Aerial-based Inventory Methods for Selected Ungulates: Bison, Mountain Goat, Mountain Sheep, Moose, Elk, Deer and Caribou

Standards for Components of British Columbia's Biodiversity No. 32

Prepared by
Ministry of Sustainable Resource Management
Terrestrial Information Branch
for the Terrestrial Ecosystems Task Force
Resources Inventory Committee

March 2002

Version 2.0

Published by the
Resources Inventory Committee

National Library of Canada Cataloguing in Publication Data

Main entry under title:

Aerial-based inventory methods for selected ungulates
[electronic resource] – Version 2.0

ISBN 0-7726-4704-6

1. Ungulates - British Columbia. 2. Mammal populations - British Columbia. 3. Aerial photographs in wildlife management - British Columbia. 4. Ecological surveys – British Columbia – Methodology. I. British Columbia. Ministry of Sustainable Resource Management. Terrestrial Information Branch. II. Resources Inventory Committee (Canada). Terrestrial Ecosystems Task Force. Elements Working Group.

QL737.U4A37 2002 333.95'9611'09711 2002-960022-7

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Preface

This manual presents standard methods for inventory of selected ungulates in British Columbia at three levels of inventory intensity: presence/not detected (possible), relative abundance, and absolute abundance. The manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity. Version 2.0 of this ungulate manual has undergone only minor revisions from version 1.0. These include formatting upgrades and the addition of new references to a moose sightability model developed in British Columbia.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series, which present standard protocols designed specifically for group of species with similar inventory requirements. The series includes an introductory manual (Species Inventory Fundamentals No. 1) which describes the history and objectives of RIC, and outlines the general process of conducting a wildlife inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The Species Inventory Fundamentals manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in inventories, which involve either of these activities.

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

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve 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:

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Acknowledgements

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

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

For further information about the Resources Inventory Committee and its various Task Forces, please access the Resources Inventory Committee Website at: http://www.for.gov.bc.ca/ric.

Terrestrial Ecosystems Task Force

All decisions regarding protocols are the responsibility of the Resources Inventory Committee. Background information and protocols presented in this version are based on substantial contributions from Ian Hatter. In addition, Keith Simpson, Dave Hatler, Johan Stroman, Ian Hatter and John Kelsall contributed to an earlier unpublished draft, '*Aerial Inventory of Large Mammals in British Columbia'* which was funded by the B.C. Corporate Resources Inventory Initiative (CRII) in March 1993. This version of the manual was edited by James Quayle.

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1. INTRODUCTION

As the traditional group of "game" species, wild ungulates have long been a primary focus for wildlife managers and researchers. Development of survey techniques for these species dates back to the beginning of modern wildlife management, and a tremendous volume of literature has been produced on the subject in the last century. From a techniques standpoint, survey methods for ungulates have evolved into two broad categories: aerial methods and ground-based methods. The purpose of this manual is to provide wildlife biologists in British Columbia with a guide for selecting and using the most appropriate aerial based survey techniques. The species considered here are the native ungulates that occur in British Columbia: bison (*Bison bison*), mountain goat (*Oreamnos americanus*), mountain sheep (*Ovis canadensis, Ovis dalli*), moose (*Alces alces*), elk (*Cervus elaphus*), mule and black-tailed deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and caribou (*Rangifer tarandus*).

Inventory information is essential for informed management and effective conservation of ungulates. The inventory protocols defined here involve the use of aircraft, and range from reconnaissance (presence/not detected (possible)) surveys to locate and delineate populations, through the gathering of information on population numbers, and age and sex composition. Inventories may be used to survey populations repeatedly to show trends over time (relative or absolute abundance) or gain detailed information on numbers or density at one point in time (absolute abundance). Elk, moose, caribou, mountain sheep, mountain goat, and bison can be assessed by well designed aerial surveys. Mule and white-tailed deer can be successfully inventoried only in certain habitats or under certain conditions. Black-tailed deer, which occupy dense coastal habitats, can generally not be inventoried adequately by aerial surveys.

Several comprehensive ungulate aerial survey manuals exist for specific techniques and species, e.g., Norton-Griffith (1978), Oswald (1982), Gasaway *et al.* (1986) and Unsworth *et al*. (1994). It is not our intention to re-state those documents, but only to indicate where their use is appropriate in British Columbia. However, the reader is encouraged to become familiar with these documents, as well as the other literature cited.

2. INVENTORY GROUP

Numerous publications on the general biology and ecology, distribution, movements and habitat use of ungulates are available. The mammalian species notes (American Society of Mammalogy) provide an excellent summary on the general biology and ecology of ungulates. Information pertaining to ungulate distribution, movements and habitat use in British Columbia are available in the Preliminary Species Management Plan series for British Columbia, published by the B.C. Ministry of Environment, Lands and Parks. Specific details on species ecology, relevant to the survey protocols, are outlined in Section 4.

Standardized protocols to inventory ungulates in the various biogeoclimatic zones of British Columbia are highlighted in Table 1. Detailed information on these protocols is described in the following sections. The species-specific guidelines (Section 4) provide additional information on ungulate ecology, and describe how such information may be accommodated into an inventory design.

Table 1. Recommended aerial survey techniques and timing for classification and population estimates of ungulates in different biogeoclimatic zones of British Columbia. Ground surveys are recommended ($_g$) for some species where aerial surveys are not possible.

		BIOGEOCLIMATIC ZONES													
SPECIES	**Inventory Level (Month)**	**CDF**	**CWH**	**MH**	**ICH**	**BG**	**PP**	**IDF**	**MS**	**ESSF**	**SBS**	**SBPS**	**BWBS**	**SWB**	**AT**
BISON	Popn & Comp (Jan-Mar)	-	-	-	-	-	-	-	-	-	-	-	-	TC	-
MOUNTAIN GOAT	Comp (July)	-	TC	TC	TC	-	-	TC	TC	TC	-	-	TC	TC	TC
	Popn (Aug-Nov)	-	TC	TC	TC	-	-	TC	TC	TC	-	-	TC	TC	TC
MOUNTAIN SHEEP	Comp (Nov-Dec)	-	-	-	-	TC_g	TC_g	TC_g	TC_g	-	-	-	TC	TC	TC
	Popn (Jan-Feb)		-	-	-	-	-	TC	TC	TC	TC	-	-	TC	TC
MOOSE	Comp (Nov-Dec)	-	-	-	-	-	-	SB	SB	-	SB	SB	ET	ET	-
	Popn (all areas Jan-Feb)	-	-	-	-	-	-	SB	SB	-	SB	SB	SB	SB	-
	(Dec-Jan)	-	-	-	SB	-	-	-	-	-	-	-	-	-	-
	(level terrain Jan-Feb)	-	-	-	-	-	-	-	-	-	-	-	ST	ST	-
ELK	Popn & Comp (Jan-Mar)	-	-	-	-	-	SB	SB	SB	-	-	-	SB	SB	-
	Popn (Jan-Mar)	-	-	-	TC	-	-	-	-	-	-	-	-	-	-
DEER	Recruitment (Apr-May)	ET_g	ET_g	-	ET_g	ET_g	ET_g	ET_g	-	-	-	-	ET_g	-	-
	Popn (Jan-Feb)	-	-	-	-	-	*	*	-	-	-	-	SB	-	-
	Popn (Apr-May)	-	-	-	-	*	-	-	-	-	-	-	-	-	-
NORTHERN CARIBOU	Popn & Comp (Oct-Nov)	-	-	-	-	-	-	-	-	SB	-	-	SB	SB	SB
	Comp (Oct1-14) Rainbow Mt	-	-	-	-	-	-	-	SB	SB	-	-	-	-	
	Popn (Jan-Mar) (Rainbow Mt)	-	-	-	-	-	-	-	SB	SB	-	-	-	-	SB
MOUNTAIN CARIBOU	Popn & Comp (Feb-Apr 15)	-	-	-	-	-	-	-	-	TC	-	-	-	-	-

Inventory Level: Popn - population (to locate and delineate), Comp - composition (age and sex)

Aerial techniques: TC - total count (stratified when possible), SB - stratified random block, FT - fixed-width transect, ET - encounter transect, HS - aerial search of population concentrations or "hot spots".

Ground techniques: ET_g - encounter transect, TC_g - total count, MR_g - mark and recapture of radio-collared bears. * SB may be possible in localized areas.

3. PROTOCOLS

3.1 General Considerations for Inventory

3.1.1 Inventory objectives

The most important step in a the inventory process is to define the objectives clearly and precisely in order to determine the staff, level of effort, and budget required. To meet the desired objectives, adequate resources must be available. While a multitude of survey objectives are possible, they may be generalized as objectives to estimate population distribution (presence/not detected (possible)), relative or absolute abundance, or herd composition.

Because habitat affinities and optimal survey times vary between species, it is rarely advisable to attempt to survey more than one ungulate species at a time. Therefore, to obtain valid results, sufficient funds should be allocated to inventory different species and their particular habitats separately. Exceptions are presence/not detected (possible) surveys (also called reconnaissance or distribution surveys), where more than one species may be inventoried simultaneously.

In some cases, it may be possible to plan contingency surveys if the primary objective is unattainable due to unexpected problems with logistics, weather, or animal behaviour. In any case, surveys should not be conducted under unsuitable conditions. Heroic perseverance in poor weather puts lives, and the quality of data being gathered, at risk.

3.1.2 Selecting the survey area

Once survey objectives have been established the next step in inventory is to define the area to be surveyed.

Presence/not detected (possible) surveys (also called reconnaissance or distribution surveys), are usually area-based. A reconnaissance survey might cover one or more administrative management units, one or more watersheds, the area described by one or more Universal Transverse Mercator (UTM) grids, or a relatively small study area defined by a proposed industrial development. In the latter case, where an impact assessment is the primary objective, the survey area should be large enough so that the proposed development can be assessed in perspective. For example, the presence of animals in a valley slated for development may be more meaningful if it is known that there are, or are not, animals in adjacent valleys.

The boundaries for abundance and composition surveys are often arbitrary, directed to areas as large as management units, regions or ecoprovinces, or as small as some specified portion of winter ranges (e.g., a portion involving a habitat enhancement project). In such cases, the composition data may serve as an indicator or index of local population performance.

The ideal survey boundary, however, is one that encloses a natural population, or discrete, contiguous group, so that changes in numbers can be distinguished from changes in distribution. In most areas, sub-populations, which are discrete during the period of the survey can be defined. Caughley (1977:5) provides an illustration of the effect of imposing various size study areas on a hypothetical population. Potential for animal movement across study area boundaries is reduced as the size of the area is increased.

For population surveys referable to particular management areas or parks, it is important to consider the boundaries of the natural population first. Inventories based on administrative boundaries usually risk missing an important part of the population and therefore may seriously bias the results. This is because the resulting population estimates could vary considerably from survey to survey, simply as a result of animals moving in and out of the area. Management unit boundaries have been used for surveys to relate inventory data to harvest data. However, for reasons stated above, management unit boundaries are usually unsuitable for defining survey area boundaries. If a survey boundary falls out of one's area of jurisdiction, it may be possible to call on other agencies or interests to assist in funding the inventory.

Defining population boundaries requires knowledge of the target animal's annual and seasonal ranges, as well as physical limiting factors such as snow depth, elevation, terrain, or habitat type. The distribution of many ungulates is most restricted in winter, and the entire population may be enclosed within a small survey area. Major physiographic barriers such as large lakes, rivers, or rugged mountain ranges can usually be used as boundaries for populations.

There are a variety of potential sources of information to help determine the annual or seasonal distribution of a population intended for study. Review the results of any prior research or inventory of an area, particularly if radio tracking or visual marking was involved. Talk to the people who conducted the studies. Local naturalists, trappers, guides or hunters may also be able to provide useful information.

Mark the limits of distribution, and areas of concentration, of the target population on topographic maps, preferably at a scale of 1:250,000. Where available, 1:100,000 or 1:50,000 scale maps can provide more detail. Biophysical maps and 1:250,000 Canada Land Inventory ungulate maps may provide useful information about distribution patterns. For poorly known populations, it may be possible to predict areas of concentration based on topography, vegetation, and normal snow depths. Features such as elevation, slope, and aspect, may also be used to help define the probable limits of population distribution.

Provincial Ministry of Forestry and Ministry of Sustainable Resource Management offices may have local vegetation or habitat maps available, and information on populations.

Ultimately, survey boundaries should reflect objectives, animal distribution, and available budget. After existing information is assessed, reconnaissance flights over the survey area should be thorough enough to confirm what is known or suspected, and to fill in significant gaps in the needed preliminary information.

3.1.3 Sample units

It is almost always advisable to subdivide a survey area into sampling units (e.g., blocks, quadrats, transects), preferably with boundaries that are clearly recognizable from the air. For small blocks, visible boundaries such as roads, lakes, creeks, rivers, clearings and other topographic features may be used. Preferably, however, sample units should be bounded by natural features such as rivers, steep ridges or highways that would minimize short-term movements of animals between units. Selecting boundaries where animals rarely occur will minimize decisions regarding whether animals are inside or outside a sample unit. Vegetation edges should not be used since animals frequently cross between openings and adjacent cover.

For reconnaissance and composition surveys, the sampling unit approach facilitates descriptions and comparisons of animal distribution within or between surveys, and for portions of the study area. Search times for each sampling unit can be estimated to enable preplanning of the use of aircraft time and logistics. Breaks between unit searches provide convenient refueling and rest stops.

For abundance surveys involving sampling, sample units are an essential part of the survey design. Blocks are defined by topographic features and vary in size and shape while quadrats are equal in size and shape. Quadrats should only be considered for use in level homogenous terrain with GPS (NAD83) navigation equipment, to ensure accurate boundary identification (see section 3.1.8). Surveys of blocks based on recognizable topographic features may also incorporate use of navigation equipment. Blocks are recommended for sampling units in the rugged terrain most common in British Columbia. Some knowledge of the target species spatial pattern is useful for determining the appropriate sample unit size and survey methods.

A number of factors will determine appropriate sampling unit size. The extent of daily and weekly movements of animals is an important consideration. If units are too small, animals will readily move between them, and double or under-counting may occur. If units are too large, observer fatigue will affect accuracy. Usually, the search time for a sample unit should be about one hour. Because search intensity may range from 1 to 5 minutes per km^2, sample units should be from 10 to 30 km^2. The number of animals encountered, and the extent of vegetation cover, increases the search time for a given area. Large units (30 km^2) can be used in open terrain but smaller units (10 km^2) are better where cover requires more intensive searches and/or animal densities are higher. A major drawback of small sampling units for low-density populations is the possibility of zero counts, which violate some of the statistical assumptions of the data analysis.

3.1.4 Stratification

The precision of a population estimate can be improved by careful stratification of sampling units before the survey. This involves stratifying the units into categories of expected animal numbers or density, based on interpretation of existing information. This may include personal knowledge of the area, results of a reconnaissance survey, or results of previous stratified surveys.

The quality of stratified random block surveys depends on the accuracy of stratification. Initial guesses are dependent on the experience of the biologist in judging animal numbers based on all available information. Those guesses are refined with a reconnaissance (pre-stratification) survey where each unit is viewed and judged on the basis of animals or tracks seen, and on physical characteristics such as terrain, snow depth, and vegetation (Gasaway *et al*. 1986; Unsworth *et al*. 1994). The accuracy of the preliminary stratification will be confirmed, or refuted, when the sample units are surveyed.

Reconnaissance surveys to define strata should be done shortly before intensive surveys of the sampling units, because strata designations may change quickly with weather conditions or animal movements. Reconnaissance flights are usually done effectively using fixed-wing aircraft. When stratifying blocks, fly one pass over each block to count animals and assess track abundance. The expected numbers of animals per sample unit in each stratum will vary with study areas and size of sampling units.

Stratified surveys can save time and money compared with unstratified surveys. A well-stratified survey imparts greater confidence in the estimates for sample blocks, which are not counted. When done well, fewer sample units can be surveyed in shorter time and at lower cost than an unstratified survey with the same or better precision. Section 3.6.2 discusses optimal allocation of sampling effort within strata for high precision. Refer to Gasaway *et al.* (1986:12-13) for further details on stratification.

3.1.5 Survey timing

Survey timing will be constrained by overall objectives. For instance, to provide data on ungulate occurrence in early summer for a particular ridge slated for development, surveys are required in early summer. Likewise, a requirement for data on caribou calving and early survival can only be satisfied by conducting a survey shortly after calving. However, for objectives related to measuring population size and structure, the appropriate time is often in winter when ungulates are most easily sighted, restricted in distribution, and sex-age composition most accurately represented. Summer surveys are appropriate for white animals (e.g., mountain goats and Dall's sheep) which are difficult to see against snow. Spring surveys may be more appropriate for deer.

Selection of the best time for a survey is based on predictable seasonal patterns of distribution and behaviour, which can be modified by varying local or climatic conditions. Table 2 summarizes the optimal times for surveys to estimate composition or population size for each species and biogeoclimatic zone in British Columbia. The suggested timing for each species in portions of the province is discussed more fully in Section 4.

Within the optimum time frame for a survey, it is important to maintain some flexibility in scheduling, to have staff and funds available, and be ready to move when weather is favourable. A survey pre-scheduled into a narrow time slot, to accommodate personal schedules, risks being adversely affected by weather or other unpredictable factors.

Table 2. Recommended timing for aerial surveys in British Columbia by objective and biogeoclimatic zone.

Species	Biogeoclimatic Zone[1]	Survey Objective[2]	Survey Method[3]	Survey Timing
Bison	SWB	P, A, C,	TC	Jan.-Mar
Mountain Goat	All	P, C	TC	July
	MH, BWBS, SWB, AT	P, C	TC	Aug - Sept
	MS, ESSF, SBPS	P, C	TC	Sep - Oct
	CWH, ICH, IDF	P, C	TC	Oct - Nov
Mountain Sheep	BG, IDF, MS, PP	P, A, C	TC	Jan - Feb
	ESSF, BWBS, SWB, AT	P, A, C	TC	Jan - Feb
	BWBS, SWB, AT	C	TC	Nov - Dec
Moose	IDF, MS, SBPS	C	SB	Nov - Dec
	IDF, MS, SBPS	P, A, C	SB	Jan - Feb
	ICH	P, A, C	SB	Dec - Jan
	SBS, SWB	C	SB	Nov - Dec
	BWBS, SWB	C	ET	Nov - Dec
	SBS, BWBS	P, A, C	SB	Jan - Feb
	SBS, BWBS, SWB	P, A, C	FT	Jan - Feb
Elk	SWB, BWBS	P, A, C	SB	Jan - Mar
	IDF, MS, PP	P, A, C	SB	Jan - Mar
	ICH	P, C	TC	Jan - Mar
Mule Deer	BWBS	P, A, C	SB	Jan - Feb
	BG (localized areas)	P, A, C	SB	Apr - May
	PP, IDF (localized areas)	P, A, C	SB	Jan - Feb
Northern Caribou	ESSF, BWBS, SWB, AT	P, A, C	SB	Oct - Nov
	MS (Rainbow Mt.)	P, C	SB	Oct 1- 14
	ESSF, MS, AT (Rainbow Mt)	P, A, C	SB	Jan - Mar
Mountain Caribou	MS, ESSF	P, A, C	TC	Feb - Apr

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[1] For biogeoclimatic zone code definitions see Appendix A.

[2] P=presence/not detected (distribution), A=abundance (population estimate); this is absolute abundance if correction is made for sightability bias, and relative abundance if no correction is made, C=sex/age composition.

[3] TC=total count, SB=stratified random block, ET=encounter transect, FT=fixed-width transect, HS='hot spots' or searches in concentration areas.

3.1.6 Personnel

An experienced professional biologist should undertake the design, logistic planning, and data analysis for inventories. When necessary, specialists or persons with additional experience, should be consulted to save time, money, and frustration. Prior to initiating major inventory surveys, a short workshop with inventory experts present, may be useful to update inexperienced personnel on survey procedures and requirements. Standardizing as many controllable factors as possible must be emphasized to make the surveys repeatable in the future.

Window space, aircraft safety, and the availability of competent personnel will dictate the number of observers used in an aircraft. Aerial surveys require at least three, and preferably four, experienced observers per aircraft, including the pilot. The person sitting beside the pilot is responsible for navigation, identification of survey unit boundaries, placing animal locations (group numbers) on a map, spotting and classifying. The observer behind the navigator should spot and record classification and group size data opposite the group number. The observer behind the pilot spots and classifies only.

When choosing the number of observers for a survey, aircraft performance and safety are factors in the decision. Hovering required to classify animals is more difficult and, in turbulent mountain flying conditions, safety margins are reduced. For high elevation surveys in rugged terrain where animals are highly visible, a fourth observer may be more of a liability rather than an asset. If a fourth observer is deemed to be necessary, an alternative is to use a more powerful aircraft.

To the extent possible, survey personnel should have experience and demonstrated ability with the methods involved and with the target species. Two qualified observers should be on flights where a trainee is included. Although experienced pilots may cover their side of the aircraft, it is recommended that the trainee sit behind an experienced observer. The pilot's primary responsibility is to fly safely and follow the navigator's directions, but may assist in spotting as well.

Surveying from an aircraft may cause nausea, particularly if search patterns are circular, or if the air is turbulent. Nausea makes it difficult to concentrate, to effectively sight animals and to record data. It may also put observers to sleep. The use of Gravol, accupressure straps, or other remedies is recommended for observers prone to motion sickness. Some observers report that Gravol does not affect their spotting ability, while others find it causes disorientation and drowsiness. Thus, it is preferable to have a navigator who is familiar with the area and does not suffer motion sickness.

3.1.7 Pilots and aircraft

Aerial surveys require low level flying, often in rugged terrain where margins for error are small. Some survey methods are safer than others are. Straight and level transect surveys are much safer than quadrat or block counts, where circling and low speed turns are frequent. The two primary attributes of good survey pilots are interest and experience. Clearly, a pilot with an interest in wildlife will invest more in the job at hand. Experience includes general flying experience, preferably in the survey region or ecoprovince, and wildlife survey experience. Pilots should have 1000 hours of general flying experience. Pilots should also be available for the full survey period. Grigg (1979) provides a useful summary of safety considerations for aerial survey flying.

Pilots must be competent, cautious, and able to recognize and avoid potential hazards such as wind shear and down draughts on mountain ridges. Aircraft may stall when flying downwind at slow speeds, and there is little opportunity to recover when 30 m above the trees. Pilots should advise the navigator when something requested is risky. Skilled pilots whom smoothly coordinate bank and turn rates, may also reduce the chances of motion sickness.

Pilots experienced and skilled in spotting and herding animals are a great asset. Aerial maneuvers required to hold or move animals, so they are seen to best advantage by expert observers, requires some anticipation by the pilot to be most effective. Pilots with those skills should be sought for aerial survey work. Many pilots must be reminded to position aircraft so that the observers, not the pilot, have the best view.

There are several considerations when choosing and using aircraft. Fixed-wing aircraft should be high wing monoplanes. Consider the size and power of the aircraft for the load requirements. What are the cruising and stall speeds? How will it perform on the airstrips that are available, and will those airstrips be functional if it rains or snows? What is the cost per hour? What type of fuel is required and where is it available? Will you need to place drum fuel at refueling sites, and if so do you need a pump and filter? Also consider if you will require private airstrips as refueling points.

The specifications and performance data for some aircraft available in British Columbia are summarized in Table 3. Some additional points are worth noting.

Bell Jet Ranger helicopters are widely available. They offer good viewing from forward and rear seats, particularly when rear bubble windows are installed. They can carry up to four passengers plus the pilot. As with all aircraft, remember that hovering or slow flight requires more fuel per hour than cruising. With full fuel tanks the lifting capacity is about 1000 lb., the equivalent of five people.

Hughes 500 helicopters are not as commonly available as Jet Rangers are. They are more maneuverable and safer than Jet Rangers, due to their shorter 4-blade rotors, and they tend to disturb animals less. Fuel capacities, passenger space, and charter costs are similar to Jet Rangers. They are useful for capture and marking, but less effective for aerial surveys due to viewing constraints.

The Hiller 12E helicopter is a turbo charged piston driven machine, which carries a passenger on either side of the pilot. They offer excellent visibility since the entire front and sides of the machine are a transparent bubble. They are less maneuverable than the Bell or Hughes. While extensively used in the United States, they are relatively rare in British Columbia. They are also more tiring to fly in, due to noise and vibration.

The Bell 47 G, not shown on Table 3, is also piston driven, and may or may not be turbo charged. Without turbo chargers, they are not powerful enough for aerial surveys. They seat two passengers to the left of the pilot and offer excellent visibility through a bubble front. Their fuel capacity of 45 gallons allows 2.5 hours flying. Their lifting capacity is about 1200 lb. The cruising speed is 80 mph.

The Jet Ranger is usually the helicopter of choice because of availability, comfort, and visibility. Such turbine driven machines have better safety records than piston driven helicopters. Turbines are more reliable and their extra power can be used to pull out of unexpected dangerous situations. However, piston driven helicopters cost much less, and for extensive surveys in appropriate terrain, the use of cheaper machines can greatly increase survey coverage.

The Cessna 172 is a high wing, four passenger aircraft, commonly available in British Columbia. Visibility is good from the side windows but not over the front. Minimum air speeds down to 60 mph are possible. Slow flight capability allows great maneuverability, which is particularly important for flying in narrow mountain valleys and for telemetry work.

Cessna 180, 182, 185, and 206 are larger than the 172, and have greater power and range. Some have retractable landing gear. Their stalling speed is about 80 mph, so turning in narrow valleys requires steeper banking, and exerts more G forces than in the 172. That characteristic may substantially increase the chance of motion sickness, particularly for rear seat passengers.

The Supercub holds the pilot and one observer in tandem. They are often used in Alaska and the Yukon. The PA-12 is roomier and holds two observers. Both have 150 HP engines unless modified, and they use six to seven gallons of fuel per hour. They may run on regular automobile, as well as aviation gasoline. They have low stalling speeds, short take-off, high maneuverability, good visibility, and are economical. They are especially good for reconnaissance surveys and surveys over difficult terrain. Few are available commercially in British Columbia, but many are privately owned.

The Heliocourier, not shown on Table 3, is comparable to a small Cessna in carrying capacity. It is considered an excellent short take off and landing aircraft. Popular in Alaska and the Yukon, it is rarely available commercially in British Columbia.

As noted previously, fixed-wing aircraft are most suitable for reconnaissance-type surveys. They are commonly used for pre-stratified surveys.

Table 3. Specifications and performance data for recommended aerial survey aircraft in British Columbia.

Type of Aircraft	**Payload**[4] (lb.)	**Fuel** (imperial gallons)	**Cruise Speed** (mph)	**Range** (hr/tank)	**Stall Speed** (mph)	**1993 Rates** ($/hr)
Fixed-wing						
Cessna 172	581	51	138	4	58	135
Cessna 180	852	73	164	4	62	180
Cessna 182	827	73	180	5	62	180
Cessna 185	1,158	70	169	3	64	200
Cessna 206	1,142	73	169	3	71	225
Maule (Supercub)	522	52	154	3	62	n/a
Beaver	1,500	79	100	4	60	380
Single Otter	2,400	200	130	4	55	656
Twin Otter	2,502	358	155	3	74	1154
Helicopter						
Hiller 12E4	748	72	70	2	n/a	350
Bell JetRanger3	985	74	132	3	n/a	700
Bell LongRanger3	1,095	89	129	2	n/a	875
Hughes 500D	960	52	164	2	n/a	700

3.1.8 Navigation and use of GPS equipment

The forward observer or navigator is responsible for directing the pilot, and defining search area boundaries for the other observers. The navigator records the flight lines, group locations, and keeps the pilot and observers apprised of the intended search pattern. Accurate in-flight mapping of flight lines and observations is required to insure that all habitat is covered, while avoiding overlapping coverage and double-counts of animals.

Use of electronic navigation equipment, if available, can greatly reduce the time and attention required to accurately map flight lines and animal locations. Flight time can be decreased up to 24% using LORAN-C (Long Range Navigation), rather than conventional navigation with map

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[4] Payload (lb) is the weight of the load that can be carried with full fuel.

references (Boer *et al*. 1989). Information on group size, classification, and habitat must still be recorded separately.

Two radio signal navigation systems are available in British Columbia. LORAN-C has ground based transmitters and provides coverage south of Highway 16 in British Columbia. GPS (Global Positioning System) is satellite based and provides coverage worldwide (use NAD83). All 21 satellites have been operational as of December 1993. Both systems operate by measuring the time that pulsed radio signals transmitted from known locations take to reach your receiving unit. Some aircraft-based GPS systems also detect and use LORAN-C signals to enhance their accuracy.

GPS systems were designed for installation in aircraft, but portable units for ground based surveys are also available. Portable units do not have LORAN-C capability. All systems provide standard navigation functions including continuous position monitoring; recognition of departure, destination or other waypoints using latitude/longitude or UTM (Universal Transverse Mercator) coordinates; and course correction, ground speed and time/distance to destination. Depending on memory capacity, aircraft positions (flight-lines) can be continuously recorded and numbered waypoints (animal locations) can be entered by pushing a button as you pass over them. Information recorded can then be down-loaded to a personal computer using the serial port for use with GIS or other software systems.

Navigation computers, which interface with GPS units are also available, and can be used to define search areas, and lay out grid lines. The on-board computer and display allows continuous tracking of aircraft position relative to predetermined grid lines, and recording of survey information in ASCII files on 3.5" disks.

Standard GPS receivers have the capability of recording locations to within 15 m. However, the American military, which owns the satellite system, has intentionally degraded the accuracy to 100 m (328 ft) for security reasons. Where LORAN-C is available, 15 m (49 ft) accuracy can be attained, but its accuracy can be affected by mountainous topography and radio signal noise. The accuracy of navigation systems should be verified by comparing fixes with known locations in each survey area prior to beginning the survey. Additional accuracy can be obtained by using data collected at Community Base Stations to differentially correct data obtained from any receiver operated in the field within a 500 km (310 mi) radius of the base station. In 1993, Northern Forest Management operated two GPS Pathfinder Community Base Stations, in Kelowna and Prince George, and their corrective data was available for a user fee of $14.00 for each one hour time period file. Twenty-four files are created and stored each day at the base station, and can be accessed by modem. With PFINDER differential correction software, accuracy to 15 m (49 ft) can be assured, and accuracy within 2 to 5 m (6.5 to 16.5 ft) is expected.

If transects are flown without a GPS system, pilots must fly along a predetermined line and adjust for wind strength and direction. That is done by orienting via landmarks, and following compass courses. At low altitudes, drift can be detected and adjusted for. If a pilot gets off course, the best thing to do is interrupt the transect, climb to establish some points of reference, reestablish your location, and then resume the transect. If you are far off course, fly the transect again.

Fixed-width transects require maintaining a constant height above the ground. Radar altimeters are expensive, but give a constant and direct read-out of height above terrain. With experience, a subjective sense of correct height can be gained by learning the size that certain objects appear at the desired height. That will reduce the need to constantly watch the altimeter. Mammals may be a useful reference, but trees are not.

Navigation systems have great potential for application to aerial or ground survey techniques. Use of a navigation computer will allow consistent coverage of search areas with little chance of missing areas or double coverage. The end points of transect lines, block boundaries, and animal locations can be more accurately recorded. The navigator is also free to spend more time searching for and classifying animals. The applicability of such systems should be assessed using controlled field tests in British Columbia. An affordable system should be a standard piece of equipment in aerial inventory work.

A large number of aircraft based GPS receivers are available. LORAN-C only receivers should not be considered for purchase since the system does not cover the whole province. However, many GPS receivers also have LORAN-C capability. Portable ground based units are less expensive than aeronautical equipment, but their antennae systems are not approved for external mounting on aircraft. A ground based GPS unit with an approved aircraft antennae system would provide the best value portable system.

3.1.9 Equipment

The following equipment is recommended for aerial surveys in British Columbia. It is a modified list from Grigg (1979) and Gasaway *et al.* (1986). For large population estimation surveys involving several aircraft, Gasaway *et al*. (1986) recommended a minimum quantity (in parentheses). Smaller and less intensive surveys will require less, and may not need all the items listed.

- Topographic maps (7 sets of 1:50:000 scale (or suitable alternative), and 4 sets of 1:250,000).
- Coloured pencils
- Grease pencils (3 colours, 3 each)
- Large eraser (4)
- Large scissors (3 pairs)
- Large felt-tip markers (2)
- Transparent coloured markers (3)
- Clear tape (8 rolls)
- Masking tape (1 roll)
- Heavy gauge acetate, at least 100 cm (40") wide (enough to cover 1:63,360 map (or equivalent) of entire survey area)
- Expandable file folders for map storage and data sheets (6)

Inflight equipment

- Clipboards
- Survey data sheets
- Number two lead pencils (bring extras)
- Intercom and headsets
- Spare batteries for intercoms
- Polar compensating planimeter (1)
- Tracing paper to be used with planimeter
- Pad of writing paper
- 3-ring notebook to store all forms, calculations and notes
- Survey forms (see Section 3.1.10)
- Binoculars

Personal gear

- Warm clothing (including hat and gloves)
- Sunglasses (amber tint for overcast days)
- Dark outer layer to minimize reflection on windows
- Watch
- Ear plugs
- Air-sickness pills and bags

Other equipment

- Camera and film
- Tissues
- Window-cleaning bottle and rag
- Tie-down pegs and ropes
- Foam pads to sit on in plane

Survival gear

- First Aid kit (should include 3 elastic bandages, 3 triangular bandages, aspirin, clove-oil, antiseptic, various small bandages, sport tape)
- Thermal reflective blankets or sleeping bags
- Bivouac sack(s)
- Matches (in water-proof container)
- Knife
- Small hatchet
- Wire saw
- 10 m 1/4" rope or nylon cord
- Tarp
- Flare gun
- Water
- Food rations

3.1.10 Survey forms and data recording

Standardized forms are necessary to ensure that data are not omitted, and that between-survey results, perhaps with different observers, can be compared. Be aware that the standardized data forms associated with this manual may not have all the fields required by sightability models, if you choose to use one. Biologists that choose to use a regression model to correct for sightability bias will need to consult a publication that describes the chosen model for a description of the variables required and how they should be collected.

Maps must also be used for locating sample unit boundaries, and if navigation systems are not available, for navigation and recording sightings. Using large maps in a confined cockpit can be awkward. Maps of the survey sample units can be copied, cut, pasted onto stiff backing, then laminated to make observation and note-taking more convenient. Maps and air-photos can be filed in a ring binder for easy access.

The navigation equipment recommended in Section 3.1.8 is highly reliable. Navigation computers provide a continual display of the information recorded so that data collection can be verified as the survey proceeds. Data recording on paper is recommended, although tape recorders may be used to allow continuous recording of data without looking away from the search area. Tape recorders may also reduce the possibility of motion sickness, which can be brought on by writing. However, tape recorders can fail for mechanical or electrical reasons, and usually without letting you know. If you decide to use tape recorders:

- become intimately familiar with the machine and its controls (particularly "record" and "pause");
- test batteries before the survey and daily thereafter;
- replace batteries if in any doubt about whether they will last;
- test the machine if it is bumped or dropped;
- use two tape recorders simultaneously to reduce the risk of losing data; and
- transcribe the notes daily.

For all surveys the date, start/stop times, personnel, weather, aircraft and survey type must be recorded. Observations of animals (or their sign) should be recorded by consecutive group number. Animal groups may range from a single animal to many animals associated together. The navigator records the flight line and each observation as a group number on a topographic map or with GPS. Navigation equipment may be essential to accurately record irregular flight lines. The mapping symbology for ungulate capability classification (Demarchi *et al*. 1983:41) is recommended. Accurate mapping allows each observation to be referenced to elevation, aspect and slope. Where observations are being recorded on paper, a second observer (usually the observer located behind the pilot) records the number, sex and age classification and behaviour of the group beside the group number on the appropriate survey form. Collecting additional descriptive information is optional. However, for absolute abundance surveys, collecting information such as per cent vegetation cover, per cent snow cover, activity and habitat type is recommended, since these are important factors used in sightability correction models (see Section 3.6.3). Use the standard list of habitat types (broad ecosystem units) for British Columbia.

3.1.11 Logistics and safety

In most cases, the budget allotted to a survey will determine the level of effort and area covered. It is important to allocate funds to planning, analysis, and reporting, as well as to carrying out the survey. Aircraft charter usually accounts for most of the budget required for surveys. Planning, and analysis of current information and past surveys, can greatly improve the quality of survey results for little additional cost. As noted elsewhere, accurate stratification is a key component for all surveys, and can substantially reduce the flying time required to reach acceptable levels of precision.

In order to plan a survey, the area and expected number of sample units (SU) should be defined or estimated. Also incorporate costs for stratification surveys to confirm population boundaries and strata. This may include an overflight with a fixed-wing aircraft to define population boundaries, and a stratification flight of each sample unit using either fixed-wing aircraft or helicopter depending on the density of cover, and the expected difficulty in sighting animals or their tracks. Initially plan to survey at least five sample units in each stratum. As a general guideline, 20 sample units in open habitat should incorporate 600 km^2 (30 km^2/SU), and in dense habitat, 200 km^2 (10 km^2/SU). Employ optimal allocation procedures for further sampling (see Section 3.6.2). Generally, optimal allocation results in greatest sampling effort in the high strata (e.g., 90%), less in the moderate strata (e.g., 50%), and least in the low strata (e.g., 30%), in terms of the proportion of SU's surveyed.

High density sample units normally require more time to survey because of the time required to count and classify animals. The average time for all sample units should be about one hour, so the total time required, and approximate cost can be estimated once the number of sample units is defined (e.g., 20 blocks @ 1 hr/block @ $700/hr = $14,000).

Ferry time between sample units, and for refueling must also be estimated, and should be <10% of the flying budget. If fuel is not available within 10 to 20 minutes flying time of a survey area, consider slinging drums in with the helicopter or having some delivered by a pick-up truck, a Beaver aircraft (five 45 gallon drums), or an Otter aircraft (10 drums). Jet Rangers require about 25 gallons per hour, so one drum equals about two hours flying.

Ideally, the helicopter should be based in the survey area during the period of the survey. That requires arranging for meals and accommodation for the crew. Bases in the area allow you to start searches earlier and finish later each day, and also to interrupt surveys if weather is poor. That is most important where helicopter bases are far from the survey area, and the prospect of spending the night in a freezing helicopter may cause you to fly in dangerous conditions.

Survey aircraft should have a regular hourly radio check-in with a base station, a requirement with some government Ministries. If a check-in is missed, the base station should attempt to contact the aircraft. If the aircraft does not respond within one hour, the flight following service should initiate a search and rescue operation by calling 1-800-742-1313. Information on the last location of the aircraft, aircraft type and colours, crew members, and probable destination must be provided to search and rescue. It is advisable to provide the flight following service with a map showing the sample units being surveyed, and the expected dates that each will be flown. They can be updated during radio contacts.

Personnel should be briefed by the pilot on aircraft safety procedures. All personnel should be familiar with the location and operation of the emergency locator transmitter, and with the aircraft radio. Suitable seasonal clothing and survival gear must be carried in the aircraft.

3.2 Sampling Standards

3.2.1 Standards for accuracy and precision

Accuracy refers to how close the parameter estimate is to the true population parameter, and it can be improved by accounting for biases such as sightability. Precision is the closeness of repeated measurements to the mean population estimate. Precision is quantified by the sampling variance, and can be improved by replicating surveys, increasing the number of sample units, stratifying samples into groups where variation is expected to be lower, and by optimal allocation of sampling effort.

Accuracy and precision are both important for good survey estimates (Gill *et al.* 1983). Without those measures it is difficult, if not impossible, to compare studies over time or between areas. Bias can be classified into two types: 1) small sample bias and 2) model bias. Model bias is the more serious of the two, since increasing sample size usually does not reduce the magnitude of the bias. All sample-based estimates are based on statistical models, which depend on one or more assumptions. If all of the assumptions of the statistical model are not met, model bias results.

Precision is commonly indicated by associating confidence intervals with the estimate. A confidence interval gives the known probability ($1 - \alpha$) that the actual value of a parameter will be included within the interval. It is recommended that $\alpha = 0.10$ so that confidence intervals will provide a 90% probability that the actual value of a parameter will be included within an interval.

The reliability levels (accuracy and precision) required for population surveys depend on at least three factors: (1) the decision risk, *i.e.,* the "cost" and likelihood of being wrong in the projected effect; (2) the natural variation in the parameters or characteristics to be measured; and (3) the technology and resources (*i.e.,* people, time and money) available to measure the key parameters (Salwasser *et al.* 1983). Three reliability levels are recommended for aerial ungulate inventories, based on intended uses (Table 4).

Table 4. Recommended accuracy and precision for inventory of ungulates in British Columbia at three levels of inventory use.

Level	Confidence Interval	Allowable Error	Intended Use
1	90%	± 15%	Inventory Development Population Research Inventory of Red/Blue Listed Species
2	90%	± 25%	Intensive Population Management Inventory of Yellow Listed Species
3	90%	± 50%	Less Intensive Management

In addition to establishing *Type 1* errors (α levels), *Type 2* errors (β levels) should also be specified when using statistical tests. Gasaway *et al.* (1986:61) and Gerrodette (1987) provide a good discussion of *Type 1* and *2* errors as they relate to population estimation. Briefly, the test of a null hypothesis results in accepting or rejecting the hypothesis, based on some estimated risk of being wrong. The probability of rejecting the hypothesis when it is true is referred to as a *Type 1* error. The largest recommended acceptable risk of committing a *Type 1* error is $\alpha = 0.10$. A *Type 2* error (β) is the probability of concluding that the null hypothesis is true when in fact it is false. The largest recommended acceptable risk of committing a *Type 2* error is $\beta = 0.20$. This will provide for statistical power (probability of rejecting the null hypothesis when null hypothesis is false) of 0.80.

3.2.2 Standards for sex and age classification

Ungulate surveys are often used to provide information on population sex and age structure, in addition to data on population size or distribution. The usual procedure has been to conduct intensive flights over selected areas of wildlife concentration, and to classify animals according to specified sex and age criteria. However, classification surveys at wildlife concentrations are often biased, sometimes severely so. A representative portion of the population should be surveyed to account for differential habitat preferences between sex and age classes. Replicating classification surveys will not overcome bias, if differences in habitat preferences between sex/age classes are not considered.

Jones (1984) proposed a classification level system for ungulates, which is used here, with some slight modifications (Table 5, 6, 7 and 8). The simplest levels of classification require distinguishing between adults and juveniles (Level 1), or between adult males, adult females, and juveniles (Level 2). Level 3 distinguishes between adult and yearling males. Level 4 includes three to four classes of mature males, which are based on horn curl, and antler size and shape.

Juvenile animals or young (less than one year old) can be distinguished for all species based on body size. For deer, elk, and moose, males can be distinguished from females when they have their antlers. For cervids, large antlered males drop their antlers earlier than others. Antler drop varies regionally, but usually begins in late November for caribou, in late December for moose, in January for deer, and late February for elk. For sheep, goats, bison and caribou, distinguishing between young males and females can be difficult, since both carry small horns or antlers. Correct classification requires close observation from a helicopter, or from the ground using spotting scopes. Adult moose and caribou can be classified as male or female by using the white (moose) or black (caribou) vulval patch to identify females. Close viewing of the antler scars on males is sometimes possible, but usually difficult. Urination posture may also be used, but requires longer term observations. Using standard aerial inventory methods, young males may be unavoidably included in the adult female class for mountain sheep, mountain goat, and bison. Animals which cannot be identified with certainty should be counted as unclassified. These include animals, which slip into dense cover before they can be viewed more closely, or can not be identified in the midst of large groups. There are two categories for them; unclassified adults (unsexed but known not to be juveniles) and unknown (neither sex nor age is determined). All levels of classification should use those categories for clarity. There is little benefit to guessing at classifications.

When surveys are focused on obtaining population estimates, and many animals are enumerated quickly from the air, only unambiguous classification criteria should be used. The choice will depend on survey objectives, type of aircraft and seasonal timing (note: Level 4 classifications may require ground stations using spotting scopes). Although some experienced personnel may be able to classify animals to a higher level (e.g., Level 4), for consistency and accuracy we recommend using straight forward criteria requiring minimal judgment and time. The Level 2 or 3 classifications will normally be sufficient. Level 4 classifications are generally only required where detailed information is male age structure is required (e.g. mountain sheep). Consult Simpson *et al*. (1993) for diagrams of Level 4 classification of ungulates. The four levels of ungulate classification, and their intended uses are summarized in Table 5.

It is important to maintain consistent classification standards between surveys. Where data are being compared between areas, managers should insure that the same standards are used throughout. Consistent classification is required to calculate standard population ratios and allow comparison between populations. Numerous factors can affect the results of classification surveys, particularly where some sex/age classes in a population are more dispersed or less visible than others. In stratified random sampling, animals must be classified in all strata. Although focusing on high strata may allow classification of the most animals, the sex/age structure of populations often differs between strata. This is most notable for elk where many mature bulls are found in the low strata. Similar relationships have been noted for other species. A representative count can be assured if all parts of the area occupied by a population are surveyed adequately. Common biases reported for each species are identified in Section 4.0.

Table 5. Classification criteria for aerial ungulate surveys.

Level	Classification Criteria	Population Ratio[5]
1	juvenile (<1 yr.)/adult (> 1 yr.)	• natality (births/100 adults) • recruitment (short yearlings/100 adults)
2	male/female/juvenile	• sex ratios (males/100 females) • recruitment (juveniles/100 females)
3	adult male/yearling male /female/juvenile	• male recruitment (yearling males/100 adult males or yearling males/100 adult females)
4	see individual species	• mature male age structure (class I/class II/class III/class IV)

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[5] higher classification levels can be used to derive lower classification population ratios.

Table 6. Recommended standard sex and age classification criteria in British Columbia for black-tailed deer, mule deer, and white-tailed deer using aerial survey techniques.

Species	Sex/Age	Composition	Description
Black-tailed Deer	juvenile	fawn	• spotted pelage in summer • smaller body size and shorter nose in winter
	female	doe	• medium size and no antlers • adult does may be accompanied by fawns
	male	yearling buck	• spike or antlers with 1 and/or 2 points
		Class I	• small 2 point or 2/3 points per antler
		Class II	• medium 2 or 3 point or small 3 point, light antlers
		Class III	• large 3 or 4 points/antler, or 5 points, heavy antlers
Mule Deer	juvenile	fawn	• spotted pelage in summer • smaller body size and shorter nose in winter
	female	doe	• medium size and no antlers • adult does may be accompanied by fawns
	male	yearling buck	• spike or 2-points on one or both antlers
		Class I	• large 2 point or small 3 point antlers
		Class II	• medium size antlers with 3 points/antler
		Class III	• medium size with 3 or 4 points/antler • moderate to large bodied
		Class IV	• large antlers with 4 or 5 points/antler
White-tailed Deer	juvenile	fawn	• spotted pelage in summer • smaller body size and shorter nose in winter
	female	doe	• medium size and no antlers • adult does may be accompanied by fawns
	male	yearling buck	• spike or 2-points on one or both antlers
		Class I	• large 2 point or small 3 point antlers
		Class II	• medium size antlers with 3 points/antler
		Class III	• medium size with 3 or 4 points/antler • moderate to large bodied
		Class IV	• large antlers with 4 or 5 points/antler

Table 7. Recommended standard sex and age classification criteria in British Columbia for elk, moose and caribou using aerial survey techniques.

Species	Sex/Age	Composition	Description
Elk[6]	juvenile	calf	- small body size without antlers
	female	cow	- medium size without antlers
	male	yearling bull	- spike antlers or with light 1 to 2 point antlers
		Class I	- small antlers with 3 or 4 points (raghorn)
		Class II	- large 4 pt antler, small 5 pt antler, spindly (raghorn)
		Class III	- large 5 pt antler, small 6 pt antler, heavy antlers
		Class IV	- large antlers with 6 or 7 pts/antler, massive
Moose	juvenile	calf	- small body size without antlers
	female	cow	- no antlers and short bell, medium size - distinguished by white vulval patch - usually has a light brown face colour - sometimes accompanied by calf
	male	yearling bull	- antler, if palmated, does not extend beyond eartip - antler pole type, usually a spike or fork
		Class I	- antler palmated, extends beyond tip of ear - browtine a spike or fork
		Class II	- antler palmated, extends beyond tip of ear - brow tine palmated with usually 2 or more points - innermost points of brow palm close over face
		Class III	- antlers palmated, but smaller than Class II - brown tine usually a spike or fork, like Class I
Caribou	juvenile	calf	- antlers (if any) are short (spikes) with velvet - darker body and smaller than adults
	female	cow	- small antlers 2-3 times the ear length - black vulval patch
	male	yearling/Class I	- small antlers which are 2-3x the ear length - similar to females, but no vulval patch
		Class II	- antlers larger than females - antlers are lighter and smaller than Class III bulls - antlers without shovels
		Class III	- large, heavy-beamed antlered males - antlers with many points and a palmated brow tine - may have shovel with few points, but heavy beams

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[6] Roosevelt Elk: Class II - large 4 pt or 5 pt; Class III- very large bulls (≥ 6 pt.); Class IV - no classification.

Table 8. Recommended standard sex and age classification criteria for bison, mountain goat, and mountain sheep using aerial survey techniques.

Species	Sex/Age	Composition	Description
Bison	juvenile	calf	• small, light brown
	female	cow	• medium size, difficult to distinguish from yearling males
	male	bull	• largest in size, horns also largest
Mountain Goat[7]	juvenile	kid	• small body size, short horns, usually with female
	yearling		• larger than kid but smaller than adult • juvenile face, shorter muzzle • horns shorter than ears in early-mid summer • usually in groups with females and kids
	female	nanny (2+ yr.)	• shaggy coat in July • squatting urination posture • black vulval patch when tail raised • horns have a fairly sharp kink at the tip • horns thinner and more wide-spread than males • horns V-shaped from the front • head and shoulders less massive than males
	male	billy (2+ yr.)	• smooth coat in July • scrotum visible in summer coat • stiff-legged “rocking horse” gait • horns thicker and closer together than in female • stretching urination posture • head and neck massive compared to female

Table 8 continued on next page.

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[7] Under exceptional circumstances it may be possible to identify 2+ yr. males, 2+ yr. females, 2 yr. males, 2 yr. females, yearlings and kids (Chadwick 1983; Smith 1988)

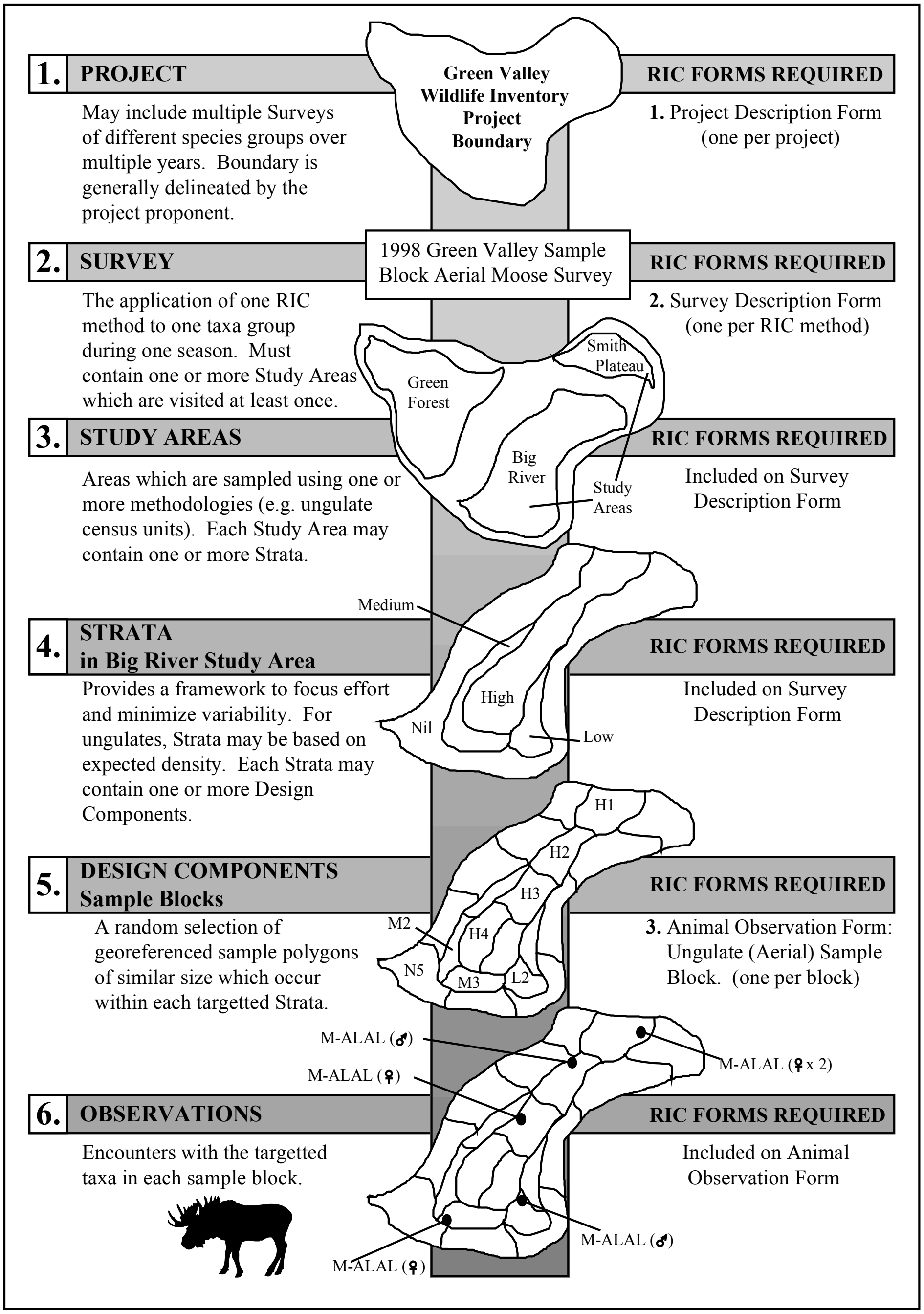
Mountain Sheep	juvenile	lamb	- small with small horns
	female	yearling	- larger than lambs in horn and body size but not as large as adult females or yearling males
	female	adult	- < 1/2 curl horns, often difficult to distinguish from yearlings
	male	yearling	- identified in bighorn sheep, but often difficult to distinguish from adult ewes in thinhorn sheep - horn size greater and bases are slightly wider and more divergent than ewes
		Class I	- horns larger than females or yearling rams - often difficult to separate from yearling rams - 2 year old ram (Peace-Liard)
		Class II	- horns over 1/2 curl, but less than 3/4 curl - body size smaller than Class III ram - 3 year old ram (Peace-Liard)
		Class III	- horns over 3/4 curl but less than full curl - 4 year to full curl ram (Peace-Liard)
		Class IV	- full curl horns (to bridge of nose) or greater

3.2.3 Habitat data standards

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

3.2.4 Survey design hierarchy

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



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. ungulate census units). Each Study Area may contain one or more Strata.

RIC FORMS REQUIRED

Included on Survey Description Form

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

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)

6. OBSERVATIONS

Encounters with the targetted taxa in each sample block.

RIC FORMS REQUIRED

Included on Animal Observation Form

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

3.3 Inventory Surveys

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

Table 9. Types of inventory surveys, the data forms needed, and the level of intensity of the survey.

Survey Type	Forms Needed	Intensity
Classification	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - Ungulate • Animal Observations Form- Aerial Ungulate Classification	• PN
Encounter Transect	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - Ungulate • Animal Observations Form- Aerial Ungulate Encounter / Fixed-width Transect	• PN
Fixed-width Transect	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - Ungulate • Animal Observations Form- Aerial Ungulate Encounter / Fixed-width Transect	• RA
Sample-based Counts	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - Ungulate • Animal Observations Form- Aerial Ungulate Sample Block	• AA
Total Count	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - Ungulate • Animal Observations Form- Aerial Ungulate Sample Block	• AA

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

3.4 Presence/Not Detected

Recommended method: Encounter transects (Linear Transects)

Presence/not detected (possible) inventories (also called reconnaissance or distribution inventories) usually involve relatively low intensity surveys to determine animal distribution, composition and broad habitat associations. Habitat protection investigations and surveys associated with habitat suitability/capability mapping may fall into this category. Such surveys usually produce limited data on population size, and composition ratios obtained from these surveys may be biased. Thus, they are most useful in areas where there is minimal or no information. A specialized and important use of these surveys is as pre-surveys for intensive sample-based absolute abundance inventories.

3.4.1 Encounter transects

The recommended protocol for conducting presence/not detected (possible) surveys is encounter transects. These should not be confused with line transects or transects of indefinite width where the right angle distance of each animal from the transect line is recorded (Caughley 1977:39). Encounter transects (ET) are flown by either fixed-wing aircraft or helicopter, and all visible animals are counted and classified. Encounter transects may follow predetermined straight lines, contours, or drainages. When classification is conducted, it will normally be necessary to deviate from the transect line to ensure accurate classification of the animals. Following the classification, the pilot should be instructed to resume the transect line. While the method provides information on population composition and general distribution, it lacks a measure of the area surveyed, and consequently neither densities nor population size can be estimated. The number seen on each transect flown will vary greatly depending on vegetative cover and prevailing weather conditions, regardless of the number of animals present. The technique is most useful for species in homogeneous habitats, and where visibility is good (e.g., moose in deciduous forests, sheep on alpine ridges). Systematically spaced lines throughout the survey area may allow for calculation of indices such as animals per hour or animals per kilometre (relative abundance). It probably also provides the least biased composition data.

3.5 Relative Abundance

Recommended method(s): Fixed-width (Strip) transects

Determining relative abundance requires holding bias constant in the survey method. Indices of abundance are usually expressed as animals per unit area, distance, or time. Techniques for obtaining indices have been developed for several species and habitats in British Columbia and are being used increasingly for management and research purposes. Consistent methodology is critical to maintain constant bias. As noted in Section 3.4.1, encounter transects can sometimes be used for relative abundance. Fixed-width transect sampling, however, is the recommended protocol.

3.5.1 Fixed-width transects

When using fixed-width transects (FT), only animals within a defined survey area (strip) are counted. Fixed-widths can be defined by marks on the airplane struts, or by placing a board across the helicopter skids and calibrating that with a mark on the bubble window. The strip width is usually ≤ 200 m, but may vary with vegetative cover. Transects may be laid out in either a systematic or random pattern. Ideally, transects should be located in the direction of greatest density variation, usually perpendicular to contours (Caughley 1977). While the number of animals seen can be converted to a density estimate with an associated variance (Caughley 1977:31), it is recommended that fixed-width transect estimates be used for relative abundance (trend line monitoring), and only where visibility bias can be held constant.

Fixed-width transects provide the best results when animals are randomly distributed over large areas of homogeneous habitat. Variation in habitat types can cause large variation in the number of animals seen per transect. Animals which are aggregated can also cause large variations in the density estimate per transect and reduce the precision of the survey. The Boreal and Taiga Plains ecoprovinces in northeastern British Columbia, and possibly Nechako Lowland (Sub-Boreal Interior ecoprovince) are areas in British Columbia which appear to be best suited for fixed-width transect surveys.

The most common bias in fixed-width transects is associated with the difficulty in maintaining precise transect width. Small changes in the height of the aircraft or in observer position can result in large variations in the width of the area surveyed. Maintaining consistent transect width is often difficult or impossible in rugged terrain. When available, LORAN-C or GPS equipment is useful to track position in terrain with few landmarks. Flying by compass or using a distant object on the horizon helps on flat homogenous habitats.

3.6 Absolute Abundance

Recommended method(s): Total counts, Sample-based counts (see Section 4 for species-specific recommendations).

Determining absolute abundance requires estimation of both the bias and precision of the survey methods. Total counts and sample-based survey designs (e.g., stratified random block surveys) are the two basic methods for estimating absolute abundance. Total counts are often possible for species such as mountain goats, which occupy discrete mountain blocks. However, for other species such as moose and elk, which have a more contiguous distribution over the landscape, cost and logistic constraints favour using sample-based survey methods. These results are then extrapolated to the entire survey area to estimate absolute abundance with statistical confidence limits. Both methods require independent estimates of sightability, in order to correct survey bias for animals missed.

Surveys should be done when the target species is most restricted in distribution, or most visible. Generally, aerial surveys for ungulates must encompass areas of at least 200 km^2 to enclose discrete populations. In most cases ungulate survey areas will be much larger. When survey areas are less than 200 km^2, total counts should be used rather than sample counts. In open habitats, where sightability is high and search times can be reduced, areas up to 600 km^2 can be censused for reasonable cost using total count methods.

3.6.1 Total counts

Total counts are the simplest in principle. They are intended to enumerate all animals using 100% flight coverage of the study area. Alpine areas are usually small, and thus the technique is practical for surveying mountain sheep and goats, and sometimes caribou.

It is usually difficult or impossible to actually count every animal. Some animals are reclusive, and others are simply missed. Without some estimate of the numbers missed, or sightability of animals, the accuracy of total counts is always in question. Only in open habitats where sightability bias is low, will total counts approach an estimate of absolute abundance. Replicating surveys can help to determine how variable actual sightability may be.

Definition of survey sample units is recommended for total counts (TC). However, instead of randomly selecting sample units to survey, all the units are counted. Delimiting the sampling units provides clear definition of the areas to be surveyed. In-flight survey procedures for the sample units follow those outlined for sample-based counts.

3.6.2 Sample-based counts

Sample-based surveys are required wherever it is impractical to survey the entire area occupied by a population. In sampling surveys, a portion of the population is counted within defined sample units (e.g., quadrats or blocks). The results are then used to estimate animal abundance throughout the study area. Increasing search intensity can increase sightability but for some low density populations or cryptic species living in dense cover (e.g., coast black-tailed deer), no aerial search methods are adequate.

In all survey methods where animals are counted in sample units, there is an associated edge effect. When an animal is near a sample unit boundary, a decision must be made to count it as "in" or "out". Keen surveyors may prefer to include those animals rather than ignore them, which biases the results upward. In stratified random block surveys, careful definition of sample unit boundaries using obvious features will reduce that problem. Where the problem persists, only 50% of such observations should be included as “in”.

If the animals being surveyed are expected to move appreciably, adjacent survey sub-units should be completed within the shortest possible time to minimize chances of double- or under-counting due to animals shifting between units. Choosing a larger sample unit size may also help to alleviate this problem.

Sample units

Sample units (SU’s) may include both blocks and quadrats. Blocks are irregularly shaped polygons (Gasaway *et al*. 1986:6-10), which are variable in size. Surveys should, however, attempt to keep block size as constant as possible, since large variations in block size will increase the variance of the survey estimate. They are particularly well suited to rough mountainous terrain and clumped animal distributions, both conditions that apply well to ungulates in British Columbia. Quadrats are square (e.g., 5 x 5 km^2) or rectangular in shape (e.g., 3 x 8 km^2). The major disadvantage of quadrats is locating SU boundaries. However, with GPS and LORAN-C, this is becoming less of a problem.

Searching sample units is a dynamic process, and requires that the navigator define the flight pattern prior to initiating the search. The flight pattern must be appropriate to survey all terrain, and enable identifying, plotting, distinguishing, counting, and classifying each group of animals. Gasaway *et al*. (1986:29) provide a useful example of flight patterns in varied terrain. Large sample units may require subdivision into smaller units. This reduces the chance of double counting, since flight lines can be shortened, the time between passes is reduced, and animals located on adjacent lines can be more easily recalled and distinguished. That is especially important for deer and elk, and even sometimes moose, which may move long distances in a short time when disturbed. Goats and sheep may move quickly to different elevations.

Regardless of whether blocks or quadrats are chosen as the SU, all SU’s should be pooled into strata of differing density, thereby assigning as much total variance as possible to differences among strata (Gasaway *et al*. 1986:7-19). In addition to increasing precision, stratification allows optimal allocation of sampling effort, thereby getting the most precision possible. Even a poor stratification will likely improve precision compared to unstratified random sampling.

In stratified random sampling, each sample unit is selected randomly without replacement from each stratum using a computer or a table of random numbers. The standard procedure is to initially count at least five sample units from each stratum (e.g. five low, five medium, and five high sample units).

Gasaway *et al*. (1986) describe the sampling method for stratified random block (SRB) surveys in six basic steps, which should be applied to all SRB surveys in British Columbia.

1. Define the population of interest, the information required, and the survey area using reconnaissance surveys if needed.
2. Delineate all possible sample units on topographic map or air photos of the survey area.
3. Divide the survey area into three to five strata, based upon the expected number of animals in each SU, determined from existing information or from a stratification survey.
4. Select a number of sample units randomly from each stratum, if the entire area cannot be surveyed with existing funds.
5. Fly surveys of selected sample units and employ standard methods to estimate the percentage of animals that were missed.
6. Calculate an estimate of population size and structure including confidence intervals around the estimates.

Following are some specific recommendations for in-flight block survey procedures (#5 above):

1. Animals are counted and classified using transects located within the sample unit. Transects are straight in flat terrain and follow contour lines in mountains. During the search, the observers are responsible for the field from the center of the aircraft to half way to the next transect on their side of the aircraft. Animals spotted outside the transect width should be noted on the map and the pilot and navigator informed. The pilot and navigator should then decide based on the conditions and location of the animal(s) whether to proceed to count and classify the group or wait until flying the next transect.
2. Sample units in mountainous terrain should be surveyed from low to higher elevation, because animals move more slowly up-slope and you will be less likely to miss them. The best survey pattern is usually along contours, starting from the lowest elevation and working systematically upward in jumps of 100 to 150 m, depending upon topography and cover. When tracks are sighted in fresh snow, circle the area to help locate the animals. Climbing slightly can assist in spotting animals in tall timber.
3. When a group of animals is seen, the pilot and navigator are directed to the area. If the group begins to move, make a mental note of where the animal(s) were first sighted. The group is then counted and classified as quickly as possible, using the helicopter to herd or hold the animals as necessary. Remember to scan for other groups as you approach. It is common to concentrate on one group and miss others. Following classification, you may need to return to the location where the animals were first spotted in order to collect the required auxiliary habitat-related information.

For standard stratified random block surveys, program MOOSEPOP can be used to calculate population estimates, confidence intervals, and estimates of numbers in each sex/age class. For stratified random quadrat surveys, a slight increase in precision may be obtained by using the statistical procedures outlined by Caughley (1977:28-30).

Optimal allocation of sampling effort

Optimal allocation is a means to use available funds most efficiently to attain the highest possible level of precision. Optimal allocation allocates sampling effort among strata on a daily basis during the survey, based on observed sample variance estimates of the strata (Gasaway *et al.* 1986). Five sample units in each stratum (e.g., high, medium and low) is generally considered the minimum sample size, prior to initiating optimal allocation. Further sampling effort is then applied to the strata based on the results of the allocation formula.

For large survey areas with many blocks, optimal allocation may limit your ability to preplan the order in which blocks will be surveyed. Adjacent units may have to be done several days apart. Ferry time will be substantially increased and refueling requirements cannot be as accurately preplanned. Nonetheless, optimal allocation will still provide better precision, than equal sampling of strata for a fixed cost.

The recommended procedure for calculating optimal allocation of sampling effort in SRB surveys is described by Gasaway *et al.* (1986:43-52), and should be consulted. These calculations can be performed with the program MOOSEPOP, which is available from Daniel J. Reed, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701. The program also performs optimal allocation of effort between standard and intensive searches (see Section 3.6.3.).

3.6.3 Estimating numbers missed

Whenever a wildlife population is surveyed, some animals are inevitably missed (referred to as sightability or visibility bias). That results in an underestimate of the population size. Vegetation cover is probably the single, most important factor affecting the sightability of animals in British

Columbia. This is because much of the ungulate winter range in the lower two-thirds of the province consists of closed or semi-closed canopy coniferous forests.

There are a number of ways of improving sightability when conducting an aerial survey:

1. Use slower flying aircraft with good visibility.
2. Use as many good observers as the aircraft and conditions will allow.
3. Use higher search intensity (min/km2) in undulating terrain and dense forest cover.
4. Circle observed animals to detect animals nearby.
5. Use overlapping transects to ensure adequate coverage in dense forests.
6. Use smaller sample units that require less overall search time, to reduce observer fatigue and thus reduce sightability bias.
7. Choose a time period in the annual cycle during which the highest proportion of the population is in open or relatively open habitats.
8. Choose the time of day when animals are most active and/or least likely to be using thick cover.
9. Choose weather/light conditions that maximize animal activity and visibility.

All those methods help to improve sightability, but some animals will still be missed. While increasing sample size can improve the precision of a population estimate, improving accuracy requires an estimate of the number of animals missed.

If sightability is not accounted for, the population estimate will be biased. That bias usually means that the reported confidence intervals will not include the true population density the specified percentage of the time (Gasaway and Dubois 1987). Thus, missing 20% of moose in the surveyed sample units could result in a confidence interval being closer to 50% rather than the stated 90%. Many past surveys in British Columbia have not provided an estimate of sightability. Rather, in most cases, sightability has either been ignored or an informed guess, based on sightability estimates determined from other studies, has been used to adjust the population estimate. Guesses should be discouraged, as they do not provide objective measures that can be used consistently over time.

There are three methods recommended for estimating sightability: two stage sampling, mark /resight of animals, and sightability models. The latter, sightability models, have recently been developed for use in Idaho (Unsworth *et al*. 1994), and will require more testing for species, such as elk, under conditions in British Columbia. However, a BC-specific model that corrects for sightability bias on moose surveys has been developed and is available for use in the province (Quayle *et al.* 2001). A description of the model is available in Appendix C.

Two stage sampling

Two stage sampling uses a repeated survey of animals in a given sample unit. The "two samples" can then be used to estimate a ratio of how many animals are being missed in the survey. There are two basic approaches used. One resurveys a sample unit or portion thereof, immediately after the initial survey (Gasaway *et al*. 1986). The other uses two observers simultaneously, and compares the counts to estimate sightability (Magnusson *et al.* 1978; Cook and Jacobsen 1979; Caughley and Grice 1982).

The Gasaway method (Gasaway *et al*. 1986:30-36) is the recommended two stage sampling method. It uses an intensive re-survey of a portion of a sample unit in a stratified random block count. It is flown in medium and high density blocks using a 2- to 3-fold increase in search intensity (min/km^2). The number of blocks to be resurveyed intensively is calculated by the optimal allocation method (Gasaway *et al.* 1986:48-49). The sightability correction factor is calculated by dividing the number of animals seen during the intensive search, by the numbers seen in the standard search. Minimizing time between the standard and intensive search is essential to reduce the chances of animals moving in or out of the block.

The two stage sampling method is most useful in relatively open habitat for large species, such as moose in the northern 1/3 of the province. In much of the rest of British Columbia and for smaller, more cryptic ungulates, the "intensive" survey will still miss a substantial number of animals. Under these conditions, mark/resight methods are preferred. Program MOOSEPOP should be used to perform the calculation for two stage sampling.

Mark and resight

Although relatively costly, and at times limited in accuracy, mark and resight surveys often provide the best method for adjusting survey results for sightability bias. Mark-resight is a modification of mark-recapture methods. Many texts on animal sampling, such as Caughley (1977) and Krebs (1989), provide excellent reviews and discussion of mark-recapture techniques, and at least one of these texts should be consulted prior to initiating a mark-resight survey.

The basic mark and resight procedure is to randomly mark a portion of the animals and then resurvey the area. The proportion of the marked animals missed during standard surveys can be used to estimate the proportion of the population missed in each survey unit. A number of methods can be used to mark animals including ear tags, collars, and paint ball marking. Applying visual marks such as ear tags and collars requires capture and handling. Since the cost of handling large mammals is high, it is best to install radio collars on captured animals, as radios help to ensure that the assumptions of mark-resight sampling are being met. Paint marking using an air-powered paint gun allows animals to be marked without handling them, and many animals can be marked in a short time (e.g., 20 per hour for goats in the Babine Mountains, Cichowski *et al*. 1991). Currently, the paint marking technique is only recommended for mountain goats, although research on other ungulates is encouraged. Where paint marking is used, animals should be paint marked on both sides or on the back to make later identification of marked animals more certain.

The Petersen mark-recapture method is the simplest and probably the most commonly used method in aerial survey work. It involves marking animals in one session and surveying the area again in another session.

The Peterson method relies on several statistical assumptions:

1. all animals have equal probability of being marked;
2. animals are not leaving (emigration/mortality) or entering (immigration/natality) the survey population between marking and recapture;
3. marking animals will not affect their future catchability (i.e., probability of detection of a marked animal is the same as an unmarked animal);
4. no marks are lost between the marking and recapture (resight) periods;
5. all marked animals counted during the survey are identified as marked; and
6. animals are not counted more than once during a sample.

Because different age/sex classes often occupy different habitats, the assumption of equal marking probability is unlikely to be met under most conditions. Also, the assumption of equal probability of sighting marked and unmarked animals may be violated, if marked animals have a greater tendency to detection from aircraft.

Both visual marks and radio-collars can be used, however the latter are recommended because they enable validation of four of the assumptions stated above:

1. radio-collared animals can be monitored after the survey to determine whether marked animals left or entered different survey areas;
2. the movements and behaviour of collared animals can be monitored to assess their detectability relative to unmarked animals;
3. loss of marked animals can be detected; and
4. by relocating marked animals immediately after a survey area is completed, it is often possible to determine the reasons that animals were missed, including failure to spot marks.

Program NOREMARK (White 1996) should be used to compute estimates of population size for an ungulate population with a known number of marked animals and one or more resighting occasions. This program allows for resightings or recaptures of marked animals, and the number of unmarked animals observed on one or more replicate surveys are used to compute population estimates. Four different estimators are provided in the program, each with different assumptions about individual heterogeneity and immigration and emigration to and from the study area. The program is available through the internet at the following WWW (World Wide Web) site: http://www.cnr.colostate.edu/~gwhite/software.html.

Sightability models

Sightability models were initially developed for elk in Idaho (Samuel 1984), but more recently have been applied to mule deer, moose, mountain sheep, and caribou (Unsworth *et al.* 1994). In open and semi-closed habitats (observers must see at least 1/3 of the animals present), they offer a suitable alternative to double-stage sampling or mark-resight for estimating visibility bias. While this technique holds considerable promise for ungulate inventory in British Columbia, it still requires more testing for most species in the province (excepting moose) before it is adopted as a standardized methodology. We do, however, recommend and encourage further testing and refinement of this methodology within the province. We also encourage collection of % vegetative cover, % snow cover and activity as User Statistics for all absolute abundance surveys. Once sightability models have been developed and verified, standardized sightability corrections incur little additional cost to the survey, and greatly improve the value of census information. We expect that following the required research, sightability models will become the survey method of choice for correcting ungulate visibility bias from aerial surveys in British Columbia.

A moose sightability model that is specific to British Columbia has recently been developed from data collected in the Kamloops area (Quayle *et al.* 2001). This model requires that observers estimate the % vegetative cover over each group of moose sighted and uses this variable to estimate the number of moose missed. Quayle *et al.* (2001) also describe the parameters under which use of the model is appropriate and provide direction for conditions under which sightability can be maximized. Biologists conducting moose surveys to estimate absolute abundance should review Appendix C for more information.

The BC moose model, as well as all of the models developed for other ungulates at the University of Idaho, can be run using a software package called AERIAL SURVEY. This software will estimate population size and composition for several ungulates in Idaho and can be adapted to run the BC moose model as well. AERIAL SURVEY, version 4.0 is available from: Oz Garton and Fred Leban, Department of Fish and Wildlife, University of Idaho, Moscow, Idaho 83844-1136. The manual accompanying the software provides detailed instructions for data recording, data entry and running the program. It also provides direction as to how to adapt the program to utilize new models.

It should be noted that the “Idaho” sightability models do not consider survey unit size in developing its population estimate. The “Gasaway” SRB method calculates a density per unit area and applies the density to estimate numbers per unit area in unsurveyed sub-units. Larger sub-units will always have higher predicted numbers than smaller sub-units in the same stratum. The Idaho models assume that sub-units are defined to enclose similar numbers of animals, regardless of sub-unit size. This method may be more appropriate for elk, sheep, goats and bison that are more highly clumped and predictable in distribution.

3.7 Detecting Changes in Sex and Age Composition

The number of animals in particular sex or age categories is one of the most common statistics reported from ungulate inventories. These statistics are typically expressed as age and sex (e.g., bull/100 cow and calf/100 cow) ratios, which provide information on herd composition and recruitment. However, to be meaningful, sex/age ratios should be based on statistically reliable sample sizes, and should be reported with 90% confidence intervals. Statistical tests should also be conducted to determine if two or more ratios are significantly different.

Four basic approaches have been used to measure population ratios and statistical variance. The simplest approach has been to treat individual animals as the sampling unit and assume that individuals are independently and randomly sampled from the population (Czaplewski *et al.* 1983). This assumption is almost always violated with ungulates, and it is generally recognized that a better approach is to use cluster sampling which treats groups of animals as the sampling unit (Bowden *et al.* 1984). If absolute abundance is measured through a stratified random survey design then the procedures outlined by Gasaway *et al.* (1986) can be used to estimate sex/age ratios and their statistical precision. A limitation of Gasaway's method is that it does not explicitly account for differential visibility of age or sex classes when calculating ratios or their variance. An alternative estimation procedure has been developed by Samuel *et al.* (1992) that considers both errors associated with survey design (either simple or stratified random sampling) and visibility bias.

Although generally not recommended, classification or reconnaissance surveys may be used to estimate sex/age ratios and confidence limits using Czaplewski's method. Sample sizes should be determined prior to the survey, based upon desired levels of precision and allowable error (Section 3.2.1) and an estimate of the ratio of interest:

$$n = \frac{Nz^2 pq}{e^2(N-1) + z^2 pq} \qquad \mathbf{1}$$

where:

1. n is the required number of animals to be classified (e.g., bucks and does to determine buck:doe ratios),
2. p is the proportion of the sample comprising the sex/age class of interest (e.g., bucks/[bucks+does]),
3. q is $1 - p$,
4. N is the estimated population size (bucks and does),
5. z is the 2-tailed value from the normal distribution, and
6. e is the allowable error (as a proportion of p).

Significant differences in ratios or percentages can be tested using chi-square contingency tables (Zar 1984). Yates correction for continuity should be used for 2x2 contingency tables. Often it is desirable to conduct a second survey to determine if a significant change in sex/age composition has occurred (e.g., increase in % caribou calves following wolf control). Snedecor and Cochrane (1978:221-223) describe a method for calculating the required sample size for the second survey in order to test for a differences between two population ratios (e.g., % calves). That requires identifying both *Type 1* and *Type 2* errors (see Section 3.2.1).

If the composition of each animal group is recorded, which is recommended, then cluster sampling formulas can and should be used to estimate population ratios and confidence intervals (Cochrane 1977:65-68; Bowden *et al.* 1984). Required sample sizes and confidence limits may be based on simple random sampling of animal groups (Schaeffer *et al.* 1979), or using a 2-stage sampling design where land units (e.g., blocks, quadrats, transects) constitute the first-stage sampling units, and groups of animals located within each sample unit comprise the second-stage (Bowden *et al.* 1984).

Population surveys incorporating stratified random sampling should use the procedure outlined by Gasaway *et al.* (1986:83) to estimate sex/age composition and confidence intervals (available in program MOOSEPOP).

3.8 Detecting Changes in Abundance

Detecting changes in abundance is vital for both monitoring populations and evaluating management programs (e.g., impact of forest harvesting or hunting regulations). In total count surveys, all animals are assumed to be counted, and thus any difference in numbers indicates a change in abundance. However, in virtually all cases these surveys do not provide exact measures of abundance, and statistical procedures which adjust for sightability are required to detect changes in abundance.

The most common statistical procedure for determining the probability that two population estimates differ in size is the Student's t test. Gasaway *et al.* (1986:61-66) provides an excellent discussion for detecting changes in moose populations using the t-statistic (t'), and standard statistical texts discuss the procedure as well (e.g., Zar 1984:126). The null hypothesis is: there is no change in abundance between the two surveys. t' is calculated as

$$t' = \frac{T_2 - T_1}{\sqrt{V(T_1) + V(T_2)}} \qquad \textbf{2}$$

where T_1 estimates and T_2 are population estimates from the two surveys, and $V(T_1)$ *and* $V(T_2)$ are the associated variances. The degrees of freedom (df_t) is calculated as:

$$df_t = \frac{\left[V(T_2) + V(T_1)\right]^2}{\frac{V(T_2)^2}{df_2} + \frac{V(T_1)^2}{df_1}} \qquad \textbf{3}$$

where df_1 and df_2 are the degrees of freedom associated with each survey estimate.

Gasaway *et al.* (1986:63) point out that if you do not detect a significant decline, then you should determine if the *null hypothesis* can be accepted with a tolerable probability of committing a *Type 2* error (probability of concluding no change in abundance when a change occurred). This involves calculation of statistical power (1- β), or the probability of rejecting a false null hypothesis. Usually, it is difficult to statistically detect changes over a short periods because of imprecision in census estimates, e.g., one or two years. For example, Gasaway and Dubois (1987) indicate that with confidence intervals of ± 20%, a population must increase or decline about 20% to detect a significant ($p<0.05$) change in abundance. If the population is increasing 3.7% per year, then five years would be required between surveys to detect a significant difference. Gasaway *et al.* (1986:65) discuss planning surveys to detect specified population changes and provide formula for estimating the required precision from a second survey, after the first survey has been completed.

3.9 Estimating Rates of Population Change

Virtually all analyses of the dynamics of wild populations involve the concept of a rate of increase or population change. Sinclair and Grimsdell (1978) provide an excellent introduction to calculating rates of change from a time series of population estimates, and van Ballenberghe (1983) discusses estimating rate of change in moose populations.

The rate of population change (increase or decline) is estimated from two or more population estimates (or relative abundance indices) over time. The rate estimator depends on the trajectory of the population growth curve, e.g., linear growth, exponential growth, or logistic growth. If the time series is relatively short, then exponential or geometric growth is usually assumed. While there are numerous formulae for calculating λ, the finite rate of population change, population rates of change are most easily obtained by log-linear regression of abundance versus time in years, *i.e.,*

$$\log_e N_t = \log_e N_0 + t \log_e \lambda \qquad \mathbf{4}$$

which is of the general form of the usual linear regression equation, $y = a + bx$, with N_t the number of individuals (or population index) in year t, N_0 is the number of individuals in the initial year or year zero, and λ is the finite rate of change (slope $b = \log_e\lambda = r$ where r is the exponential rate of increase, $e^r = \lambda$, and e is the base of natural logarithms [2.7182818]).

If both the population estimate and the variance are known, then the formulae outlined by Gasaway *et al.* (1986:67) should be used to calculate rate of change, its associated variance and CI's. Gasaway and Dubois (1987) note that meaningful rates of change can best be estimated when a population makes a statistically significant change. Therefore, before estimating rates of change, determine if initial and final population estimates differ statistically with appropriate statistical tests (see Section 3.8).

Gerrodette (1993) has provided software to facilitate the assessment of trend lines from annual estimates or indices of population abundance. Program TRENDS can be used to determine: (1) how many years monitoring should continue to detect a change; (2) how precise the survey data must be; (3) how large a change can be detected; and (4) what is the probability of detecting a change (obtaining a significant slope to the regression line), given that change really is occurring?

4. Species Specific Guidelines

The purpose of this section is to provide some species specific guidelines for the inventory of ungulates in British Columbia. The emphasis is on surveys designed to assess absolute abundance and composition.

4.1 Bison

Recommended method(s): Total counts

Plains bison are restricted to three drainages (Halfway, Sikanni, and Besa River) in northeast British Columbia (Northern Boreal Mountains and Boreal Plains ecoprovinces, SWB and AT biogeoclimatic zones). The herd originated when animals escaped from a game farm on the Halfway River. The main population is located in the Sikanni Chief drainage. Favoured habitats are open grassland areas. Because they tend to remain in large groups, the bison are conspicuous and may be surveyed using total count methods.

Young of the year are easily distinguished by their very small size relative to adults and by their light brown pelage. Adult bulls can be distinguished from cows by much greater body size and by the massiveness of the horns. As with other species, young males may be easily confused with adult females and identification of yearling classes is dependent on the experience of the classifier.

4.2 Mountain Goat

Recommended method(s): Total counts with accuracy confirmed by mark/resight.

The improvement of inventory methods for mountain goats has long been a priority for research in British Columbia (Eastman 1977), but little progress has been made.

4.2.1 Survey methods

Because goats often occur in discrete blocks of relatively open upland habitat, total counts, usually from the air (Hebert and Woods 1984) but occasionally from the ground (Fox 1984; Forbes 1992) have been the most common survey method. However, there have been attempts to use stratified sampling procedures (Van Drimmelen 1986; Houston *et al*. 1986, 1991), and at least two attempts at mark/resight estimation using radio-marking in one case (Smith and Bovee 1984) and paint-marking in the other (Cichowski *et al*. 1991).

Goats are contagiously distributed in summer, when they are most visible, and stratified sample units must be based on those concentration areas. Large confidence intervals will result from simple random sampling of contagiously distributed animals. The mark/resight method utilizing paint balls is the most promising alternative now available for providing statistically enhanced estimates at reasonable cost. However, additional research is needed to ascertain the amount and nature of marking required, to assess assumptions (Smith and Bovee 1984) and to determine whether the trauma of marking may bias results on the subsequent survey flight.

We recommend that the total count method is continued within stratified land units and that mark/resight methods be employed to correct survey results for missed animals. Locations of important habitat features such as mineral licks or heavily used trails should be marked on the flight map.

4.2.2 Defining search areas and stratification

Densities are rarely recorded for goats, and few inventories have reported the size of the areas surveyed (Hebert and Turnbull 1977). Mountain goats may make long seasonal movements across timbered lowlands and inhospitable terrain such as extensive ice fields (Nichols 1985). Consequently, it is not safe to assume that high altitude boundaries near tree line, or an apparently isolated mountain, will necessarily enclose a discrete population. In most cases, surveys to determine numbers should be directed at whole mountain ranges, or portions that can be separated by barriers that would limit the dispersal of goats (see Fox 1984).

In some areas, female goats reportedly inhabit the most visible and accessible cliffs. By age 2, males begin to disassociate themselves from nursery groups. Except during the mating season, from mid-November to early December, males associate mostly with other males. Adult males are often missed in surveys because they are widely dispersed and solitary. Survey area boundaries must ensure that peripheral areas inhabited by older males are included.

The conspicuous visibility of individual goats promotes the expectation that sightability for the species is high. However, goats may be out of sight during surveys for several reasons including:

1. animals in low elevation sites while migrating to other summer ranges;
2. animals visiting mineral licks below timber-line; and
3. animals hiding from the survey aircraft.

On the last point, observers have noted that goats may show extreme fright and hiding responses to aircraft (Ballard 1975; Hazelwood 1983; Jones 1984) especially from helicopters.

Mountain goats are seasonally migratory. In summer, coastal goats in the Olympic Mountains occupy areas above 1500 m (Houston *et al.* 1986). They use winter ranges above 1500 m and descend to rock outcrops as low as 300 m. Seasonal ranges may overlap or be up to 8 km apart. Smith and Bovee (1984) considered year-round habitat for coastal goats in Alaska to include all areas above 800 m and lower elevation winter range. Both forested habitats well below timberline and alpine zones support high-density coastal and interior goat populations in winter (see Smith and Bovee 1984). Slopes with southern aspects are preferred.

Nursery groups of females and juveniles range in size from two to 25 or more individuals. From early summer through August, group size is large on feeding grounds or at mineral licks. As summer progresses, goats disperse and groups get smaller.

Habitat types can be used to define the areas in which goats are likely to be found. Boundaries of sample units for goats should follow creeks or other low areas below the areas of goat concentration. The tree line may set a useful lower elevation boundary in northern populations (Northern Boreal Mountains ecoprovince). If units are too large, there is risk of double counting mobile goats. Van Drimmelen (1986) used sample units from 11 to 32 km^2, with a mean of 19 km^2. Smith and Bovee (1984) reported high densities of coastal goats (2.3 goats/km^2) in year-round habitats compared to estimates in Yoho National Park (1.5 goats/km^2). According to Warkentin (pers. comm.), treeline is not necessarily a useful lower elevation boundary for goat surveys, but a temperature range of $\pm$10° C may be. Goats in the Kootenays are often found in a 300 m elevation band about that temperature from mid-July through early September.

4.2.3 Survey timing

Goats may be most accurately classified to sex and age during the first three weeks of July, with the best period about mid-month. At that time, identification of adult males and females is assisted by moulting patterns. Winter surveys, unless to determine seasonal distribution, are not recommended because of difficulties related both to habitat selection and the cryptic aspects of white animals on a white background. There is no seasonal timing that provides complete data on both composition and numbers. Total counts in summer focus on composition, but it is not known if the composition data are biased. The timing to provide the highest total counts may vary from place to place. Opinions on best timing include “mid-July to mid-August” (Nichols 1985), with “mid-August to late September” for coastal Alaska (Smith 1984); late August to mid-September” in the northern interior of British Columbia (Northern Boreal Mountains, Taiga Plains, Boreal Plains ecoprovinces). “August to early October” for southern and central British Columbia (Sub-Boreal Interior, Central Interior, Southern Interior, Coast and Mountains ecoprovinces); and “August to September” for the Southern Interior Mountains ecoprovince.

Early morning and late evening are poor for surveys on clear days, because of glare and shadow conditions caused by direct, low angle sunlight. The best survey conditions in terms of observer comfort, visibility, and animal activity are thought to be "...high overcast skies, soft light, no turbulence" in Alaska (Nichols 1980). Fox (1977) found goats congregating into larger groups, and moving into open, up-slope areas on clear days following stormy weather. He believed that the best counts could be accomplished in the late afternoons of such days. On clear, hot summer days, between about 11:00 and 16:00 hours, goats may remain inconspicuously bedded in cool areas such as timber, caves, crevices, north-slope shadows, ravines, and snow banks (Ballard 1975; Nichols 1980; Jury 1984). To maximize sightability, goat surveyors should keep a careful eye on prevailing weather.

4.2.4 In-flight survey procedures

Piper Supercub aircraft have been used for goat surveys (Ballard 1975; Nichols 1980). However, helicopters provide greater safety, better visibility, and more flexibility in aerial maneuvering or herding animals about. Turbine driven helicopters, especially the Bell 206 with bubble windows at the rear seats are preferred, although the Hughes 500D disturbs the animals less.

Within each sample unit, flight lines should be routed over potential goat habitats in a pattern, determined in-flight, that provides opportunity to see all animals present. The best pattern is usually along contours, starting from the lowest level and working systematically upward, in jumps of 100 to 150 m depending on topography and cover. Airspeed may be varied to insure optimum sightability of goats as terrain varies.

Where long expanses of habitat require passes at several levels of elevation, coverage should be accomplished in segments bounded by recognizable natural features, such as between two glaciers or within a particular basin. If goats are observed above any contour line transect being followed, they can be noted on the map, but not formally recorded until a transect passes their elevation. That procedure ensures that moving animals are neither missed nor counted twice.

4.2.5 Classification

Ideally, goats should be directed up open mountain slopes. Goats appear to respond better to aircraft approaching from downslope, rather than overhead. Herding goats can assist in classification. Restricting goat access to escape terrain allows better classification, but can also result in pandemonium and unwanted stress. Large, dispersed groups of animals are sometimes most easily segregated as adults and kids (Level 1) during a high elevation approach. Large herds can be approached and classified at a distance, which results in less movement and stress on animals. For better viewing, large groups can be "broken" into sections and classified in smaller groups. Smaller groups can be dealt with closer at hand.

Level 3 classification should be used in July and, to the extent possible, Level 2 later. Yearlings are not readily distinguished from other young adults by late summer, especially in large groups. It is also difficult to separate young males from young females at that time, and male ratios will therefore be low. Distinguishing sub-adults (or two years olds - Level 4) can be difficult. Hatler and Hazelwood (1985) expressed some doubt about making that distinction from the air, especially in large groups, and a recent study in Montana (Smith 1988) has confirmed that difficulty.

Moult and body size have helped classification of goats in July (Nichols 1980; Hatler and Hazelwood 1984; 1985). Horn morphology, commonly cited as an aid in classification, is difficult to apply reliably from the air. The flow of decisions in classification in Figure 2 was adapted from Hatler and Hazelwood (1984). It should be confirmed with the features from Table 5.

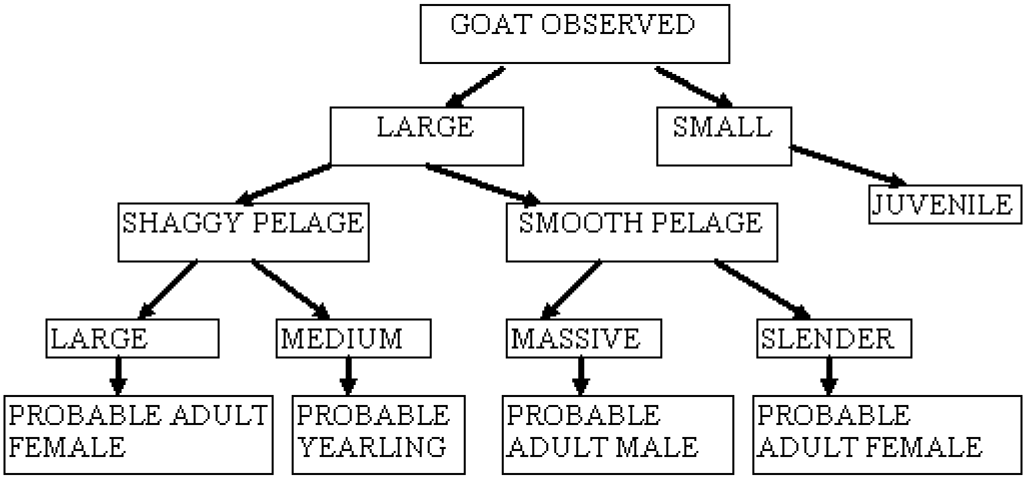


Figure 2. Flow of decision making in classification of goats (adapted from Hatler and Hazelwood 1984).

Hatler and Hazelwood (1984) noted that most classification errors occur in the smooth pelage category. Young males are easily missed in large groups, and sub-adults cannot be readily distinguished from adult females. Shaggy nannies and yearlings can also be confused in large groups. Dry nannies will moult earlier than those bearing young. Kids can often be missed because they hide behind or under nannies.

After July, moult features no longer help in classification, and the genitalia are usually obscured by lengthening body hair. Other features still apply, but it may not be possible to sex adults with confidence. Juveniles are still recognizable by body size, but yearlings have grown to sizes overlapping with older classes, and cannot be consistently segregated. Thus, a somewhat compromised Level 2 is the only practical classification standard for surveys in late summer and fall.

4.2.6 Estimating numbers missed

Few mountain goats have been radio-collared in British Columbia, so estimates of sightability using mark/resight analysis have not been possible. Many surveys have used the assumption that sightability is not biased between sex and age classes, and that all goats are seen (Smith and Bovee 1984). However, Foster (1982) reported average sightability of only 42% in west-central British Columbia (Central Interior ecoprovince). Smith (1984) reported 30% sightability in coastal Alaska, using fixed-wing aircraft and telemetry. Warkentin (pers. comm.) suggests that: sightability of kids is lower in escape terrain as they hide behind nannies; sightability of billies is lower than nannies from mid-July through August; and sightability of nanny and kid groups is lower than that of billies in June and early July, when they may still be on mineral licks in timber.

Smith and Bovee (1984), using mark/resight surveys on a coastal goat population, calculated density estimates on winter and on year-round range at 4.4 and 2.0 goats/km^2 respectively. They reported an estimate for goats, varying ±15% about the mean at confidence levels of p=0.95. Because of the "limited and variable sightability of coastal goats, they thought that no uncorrected count should be taken as more than an index of the population size".

Cichowski *et al.* (1991) used mark/resight techniques to study goat populations in the Babine Mountains Recreation Area. Goats were marked from a Bell 206 helicopter using a paint gun. One goat was marked per five minutes of flying time. Observing goats on both sides for paint marks proved difficult in large groups (>20). Cichowski *et al.* (1991) recommend marking all goats on the same side to increase survey efficiency. It is not known if marked and unmarked goats were equally observable.

4.3 Mountain Sheep

Recommended method(s): Total counts

As with mountain goats, mountain sheep often occur in fairly discrete blocks of open upland habitat. Inventories are usually total counts with classification from the air (Burles and Hoefs 1984; Elliott 1985; Steventon 1985; Stelfox 1990; Schultze 1992). Ground counts have been used on some accessible seasonal ranges (Hoefs and Bayer 1983). In British Columbia, seasonal ranges of many thinhorn sheep populations are still being learned, such that surveys are combined reconnaissance and population estimation. The ranges and winter concentration areas of most southern bighorn sheep populations are much better defined (Southern Interior Mountains, Central Interior and Southern Interior ecoprovinces).

4.3.1 Survey methods

Running, weaving sheep are difficult to classify, or even count, from the air. The alternative, ground counts, also present problems when sheep are at a distance, and partly obscured within groups and by cover. Aerial surveys are the only practical method of inventorying remote populations. Aircraft must also be used to survey broken terrain and partially forested slopes. Ground counts may be possible during aerial searches, by landing near large herds. Ground counts will provide much better classification and count information for large groups, which congregate on open slopes. Total counts are recommended.

4.3.2 Defining search areas and stratification

Sheep cannot tolerate deep snow. They generally begin leaving summer ranges in September, and virtually all are on winter ranges by November. Open, snow-free slopes form the core winter ranges in all areas. In southern bighorn populations (Southern Interior Mountains, Central Interior and Southern Interior ecoprovinces), those areas are most often within the BG, PP, IDF, or MS biogeoclimatic zones on warm south aspects where snow accumulation is minimal. A few southern herds also use windswept alpine ridges. Snow free alpine ridges in the AT and SWB biogeoclimatic zones form the core of winter range for most northern sheep (Northern Boreal Mountains ecoprovince).

Reconnaissance surveys are still required for many northern populations whose winter distribution is poorly defined. Low snow sites used by sheep in winter are relatively easy to recognize. Locating rutting areas may be more difficult. Winter ranges have been defined for southern herds (e.g., Stoddart, Columbia Lake, Premier, Bull and Wigwam herds in the East Kootenay). Low strata search areas should be defined around core winter ranges to locate dispersed groups, particularly rams.

4.3.3 Survey timing

Because of their use of open habitats, sheep are visible at most times of the year. However, they are generally best counted and classified during two time periods. Trophy male bighorn sheep are most successfully enumerated during the rut in November (Stelfox 1990) or December (Southern Interior Mountains ecoprovince). Incidental observations suggest that the rut, in the last half of November, also has potential for inventory of Stone's sheep. The preferred timing for population estimates for Stone's and bighorn sheep is late February through March, when animals are concentrated on winter ranges (Elliott 1985; Stelfox 1990; Schultze 1992). The best period will vary annually with weather and snow conditions. In the Thompson-Nicola (Southern Interior ecoprovince), early spring (late March/April) is best for population estimates when sheep concentrate on green-up areas. However, older males may be underestimated at this time.

Dall's sheep, which are not visible against snow, are usually surveyed in spring before lambing (Nichols 1978), or in early summer (Burles and Hoefs 1984). During six counts of Dall sheep in the Tatshenshini River area (Tatshenshini Basin, Coast and Mountains ecoprovince) between June 1988 and June 1990, the highest counts were in September 1988 (241) and June 1990 (266). Comparable numbers on the other flights were as follows: June 1988 - 98; February 1989 - 126; April 1989 - 133; and September 1989 - 144 (Hatler 1990). The low counts of June 1988 and September 1989 were ascribed to adverse climatic conditions.

Surveys for all subspecies are conducted in June for neonatal recruitment, and July for two to three month recruitment and summer distribution. Rams will be underestimated then due to their solitary habits and use of rough terrain. April surveys, currently used in the Ashnola, may also be used to estimate 12 month lamb recruitment, before sheep disperse from winter ranges.

4.3.4 In-flight survey procedures

Dall's sheep have been regularly surveyed from small fixed-wing aircraft, especially Supercubs (Nichols 1978; Simmons *et al.* 1984). Nichols notes that helicopters provide "more accurate" surveys, but create more disturbance. Many northern sheep ranges (Northern Boreal Mountains ecoprovince) are in more open and gentle terrain than exists in most of British Columbia. We recommend the use of Jet Ranger helicopters for sheep surveys.

Large groups of sheep should be counted, and the number of lambs determined, while circling high enough so that they do not bunch and run. The proportions of harvestable and younger rams should be determined, based on appropriate horn size regulations for the survey area. That requires a closer approach or, preferably, landing the aircraft for observation with a spotting scope.

4.3.5 Classification

Consistent recognition of some classes of sheep varies with the season. Yearlings are readily distinguished in surveys conducted from winter to about June, but may be difficult to recognize thereafter. The most difficult distinction in all seasons is between young (Class I) males and adult females, particularly in large groups. Most who have attempted to make that distinction from the air have expressed uncertainty about the results (Steventon 1985; Schultze 1992). Judging from a collection of Dall sheep undertaken by Simmons *et al.* (1984), that lack of confidence is justified. Of 112 sheep shot from a helicopter, that were suspected to be rams, but "...were not clearly identifiable as rams", only 11 (9.8%) turned out to be Class I rams.

Adult males are classified as Class I, II, III, or IV on the basis of horn curl (Geist 1971). When viewed from an aircraft, Class I rams, which have not reached 1/2 curl, do not show their horn tips. Class II rams, between 1/2 curl and 3/4 curl, show the horn tip. Class III, between 3/4 and full curl, show an upward curl from above and little weight at 1/2 curl. Class IV rams (full curl) have horns that do not appear to taper from their base to the 1/2 curl point. Assuming a survey in May in a southern Yukon population, those classes generally correspond to the following age groupings: Class II - three to five years, Class III - six to eight years, Class IV - nine years and older (Hoefs and Cowan 1979). Age estimates need to be confirmed in each ecoprovince and region.

For bighorn sheep, yearling rams and Class I rams appear distinct in winter (Bill Warkentin, personal observations). Class II to IV rams may be found with other classes in the winter, from about November through April, but most will move to separate ranges for the rest of the year.

Yearling and 2-year-old rams (Class I) are usually in nursery bands and, as noted above, are difficult to consistently distinguish from adult females, especially in winter pelage. In summer, the 2-year-old males are usually somewhat larger and have longer horns and larger horn bases than most females. They also show testicles when viewed from the rear, but it is difficult to attain that view from an aircraft. Adults with yearlings (winter) and/or lambs in summer are almost always females. However, most other adults in a nursery group are most honestly assessed simply as "unclassified adults".

4.3.6 Estimating numbers missed

Like goats, sheep will hide from aircraft. Hoefs and Bayer (1983) enhanced counts of Dall's sheep by reference to marked animals, but the details of that were not elaborated. Simmons (1971) marked large numbers of Dall's sheep with a modified crop spray apparatus on a fixed-wing aircraft, but used the marked animals for studies of movements rather than population estimation. The procedure and equipment used by Cichowski *et al.* (1991) for marking mountain goats should work for sheep as well. Radio-collared bighorn sheep have been available for use in population studies and estimation of sightability, but no details have been reported from that work (P. Davidson, pers. comm.). Dye marking and the two stage sampling procedure, proposed by Stelfox (1990), appear to be the most economical methods available to improve estimates of sightability in sheep populations. Opportunities to use radio-collared animals for sightability research should be addressed.

4.4 Moose

Recommended method(s): Stratified random block survey

Moose are the most common and widespread ungulate in the boreal forest of British Columbia. They occur in most biogeoclimatic zones, but are rare or absent on the coast (CWH, CDF, MH biogeoclimatic zones) and in the dry hot interior (PP, BG biogeoclimatic zones). Moose do occur in small numbers in CWH biogeoclimatic subzones in a few coastal drainages (e.g., Nass Ranges, Northern Coastal Mountains, Coastal Gap and Pacific Ranges). Moose tolerate deep snow, commonly up to 70 cm. Because they tend to occur singly or in small family (cow/calf/yearling) groups in winter, they are typically more widely scattered than other species. Average density is a more accurate descriptive parameter for wintering moose than it is for contagiously distributed species. Moose attain densities of 5 per km^2 on some winter ranges, but densities of 1 to 2 per km^2 are more typical.

Stratified random block counts have been used for inventories in central and northern British Columbia (Southern Interior, Northern Boreal Mountains and Sub-Boreal Interior ecoprovinces). Steventon (1984) compared transect surveys to random quadrat surveys, and concluded that quadrats provided more precise data. Transects were considered most appropriate to obtain general distribution and population structure data.

4.4.1 Survey methods

Inventory procedures for moose in northern ecosystems are developed and thoroughly described by Gasaway *et al.* (1986). The standard procedure for moose inventory is the stratified random block survey, conducted from December to March. In Thompson-Nicola (Southern Interior ecoprovince), surveys should be conducted before mid February when moose tend to move into dense timber.

4.4.2 Defining search areas and stratification

Moose are found mainly in riparian habitats, shrublands, wetlands, and deciduous forests. They most often associate with moderate terrain, but some important ranges are on steep slopes with abundant deciduous vegetation. Typical moose home ranges are 20 to 30 km^2 in winter. Most moose leave areas where snow depths exceed 70 cm. Moose regularly faced with deeper snow have specialized winter ranges that provide relief. Such ranges may be along river valleys where solar insolation and wind reduce snow depths (SWB, BWBS, SBS biogeoclimatic zones), or where flowing water maintains snow free corridors and dense coniferous forests provide shelter (ICH biogeoclimatic zone). In other areas (ESSF, SBPS, MS biogeoclimatic zones), moose move to lower elevation drier biogeoclimatic zones (IDF) where snow depths are minimal.

Valley bottom riparian areas typically contain concentrations of moose. In winter, small rivers freeze over, and may be poor sample unit boundaries. Adjacent forests are important for cover, and should be included within the blocks defined around open feeding habitats to minimize the potential for between block movements. Dense coniferous forests are particularly important for snow shelter in the ICH zone. Local knowledge is important in defining search areas and strata, due to the variability in habitat use patterns between zones. Telemetry Information is most useful in defining expected moose distribution.

Sample unit size for moose stratified block counts have ranged from 10 to 50 km^2 (Steventon 1988). However, most sample units are from 15 to 35 km^2. We recommend units of 10 to 30 km^2.

4.4.3 Survey timing

The best time to classify moose is from late November to mid-December, prior to antler drop in males. At that time classifications can accurately measure six month calf recruitment and male age structure. Harper (1985) reported increased survey costs in part due to extra time spent sexing adults, since nearly all bulls had dropped their antlers in late January when the survey was done. Jury (1986) recommends having surveys ready to go by mid-December, weather and snow conditions permitting. However, late winter (February and March) is generally the best period to estimate population size and calf recruitment. However, as winter progresses calves may wander progressively further from their cows, and a biased classification may result if some are missed (Simpson, unpubl.).

Gasaway *et al.* (1985) report that variable and low sightability in May and June (26 to 36%), precluded accurate estimates of population size or trends of change. Prior to calving, yearling:cow ratios were overestimated. In May and June, calf:cow ratios were underestimated, and in June, bull:cow ratios were overestimated.

Jury (1987), Harper (1985) and others have reported that population composition varies between strata. Hence classifying a few strata, and extrapolating results produce biased results. All strata should be sampled to obtain composition data representative of the whole study area.

4.4.4 In-flight procedures

Jury (1985) reports that stratification flights were done at 140 to 150 km/h and 200 to 400 m above ground. Surveys by fixed-wing aircraft ranged between 100 and 130 km/h, while helicopter surveys ranged between 80 to 100 km/h. Steventon (1984) reported flight height from 50 to 150 m, and an average fixed-width transect width of 300 m.

Gasaway *et al*. (1986) recommends a search intensity of 1.5 min/km^2 in Alaska, although intensive surveys in northern British Columbia (Northern-Boreal Mountains, Boreal Plains ecoprovinces) typically average about 2.5 min/km^2. Search intensities in the Thompson-Nicola region (Southern Interior province; ESSF, MS, and IDF biogeoclimatic zones) have ranged up to 4.6 min/km^2. Appropriate search intensity levels will vary depending on strata, vegetation cover, and the estimated moose density, but even under the best conditions should be at least 2.0 min/km^2.

4.4.5 Classification

Adult male moose are classified on antler size and palmation. Light snout colouration, small bell size, and the white vulval patch of females help in differentiating males and females. Note that the bull criteria given in Table 7 does not apply to the small, dark Shiras moose of southeastern British Columbia. Shiras bulls have much smaller antler sizes. Classification for Shiras moose should be confirmed regionally.

If the proportion of Unclassified adults in a survey is small, these can be apportioned to the bull and cow segments using the ratio of antlerless bulls to lone cows in the overall count (Jury 1986). Using the bull/cow ratio from high strata only may bias results.

4.4.6 Estimating numbers missed

Tärnhuvud (1985) defined the following characteristics for "good" and "acceptable" conditions for conducting moose surveys.

"good"

- more than 30 cm of snow on the ground
- complete snow cover in the trees
- 0.5 to 3 days after at least 5 cm snowfall

"acceptable"

- more than 30 cm of snow on the ground
- 50% snow cover in the trees
- > 3 to 5 days after at least 5 cm snowfall

Quayle *et al.* (2001) also outline conditions under which sightability can be maximized in moose surveys in BC. In addition, they describe a BC-specific model for correcting sightability bias in absolute abundance surveys of moose. The model requires that observers collect % vegetative cover data (to the nearest 20%) for each group of moose observed in addition to the usual data recorded during a moose survey. Biologists who wish to make use of the model developed by Quayle *et al.* (2001) should review Appendix C.

4.5 Elk

Recommended method(s): Stratified random block counts with correction for sightability. Research into appropriate survey methods for estimating absolute abundance of Roosevelt elk is still required.

Rocky Mountain elk are found mainly in southeast (Southern Interior Mountains; MS, IDF, PP) and northeast (Northern Boreal Mountains; SWB, BWBS) British Columbia. Smaller populations occur in the Okanagan Region and near Lytton (Southern Interior ecoprovince; IDF, PP). Roosevelt elk are restricted to Vancouver Island and the Sunshine Coast (Georgia Depression ecoprovince, Eastern and Western Vancouver Island ecoregions; CWH, CDF)).

4.5.1 Survey methods

Stratified random block counts are recommended for elk surveys except on Vancouver Island. Roosevelt elk will require mark-resight estimators because of low sightability in coastal forests. The elk survey methodology described by Unsworth *et al*. (1994 has been used in the East Kootenay (Southern Rocky Mountain Trench ecoregion; IDF, PP, MS biogeoclimatic zones; Simpson 1992a, 1992b), and may be appropriate for northeast British Columbia (Northern Boreal Mountains, Boreal Plains ecoprovinces; BWBS, SWB biogeoclimatic zones). In the latter, the Gasaway moose survey methodology has been applied to elk, but with smaller black sizes, and also appears to provide suitable estimates of survey precision. Low sightability may limit the effectiveness of sightability models in the ICH biogeoclimatic zone (Columbia Mountains and Highlands ecoregion), although sightability trials are underway in Idaho within ICH biogeoclimatic zones forest types (Dave Leptich, pers. comm.).

4.5.2 Defining search areas and stratification

Elk are contagiously distributed in winter. Snow depth and condition are thought to determine elk distribution primarily by limiting forage. Heavy snowfall will restrict animals to low elevations. Deep snow facilitates surveys, and the highest population counts have been obtained in severe winters (Samuel 1984). Use of grassland areas is not restricted by 20 cm new fresh snow, but with crusting or depths of 30 cm or more, elk will move into shrub and conifer dominated habitats. Depths of more than 60 cm restrict mobility, and elk will move to lower elevation forested habitats. Crusting in late winter restricts use of grassland by elk to periods when solar radiation softens the snow (Peck and Peek 1991).

Distinctive ridge-tops or large rivers should be used as block or sample unit boundaries. If a survey area is flat, roads or fence lines may be used as sample unit boundaries.

Sample units of 8 to 16 km^2 in size are good for timbered or partially timbered habitats. Open habitats (sagebrush and grass) can be 30 to 50 km^2 because they can be surveyed rapidly. Low density strata units should be kept small (10 to 15 km^2), and high density units larger (30 to 50 km^2), so large wandering groups of elk will not be missed. Sample units should require about one hour of helicopter survey time.

Based on previous knowledge of their study area, Unsworth *et al.* (1994) stratified blocks with expected numbers of elk as 0 to 35 (low), 36 to 85 (medium) and 86+ (high). A pre-survey flight is required for accurate stratification. If there is little information, Unsworth *et al.* (1994) recommend two levels (0 to 50 and 50+) for the first surveys in an area. All ranges, except those of extremely low potential, should be included. In some cases, islands of suitable habitat exist due to favourable aspect or vegetation. Include those areas and rate surrounding areas as nil.

As for moose, surveys should immediately follow stratification. Elk movements in that time can easily affect the accuracy of stratification and thus the population estimate.

4.5.3 Survey timing

The best time to survey elk is when snow conditions, and cold, force animals onto the lowest portions of their winter range, usually in January or February, before the antlers are dropped. Search areas are then much reduced in size. Green vegetation in spring concentrates larger groups. However, in spring, snow does not restrict movement, and entire sub-units at high elevation must be surveyed. Antler drop will affect composition estimates in spring surveys (Unsworth *et al.* 1994).

4.5.4 In-flight survey procedures

Blocks are surveyed entirely by flying overlapping transects on flat ground, or contours in steep terrain. When block counts are done in mountainous regions, flying contours at 90 m intervals in dense cover, and at 150 m intervals in areas with more open cover may be appropriate. Above canopy altitude should be 30 to 45 m along the contour center line. Fly at a ground speed of 65 to 80 km/h. Canyons should be flown 30 m higher than the contour line, dropping to the original contour when leaving, to avoid missing canyon bottom areas (Unsworth *et al*. 1994). Terrain and timing differences are the main differences of in-flight procedures for elk and moose.

When a group of elk is sighted, it should be circled to ensure that all animals are seen. The group may be moved slowly to an area, which has already been surveyed. Total group size should be determined first, calves and bulls can be counted individually and remaining animals are classed as cows, although some will be female yearlings.

4.5.5 Classification

Bull elk often occupy peripheral and denser habitats than cows, and occur in smaller groups. Bulls are, therefore, more frequently missed during aerial counts and bull:cow ratios are often underestimated (Samuel 1984). Sampling in all strata, and using estimates corrected for sightability biases, will provide the most accurate population composition estimates.

Elk are easily classified because males retain their antlers through February. Females are antlerless. Yearling females cannot be reliably distinguished from older cows. Level 1 should be used for reconnaissance after antler drop; Level 2 for early winter reconnaissance; and Level 3 for composition and population inventory. Table 7 shows sex/age classification characteristics. Classification of large groups may be difficult. Sub-sampling large groups should be avoided. A sub-sample approach may yield misleading results, which deviate from the true group composition (Unsworth *et al.* 1994).

4.5.6 Estimating numbers missed

Unsworth *et al.* (1994) consider group size, percent vegetative cover and snow cover as the most important factors influencing elk sightability. Flying surveys in open habitat with extensive snow cover, when group sizes are large, results in the most accurate population estimates.

Currently, the Idaho elk sightability model is not recommended for use for Rocky Mountain elk in British Columbia, until more sightability trials have been conducted, and the influence of using Jet Ranger (Bell 206) aircraft have been evaluated. Nonetheless, it would be prudent to begin to record group size, percent vegetative cover and percent snow cover so that survey estimates may be corrected at a later date, when the sightability trials have validated the model for British Columbia conditions. Methods for estimating those variables are given in Unsworth *et al*. (1994).

Roosevelt elk will almost certainly require use of mark-resight estimators to correct for missing animals.

4.6 Deer

Recommended method(s): Ground Based survey methods, except Boreal Plain Ecoprovince where Stratified Random Blocks may be used.

Aerial inventory techniques have been unsuccessful for deer. Significant portions of every population remain in forest cover and sightability, particularly in coniferous forests, is very low. A few exceptions exist for mule deer, but white-tailed and black-tailed deer cannot be reliably censused from the air in British Columbia.

4.6.1 Survey methods

Standard stratified random block counts, using helicopters, were used successfully to estimate mule deer population size in the Boreal Plains ecoprovince (BWBS biogeoclimatic zone). Sightability was near 100%, based on resightings of collared animals (Rob Woods, pers. comm.). Deer are concentrated on south aspect river breaks in mid-winter, where there is no coniferous cover and limited deciduous cover. Deer show strong fidelity to small ranges in winter (Simpson and Gyug 1991), so movements are limited and replicate counts of blocks were virtually identical. Gasaway's software was used to estimate population size with no sightability correction factor. The applicability of this method in other areas has not been tested but similar methods can be used wherever deer congregate on open sites.

For other areas of the province, and even in the best conditions, with animals concentrated on sparsely forested slopes, sightability of collared animals remains below 50%. Similar low sightability was reported by Fuller (1990) in eastern deciduous forests for white-tailed deer. Aerial surveys for deer populations in coniferous forests are not recommended except at the reconnaissance level. More information on the visibility of white-tailed deer in the Peace region (Boreal Plains ecoprovince) is required before aerial surveys could be recommended for that species in deciduous forests.

4.6.2 Classification

Level 2 and 3 classifications are recommended during early winter. For mid-late winter and spring, only Level 1 should be used (Table 6).

4.7 Caribou

Recommended method(s): Northern Caribou: stratified random block and telemetry; Mountain Caribou: stratified total counts.

The adequacy of caribou inventory in British Columbia has been questioned (Stevenson and Hatler 1985; Hatler 1987), and debated (Page 1990; Hatter and Hatler 1990). Improving inventory methods for the species remains a priority matter (Eastman *et al*. 1990). Traditionally, caribou inventory has consisted of total counts with classification, usually from the air, at known concentration areas above treeline (Hatler 1987). However, a large portion of any population may simultaneously remain in forest habitats, where they are less visible. In the south (Sub-Boreal Interior, Central and South Interior, Southern Interior Mountains ecoprovinces), mountain caribou use forested habitats most of the year, and are difficult to observe. Satisfactory population estimates have been obtained in the Yukon, using a stratified random block design (Farnell and Gauthier 1988), but an attempt to use that method in Tweedsmuir Park failed because of very low sightability and poor snow conditions (Marshall 1990).

While there is a need for research on new survey methods, regions that have well established traditional inventories should likely maintain them, for comparative purposes, until new methods are proven.

4.7.1 Survey methods

The most desirable method is stratified random block sampling, using mark-resight procedures to make corrections for sightability and measurement of precision. In many areas, stratified total counts with classification are possible if timing is carefully chosen. Methods currently recommended for elk may be appropriate for caribou, if sightability tests using radio-collared animals are used to validate model parameters. The technique of Gasaway *et al.* (1986) has been used successfully for caribou and could also be used to generate corrected estimates.

4.7.2 Defining search areas and stratification

Because caribou are contagiously distributed, wide-ranging, and usually segregated more or less by age and sex, population definition and representative sampling is difficult. In some areas, radio-collared animals may help establish the practical limits and boundaries of a survey, while in others, apparently discrete blocks of habitat bounded by major terrain features may be used. However, few terrain features are formidable enough to impede traveling caribou.

Northern Caribou: The following variables were used by Hatler (1987) to determine search areas to focus on in Spatsizi Park (Northern Boreal Mountains ecoprovince; BWBS, SWB biogeoclimatic zones). These results may apply to other areas in northern British Columbia.

Radio-collared female caribou used open sub-alpine areas from November to April (1300 to 1600 m). They descended to their lowest mean elevation (1200 m) in May, moved to the highest elevations in June and July (1700^{+} m), and moved down slightly in fall (1600 m). Males followed a similar pattern, but were less likely to be in sub-alpine areas during the rut. Caribou used coniferous forest most from December to May. In most years, caribou were less visible in winter and spring than in summer. However, in a few winters with heavy snow fall, caribou were forced to use high elevation ridges, where a large number could be seen. Caribou were consistently most visible from July to mid-September.

Collared caribou were less widely distributed in Spatsizi in winter and spring (<2,000 km^2) than in summer. In June, they dispersed over 6,000 to 10,000 km^2. By October and November, they moved back within areas of 3,000 km^2 and about 500 km^2 respectively. Group sizes were smallest from spring to early summer, peaked in fall when they were easiest to locate, and decreased through winter.

Farnell and Gauthier (1988) used a stratified sampling design in the Yukon. Two survey areas were delineated on winter range with help from radio-collared animals. Variable sized survey blocks "...large enough such that movement of animals among [them] over a 24 hour period is unlikely", were established, and the entire area was flown intensively at low level with a fixed-wing aircraft to stratify the blocks. Based on the density of caribou and sign seen during the stratification survey, two strata (high and low) were established. They were then sampled on an optimal allocation basis by helicopter, at a search intensity of about 0.64 min/km^2. Sightability correction factors were determined only for high strata (1.3 for one area and 1.7 for the other), using more intensive (1.92 min/km^2) re-surveys of some blocks.

Mountain Caribou: Winter distribution varies greatly among mountain caribou depending on the depth and hardness of the snow pack (Antifeau 1980). Caribou move to high elevation parkland in late winter when consolidated deep snow allows them to feed on arboreal lichens. Then the population can be easily delimited using fixed-wing aircraft flights, and noting areas with tracks. Once a group of caribou establishes use of a ridge, they seldom move to another in the same winter (Simpson and Woods 1988; Seip 1990). In years when stratification flights indicate that many caribou remain in forested habitats, sampling units should be defined and searched within appropriate areas. Definition of search areas will depend on snow conditions and habitat selection of the animals.

Mountain caribou tend to use different ridges each year. In order to reliably enclose a predicted number of caribou, sampling units should be large (> 30 km^2), and incorporate several adjacent ridges. Large units can be used because sightability in parkland is high with minimal search effort (0.5 to 1.0 min/km^2). Snow conditions and timing are the most important elements in late-winter surveys for caribou, to ensure that most of the population can be seen. At other seasons, mountain caribou cannot be surveyed because they are generally in very dense coniferous forests.

4.7.3 Survey timing

Optimal timing for caribou surveys varies among the different provincial populations. The central problems in each area are to identify when caribou are occupying habitats where they are most visible, and to minimize biases in representation of sex and age classes (Hatler 1987). The best time to census caribou would be when they occur in large groups in restricted areas. Large groups of animals are rarely missed, even in densely forested (low strata) habitat, by intensive helicopter surveys. Even though animals may be more visible in summer, the large search area required may negate the benefit of reduced vegetation cover (Hatler 1987). The best time period for population surveys for northern caribou appears to be October to November, while late winter appears optimal for mountain caribou.

Northern caribou: May be accurately censused, particularly in the north (Northern Boreal Mountains ecoprovince; AT, SWBS biogeoclimatic zones), when occasional very deep snow forces animals out of timbered areas onto windblown uplands. Such winter occurrences in open uplands provide opportunities for obtaining near total counts, which can be valuable as checks against results from other sampling procedures (Hatler 1987). To take advantage of such winter distributions when they develop, a flexible budget is required. The fall rut count, used extensively in the north (Northern Boreal Mountains), has produced biased results in the past because searches of low strata and corrections for sightability have not been possible.

Mountain caribou: Results of telemetry studies among southern mountain caribou, indicate that late winter provides the best time to obtain unbiased estimates of population size and structure (Servheen and Lyon 1989; Seip 1990). Groups sizes are largest, sexual segregation is minimal, and sightability is high in March (Simpson and Woods 1988). Seip (1990) estimated that 83% of mountain caribou can be seen in March using helicopter searches of subalpine parkland habitats.

Summer snowpatch surveys have been used for population estimates in southern areas (Southern Interior Mountains ecoprovince; AT, ESSF biogeoclimatic zones) during hot weather in July and August. Some caribou use high elevation snowpatches to cool off, but the behaviour is not universal and the proportion of the populations visible may be very low (Seip 1990). Summer surveys for mountain caribou are not recommended.

4.7.4 Classification

Fall counts conducted only in high strata should not be used to estimate caribou population size or composition in British Columbia. In Spatsizi, females with calves appear less likely than those without, to be present in rut concentration areas (Hatler 1987). Calf abundance appears to be inversely proportional to group size. Post-calving surveys may be done from June 15 to 30th to determine calving success, but bulls and non-parous females will be under-represented.

There is no seasonal survey timing that allows recognition of both yearlings and the different size classes of adult males. Young caribou grow and develop quickly. Calves, especially males, may be 60 to 70% the size of their mothers, and may have antlers 20 to 30 cm long by October, when five months old. By late winter, observers must look carefully to distinguish calves from adults. Those young animals can be consistently classified as yearlings, from the air, for only a short time around their first birthdays. Even then, unless they are with their cows, they are difficult to distinguish. Level 3 classification separates three different size classes of bulls (large, medium and small), based on antler development. In northern British Columbia (Northern Boreal Mountains ecoprovince; BWBS, SWB, AT biogeoclimatic zones), those distinctions can be made with some reliability by about mid-July, and until about early November when the older males start to drop their antlers (Hatler 1986). In late-winter, large bulls are the only caribou, which consistently do not have antlers. Mature bulls can also be distinguished by antler scars, body size, their heavy chest, and prominent shoulder hump.

In the Spatsizi Park area, some females may have antlers that are larger, and with more points than is the case for many small males. One female captured had main beams 66 cm long, with 11 points on one side and 13 on the other (Hatler 1986). The most reliable method of determining sex of caribou is observation of their rumps when their tails are raised. Females of all ages show a black vulval patch, while males of all ages generally show only white in that area, with sometimes a slight faecal staining. Small antlered adults that do not have a calf at heel should be classified as unclassified adults, if a rear view is not achieved.

Calves are separable from adults primarily by their smaller size. They have shorter faces, somewhat darker coats through about mid-winter, and those with antlers usually have only spikes or forks in velvet. Table 7 shows sex/age classification characteristics of caribou.

4.7.5 Estimating numbers missed

Farnell and Gauthier (1988) generated sightability correction factors on two survey areas in the Yukon by intensive resurveys of some high stratum blocks (two stage sampling). Mark/resight estimates are a possibility, particularly where radio-collars are in use (Hatler 1987; Marshall 1990). Sightability models for caribou may be possible and should be pursued in areas where radio-collared animals are available. Since group size is an important criterion for predicting numbers missed, the large variation in group sizes of caribou should facilitate testing of the relationships between sightability, group size, and vegetative cover.

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.

ABUNDANCE: Refers to the number of individual animals . It can be expressed as relative abundance, wherein populations are ranked according to population size, or as absolute abundance, wherein the number of individuals in the population is known or estimated.

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

BIAS: The difference between the expected value of a population estimate and the true population size.

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

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

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

CREPUSCULAR: Active at twilight

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.

DIURNAL: Active during the daytime

ECOREGION (CLASSIFICATION): A unit within the ecoregion classification framework that describes units of land representing areas with similar climatic processes, physiography, vegetation zonation, and wildlife potential. Units are mapped in a hierarchical structure from ecodomain (global), ecodivision (continental), ecoprovince (subcontinental), ecoregion(provincial), to ecosection (regional).

ECOSYSTEM: An ecosystem is a functional unit consisting of all living organisms in a given area and all the non-living physical and chemical factors of the environment; can be of any size, but functions as a whole unit; also, see Ecoregion classification.

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

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.

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

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.

POPULATION INDEX: A statistic that is related to population size.

POPULATION MONITORING: The process of collecting and analyzing demographic information to evaluate population status and trend.

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

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

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

PROJECT AREA: An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventory. Sampling for species generally takes place within smaller, representative study areas so that results can be extrapolated to the entire project area.

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

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

RECRUITMENT: The number of animals within a population at a specified stage of life, usually juveniles at one year of age.

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/]

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

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

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

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

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

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

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

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

Literature Cited

Antifeau, T.D. 1980. North Thompson River mountain caribou study. A progress report to the Min. Environ., Fish and Wildlife Br., Kamloops, BC. 35pp.

Ballard, W.B. 1975. Mountain goat survey techniques evaluation. Alaska Dep. Fish and Game, Pittman-Robertson Prog. Rep., Proj. W-17-7, Job 12.2R, Juneau. 21pp.

Boer, A.H., G.R. Redmond and T.J. Pettigrew. 1989. LORAN-C: A navigation aid for aerial surveys. J. Wildl. Manage. 53(1):228-230.

Bowden, D.C., A.E. Anderson and D.E. Medin. 1984. Sampling plans for mule deer sex and age ratios. J. Wildl. Manage. 48:500-509.

Burles, D.W., and M. Hoefs. 1984. Winter mortality of Dall Sheep, *Ovis dalli dalli*, in Kluane National Park, Yukon. Can. Field-Nat. 98:479-484.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, NY. 234pp.

Caughley, G., and D. Grice. 1982. A correction factor for counting Emus from the air and its application to counts in Western Australia. Aust. Wildl. Res. 9:253-259.

Chadwick. D.H. 1983. A beast the color of winter - the Mountain Goat observed. Sierra Club Books. San Francisco. 208pp.

Cichowski, D.B., D. Haas and G. Schultze. 1991. Population estimation of mountain goats in the Babine Mountains Recreation Area, July 22-24. Unpubl. Rep., BC Parks Br., Prince George, BC. 16pp.

Cochrane, W.G. 1977. Sampling techniques. 3rd ed. John Wiley and Sons, New York, NY. 428pp.

Cook, R.D., and J.O. Jacobsen. 1979. A design for estimating visibility bias in aerial surveys. Biometrics 35:735-742.

Czaplewski, R.L., D.M. Crowe and L.L. McDonald. 1983. Sample sizes and confidence intervals for wildlife population ratios. Wildl. Soc. Bull. 11:121-128.

Demarchi, D., B. Fuhr, B.A. Pendergast and A.C. Stewart. 1983. Wildlife capability classification for British Columbia: An Ecological (Biophysical) Approach for Ungulates. MOE Manual 4. Min. Environ., Victoria, BC. 56pp.

Eastman, D.S. 1977. Research needs for mountain goat management. Pages 160-168 *in* W. Samuel and W.G. MacGregor (eds). Proc. 1st Internatl. Mountain Goat Symp., Kalispell, MT.

Eastman, D.S., R. Page and G. Jones. 1990. Research and development priorities for caribou management in British Columbia. Pages 54-72 *in* D. Hebert (ed). Proc. Caribou Workshop, 24-26 Nov. 1988, Williams Lake. B.C. Min. Environ., Victoria, BC.

Elliott, J.P. 1985. Muskwa wolf management project of northeastern B.C. 1984-1985 annual report. Wildl. Work. Rep. No. WR-14, Wildl. Br., B.C. Min. Environ., Fort St. John, BC. 44pp.

Farnell, R., and D.A. Gauthier. 1988. Utility of the stratified random quadrat sampling census technique for woodland caribou in Yukon. Proc. 3rd North Amer. Caribou Workshop, Alaska Dept. Fish and Game, Juneau. Wildl. Tech. Bull. No. 8:119-132.

Floyd, T.J., L.D. Mech and M.E. Nelson. 1979. An improved method for censusing deer in deciduous-coniferous forests. J. Wildl. Manage. 43:258-261

Forbes, R.D. 1992. Meager Creek goat census - 1992. Unpubl. rep.,B.C. Min. Environ., Surrey, BC. 5pp.

Foster, B.R. 1982. Observability and habitat characteristics of the mountain goat (*Oreamnos americanus* Blainville 1816) in west-central British Columbia. M.Sc. Thesis, U.B.C. 134pp.

Fox, J.L. 1984. Population density of mountain goats in southeast Alaska. Pages 51-60 *in* M. Hoefs (ed). Proc. Fourth Biennial Symp., Northern Wild Sheep and Goat Council. Yukon Wildl. Br., Whitehorse, BC.

Fox, J.L. 1977. Summer mountain goat activity and habitat preference in coastal Alaska, as a basis for assessment of survey techniques. Pages 190-199 *In*: W. Samuel and W.G. MacGregor (eds). Proc. 1st Internatl. Mountain goat Symp.,Kalispell, MT.

Fuller, T.K. 1990. Dynamics of a declining white-tailed deer population in North-Central Minnesota. Wildl. Monogr. 110:1-37.

Gasaway, W.C., and S.D. Dubois. 1987. Estimating moose population parameters. Swedish Wildlife Research, Suppl. 1:603-617.

Gasaway, W.C., S.D. Dubois and S.J. Harbo. 1985. Biases in aerial transect surveys for moose during May and June. J. Wildl. Manage. 49(3):777-784.

Gasaway, W.C., S.D. Dubois, D.J. Reed and S.J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the Univ. Alaska, Number 22, Institute of Arctic Biology. 108pp.

Geist, V. 1971. Mountain sheep: A study in behaviour and evolution. Univ. Chicago Press, Chicago. 383pp.

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68(5):364-72.

Gerrodette, T. 1993. TRENDS: Software for a power analysis of linear regression. Wildl. Soc. Bull. 321:515-6.

Gill, R.B., L.H. Carpenter and D.C. Bowden. 1983. Monitoring large animal populations: The Colorado experience. Trans. N. Amer. Wildl. Conf. 48:330-341.

Grigg, G.C. 1979. Aeronautical aspects of biological aerial surveys. Proceedings of a workshop held in University House, Australian National University, Canberra, Australia. p.63-74+

Harper, F.E. 1985. Moose Inventory Report for Peace River Area, Management Units 7-32 and 7-44 Winter 1984-85. Unpubl. rep., BC. 29pp.

Hatler, D.F. 1986. Studies of radio-collared caribou in the Spatsizi Wilderness Park area, British Columbia, l980-84. Spatsizi Assoc. for Biol. Res., Rep. No. 3. Smithers, BC. 202pp.

Hatler, D.F. 1987. Perspectives on inventory of Caribou in British Columbia. Spatsizi Association for Biological Research Rep. No. 4, Wildl. Rep. No. R-14, MOEP, Victoria, BC. and SABR, Smithers, BC. 93pp.

Hatler, D.F. 1989. Mountain goat surveys in Tatlatui Provincial Park, British Columbia, 1989. Unpubl. Rep. for B.C. Min. Environ., Lands and Parks, Northern Region, Prince George, BC. 20pp.

Hatler, D.F. 1990. Wildlife survey results, Windy Craggy Study Area, June 1990. Unpubl. rep. for Norecol Environmental Consultants, Vancouver, BC. 23pp.

Hatler, D.F., and W.G. Hazelwood. 1984. Mountain goat surveys in Spatsizi Wilderness Park, British Columbia, July 1984. Unpubl. rep., BC. Min. Lands, Parks and Housing, Victoria, BC. 81pp.

Hatler, D.F., and W.G. Hazelwood. 1985. Mountain goat surveys in the Tatlatui, Spatsizi and Mt. Edziza Provincial Park areas, British Columbia, July 1985. Unpubl. rep., BC. Min. Lands, Parks and Housing, Victoria. 97pp.

Hatter, I., and D.F. Hatler. 1990. How imperfect is caribou inventory?: a response. Pages 47-52 *in* D. Hebert (ed). Proc. Caribou Workshop, 24-26 Nov. 1988, Williams Lake. BC. Min. Environ., Victoria, BC.

Hazelwood, W.G. 1983. Fish and Wildlife 1982/83 ungulate surveys. Unpubl. rep., B.C. Fish and Wildl. Br., Victoria, BC. 53pp.

Hebert, D.M., and W.G. Turnbull. 1977. A description of southern interior and coastal mountain goat ecotypes in British Columbia. Pages 126-146 *in* W. Samuel and W.G. MacGregor (eds.) Proc. First. Intl. Mtn. Goat Symp. Kalispell, Mont. 243pp.

Hebert, D. and R. Woods. 1984. A preliminary analysis of intensive, unreplicated survey data for mountain goat populations in British Columbia. Pages 506-513 *in* M. Hoefs (ed).Proc. Fourth Biennial Symp., Northern Wild Sheep and Goat Council. Yukon Wildl. Br., Whitehorse, BC.

Hoefs, M., and M. Bayer. 1983. Demographic characteristics of an unhunted Dall sheep (*Ovis dalli dalli*) population in southwest Yukon, Canada. Can. J. Zool. 61:1346-1357.

Hoefs, M., and I.McT. Cowan. 1979. Ecological investigation of a population of Dall sheep (*Ovis dalli dalli* Nelson). Syesis 12: Supplement 1.

Houston, D.B., B.B. Moorhead and R.W. Olson. 1986. An aerial census of mountain goats in the Olympic Mountain Range, Washington. Northwest Sci. 60:131-136.

Houston, D.B., B.B. Moorhead and R.W. Olson. 1991. Mountain goat population trends in the Olympic Mountain Range, Washington. Northwest Sci. 65:212-216.

Ingham, L. 1991. Donald Block 1991 Winter Moose Inventory, Environmental Consulting, Harrop, BC for B.C. Hydro.

Jones, G.W. 1984. Guidelines for wildlife inventory in provincial parks. Parks and Outdoor Recreation Division, BC. 32pp.

Jury, D.N. 1984. Mountain Goat Surveys MU 3-35, 36, 37, 42. Unpubl. rep., BC. Min. Environ., Kamloops, BC. 11pp +.

Jury, D.N. 1985. A Random Stratified Block Moose Survey of MU 3-12. Jan 1985. Unpubl. rep., BC. Min. Environ., Kamloops, BC. 22pp.

Jury, D.N. 1986. MU 3-19 Stratified Random Block Moose Survey Unpubl. rep., BC. Min. Environ., Kamloops, BC. 23pp.

Jury, D.N. 1987. MU 3-30 Stratified Random Block Moose Survey. Unpubl. rep., BC. Min. Environ., Kamloops, BC. 22pp.

Krebs, C.J. 1989. Ecological Methodology. Harper & Row, Publishers, Inc. New York, NY. 654pp.

Magnusson, W.E., G.J. Caughley and G.C. Grigg. 1978. A double survey estimate of population size from incomplete counts. J. Wildl. Manage. 42(1):174-176.

Marshall, R. 1990. An assessment of an attempted survey of the Tweedsmuir Park caribou herd (1990). Unpubl. rep., BC. Min. Environ., Smithers, BC. 13pp.

Nichols, L. 1978. Dall's sheep. Pages 173-189 *in* J.L. Schmidt and D.L. Gilbert (eds). Big game of North America, ecology and management. Wildl. Manage. Inst., Stackpole, Harrisburg, PA.

Nichols, L. 1980. Mountain goat management techniques studies. Alaska Dep. Fish and Game, Pittman-Robertson Final Rep., W-17-9, Job 12.2r and W-17-10 and 11, Job 12.3 R, Juneau. 51pp.

Nichols, L. 1985. Mountain goat fidelity to given areas by season and seasonal movements. Alaska Dep. Fish and Game, Pittman-Robertson Final Rep., W-21-1 and 2, W-22-1,2 and 3, Job 12.5R, Juneau. 72pp.

Norton-Griffiths, M. 1978. Counting animals. Handbook #1 Serengeti Ecological Monitoring Programme. Nairobi, Kenya. 2nd ed. 139pp.

Oswald, K. 1982. A manual for aerial observers of moose. Ontario Min. of Nat. Res. 103pp.

Page, R.E. 1990. How imperfect is caribou inventory? Pages 34-46 *in* D. Hebert (ed). Proc. Caribou Workshop, 24-26 Nov. 1988, Williams Lake. B.C. Min. Environ., Victoria, BC.

Peck, V.R., and J.M. Peek. 1991. Elk, *Cervus elaphus*, habitat use related to prescribed fire, Tuchodi River, BC.

Quayle, J.F., A.G. MacHutchon and D.N. Jury. 2001. Modeling moose sightability in south-central British Columbia. Alces (37).

Resources Inventory Committee. 1998. 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 Version 2.0. Min. Environ., Lands and Parks, Resources Inventory Branch, Victoria, BC. 225pp.

Salwasser, H., C.K. Hamilton, W.B. Krohn, J. Lipscomb and C. Thomas. 1983. Monitoring wildlife and fish: mandates and their implications. Trans. N. Amer. Wildl. Conf. 48:297-307.

Samuel, M.D. 1984. An evaluation of elk sightability in North Central Idaho with application to Aerial Census and herd composition counts. Ph.D. Thesis, Univ. Idaho. 118pp.

Samuel, M.D., R.K. Steinhorst, E.O. Garton and J.W. Unsworth. 1992. Estimation of wildlife population ratios incorporating survey design and visibility bias. J. Wildl. Manage. 56:718-725.

Schaeffer, R.L., W. Mendenhall and L. Ott. 1979. Elementary Survey Sampling. 2nd. ed. Duxbury Press, North Scituate, Mass. 279pp.

Schultze, G. 1992. March 1992 Inventory of the Todagin sheep population. Unpublished report, Wildl. Br., B.C. Min. Environ., Land and Parks, Smithers, BC. 16pp.

Seip, D.R. 1990. Ecology of woodland caribou in Wells Gray Provincial Park. Wildl. Bull. No. B-68, B.C. Min. Environ., Wildl. Br., Victoria, BC. 60pp.

Servheen, G., and L.J. Lyon. 1989. Habitat use by woodland caribou in the Selkirk Mountains. J. Wildl. Manage. 53:230-237

Simmons, N.M. 1971. An inexpensive method of marking large numbers of Dall sheep for movement studies. Pages 116-126 *in* E. Decker (ed). Trans. First North Amer. Wild Sheep Conf., Dep. Fishery and Wildl. Biol., Colorado State Univ., Fort Collins, CO.

Simmons, N.M., M.B. Bayer and L.O. Sinkey. 1984. Demography of Dall's sheep in the Mackenzie Mountains, Northwest Territories. J. Wildl. Manage. 48:156-162.

Simpson, K. 1991. Peace River Site C Hydroelectrical Development Environmental Assessment Consumptive Wildlife Resources. Unpubl. rep. for B.C. Hydro. June 1991. 45pp.

Simpson, K. 1992a. Elk inventory in the Elk valley. Unpubl. rep., B.C. Min. Environ., Cranbrook, BC.

Simpson, K. 1992b. Elk inventory in the East Kootenay Trench. Unpublished report for B.C. Environ., Cranbrook, BC. 58pp.

Simpson, K., and G.P. Woods. 1988. Movements and habitats of caribou in the mountains of southern B.C. Min. Environ. and Parks, Wildl. Bull. No. B-57, Victoria, BC. 36pp.

Simpson, K., and L.W. Gyug. 1991. Movements, habitats and status of mule deer and moose populations influenced by the Okanagan Connector Freeway. Unpubl. rep., Min. Environ., Penticton and Min. Highways, Victoria, BC. 60pp.

Simpson, K., D. Hatler, J. Stroman, I. Hatter and J.P. Kelsall. 1993. Aerial inventory of large mammals in British Columbia. Unpubl. CRII report to Min. Environ., Victoria, BC. 163pp.

Sinclair, A.R.E., and J.R. Grimsdell. 1978. Population dynamics of large mammals. Handbook No. 5. Serengeti Ecological Monitoring Programme, Nairobi, Kenya. 45pp.

Smith, B.L. 1988. Criteria for determining age and sex of American Mountain Goats in the field. J. Mamm. 69(2):395-402.

Smith, C.A. 1984. Evaluation and management implications of long-term trends in coastal mountain goat populations in southeast Alaska. Pages 395-424. *in* M. Hoefs (ed). Proc. Fourth Biennial Symp., Northern Wild Sheep and Goat Council. Yukon Wildl. Br., Whitehorse.

Smith, C.A. and K.T. Bovee. 1984. A mark-recapture census and density estimate for a coastal mountain goat population. Pages 487-498 *in* Hoefs, M. (ed). Proc. of the Fourth Biennial Symp. of the N. Wild Sheep and Goat Council, April 30- May 3, 1984, Whitehorse, YT.

Snedecor, G.W., and W.G. Cochrane. 1978. Statistical Methods. 6th ed. Iowa State Univ. Press. Amers, IA. 593pp.

Stelfox, J.G. 1990. Radium Bighorn sheep herd. Cooperative management plan. Kootenay National Park and B.C. Min. Environ., Wildl. Br., Cranbrook, BC. 67pp.

Stevenson, S.K., and D.F. Hatler. 1985. Woodland caribou and their habitat in southern and central British Columbia. B.C. Min. For., Land Manage. Rep. No. 23, Victoria. 355pp.

Steventon, D. 1984. Development of a moose inventory program, Peace Zone, Northern Region. Unpubl. interm. rep., Fort St. John. 15pp.

Steventon, D. 1985. The white sheep of northwest British Columbia - a population and range inventory. Unpubl. rep., B.C. Min. Environ., Smithers, BC. 28pp.

Steventon, D. 1988. Southeast Skeena Moose Inventory and Implications for management (Draft). Unpubl. rep., B.C. Min. Environ. and Parks, Smithers, BC. 12pp.

Tärnhuvud, T. 1985. Development of moose survey methods, unpublished report, Swedish Univ. Agricultural Sciences, Dept. of Wildlife Ecology, Uppsala, Sweden. 18pp.

Unsworth, J.W., L. Kuck, E.O. Garton and B.B. Compton. 1987. Elk ecology job progress report W-160-R-14, Study 11, Idaho Dept. of Fish and Game. 44pp.

Unsworth, J.W., F.A. Leban, D.J. Leptich, E.O. Garton and P. Zager. 1994. Aerial Survey: User's Manual with Practical Tips for designing and conducting aerial big game surveys. 2nd ed. Idaho Dept. Fish Game, Boise, ID. 84pp.

Van Ballenberghe, V. 1983. Rate of increase in moose populations. *Alces* 19:98-117.

Van Drimmelen, B. 1986. Telkwa Mountains mountain goat inventory. Unpubl. rep., Wildl. Br., B.C. Min. Environ., Smithers, BC. 20pp.

White, G.C. 1996. NOREMARK: Population estimation from mark-resighting surveys. Wildl. Soc. Bull. 24:50-52.

Zar, J.H. 1984. Biostatistical analysis, 2nd ed. Prentice-Hall, Inc. Englewood Cliffs, NJ. 718pp.

Appendices

Appendix A. Biogeoclimatic zones and broad ecosystem units for wildlife surveys in British Columbia

Biogeoclimatic zones (BGC) are climatically distinct areas usually named after the dominant tree species. The zones are differentiated by distinct vegetation and soil patterns. There are 14 biogeoclimatic zones in B.C.

1. Alpine Tundra (AT)
2. Spruce-Willow Birch (SWB)
3. Boreal White and Black Spruce (BWBS)
4. Sub-Boreal Pine-Spruce (SBPS)
5. Sub-Boreal Spruce (SBS)
6. Mountain Hemlock (MH)
7. Engelmann Spruce - Subalpine Fir (ESSF)
8. Montane Spruce (MS)
9. Bunchgrass (BG)
10. Ponderosa Pine (PP)
11. Interior Douglas-Fir (IDF)
12. Coastal Douglas-Fir (CDF)
13. Interior Cedar-Hemlock (ICH)
14. Coastal Western-Hemlock (CWH)

A Broad Ecosystem Unit is 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). Broad Ecosystem Units are meant to be used for small scale mapping of large area, mainly at the 1:250 000 scale.

Within Broad Ecosystem Unit, variation of vegetation and animal use occurs by Biophysical Area (Wildlife Ecosystem), Biogeoclimatic Unit, site characteristics and successional stage.
For a list of Broad Ecosystem Units of B.C. see *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* Version 2.0 (RIC 1998) on the RIC website at http://www.for.gov.bc.ca/ric/Pubs/teEcolo/index.htm.

Appendix B. Habitat Class Modifiers and Successional Stages

Habitat Class Modifiers

Symbol	Phase
c	coarse-textured soils
g	gently sloping (alpine only)
f	fine-textured soils
l	shallow (lithic) soils
m	moist soils
n	cool (northerly) aspect (west northwest to southeast)
s	steep, warm (southerly) aspect (southeast to west)
t	moderate sloped, warm (southerly) aspect (southeast to west)
u	upper elevation, gentle slope (forested areas)

Successional Stages

Symbol	Stage
0	non-forested units (alpine, wetlands)
1	recent disturbance (fire, logging)
2	young forests, coniferous (< 60 years)
3	young forests, broad-leaved or mixed (< 60 years)
4	mature forests, coniferous (60 to 140 years)
5	mature forests, broad-leaved or mixed (60 to 140 years)
6	old-growth (> 140 years)

Appendix C. Moose sightability model for south-central British Columbia. Reprinted with permission from Alces, vol. 37.

MODELING MOOSE SIGHTABILITY IN SOUTH-CENTRAL BRITISH COLUMBIA

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ABSTRACT: We developed a model to correct sightability bias in aerial surveys of moose in British Columbia, following the approach of Anderson (1994). Sightability trials were conducted in the province's southern interior by searching sample blocks where radio-collared moose were known to occur. Relevant attributes that were believed to affect the sightability of collared moose were recorded, and used as the basis for a logistic regression model of sightability. Univariate analysis of seen/unseen moose revealed percent vegetation cover, percent snow cover, and daily temperature were all significantly influencing whether a moose was seen or not. However, multivariate analysis suggested that vegetation cover was the only significant influence on sightability. This mirrors the results of analysis of moose trials in western Wyoming that used the same study variables, as well as 6 additional ones. Two logistic regression models were developed for moose sightability; one based on 5 classes of vegetation cover and a second, apparently less accurate model, based on 3 classes of vegetation cover.

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Key Words: Aerial census, sightability, visibility bias.

Aerial surveys are widely used to census moose in British Columbia. It is recognized, however, that aerial surveys underestimate animal abundance due to visibility or sightability bias, the failure to observe all animals from the air (Caughley 1974, LeResche and Rausch 1974, Samuel *et al.* 1987). The magnitude of sightability bias depends on numerous factors, including animal behaviour and dispersion, observers, weather, vegetation cover and cover type, search rate, snow cover and condition, and equipment. Sightability bias not only limits the usefulness of observed population estimates, but may also bias estimates of age and sex ratios if habitat selection by bulls, cows, or cows with calves results in different visibility factors (Samuel *et al.* 1987).

In British Columbia, aerial surveys generally use a stratified random block (SRB) design (Gasaway *et al.* 1986). The most common means of correcting for sightability bias during SRB surveys is the sightability correction factor (SCF); usually the product of an observed SCF (SCFo) and a correction factor constant (SCFc) (Gasaway and DuBois 1987). Both subjective and quantitative methods have been used to estimate SCFc's in British Columbia. These include a modification to Gasaway *et al.*'s (1986) technique in which high intensity searches are performed at the outset of the survey with the intent of eliminating the necessity for estimating SCFo. The SCFc is then directly applied to the estimated number of animals (Hatter 1992).

Despite these attempts to correct for sightability bias in B.C., Hatter (1992) suggested that the problem has not been adequately resolved. Most survey areas in B.C. contain a mosaic of diverse habitat types ranging from relatively open habitats dominated by deciduous shrubs to closed coniferous forest stands. Best guesses at SCFc, based on survey evaluations, provide no objective assessment of reliability. Most surveys have not had a large enough sample to properly measure sightability bias (sample size bias), and even for more intensive searches, the SCFc's are probably still biased because it is unlikely that searchers see all of the moose (model bias). As well, precision tends to be overestimated when variance estimates for the SCFc are not used when calculating confidence intervals (CI) on a density estimate.

For these reasons, the decision was made to develop a moose sightability model, similar to an elk model developed in Idaho (Samuel 1984, Samuel *et al.* 1987) and a moose model recently developed in Wyoming (Anderson 1994, Anderson and Lindzey 1996). Aerial trials would be undertaken to determine the influence of environmental and observer factors on the sightability of moose during standard surveys. Trial data would then be used to develop a predictive model of sightability that could be incorporated into a SRB or total count survey design.

STUDY AREA

Sightability trials were conducted on moose winter range within the upper portions of the Deadman River and Criss Creek valleys, 40-50 km northwest of Kamloops, British Columbia. Both drainages are relatively shallow sided in the upper reaches (1000 - 1300 m ASL) where trials were conducted. Trials were conducted in the Sub-Boreal Pine-Spruce, Montane Spruce, and Interior Douglas Fir biogeoclimatic zones of the two drainages (BC Ministry of Forests 1992). These three zones are characterized by the highest densities of moose in south-central British Columbia (Jury 1992).

The characteristic tree species of the Montane Spruce zone are Engelmann spruce (*Picea engelmannii*) and hybrid spruce (*Picea glauca x engelmannii*) and varying amounts of subalpine fir (*Abies lasiocarpa*). Due to past wildfires, successional forests of lodgepole pine (*Pinus contorta*) and trembling aspen (*Populus tremuloides*) are common. The Sub-Boreal Pine-Spruce zone is also characterized by many even-aged lodgepole pine stands as a result of past fires. A minor amount of white spruce (*Picea glauca*) regeneration occurs as well. At higher elevations in the Interior Douglas Fir zone, fires have frequently created even-aged lodgepole pine stands, but Douglas-fir (*Pseudotsuga menziesii*) is the dominant tree.

The moose winter range in the upper Deadman and Criss Creek valleys is characterized by extensive riparian bottomlands of willow (*Salix spp.*) and red osier dogwood (*Cornus stolonifera*). These heavily used forage areas are bordered by dense stands of Engelmann spruce that provide important security and thermal cover. The valley slopes, low hills and ridge tops support mixed stands of trembling aspen, lodgepole pine and Douglas fir, important foraging and resting habitats during the early and mid-winter period. Dense conifer stands scattered throughout the winter range provide important thermal cover which moose move into in mid February.

METHODS

Sightability Trials

Moose were captured and radio-collared during the winters of 1991/92 and 1995/96. Animals were darted from a helicopter and immobilized with 3.6 - 3.9 mg of Carfentanil. Individual moose were ear-tagged with a unique color combination of tags and radio-collared (Lotek Engineering Inc., Newmarket, Ont.). The sex of each moose was determined and its age estimated before 400 mg of the Cartentanil antagonist, Naloxone hydrochloride (Narcan), was administered to aid recovery.

During sightability trials, attempts were made to standardize all factors that were controllable, such as, aircraft, pilot and observers. A Bell 206 helicopter was used for all trials, and standard roles were assigned to observers. The navigator sat next to the pilot and they radio-located moose, delineated block boundaries, searched for moose, and recorded data. The primary observer sat behind the navigator and was responsible for determining the height and speed of the search and making the final decision on data to be recorded. An additional observer sat behind the pilot during all trials. Temperature was recorded at the beginning of each day.

The trial procedure differed from that used by Samuel *et al.* (1987) and Anderson (1994). The general location of the animal was used to define the survey block boundaries. The navigator determined the general location of one or more radio-collared moose by flying over them at 700 - 1000 m above the ground. The navigator, or in later trials, the pilot, got a rough idea of where the moose were located, but not a specific location. The other observers could not hear the radio receiver, so remained unaware of the animal's general location. A rectangular survey block encompassing 1.0 - 5.5 km^2 was drawn around the moose's general location on a 1:60,000-scale air photo. Prominent terrain features were used as sides or corners. Block boundaries were drawn such that the moose could have been anywhere within the block.

Once a block was defined, an intensive search of the block was flown at approximately 100 - 200 m above ground (depending on habitat type) at a ground speed of 80 - 95 km/hr. As much as possible, search intensity was kept consistent and equal within and between sample blocks. All observers searched the block and when a group (*i.e.*, 1 or more moose) was seen, the observer directed the attention of the pilot and other observers to the area. The activity of (*i.e.*, moving, standing, or bedded) and percent vegetation cover surrounding the first animal sighted in the group was immediately noted. Moose were closely examined to determine whether they were collared or not. Whenever a radio-collared moose was observed, animal activity, percent vegetation cover, cover type, and percent snow cover were recorded.

Estimating percent vegetation cover from the helicopter required a certain amount of mental averaging. Figures developed by Unsworth *et al.* (1991) were used to help in these estimations. The percent cover of vegetation was considered to be the average canopy cover within a 10 m radius of the first moose sighted in a group, even if the first moose seen was not the member of the group collared with a radio transmitter. It was rationalized that the rest of the moose in the group would have remained unseen if not for the conditions associated with the first moose seen. Any vegetation that blocked the observers' view of the moose was considered part of the canopy (Unsworth *et al.* 1991). Cover was generally estimated at an oblique angle from the height that the search was conducted. Cover type was recorded in this study but was not recorded by Samuel *et al.* (1987). Although nine cover types were previously described by MacHutchon and Jury (1994), these were reduced to 3 cover types for statistical analyses, *i.e.*, 1) open meadow/shrub; 2) deciduous/mixed forest; and 3) conifer forest. For surveys prior to 1999, the search time was noted upon the completion of the search, including the time spent circling groups of moose looking for a radio-collar. Group composition was not consistently documented for all trials, and so these data are not complete.

Any radio-collared moose that were not seen within the survey block during the standard search were located with the telemetry receiver. Once the moose was located, group composition, animal activity, percent vegetation cover, cover type, and percent snow cover were recorded.

Model Development

The first step in model development was to determine the visibility of moose for the different classes of each independent variable, such as sex/age class, primary observer, animal activity, cover type, group size, vegetation cover, snow cover, and search rate.

Univariate analyses, using the maximum number of observations available for each variable, were used to statistically test the relationship between the independent variables above and the dichotomous dependent variable, *i.e.*, moose groups seen or missed (Anderson and Lindzey 1996). The maximum number of observations available for each variable were used Categorical or discrete independent variables (*i.e.*, sex/age class, primary observer, animal activity, and cover type) were tested using likelihood ratio chi-square analysis (also called the G-test) (StatSoft 1996). Continuous independent variables (*i.e.*, group size, % vegetation cover, % snow cover, and search rate) were tested using univariate logistic regression (SAS Inc. 1996; *sensu* Anderson 1994). Pearson correlation coefficients were used to evaluate the correlation between variables that significantly influenced sightability. Other interactions involving continuous variables were examined using t-tests and analysis of variance techniques; Chi-square contingency analysis was used to compare categorical variables (StatSoft Inc. 1996).

Multivariate analyses were conducted using stepwise logistic regression (SAS Inc. 1996) to determine which independent variables had a significant influence on the dependent variable (i.e., groups seen or missed; Samuel *et al.* 1987, Anderson and Lindzey 1996). A variable was considered to be important in predicting sightability when its stepwise improvement Chi-square exceeded a 5% significance level based on improvement in the likelihood ratio (Samuel *et al.* 1987).

In logistic regression, the probability of an event, *y*, occurring is directly estimated from the model, which can be written as:

$$P(y)=\frac{e^{z}}{1+e^{z}}$$

where Z is the linear combination $Z=B_0+B_1X_1+B_2X_2+...+B_pX_p$; B_0 and $B_1 ... B_p$ are coefficients estimated from the data; $X_1 ... X_p$ are the independent variables; and e is the base of the natural logarithms, approximately 2.718. The inverse of P(y) is the correction factor applied to each group observed during surveys (Anderson and Lindzey 1996).

RESULTS

Sightability Trials

Thirty-three moose were captured and radio-collared, 25 males and 16 females. Most moose were involved in at least one sightability trial. Trials were flown in January, February, March, and December 1993; January, and March, 1994; and February and December 1996; and March 1999. Ninety-eight blocks containing 1-3 radio-collared moose were surveyed for a total of 105 trials. Ninety-four of these trials had a complete set of variables. The remaining 11 trials were incomplete as the focal moose had been moving, thereby not allowing estimation of the percent vegetation cover at its initial position. Trials were discarded for animals missed during the initial search that were found moving once a receiver was used to locate them. This raised a concern that the activity "moving" could only be reliably recorded for moose that were not missed during trials. As a result, standing and moving were amalgamated into one activity (*i.e.*, active) in the analyses to eliminate this potential bias.

The helicopter pilot was the same during 1993, 1996, and 1999, but different during 1994; however, differences in pilots did not appear to effect sightability ($X^2 = 0.007$, $P = 0.935$).

Model Development

Sightability data were obtained on 105 groups of moose under a variety of conditions (Table 1). Overall sightability was 49% for these 105 groups. There was no significant difference in the visibility of bull groups or cow groups ($X^2 = 0.59$, $P = 0.4436$). Although data collected in 1999 did not separate out cow/calf groups, analysis of data prior to 1999 revealed no difference in visibility of bull groups (50%, $n = 26$), cow groups (72%, $n=18$) and cow/calf groups (42%, $n = 12$; $X^2 = 3.37$, $P = 0.185$). In addition, there was no difference in the average vegetation cover used by bull groups (mean = 47%, SD = 21%, $n = 38$) versus cow groups (mean = 41%, SD = 21%, $n = 56$; $t = 1.25$, $P = 0.214$). Cow groups appeared to use non-conifer cover types more than bulls, reflected by a significant difference in the use of the 3 habitat cover types by cows and bulls ($X^2 = 8.00$, $df = 2$, $P = 0.018$).

Univariate analyses of the independent variables suggested that percent vegetation cover, percent snow cover and daily temperature significantly influenced moose sightability (Table 1). Correlations between daily temperature, percent snow cover, and percent vegetation cover were insignificant with the exception of a significant, but weak, correlation between daily temperature and percent vegetation cover ($r = 0.23$, $P < 0.05$). As well, daily temperature was not significantly affected by animal activity nor habitat type ($F = 0.34$, $P = 0.562$ and $F = 0.096$, $P = 0.759$, respectively).

Habitat type was insignificant even though moose in openings or in open forest were more visible than those in conifer forest (Table 1), and there was a significant difference ($t = 3.69$, $P = 0.001$) in mean vegetation cover at moose locations in spruce dominated forest (mean = 60%, SD = 23%, $n = 18$) versus pine dominated forest (mean = 40%, SD = 21%, n =35). Activity was also insignificant to sightability although bedded moose occupied significantly greater ($t = 2.05$, $P = 0.043$) vegetative cover (mean = 47%, SD = 21%, $n = 30$) than did active moose (mean = 36%, SD = 25%, $n = 74$). Primary observer was held constant for the majority of surveys (81%) and did not influence sightability. Similarly, search rate did not have a significant influence on sightability, although search rates were often higher for conifer-dominated blocks, exceeding 5.00 min/km^2 in 53% of the cases ($n = 49$).

Multiple logistic regression analysis of the 94 complete trials indicated that percent vegetation cover was the only important predictor of moose sightability (Table 1). None of the other variables significantly influenced sightability once percent vegetation cover was entered into the stepwise model. Under certain vegetation cover, moose had a very low probability of being seen, as sightability decreased substantially when vegetative cover approached 60% (Figure 1). Of 18 moose in closed forest stands with >60% cover, only 1 was detected. In three cases, extensive searches with the telemetry receiver were conducted and the moose still could not be seen. The observers had to land, search the location site, and backtrack to where the moose had been bedded. No moose were seen in >70% cover. In Wyoming, Anderson (unpubl. data) found that sightability decreased substantially above 40% cover, decreasing to zero at >70% cover.

Anderson and Lindzey (1996) felt it was necessary to group percent vegetation cover into broader classes. This would a) reduce covariate patterns, thus reducing computational complexity and allowing P-values to be obtained for imbalanced categorical variables included in the model, and b) reduce the potential bias from field estimation errors of percent vegetation cover. Although both Anderson (1994) and Anderson and Lindzey (1996) used 17% intervals, the classes used for percent vegetation cover in Table 1 and Figure 1 were based on categories of 20% as this produced the greatest X^2 value when logistically regressed against sightability (compared to $X^2 =$

37.47 at 17.5% and $X^2 = 40.51$ at 10%). These classes were then treated as a continuous variable in regression analysis.

Preliminary Sightability Models for South-central B.C. — Our initial sightability model used vegetation cover classes of 20% as outlined in Table 1. The linear regression portion of this model was:

$Z = -4.2138 + 1.5847$(Vegetation Cover Class 1 - 5).

The estimated standard errors for the intercept and vegetation cover class were 0.8844 and 0.3339, respectively. This model correctly classified 78% of 51 observations where a moose was seen and 79% of 43 observations where a moose was not seen; overall correctly classifying 79% of the total 94 observations as seen or missed.

A second sightability model was developed in which vegetation cover was categorized into just three classes, <30% (87% seen), between 30 & 60% (55% seen), and >60% (6% seen). Using fewer categories was intended to reduce observer bias in estimating cover in the field, as well as reduce the time and cost necessary to classify each moose group seen. The linear regression portion of this model was:

$Z = -4.3179 + 2.1972$(Vegetation Cover Class 1 - 3).

The estimated standard errors for the intercept and vegetation cover class were higher than the 5-class model, at 0.9485 and 0.4792, respectively. This model underestimated the number of moose seen, correctly classifying only 53% of 51 observations where a moose was seen. In contrast, it correctly classified 91% of 43 observations where a moose was not seen, and overall, correctly classified 70% of the total 94 observations as seen or missed.

DISCUSSION

Estimates of sightability based on univariate analysis alone will tend to overestimate the number of significant factors, usually because these factors are correlated with the dominant variables; in this case, percent vegetation cover (Samuel *et al.* 1987, Anderson and Lindzey 1996). This was the case in model development from the south-central British Columbia data. Univariate analysis revealed that three variables were significant to sightability: percent vegetation cover, snow cover and daily temperature. The first two of these have obvious influences on an aerial observer's ability to detect a moose, by obscuring the line of sight between observer and moose, and affecting the continuity of the contrasting, white background. However, multivariate analyses indicated that percent vegetation cover was the main factor influencing the sightability of moose, so much so that snow cover and daily temperature became insignificant. In similar studies, Anderson (1994) and, subsequently, Anderson and Lindzey (1996) evaluated the relationship of 12 biological and procedural variables to the sightability of 104 moose groups containing radio-collared individuals on 3 study areas in western Wyoming. After multivariate analysis, they found percent vegetation cover to be the only variable with significant influence on sightability. In addition to the variables used in this study, Anderson and Lindzey (1996) also included topography, light intensity, group size, time of day, study area, and distance of the moose group to the flight.

The importance of vegetation cover on ungulate sightability has been stressed by numerous studies (see Samuel *et al.* 1987), and so its significance in a British Columbia model is not unexpected. In several other studies, vegetation appears to influence sightability in concert with behavioral variables such as activity and group size. Drummer and Aho (1998) found vegetation cover, as well as activity and group size, to influence suitability in Michigan. Samuel *et al.* (1987) found that group size and vegetation cover were the most important influences on elk sightability during helicopter surveys in Idaho. Gasaway *et al.* (1985) suggested that habitat type, group size, and activity were the main influences on moose sightability in Alaska. They felt group size and activity might be correlated, but they didn't address the relationship between habitat characteristics and other factors (Anderson and Lindzey 1996). Anderson and Lindzey (1996) suggested that habitat type and group size was correlated with vegetation cover in Wyoming and that moose activity was not important. Activity was similarly unimportant in this study, although the significant difference in the percent vegetative cover for bedded versus active moose hints at a possible interaction between activity and cover. Anderson and Lindzey (1996) suggested that the differences between their results and Gasaway *et al.* (1985) might have been because Gasaway *et al.* (1985) used fixed-wing aircraft and they used helicopters. Crête *et al.* (1986) had earlier reported that moose behavior was more sensitive to fixed-wing aircraft surveys than helicopter surveys. Helicopters were also used during this study.

Although it has no direct influence over sightability, it is possible that daily temperature might track changes in secondary variables, such as activity and habitat type, which alone did not influence sightability but may cumulatively have an effect. This reasoning was supported by some sets of observations, such as the exclusive occurrence of moose in habitats without tree cover when temperatures were colder than -10°C, the minimum for the data (range: -12 to 1°C). However, the general trend in the data did not support this idea, demonstrating rather that daily temperature was not significantly affected by animal behavior or habitat. Similarly, we expected that temperature may correlate to percent vegetation cover, and, to a weak extent, this proved to be true. Perhaps this trend may have been stronger if temperature had been recorded at the beginning of each trial rather than simply at the start of the day. Apparently whatever aspect of daily temperature explains variation in sightability was shared by percent vegetation cover in multivariate analysis.

Snow cover had a significant univariate, but not multivariate, effect on sightability in this study, and other authors have suggested it can be an important factor (LeResche and Rausch 1974, Gasaway *et al.* 1986). Like Samuel *et al.* (1987) and Anderson and Lindzey (1996), we believe snow cover was not a factor in our multivariate model because of the limited range of snow cover tested. Snow cover was 80% or greater at all but two moose locations. By early March at lower elevations and mid-March at higher elevations, however, there were increasingly large bare patches in some of the survey blocks, particularly around the base of trees. Radio-collared moose were never seen on the bare patches, even though these bare, often dark patches were believed to distract observers and hamper their search efficiency.

Many previous studies that examined observer differences over a wide range of observer experience have found important differences (Anderson and Lindzey 1996). Recent studies using multivariate analyses have found that differences among experienced observers are usually correlated with other factors (Samuel *et al.* 1987, Ackerman 1988, Anderson and Lindzey 1996). In all cases, however, researchers have stressed the importance of using experienced observers. Factors that were controllable during this study, such as primary observer, pilot, and helicopter, were kept constant as much as possible, so there was little chance of seeing an influence of these factors on moose sightability in the analyses. In real survey situations, however, it often is not possible to have the same primary observers during stratified random block surveys over a number of days. If alternate observers have to be used then they should be as experienced as possible.

We saw 49% of 105 groups with radio-collared moose. This detection rate was lower than 59% of 104 groups seen by Anderson and Lindzey (1996), yet surveys in this study occurred earlier in the winter with a higher average search rate (where it was recorded; B.C.: mean = 5.62 min/km^2, SD = 2.79 min/km^2 versus Wyoming: mean = 4.7 min/km^2, SD = 1.2 min/km^2). Despite the lower overall detection rate in this study, 24% of moose groups in vegetation cover >40% and 43% in conifer dominated stands were seen, while Anderson and Lindzey (1996) saw only 14% of moose groups in vegetation cover >40% and 33% in conifer dominated stands. The B.C. study area appears to have had a much higher percentage of conifer dominated habitat than the 3 Wyoming study areas (see Anderson 1994). This may contribute to the lower overall detection rate. However, the occurrence of radio-collared moose in conifer dominated habitat differed only slightly between British Columbia (59%) and Wyoming trials (56%). The overall detection rate during this study was also lower than the 43-68% of LeResche and Rausch (1974), the 57% of Thompson (1979), the 64% of Rolley and Keith (1980), the 73% of Crête *et al.* (1986), and the 78% of Peterson and Page (1993). Direct comparisons among studies are difficult, however, because of differences in aircraft type, number of observers, search intensity, and moose habitat use.

Two moose sightability models were developed from the B.C. data. The models differ by their amount of simplification of the percent vegetation cover classes. As vegetation cover classes were simplified, the standard errors of the model coefficients increased, which would likely increase the confidence limits around each group estimate and decrease the precision of the population estimates. As a result, there appear to be significant trade-offs in precision associated with simplifying the model, reflected in the diminished ability of the 3-class model to predict moose sightability, particularly for moose that were seen. We do not recommend this model as it appears to introducing additional error to sightability correction by oversimplifying. In addition, Anderson and Lindzey (1996) caution that, despite having simplified vegetation cover classes in their sightability model, percent vegetation cover should be estimated using 5% categories during actual surveys to guard against inaccurate estimates of the vegetation cover class.

The 5-class model appears promising, but will need to be properly tested before it can be recommended. The model should generally be applied only in conditions that fall within the limits of the data on which it is based. This includes daily temperatures ranging from -12 to 1°C and snow cover greater than 80% (preferably 100%). As well, when moose shift from open to dense canopy habitats, sightability and confidence in estimating moose population parameters decreases, resulting in larger confidence intervals. A careful sampling design, including timing surveys for when moose are most likely to be using open habitats, will be important to obtain the most precise population estimates (Anderson and Lindzey 1996). Only experienced observers should be used during aerial surveys of moose. If all observers are experienced then their individual differences appear to be correlated with other sightability influences (Samuel *et al.* 1987, Ackerman 1988, Anderson and Lindzey 1996). Sampling protocols used during the development of a moose sightability model should be rigorously followed during application of the model (Anderson and Lindzey 1996). This will require incorporating moose sightability into stratification during survey design.

It appears questionable whether a model could be developed using a combined data set from both south-central B.C. and Wyoming. There appears to be a greater abundance of habitats with dense vegetation cover in British Columbia and there are apparent differences in survey protocol between the two data sets. Pooling the data may also mask any regional differences in moose behavior and ecology that originally motivated the development of the B.C. specific model.

ACKNOWLEDGEMENTS

Funding for this project was provided by Forest Renewal British Columbia and the B.C. Ministry of Environment, Lands and Parks. Thanks to helicopter pilots Doug Smallman and Terry Curell of Cariboo Chilcotin Helicopters, primary observers Doug Jury and Grant MacHutcheon, and numerous secondary observers including Sue Lemke, Grant MacHutcheon, Ian Hatter, Eddie Jules, Kurt Kier and Fred Harper. Peter Ott, Ian Hatter, Edward "Oz" Garton, and Chuck Anderson provided comments and statistical guidance.

LITERATURE CITED

ACKERMAN, B. B. 1988. Visibility bias of mule deer aerial census procedures in southeast Idaho. Ph.D. Thesis, Univ. Idaho, Moscow, Idaho. 106 pp.

ANDERSON, C. R. 1994. A sightability model for moose developed from helicopter surveys in western Wyoming. M.S. Thesis, Univ. Wyoming, Laramie, Wyoming. 71 pp.

ANDERSON, JR., C. R., and F. G. LINDZEY. 1996. Moose sightability model developed from helicopter surveys. Wildl. Soc. Bull. 24:247-259.

BRITISH COLUMBIA MINISTRY OF FORESTS. 1992. Biogeoclimatic zones of British Columbia. B.C. Min. Forests, Res. Branch, Victoria, B.C. Map.

CAUGHLEY, G. 1974. Bias in aerial survey. J. Wildl. Manag. 38:921-933.

CRÊTE, M., L. RIVEST, H. JOLICOEUR, J. BRASSARD, and F. MESSIER. 1986. Predicting and correcting helicopter counts of moose with observations made from fixed-wing aircraft in southern Québec. J. Appl. Ecol. 23:751-761.

DRUMMER, T.D. and R.W. AHO.1998. A sightability model for moose in upper Michigan. Alces 34:15-20.

GASAWAY, W. C., S. D. DUBOIS, and S. J. HARBO. 1985. Biases in aerial transect surveys for moose during May and June. J. Wildl. Manag. 49:777-784.

GASAWAY, W. C., S. D. DUBOIS, D. J. REID, and S. J. HARBO. 1986. Estimating moose population parameters from aerial surveys. Biology Paper No. 22, Univ. Alaska, Fairbanks, Alaska. 108 pp.

GASAWAY, W. C., and S. D. DUBOIS. 1987. Estimating moose population parameters. Swedish Wildl. Res. Suppl. 1:603-617.

HATTER, I. 1992. Improving moose density surveys in British Columbia: a research proposal. Pages 177-183 *in* D.F. Hatler, ed. Proc. moose harvest management workshop, 1991. B.C. Min. Environment, Lands and Parks, Wildlife Branch, Victoria, B.C.

JURY, D. 1992. Moose harvest management statement, Thompson-Nicola Sub-region. Pages 114-117 *in* D.F. Hatler, ed. Proc. moose harvest management workshop, 1991. B.C. Min. Environment, Lands and Parks, Wildlife Branch, Victoria, B.C.

LERESCHE, R. E., and R. A. RAUSCH. 1974. Accuracy and precision of aerial moose censusing. J.Wildl. Manag. 8:175-182.

MACHUTCHON, A. G., and D. JURY. 1994. Moose visibility bias trials, Thompson-Nicola Sub-region, 1993-1994. Southern Interior Region, B.C. Min. Environment, Lands and Parks, Kamloops, B.C. 19 pp.

PETERSON, R. O., and R. E. PAGE. 1993. Detection of moose in mid-winter from fixed-wing aircraft over dense forest cover. Wildl. Soc. Bull. 21:80-86.

ROLLEY, R. E., and L. B. KEITH. 1980. Moose population dynamics and winter habitat use at Rochester, Alberta, 1965-1979. Can. Field-Natur. 94:9-18.

SAMUEL, M. D. 1984. An evaluation of elk sightability in north central Idaho with application to aerial census and herd composition counts. PhD. Thesis, Univ. Idaho, Moscow, Idaho. 118 pp.

SAMUEL, M. D., E. O. GARTON, M. W. SCHLEGEL, and R. G. CARSON. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. J. Wildl. Manag. 51:622-630.

SAS INC. 1996. SAS for Windows, Release 6.0. SAS Inc., Cary, N. Carolina.

STATSOFT INC. 1996. Statistica for Windows, Release 5.1. Tulsa, OK.

THOMPSON, I. D. 1979. A method of correcting population and sex and age estimates from aerial transect surveys for moose. Alces 15:148-168.

UNSWORTH, J. W., F. A. LEBAN, G. A. SARGEANT, E. O. GARTON, M. A. HURLEY, J. R. POPE, and D.J. LEPTICH. 1991. Aerial Survey: user's manual. Idaho Dep. Fish and Game, Boise, Idaho 54 pp.

Table 1. Moose sightability trial results by independent variable for the Deadman River and Criss Creek study area, south-central B.C.

			Univariate[a]		Multivariate[b]	
Variable	*n*	% Seen	X^2	*P*	X^2	*P*
DISCRETE						
SEX:			0.588	0.443	0.214	0.644
Bull(s)	41	44				
Cow(s)	64	52				
PRIMARY OBSERVER:			3.50	0.061	1.22	0.268
Observer1	85	53				
Not Observer1	20	30				
ANIMAL ACTIVITY:			2.41	0.121	2.84	0.092
Bedded	30	37				
Active	74	54				
COVER TYPE:			8.28	0.159	0.165	0.685
Open Meadow/Shrub	4	100				
Deciduous/Mixed Forest	36	61				
Conifer Forest	58	44				
CONTINUOUS						
VEGETATION COVER (%):			40.625	**<0.001**	40.625	**<0.001**
0-20	18	91				
21-40	31	83				
41-60	27	55				
61-80	11	20				
>80	7	0				
SNOW COVER (%):			8.050	**0.005**	1.47	0.226
0-25	1	0				
26-75	1	0				
76 - 99	12	25				
100	88	58				
DAILY TEMPERATURE (°C)			13.16	**<0.001**	3.79	0.051
-12 to –10	21	81				
-9 to –5	37	49				
-4 to 0	41	39				
>0	6	0				
SEARCH RATE (min/km^2):[c]			0.46	0.497	1.38	0.240
2.00-4.99	23	48				
5.00-7.99	17	47				
8.00-10.99	5	40				
11.00-13.99	4	75				

[a] Univariate results from X^2 contingency analyses of discrete independent variables (G Test) and logistic regression analyses of continuous independent variables.

[b] Final significance of independent variables after stepwise logistic regression with only percent vegetation cover included in the model ($P<0.05$, $n=94$).

[c] Univariate and multivariate analyses with search rate include fewer trials as these data were not collected after 1996.

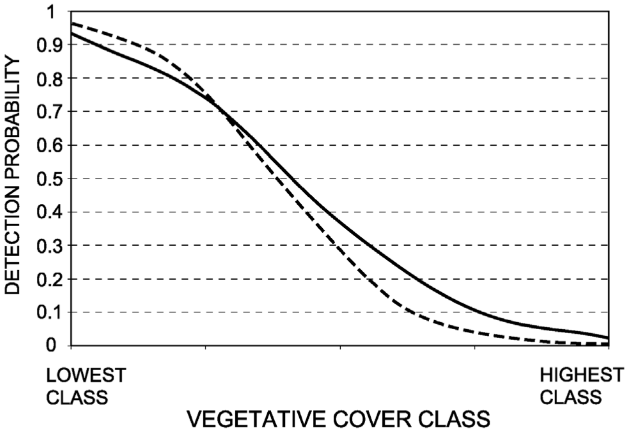

Figure 1. Probability of detecting moose by vegetative cover class in south-central British Columbia, as described by the logistic regression, Z = -4.2138 + 1.5847(Vegetative Cover Class 1 - 5). Cover classes are 20% intervals between 0 and 100%.