTEMS
BG Sphagnum Bog
ES Estuary
FE Sedge Fen
FS Fast Perennial Stream
IM Intertidal Marine
IN Intermittent Stream
LL Large Lake
LS Small Lake
ME Meadow
MR Marsh
OW Shallow Open Water
RE Reservoir
SC Shrub-Carr
SH Shrub Fen
SP Slow Perennial Stream
ST Subtidal Marine
SW Shrub Swamp
WL Wetland

NON-FORESTED SUBAPLINE AND ALPINE ECOSYSTEMS
AG Alpine Grassland
AH Alpine Heath
AM Alpine Meadow
AN Alpine Sparsely Vegetated
AS Alpine Shrubland
AT Alpine Tundra
AU Alpine Unvegetated
SG Subalpine Grassland
SM Subalpine Meadow
SU Subalpine Shrub / Grassland

SPARSELY VEGETATED ECOSYSTEMS
CL Cliff
GB Gravel Bar
GL Glacier
PO Lodgepole Pine Outcrop
RO Rock
TA Talus
UV Unvegetated

URBAN / INDUSTRIAL / AGRICULTURAL ECOSYSTEMS
CF Cultivated Field
MI Mine
OV Orchard / Vineyard
RM Reclaimed Mine
TC Transportation Corridor
TR Transmission Corridor
UR Urban

Appendix G. Review of current software for population analysis by J. Boulanger and Dr. C. Krebs (January 1998).

1.0 Guidelines for evaluation of computer packages

A large number of computer packages exist for the analysis of ecological data. There is a great degree of variation in packages in terms of user friendliness, and the degree of statistical knowledge needed for the proper use and interpretation of results. In this section, we will present a general review of each package we have mentioned, and will provide information on how to acquire packages, usually via the internet.

Our list of software packages is not exhaustive and other reviews of general statistical software should be consulted (Ellison 1992, Ellison 1993). We discuss here the most popular estimation packages that offer up to date estimation methods.

1.1 Explanation of software ratings

We evaluated packages in terms of two main criteria; ease of use, and the degree of statistical knowledge needed for use of the package. It is important to view each of these ratings separately. Ease of use corresponds to how easy it is to put data into the program, and generate results. The amount of documentation, user-friendliness, and explanation of results in the output will influence this rating. The degree of statistical knowledge corresponds to the complexity of statistics within the package, and how difficult it is to interpret results. Note that some of the newer methods are inherently complex, and a statistician will be required regardless of how user friendly the package may be. Examples of this are programs DISTANCE and MARK, which incorporate state of the art quantitative methods that will extend inference from traditional methods, but also involve complex statistical theory. Table G1 documents the upper and lower rating classes.

Biologists should not be discouraged by the more complex packages for they offer greater flexibility and power of statistical inference than traditional methods. It is worth the investment to consult a professional statistician for advice on optimal study design and data analysis especially when thousands of dollars are being spent on field sampling efforts!

Table G1. General rating of statistical software.

Rating	Ease of use	Statistical Knowledge
1	Easy to use, possibly windows based.	Much documentation, and easy to interpret output. Simple statistical output.
4	Difficult to use, requires programming and training.	Advance statistical knowledge needed for use and interpretation of output.

Many of these packages can be downloaded off the internet. There are a few sites which contain all the programs mentioned in this review (unless noted otherwise). The sites which contain software information and downloads are listed in Table G2. The number (No.) of site is cross referenced with Tables 3-7 to minimize search time for software downloads. These sites also contain additional programs, and information about population analysis. We strongly suggest that biologists use these sites for they contain up to date information and **free** software which is well worth the subscription price to an internet provider. An updated list of links to sites and software listed in tables 2-7 will be maintained on John Boulanger's Integrated Ecological Research web page (http://www.ecological.bc.ca).

Table G2. World wide web addresses for software downloads and information.

No.	Software site name and address	Comments
1	Wildlife Society Bulletin Software Contributions http://www.mp1-pwrc.usgs.gov/tws/contr.html#Contr	Source of software from manuscripts published in the Wildlife Society Bulletin
2	Software for power analysis http://www.zoology.ubc.ca/~krebs	Exhaustive list of all power analysis packages as covered in Thomas and Krebs (1997)
3	Gary White/ Colorado State University http://www.cnr.colostate.edu/~gwhite/software.html	Best source for CAPTURE, MARK, and NOREMARK
4	Patuxtent Software Archive http://www.mbr.nbs.gov/software.html	A wide variety of software for analysis. Best source for JOLLY and JOLLYAGE
5	Illinois Natural History Survey http://nhsbig.inhs.uiuc.edu/www/index.html	A variety of software cross referenced by analysis objective. Includes Krebs (1989) and KREBS/Windows programs
6	U.S. National Biological Survey http://www.im.nbs.gov/	Monitoring info and interactive study design planner for monitoring projects
7	Evan Cooch's MARK Page http://www.biol.sfu.ca/cmr/mark/index.html	Download MARK and very readable user's manual plus other information.

2.0 Power analysis packages

Thomas and Krebs (1997) provide a detailed discussion and testing of power analysis packages currently available. Most of these packages, as well as a document version of Thomas and Krebs (1997) is available for download from the "Software for Power Analysis" web page listed in Table G2. It is beyond the scope of this paper to list all the good power analysis packages so we refer people to the power analysis web page and Thomas and Krebs (1997).

We will list a few packages that have been repeatedly referenced in manual reviews, and were rated as excellent by Thomas and Krebs (1997). In particular, program MONITOR is an easy to use power analysis package for trend data and is available for free from the U.S. Biological Survey web page. For stand-alone sample size calculation for most statistical tests, NQUERY ADVISOR, PASS, POWER AND PRECISION, and STAT POWER were rated highly. These programs do cost money, and for biologists on a budget GPOWER offers a less friendly but free alternative. Finally, most standard statistical packages such as EXCEL, SAS, SYSTAT, SPLUS, and NCSS have some type of built in power analysis procedure, or have add-on procedures that are sometimes available as shareware. See Thomas and Krebs (1997) and the power analysis web page (Table G2) for information pertaining to specific packages, and for detailed reviews of the packages mentioned above. A MSWord version of Thomas and Krebs (1997) can be downloaded for free from the power analysis web page listed in Table G2.

3.0 Packages for analysis of relative abundance data

There are many packages available for analysis of trend data, and comparison of abundances in different areas. Many times the best package is the one that a person knows the best. Of all the packages available, a few newer ones stand out as being easy to use, and offer a wide variety of statistical options. However, flexibility and ease of use is many times a sliding scale. Packages that are programming-based such as SAS and SPLUS are infinitely flexible, but difficult to use whereas many of the newer windows based, menu driven packages such as EXCEL are easy to use but less flexible. There are many general statistics programs available. We suggest biologists consult Ellison (1992) for a more comprehensive review of statistical packages. We offer some general comments on some of the newer packages in Table G3.

Table G3. Comments on statistical packages for relative abundance

Name/Source	Ease of use	Comments
NCSS (Windows) NCSS Statistical Software,329 North 1000 East. Kaysville, UT 84037	1	• Easy to use menu driven program with good graphics • Less expensive then most competing programs. • Information and trial download available from: http://amsquare.com/ncss/
Krebs Ecological Methodology (W[5] *Exeter Software, 47 Route 25A, Setauket, New York*	2	• DOS-based ecological methods programs as described in Krebs (1989) and Krebs (1998). • Windows based version is now available. • Web Site http://www.exetersoftware.com/
Krebs for Windows[5](Win3.1) *John Bruzustowski, Dept. of Biology, University of Alberta, Edmonton, Alberta*	1	• A windows based version of some of Krebs (1989) programs as well as a few additional programs • Available for free download from Illinois Natural History Survey Site (Table G2).
RT (DOS) *WEST Inc., 2003 Central Ave., Cheyenne, WY 82001*	3	• Commercial program for randomization tests as described in Manly (1997) • 30 day trial version available from WEST-Inc. web site http://www.west-inc.com/west-inc.htm
SAS/JMP *SAS Campus Drive, Cary NC, 27513*	4	• SAS is infinitely flexible, and comprehensive but is also difficult to learn, complex, and expensive. • JMP is a windows based graphical package which is much easier to use but less comprehensive than SAS • Web information available from http:/www.sas.com

See Table G2 for web pages cross referenced with superscript numbers

4.0 Packages for absolute abundance estimates

4.1 Mark-recapture estimation software for open populations

Open population/survival rate analysis: The Jolly-Seber model is frequently used for population monitoring and survival rate estimation (JOLLY, JOLLYAGE, RDSURVIV). Many new powerful packages exist for survival rate estimation, and testing of biological hypothesis using generalized linear models or related methods. (MARK, POPAN). These new packages are the “way of the future” allowing robust inference for a variety of biological hypothesis regarding species survival, and associated demographic rates (Table G4).

Table G4. Mark-recapture estimation software for open populations

Name/Source	Ease of use	Statistical difficulty	Comments
JOLLY&JOLLYAGE (DOS)[4] *James Hines, Biological Resources Division, USGS, 11510 American Holly Dr. #201,Patuxent Wildlife Research Center, Laurel, MD 20708-4017.*	2	2	• Survival and population estimation using Jolly Seber models • Includes age-specific models, tests of model assumptions, and special case models • Easiest to use J.S/Open model package but also the least flexible in terms of models • Documentation: Pollock *et al.* (1990)
RDSURVIV (DOS)[4] *James Hines; address same as above*	3	4	• Further extends program JOLLY to allow estimates of survival when Pollock’s robust design is used • Documentation; Download web page from Patuxtent
MARK (Win95 or WinNT)[3] *Gary White/Dept. Fish and Wildl. Biology, Colorado State University, Ft. Collins, Colorado 80523*	1	4	• The most comprehensive, flexible program incorporating survival analysis, closed models, and band recovery models • Does not allow population size estimates • Windows based and interactive • Users manual in press (Cooch and White)
POPAN (DOS & Windows)[3] *Neil Arnanson & Carl Schwarz Department of & Statistics Simon Fraser University, Burnaby, BC Canada*	3	3	• Survival and population estimation • Less analysis options then MARK but does allow population estimates • Very flexible, uses a batch program language similar to SAS. • Manual and download available from web: http://www.cs.umanitoba.ca/~popan/
Jolly (DOS &Windows)[5] *Charles Krebs, Ecological Methods software*	2	1	• Basic Jolly-Seber estimates as detailed in Krebs (1989)

See Table G2 for web pages cross referenced with superscript numbers

4.2 Mark-recapture estimation software for closed populations

Closed population estimate packages are used for estimates of abundance or density. Closed models make the restrictive assumption of demographic and geographic closure during sampling but also can accommodate unequal capture probabilities between animals (CAPTURE) (White *et al*. 1982). Note that program MARK listed in Section 4.1 incorporates closed models as a method of testing hypothesis concerning the abundance of a population. Therefore, the use of MARK is recommended when closed population estimates are to be compared between populations or over time.

Table G5. Mark-recapture estimation software for closed populations

Name/Source	Ease of use	Statistical difficulty	Comments
CAPTURE (DOS)[3] *Gary White/Dept. Fish and Wildl. Biology, Colorado State University, Ft. Collins, Colorado 80523*	2	2	• Comprehensive-includes 11 estimation models • Includes useful simulation routine for evaluation of models and study design • Documentation: White *et al.* (1982) provides detailed discussion of M-R theory and use of CAPTURE-Available for *free* from web page
LINCOLN, SCHNABEL (DOS)[5] *Charles Krebs, Ecological Methods software*	2	1	• Basic Lincoln-Peterson and Schnabel-Schumacher estimates as detailed in Krebs (1989)

See Table G2 for web pages cross referenced with superscript numbers

4.3 Mark-resight estimation software

NOREMARK is specifically designed for mark-resight data from both open or closed populations. The Lincoln-Peterson estimator can also be used with mark-resight data in *limited* situations, but the use of NOREMARK is preferable.

Table G6. Mark-resight estimation software

Name/Source	Ease of use	Statistical difficulty	Comments
NOREMARK (DOS)[3] *Gary White/Dept. Fish and Wildl. Biology, Colorado State University, Ft. Collins, Colorado 80523*	1	2	• Comprehensive-includes 4 estimation models • Includes an easy to use simulation module routine for aid in sample size determination • Documentation: Users manual available with download from web page
LINCOLN (DOS)[5] *Charles Krebs, Ecological Methods software*	2	1	• Basic Lincoln Peterson estimates as detailed in Krebs (1989)

See Table G2 for web pages cross referenced with superscript numbers

4.4 Distance methods estimation software

The most comprehensive program for line transect, point count, and other distance estimates is program DISTANCE. This program incorporates state of the art modeling procedures allowing flexible and robust estimation for these methods. It is currently available in DOS and in a windows test version. Traditional transect methods are incorporated in TRANSECT. TRANSAN offers line transect models which use similar methods to DISTANCE.

Table G7. Distance methods estimation software

Name/Source	Ease of use	Statistical difficulty	Comments
DISTANCE (DOS&Win95)[3] *Jeff Laake, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle WA, 98115*	2	3	• Comprehensive, flexible and powerful. • Requires advanced statistical knowledge • Documentation: Buckland *et al.* (1993) (methods) and Laake *et al.*1993, (software). Laake *et al.* (1993) and software can be downloaded from DISTANCE web page http://nmml01.afsc.noaa.gov/distance/map.htm • New windows version 3.5
TRANSECT (DOS)[5] *Gary White/Dept. Fish and Wildl. Biology, Colorado State University, Ft. Collins, Colorado 80523*	2	3	• Uses a variety of estimators for line transect data • Not as flexible as DISTANCE • Methods sub-optimal as compared to DISTANCE
TRANSAN[1] *(DOS) Rick Routeledge, Department of Mathematics and Statistics, Simon Fraser University. Burnaby, British Columbia*	2	3	• Applies shape restrictions to detection curves using methods similar to DISTANCE as discussed in Routledge and Fyfe (1992). • Less comprehensive then DISTANCE but also less complex.

See Table G2 for web pages cross referenced with superscript numbers