Moose recruitment and population trends in the Lake Revelstoke Valley, 2003 – 2010

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SUMMARY

The moose population in the Lake Revelstoke Valley has been monitored annually from 2003 – 2010 using 17 pellet transects. Results from these transects indicate a decline of > 60 % during this time frame, but the 2010 estimate suggests that the population trend has stabilized or increased slightly. The pellet data were compared to various aerial censuses done over the same time period, and these independent methods suggest a similar rate of decline. By using the pellet-based data, there currently appears to be approximately 627 (349 – 967, 90% CI) moose in the study area. Also, using data from the aerial censuses, I summarized calf: cow ratios from 2003 – 2010. The raw (uncorrected for sightability) estimate for 2010 is 32 calves: 100 cows, perhaps indicating a density dependent increase in recruitment relative to 2003 levels (22:100 cows), when the moose population was much higher. If there is indeed a density dependent increase in recruitment, and given that cow harvest tags have been reduced to six for the fall 2010 harvest, we may expect an increase in the moose population in 2011.

INTRODUCTION

Moose (*Alces alces*) are thought to be an important species in the Columbia Mountains because of the role they play in supporting predator populations that overlap with endangered mountain caribou (*Rangifer tarandus*). Although a variety of historic (Bergerud 1974) and contemporary factors (Wittmer et al. 2007) have influenced the decline of mountain caribou, the current threat is caused by excessive predation (Seip 1992, Wittmer et al. 2005). It appears that increases in moose and deer (*Odocoileus* sp.) have led to increased predator numbers, which leads to increased predation rates on caribou. The conversion of old forests to early seral stands is one factor that has influenced the increase in abundance of moose and deer (Rempel et al. 1997).

Options to recover caribou include reducing forest harvesting, reducing predators directly, or reducing the alternate prey that support predator numbers. Although these options are not mutually exclusive, it is becoming increasingly clear that reducing forestry, on its own, will not recover caribou because it will take decades for early seral stands to become trees again, and in the meantime caribou populations will continue to go extinct (Wittmer et al. 2010). In contrast,

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directly reducing predators positively affects caribou recruitment, and in some cases survival rates (Bergerud and Eliot 1986, Seip 1992, Hayes et al. 2003). However, as soon as predator control is stopped, predator numbers quickly rebound, as long the alternate prey are still abundant (Hayes et al. 2003). Furthermore, predator control is now much less acceptable to the public (Orians et al. 1997), and governments rarely implement this tactic for longer than five years. Finally, the option of reducing alternate prey (moose in our case), if done without concurrent predator reduction, is risky because predators may feed on caribou for a short time until predators also decline in numbers (see Courchamp et al. 2003). Therefore, it is important that moose are not reduced too quickly, and to do so, it is necessary to carefully monitor their abundance.

In this report, I present the results of pellet transect data collected in 2010. These data were used to estimate the relative change in moose abundance. The same transects have been surveyed since 2003 so I summarize these data across all years. For comparative purposes, I also present aerial census data collected in 2003, 2006, 2007 and 2010 to determine the degree of corroboration between these independent methods. Finally, because calf recruitment is an important component affecting ungulate population growth (Gaillard et al. 1998), I present calf composition data surveyed in winter 2010, and compare these values to data collected periodically since 2003.

STUDY AREA

The study area is the Lake Revelstoke Valley, bounded by the Selkirk Mountains to the east and the Monashee Mountains to the west. This area also corresponds to wildlife management units 4-38 and 4-39 (Fig. 1). Additional details on vegetation and topography can be found in Apps et al. (2001) or Poole and Serrouya (2003).

METHODS

Pellets

Field methods for the pellet transects have been described in detail in Poole and Serrouya (2003). Briefly, 17 straight-line transects, averaging 1.3 km in length, were established and oriented from valley bottom upslope (Fig. 1). The number of transects sampled was based on a power analysis done from a pilot study in the Lake Revelstoke Valley (Poole and Serrouya 2003). The number of ungulate pellets groups were recorded in circular plots that were 100 m^2 and located every 50 m along the transects. Pellets were cleared from the plots after they were surveyed. Plots were permanently established and marked using a wooden stake. Plots were sampled each year in May or early June, after snowmelt but before excessive vegetation emergence which makes finding pellet groups more difficult.

I report the number of pellet groups per "countable plot", i.e. plots that could be sampled each year. Some plots were lost from the sample among years because of wildfire, recent logging activity, or flooding. I also report the presence of a pellet group in a plot (i.e. ≥ 1 pellet group) per countable plot, because it was suggested that this would result in less variation than the number of pellet groups/countable plot.

I also comment on how the precision varied over time, to determine if the precision (i.e. reliability of the estimate) changes as the population size changes. To estimate precision, I treated each transect as the sample unit, bootstrapped these, and report 90% CIs using the percentile method (Efron and Tibshirani 1993).

2010 aerial census and calf composition

A stratified-random block (SRB) aerial census to estimate absolute moose abundance was done in the study area in 2003 and 2007. In addition, partial censuses were done in 2006 and in 2010. Partial censuses mean that only a small number of blocks were flown, too few to estimate absolute abundance, but useful to estimate recruitment and sex ratios. Survey block boundaries were generally consistent across years and averaged 19.7 km^2 (±0.91 SE; range 8.5–35.0 km^2, $n = 53$), and these were usually surveyed in mid-January. For the 2010 partial census, I selected blocks that were flown somewhat consistently since 2003 (including the complete censuses), to try and provide an independent measure of relative change in moose abundance over time. I present the abundance estimates from the 2003 and 2007 SRB censuses, but present the proportional changes from the raw counts for the same 5 survey blocks sampled in 2006 and 2010 to determine how this index compared to proportional changes from the pellet data. I compared these independent measures (pellets vs. aerial censuses) to provide information on the suitability of various methods to track the moose population.

While surveying moose from the helicopter I used the same methods outlined in Poole and Serrouya (2003) and Serrouya and Poole (2007), which are based on the standard methods from Resources Inventory Committee (2002) and Gasaway et al. (1986). Calf composition (recruitment) was reported as calves per 100 cows. Cows were identified by lack of antlers, a vulva patch, and head shape, whereas calves were identified by body size and shape. I used a real-time GPS-GIS interface to ensure that flight lines were approximately 300 m apart, and to keep track of the block boundaries. I recorded vegetation cover around each moose group to apply a sightability correction factor (Quayle et al. 2001).

In January 2010 I completely surveyed 5 blocks to estimate calf recruitment (and to compare changes in relative abundance within these same blocks since 2003; Fig. 2), then was informed by Ministry of Environment staff that there were additional funds to survey more moose. Therefore, instead of surveying additional blocks, we agreed to "high-grade" low-elevation areas to try and sample as many cow moose as possible to improve the precision of calf: cow estimates. Survey lines are presented in this report to enable repeatability of this census.

RESULTS

Moose population trends

The spring of 2010 was unusual in that there was early snow melt and green up at low elevations, but snow remained longer than usual at mid to high elevations. This posed some challenges because we had to balance surveying the lower portion of transects to avoid too much new vegetation, which makes it more difficult to find pellets, vs. waiting for snow to melt at higher elevations because snow cover makes it difficult to survey those plots.

Results from 2010 pellet data indicate that the moose population has stabilized or increased from the previous year (Fig. 3). However, as with most trend analyses, sampling variation does not allow for definitive conclusions on an annual basis. Error bars of moose abundance estimates from successive years overlap, but those 2 – 4 years apart generally do not overlap. In Table 1 I present the number of moose pellet groups per "countable plot", along with deer pellet groups to provide a relative indication of the abundance of deer vs. moose in the study system. From 2003 – 2010, a total of 924 moose pellet groups were recorded, compared to 55 deer pellet groups, indicating that deer pellets were on average 6% as abundant as moose pellets (Table 1).

Table 1. Trends of moose pellets (presence [≥ 1 pellet groups in a plot] and number of pellet groups) in the Revelstoke study area from 2003 to 2010. Also shown is annual rate of change (λ) and average annual λ. Deer pellets are shown for comparison.

		Moose pellets						Deer pellets
		Presence of at least 1 pellet group			# pellet groups			
Year	Effort (Countable plots)	Presence	detection/ effort	λ	# pellet groups	detection/ effort	λ	# deer pellet groups
2003	484	115	0.24		194	0.40		12
2004	482	113	0.23	0.99	228	0.47	1.18	2
2005	481	84	0.17	0.74	134	0.28	0.59	7
2006	465	73	0.16	0.90	97	0.21	0.75	14
2007	462	49	0.11	0.68	84	0.18	0.87	3
2008	461	45	0.10	0.92	70	0.15	0.84	2
2009	467	30	0.06	0.66	48	0.10	0.68	4
2010	465	46	0.10	1.54	69	0.15	1.44	11
2003 - 2010 (mean annual lambda)				0.88	Total = 924		0.87	Total = 55

In Figure 3 I present the moose pellet data but set the initial estimate to 1650 moose based on the 2003 aerial abundance estimate, and show the relative change over time using the rate of change based on the pellet data. Furthermore, I show the rate of change based on the aerial census done in 2003 (SRB census), 2006 (partial census), 2007 (SRB census), and 2010 (Partial census). For the 5 blocks sampled consistently in 2003, 2006, and 2010, we observed 297, 205, and 104 moose respectively (raw counts; Appendix 1). We present these data in Figure 3 as the proportional change relative to the 2003 estimate of 1650 (see 'X's in Fig. 3). There was generally a high corroboration between the rate of change from the pellet data and estimates made from the aerial survey SRB and partial census data. However, note that it was not appropriate to calculate uncertainty for the 2006 and 2010 partial aerial censuses because only 5 blocks were sampled thus precision would have been very poor – therefore only point estimates are provided for those years.

Composition counts

The calf composition was highly variable among the 5 blocks surveyed, ranging from 0 to 64.7 calves per 100 cows (Table 2). When considering the data collected for the 5 blocks and the subsequent ``high grading``, the calf ratio was 31.6 based on raw counts and 27.0 based on sightability corrected counts (Table 3). By comparing raw calf ratios from 2003 – 2010 (Table 4), there appears to be an increase in calf ratios as the moose population declined (Fig. 3), but this relationship was not as clear when the sightability correction factor was applied (Table 4).

Table 2. Results for the 2010 moose composition survey for the 5 survey blocks that were counted in previous censuses done in the Lake Revelstoke Valley. This table does not represent all the data collected during the 2010 census because additional surveying was conducted outside these 5 blocks. The data in this table may be used as an index of population change over time by comparing values from the same survey blocks (See Appendix 1).

RAW COUNTS

Block no.	Location	Cows	Calves	Bulls	Unclass	Total	Calves:100 cows	Bulls:100 cows	Survey time (Minutes)
49	Goldstream front	15	1	8	3	27	6.7	53.3	136
53	Goldstream mid	5	2	8	2	17	40.0	160.0	104
58	Goldstream back	17	11	6	2	36	64.7	35.3	113
2	Pat creek	12	3	2	2	19	25.0	16.7	79
63	Downie back	3	0	2		5	0.0	66.7	96
	TOTAL	52	17	26	9	104	32.7	50.0	

SIGHTABILITY CORRECTED COUNTS

Block no.	Location	Cows	Calves	Bulls	Unclass	Total	Calves:100 cows	Bulls:100 cows
49	Goldstream front	29.0	1.0	13.5	16.0	59.6	3.6	46.7
53	Goldstream mid	13.9	2.8	15.5	5.5	37.7	20.0	111.9
58	Goldstream back	28.0	18.9	7.2	5.5	59.6	67.3	25.7
2	Pat creek	16.1	3.6	13.2	5.5	38.5	22.3	81.9
63	Downie back	16.0	0.0	3.8	0.0	19.8	0.0	24.0
	TOTAL	103.0	26.3	53.3	32.6	215.2	25.5	51.7

Table 3. Results for the 2010 moose composition count for the entire area surveyed in the Lake Revelstoke Valley (see Fig. 2 for survey lines).

Class	Raw counts	Sightability corrected counts
Cows	76	125.3
Calves	24	35.4
Yearling bulls	4	6.5
Adult bulls	38	61.1
Unclassified	9	29.5
Calf: 100 cow	31.6	27.0
Bull: 100 Cow	55.3	54

Table 4. Trends of calf and bull ratios from 2003 – 2010 in the Lake Revelstoke Valley (95 CIs in brackets).

	Raw counts		Corrected for sightability	
Year	Calves:100 cows	Bulls:100 cows	Calves:100 cows	Bulls:100 cows
2003	22 (18-27)	77 (66-89)	24 (17-32)	83 (56-109)
2006	25 (19-32)	52 (43-60)	24 (16-32)	51 (30-82)
2007	26 (22-30)	73 (55-91)	28 (21–36)	85 (47–123)
2010	32 (22-42)	55 (46-64)	27 (23-31)	54 (46-61)

DISCUSSION

As with most large-mammal censuses, sampling variance makes it difficult to determine, on an annual time scale, if the population is changing. It is more certain that the moose population has declined substantially since 2003, by approximately 62%. By "anchoring" the first pellet transect data recorded in 2003 to the aerial census done that same year, I was able to use the relative change in pellet abundance to obtain a current (2010) estimate of 627 moose (349 – 967, 90% CI). This estimate is close to the relative change in raw moose numbers for 5 blocks surveyed at several intervals since 2003 (577 estimated for 2010 using the aerial method; Fig. 3). These values (577 – 627 moose) are close to estimates obtained from the study area in the mid 1990s (Serrouya et al. in prep), but still above 204 moose estimated in 1984 by Bradley (1986, cited in Ingham 1991).

Despite the higher sampling variance noted in 2010, it appears as though the moose population has stabilized or increased. The pellet data suggests an increase of 44 – 54 % since 2009. This increase occurred despite the allocation of more than 60 cow/calf permits for the fall 2009 hunting season. Out of that allocation, it is estimated that 4 calves and 18 cows were harvested (Ministry of Environment LEH survey, T. Szkorupa). Although the moose rate of increase from 2009 to 2010 is not possible based on recruitment alone, it is plausible that immigration from adjacent areas, where moose were not aggressively reduced, could account for some of this change. A potential increase in calf: cow ratios may also account for the apparent stabilization of the moose population (see below). Finally, a recent decline of the wolf population (Van Oort et al. 2010) probably also factored in to the reduced rate of decline of the moose population.

Estimates of changes in calf ratios from 2003 - 2010 depended upon the method applied. Raw counts (i.e. uncorrected for sightability) showed an increase from 22:100 cows to 32:100 cows, whereas the sightability corrected counts suggest little change. With small sample sizes from the 2010 cow survey (which is an inherent outcome of a small moose population), corrected counts are highly sensitive to extreme values of cover estimates. For example, one cow seen in dense (e.g. 85%) cover means that this cow contributes 72 cows to the estimate, but if the estimate was 75% cover, the cow contributes 12 cows. These multiplication factors can have a huge influence on the calf: cow ratio calculation, because if the number of calves seen is the same, then the difference between 72 and 12 cows is enough to significantly affect calf cow ratios, particularly given that only 76 cows were actually observed in the total sample. Plus, if the cow in dense cover had a calf, there is a high chance that the calf would be missed because calves are smaller and less visible, and therefore would not be included in the correction factor. During the census we debated whether a cow was in 75 or 85% cover, and this one observation would significantly affect the outcome of the corrected calf: cow estimate. Taken together, this information suggests that it may make more sense to consider the raw counts for comparing changes in composition over time.

It is encouraging that several independent methods suggest a similar rate of decline in the moose population. Pellet transects can be done relatively inexpensively (< $6000/yr, depending if some transects can be done by government staff), but aerial censuses can provide valuable information on the composition of the population. A mix of both methods seems to be working well given the objectives of the moose reduction experiment in this study system. Unfortunately, the precision of the 2010 pellet-based estimate was poor relative to most previous years. Decreasing precision is a predictable outcome of a smaller population (given the same sampling effort), but I note that precision from the 2008 and 2009 estimates were much better than the current year despite a smaller mean estimate. The higher sampling variance recorded in 2010 makes it more difficult to make definitive conclusions about the current trend. However, if the 2010 estimate is assumed to be reliable, then the moose population has increased to levels seen in 2007, which may not be compatible with an objective of reducing moose to historic (i.e., pre-logging) levels. Because moose are being reduced to indirectly reduce predator numbers and thus reduce predation rates on caribou, allowing moose numbers to increase may not be ideal for caribou recovery. Given that cow tags are being reduced from >60 to 6 for the upcoming 2010 hunting season, it is possible that the moose population will increase in 2011. A recently declining wolf population and a possible increase in moose recruitment would further contribute to an increase in moose abundance. It would be ideal if the number of cow/calf permits released for the subsequent fall harvest could be allocated after the spring pellet transects are done, which usually happens by mid-June. Currently, cow/calf permits are allocated before the spring pellet-based moose population estimate is calculated. Waiting for the pellet data to be collected would allow for a more “real-time” management of the moose population.

Finally, I also recommend that the same 5 blocks highlighted in this report be flown each time a composition count or SRB survey occurs. In 2007 one of these blocks was not flown, to adhere to the strict SRB design, but this design could be altered slightly or additional blocks could be flown to make sure the same 5 are surveyed for consistency.

Deer

The pellet transects were not designed to detect changes in deer abundance, as can be noted by the high inter-year variability of the deer pellets. However, the abundance of deer pellets may be useful to estimate the number of deer relative to moose, when an average is considered across several years. Overall, deer pellets were about 6% as abundant as moose pellets, suggesting that there are probably less than 200 deer in the study system.

ACKNOWLEDGEMENTS

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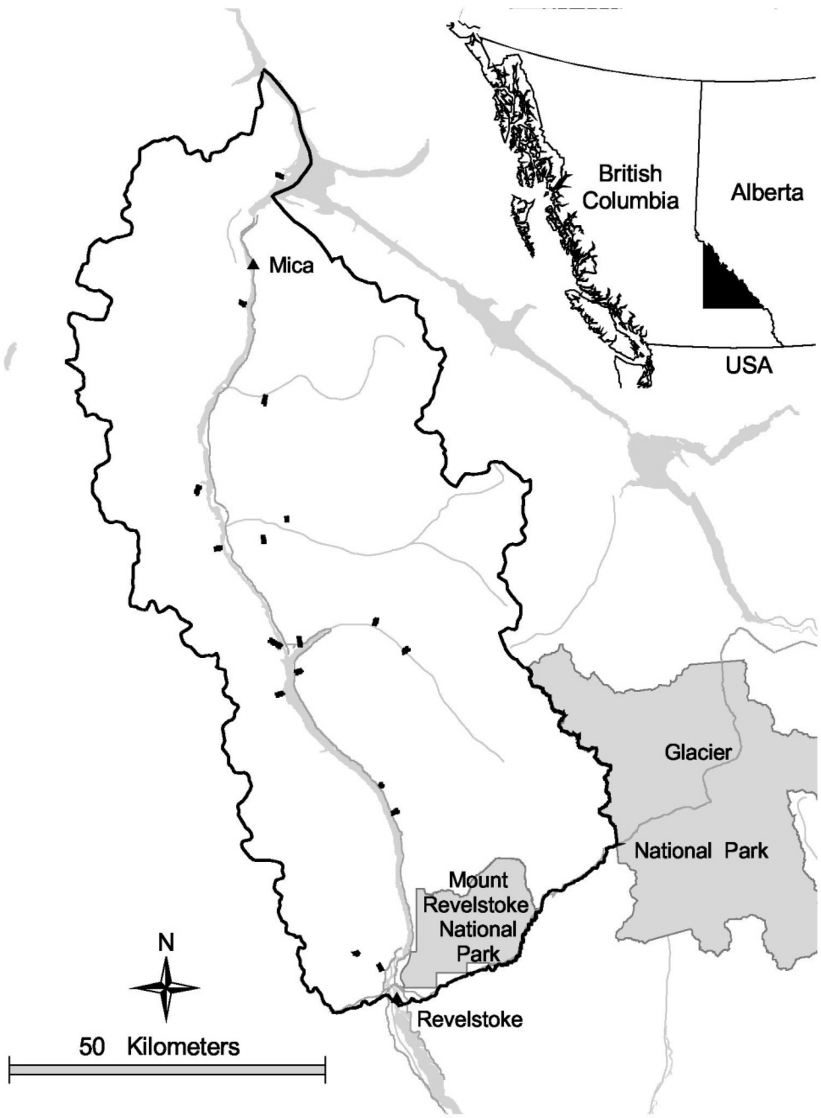
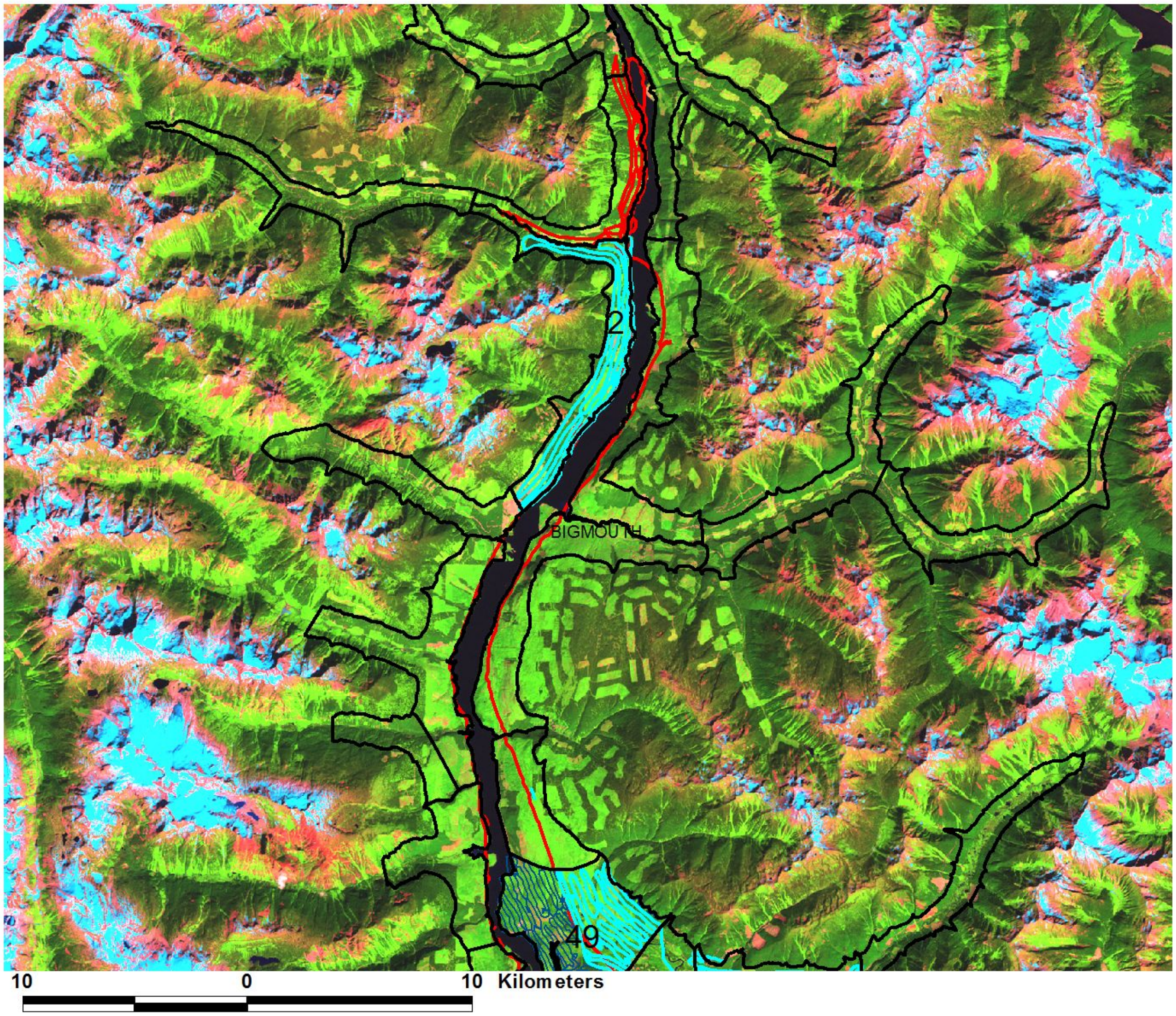


Figure 1. Study area (black outline) showing the location of 17 pellet transects (black dashes).

2A)



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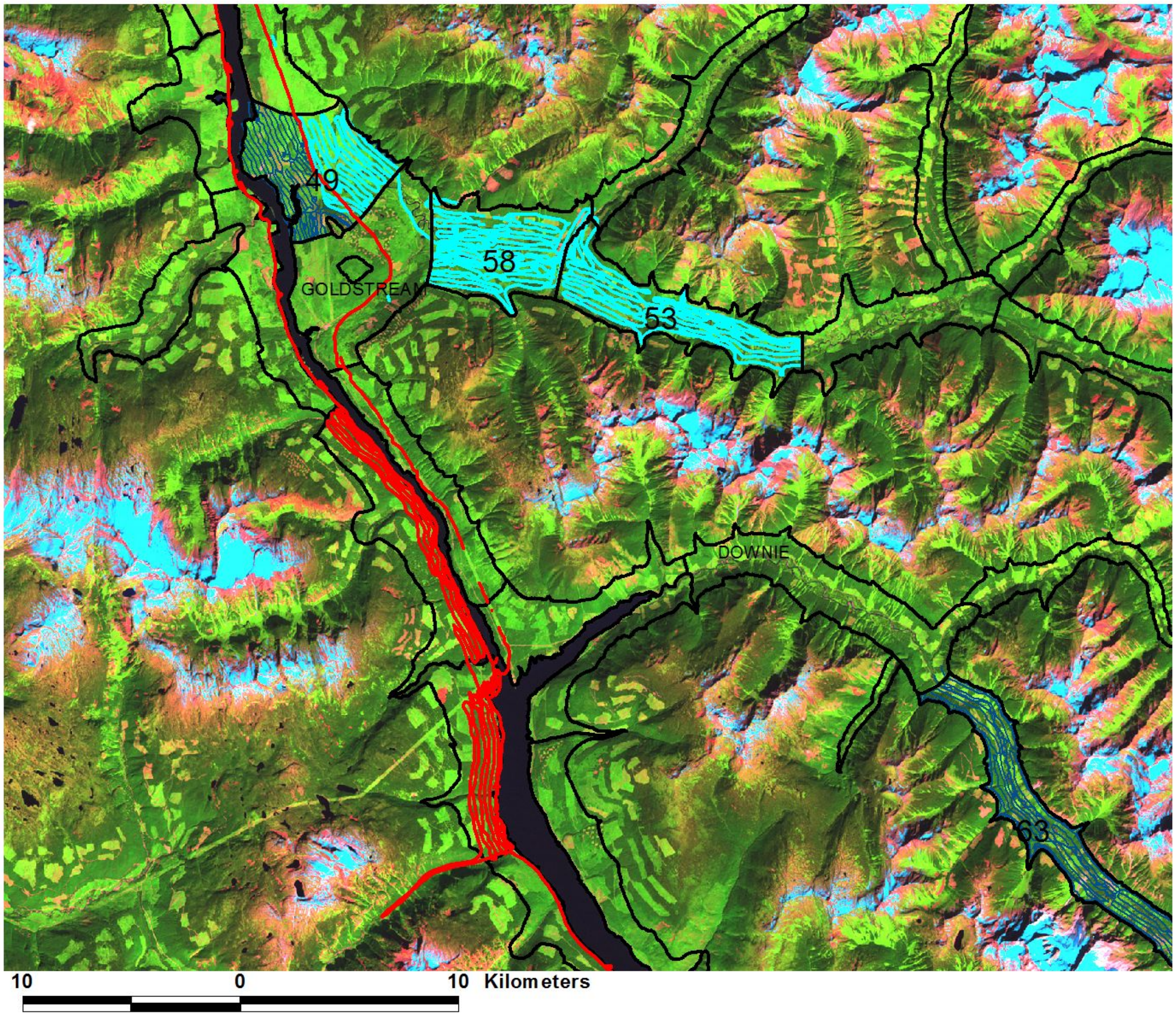

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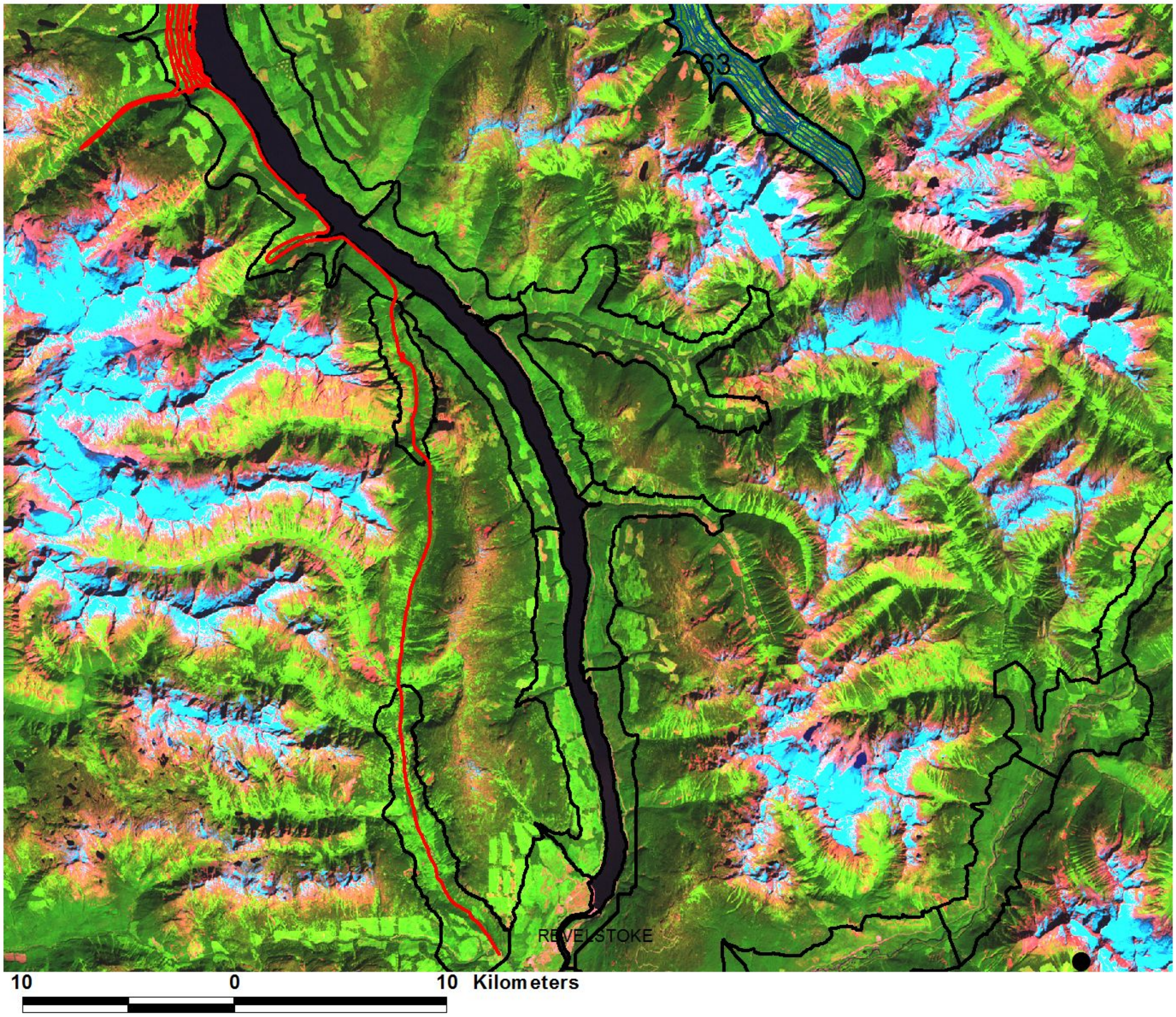

Figure 2a-c. Study area depicting flight lines surveyed on January 6 and 8 2010 (light and dark blue, respectively). On these dates, blocks 2, 49, 53, 58, and 63 were flown as per previous censuses in the study area using standard methods. On February 6 2010, a “high-grade” approach was used (red line) to increase sample size of cows to improve precision of calf: cow estimates. Black outline are survey block boundaries (Poole and Serrouya 2003).

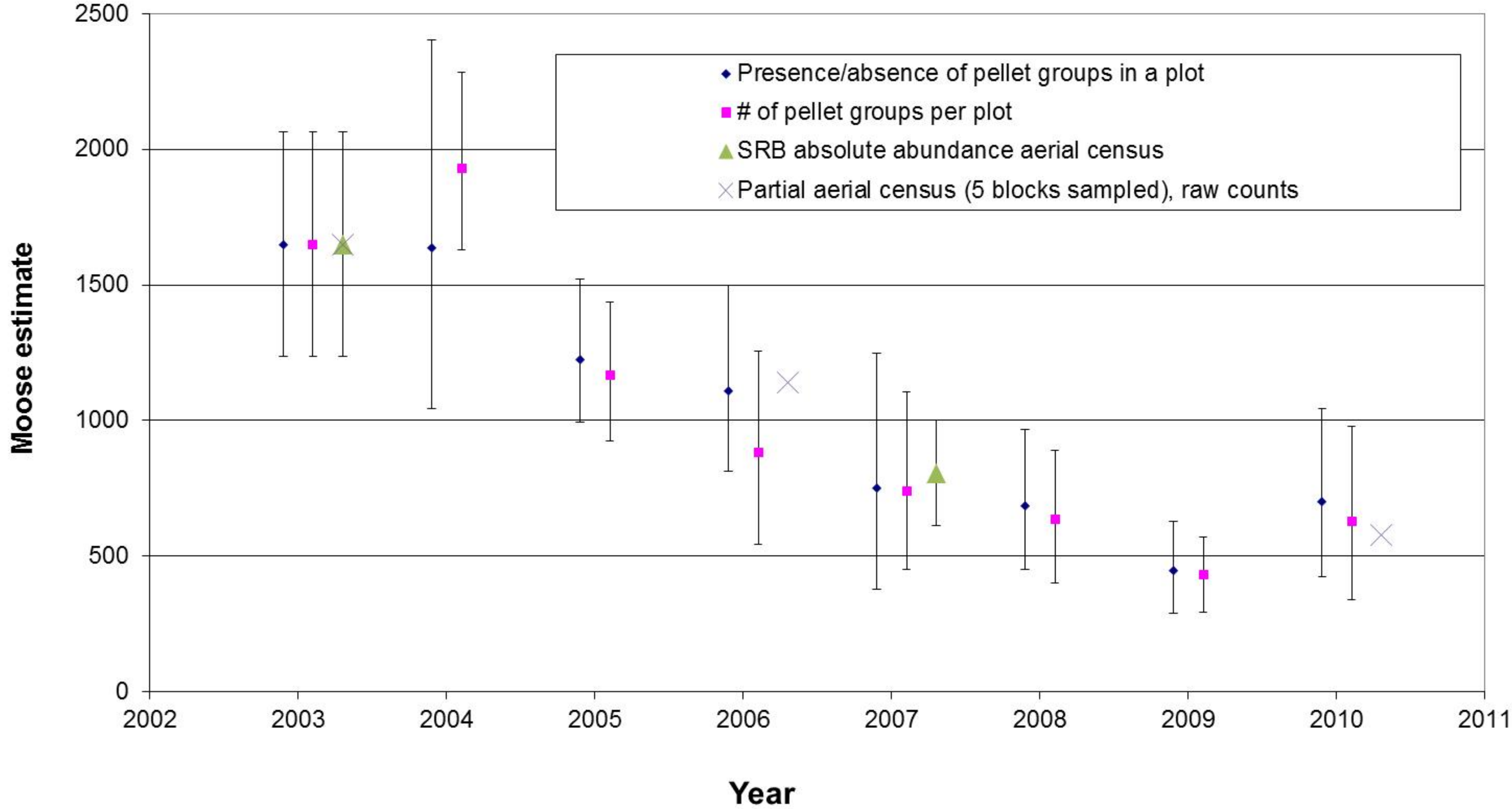

Figure 3. Changes in moose abundance in the Lake Revelstoke Valley from 2003 – 2010. Four different monitoring methods are presented. Two are based on the relative change of pellet group abundance from 17 pellet transects (set initially to 1650 moose, based on the 2003 SRB census): The number of pellet groups in the circular plots, compared to the presence of ≥ 1 pellet group in the plot. The other two methods are based on aerial censuses: Stratified random block (SRB) surveys designed to estimate absolute abundance, and partial censuses where the same 5 blocks were flown (based on the relative change in the raw number of moose observed over time in those 5 blocks).

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APPENDIX 1: Summary of 5 survey blocks counted in 2003 and 2006. These values can be used as a comparison against Table 2, because the same blocks were flown in 2010. The summary below was prepared by Kim Poole and R Serrouya and some of the details were presented in Serrouya and Poole (2007; but not the cow/calf/bull breakdown).

Revelstoke moose census comparison, 2003 and 2006 20/01/2006

K. Poole, AWR

		Raw counts			Corrections from spreadsheet application of detection probs Corrected for Sight (Quayle01)			Corrected for Sight (PG05)			Effort (min/km2)	
MU	**Area**	**2003**	**2006**	**Change**	**2003**	**2006**	**Change**	**2003**	**2006**	**Change**	**2003**	**2006**
2	Pat Ck S	27	30	111%	32.3	55.5	172%	31.3	58.2	186%	3.9	4.4
53	Goldstream Upper	36	32	89%	57.7	38.4	67%	62	37.6	61%	4.3	4.6
63	Downie Upper	37	23	62%	59.8	26.9	45%	64.6	26.2	41%	2.9	3.2
49	Goldstream Front N	93	71	76%	124.9	119.5	96%	127.3	125.5	99%	4.9	6.2
58	Goldstream Mid	104	49	47%	142.4	54.5	38%	145	52.8	36%	5.1	4.1
	Sum	**297**	**205**	**69%**	**417.1**	**294.8**	**71%**	**430.2**	**300.3**	**70%**	**4.22**	**4.48**

	Aerial Survey outputs with BC model (Quayle) 2003		2006		Aerial Survey outputs with BC model (+PG data) 2003		2006	
	Est	**90% CI**	**Est**	**90% CI**	**Est**	**90% CI**	**Est**	**90% CI**
Total	**403**	51	**286**	43	**414**	63	**291**	52
Cows	187	15	157	32	182	14	159	40
Bulls	111	21	78	20	113	27	81	26
Calves	45	10	39	10	45	9	38	10
Unclass.	61	35	12	6	75	45	12	6
Calf:cow ratio	**24**	5.4	**25**	8.1	**25**	5.5	**24**	8.7
Bull:cow ratio	**59**	12.2	**50**	16.6	**62**	15.4	**51**	21.1
Change			**71%**				**70%**	
Average Veg cover (%)	18.2		17.6					
Sight correction (AS Quayle)	35.7		39.5					
Sight correction (AS PG)	39.4		42.0					