A STRATIFIED RANDOM BLOCK MOOSE CENSUS OF WELLS GRAY PARK

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II. Abstract

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As part of a comprehensive program to evaluate wildlife populations and habitats in Wells Gray Park, an intensive moose census was conducted in January and February, 1984. A stratified random block survey, followed by two classified counts, was used to estimate moose population size and structure.

A 3102 km^2 study area was divided into high, medium, low, and extra low moose density strata. The strata were further divided into 134 sample units (SU's) averaging 19.4 km^2

in size. Nineteen SU's were randomly selected and were searched at a mean intensity of 3.8 min./km^2. Portions of 3 SU's in the high and medium strata were resurveyed at a greater intensity to establish a sightability correction factor (SCF). The SCF for the high and medium density strata was 1.03. The SCF for the low density stratum (low and extra low were combined) was assigned a value of 1.25 on a "best guess" basis.

A total of 475 moose were observed. Calculated moose densities were 2.69, 1.23 and .05 moose/km^2. The calculated winter moose population estimate, corrected for sightability (xSCF), was 852 +/-18% at the 90% confidence interval.

Classified counts were conducted in selected areas of the high and medium strata on January 22nd, and repeated on February 6th. Two hundred eighty-six moose were classified on the first count and 283 were classified on the second count. The mean ration of bulls:cows was 81:100. The ration of calves:cows varied from 40:100 on the first survey to 24:100 on the second survey, with a mean of 31:100. The difference in the calf:cow ratio between surveys was attributed to the movement of some cows with calves away from the classification areas (into the timber) and the movement of barren cows into one of the classifications areas (Green Mountain). The moose population was considered fairly productive on the basis of the calf:cow ration and the observation of a 24% twinning rate.

A southward movement of moose between classified counts was observed. At elevations above 900m (3,000 ft.) there was also a movement of moose into denser habitat between classified counts. These shifts in distribution and habitat use were related to an increase in snow depth above 900m.

It was recommended, for future surveys, that smaller sample units and a new stratification be used. It was also recommended that consideration be given to controlled burning or logging to enhance moose habitat, with the provision that caribou winter range be protected.

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1.0 Introduction

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Wells Gray Provincial Park covers 5340 square kilometers of predominantly wilderness terrain in the Cariboo Mountains of east central British Columbia (Fig. 1). The southwestern portion of the park is characterized by the broad valleys of the Clearwater and Murtle Rivers whereas most of the remainder of the park is mountainous with numerous permanent ice fields in the northern regions. Annual precipitation is relatively light at Mahood Lake in the southwest corner of the park but increases greatly to the east and north. Annual precipitation at Hemp Creek near the southern entrance to the park is 56 centimetres (22 in.) but probably exceeds 100 centimetres (39 in.) in the mountains (Edwards and Ritcey, 1967). Edwards and Ritcey (op. cit.) describe the vegetation as being characterized by dry Douglas Fir (*Pseudotsuga menziesii*) forests on warm slopes at low elevations in the southern part of the park while low elevations near the mountains are covered by wet forests characterized by Red Cedar (*Thuja plicata*) and Western Hemlock (*Tsuga heterophylla*). From 1200 metres (4000 ft.) to about 2100 metres (7000 ft.) lies a deep belt of Subalpine Forest consisting typically of White Spruce (*Picea glauca*) and Alpine Fir (*Abies lasiocarpa*).

There has been a history of extensive fires in the southern portion of the park below 1200 metres. Edwards (1954) estimated that 60 percent of this area had been reduced from a climax forest to an early seral stage by the mid fifties. The vegetation in these areas is characterized by willows (*Salix spp.*), Trembling Aspen (*Populus tremuloides*), birches (*Betual papyrifera* and *Betula glandulosa*), and Lodgepole Pine (*Pinus contorta*). Despite natural succession much of this area was still covered by deciduous and mixed deciduous – coniferous forests at the time of this study. R. Ritcey (pers. comm.) conducted controlled burns in selected areas of the southern part of the park from 1966 to 1971. Logging has also occurred in the vicinity of Flourmill Creek and Pendleton Lakes.

Moose were very scarce in the park prior to a major fire which swept up the Clearwater Valley in 1926 (Ritcey, 1982). Subsequent colonization occurred and the moose population increased to an estimated 2000 animals by 1952 (Edwards, 1954a). The population continued to increase until the late fifties to early sixties when there were an estimated 3000 moose, according to R. Ritcey (pers. comm.). The population has decreased since that time, the cause of which, according to Ritcey (1982), was a reduction in the amount of winter foliage available to moose as a result of forest succession. Moose surveys were conducted in most years between the fifties and mid-seventies with the last one prior to this study having been conducted in 1978.

The continuing forest succession in the park will likely lead to further reductions in moose populations. Habitat management will be needed to maintain moderate moose abundance. As well, there is a possibility of future logging development, and resulting habitat modification, in the park.

In order to properly define objectives for the management of wildlife populations and habitat, it is essential to conduct basic inventories. A comprehensive three year program, in cooperation with the Ministry of Environment, has been designed to conduct biophysical habitat evaluations and population surveys. The studies were set up as part of the Master Planning Process currently underway in Wells Gray. The first phase of the program was to estimate moose population size and structure by way of a stratified random block moose census and classified counts.

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Figure 1. Wells Gray Provincial Park in relation to the rest of the province.

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2.0 Methods

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The basic methodology we employed to conduct this study is fully described by Gasaway et al. (1981). We chose a 3102 km^2 (1211 mi^2) study area located for the most part south of a line across the park from the north end of Clearwater Lake to Azure Lake (Fig. 2). We assumed that the remaining 2238 km^2 (874 mi^2) of the park contained no moose.

The study area was initially divided into high, medium, low, and extra low moose density strata ranging in elevations from 515-2355m (1700-7775 ft.). Strata boundaries were determined by regional Ministry of Environment personnel, especially R. Ritcey who has may years of experience with the wildlife of Wells Gray Park. The designation of moose winter range on the Canada Land Inventory map of the area was also used in determining the strata boundaries.

Each strata was divided into individually numbered sample units (SU's) on 1:50,000 topographic maps (on file in Victoria). In addition, all SU's in the high and medium strata were plotted on 1:25,000 coloured aerial photographs, using roads, lakes, watercourses, and vegetational and geological features as boundaries.

M. Sather of Park Programs Branch and A. Stewart of the Ministry of Environment flew the study area in a Cessna 182 on wheels on January 15 and 16, for a total of 10.4 hours in order to field proof the stratification that had been proposed in the office. We observed no sign of moose above 1515 metres (5000 ft.), hence we concentrated most of our efforts during these flights on the lower elevations, particularly in the high and medium density strata. As a result of these flights strata and SU boundaries were changed as required.

After the stratification flights were completed we determined the optimum allocation of search efforts (ie. The number of SU's to be done in each stratum) based on the total number of SU's that we could afford to survey, the estimated number of moose in each stratum, and the estimated total number of moose in all strata. We chose a search intensity of 3 min./km^2 (4.5 min./mi^2) suggested by Gasaway et al. (op. cit.) for moose surveys in Alaska. It was decided that this higher search intensity was necessary because much of our study area is covered by mature forest making it difficult to sight moose.

All sample units were arranged in order by selection from a random numbers table. Of those SU's which were selected for surveying, the first five (or two and three in the case of the low and extra low strata) were surveyed in the most efficient manner and the remainder were surveyed in the order which they had been selected from the random numbers table.

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Figure 2. The study area showing moose density strata.

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We began the random block survey on January 17 and completed 18 sample units by January 21. One SU was flown January 23. We used a Bell Jet Ranger 206 helicopter with bubble windows in the rear to conduct the survey. Transects were flown approximately ¼ kilometer apart at speeds varying from 70 km/h (45 mph) over thick, mature forests to 90 km/h (55 mph) over lightly wooded areas. When moose were sighted we circled, if necessary, to ensure that all animals were accounted for.

M. Sather of Parks and A. Stewart of Environment participated throughout the random block survey while various Park Programs Branch staff from the region and Victoria acted as observers in the left rear seat. Sather sat in front navigating, observing, and plotting moose observations on a map or aerial photograph, while Stewart sat in the rear right observing and recording observations. Sather also recorded some information on a Sanyo portable tape recorder with remote microphone. Observers were in contact with each other at all ties via intercom.

Observations were recorded on a standard moose survey form (Appendix 1). We recorded all information on the form with the exception that we did not attempt to classify all moose as to male or female; however, we did record all calves observed. Also, we did not record tracks, since the last snowfall was seven days prior to the beginning of the random block survey and there were many old tracks present. We also felt we could not afford the time required to determine whether fresh tracks were of moose inside or outside the SU at the time of survey.

On the fourth and fifth days of the random block survey two SU's were chosen from the medium stratum and one SU from the high stratum to determine the sightability of moose in these strata. Sather chose a quarter of each SU, unknown to other members of the survey team, in which moose were observed and which contained habitat representative of most areas of the high and medium strata. This quarter was flown at a higher intensity than the original survey and results were compared to establish a sightability correction factor (SCF).

Upon completion of the survey, the sizes of sample units, strata, and nil areas were accurately calculated with a Hewlett-Packard model 9864 digitizer. Final calculation of the estimated total population and confidence interval was made. Since only five SU's were flown in the low and extra low strata these strata were combined into one low stratum to obtain the population estimate. We had intended to sample at least three SU's from each stratum but as a result of surveying SU L1 this SU was transferred to the medium stratum (M17). This procedure is permissible according to Gasaway and Harbo (op. cit. p.19) since L1 was stratified on the basis of elevation rather than observed moose density.

The population estimate and confidence interval obtained was corrected for sightability. The high and medium strata population estimates were multiplied by SCF obtained in the field plus a factor of 1.03 obtained by Gasaway et al. (op. cit.) to account for moose missed during the high intensity survey. We did not obtain a SCF for the low density stratum but used a "best guess" of 1.25. Although sightability of moose was low in the thick timber covering much of the low stratum, which suggests a higher SCF be used, observations of tracks indicated few moose were present and we searched more intensively where fresh tracks were seen. In addition, the canopy cover was generally less and the sightability of moose greater in subalpine habitat above 1365 metres (the original extra low stratum).

A moose classification survey was flown by helicopter in selected areas of the high and medium strata on January 22nd by G. Jones of the Park Programs Branch and A. Stewart. These observers flew the same areas on February 6th.

3.0 Results

3.1 Survey Conditions

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Conditions were fair throughout the survey. We were able to complete the survey in nine consecutive days with a follow-up classification flight fourteen days later. The skies were typically covered by a high overcast or a low thin overcast with some sunny periods and snow flurries on January 21st and 22nd. Conifers were usually heavily laden with snow, decreasing sightability of moose. Snow conditions were classified as poor to moderate using the system described by Gasaway et al. (op. cit.) wherein the snow was aged as old (>4 days) and the vegetation cover was characterized by 'some low vegetation showing' to 'complete coverage.' Measured snow depths on January 21st were: 50cm (20 in.) at Battle Creek, 55cm (22 in.) at Helmcken Falls Lodge, and 65cm (26 in.) at the south end of Clearwater Lake.

3.2 Study Area, Sample Units and Search Intensity

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The 3102.5 km^2 study area was comprised of sample units totaling 2644.7 km^2 (Table 1), and nil areas (including lakes) totaling 457.8 km^2 (Fig. 2).

Initially, the study area was divided into 9 high, 10 medium, 50 low and 65 extra low SU's for a total of 134. After the stratification flights the composition was changed to 6 high, 15 medium, 34 low and 81 extra low SU's for a total of 136. After the random block survey one low SU was changed to medium. Sample units ranged in size from 5.9 to 38.9 km^2 (2.3 – 15.2 mi^2) with a mean size of 19.4 km^2 (7.8 mi^2) (Table 1). There was no significant difference in the mean size of sample units between strata.

Nineteen SU's were searched; 6 from high, 8 from medium, 2 from the low and 3 from the extra low stratum. Search intensity ranged from 2.9 to 5.6 with a mean of 3.8 minutes/km^2 (9.7 min./mi^2). Search intensity was greatest in the medium stratum at 4.0 min./km^2 and least in the extra low stratum at 2.4 min./km^2.

Table 1. Size of strata and sample units and search intensity of sample units.

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Strata			Sample Units					
			Size (km^2)			Search Intensity (min./km^2)		
Density	**Size km^2**	**No. of SU's**	**Range**	$\bar{X}$	**± S.D.**	**No. of S.U.'s**	**Range**	$\bar{X}$
High	108.0	6	14.2 – 22.5	18.0	±3.46	6	2.9 – 4.7	3.4
Medium	310.7	16	5.9 – 30.8	19.4	±6.95	8	3.0 – 5.6	4.0
Low	627.5	33	7.4 – 34.0	19.0	±5.40	2	2.4 – 4.3	3.1
Extra low	1598.5	81	8.3 – 38.9	19.7	±6.51	3	1.3 – 3.2	2.4
Total	2644.7	136	5.9 – 38.9	19.4	±6.25	19	2.9 – 5.6	3.8

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Figure 3. The Green Mountain Burn attracts the greatest concentration of moose during winter in the park.

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Figure 4. A group of moose on Green Mountain.

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3.3 Allocation of Search Effort.

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Determination of the number of SU's per stratum to be sampled was calculated from the following formula proposed by Gasaway et al. (op. cit.).

$$E1 = \frac{U.M_i}{\sum_{j=1}^{n} M_j}$$

where: E1 = number of SU's to be surveyed in a stratum
U = total number of SU's that the biologist can afford to survey in all strata
Mi = estimated number of moose in each stratum (estimated density x estimated area)
Mj = estimated total number of moose in all strata

We could afford to survey a totaal of 20 SU's based on a search intensity of 3 min./km^2 (actual search intensity was 3.8 min./km^2) and an average SU size of 20 km^2. Estimated areas were 105, 280, 400 and 1900 km^2 and estimated moose populations were 210, 250, 100, and 95 for the high, medium, low and extra low strata respectively (Table 2). Note that the estimated areas differ somewhat from the actual areas (Table 1). Computation of the formula suggested that we should survey 6 high, 8 medium, 3 low and 3 extra low sample units (Table 2).

The calculations were:

High stratum: $E_h = \frac{20 \times 210}{655} = 6.4$

Medium stratum: $E_m = \frac{20 \times 250}{655} = 7.6$

Low stratum: $E_i = \frac{20 \times 100}{655} = 3.1$

Extra low stratum: $E_e = \frac{20 \times 95}{655} = 2.9$

Table 2. Allocation of Search Effort

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Stratum	Estimated size (km^2)	Estimated moose density ($/km^2$)	Estimated moose population (M_i)	No. of SU's to be surveyed (E_i)
High	105	2	210	6.4 (6)
Medium	280	0.9	250	7.6 (8)
Low	400	0.25	100	3.1 (3)
Extra low	1900	0.05	95	2.9 (3)
Total	2685		655 (M_j)	20

3.4 Moose Sightability Correction Factor (SCF)

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Three SU's were tested to establish a SCF for the high and medium strata. Of 41 moose observed during intensive re-surveys, 30 were observed during initial surveys, resulting in a SCF of 1.01 (Table 3). Overall search intensity during re-surveys was 4.9 min./km^2 versus 3.7 min/km^2 during initial surveys.

Table 3. Moose sightability correction factor.

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Initial Survey			Intensive Survey		
SU	**No. of moose observed**	**Search Intensity (min./km^2)**	**No. of moose observed**	**Search Intensity (min./km^2)**	**SCF**
M1	17	4.3	17	3.7	1.00
M5	14	4.1	14	5.6	1.00
H5	9	2.9	10	5.0	1.11
Total	40	3.7	41	4.9	1.03

3.5 Number of Moose Observed and Moose Habitat Preference

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A total of 475 moose were observed during the random block survey; 280, 181, 1 and 3 in the high, medium, low and extra low stratum respectively (Table 4). Forty-nine decimal five percent of the moose were observed in coniferous-deciduous habitat and 37.9% in deciduous habitat, with the remaining 12.6% found in marsh, riparian, clearcut and Lodgepole Pine habitats. The high density stratum contained much of the deciduous habitat in the study area with 171 of 290 (58.9%) moose found in this habitat type in this stratum. Much of the best moose habitat in the medium stratum was in mixed coniferous-deciduous habitat with 132 of 181 (72.9%) moose in this stratum found in this habitat type. The low and extra low strata contained predominantly coniferous habitat with 3 of 4 moose observed in this habitat type.

Table 4. Moose Observations and Habitat Type

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Moose Observed In Habitat Type										
Stratum	**M**	**R**	**CC**	**SL**	**D**	**PL**	**C**	**CD**	**?**	**Total**
High	3	4	0	0	171	3	4	103	2	290
Medium	1	5	32	0	9	0	2	132	0	181
Low	0	0	0	0	0	0	1	0	0	1
Extra Low	0	1	0	0	0	0	2	0	0	3
Total	4 (.9%)	10 (2.1%)	32 (6.7%)	0	180 (37.9%)	3 (.6%)	9 (1.9%)	235 (49.5%)	2 (.4%)	475

M - marsh **R** – riparian **CC** – clearcut **SL** – low shrub **D** – deciduous **PL** – lodgepole pine **C** – coniferous **CD** – coniferous-deciduous **?** – habitat unknown

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Figure 5. Murtle Lake is surrounded primarily by dense forests supporting few moose in winter.

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Figure 6. Logged areas such as this one between Blackwater and Hemp Creeks provide winter forage for moose.

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3.6 Moose Population Estimate and Confidence Interval

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The density of moose in each stratum (r) was calculated by dividing the total number of moose in all SU's that were surveyed by the total surface area of all SU's that were surveyed. The moose population estimate for each stratum (T) was obtained by multiplying r by the total surface area of each stratum (A). The population estimate for the park ($\check{T}_t$) was obtained by adding the strata population estimates. The variances of the population estimates were also calculated (See Appendix 3 for details). The results are shown in Table 5.

Observed moose densities were: 2.69, 1.23 and 0.05 moos/km^2 in the high, medium and low density stratum respectively. Note that the low and extra low strata were combined into one low stratum. The population estimates are 290 382 and 111 moose in the high, medium, and low stratum respectively, for a total of 783 moose (uncorrected for sightability.)

Table 5. Moose population estimate, uncorrected for sightability.

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Stratum	No. of moose in all SU's surveyed	Area of all SU's surveyed (km^2)	No. of moose/km^2 (r)	Stratum area in km^2 (A)	Population estimate ($\check{T}$)	Variance of pop. est. [V($\check{T}$)]
High	290	108	2.69	108	290	0
Medium	181	146.7	1.23	310.7	382	4041.5
Low	4	85.4	0.05	2226	111	2174.5

Total	475	340.1		2644.7	783 ($\check{T}_t$)	6216.0 [V($\check{T}_t$)]

The confidence interval (CI) for the population estimate defines the degree of certainty with which the population estimate was made. Calculation of the CI for this study is shown in Appendix 3. When = 0.9 the CI = 783 ±142 moose. This is called the 90% CI. When = 0.95 (95% CI) the CI = 783 ±174 moose. This means that, with 90% certainty, we can say there are between 642 and 924 moose in the park or, with 95% certainty, that there are between 609 and 957 moose in the park. These estimates are uncorrected for sightability.

The population estimates, corrected for sightability, are shown in Table 6. The corrected population estimates for the high, medium and low strata are 308, 405 and 139 moose respectively, and the corrected total population estimate is 852 moose.

The moose in Wells Gray Park winter in that part of the study area below about 1515 metres (5000 ft.) comprising about 1614 km^2. The overall density of moose in this area was 0.53 moose/km^2 (1.35/mi^2) (852/1614).

The confidence interval actually pertains only to the medium and low density strata since the high density stratum was totally surveyed and therefore has no variance (Table 5). Therefore, we corrected the CI for sightability by the same factor that the population estimate for the medium and low strata combined was corrected. The uncorrected population estimate for the medium and low strata combined was 493 moose (Table 6). The corrected population estimate for these strata was 544 moose (Table 6). Thus, the population estimate for these strata was corrected by an overall factor of 1.10 (544/493). This correction factor, applied to the CI, resulted in a final moose population for the park of 852 ±191 (661-1043) at the 95% CI. Expressed in another way, the population estimate is 852 ±18% at the 90% CI or 852 ±22% at the 95% CI.

Table 6. Moose population estimate, corrected for sightability.
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Stratum	**Uncorrected population estimate**	**Correction factor**	**Corrected population estimate**
High	290	X1.03 x 1.03	308
Medium	382	X1.03 x 1.03	405
Low	111	X1.25	139
Total	783		852

3.7 Moose Population Structure
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Partial classifications were obtained during the stratified random block count. Intensive classified counts were conducted in 5 areas of the medium and high density strata on January 22nd and February 6th. Results are show in Table 7.

A total of 293 moose were counted on January 22^{nd} and 285 on February 6^{th}. Forty-eight percent (141/293) of the total were found on Green Mountain on January 22^{nd} compared to 68% (194/285) in the same area on February 6^{th}. The overall ratio of bulls:100 cows was 81:100 and varied from 90:100 on January 22^{nd} to 73:100 on February 6^{th}. Seventy-nine percent (88/112) of the bulls had shed their antlers by January 22^{nd} compared with 98% (106/108) by February 6^{th}.

The overall ratio of calves:100 cows during the classified counts was 31:100 and varied from 40:100 on January 22^{nd} to 24:100 on February 6^{th}. The estimated ratio of calves:100 cows during the random block survey was comparable. The ratio of calves:100 adults observed during the random block survey was 18:100 (74/401) (Table 7). Applying the overall ratio of 81 bulls:100 cows observed during classified counts to this ratio results in an estimated 33 calves:100 cows (18 x 1.81) observed during the random block survey.

We observed a high rate of twinning of calves. Sixteen of 55 (29%) of cow-calf groups observed during the random block survey were twins compared with 9 of 41 (22%) groups on January 22^{nd} and 5 of 29 (17%) groups on February 6^{th}. Overall, 30 of 125 (24%) of cow-calf groups observed were twins.

A total of 569 moose were classified during intensive surveys (Table 7). Of this total there were 217 (38%) cows, 268 bulls (47%), and 84 (15%) calves. Applying these percentages to the population estimate of 852 moose means that there are an estimated 324 bulls, 400 cows, and 128 calves in the park.

Table 7. Moose sex and age ratios.

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		Moose Observed						**Sex and age ratios**
Date	**Area**	**Bulls**	**Cows**	**Calves**	**UC AD**	**UC**	**Total**	**Bulls: 100 cows: calves**
Jan. 22	**Green Mt.**	64	49	27	0	1	141	130: 100: 55
	Hemp Ck.	24	45	15	0	1	85	53: 100: 33
	Archer Ck. Flourmill Ck. Pyramid Mt.	24	30	8	0	5	67	80: 100: 27
	Total	112	124	50	0	7	293	90 100: 40
Feb. 6	**Green Mt.**	75	99	20	0	0	194	76: 100: 20
	Hemp Ck.	19	21	5	0	2	47	90: 100: 24
	Archer Ck. Flourmill Ck. Pyramid Mt.	11	24	9	0	0	44	46: 100: 38
	Total	105	144	34	0	2	285	73: 100: 24
Grand total		217	268	84	0	9	578	81: 100: 31
Jan. 17-23	**Survey Blocks**	34	58	74	309	0	475	N/A

UC AD – unclassified adult **UC** – unclassified

3.8 Other Wildlife

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Other wildlife species were recorded during the reconnaissance, random block, and classified flights.

Mule Deer

One hundred twenty-three Mule deer were observed during the random block survey; 15 males, 10 females and 98 unclassified. Eighty-six deer were observed on the north side of Mahood Lake in SU's M12 and L47. Thirty-seven deer were observed on Green Mountain.

Caribou

Four caribou were observed on Table Mountain during the reconnaissance flights and 2 caribou were observed in the dense forest east of Clearwater Lake during the survey of SU L25.

Wolf

A pack of 5 wolves (4 black, 1 grey) were observed near the Stillwater area of the Murtle River. Tracks of an additional 5 wolves were observed on Hobson Lake. Based on the sightings of wolves and wolf tracks, we estimate a minimum population of 10 wolves in the park.

Coyote

Three coyotes were observed, 2 near Mahood Lake and 1 near Battle Creek.

3.9 Survey Costs

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a) Purchase of Materials			
- Aerial photographs	-275 coloured photos @ $0.90 each		$247.50
	-416 black and white photos @ $0.56 each		232.97
- Topographic maps - 32 @ $1.00 each			32.00
- Film – 2 rolls and developing			19.00
- Grease pencils – 3 @ $1.25 each			3.75
- Tape recorder batteries			3.50
		Total	$538.72
b) Transportation costs			
- Airfare Victoria-Kamoops return 4 trips @ $220.00 each			880.00
- Charter flight Williams Lake – Clearwater			185.00
- Vehicle costs			335.00
- Taxi			158.00
- Misc. travel expenses (phone calls)			23.00
		Total	$1,581.00
c) Food and Lodging			
- 2 preparatory trips to Kamloops – 7 man days			315.00
- Survey – 31 man days			2,165.00
		Total	$2,480.00
d) Labour Costs			
- Pre-survey preparation (organizing survey format, contacting regional staff, purchase of supplies, preparation of aerial photos and maps)			

27 man days @ $87 each.		2,349.00
- Survey – 29 man-days @ $90 each.		2,610.00
- Analysis of data and report writing		
30 man-days @ $87 each.		2,610.00
	Total	$7,569.00
e) Aircraft Rental		
Fixed wing: 10.4 hrs. @ $151/hr. (incl. fuel)		1,570.40
Helicopter: 37.2 hrs. @ $475/hr. (incl. fuel & pilot expenses)		17,670.00
	Grand Total	$31,409.30

The total cost of the survey was $31,409.30. Aircraft rental accounted for 61% of the total cost, labour 24%, food and lodging 8%, transportation 5% and materials 2%.

4.0 Discussion

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Results of this study show that the moose census methodology described by Gasaway et al. (op. cit.) in Alaska can be used to census moose in the Cariboo Mountains of British Columbia. The estimated moose population in Wells Gray Park was 852 ±18% at the 90% CI which is within the limits suggested by these authours, who recommend striving for precision equal to or greater than a 90% CI which has outer limits of ±20% of the population estimate. The population estimate obtained in this study refers to the winter moose population only. Some moose wintering in the park may have their summer range outside the park and vice versa.

The major obstacle in achieving a reliable moose population estimate for Wells Gray Park is the presence of a large area of dense mature forest in which it is difficult to sight moose. In Alaska, Gasaway et al. (op. cit.) used one sightability correction factor (SCF) for all three strata, however, in Wells Gray Park, we found it necessary to use a separate SCF for the low density stratum due to the predominance of dense forest and the low sightability of moose in this stratum. In order to obtain an SCF for the low strata it would be necessary to test a very large area. This procedure is prohibitively expensive, in addition to which, even during intensive searches, sightability of moose remains low. For these reasons we could not objectively define an SCF for the low density stratum but had to rely upon a "best guess." The best solution we can suggest to reduce the problem of low sightability in dense habitat is to maintain a high search intensity. Due to the necessity of maintaining a high search intensity, the cost of obtaining a reliable moose population estimate in Wells Gray park is high. However, the results of this study indicate that the expenditure is worthwhile; whereas, to attempt the survey without the level of funding we had is apt to lead to results of dubious value.

The moose population in Wells Gray Park has declined from about 3,000 in the early sixties to 850 at the present time. This represents a decline of about 70% in 20 years. This decline has been attributed to a reduction in the quantity of available moose browse as a result of forest succession (Ritcey, 1982). This conclusion is supported by our observation that most of the high and medium strata was located in burned or logged habitat below 1360 metres, whereas most of the low stratum was located in mature forest, or the zone above 1360 metres. It appears that, barring significant natural fires, the moose population will continue to decline unless some habitat alteration such as burning or logging is performed. If such habitat alterations are performed care must be taken not to eliminate winter range of the Wells Gray caribou which depend upon mature forest for over-winter survival. Edwards (1954) noted that the decline of the Wells Gray caribou in the past 50 years coincided with large fires in the Clearwater valley in the 1920's and 1930's.

Despite the fact that the Wells Gray moose population has declined, two factors indicate that the current population is quite productive. The high rate of twinning (24% of cow-calf groups) observed is one of these factors and the other is the relatively high calf:cow ratio. We observed a ratio of 40 calves:100 cows on January 22nd compared to only 21 calves:100 cows (27:126) observed by Jones (1984) in Tweedsmuir Park, 400 km to the east, on January 18-19, 1984. However, the calf:cow ratio we observed may be typical of the Cariboo area. Jury and Ritcey (1983) observed a calf:cow ratio of 39:100 (21:54) in Management Unit 3-30, approximately 80 km south-southwest of our study area, between January 12 and February 14, 1983.

Calf:cow ratios we observed varied markedly; from 40:100 on January 22nd to 24:100 on Febrary 6th. The same area were classified on both dates and the number of moose classified was almost identical, with 286 classified on January 22nd and 283 classified on February 6th. Between the two surveys the number of calves observed decreased from 50 to 34 while the number of cows observed increased from 124 to 144. There appears to have been movement of cows with calves from open habitat where the classified counts were done to more heavily timbered habitat. However, the reduction in the calf count could also be due, at least in part, to mortality. At the same time there was a movement of cows without calves into the classification areas. The combination of the movement of cows with calves from the classification areas and the movement of barren cows into the classification areas resulted in a substantial reduction in the calf:cow ratio between surveys. The best ratio to use for management purposes is probably an average of the two surveys: that is, 31 calves:100 cows.

The bull:cow ratio also varied somewhat between surveys, decreasing from 90:100 on January 22nd to 73:100 on February 6th. This difference was caused by an increase in the number of cows observed, from 124 to 144 plus a small reduction in the number of bulls observed, from 112 to 105. These substantial differences in age and sex ratios between surveys show that the timing of classified counts can significantly affect the results obtained.

The distribution of moose also changed markedly between classified counts. There was an increase of 53 moose observed on Green Mountain and a decrease of 61 moose observed in all other areas combined. There appears to have been a movement of moose southward between surveys, probably in response to an increase in snow depths at higher elevations.

There were several days of heavy rain below about 900 m (3,000 ft.) and snow above this elevation during the last week in January. Consequently, snow depth decreased at Green Mountain between surveys but increased in most of the other areas classified. Observers noted moose wallowing in deep, crusted snow at Archer Creek on February 6th. Observers also noted that moose were utilizing denser habitat in areas other than Green Mountain on February 6th compared to January 22nd. This was also likely a response to an increase in snow depth. This shift in habitat use may have been partly responsible for the lower count (91 versus 151) in areas other than Green Mountain on February 6th compared to January 22nd. However, the concurrent increase in moose at Green Mountain suggests that some moose also moved southward.

Results of this study allow an evaluation of predation on moose in Wells Gray Park. Studies in Alaska indicate when there are fewer than 30 moose per wolf, predation may limit moose populations (Gasaway et. al, 1983). Substantial predation usually results in low calf ratios and few twin calves surviving. In Wells Gray, we estimate a ratio of about 85 moose per wolf (850 moose, 10 wolves), well above the point where predation could reduce populations. The observed ratio of about 32 calves:100 cows, and the 24% twinning rate, indicate that there is minimal predation on calves. Evaluation of the moose-wolf ratios and the calf-cow ratios indicates that predation currently has little effect on moose in Wells Gray Park.

The timing of the stratified random block survey appears to have been good since, had the survey been conducted later, moose would have been less sightable due to their occupation of denser habitat. The most critical factor in timing of the survey appears to be snow depth. Snow depth must be sufficient to cause moose to congregate on their winter range where they are easier to count, but not so great that they seek refuge in the timber once they are on their winter range. A snow depth of about 50 cm (20 in.) at the southern end of the park is probably a fair indicator of good survey conditions.

5.0 Recommendations

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1. Plotting of sample units on aerial photographs is useful, but time consuming and not mandatory. Topographic maps of 1:50,000 scale will suffice if survey preparation time is limited.
2. Sample units should be smaller in order to reduce observer fatigue. A mean SU size of about 12 km^2 is suggested. With better stratification the smaller SU size should not adversely affect the variance of the population estimate.
3. Future random block surveys should be better stratified. The study area was restratified based on information gained during this survey. Maps showing the new stratification will be kept on file in Victoria and the region for future reference.
4. It appears that January is the best time to conduct the random block and moose classification surveys. Indications are that, during February, moose begin to utilize thicker forest habitat making it more difficult to observe them. This shift in habitat use likely depends largely on snow depth and crusting, and, during a winter of light snowfall, it may be feasible to conduct surveys in February or even

March. However, it is advisable to plan surveys for January, using a snow depth of about 50 cm at the south end of the park as a guideline.

5. Consideration should be given to allowing controlled burning or logging in selected areas to enhance moose habitat. However, the benefits of moose habitat enhancements must be carefully weighed against the possible adverse effects of such enhancement on other wildlife species, particularly caribou. The former winter range of caribou should be delineated as accurately as possible. What was once caribou winter range can become caribou winter range again.

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Appendices

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Appendix 1. Moose survey form for population estimation

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Appendix 2. List of sample units and moose observed, Wells Gray Park moose survey.

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Sample Unit	Size (km^2)	Surveyed	No. of Moose observed
H1	14.6	Yes	103
H2	22.5	Yes	86
H3	14.2	Yes	9
H4	20.0	Yes	38
H5	20.5	Yes	12
H9	16.2	Yes	42
M1	23.5	Yes	32
M2	15.1	Yes	40
M3	18.3	Yes	7
M4	14.3	No	-
M5	17.5	Yes	39
M6	12.5	No	-
M7	25.9	No	-
M8	30.8	No	-
M9	15.6	Yes	29

Sample Unit	Size (km^2)	Surveyed	No. of Moose observed
M11	25.5	No	-
M12	28.4	Yes	19
M13	5.9	No	-
M14	16.4	Yes	8
M15	26.2	No	-
M16	22.9	No	-
M17	11.9	Yes	7
L2	21.5	No	-
L4	24.6	No	-
L5	25.7	No	-
L7	22.2	No	-
L17	24.0	No	-
L20	15.9	No	-
L21	7.4	No	-
L22	11.7	No	-
L23	17.4	No	-
L24	19.8	No	-
L25	20.8	Yes	1
L27	21.7	No	-
L28	26.7	No	-
L30	20.7	No	-
L31	21.7	No	-
L32	21.0	No	-
L33	12.1	No	-
L34	15.2	No	-
L35	13.5	No	-
L36	18.0	No	-
L37	20.1	No	-
L38	23.3	No	-
L39	23.5	No	-
L40	23.2	No	-
L41	17.6	No	-
L42	15.4	No	-
L43	17.8	No	-
L44	14.3	No	-
L45	17.0	No	-
L46	34.0	No	-
L47	14.3	Yes	0
L48	10.5	No	-
L49	14.9	No	-
E1	10.5	No	-
E2	9.4	No	-
E4	16.5	No	-
E5	18.1	No	-

Sample Unit	Size (km^2)	Surveyed	No. of Moose observed
E6	8.3	No	-
E7	13.7	No	-
E8	15.3	No	-
E9	15.1	No	-
E10	16.4	Yes	0
E11	10.0	No	-
E12	9.1	No	-
E13	9.6	No	-
E14	19.5	No	-
E15	12.5	No	-
E16	18.6	No	-
E17	15.8	No	-
E18	19.7	No	-
E19	19.0	No	-
E20	12.8	No	-
E21	11.3	No	-
E22	11.8	No	-
E23	14.2	No	-
E24	10.9	No	-
E25	14.3	No	-
E26	22.8	No	-
E27	24.5	No	-
E28	13.8	No	-
E29	23.0	No	-
E30	38.9	No	-
E31	29.6	No	-
E32	25.3	No	-
E34	26.1	No	-
E35	21.8	No	-
E36	26.5	No	-
E37	27.8	No	-
E38	22.9	No	-
E39	16.5	No	-
E40	27.6	No	-
E41	20.3	No	-
E42	19.4	No	-
E43	24.2	No	-
E44	18.2	No	-
E45	18.6	No	-
E46	14.8	No	-
E47	13.4	No	-
E48	13.2	No	-
E49	15.1	No	-
E50	19.9	No	-

Sample Unit	Size (km^2)	Surveyed	No. of Moose observed
E51	21.0	No	-
E52	23.4	No	-
E53	25.6	No	-
E54	32.5	No	-
E55	30.3	No	-
E56	27.7	No	-
E57	25.1	No	-
E58	20.8	No	-
E59	24.5	No	-
E60	16.3	No	-
E61	19.6	No	-
E62	25.8	No	-
E63	15.8	No	-
E64	18.5	Yes	1
E65	27.7	No	-
E66	20.3	No	-
E67	20.5	No	-
E68	13.9	No	-
E69	19.2	No	-
E70	12.2	No	-
E71	32.6	No	-
E72	21.8	No	-
E73	33.1	No	-
E74	15.4	Yes	2
E75	26.2	No	-
E76	31.4	No	-
E77	12.2	No	-
E78	13.4	No	-
E79	23.1	No	-
E80	22.0	No	-
E81	27.4	No	-
E82	27.1	No	-
E83	15.6	No	-
Total	**2644.7**		**475**

Appendix 3. Calculation of the variance and confidence interval for the moose population estimate in Wells Gray Park.

List of appendices