Lower Goldstream valley

Moose population monitoring in the Lake Revelstoke valley, 2002–2003

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EXECUTIVE SUMMARY

Moose (*Alces alces andersoni*) numbers north of Revelstoke in the northern Columbia Mountains of British Columbia appear to have increased substantially over the past 2 decades. This has led to mounting conflicts with forestry interests, and concern has been raised about the impact of a moose-supported and apparently increasing wolf (*Canis lupus*) population on a sympatric and declining mountain caribou (*Rangifer tarandus caribou)* herd. To provide a current estimate of moose numbers in this area and strengthen background data for management decisions, we conducted a stratified random block aerial survey 14–28 January 2003. The primary objectives were to estimate moose density (absolute abundance) and composition within the study area. A secondary objective was to estimate moose numbers and distribution along the Illecillewaet and Tangier rivers northeast of Revelstoke. Finally, we wanted to present methods to monitor relative abundance, and discuss using aerial methods versus a pilot study based on pellet transects.

The 1,044-km^2 study area was located along the shores of the Columbia River and Lake Revelstoke, and their tributaries, from the town of Revelstoke in the south to Kinbasket Lake (Encampment Creek) in the north, including the Jordan River northwest of Revelstoke, and the Illecillewaet and Tangier rivers northeast of town (the latter of particular interest to Parks Canada). We counted 166 moose during stratification flights. Sample unit (SU) boundaries and designations were adjusted subsequent to the stratification flights, resulting in 53 SUs in density strata: 9 high, 18 medium, and 26 low strata.

We estimated population size using program MOOSEPOP with sightability correction (modelled from recent British Columbia data) applied to each stratum calculated using program AERIAL SURVEY. During the survey we counted 639 moose in 337 groups, including 318 cows, 69 calves, 212 bulls, and 40 unclassified adults. Group size ranged from 1 to 10 moose. We calculated a naïve (uncorrected for sightability) estimate of 954 moose. When the sightability correction was applied, our estimate was 1,650 moose (±415 moose or 25.2% [90% confidence interval]; 1,235–2,066 moose). The overall sightability correction factor was 1.72. Corrected density averaged 1.58 moose/km^2 within the study area (0.17, 2.06, and 3.54 moose/km^2 in low, medium and high strata, respectively). The bull:cow ratio was high (77 or 83 bulls:100 cows, depending upon the program), but the calf:cow ratio was low (22 or 24 calves:100 cows).

At the request of Parks Canada, we spent additional time surveying the Illecillewaet and Tangier drainages northeast of Revelstoke. We observed 6 moose, and from our coverage and observed tracks suggest that roughly 15–20 moose may inhabit these drainages, with a concentration in the Tangiers and a few scattered animals along the valley bottom of the Illecillewaet River. Substantial annual mortality from collision with vehicles and trains may have suppressed moose numbers in this area.

To monitor relative abundance of moose within the study area on an annual basis we established 13 transects (mean = 1,446 m) in fall 2002 in a stratified random design pattern. We counted and cleared moose pellet groups every 50 m within 5.65 m radius plots (100 m^2). Three hundred and seventy-six plots were sampled along these transects, and 183 moose pellet groups were counted. Mean number of moose pellet groups per plot was 0.48 (SE = 0.054), and 27% of the plots contained at least 1 pellet group.

Comparisons with previous survey data suggest that moose numbers in the study area have more than doubled in the past 9–12 years. Given current harvest rates, hunter harvest likely could be more than doubled while still maintaining a stable population. Given the importance of Lake Revelstoke moose numbers in the context of wolf/caribou dynamics and forestry concerns, we recommend annual moose population monitoring. We suggest that a stratified random block survey be conducted every 5 years, with annual trend monitoring conducted by either pellet-group transects or aerial surveys of a sample of sample units in high and medium density areas. The former method may be less costly with the use of local volunteers, but will not provide data on age and sex ratios.

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INTRODUCTION

Moose (*Alces alces andersoni*) numbers north of Revelstoke in the northern Columbia Mountains of southeastern British Columbia appear to have increased substantially over the past 2 decades. In the late 1970s to the early 1980s, moose apparently numbered roughly 250–275 animals in the Columbia Valley from Revelstoke north to the Mica Dam, primarily residing in valley-bottom, riparian dominated and adjacent forested habitats during winter (Bonar 1983). Construction of the Revelstoke Dam in 1983 flooded the valley, eliminating much of this heavily utilized habitat. However, large increases in the amount of young seral habitat resulting from extensive logging appear to have resulted in an increase in moose habitat and population numbers. This is a common phenomenon throughout much of their range (Thompson and Stewart 1997). In 1991, L. Ingham (Columbia Basin Fish and Wildlife Compensation Program [CBFWCP], unpublished data) conducted a total count survey of the area using 15 hours of helicopter time and counted 261 moose. In February 1994, J. Krebs (CBFWCP, unpublished data) used 24 hours of helicopter time for a total count survey and counted 418 moose. Three blocks in the Goldstream valley were recounted in January 1995. No sightability corrections were recorded during these surveys. Current estimates for the area range from 600–800 moose (G. Woods, BC Ministry of Water, Land and Air Protection [MWLAP], personal communication).

Moose numbers appear to have increased to the point where conflicts with forestry interests are mounting, resulting primarily from browsing and bark stripping damage to plantations (D'Eon et al. 2002). There is also a desire among managers to maximize recreational opportunities from this population. In addition, concern has been raised about the impact of a moose-supported and apparently increasing wolf (*Canis lupus*) population on a sympatric and declining mountain caribou (*Rangifer tarandus caribou)* herd. To provide a current estimate of moose numbers in this area and strengthen background data for management decisions, we conducted a stratified random block aerial survey in January 2003. The primary objectives were to estimate moose density (absolute abundance) and composition within the study area. A secondary objective was to estimate moose numbers and distribution along the Illecillewaet and Tangier rivers northeast of Revelstoke. Finally, we wanted to present methods to monitor relative abundance, and discuss using aerial methods versus a pilot study based on pellet transects.

STUDY AREA

The study area was located in the northern Columbia Mountains along the shores of the Columbia River and Lake Revelstoke, and their tributaries, from the town of Revelstoke in the south to Encampment Creek in the north (Fig. 1). Valley-bottom elevation is approximately 430 m (below the Revelstoke Dam) to 570 m asl, and surrounding ridges and mountain peaks range from 2,000–3,000 m. The valley is bisected by the Lake Revelstoke reservoir, which varies in width from 250–1,400 m, but is usually about 700 m wide. On the east side of the reservoir, there is a 2-lane highway that parallels the shoreline, usually within 100 m, that was built to service Mica Dam and is now also primarily used by recreationists and logging trucks. In contrast, the west side of the reservoir has limited roads and is accessible only by boat or small ferry, except at its northern tip. The study area encompassed most of the lower elevations of Wildlife Management Units (MU) 4-38 and 4-39.

The dominant biogeoclimatic subzone and variants in the study area are Interior Cedar-Hemlock wet-cool (ICHwk1), very wet-cool (ICHvk1) and to a small extent moist-warm (ICHmw3), at lower elevations (Braumandl and Curran 1992). Upper elevation areas are dominated by Engelmann spruce-Subalpine fir very wet-cold (ESSFvc). The transition between the ICH and ESSF zones occur at approximately 1,280–1,400 m, depending on the subzone-variant and aspect. Dominant tree species in these ICH subzones are western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*) and to a lesser extent Douglas-fir (*Pseudotsuga menziesii*). At higher elevations, where the ESSF replaces the ICH, large tracts of Engelmann spruce (*Picea engelmanii*) and subalpine fir (*Abies lasiocarpa*) occur.

Habitat within the moose inventory study area primarily included a mosaic of mature and old growth forests, extensive areas of young forest at a range of ages since clear-cut logging, riparian forests and shrublands, and upper-elevation basins and avalanche chutes.

The study area has a wet climate with an average of 946 mm of precipitation annually (425 cm of snow falls annually; Environment Canada climate normals, unpublished data). Mean July and January temperatures for Revelstoke are 18.2 and –5.3°C, respectively. Snow survey (depth) and snow pillow data (snow water equivalent) were obtained from government web sites (http://srmwww.gov.bc.ca/aib/wat/rfc/river_forecast/snowp.htm). Snow water equivalent is significantly related to snow depth ($r^2 = 0.82$; Delgiudice et al. 2001). All data sources suggest that snow depths during January 2003 were significantly below average for that time of year. Snow pillow data from a monitoring station at Mount Revelstoke at 1,830 m elevation indicate that snow depths from mid- to late January were about 30% below normal (9 years of data). Snow survey measurements at the Downie Slide (980 m elevation) were 35% below normal during 1 February 2003 measurements (17 years of data).

Moose were probably the main ungulate prey for wolves in the area. Black bears (*Ursus americanus*) and grizzly bears (*U. arctos*) were also comparatively abundant in the study area (G. Woods, personal communication), while cougars (*Felis concolor*) were present but probably rare (Serrouya and D'Eon 2003). White-tailed deer (*Odocoileus virginianus*) and mule deer (*O. hemionus*) were found at low densities, primarily in the southern portions of the study area, and the Revelstoke (north Columbia Mountains) mountain caribou herd utilized the area seasonally (Apps et al. 2001). Mountain goats (*Oreamnos americanus*) were also present in moderate numbers. An open hunting season for moose occurred in this area up until 1991, after which all moose hunting was by limited entry permit (LEH; a lottery).

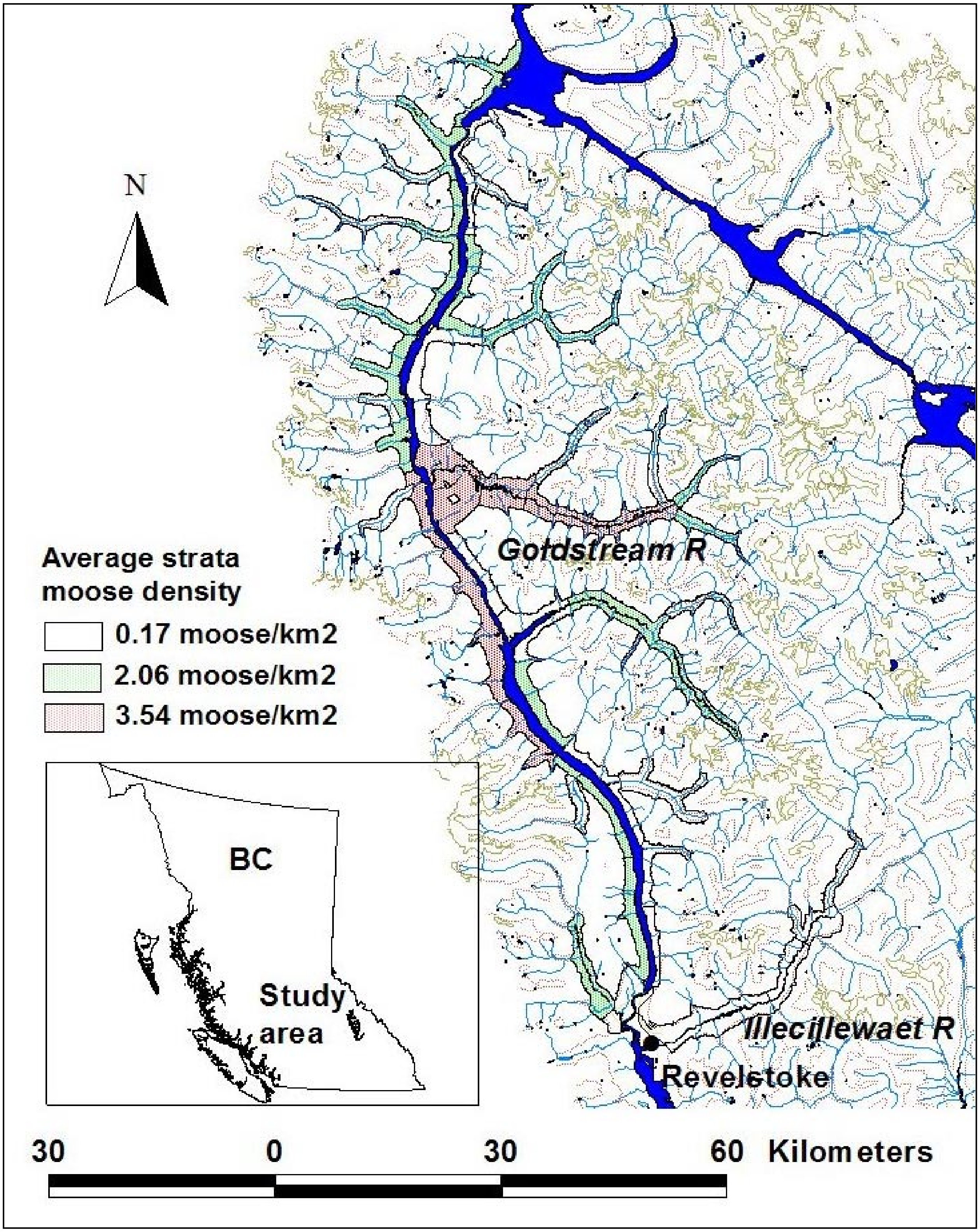

Figure 1. Lake Revelstoke moose inventory study area, 15–28 January 2003. The polygons on the map show the location of the sample units (SUs), shaded to stratification density (low, medium, high).

METHODS

Sampling strategy

We followed a stratified random block design, using procedures modified from Gasaway et al. (1986), Timmermann (1993), Timmermann and Buss (1997), and Resources Inventory Committee (2002). Background information on moose in the area was compiled during discussions with CBFWCP and government staff, from survey data from the mid-1990s, and from a recent winter track count study (Serrouya and D'Eon 2002). We delineated the pre-stratification study area of interest to include all potential moose winter range on both sides of the Columbia River and Lake Revelstoke, from Revelstoke north to Kinbasket Lake (to Potlatch Creek on the east side, and Encampment Creek on the west side), including the Jordan River northwest of Revelstoke, and the Illecillewaet and Tangier rivers northeast of town (the latter of particular interest to Park Canada; Fig. 1). Within this study area we delineated sample units (SUs) based primarily on the layout proposed by Heaven et al. (1998). These SUs and their designation (into expected high, medium and low moose densities) were based primarily on the total count surveys conducted in 1994 and 1995 (J. Krebs, personal communication).

To verify our SU boundaries and initial stratification, we conducted stratification flights using a Cessna 337 fixed-wing aircraft, with a pilot, a navigator (next to the pilot) and 2 backseat observers. One observer differed among days, but the other observer and the navigator were present for both flights. All persons participated in locating animals and tracks. Flight speed was 160–180 km/h at an altitude of 100–150 m above ground level. Hard copy maps were used for navigation and mapping and a rear-seat observer recorded moose (not classified) and track (categorized into few, some, or many) sightings.

Our stratification flight pattern generally meandered among our areas of interest (Gasaway et al. 1986), with a special focus on the back end of side drainages off of Lake Revelstoke, and determining how high in elevation moose were present. Simpson et al. (1988) suggested that early-winter range extended to 1,219 m and late-winter range was restricted to <914 m. Previous aerial surveys in this area in 1994 and 1995 suggested almost all moose were below about 1,100 m elevation (J. Krebs, personal communication). Track counts conducted during February and March 2002 suggested 95% of moose occurrence was below 1,000 m elevation (Serrouya and D'Eon 2002). However, both of these latter studies occurred during the mid-winter, deep snow period when moose would be expected to be at lower elevations compared to early winter. In addition, the near-record low snow depths encountered during our survey may have resulted in moose being distributed more widely and at higher elevations.

Sample unit boundaries and designations were adjusted subsequent to the stratification flights, based primarily on the number of moose and tracks observed, along with historical information and a subjective habitat assessment. We removed the back end of several drainages where we found no evidence of moose. Based on our observations during the stratification flight, we retained the 1,100 m elevation boundary for SUs on the west side of the lake, and used the 1,200 m boundary for main drainages on the east side of the lake (including Mica, Bigmouth, Downie, Carnes, and La Forme creeks and Goldstream River). The resulting study area was 1,044 km^2.

We used a Bell 206B Jet Ranger helicopter during the census, with a pilot, navigator/computer operator (next to the pilot), and two rear-seat observers, one of whom also recorded sightings. The same navigator/observer was present for all flights, and 1 observer was present for 4 of the 7 survey days. Other observers changed throughout the survey. All helicopter occupants participated in locating animals. Each selected SU was covered at 60–90 km/h airspeed and 75–125 m above ground. We searched each SU along 200–300 m wide transects, usually flown along parallel lines back and forth across the SU or contouring steeper terrain. We used a real-time Global Positioning System (GPS) – Geographic Information System (GIS) interface to track our flight path within each SU and ensure complete and accurate coverage. We used the DNR Garmin extension for ArcView (Version 1.2.4; T. Loesch, Minnesota Department of Natural Resources) to provide locations from a Garmin 76 GPS (Garmin Industries, Olathe, Kansas, USA) to an ArcView (Environmental Systems Research Institute, Redlands California, USA) coverage run on a laptop computer. Moose locations were recorded using the GPS, which were then uploaded to the ArcView coverage.

We circled all moose groups to determine sex and age of each animal (Timmermann and Buss 1997) and determine if the group was within the SU along boundaries. Smaller body size and a shorter face identified calves. Cows were identified primarily by the presence of a white vulva patch, and to a lesser extent by colour of the snout, the size and shape of the bell, and the presence or absence of pedicel scars. Bulls were separated into teens, sub-prime, prime or antlerless. Some animals could not be classified, and were designated as unknown.

For each moose group (1 or more) observed we estimated percent vegetation cover (perhaps best described as screening cover) around the first animal seen in the group to the nearest 10% starting at 5% (e.g., to 5%, 15%, 25%, etc.) measured obliquely within a 9–10-m radius around each group of moose (Anderson and Lindsey 1996, Unsworth et al. 1998, Quayle et al. 2001). We regularly discussed and standardized our estimates of oblique cover.

At the request of Parks Canada, we spent additional helicopter time (2 hours total) surveying the Illecillewaet and Tangier drainages northeast of Revelstoke to provide minimum number and a rough "guesstimate" of moose numbers in those drainages. We combined observations of moose and tracks from the stratification flight, intensive survey of much of SU 28 in the Illecillewaet valley, and a reconnaissance-level helicopter flight.

Data analysis

We determined the population estimate using program MOOSEPOP (Version 2.0; R.A. DeLong and D.J. Reed, Alaska Department of Fish and Game, Fairbanks, Alaska, USA) with sightability correction applied to each stratum calculated using program AERIAL SURVEY (Unsworth et al. 1998). Detection probabilities were determined using sightability data from a recently developed British Columbia model (Table 1; Quayle et al. 2001). In the British Columbia model, 5 cover classes were used, separated at the 20%, 40%, etc. boundaries of percent vegetation cover. To avoid these class division boundaries, we estimated vegetation cover for each moose group to the nearest 5%, 15%, 25%, etc. We calculated the population estimate using a spreadsheet program developed by MWLAP (HEARDPOP; J. Quayle, MWLAP, unpublished data), where the estimate variance was calculated as a sum of the sampling, sightability and model variances. We attempted to fly enough SUs to attain 90% confidence intervals (CI) of less than ± 25% of the mean (Resources Inventory Committee 2002).

Table 1. Vegetation cover classes and their associated detection probability and sightability correction factors (program AERIAL SURVEY, Unsworth et al. 1998, as modified using Quayle et al. 2001).

Vegetation class	Percent vegetation cover	Detection probability	Sightability correction factor
Class 1	0–20	0.9423	1.06
Class 2	21–40	0.7492	1.33
Class 3	41–60	0.3791	2.64
Class 4	61–80	0.1224	8.17
Class 5	81–100	0.0344	29.07

Pilot study using pellet group counts

Although the above methodology provides absolute abundance, it is unlikely that such an intensive monitoring program will be feasible every year or even every second or third year. To "fill in" the gaps between absolute abundance surveys, we intend to monitor relative abundance using less expensive methods, one of which is pellet transects. We therefore initiated a pilot study involving pellet group counts (Neff 1968, Timmermann and Buss 1997), with the intention of possibly comparing the precision of this approach to other methods such as reduced-intensity aerial surveys.

The goals of this first year of sampling were to establish plots, count pellet groups, and clear plots of pellets. As well, the frequency distribution of pellet groups per plot will be used to evaluate the feasibility of this methodology, and to provide an opportunity to estimate the precision based on a given sampling effort.

We established 13 straight-line transects, oriented perpendicular to contour lines. Transect placement was based on a stratified random design, using a subset of transects established by Serrouya and D'Eon (2002) as part of a winter track count study (see their document for details). Every 50 m we established a semi-permanent plot centre using a small wooden stake, and counted all ungulate pellet groups within a 5.65 m radius (100 m^2). A moose pellet group consisted of a cluster of one or more winter moose pellets, which are faecal material deposited during winter (generally October through May) in the form of pellets, as opposed to summer faecal material (nonpelletized; Murie 1974). Winter moose pellets are usually oblong or round, smooth, and composed almost exclusively of woody material. More than 50% of the pellet group had to be in the plot to be considered part of the sample. Plots were then cleared of all pellets to avoid double counting in subsequent years. This first set of measurements will be interpreted cautiously, because it is unclear what the time span was for pellet deposition. This time span is related to pellet decomposition rates. If decomposition rates are relatively rapid (i.e., <1 year) then we can consider using the first year of data. We marked pellets to determine decomposition rates, and will continue to do so next spring. We also recorded several biophysical attributes at each plot, including slope, aspect, tree species composition, and percent shrub cover.

RESULTS

Population size and density

Stratification flights occurred 14–15 January 2003. Weather conditions during stratification and survey flights were generally good with mostly overcast skies and light winds (winds were moderate out of the north on 1 survey day). Temperatures ranged from –5 to +2°C for all survey days except one (–10°C). Snow cover was complete, although low snow depths meant that considerable low shrub vegetation was showing.

During the 5.8 hours of the stratification flights we counted 166 moose. Based on these flights, we refined SU boundaries and designations to assign 53 SUs in density strata: 9 high, 18 medium, and 26 low. SU averaged 19.7 km^2 in size (±0.91 SE; range 8.5–35.0 km^2). We surveyed 21 SUs: all 9 high SUs, 7 randomly selected medium and 5 randomly selected low SUs. Despite 2 days of effort, we were unable to survey our fifth low SU (SU 32, in the Illecillewaet valley) because of low cloud and fog, and therefore substituted the next SU randomly chosen from the low stratum to complete the survey.

The helicopter survey was conducted 16–22 and 28 January. We flew 39.3 hours, and spent 30.1 hours on survey; average survey intensity was 4.1 minute/km^2 (±0.17; range 2.7–5.3 min/km^2). We counted 639 moose in 337 groups (Table 2), including 318 cows, 69 calves, 212 bulls, and 40 unclassified adults. Group size ranged from 1 to 10 moose. We calculated a naïve (uncorrected for sightability) estimate of 954 moose. When the sightability correction was applied, our estimate was 1,650 moose (±415 moose or 25.2% [90% confidence interval]; 1,235–2,066 moose). The overall sightability correction factor was 1.72; sightability correction varied among strata (1.12, 1.92, 1.65 for low, medium and high strata, respectively). Corrected density averaged 1.58 moose/km^2 within the study area (0.17, 2.06, and 3.54 moose/km^2 in low, medium and high strata, respectively).

Table 2. Moose population estimate statistics for the Lake Revelstoke moose inventory, January 2003.

Parameter	Stratum 1 (low)	Stratum 2 (medium)	Stratum 3 (high)	Total
No. of SU in stratum	26	18	9	53
No. of SU surveyed	5	7	9	21
Total stratum area (km^2)	439.2	382.7	222.0	1,043.9
Area of surveyed SUs (km^2)	86.3	139.5	222.0	447.8
Moose observed	13	150	476	639
Uncorrected (naïve) estimate	66	412	476	954
Sightability correction factor	1.12	1.92	1.65	1.72
Corrected population estimate	74	790	786	1,650
Corrected density (moose/km^2)	0.17	2.06	3.54	1.58
Sampling variance	1,313	3,156	0	4,469
Sightability variance	20	4,654	4,682	9,356
Model variance	0	1,611	1,230	2,841
Total variance	1,684	34,730	16,115	52,529
Standard error	41	186	127	229
Coefficient of variation	0.55	0.24	0.16	0.14

During the stratification flight we observed 3 moose in the lower Illecillewaet River valley near Greeley, about 6–8 km east of Revelstoke (Fig. 2). During the helicopter flight we observed 3 moose, including a cow and calf, in the upper Tangier about 5–7 km up from the Illecillewaet River; no moose and 3 sets of tracks were seen during the intensive survey of SU 28. Both flights were conducted about 2 days after snowfall, facilitating identification of recent tracks. Combining data from both flights, moose tracks were observed in 6–7 areas not closely associated with the 6 observed animals. We suggest that roughly 15–20 moose may inhabit these drainages, with a concentration in the Tangiers, and a few scattered animals along the valley bottom of the Illecillewaet River.

Composition

The bull:cow ratio was high, but the calf:cow ratio was low (Table 3). Of 61 cows with calves, 6 had twin calves, and 3 of these 6 were in the SU directly south of Pat Creek. Two lone calves were observed, both in the Jordan River drainage. Three quarters of the bulls were antlerless; only 3 prime bulls were observed. Corrected for sightability (and ignoring unclassified moose), the estimated number of bulls, cows and calves were 521, 625, and 100, respectively. If the number of unknown moose corrected for sightability were in the same proportion as classified animals (a questionable assumption), then the estimated number of bulls, cows and calves were 690, 828, and 133, respectively.

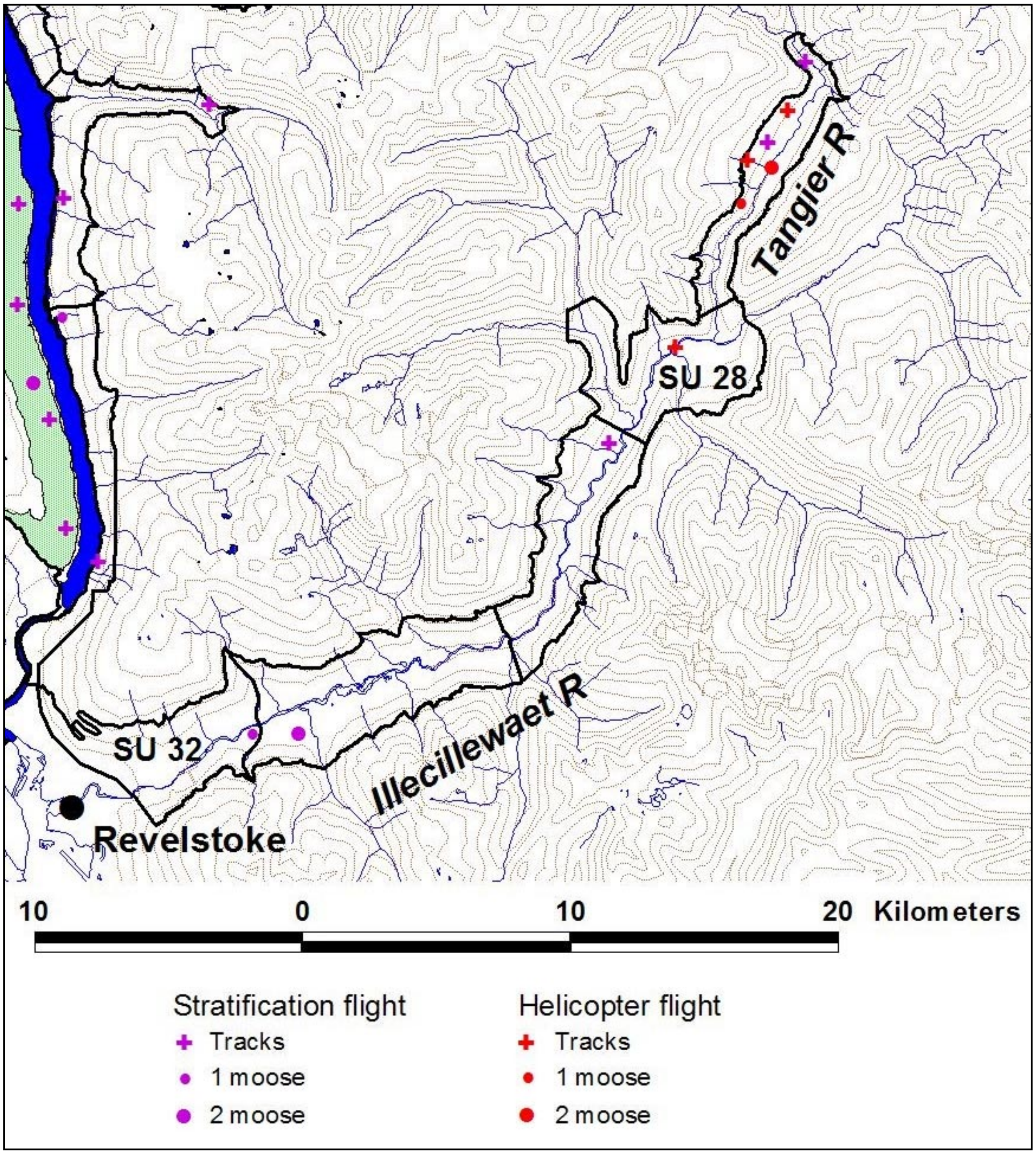

Figure 2. Location of moose track and animal sightings during stratification and helicopter surveys of the Illecillewaet and Tangier valleys, January 2003. Dark outlines represent sample unit boundaries, but additional areas beyond these boundaries were covered during the stratification flight. Sample units 28 and 32 are noted.

Table 3. Number of bulls and calves per 100 cow moose in the Lake Revelstoke study area, January 2003. Data from 599 moose classified (639 observed minus 40 unclassified).

Analysis source	Bulls:100 cows (90% CI)	Calves:100 cows (90% CI)
Gasaway (MOOSEPOP)	77 (66–89)	22 (18–27)
Corrected for sightability (AERIAL SURVEY)	83 (56–109)	24 (17–32)

Distribution

We were unable to detect a pattern to the distribution of age and sex classes among the areas surveyed. Although most moose observed were in vegetation cover classes 1 and 2, 9% of bulls and cows, 13% of calves, and 53% of unclassified moose were in cover classes 3, 4 and 5 (Table 4). Mean vegetation cover did not differ substantially among age and sex categories, except that the mean vegetation cover was far higher for moose that could not be sexed and aged.

Table 4. Number and percent of moose observed by vegetation cover class, Lake Revelstoke study area, January 2003.

	Vegetation cover class						
	1	2	3	4	5	Total	Mean % veg cover
Bulls	156 (74)	36 (17)	8 (4)	12 (6)	0	212	18
Cows	207 (65)	82 (26)	21 (7)	8 (3)	0	318	19
Calves	43 (62)	17 (25)	7 (10)	2 (3)	0	69	20
Unknown	10 (25)	9 (23)	6 (15)	13 (33)	2 (5)	40	44

Pellet counts pilot study

We intended to sample 20 transects but only established 13 because of the onset of snowfall. Transects were sampled between 16 October and 8 November 2002. Transects averaged 1,446 m long (SE = 92, range 850–2,050 m). A total of 376 plots was sampled along these transects, meaning that 37,600 m^2 were searched for pellets. We recorded 183 moose pellet groups, as well as 2 deer and 3 caribou pellet groups. The frequency distribution of number of pellets per plot followed a negative binomial distribution (Table 5; Krebs 1989). Mean number of moose pellet groups per plot was 0.48 (SE = 0.054, n = 376). Twenty seven percent of the plots contained at least 1 pellet group. Variance partitioning revealed that the between-plot variance was 3X greater than the between-transect variance (73.7% vs. 26.3%), meaning that reducing the number of plots per transect is probably not a good idea. We also simulated the expected precision based on different sampling intensities (i.e., varying the number of transects, but assuming all transects were 1,450 m long [29 plots/transect]). Given a mean detection rate of 0.48 pellet groups/plot, and a between-transect SD of 0.34 (values of current dataset), precision did not increase significantly after about 16–20 transects (Fig. 3). We did the same calculation assuming a mean detection rate of 0.048 (10% of the original detections) using the same SD (0.34; a conservative approach, because the coefficient of variation in this case would be much larger). While precision was poorer, especially at the lower end of the sampling effort, a similar pattern could be expected using 16–20 transects (Fig. 3).

Table 5. Frequency distribution of the number of moose pellet groups per plot, across 13 transects. Data collected in the Lake Revelstoke valley, October–November 2002.

No. of pellet groups per plot	Frequency
0	274
1	61
2	23
3	8
4	3
5	4
6	1
7	2

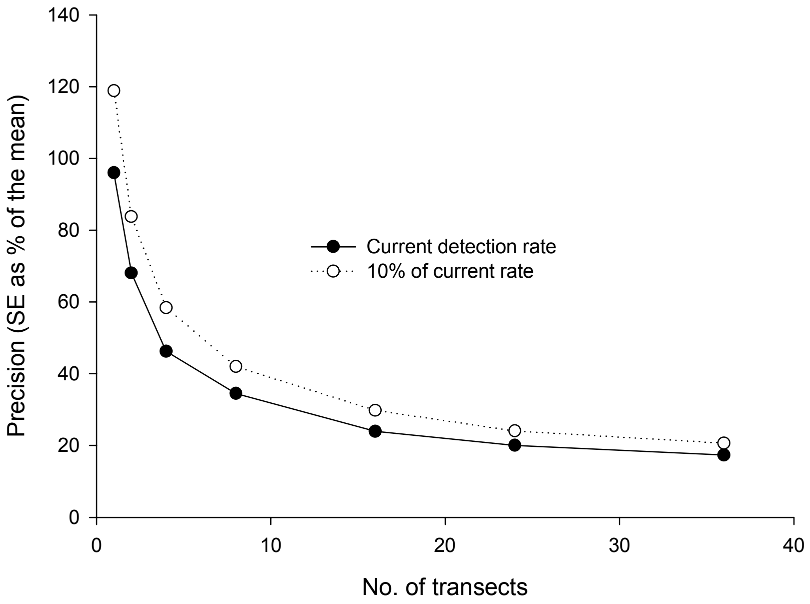

Figure 3. Expected precision of mean moose pellet groups based on number of transects using Monte Carlo simulations. Transects are assumed to be 1,450 m long and include 29 sampling stations. Precision is based on detection rates collected from the fall of 2002, but also shown is the expected precision based on 10% of those detections.

DISCUSSION

Survey methods

We suggest the results of this survey are a reasonable estimate of moose present in the study area. Our stratification benefited greatly from the knowledge of moose distributions from previous surveys. Surveys of additional SUs would have in all likelihood reduced the confidence intervals about our mean estimate, but the expected modest benefits in increased accuracy and precision would have likely been minimal for the additional expenditure.

The vegetation cover sightability correction observed in this study (1.72) was high compared to studies conducted elsewhere in central British Columbia. Within the Sub-Boreal Spruce (SBS) biogeoclimatic subzones, average sightability correction were reported as 1.41 for management units around Prince George (Heard et al. 1999), and 1.16 for the McGregor River and Herrick Creek watersheds (Heard et al. 2001). Poole et al. (1999) obtained corrections of 1.26 and 1.40 for 2 study areas in the central Okanagan (primarily in Interior Douglas-Fir [IDF] and Montane Spruce [MS] subzones). It seems reasonable that our average correction factor within the Lake Revelstoke study area is higher than these other areas because of the occurrence of more closed canopy forests and older, densely stocked cutblocks. This is at least partially the result of the high rainfall experienced in these wetter ICH subzones.

Use of closed canopy forests by this population is not insignificant. We occasionally saw moose and often saw fresh moose tracks (and no moose) in mature, closed canopy forests. During mid-winter track counts conducted in 2002, 22% of tracks were in areas with >40% canopy cover, and 15.8% of tracks were in structural stage 5–7 stands (young, mature and old forests, respectively; Serrouya and D'Eon 2002). It is difficult to relate oblique vegetation cover to canopy cover as measured on the ground. Assuming that 35% oblique vegetation cover roughly equates to 40% canopy cover, we observed 12% of animals and estimated (corrected for sightability) 28% of animals in >40% oblique cover. This comparison suggests that the proportion of moose estimated to be using mature, closed canopy forests was roughly similar using presumably unbiased or less biased track counts (22%) and our potentially biased aerial sightability correction (28%).

The sightability model we used was developed in Sub-Boreal Pine-Spruce (SBPS), MS, and IDF subzones in the Kamloops area (Quayle et al. 2001). The forests in that area are characterized by dominant species that differ from the Lake Revelstoke area, and the degree and distribution of cover within cutblocks and riparian area is unknown. However, we believe this model can be applied to our study because although survey effort was higher during model development (mean 5.62 min/km^2) compared to our survey (4.1 min/km^2), sightability of moose groups in model development was not excessively high (49%; Quayle et al. 2001), suggesting that the model was not biased to more open habitats. Average sightability correction differed among strata in our study, but the low correction value for the low strata (1.12) is likely a function of the few moose sampled ($n = 13$).

We found only a subtle difference in selection for mean vegetation classes among age and sex groups. Mean vegetation cover of calves was only slightly higher than bulls and cows, and calves made slightly more use of class 3 and 4 vegetation cover classes than cows and bulls. Heard et al. (1999, 2001) observed no segregation among age and sex categories by vegetation cover in central British Columbia. Others have suggested than cows with calves select denser cover, in part for increased predator avoidance (Thompson and Vukelich 1981, Miquelle et al. 1992, Peek 1997).

Population status, composition and distribution

It is difficult to compare corrected moose densities obtained in this inventory with past total count surveys, because no measures of vegetation cover were recorded prior to this survey. However, some indication of changes in moose numbers can be obtained from uncorrected counts. Total count surveys of roughly the same entire study area were conducted in 1991 and 1994, and observed 261 and 418 moose, respectively (L. Ingham and J. Krebs, unpublished data). We observed 639 moose, but surveyed less than half of the study area (albeit, all of the designated high SUs and almost half of the 18 medium density SUs). However, more direct comparisons can be made for the high-density Goldstream valley, where approximately 120 km^2 have been intensively surveyed in 1991, 1994, 1995 and 2003. In 1991, 51 moose were counted in this area (survey effort unknown). In 1994, 130 moose were counted (survey effort unknown, but likely slightly less than our survey intensity). In 1995, 171 moose were observed with 8.5 hours of helicopter time. Using 9.5 hours of helicopter time, we observed 326 moose. Moose numbers also appear to have increased outside of the core Goldstream areas. In 1994, 19 moose were observed in the 2 SUs adjacent to Pat Creek, on the west side of the reservoir across from the town of Mica (effort unknown; J. Krebs, unpublished data). We observed 56 moose in this same area. Acknowledging that moose sightability and distribution may have changed over time, these results do suggest that moose numbers in the Goldstream and probably elsewhere in the study area have more than doubled in the past 9–12 years.

Moose densities in the Lake Revelstoke study area appear to be similar to or higher than densities observed elsewhere in central British Columbia. Hatter (1998) summarized census data for central and northern British Columbia over the previous 15 years. With the exception of survey areas in northeastern parts of the province, comparatively few surveys indicated moose densities >1.0/km^2. Moose densities in the McGregor River and Herrick Creek watersheds were estimated at 0.45/km^2 (Heard et al. 2001). In the broad Prince George area, estimated moose densities were 1.33/km^2, with 2.75 moose/km^2 in the highest density strata (Heard et al. 1999). Densities in the Okanagan valley ranged from 0.23–0.46 moose/km^2 (Poole et al. 1999), and in the Thompson-Nicola subregion were 0.27–0.36 moose/km^2 (Jury 1986). The highest density moose winter range in the East Kootenay was estimated to have roughly 0.30–0.70 moose/km^2 (Halko et al. 2000). Comparison with other areas should be made judiciously, however, because of differing interpretations of study area/census area size and the distribution of moose winter range at the landscape level. In mountainous areas, winter range is generally bounded by elevation (driven by snowfall). However, in sub-boreal landscapes, for example in the Prince George area, most of the landscape is potential moose winter range.

The Goldstream valley had the greatest number of moose in the study area, a corrected total of 580 moose (4.8/km^2; 35% of the study area estimate). These densities rival some of the highest densities observed in British Columbia, albeit for a comparatively small area. A combination of low-elevation riparian shrub lands, early seral cutblocks, with occasional shrub-covered avalanche chutes appear to provide excellent moose winter range with high amounts of forage.

Although we recognize that we probably failed to encompass all wintering moose within our study area bounds, our use of the 1,100–1,200 m elevation cut-offs appeared justified. We found few moose or tracks near the upper elevational boundaries of SUs. When a moose group was spotted, we generally circled the group overhead roughly 50–75 m above ground level before recording the GPS location. Although a crude estimate of moose elevation, we found <1.5% of moose groups (n = 337) had GPS altitude recordings >1,100 m asl.

The bull ratio estimated for the study area (83 bulls:100 cows) was high compared to most areas in the province (Hatter 1998, Halko et al. 2000). Only 4 of the 64 surveys summarized for central and northern British Columbia had bulls ratios ≥70 bulls:100 cows (Hatter 1998). High bull ratios were observed in 4 management units in the East Kootenay during winter 2000 (range 80–100 bulls:100 cows; L. Ingham, unpublished data), and the average bull ratio was 60 bulls:100 cows (range 31–131) in 10 East Kootenay management units surveyed in 2000 (Halko et al. 2000). In 1994 the observed bull ratio in the Lake Revelstoke area was 63:100 cows (J. Krebs, unpublished data), which would be most appropriately compared to our observed bull ratio [77:100 cows]). High bull ratios are likely indicative of a lightly hunted population (Hatter 1998).

Whereas Krebs (unpublished data) observed 78 calves:100 cows during the 1994 Lake Revelstoke survey, we observed comparatively low calf ratios (24 calves:100 cows). Only 4 of the 64 surveys summarized for central and northern British Columbia had calf ratios ≤25 calves:100 cows (Hatter 1998). Through nearly 3 decades of monitoring in the Prince George area, mean calf ratios only once dropped below 30 calves:100 cows, and most years was between 30–55 calves:100 cows (Heard et al. 1999). A decreasing trend was observed in the Prince George area through the 1990s. However, surveys in 10 management units in the East Kootenay in 2000 detected an average of 23 calves:100 cows (range 10–63; Halko et al. 2000). In 4 management units in the East Kootenay in 2002, the calf ratio ranged from 27–35 calves:100 cows (L. Ingham, unpublished data). The calf:cow ratio required to maintain a stable population in the absence of hunting has been estimated at about 25 calves:100 cows (at 6–9 months of age; Bergerud 1992), but may rise to 30–45 calves:100 cows in harvested populations depending on the adult harvest and natural mortality rates (Hatter and Bergerud 1991). Reasons for the apparent low calf ratio are unknown, but may relate to weather conditions (primarily snow accumulation and spring/summer rainfall), density dependent factors, or predation (Ballard 1992, Van Ballenberghe and Ballard 1997). Observation of twin calves (10% of calf groups in this survey) is generally indicative of good nutritional status of cows (Franzmann and Schwartz 1985, Schwartz 1997).

Suspected wolf tracks were noted in several areas during our survey, most notably in the upper Goldstream area where we observed our only moose kill (off Stitt Creek) and an injured moose which was obviously in the process of being preyed upon by a pack of 3–4 wolves (based on tracks, blood in the snow, limited movement by the cow moose, and open wounds on its flanks). Numbers of wolves within the study area are unknown, but there is a general consensus that wolf numbers have increased over the past decade (B. Glaicar, Monashee Outfitting Ltd., personal communication). Natural wolf:moose ratios suggest that the Lake Revelstoke moose population could support about 45 wolves (Messier 1994). However, grizzly bears and black bears have been shown to be the most important source of calf moose mortality in almost a dozen studies across North America (Ballard 1992), and thus, given their relative commonness within the study area, may exert a greater impact on the population than wolves.

The high bull ratio and low calf ratio is consistent with what one would expect in a lightly harvested, predator-limited population (Ballard 1992, Ballard and Van Ballenberghe 1997, Timmermann and Buss 1997). Resident and non-resident harvests from 1996–2000 averaged roughly 33 moose annually, 70% as bulls (MWLAP files, Nelson, B.C.). Limited entry hunting tags available for both management units 4-38 and 4-39 increased in 2001 and totalled 60 tags in 2002, distributed among bull only (23 tags), cow/calf/spike bull (27), and spike bull/antlerless tags (10; the early winter road hunt). Outfitters in the area have been assigned a total of 4 bull moose tags, and native (unregulated) hunting is thought to be negligible. Even given suspected high resident LEH hunting success, it is reasonable to assume that the recent harvest for the area is not more than 45–50 moose/year, with a bias to bulls. This equates to an approximately 3% annual harvest rate. Empirical studies suggest that sustainable harvest rates may range from 5% (in the presence of lightly hunted wolf and bear populations) to 10% (when predators are more heavily hunted) (Gasaway et al. 1992, Hatter 1998). In the Prince George area, with a full compliment of predators, an average 7% harvest rate (primarily, but not exclusively bulls) appeared to be sustainable (Heard et al. 1999).

A substantial number of moose are killed in collisions with vehicles and trains each year within the study area. Roughly 20 moose have been killed annually over the past decade along Highway 23 north of Revelstoke, although mortalities appear to have decreased to 5–6/year over the past 2–3 years (D. Gilowski, VSA Highway Maintenance Ltd., Revelstoke, personal communication). East of Revelstoke, an average of 3 moose has been killed annually on the Trans Canada Highway over the past 5–10 years (D. Gilowski, personal communication), and trains have killed 3–5 annually over the past 5 years (B. Richie, CP Rail, Revelstoke, personal communication). Thus, a minimum of about 6 moose die annually in traffic/train collisions in the Illecillewaet Valley; this may be one reason that moose densities do not appear to be higher in this area.

Critique of methods

The aerial survey was conducted during a winter of unusually low snowfall, which may have resulted in moose distribution that differed from that found during a winter of more normal snowfall. However, thorough stratification coverage and few moose in the upper elevation bounds of our sample units suggest that we covered all areas of current moose habitat.

A sample (>20) of widely-distributed radiocollared moose would benefit our estimate of absolute abundance by providing marked animals to help define the bounds of the study area (census zone), clarify the distribution of moose among habitat types and cover classes, and build a simple, local sightability correction factor.

MANAGEMENT RECOMMENDATIONS

The large increase in numbers of moose in the Lake Revelstoke area over the past decade suggests that current harvest and mortality rates are insufficient to stabilize the population. An annual harvest of roughly 7–8%, primarily but not exclusively bulls, may be an approximation of the optimum sustained yield for this population (Gasaway et al. 1992, Hatter 1998, Heard et al. 1999); this equates to an annual harvest of from 115–130 moose, more than double the current annual harvest. Changes in the ratio of bulls, cows and calves in the harvest will affect the optimum sustained yield. Harvest rates will have to be much higher and targeted more towards cows and calves to decrease the population.

Given the importance of Lake Revelstoke moose numbers in the context of wolf/caribou dynamics and forestry concerns, and the goal to reduce moose populations through increased hunter harvest (G. Woods, personal communication), we recommend annual moose population monitoring. However, annual *absolute abundance* surveys would not be an efficient use of funds. We recommend monitoring *relative abundance* each year, using pellet transects and/or reduced intensity aerial surveys, until the efficacy of these methods can be compared.

Pellet transects are cost effective and could potentially provide reasonable precision for inter-annual trend comparisons. Monitoring 16 transects (See results section) would cost approximately $16,000, including fieldwork, data entry, and analysis (note that this does not consider the use of volunteers from the local hunting club, which has been discussed with its members). Transects would be surveyed each spring. Pellet counts do not require any assumptions associated with aerial sightability correction factors, which are often derived from other study areas. Disadvantages include the lack of information on age or sex class ratios.

If we were to use aerial survey methods, we would sample a subset of the high and medium SUs that we surveyed this year, and compare minimum counts (corrected for sightability), and possibly include a measure of precision. Low stratum SUs account for so few moose (4.5% of total estimate) that they would not be cost-effective to sample. We would include medium SUs in our monitoring because using high SUs alone could result in missing any effects of range contraction or changing densities outside the core of the study area. High SUs are concentrated in the centre of the study area, which could exacerbate this problem. This is a common concern of population estimates that are focussed only in the best habitats. Finally, medium SUs account for a substantial proportion of the population (47.9%, compared to 47.6% for high SUs), so ignoring them could cause misleading results. Therefore, we recommend sampling 4 medium and 4 high SUs. These SUs would be randomly selected during the first year of monitoring (selecting the medium SUs from those surveyed in 2003), and retained for survey during each year of monitoring. Annual aerial monitoring would require about 17 hours of helicopter time (~$13,800). Including personnel and data analysis, the total cost would be about $18,000 annually. An advantage of aerial survey monitoring over pellet group counts would be an indication of changes in age and sex ratios in the population.

Therefore, we recommend that an absolute abundance survey, as done in 2003, be conducted approximately every 5 years. To track the relative abundance of the population between complete surveys we suggest choosing either pellet group transects or sub-sampled aerial surveys. Since pellets require clearing each year, it would not be appropriate to mix relative trend monitoring strategies. With local volunteer input, pellet group counts could be conducted for considerably less money than aerial surveys, but additional effort would be needed to track age and sex ratios.

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