Ground-based Inventory Methods for Selected Ungulates: Moose, Elk and Deer

Standards for Components of British Columbia's Biodiversity No. 33

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Preface

This manual presents standard methods for ground 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.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series which present standard protocols designed specifically for group of species with similar inventory requirements. The series includes an introductory manual (Species Inventory Fundamentals No. 1) which describes the history and objectives of RIC, and outlines the general process of conducting a wildlife inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The Species Inventory Fundamentals manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for vertebrate taxonomy (No. 2), animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in inventories which involve either of these activities.

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

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

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

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

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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, Todd E. Mahon and David F. Hatler contributed to an earlier unpublished draft, *Standardized Methodologies for the Inventory of Biodiversity in British Columbia: Ground-based Census Techniques for Selected Cervids.*

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

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1. INTRODUCTION

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 ground-based survey techniques. The species considered here are five of the six cervids that occur in British Columbia: moose (*Alces alces*), fallow deer (*Dama dama*), elk (*Cervus elaphus*), mule/black-tailed deer (*Odocoileus hemionus*) and white-tailed deer (*O. virginianus*).

Inventory information is essential for informed management and effective conservation of ungulates. The inventory protocols defined here range from reconnaissance (presence/not detected (possible)) surveys to locate and delineate populations, to conducting herd composition surveys, through to estimating relative abundance and absolute abundance of cervids. 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). While well designed aerial survey methodologies have been developed for moose and elk, ground-based methodologies have also been applied to these species (e.g. Franzmann *et al*. 1976, White and Eberhardt 1980, Rowland *et al*. 1984). Mule/black-tailed, white-tailed deer and fallow deer, however, are generally inventoried by ground-based surveys.

Many published papers, reports and manuals exist on ground-based ungulate survey techniques. It is not our intention to re-state those documents, but rather to indicate where their use is appropriate in British Columbia. However, the reader is encouraged to become familiar with these documents, many of which are referenced in the 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) provides an excellent summary on the general biology and ecology of cervids. The following species accounts are intended as a general overview, and identify some aspects of cervid ecology relevant to the survey protocols described in this manual.

2.1 Moose (*Alces alces*)

General Ecology

The largest of the cervids, the moose is a northern species, ill-adapted to withstand high temperatures (Kelsall and Telfer 1974), and long-legged enough to cope well with snow depths up to 80 cm (Kelsall 1968; Eastman 1977). Moose eat a variety of plant foods, especially in summer, but their winter feeding constitutes a major adaptation to northern environments. They are primarily browsers, in an area where snow cover may make plants other than trees and shrubs largely inaccessible for part of the year. Across the continent, a few species of deciduous shrubs (willow, birch, aspen and red osier dogwood) and one conifer (balsam fir) are the key browse species (Eastman 1977). As outlined in Franzmann (1981), there are a number of factors which affect moose numbers directly, including predation, natural accidents, disease/parasite problems, hunting, and collisions on human transportation corridors. Effects to moose populations resulting from habitat changes are usually mediated indirectly, often through effects on natality (Eastman 1977) or by migration, but occasionally also through changes in condition which result in mortality (e.g., starvation or malnutrition-related diseases (see Hatter 1949)). Geist (1971) referred to the shrub communities within forested areas (e.g., along watercourses and in the subalpine zone) as "permanent" moose habitats, and labeled the new secondary successional communities following major disturbances (e.g., fire) as "transient" moose habitats. Permanent habitats are important in their support of moose populations between the transient habitats, both spatially and temporally, but the really conspicuous increases and maintenance of large numbers of moose generally occur in the latter (Edwards 1954; Peek 1974).

Distribution and Habitat In British Columbia

Although the species is primarily associated with the boreal forest over most of its range, in British Columbia it exploits a variety of habitats ranging from alpine meadows to tidewater wetlands (Eastman 1977). It occurs throughout the province, except on the coastal islands, with representation in all of the ecoprovinces. It is also found in all of the biogeoclimatic zones in the province, although the species occurs only intermittently in the Coastal Western Hemlock and adjacent Mountain Hemlock biogeoclimatic zones, and is not a regular resident of unforested or sparsely forested zones in the interior (e.g., Alpine Tundra, Bunchgrass, and probably Ponderosa Pine).

Seasonal Distribution and Movements

Seasonal migrations are usually along an elevational gradient, up in summer and down in winter, and may involve movements of up to 60 km in western mountains (Hatter 1950; Edwards and Ritcey 1956; Van Ballenberghe 1977). All of the above authors, and others, indicate that the nature and occurrence of seasonal movements are usually related to changes in snow depths.

Grouping Patterns

Moose are usually dispersed in relatively solitary fashion (singles of either sex or cow/calf pairs) during the snow free season until rut, i.e., from about May through mid-September in most of British Columbia. Groups of 3 to 6 are common during the rut (mid-September through mid-October). Suitable winter habitats are limiting in most areas, and the animals tend to aggregate in that season. Thus, the highest local densities occur in winter, and particularly during the deepest snow periods (Franzmann 1981).

Daily Activity

Moose may be active at any time during the day or night with peaks in foraging usually at dawn and dusk (Stevens and Lofts 1988).

Distinctness of Sign

Moose pellets and tracks are generally quite distinct and recognizable, primarily by size and to some extent by shape, but smaller moose tracks and pellets can sometimes be confused with those of elk. Pellet volumes were used by MacCracken and Van Ballenberghe (1987) to classify pellet groups originating from adult males, adult females or yearlings. Thus, it may be possible to estimate population age-sex ratios using pellet counts.

2.2 Elk (*Cervus elaphus*)

General Ecology

Elk are primarily grazers, preferring grasses and forbs. In the winter, they may paw through snow to obtain dry grass, although they are often forced to browse on shrubs and deciduous trees (Banfield 1987). Home range size can vary widely, depending on distances between summer and winter ranges. During the rut, bulls typically establish territories onto which they collect or attract a harem of cows and their calves. Over the mating season bulls frequently emit a vocalization known as a "bugle" to identify their territory, challenge other bulls and possibly attract cows (Peek 1987). Combat between adult bulls competing for cows is intensive and can result in death, though most wounds are minor. Two subspecies *C. e. nelsoni* (the Rocky Mountain Elk) and *C. e. roosevelti* (the Roosevelt Elk) occur in British Columbia. The latter subspecies is blue-listed.

Distribution and Habitat In British Columbia

Elk occur in a patchy distribution over the eastern half of the province and as isolated populations on Vancouver Island, the south coast (Sechelt Peninsula) and on the Queen Charlotte Islands. The greatest densities are found in the East Kootenay and

Muskwa/Kechika areas (Stevens and Lofts 1988). Within their disjunct range, elk show a broad tolerance for different habitats and successional stages, and utilize all biogeoclimatic zones. Terrain and availability of cover appear to be more important than habitat class. Ideal landforms range from floodplain areas with adjacent river breaks to steep avalanche tracks (Luttmerding *et al.* 1990). They forage in a variety of habitats including most forest types, subalpine parkland, wetlands, meadows, agricultural areas, riparian areas and alpine tundra. Optimal habitat consists of open areas interspersed with patches of trees or dense shrubs (Banfield 1987).

Seasonal Distribution and Movements

Seasonal movements usually occur between summer and winter ranges. Movements are greatest in mountainous regions, where most elk spend the summer at higher elevations and the winter on lower slopes and in the valleys where less snow accumulates. Migrations of >80 km can be common. Generally winter ranges are smaller than summer ranges, resulting in higher densities in winter.

Grouping Patterns

Elk are the most gregarious of the species in this inventory group, with some variation between sexes, seasons and populations. Herds of dozens to hundreds of animals are common (Banfield 1987). Cows seek seclusion during and immediately after calving, but usually reassociate to form cow-calf groups a few weeks after parturition (Peek 1987). Herd size also seems to be related to openness of habitat, with the largest groups forming in the most open habitats (Knight 1970), possibly for security against predators (Peek 1987). As with other ungulates that concentrate on winter ranges, aggregations are generally lowest in summer and highest in winter (Peek 1987).

Daily Activity

Elk can be active at any time, but tend to be mostly crepuscular. They generally forage in the early morning and evening, and spend the middle of the day and the middle of the night resting and ruminating (Banfield 1987; Stevens and Lofts 1988).

Distinctness of Sign

Elk pellets and tracks are distinguishable from most other ungulates, although there is some overlap with moose. Generally, elk tracks are smaller and proportionately shorter, and their pellets are rounder, than those of moose, but they can not always be separated with certainty where the species overlap.

2.3 Mule/Black-tailed Deer (*Odocoileus hemionus*)

General Ecology

As described in Cowan and Guiguet (1973), three subspecies of the mule deer are recognized in British Columbia: *O. h. hemionus* (Rocky Mountain mule deer), *O. h. columbianus* (coast or Columbian black-tailed deer) and *O. h. sitkensis* (Sitka black-tailed deer). The mule deer is the most numerous ungulate in British Columbia and is second only to moose as the most widely distributed (Petticrew and Jackson 1980; Petticrew and Munro 1979). The numbers and range of this species have increased in British Columbia since European settlement because logging, burning and agricultural activities have increased forage by creating large areas with early and intermediate seral stages (Mackie *et al.* 1987). Mule deer are 'intermediate feeders' grazing on herbaceous material and browsing on woody forage (Anderson and Wallmo 1984). Their diet includes a variety of grasses, forbs, shrubs, trees, sedges, agricultural crops, mushrooms and lichens, depending on season (Petticrew and Jackson 1980). Optimum growth is dependent upon adequate quantities of highly digestible succulent forage, although in winter deer must rely more exclusively on woody browse, arboreal lichens and other low quality food. Under winter conditions they typically experience an energy deficit that must be met by drawing on fat reserves accumulated during the summer and fall (Mackie *et al.* 1987). Home range size varies widely among individuals, sexes and habitat (Stevens and Lofts 1988). During the rut dominant bucks may establish territories (Mackie *et al.* 1987). Population size may be controlled by predation, disease/parasites, hunting, winter severity and indirectly by habitat changes (Anderson and Wallmo 1984).

Distribution and Habitat in British Columbia

The mule deer is common throughout most of the province with the exception of northwestern and north central regions where it occurs only in restricted localities. Among subspecies, *O. h. hemionus* has the widest distribution, throughout the interior from the Coast mountains east to the Rockies. *O. h. columbianus* is found on the mainland coast and offshore islands from Smith Sound south to the International Boundary and *O. h. sitkensis* occurs on the mainland coast and offshore islands north of Smith Sound to the Alaska-B.C. border (Banfield 1987). Densities are highest along the coast, including the Queen Charlotte and Vancouver Islands, but a fair number also occur in the Kootenay, Caribou, Okanagan and Thompson-Nicola Regions, and in the Peace River area (Petticrew and Jackson 1980). The species occupies a wide range of habitats from sea level to alpine tundra (Cowan and Guiguet 1973) and occur in most of the province's biogeoclimatic zones. It has a broad tolerance for a variety of landform types and generally inhabits steeper and more broken terrain than do white-tailed deer (Luttmerding *et al*. 1990). Lower elevation areas provide critical winter range in all ecosections, but especially in mountainous regions (Cowan and Guiguet 1973; Petticrew and Jackson 1980). Steep south-facing slopes are important in many areas because they often have less snow throughout the winter and are the first areas to green up in early spring (Luttmerding *et al.* 1990). South facing old growth provides important winter range for black-tailed deer in coastal forests (Harestad *et al*. 1982).

Seasonal Distribution Patterns

Significant seasonal movements occur throughout the province, typically from large summer ranges at upper elevation habitats to lower, more restricted winter ranges (Cowan and Guiguet 1973; Petticrew and Jackson 1980). Movements of up to 120 km between seasonal ranges have been recorded in the Cariboo region (Stevens and Lofts 1988). Rather than migrating, some black-tailed deer populations in low elevation areas undergo a local seasonal shift associated with changes in food availability (McNay and Davies 1985), though there are usually some migratory animals in low elevational populations as well.

Grouping Patterns

Mule/black-tailed deer are usually found singly or in small groups (2-5), with loose associations of larger groups forming during the rut, on winter range, or at locally abundant food supplies (Cowan and Guiguet 1973; Mackie *et al*. 1987). This species tends to be more gregarious than white-tailed deer (Banfield 1987).

Daily Activity

Mule/black-tailed deer can be active at any period of the day or night, depending on several factors including human disturbance (Mackie *et al.* 1987), but are generally most active at dawn and dusk, less active at night and least active during the day.

Distinctness of Sign

Mule deer pellets and tracks are similar to those of white-tailed deer and can not be distinguished where both species occur. However, they are distinguishable from the other ungulates in this inventory group (Murie 1975).

2.4 White-tailed Deer (*Odocoileus virginianus*)

General Ecology

The white-tailed deer is one of the most widely distributed ungulate species in the western hemisphere and can live in a variety of habitats (Hesselton and Hesselton 1987). It is considered to be a browser although it eats a variety of food types including grasses, forbs, shrubs, trees, fruits, mushrooms and agricultural crops (Petticrew and Jackson 1980; Stevens and Lofts 1988). Home ranges for white-tailed deer are the smallest among B.C. cervids, with winter ranges usually varying between 2 to 3 km^2 (Stevens and Lofts 1988). Factors controlling population parameters are similar to those listed for the other species.

Distribution and Habitat in British Columbia

White-tailed deer are distributed in two disjunct regions of the province, the Peace River area in the northeast and the lower valleys of the Kootenay, Columbia, Kettle and Okanagan areas in the southeast. The current range of both these populations is known to be expanding, and in the Central Interior incidental reports of white-tailed deer have been made as far west as the Kispiox Valley. Habitat use includes all biogeoclimatic zones except the Coastal Western Hemlock, Coastal Douglas-Fir, and Mountain Hemlock biogeoclimatic zones. Use of higher elevation zones (Alpine Tundra, Englemann-Spruce Sub-alpine Fir, and Montane Spruce) is less than that of Mule Deer. Preferred habitats are forested areas with small openings for feeding.

Seasonal Distribution and Movements

Migrations between summer and winter ranges are similar to those described for the other cervids, although generally more linear (as opposed to altitudinal) in nature, from upper ends of valleys to lower portions of valleys (Petticrew and Jackson 1980). In non-mountainous regions, such as the Peace River area, populations are mostly non-migratory, though they probably exhibit local seasonal shifts in habitat use.

Grouping Patterns

White-tailed deer are generally considered to be more solitary than mule deer (Banfield 1987). The basic social unit is the doe and her fawn(s). Bucks occur alone or in small groups during the summer, but those groups disband before the rut. Larger groups may associate loosely at seasonally abundant food sources or on winter range (Petticrew and Jackson 1980). In deep snow conditions several white-tails may "yard up", restricting themselves to a small area where they can maintain well-beaten trails (Banfield 1987), although it is not certain they do so in British Columbia.

Daily Activity

White-tailed deer are mainly crepuscular, generally foraging in the early morning and evening, and spending both the middle portions of the day and night resting and ruminating (Banfield 1987; Stevens and Lofts 1988).

Distinctness of Sign

White-tailed deer tracks and pellets are generally indistinguishable from those of mule deer (Murie 1975).

2.5 Fallow Deer (*Dama dama*)

General Ecology

Fallow deer prefer open areas and forest edges and feed on a variety of grasses, forbs, shrubs and trees (Feldhamer *et al.* 1988). In British Columbia, wild fallow deer only occur on Sidney and James Island. Fallow deer are sympatric with black-tailed deer on Sidney Island, but competition between the two species is apparently reduced by differential habitat use of each species. In one study, fallow deer were most frequently observed in open areas, while black-tailed deer were found more frequently in coniferous forest (Moody *et al.* 1987). Densities of fallow deer in Sidney Island Provincial Park are apparently greater than has been documented for other wild populations. Densities as high as 150 deer/ 100 ha have been reported compared to ranges between 8 and 43 deer/ 100 ha for European herds (Moody *et al.* 1987**).**

Distribution and Habitat in British Columbia

An exotic species native to the Mediterranean region and Asia Minor, the fallow deer has been introduced in many parts of the world (Feldhamer *et al.* 1988). In British Columbia it was introduced to, and occurs primarily on, James and Sidney Islands although individuals occasionally swim across to the Saanich Peninsula of southern Vancouver Island (Banfield 1987). Sidney and James islands are in the Coastal Douglas-Fir Biogeoclimatic Zone, where a combination of forested habitats and natural and human-made clearings are utilized.

Seasonal Distribution and Movements

Annual distribution patterns are similar in both island populations with some minor seasonal shifts in habitat use. On Sidney Island, where hunting on private land is allowed in the fall, there may be a seasonal movement of some animals into Sidney Island Provincial Park where until 1995, there was no hunting (Moody *et al.* 1987).

Grouping Patterns

Fallow deer are highly gregarious and usually associate in small separate herds of does with their fawns and groups of bucks. The bucks join the does during the rut in the fall but leave them again in the winter (Banfield 1987).

Daily Activity

Fallow deer may be active at any time, but exhibit peak activity periods at dusk and dawn (Feldhamer *et al.* 1988).

Distinctness of Sign

Fallow deer tracks and pellets are indistinguishable from those of black-tailed deer.

3. PROTOCOLS

3.1 General Considerations for Inventory

3.1.1 Inventory Objectives

The most important step in the inventory process is to define the objectives clearly and precisely to determine whether aerial or ground-based survey methods are the most appropriate, the staff and level of effort, and the 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), 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 cervid species at a time. Therefore, to obtain valid results, sufficient funds should be allocated to inventory different species and their particular habitats separately. While it may be tempting to inventory both deer and elk on the same pellet group plots, generally the survey design will be developed for one (the primary) species. Thus, data accuracy and precision may be poor for the secondary species and fail to meet required RIC standards. Exceptions are presence/not detected surveys (also called reconnaissance or distribution surveys), where more than one species may be inventoried simultaneously.

3.1.2 Selecting the Survey Area

Ground-based methods which involve counting animals directly require fairly large open areas adjacent to roads where observability of the animals is high and a substantial area can be covered (Norton-Griffiths 1978, Anderson *et al*. 1979, Harestad and Jones 1981). Suitable natural habitats for direct counts include grasslands, alpine areas and open forest types with numerous clearings. Thus, some biogeoclimatic zones in British Columbia lend themselves to such techniques better than others (e.g. Bunchgrass, Ponderosa Pine, Interior Douglas-Fir). In more heavily forested zones (e.g. Coastal Douglas-Fir, Coastal Western Hemlock), openings caused by human development, such as fields and clearcuts, may also be used extensively by ungulates and create situations where direct count techniques can be applied. The use of open habitats by ungulates depends upon food availability within them, their relative distribution within larger habitat complexes and the biology of the species. Major forage species, including grasses, forbs and shrubs, are often more abundant in open habitats than in other areas and ungulates frequently use them preferentially.

There are two problems associated with selecting open habitats as survey areas. First, surveying a known high use habitat introduces a bias to the estimate, making it difficult to extrapolate density estimates to larger areas which incorporate different habitat types. Second, animal use of open areas will vary within and among years, depending on the relative availability of food and levels of disturbance.

3.1.3 Ungulate Winter Ranges as Survey Areas

Most ungulate populations in the province exhibit some degree of seasonal movement between summer and winter ranges (Demarchi *et al.* 1983). Those range shifts are largely a response to greater snow accumulations at higher elevations, which force animals to lower elevation winter ranges where snow depth is less.

Winter ranges of ungulates are usually smaller than summer ranges, resulting in higher animal densities. In instances of extreme snow accumulation some ungulates, especially deer, may be forced to "yard up" in large groups on small areas (Hesselton and Hesselton 1987). Surveying animals during periods of concentration can be advantageous for at least two reasons: 1) less total area has to be covered by the survey (Edwards 1954); and 2) because the populations are at higher densities less sampling may be required to obtain the sample sizes required for statistical analysis (Burnham *et al.* 1980).

The major problem with using winter ranges to survey ungulate populations is that population closure can not always be assumed. This is because animal use of the winter range can vary significantly among years, depending upon weather (Van Ballenberghe 1977). In winters with deep snow, virtually all animals in a population may concentrate on critical winter range, while in low snow years a significant proportion of the population could winter on more extensive intermediate winter range or summer range. In cases where the latter occurs, the variations in seasonal distribution could be misconstrued as population changes.

3.1.4 Survey Timing

Ungulates can be active at all times of the day and night. Relative daily activity patterns depend more on season, weather and habitat than on variation among species. Human activity/presence, such as hunting, can also greatly affect daily activity (Banfield 1987). To generalize, ungulates are usually most active during crepuscular periods, are slightly less so at night, and are least active during daylight hours. That pattern, coupled with the observation that animals are usually less wary at night (Harestad and Jones 1981), suggests that direct count methods are likely to be most efficient during early morning, late evening or during the night. Progulske and Duerre (1964) and McCullough (1982) found that night time deer activity was greatest in the first third of the nocturnal period.

Seasonal timing will be constrained by overall objectives. For example, surveying population composition for black-tailed deer can best be achieved from late summer (August) surveys when fawns travel with their dams, and again in April and May, when deer concentrate on spring ranges and are more observable. Pellet group surveys are generally conducted in early spring, before green-up of vegetation, when pellets are most visible.

3.1.5 Distinctness of Sign

In cases where absolute density estimates are not required, ungulate sign may be sufficient to infer presence/absence or it may be used as an index to determine population trends (Caughley 1977). The success of using sign depends, in part, on the ability to identify the species that produced it. Several field guides are available to help identify ungulate sign (e.g., Murie 1975; Rezendes 1992), although personal experience with the variations that occur between age classes and under different conditions are needed to ensure success. Tracks and fecal pellets are the most common kinds of sign used for this purpose, as they are sufficiently distinct to enable species identification in many areas. Where species with similar sign overlap (e.g. mule and white-tailed deer), species identification may be difficult or impossible, and the use of techniques which use sign is not advisable.

3.1.6 Personnel

An experienced professional biologist should undertake the design, logistic planning, and data analysis for inventories (see Introduction to RIC Wildlife Species Inventory Manual). 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.

To the extent possible, survey personnel should have experience and demonstrated ability with the methods involved and with the target (primary) species. Most surveys will require at least two qualified observers. Survey results from a trainee should be regularly checked by an experienced observer.

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 most 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 ground-based ungulate inventories, based on intended uses (Table 4).

Table 1. 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

Ground-based surveys are often used to provide information on population sex and age structure, in addition to data on population size, trends or distribution. Jones (1984) proposed a classification level system for ungulates, which is used here, with some slight modifications (Tables 2, 3 and 4). 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 3 to 4 classes of mature males, which are based on antler size and shape.

Juvenile animals or young (less than 1 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. Large antlered males drop their antlers earlier than others. Antler drop varies regionally, but usually begins in late December for moose, in January for mule and white-tailed deer, late February for elk and late April for fallow deer. Correct classification requires close observation. Level 4 classifications often require the assistance of spotting scopes. Adult moose can be classified as male or female by using the white 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. Animals which can not 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 animals that can not be identified in the midst of large groups. There are two categories for animals which can not be identified; unclassified adults (unsexed but known not to be juveniles) and unknown (neither sex nor age is determined). All levels of classification should use those two categories for clarity. There is little benefit to guessing at classifications.

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. A representative count requires that all parts of the area occupied by a population be surveyed adequately.

Table 2. Classification criteria for ground-based ungulate surveys.

Level	Classification Criteria	Population Ratio[1]
1	juvenile (<1 year)/adult (> 1 year)	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 (classes I/II/III/IV)

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

Table 3. Recommended standard sex and age classification criteria in British Columbia for black-tailed deer, mule deer, and white-tailed deer using ground-based 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 4. Recommended standard sex and age classification criteria in British Columbia for elk, moose and fallow deer using ground-based survey techniques.

Species	Sex/Age	Composition	Description
Elk[2]	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 point antler, small 5 point antler, spindly (raghorn)
		Class III	large 5 point antler, small 6 point antler, heavy antlers
		Class IV	large antlers with 6 or 7 points/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

[2] Roosevelt Elk: Class II - large 4 point or 5 point; Class III- very large bulls ($\geq$ 6 point); Class IV - no classification.

Species	Sex/Age	Composition	Description
Fallow Deer	juvenile	fawn	small body size 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
		Class I (2 year-old)	antlers typically with 4 points (may be 3 to 5 points) little or no palmation on antlers
		Class II	medium size antlers with palmation
		Class III	large palmated, heavy-beamed antlers

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. Ideally, habitat plots should be established at each sample unit, such as pellet group plots. For surveys that are too extensive to warrant site-level description (e.g. spotlight counts), record Broad Ecosystem Units (BEU's). Consult the introductory manual, *Species Inventory Fundamentals* (No.1*)* for habitat descriptions and codes for the BEU's.

3.2.4 Survey Design Hierarchy

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

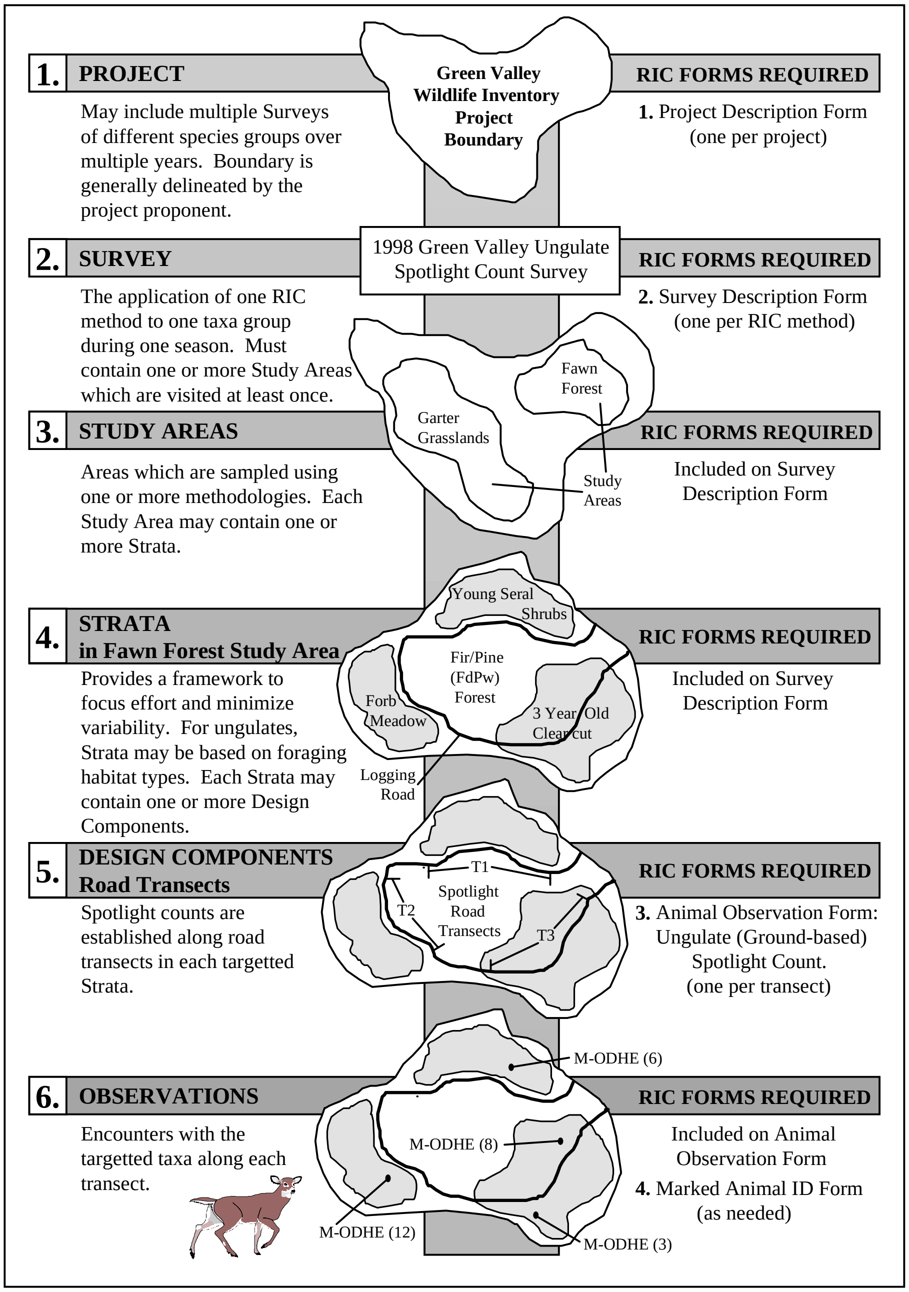
1. PROJECT
May include multiple Surveys of different species groups over multiple years. Boundary is generally delineated by the project proponent.
Green Valley Wildlife Inventory Project Boundary
RIC FORMS REQUIRED
1. Project Description Form (one per project)
2. SURVEY
The application of one RIC method to one taxa group during one season. Must contain one or more Study Areas which are visited at least once.
1998 Green Valley Ungulate Spotlight Count Survey
RIC FORMS REQUIRED
2. Survey Description Form (one per RIC method)
Fawn Forest
Garter Grasslands
Study Areas
3. STUDY AREAS
Areas which are sampled using one or more methodologies. Each Study Area may contain one or more Strata.
RIC FORMS REQUIRED
Included on Survey Description Form
Young Seral Shrubs
4. STRATA in Fawn Forest Study Area
Provides a framework to focus effort and minimize variability. For ungulates, Strata may be based on foraging habitat types. Each Strata may contain one or more Design Components.
Fir/Pine (FdPw) Forest
Forb Meadow
3 Year Old Clear cut
Logging Road
RIC FORMS REQUIRED
Included on Survey Description Form
5. DESIGN COMPONENTS Road Transects
Spotlight counts are established along road transects in each targetted Strata.
T1
T2
Spotlight Road Transects
T3
RIC FORMS REQUIRED
3. Animal Observation Form: Ungulate (Ground-based) Spotlight Count. (one per transect)
M-ODHE (6)
6. OBSERVATIONS
Encounters with the targetted taxa along each transect.
M-ODHE (8)
M-ODHE (12)
M-ODHE (3)
RIC FORMS REQUIRED
Included on Animal Observation Form
4. Marked Animal ID Form (as needed)

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 biology specialists and approved by the Resources Inventory Committee.

Table 5. 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 - Ungulates • Animal Observation Form - Ungulate (Ground-based) Classification	• PN
Spotlight Count	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - Ungulates • Animal Observation Form - Ungulate (Ground-based) Spotlight Count	• RA
Pellet Count	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - Ungulates • Animal Observation Form- Ungulate (Ground-based) Pellet Count • Ecosystem Field Form	• RA
Mark-Resight	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - Ungulates • Capture Form- Ungulate Capture • Animal Handling Form - Ungulate • Animal Observation Form- Ungulate (Ground-based) Resight by Radio Telemetry	• AA
Total Count	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - Ungulates • Animal Observation Form- Ungulate (Ground-based) Total Count	• AA

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

3.4 Presence/Not detected

Recommended method(s): See Terrestrial Vertebrate Biodiversity Reconnaissance Inventory manual for presence/not detected surveys. For known ungulate populations, herd composition surveys can be used to provide information on population composition and recruitment.

The general distribution and habitat use of the five cervids under discussion here is well known throughout most of the province (MELP Wildlife Distribution Maps). Thus there is not a great need for broad scale presence/absence sampling. Ungulates are sufficiently conspicuous, and identifiable in direct sightings, that range extensions and extra-limital occurrences will usually be documented by reports from the public and/or by incidental observations. Documenting presence by use of sign may be hampered by inability to distinguish among some species on that basis.

The RIC manual “Terrestrial Vertebrate Biodiversity Reconnaissance Inventory” is designed to provide systematic data on wildlife occurrences and distribution over a diverse landscape, and is recommended for presence/not detected sampling of cervid distribution within a defined survey area. Users wishing to delineate and establish the relative use of cervids on ungulate winter ranges should consult section 3.3.7 of that manual for the snow tracking protocol.

3.4.1 Classification Surveys

The recommended protocol for conducting herd composition surveys are encounter transects. Occasionally, however, sample blocks may be selected. The purpose of these surveys is to provide information on population composition and recruitment.

Office Procedures

- Review Section 2 ‘Conducting a Wildlife Inventory’ in the introductory manual, *Species Inventory Fundamentals* (No.1*).*
- Review 3.2.2 of this manual ‘Standards for Sex and Age Classification’.
- Obtain relevant maps for study area (e.g. 1:5,000 air photo maps, 1:20,000 forest cover maps, 1:20,000 TRIM maps, 1:50,000 NTS topographic maps).
- Identify all possible sampling units (transects or blocks) within the survey area on map sheets. Each sample unit should be of sufficient length or size to be surveyed within one sampling session (usually early morning or late evening).
- Either randomly (preferred) or systematically select sample units. If sample units are blocks, consult Sections 3.1.3 and 3.1.4 in ‘Aerial-Based Inventory Techniques for Selected Ungulates’ for appropriate procedures.
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection and Broad Ecosystem Units for the sampling units that are to be sampled.

Sampling Design

Sample units (transects or sample blocks) are either randomly (preferred) or systematically selected. Each sample unit should be of sufficient length or size to be surveyed within one sampling session.

Sample units:

1. ***Transects-*** Ground transects are often secondary roads or trails, and therefore the transect direction is predetermined. However, where feasible, systematically spaced transects through the survey area, usually orientated perpendicular to contours, and following a compass line is preferred.
2. ***Blocks-*** In some cases, it may be more practical to select permanent blocks in relatively open habitats for surveying. However, this can introduce a serious bias in the herd composition results. Thus, it is essential to verify that the blocks are providing an unbiased sample. If sample units are blocks, consult Sections 3.1.3 and 3.1.4 in 'Aerial-Based Inventory Techniques for Selected Ungulates' for appropriate procedures.

Sampling Effort

Sampling effort will depend on the level that the observed groups of animals are classified.

Personnel

- The field crew must be alert and be able to identify to species the observed ungulate groups and be able to distinguish between the class levels.
- A minimum of two people are required for road transects, a driver and an additional observer who also records sightings. Walking transects do not require a second observer.

Equipment

- Maps
- Compass or hand held GPS unit
- Data forms or tape recorder
- Clipboard or notebook
- Digital watch
- High quality binoculars (may be 7x35, 10x40 recommended)
- Spotting scope (may be 20x, 15x-45x recommended)
- Four wheel drive (4WD) vehicle (optional)

Field Procedures

- Before initiating the survey, each observer should double-check his or her classification with at least one other experienced observer for as many ungulate groups as required to consistently obtain identical classifications (a minimum of 10 groups is recommended).
- Morning surveys should start as soon as it is light enough to classify animals, and should be completed within 2 hours. Similarly, evening surveys should be completed within the last two hours of daylight.

- Verify both the start and end points of the transect or location of the boundary of the block, before starting. Be sure that the transect or block description is included on the header of the field form. This should include: observers(s); date; start time; end time; distance traveled; weather; and a unique number which identifies the transect. Each group of animals observed should be numbered sequentially on the transect (refer to data forms).
- Record each group of animals observed to Level 1, 2, 3 or 4 standards depending upon survey objectives. A group is identified by the spatial distribution of animals and by observing joint behaviour within the cluster of animals.
- Determine Broad Ecosystem Units for the group, if the transect/sample block includes more than one Broad Ecosystem Unit (BEU).

Data Analysis

- Two basic approaches have been used to determine sample sizes, population ratios and statistical variance from ground-based herd composition surveys. 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) provides the appropriate formulas for determining sample size, population ratios and variance.
- An alternative approach, which is recommended here, is known in the statistics literature as cluster sampling. Applied to herd composition surveys, cluster sampling treats groups of animals as the sampling unit. This approach assumes that groups are independently and randomly sampled from the population. Required sample sizes and confidence limits are based on either simple random sampling of animal groups (Schaeffer *et al.* 1979), or a 2-stage sampling design where land units (e.g., blocks, transects) constitute the first-stage sampling units, and groups of animals located within each sample unit comprise the second-stage (Bowden *et al.* 1984).

3.5 Relative Abundance

Recommended method(s): 1) Pellet group counts for open or closed habitats. Note: if the survey area is considered to be too large for practical application of pellet group plots, then aerial inventory methods should be used. 2) Spotlight counts for open habitats with road network.

Three techniques have potential for monitoring relative abundance: track/trail counts, pellet group counts, and transect counts. The latter may be split into day counts or night (spotlight) counts. The method to use depends on a number of variables which will vary with species, study objectives, season, habitat and access. While there is no overall 'best' method, pellet group counts and spotlight counts are recommended as the most suitable methods for monitoring relative abundance of cervids in British Columbia. Pellet group counts are most preferred, because of the comparatively high precision and accuracy with which pellet groups can be surveyed, and a high general applicability (can be used for almost any species in a range of habitats). Spotlight counts generally have a lower general applicability throughout the province (an extensive road network and open habitat are required). However, where road access is good and there is open habitat, this technique may be considered a better alternative to pellet counts. Spotlight counts have been found to be particularly useful for black-tailed deer, which typically occupy habitats with dense ground cover, making pellet group counts difficult.

3.5.1 Pellet Group Counts

First described by Bennett *et al.* (1940), fecal pellet group counts are probably the most widely used indices for monitoring ungulate abundance. Pellet group counts have been used as the primary inventory monitoring technique at the statewide level in Michigan (Bowden *et al*. 1969), at a herd level in Utah and Nevada (Robinette *et al.* 1958) and at numerous smaller study areas (Bennett *et al.* 1940; Neff 1968; Ryel 1971; Batcheler 1975; Freddy and Bowden 1983a; Stordeur 1984). The technique has been used to monitor habitat use and distribution (Collins and Urness 1981; Leopold *et al*. 1984; Loft and Kie 1988), as an index of relative ungulate abundance to monitor population fluctuations (Rowland *et al.* 1984; Stordeur 1984; Fuller 1991;1992) and in conjunction with defecation rates to estimate absolute abundance (Bennett *et al.* 1940; Eberhardt and Van Etten 1956; Neff 1968; Dzieciolowski 1973; Freddy and Bowden 1983a).

Two basic sampling methodologies exist for pellet group counts. The traditional sampling scheme involves counting pellet groups within bounded circular plots or fixed-width (strip) transects (Neff 1968). Robinette *et al.* (1958) found circular plot transects were more efficient than fixed-width transects, and required fewer transects to achieve similar precision. The required plot size is affected by the density of pellet groups in the study area (Neff 1968) and the distribution of pellet groups (i.e., uniform vs. clumped, Freddy and Bowden 1983a). Plot size should be sufficiently large to minimize the number of zero-count plots (Neff 1968). However, that must be balanced against the tendency for observers to miss more pellet groups in larger plots, which may result in under-estimates (Kie 1988). More plots are required to obtain a given level of precision when pellet group densities are low (Kie 1988), or have non-uniform distribution (Robinette *et al.* 1958, Freddy and Bowden 1983a). Generally, small areas require more sampling per unit area than larger areas for a given level of precision.

A more recently developed pellet group sampling scheme is the distance method (Batcheler 1975), which is based on the distance-to-nearest-neighbour concept (Clark and Evans 1954; Batcheler 1971). In Batcheler's (1975) design, sample points were spaced 18 m apart along randomly chosen transect lines. The distance from the sample point to the center of the nearest pellet group and the distance from that centroid to the centroid of the pellet group closest to it were measured. For both groups, a maximum distance to be searched (5.6 m for the first pellet group and 3.7 m for the second group) were chosen so that measurements were obtained at a minimum of half of the sample points. Statistical methods for this method were originally presented by Batcheler (1975) and corrected by Fisher (1979).

In a comparison using both the distance method and plots, Goulet (1984) found that the distance method required much less time and effort but provided the same accuracy and precision as the temporary plot technique. On average, it took less than half the time to complete a distance method plot as it did a plot. Those time savings might be even greater in especially brushy or difficult terrain, where the task of establishing plot boundaries and searching for pellets is very time consuming. Because of the logistical considerations, the distance method is particularly suited to work over large geographic areas where extensive rather than intensive surveys are needed (Goulet 1984).

Because the distance method is independent of plot size, search time depends on pellet group density and will be lower at high densities. Kie (1988) recommends a relatively small maximum search distance (1.8 to 3.7 m) to minimize search time. Goulet (1984), however, efficiently used a maximum search distance of 10 m. Using a larger search distance can have a significant statistical advantage by reducing the number of zero-count plots, which appreciably reduce precision when they occur.

Both temporary and permanent plots have been used for pellet group sampling. Determining which is more appropriate depends upon the objectives of the study and whether or not it is possible to differentiate between "old" and "new" pellets. In studies for monitoring trends in ungulate populations, it is necessary to be able to identify those pellets which were deposited within the last year. The standard approach for that has been to establish permanent plots and to mark or remove all pellet groups from the plots once they have been counted (Neff 1968). Methods for marking pellets have been evaluated by Kufeld (1968) who found that the visibility of pellets marked with paint ranged from 14 to 96 percent after 10.5 months. Removing each pellet group is the only way to be certain that it is not subsequently recounted in following years. Where time savings is an important consideration, and pellets are marked rather than removed, the use of yellow traffic striping paint is probably the best option (Kufeld 1968). That must be done with the understanding that for some of the pellet groups the mark will have worn off by the next year.

There are two main problems in the use of temporary plots: 1) the error associated in differentiating between new and old pellets, and 2) the potential variation in plot location when plots are re-established annually. Several authors have concluded that new pellets can be subjectively distinguished from old groups provided surveys are conducted in the spring (Ferguson 1955; Robinette *et al.* 1958; Freddy and Bowden 1983b). Further, in a study comparing permanent and temporary plots in Colorado, Freddy and Bowden (1983b) found that variation in the re-establishment of temporary plots did not result in lower precision. Both methods provided similar estimates of pellet group density, and both were equally subject to zero pellet group counts per plot and to extremes in numbers of groups. Temporary plots cost only half as much as permanent plots to establish and 16% less annually to monitor (Freddy and Bowden 1983b).

Interpretation of pellet group information must be done with caution when examining relative habitat use. Collins and Urness (1981) reported that 30% of pellet deposition occurred while deer were traveling, an activity which comprised only 4% of the animals' day. They also noted that pellet group counts did not correctly rank habitat subunit use.

Applicability of the pellet group count varies within the province. In coastal biogeoclimatic zones, the technique is less appropriate due to high (and variable) pellet deterioration rates and thick ground vegetation which increases search time and decreases pellet visibility (Harestad and Bunnell 1987). In drier biogeoclimatic zones, however, these factors are less problematic and pellet counts can provide a useful index of relative abundance.

The protocol recommended for pellet group counts in British Columbia is based on the approach outlined in detail by Smith *et al*. (1969). This approach uses linear transects with circular plots spaced at regular intervals along the transect. The plots are counted and cleared each year. While the technique has been used to estimate absolute abundance, by assuming a defecation rate and total days of occupancy on the winter range, potential errors in the defecation rate make it more suitable as a method for estimating relative abundance. The technique has been used for long-term monitoring of white-tailed deer populations in the Pend d’Oreille where population trends revealed from pellet group counts were consistent with trends revealed by spotlight counts (Gwilliam pers. comm.). The distance method of Batcheler (1975) is not recommended. If the survey area is considered to be too large for practical application of pellet group plots, then aerial inventory methods should be used.

Office Procedures

- Review Section 2 ‘Conducting a Wildlife Inventory’ in the introductory manual, *Species Inventory Fundamentals* (No.1*).*
- Ensure field survey personnel are thoroughly familiar with the pellet group survey technique described by Smith *et al*. 1969 (see Literature Cited).
- Obtain relevant maps and air photos for the study area, usually an ungulate winter (e.g. 1:5,000 air photo maps, 1:20,000 forest cover maps), delineate the survey boundary and major vegetative cover types. Calculate the size (km^2) of the study area.
- Delineate the survey boundary and transect lines on the air photos or maps. Transect lines should be oriented so they cross the drainage pattern diagonally, and the lines cross varying slope aspects and altitudinal zones. Keep a distance of at least 2 chains between lines. Determine the length of each transect line.
- Determine sample size requirements: number of plots/transect and total number of transects. Sample size requirements will vary for each study. Standard sample size calculations should be done based on a preliminary survey and the desired level of accuracy (see Sampling Design for calculations).
- Determine the size of circular plot to use. Plot size is dependent on pellet group density and should be based on a preliminary sample (see Sampling Design).

Sampling Design

- In areas where pellet group densities are believed to differ, a stratified design is recommended (Stauffer 1984).
- Linear transects are used with circular plots spaced at regular intervals along the transects. Plots are counted and cleared each year.
- Transect lines should be oriented so they cross the drainage pattern diagonally, and the lines cross varying slope aspects and altitudinal zones. Keep a distance of at least 2 chains between lines. Determine the length of each transect line.
- Determine the size of circular plot to use. A 100 ft^2 (~ 9.29 m^2) circular plot with a radius of 5.6 ft (~1.71 m) is recommended. If the ground cover is extremely dense, then a 50 ft^2 (~ 4.65 m^2) plot with radius of 4.0 ft (~ 1.22 m) may be used. Note: Plots should be large enough so that there are few zero-count plots. However, excessively large plots can take too long to search and or may result in more missed groups.
- Determine the average number of plots per transect line. Smith *et al*. (1969) provide the following formula to calculate plots/transect:

$$\overline{m} = \sqrt{\frac{c_2 s_w^2}{c_1 (s^2 - s_w^2)}}$$

where $\overline{m}$ is the average number of plots/transect, c_1 is the average time (hours) to read and clear the plot, c_2 is the average traveling time (hours) on and between transects, s_w^2 is the variance among plots on the same transect, and s^2 is the variance among all plots (determining variance will require either a pilot study, or use of data from another completed survey).

- Determine the number of transect lines to install. This will depend on the total number of person hours available for the survey, although an accepted minimum would be at least 8 to 10 transects. Smith *et al*. (1969) recommend the following formula to determine the number of transect lines:

$$n = \frac{C}{c_2 + c_1\overline{m}}$$

where n is the number of transect lines and C is the number of person hours.

[an alternative to the above is to use the sample size formula based on the normal distribution and an assumed coefficient of variation (standard deviation/mean for transects) where:

$$n = \frac{tCV}{E}$$

- where *n* is the number of transects, *t* is the student's t value of *n*, *CV* is the coefficient of variation and *E* is the confidence interval expressed as a percentage of the mean (Eberhardt 1978). Since *n* must be assumed known in order to obtain the appropriate *t* value, a trial and error (iterative) process is required to obtain the final value of *n*, or express the formula in terms of *E* (see spotlight counts)].
- Select the transects for sampling and determine plot spacing. Method 1 of Smith *et al*. 1969:12-13 is recommended: pick transects in such a way that their chance of being selected is proportional to their length. With this method, each transect will have an equal number of plots.

Sampling Effort

- The required amount of time and effort will vary for each study. It will largely depend on the distribution of pellet groups and the sample size required to achieve the desired level of accuracy.
- Established transects should be sampled annually (spring) or bi-annually (spring and fall). This involves counting and clearing all pellet groups within the circular plots along the transects. Each circular plot should be systematically searched twice for pellet groups.
- The entire survey should be completed within a one-month period, usually April or May for spring surveys and October or November for fall surveys.

Personnel

- A crew of two people is required to lay out the line of pellet plots, and to read and clear the plots.
- Field survey personnel should be thoroughly familiar with the pellet group survey technique described by Smith *et al*. 1969 (see Literature Cited).
- Field crews must be able to lay out a transect using a compass and hip chain. Only experienced crew members should be involved in the initial lay-out of pellet plots.
- One member should be experienced with pellet group surveys. They should be able to differentiate between pellets of different ages and, where possible of different species. If

both crew members are inexperienced, they should be accompanied and supervised by an experienced surveyor for a full day of on-the-job training. On the second day, a minimum of 10 plots should be searched by the experienced surveyor prior to examination by the inexperienced crew. Results should be consistent (within + 10%, e.g. if the experienced surveyor found 20 groups, the inexperienced crew should have located at least 18).

- At least one person should be familiar with the collection of habitat data.

Equipment

- Compass
- Hand held GPS
- Hip chain
- Flagging tape and marker
- Survey stakes (1/4" rebar)
- Field notebook (preferably waterproof)
- Survey data forms
- Field measuring tape or plastic chain of appropriate length
- Field map
- Clipboard and pencils
- Digital watch

Field Procedures

- A survey crew of two persons is required. Experienced crew members should lay-out the initial pellet plots.
- Mark transect end points with brightly coloured steel pegs and georeference the location with GPS.
- Install the transect by laying down plots along the predetermined compass bearing and measure plot spacing with a hip chain. The compass person should carry air photos, to reconcile the compass direction with physical terrain features observed on the ground and on the photo. The plot center should be placed exactly as indicated by the measured distance.
- Mark each plot center on the transect line with a plot center stake and georeference the location with GPS.
- Suitable plot center stakes can be made with 1/4" rebar with a loop or hook on one end. Each stake should be individually marked, e.g. with a consecutively numbered metal cattle ear tag and flagging tape.
- Read and clear the plot. Smith *et al*. 1969:16-18 provide detailed instructions for this, and their protocol should be followed. In brief, each plot should be systematically searched twice, first clockwise and then counterclockwise. The plot should be cleared completely by removing all pellets. If more than half of the pellets in the group are in the plot, count the pellet group as being in the plot. Record the total number of pellet groups on each plot (for uniformity, a minimum of 10 pellets are needed to constitute a group).
- Describe the habitat using the MOF/MELP Ecosystem Field Form. The Site Description and the Vegetation description sections of this form must be filled out (see Introduction

to RIC Wildlife Species Inventory Manual). The habitat description need only be completed once during the initial survey layout and plot clearing.

- When recording data (observers; date; start time; end time; weather; transect number and plot number, distance between plots, number of pellet groups counted), also note anything unusual about the plot location. If the plot stake is missing, it should be re-established.
- The entire survey should be completed within a one-month period.

Data Analysis

- Generally, a defecation rate will not be used. However, it is important to determine the period over which the pellet groups have been deposited. If the study population is non-migratory, it will simply be the number of days since the plots were last cleared of pellet groups. For migratory populations, the period of occupancy on the winter range should be determined in consultation with regional Wildlife Program staff.
- Determine the mean pellet group density and its variance. The mean pellet groups per plot ($\bar{x}$) is simply

$$\frac{\sum_{i=1}^{n} y_i}{m}$$

where y_i is the total number of pellet groups found on the *ith* transect and *m* is the total number of plots in the entire sample, and the variance (s^2) is

$$\frac{\sum_{i=1}^{n} (y_i - \bar{y})^2}{n(n-1)\bar{m}^2}$$

where $\bar{y}$ is the mean number of pellet groups per plot on the *ith* transect, *n* is the number of transects, and $\bar{m}$ is the mean number of plots on each transect. Then 90% confident intervals (CI's) are obtained as

$$\bar{y}$$

where *df* are the degrees of freedom (*n*-1).

- If the number of days of herd occupancy on the winter range is variable between years, then this information, along with an assumed defecation rate, should be incorporated following the procedure outlined by Smith *et al*. 1969:21. While this procedure converts pellet group densities into an absolute abundance estimate, it should only be considered a relative index, due to uncertainty about the defecation rate.

- The above method for calculating the variance and confidence intervals assumes that pellet group frequency data follows a normal distribution. Typically, pellet group data follows a negative binomial distribution because of a high number of plots with zero pellet groups. Users should therefore first determine if the normal distribution is appropriate (Zar 1984:88-96). If not, then various transformations should be considered

(Stordeur 1984), or the statistical analysis should be based on the negative binomial distribution (White and Eberhardt 1980).

- In areas where pellet group densities are believed to differ, a stratified design is recommended (Stauffer 1984).

3.5.2 Spotlight Counts

Ungulates are generally difficult to observe during daylight hours because of their cryptic appearance, secretive behaviour and low activity at that time. At night, however, many ungulates move into open areas such as cutblocks and meadows to feed (Progulske and Duerre 1964; Harestad and Jones 1981) and they tend to be less easily alarmed (McCullough 1982). Ungulates can be readily detected with spotlights at night because the light reflects from the tapetum of their eyes.

Spotlight counts are basically night time encounter transect counts which use roads as transects. Subsequently, the assumptions and requirements for spotlight counts are similar to those for transects. They have been used both to estimate population density (absolute abundance), as indices of abundance (relative abundance) and to monitor population trends from year to year (Harestad and Jones 1981; McCullough 1982; Raedeke and Taber 1985; Fafarman and DeYoung 1986). Spring spotlight counts have been found to correlate well with kill per unit effort data for black-tailed deer on Vancouver Island (Hatter and Janz 1994).

Spotlight counts may be used to estimate animal density when distances of animals from the baseline can be measured (line transect methodology), or when the effective area of the survey strip can be estimated (fixed-width (strip) transect methodology), but more research on this technique is required before spotlight counts can be considered for use as a standard method for determining absolute abundance of ungulates in British Columbia. One of the main problems with using spotlight counts is that they survey open habitats where cervids concentrate to forage. Absolute density estimates using those observations are likely to be biased and extrapolation of those estimates to larger areas may not be valid.

Two studies have examined the accuracy of the technique to estimate density. Fafarman and DeYoung (1986) found deer density estimates from spotlight counts varied between 80 and 98 percent of the assumed population density. However, McCullough (1982) attempted a comprehensive spotlight count within an enclosed deer reserve and observed only 12 to 45 percent of the known population. In that case the survey route covered all portions of the reserve, but search distances from the vehicle varied greatly among habitats and that problem was believed to partly account for the large number of deer missed. Fafarman and DeYoung (1986) calculated coefficients of variation of 27.1% and 26.3% for deer density estimates over two years. McCullough (1982) indicated coefficients of variation varied widely throughout a year, from 5 to 67 percent.

Spotlight counts of deer have been influenced by time of night, forage conditions, seasonal behaviour and various weather factors (Kie 1988). Progulske and Duerre (1964) found that most deer were seen during a four-hour period beginning one hour after sunset. Fafarman and DeYoung (1986) recommended that counts be conducted after 33% of the nocturnal time period has elapsed. In Michigan, seasonal counts varied from 12 to 13 percent of the known population in June and July, to 30 to 45 percent from December to April (McCullough 1982). Herd composition (buck:doe and doe:fawn ratios) also varied considerably throughout the year (Progulske and Duerre 1964; Fafarman and DeYoung 1986). Of the weather factors, ambient temperature had the strongest influence on deer counts with more deer seen on warmer nights (Progulske and Duerre 1964; McCullough 1982; Fafarman and DeYoung 1986).

The principal advantage of spotlight counts is that a large area can be sampled with little effort. The applicability of this technique in the province depends on the availability of open areas adjacent to roads, and their use by ungulates. In British Columbia, the technique is used most extensively to monitor black-tailed deer in coastal forests where significant cutover areas occur. Spotlight counts are particularly suited to this situation because the deer spend most of their time during the day in forest habitats where they are virtually impossible to survey (by either ground or aerial techniques) but then come out into cutover areas at night to feed. The main disadvantage of spotlight counts, when used to monitor long term trends, is habitat succession on established transects. As sites mature to the point where deer observations become inhibited, new transects have to be established through younger seral stages.

Office Procedures

- Review Section 2 ‘Conducting a Wildlife Inventory’ in the introductory manual, *Species Inventory Fundamentals* (No.1*).*
- Survey personnel should be familiar with the literature on spotlighting (see Harestad and Jones 1981, plus other Literature Cited).
- Establish the study area and consult with regional Wildlife Program staff on the location of spring ranges for deer and/or elk within this area.
- Obtain relevant maps for these areas showing road networks (e.g. 1:5,000 air photo maps, 1:20,000 forest cover maps)
- Identify potential survey routes (spotlight transects) from air photos and maps showing clearcuts or other open areas used as spring habitat, and verify the suitability of the routes with field reconnaissance.
- Establish a list of suitable spotlight transects. Transect length may vary from 0.2 to $\geq$2.0 km.
- Randomly select transects from this list until sample size requirements are met for accuracy and precision (see Data Analysis). Random selection of transects helps to ensure that transects are dispersed throughout the population being sampled.
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection and Broad Ecosystem Units (BEU’s) for each transect to be sampled. Ideally, each transect should contain only one Broad Ecosystem Unit. If a transect includes several BEU’s, it is preferable to split the transect into smaller transects, each with a different BEU.
- Each year the same transects should be counted so inter-annual population changes can be detected. Therefore, re-evaluate the transects each year to ensure that the habitat is still sufficiently open to enable spotlighting. New transects should be added as older transects are dropped due to advancing seral succession.

Sampling Design

- The main variables to consider in the sampling design are length of transects, number of transects required and number of times to sample each transect. The variables depend on the level of accuracy and precision desired (see Data Analysis).
- Surveys should be conducted when animals are concentrated on spring ranges (usually April or May).
- Surveys should be completed within as short a period of time as possible. If possible, the entire survey should be completed in one night.

- Transects should be randomly selected from a list of suitable spotlight transects. Transect length may vary from 0.2 to $\geq$2.0 km.
- Ideally, each transect should contain only one BEU.

Sampling Effort

- The required amount of time and effort will vary for each study. It will largely depend on the sample size required to achieve the desired level of accuracy and precision (i.e. the number of transects sampled and the number of replicated surveys required during animal concentration on spring ranges).
- Established transects should be sampled annually so that inter-annual population changes can be detected.
- If possible, the entire survey area should be completed in one night. To achieve this large survey areas may require 3 or more survey crews.

Personnel

- Survey personnel should be familiar with the literature on spotlighting (see Harestad and Jones 1981, plus other Literature Cited).
- A minimum survey crew of two persons is required to complete a transect: a driver and an additional observer who also records sightings on data forms. Large survey areas may require 3 or more survey crews to complete the survey within as short of period of time as possible.
- If trainees are used, they should be accompanied by an additional, experienced spotter on the right hand side of the vehicle. Generally, however, the surveys are simple and straightforward, and a new observer quickly acquires proficiency with the technique.

Equipment

- Vehicle (4WD truck)
- Maps with highlighted survey routes
- Spotlights - hand held, should be 12 volt with ideal strength between 100,000 and 200,000 cd. A 300,000 cd. spotlight may also be used, but are usually heavy and more tiring to hold.
- Binoculars (may be required to identify species)
- Data Forms
- Clipboard and pencils
- Digital watch

Field Procedures

- A minimum of two people are required to complete a transect.
- Complete the survey within as short of period of time as possible. If possible, the entire survey should be completed in one night.
- Surveys should be conducted when animals are concentrated on spring ranges (usually April or May). ***New survey areas will require an intensive series of weekly counts on a subset of transects during this period to identify the peak and duration of animal concentration on spring ranges. Subsequent surveys should be restricted to the period of maximum concentration on spring ranges.*** Some yearly variation in survey timing

may be required to adjust for annual variations in plant phenology and animal use of spring ranges.

- Transects can be started about 1 hour after sunset and may be continued throughout the duration of the night. If surveys are replicated, the order of counting the transects should be varied.
- Verify both the start and end points of the transect before starting. Be sure that the transect is included on the header of the field form. This should include: observers(s); date; start time; end time; distance traveled; weather; and a unique number which identifies the transect. It is usually not necessary to identify each group of animals as most transects should be in only one BEU.
- Transects should be driven slowly at 5 to 20 km/h, depending on visibility and road conditions.
- Spotlights are held outside the window and shone over openings in a sweeping action.
- The choroid layer of the deer's retina reflect the light, and the number of sets of eyes looking toward the vehicle are counted.
- The driver counts the left hand side of the road while the passenger counts the right and records sightings on data forms.
- If an observer is unsure of the species sighted, the vehicle should be stopped and the animal observed with binoculars.
- Although the sound of the vehicle is usually enough to cause animals to look towards the vehicle, tapping the horn occasionally helps attract their attention, especially if wind or rain masks the sound of the vehicle. Also, if a large group is spotted or when deer are moving, tapping the horn often allows a better count.
- While light rain has little effect on counts, heavy rain, wind, and fog reduce counting effectiveness, either through reduced visibility or reduced deer activity. If any of these conditions are encountered, the transect should be terminated, and the crew should proceed to the next transect. If poor conditions persist, the entire spotlight count for that night should be cancelled.

Data Analysis

- The analysis is straight forward with the survey deer/km calculated as the sum of all deer counted divided by the sum of the total km of transects.

- The required sample size (number of replicated surveys) to meet desired levels of accuracy and precision should be based upon the procedure outlined by Harestad and Jones (1981) where

  $$E = \frac{tCV}{\sqrt{n}}$$

  where E is the allowable error (expressed as a percentage of the mean), n is the number of repeated surveys, t is the student's t value for n, and CV is the coefficient of variation (standard deviation/mean). Thus, to meet intensive population management objectives (an allowable error of $\pm$ 25% of the mean, with 90% confidence intervals), 4 replicate surveys would be required if the CV$\simeq$0.25.

- Generally, it will be more efficient to increase the total length of transects to be surveyed, rather than increase the number of replicated surveys. As a rough "rule of thumb" Harestad and Jones (1981) suggested that the total length of transects should be sufficient to count at least 100 deer on each survey. This, however, should be verified by using the formula above.

3.6 Absolute Abundance

Recommended method(s): Replicated mark-resight surveys.

Six techniques have potential for estimating absolute abundance, but they are all either impractical to use in a large-scale monitoring program, or not likely to provide reliable absolute estimates. When absolute abundance estimates of ungulates are required and habitats are open, aerial surveys should be considered as the method of choice.

Drive counts can be used to get total counts but they require a large, coordinated labour force and are impractical except at very small scales (McCullough 1979). Spotlight counts using line transect methodology holds some promise for providing density estimates, but their use requires relatively open habitats adjacent to extensive road networks. In British Columbia, those open habitats usually form small patches within a mostly forested landscape and they are often preferentially sought out because they offer favourable foraging conditions (especially at certain times of the year). Because of this, density estimates of spotlight surveys are likely to be biased.

Determining absolute densities from pellet group counts requires the knowledge of how long animals have been depositing pellets in an area and their average defecation rate over that period. Although generalizations about defecation rates are frequently made in the literature (e.g., Neff 1968), other studies indicate that defecation rates vary significantly within a species depending on habitat, season and available forage. The only really valid way to incorporate pellet group data into an absolute population study is to document the defecation rates of the species being monitored through specific observations within the study area and at the time of the study.

Change-in-ratio (Paulik and Robson 1969, Otis 1980, Conner *et al*. 1986) and catch-effort methods (Seber 1982, Lancia *et al*. 1996) may also hold some promise, but both methods require substantial removals of the population, either by hunting or trapping. Thus, they are not likely to have wide-spread application, other than perhaps for small closed populations such as those found on small coastal islands.

Given the limitations of the above methods, mark-resight is considered to be the most cost-effective technique for determining absolute abundance of cervids. In most cases, successful application to ground surveys will be limited to relatively small, closed populations. Large scale application of mark-resight requires aerial surveys.

3.6.1 Mark-Resight

Mark-resighting surveys represent a more technologically advanced approach to abundance estimation using traditional mark-recapture methodology. An initial sample of animals are captured and marked with radio transmitters, but recaptures of these animals are obtained by observation, not actually recapturing them. The limitation of this procedure is that unmarked animals are not marked on subsequent occasions. The advantage of this procedure is that resightings are generally much cheaper to acquire than physically capturing and handling the animals (White 1996). The mark-resight procedures has been tested with known population of mule deer (Bartmann *et al*. 1987), white-tailed deer (Rice and Harder 1977), elk (Bear *et al*. 1989), and moose (Bowden and Kufeld 1995). Usually, it is most effectively accomplished with aerial counting, although it has been adapted to ground counting using spotlighting or daytime road transects (Strandgaard 1967, McCullough and Hirth 1988, Storm *et al*. 1992).

Critical assumptions for the general mark-resighting model are: 1) the probability of sighting of marked and unmarked animals is the same, 2) marked and unmarked animals are correctly classified, 3) marked animals are randomly distributed throughout the population, or at least resighting effort is randomly distributed throughout the population, 4) each animal has an identical, but independent probability of being resighted, 5) the number of marked animals in the population is known that in turn assumes markers are not lost or accounted for, and 6) the population is geographically and demographically close; i.e. no immigration, emigration, recruitment, or deaths occur during the population surveys in a geographically defined area. Several modifications to this model allow for individual heterogeneity of sighting probability (Minta and Mangel 1989, Bowden and Kufeld 1995), or immigration and emigration from a fixed study area (Neal *et al*. 1993). All of these models are available in a suite of mark-resight programs, known as NOREMARK (White 1996).

Office Procedures

- Review the section ‘Conducting a Wildlife Inventory’ in the introductory manual, *Species Inventory Fundamentals* (No.1*).*
- Survey crew should be familiar with the literature on mark-recapture (Krebs 1989) and mark-resighting methodology (White 1996, see also Literature Cited).
- Survey crew should thoroughly review the Animal Capture and Handling manual before commencing with a RIC wildlife inventory survey that requires capture and/or handling.
- Survey crew should be familiar with the manuals, *Live Animal Capture and Handling of Wild Mammals, Birds, Amphibians, and Reptiles* (No. 3) and *Wildlife Radio-telemetry* (No. 5).
- Establish the study area (typically an ungulate winter range) and consult with regional Wildlife Program staff to determine if an open or closed population assumption is required, and if their will likely be heterogeneity in sighting probabilities. Closed population estimators, with or without heterogeneity in sighting probability, are preferred.
- Consult with regional Wildlife Program staff to obtain a preliminary estimate of animals numbers. Use program NOREMARK (see Data Analysis) to determine the number of resighting surveys, proportion of the population to mark, and proportion of the population to resight on each occasion to achieved a specified level of precision.

- Determine the most effective method for capturing animals for radio-collaring (e.g. net-gunning, clover traps, drop-nets, aerial or ground-based darting).
- Identify potential survey routes (transects) from air photos and maps that will ensure the resighting surveys are dispersed throughout the population being sampled.
- The number of transects used in the resighting surveys should be sufficient to ensure that at least one-third of the study area is searched.

Sampling Design

- A proportion of the species population of interest is captured, marked and radio collared.
- When a sufficient number of animals have been captured and collared, a number of resighting surveys are conducted. Resighting surveys are dispersed throughout the population being sampled and cover at least one-third of the study area. If possible, the entire resighting survey should be completed within one 12 hour period.
- Consult with regional Wildlife Program staff to obtain a preliminary estimate of animals numbers. Use program NOREMARK (see Data Analysis) to determine the proportion of the population to mark, the number of resighting surveys and proportion of the population to resight on each occasion to achieve a specified level of precision.

Sampling Effort

- The effort required will largely depend on: 1) the amount of time required to capture and radio-collar enough animals; 2) the number of resighting surveys required; and 3) the proportion of the population that must be resighted on each occasion (intensity of sampling) to achieve a specified level of precision.
- Timing: allow 2-3 weeks for collared animals to redistribute after completion of capturing and marking, before initiating resighting surveys. Resighting surveys should be done at weekly intervals, if possible, with all surveys confined to the period where geographic closure is assumed (unless an open population estimator is used). If possible, resighting surveys should be completed within one 12 hour period

Personnel

- The survey crew should be familiar with the literature on mark-recapture (Krebs 1989) and mark-resighting methodology (White 1996, see also Literature Cited).
- A minimum crew of two persons is required for resighting surveys: a driver and an additional observer who also records sightings on data forms. Large survey areas may require 3 or more survey crews in order to complete the survey within as short a period of time as possible.
- Survey crew should be familiar with the Animal Capture and Handling manual before commencing with a RIC wildlife inventory survey that requires capture and/or handling.
- Survey crew should be familiar with the Radio Telemetry protocol.

Equipment

- Radio collars and associated radio telemetry equipment (see RIC Radio Telemetry manual)
- Each collar should be uniquely marked for visual identification
- Vehicle (4WD truck preferred)
- Maps with highlighted survey routes

- Spotlights - hand held, should be 12 volt with ideal strength between 100,000 and 200,000 cd. A 300,000 cd. spotlight may also be helpful for reading collar numbers.
- Binoculars (required to identify collar numbers of animals)
- Data Forms
- Clipboard and pencils
- Digital watch

Field Procedures

- Follow RIC animal handling protocols (see Animal Capture and Handling manual) and telemetry protocols (see Radio Telemetry manual) for the capture and collaring of animals. Ensure that marked animals are distributed throughout the population and over the entire study area. Collars should have a clearly visible identifiable number that can be read at a distance with binoculars.
- If the entire population is to be estimated, then the sex and age composition of marked animals should be similar to the composition of the live population, as determined from previous herd composition surveys.
- Allow 2-3 weeks after completion of trapping and marking for collared animals to redistribute, before initiating resighting surveys.
- Resighting surveys should be done at weekly intervals, if possible, with all surveys confined to the period where geographic closure is assumed (unless an open population estimator is used).
- A minimum of two people are required to complete a transect during resighting surveys, a driver and an additional observer who also records sightings on data forms. Large survey areas may require 3 or more survey crews in order to complete the survey within as short a period of time as possible. If possible, the entire survey should be completed within one 12 hour period.
- Transects should be driven slowly at 5 to 20 km/h, depending on visibility and road conditions, and cover the entire study area. For night counts, standard spotlighting procedures should be used.
- For each group of animals observed, the location (plotted on maps), weather, BEU, group size, sex and age composition, number and identification of collared animals, and identification of marks should be recorded. If marks can not be observed, the group should be checked for marked animals by scanning the collar frequencies with a radio receiver.
- After each survey, the locations of collared animals not observed should be verified to determine if they are within or outside the study area, and which marked animals, if any, have died.

Data Analysis

- Program NOREMARK (White 1996) should be used to compute estimates of population size and their confidence limits. Four different estimators are provided in the program, and the user should select the most appropriate estimator, based assumptions about individual heterogeneity in sighting probabilities and immigration and emigration to and from the study area. The program is available at the following WWW (World Wide Web) site: http://www.cnr.colostate.edu/~gwhite/software.html

3.6.2 Small Coastal Islands - A Special Case

The relatively high density and restricted range of fallow deer on James and Sidney Islands provides a unique situation where drive counts, mark-resight and change-in-ratio techniques could be tested for estimating absolute abundance. Even in these simple systems, however, the costs of these methods may be prohibitively high for a typical monitoring program. Sidney Island is too large for drive counts but the technique may be applicable on James Island. Mark-resight surveys, using foot transects, hold potential for both islands. The change-in-ratio technique could be tested if a significant proportion of the population was to be removed as part of a management program. Under that condition, replicated ground surveys before and after removal may yield a fairly accurate and precise estimate at a reasonable cost. For detailed protocols of these techniques refer to references cited earlier in the evaluation of each technique(see the introduction to section 3.6.).

Under normal conditions, the best technique for fallow deer on these two islands is probably an extensive walking ground count in forested habitats combined with replicated complete counts of deer occupying fields during the spring green-up period. However, without some correction for animals missed (e.g. method bounded counts, Robson and Whitlock 1964, but see Routledge 1982) , the resulting counts should be used as minimum population estimates. Moody *et al*. (1987) used the walking ground count method in Sidney Island Provincial Park and believed it provided an accurate total count of the deer (i.e., with few deer likely to have been missed).

Glossary

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

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

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 1984 cited in Murphy 1988).

BLUE LIST: Includes any indigenous species or subspecies (taxa) considered to be Vulnerable in British Columbia. Vulnerable taxa are of special concern because of characteristics that make them particularly sensitive to human activities or natural events. Blue-listed taxa are at risk, but are not extirpated, endangered or threatened.

CERVID: Member of the deer family.

CREPUSCULAR: Active at twilight

ENCOUNTER TRANSECT: A survey method in which an observer traverses a linear route (which may or not be straight), counting the number of animals seen on both sides of the baseline without regard to distance of animals off the line.

LINE TRANSECT: A survey method in which an observer traverses a route of fixed length, counting the number of animals seen on both sides of the baseline and records either their perpendicular distance to the baseline or their distance from the observer and the angle off the transect in which they lie.

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

PARTURITION: Giving birth to young, childbirth.

PELLET GROUP: An arbitrary number of ungulate fecal pellets in close association which resulted from one defecation by an animal; for monitoring purposes consider a pellet group as an association of 10 or more fecal pellets.

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 generally takes place within smaller study areas within this project area.

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: Includes any indigenous species or subspecies (taxa) considered to be Extirpated, Endangered, or Threatened in British Columbia. Extirpated taxa no longer exist in the wild in British Columbia, but do occur elsewhere. Endangered taxa are facing imminent extirpation or extinction. Threatened taxa are likely to become endangered if limiting factors are not reversed. Red-listed taxa include those that have been, or are being, evaluated for these designations.

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.

RUMINATE: To chew the cud.

RUT: The periodic sexual excitement of a male deer, goat, etc.

SIGN: Fecal pellets, tracks, bedding depressions (and hair found in those beds), shed antlers, feeding marks and any other kinds of marks or evidence an animal leaves.

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.

FIXED-WIDTH TRANSECT: A type of transect survey method in which a maximum fixed width out from the baseline is established, and only animals within that strip are counted (= belt or strip transect).

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

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

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

YELLOW-LISTED SPECIES: Any native species which is not red- or blue-listed.

Literature Cited

Anderson, D.R., J.C. Laake, B.R. Crain and K.P. Burnham. 1979. Guidelines for line transect sampling of biological populations. J. Wildl. Manage. 43(1): 70-78.

Anderson, A.E. and O.C. Walmo. 1984. *Odocoileus virginianus*. Mammalian Species. No. 219. Amer. Soc. Mammal.

Banfield, A.W.F. 1987. The mammals of Canada. National Museums of Canada. Univ. Toronto Press. Toronto, Ont. 438 pp.

Bartmann, R.M., G.C. White, L.H. Carpenter, and R.A. Garrott. 1987. Aerial mark-recapture estimates of confined mule deer in pinyon-juniper woodland. J. Wildl. Manage. 51:41-46.

Batcheler, C.L. 1971. Estimation of density from a sample of joint point and nearest neighbour distances. Ecology 52:703-709.

Batcheler, C.L. 1975. Development of a distance method for deer census from pellet groups. J. Wildl. Manage. 39: 641-652.

Bear, G.D., G.C. White, L.H. Carpenter, R.B. Gill, and D.J. Essex. 1989. Evaluation of aerial mark-resighting estimates of elk populations. J. Wildl. Manage. 53:908-915.

Bennett, L.J., P.F. English and R. McCain. 1940. A study of deer populations by use of pellet-group counts. J. Wildl. Manage. 4: 398-403.

Bowden, D.C. and R.C. Kufeld. 1995. Generalized mark-sight population size estimation applied to Colorado moose. J. Wildl. Manage. 59:840-851.

Bowden, D.C., A.E. Anderson and D.E. Medin. 1969. Frequency distributions of mule deer fecal group counts. J. Wildl. Manage. 33: 895-905.

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.

Burnham, K.P., D.R. Anderson and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildl. Monog. No. 72. 202p.

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

Clark, P.J. and F.C. Evans. 1954. Distance to nearest neighbour as a measure of spatial relationships in populations. Ecology 35(4):445-453.

Collins, W.B. and P.J. Urness. 1981. Habitat preferences of mule deer as rated by pellet-group distributions. J. Wildl. Manage. 45:969-972.

Conner, M.C., R.A. Lancia and K.H. Pollock. 1986. Precision of the change in ratio techniques for deer population management. J. Wildl. Manage. 50: 125-129.

Cowan, I. McT. and C.J. Guiguet. 1973. The mammals of British Columbia. B.C. Provincial Museum Handbook No. 11. Victoria, B.C. 414 pp.

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.A., 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. B.C. Min. Environ., Victoria, B.C.

Dzieciolowski, R.M. 1973. The use of pellet-group counts to census red deer (*Cervus elaphus* L.). Trans. Int. Cong. Game Biol. 11: 559-563.

Eastman, D. 1977. Habitat selection and use in winter by moose in sub-boreal forest of north-central British Columbia and relative to forestry. unpubl. Ph. D. dissertation. Univ. of British Columbia, Vancouver, B.C.

Eberhardt, L.L. 1978. Appraising variability in population studies. J. Wildl. Manage. 42:207-238.

Eberhardt, L.L. and R.C. Van Etten. 1956. Evaluation of the pellet group count as a deer census method. J. Wildl. Manage. 20: 70-72.

Edwards, R.Y. 1954. Comparison of an aerial and ground census of moose. J. Wildl. Manage. 18: 403-404.

Edwards, R.Y. and R.W. Ritcey. 1956. The migration of a moose herd. J. Mammal. 37: 489-494.

Fafarman, K.R. and C.A. DeYoung. 1986. Evaluation of spotlight counts of deer in south Texas. Wildl. Soc. Bull. 14: 180-185.

Feldhamer, G.A., K.C. Farris-Renner and C.M. Barker. 1988. *Dama dama*. Mammalian Species No. 317. Amer. Soc. Mammal.

Ferguson, R.B. 1955. The weathering and persistency of pellet groups as it affects the pellet group count method of censusing mule deer. Utah Acad. Proc. 32:59-64.

Fisher, A. R. 1979. Ambiguities in distance method for censusing deer by pellet groups. J. Wildl. Manage. 43: 969-970.

Franzmann, A.W. 1981. *Alces alces*. Mammalian Species No. 154. Amer. Soc. Mammal.

Franzmann, A.W., J.L. Oldemeyer P.D. Arneson and R.K. Seemel. 1976. Pellet-group evaluation for census and habitat use of Alaskan moose. North. Am. Moose Conf. 12:1-16.

Freddy, D.J. and D.C. Bowden. 1983a. Sampling mule deer pellet-group densities in juniper-pinyon woodland. J. Wildl. Manage. 47: 476-485.

Freddy, D.J. and D.C. Bowden. 1983b. Efficacy of permanent and temporary pellet plots in juniper-pinyon woodland. J. Wildl. Manage. 47: 512-516.

Fuller, T.K. 1991. Do pellet counts index white-tailed deer numbers and population change? J. Wildl. Manage. 55: 393-396.

Fuller, T.K. 1992. Do pellet counts index white-tailed deer numbers and population change?: a reply. J. Wildl. Manage. 56: 613.

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. 108 pp.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. Univ. Chicago Press. Chicago. 373 pp.

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

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

Goulet, L.A. 1984. Ungulate pellet group surveys on the Liard and Stikine Rivers using the plotless Batcheler's technique. pp. 26-34, *in* L.A. Stordeur (ed). Proceedings of a seminar on ungulate pellet group sampling and data analysis techniques. B.C. Min. For. WHR-7, Victoria, B.C.

Harestad, A.S. and F.L. Bunnell. 1987. Persistence of black-tailed deer fecal pellets in coastal habitats. J. Wildl. Manage. 51:33-37.

Harestad, A.S. and Jones, G.W. 1981. Use of night counts for censusing black-tailed deer on Vancouver Island. pp 83-96, *in* F.W. Miller and A. Gunn, (eds). Symposium On Census and Inventory Method for Populations and Habitats. Proc. Symp. Northwest Sect. Wildl. Soc. Banff, AB.

Harestad, A.S., J.A. Rochelle, and F.L. Bunnell. 1982. Old-growth forests and black-tailed deer on Vancouver Island. Trans. N. Am. Wildl. Nat. Resour. Conf. 47:343-352.

Hatter, I. and D. Janz. 1994. Apparent demographic changes in black-tailed deer associated with wolf control on northern Vancouver Island. Can. J. Zool. 72:878-884.

Hatter, J. 1949. The status of moose in North America. Trans. N. Amer. Wildl. Conf. 14:492-501.

Hatter, J. 1950. The moose of central British Columbia. unpubl. Ph. D. thesis. State College of Wash. Pullman. 357 pp.

Hesselton, W.T. and R.M. Hesselton. 1987. White-tailed deer. pp 876-901, *in* Wild mammals of North America, Biology·Management·Economics (J.A. Chapman and G.A. Feldhamer, eds.) John Hopkins Univ. Press. Baltimore. 1147 pp.

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

Kelsall, J.P. 1968. Structural adaptations of moose and deer for snow. J. Mammal. 50: 302-310.

Kelsall, J.P. and E.S. Telfer. 1974. Biogeography of moose with particular reference to western North America. Nat. Can. 101: 117-130.

Kie, J.G. 1988. Performance in wild ungulates: measuring population density and condition of individuals. USDA Forest Service, Gen. Tech. Rep. PSW-106. 17 pp.

Knight, R.R. 1970. The Sun River elk herd. Wildl. Monogr. 23. 66 pp.

Krebs, C.J. 1989. Ecological Methodology. Harper and Row, New York. 654pp.

Kufeld, R.C. 1968. Use of paint for marking deer pellet groups. J. Wildl. Manage. 32: 593-596.

Lancia, R.A., J.W. Bishir, M.C. Conner, and C.S. Rosenberry. 1996. Use of catch-effort to estimate population size. Wildl. Soc. Bull. 24:731-737.

Leopold, B.D., P.R. Krausman and J.J. Hervert. 1984. Comment: the pellet-group census technique as an indicator of relative habitat use. Wildl. Soc. Bull. 12: 327-326.

Loft, E.R. and J.G. Kie. 1988. Comparison of pellet group and radio triangulation methods for assessing deer habitat use. J. Wildl. Manage. 52: 524-527.

Luttmerding, H.A., D.A. Demarchi, E.C. Lea, D.V. Meidinger and T. Vold. (Eds.) 1990. Describing ecosystems in the field, 2nd Ed. MOE Manual 11. B.C. Min. Environ. and B.C. Min. For. 213 pp.

Mackie, R.J., K.L Hamlin and D.F. Pac. 1987. Mule deer. pp. 862-877, *in* Wild mammals of North America, Biology·Management·Economics (J.A. Chapman and G.A. Feldhamer, eds.) John Hopkins Univ. Press. Baltimore. 1147 pp.

MacCracken, J.G. and V. van Ballenberghe. 1987. Age-and sex-related differences in fecal pellet dimensions of moose. J. Wildl. Manage. 51:360-364.

McCullough, D.R. 1979. The George Reserve deer herd: population ecology of a K-selected species. Ann Arbor. University of Michigan Press. 271pp.

McCullough, D.R. 1982. Evaluation of night spotlighting as a deer study technique. J. Wildl. Manage. 46:963-973.

McCullough, D.R. and D.H. Hirth. 1988. Evaluation of the Peterson-Lincoln estimator for a white-tailed deer population. J. Wildl. Manage. 52: 534-544.

McNay, R.S. and R. Davies. 1985. Interactions between black-tailed deer and intensive forest management: a problem analysis. B.C. Minist. Environ. Minist. For. Res. IWIFR-22.

Minta, S. and M. Mangel. 1989. A simple population estimate based on simulation for capture-recapture and capture-resight data. Ecology 70:1738-1751.

Moody, A., Burton, B. and Moody, R. 1987. An investigation into the ecology of fallow deer of Sidney Island Provincial Park, B.C. B.C. Min. Environ., Victoria, B.C.

Murie, O.J. 1975. A field guide to animal tracks. Peterson Field Guide Series No. 9. Houghlin Mifflin Co. Boston, Mass.

Neal, A.K., G.C. White, R.B. Gill, D.F. Reed, and J.H. Olterman. 1993. Evaluation of mark-resight model assumptions for estimating mountain sheep numbers. J. Wildl. Manage. 57:436-450.

Neff, D.J. 1968. The pellet-group count technique for big game trend, census and distribution: a review. J. Wildl. Manage. 32: 597-614.

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

Otis, D.L. 1980. An extension of the change-in-ratio method. Biometrics 36:141-147.

Paulik, G.J. and D.S. Robson. 1969. Statistical calculations for change-in-ratio estimators of population parameters. J. Wildl. Manage. 33: 1-27.

Peek, J.M. 1974. On the nature of winter habitats of Shiras moose. Nat. Can. 191:131-141.

Peek, J.M. 1987. Elk. pp 851-861, *in* Wild mammals of North America, Biology·Management·Economics (J.A. Chapman and G.A. Feldhamer, eds.) John Hopkins Univ. Press. Baltimore. 1147 pp.

Petticrew, P.S. and L. Jackson. 1980. Preliminary deer management plan for British Columbia. B.C. Min. Environ., Fish and Wildl. Br., Victoria, B.C.

Petticrew, P.S. and W.T. Munro. 1979. Preliminary moose management plan for British Columbia. B.C. Min. Environ., Fish and Wildl. Br., Victoria, B.C.

Progulske, D.R. and D.C. Duerre. 1964. Factors influencing spotlight counts of deer. J. Wildl. Manage. 28: 27-34.

Raedeke, K.J. and R.D. Taber. 1985. Black-tailed deer population regulation through antlerless hunts in western Washington. In F.L. Bearson, F.F. Roberson, eds. Game Harvest Management. Caeser Kleberg Wildlife Research Institute. Kingsville, Texas.

Rezendes, P. 1992. Tracking and the art of seeing - how to read animal tracks and sign. Camden House Pub. Charlotte, Vermont. 320 pp.

Rice, W.R. and J.D. Harder. 1977. Application of multiple aerial sampling to a mark-recapture census of white-tailed deer. J. Wildl. Manage. 41:197-206.

Robinette, W.L., R.B. Ferguson and J.S. Gashwiler. 1958. Problems involved in the use of deer pellet group counts. Trans. N. Amer. Wildl. Conf. 23:411-425.

Robson, D.S and J.H. Whitlock. 1964. Estimation of the truncation point. Biometrika 51:33-39.

Routledge, R.D. 1982. The method of bounded counts: when does it work? J. Wildl. Manage. 46:757-761.

Rowland, M.M., G.C. White and E.M. Karlen. 1984. Use of pellet-group plots to measure trends in deer and elk populations. Wildl. Soc. Bull. 12: 147-155.

Ryel, L.A. 1971. Evaluation of pellet group surveys for estimating deer populations in Michigan. Michigan Dept. Nat. Res. Resource Dev. Rep. 250. 237 pp.

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

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

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters, 2nd ed. London. Griffin. 654 pp.

Smith, R.H., D.J. Neff and C.Y McCulloch. 1969. A model for the installation and use of a deer pellet group survey. Ariz. Game and Fish Dep. Spec. Rep. 1. 30 pp.

Stauffer, H. 1984. Sampling design. pp. 61-89, *in* L.A. Stordeur (ed). Proceedings of a seminar on ungulate pellet group sampling and data analysis techniques. B.C. Min. For. WHR-7, Victoria, B.C.

Stevens, V. and S. Lofts. 1988. Wildlife habitat handbooks for the Southern Interior Ecoprovince. Volume 1: species notes for mammals. B.C. Min. Environ., B.C. Min. For., Wildlife Habitat Canada, Victoria, B.C.

Storm, G.L., D.F. Cottam, R.H. Yahner and J.D. Nichols. 1992. A comparison of 2 techniques for estimating deer density. Wildl. Soc. Bull. 20:197-203.

Strandgaard, H. 1967. Reliability of the Peterson method tested on a roe-deer population. J. Wildl. Manage. 31: 643-651.

Stordeur, L.A. (editor). 1984. Proceedings of a seminar on ungulate pellet group sampling and data analysis techniques. Research Branch, B.C. Min. of For. WHR-7. Victoria, B.C. 98 pp.

Van Ballenberghe, V. 1977. Migratory behavior of moose in south-central Alaska. Internat. Cong. Game Biol. 13: 103-108.

White, G.C. and L.E. Eberhardt. 1980. Statistical analysis of deer and elk pellet-group data. J. Wildl. Manage. 44: 121-131.

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. 718 pp.