UNGULATE AERIAL SURVEY

ANALYSIS AND SUMMARY 2000, 2004 AND 2007

IN THE SOUTH SELKIRK MOUNTAINS OF

SOUTHEASTERN BRITISH COLUMBIA.

Prepared for

Fish & Wildlife Compensation Program – Columbia Basin
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EXECUTIVE SUMMARY

Fish and Wildlife Compensation Program (FWCP) conducted aerial surveys of deer winter ranges in 2000, 2004, and 2007. I analyzed this data to provide FWCP with mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*) and moose (*Alces alces*) population estimates and trends for units 4-07 and 4-08. Raw aerial survey data were corrected for sightability using program Aerial Survey (Unsworth et al 1994). Sightability of deer was corrected using the Mule Deer Hiller 12-e Winter model, of elk using the Elk Hiller 12-E Idaho model, and for moose using the Moose Hiller-Siloy Wyoming model. Total numbers of white-tailed deer increased significantly between the 2000 aerial survey (946) and the 2004 survey (1837) but remained constant between the 2004 survey and 2007 survey (1675). Similarly, total numbers of mule deer increased significantly from the 2000 survey (376) to the 2004 survey (1001) but not between the 2004 survey and the 2007 survey (1161). The white-tailed deer population appears to have grown at a mean annual rate of 1.09 between 2000 and 2007 while the mule deer population appears to have grown at an average rate of 1.17 during the same period. Elk numbers increased significantly between 2000 (214) and 2004 (416) and again between 2004 and 2007 (591). Mean annual growth of elk from 2000 to 2007 was 1.16. Like the other species, the number of moose increased significantly between 2000 (26) and 2004 (242) but remained stable between 2004 and 2007 (284). Mean annual growth of moose from 2000 to 2007 was 1.41. Fawn/Doe and calf/cow ratios matched the population trends of all species although only changes in elk ratios were statistically significant.

Cougar populations in the Kootenay region of B.C. reached a peak in 1999 and began to decline in 2000 as a result of increased harvest. Recent research suggested that mule deer and white-tailed deer increases between 2000 and 2004 were evidence that both species were limited by predators and not poor habitat or resource competition. Concomitant increases in populations of other ungulates during the same period may also be a result of relaxed predation by cougars. As cougar populations recover, it is unclear if ungulate populations will maintain high equilibrium levels or revert back to lower levels due to predator limitation.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

INTRODUCTION

Aerial surveys are widely used to quantify a variety of wildlife species populations. Cliff et al. (2007) recently used aerial survey data to assess whale shark (*Rhincodon typus*) density off the northern coast of South Africa while Udivetz et al. (2006) used sightability corrected aerial surveys to monitor dall sheep (*Ovis dalli dalli*) populations in Alaska. Sightability, or sighting probability, is the likelihood that an animal will be detected by an observer during a survey (Krebs 1999). Using logistic regression (sight/no-sight) a sightability model quantifies detection probabilities across habitats, seasons, years, species, or distances and derives the 'statistical variation in detection' for different combinations of these variables (Williams et al. 2002).

When setting harvest levels, managers require accurate, repeatable estimates of ungulate populations. Because large ungulates often exhibit seasonal and annual fluctuations and irregular movements, sightability corrected aerial surveys of winter ranges can provide an effective tool in quantifying ungulate density (Unsworth et al. 1994, Msoffe et al. 2007).

Fish and Wildlife Compensation Program (FWCP) conducted aerial surveys of deer winter ranges in 2000, 2004, and 2007. These surveys were originally designed to quantify relative densities and population trends of mule deer (*Odocoileus hemionus*) and white-tailed deer (*Odocoileus virginianus*), however opportunistic sightings of elk (*Cervus elaphus*) and moose (*Alces alces*) were also recorded. I analyzed this data to provide FWCP with mule deer, white-tailed deer, elk and moose population estimates and trends for Wildlife Management Units 4-07 and 4-08.

STUDY AREA

The study area was the wildlife management units (MU) 4-08 (Salmo River) and 4-07 (West Arm) in the Kootenay Region of southeast British Columbia (B.C.). The study area was bounded to the north and east by Kootenay Lake, to the west by the Columbia River and to the south by the Canada-US border (Figure 1).

The climate is Pacific Maritime / Continental with the majority of annual precipitation falling in the form of snow (Environment Canada, Vancouver B.C.). Environment Canada maintains weather stations on the east (Creston) and west (Castlegar) edges of the study area and provided the following data. Mean (1961 to 1990) temperatures range from –3.0 C° (January) to 19.3 C° (July) in Creston, and from –3.2 C° (January) to 19.9 C° (July) in Castlegar. Mean (1961 to 1990) annual snowfall is 140.6 cm in Creston (el. 597 m) and 224.6 cm in Castlegar (el. 494 m). Mean accumulated snow (the depth of snow in centimetres on the ground at months end) averaged 26.62 cm from 1993 to 2004 (Figure 2).

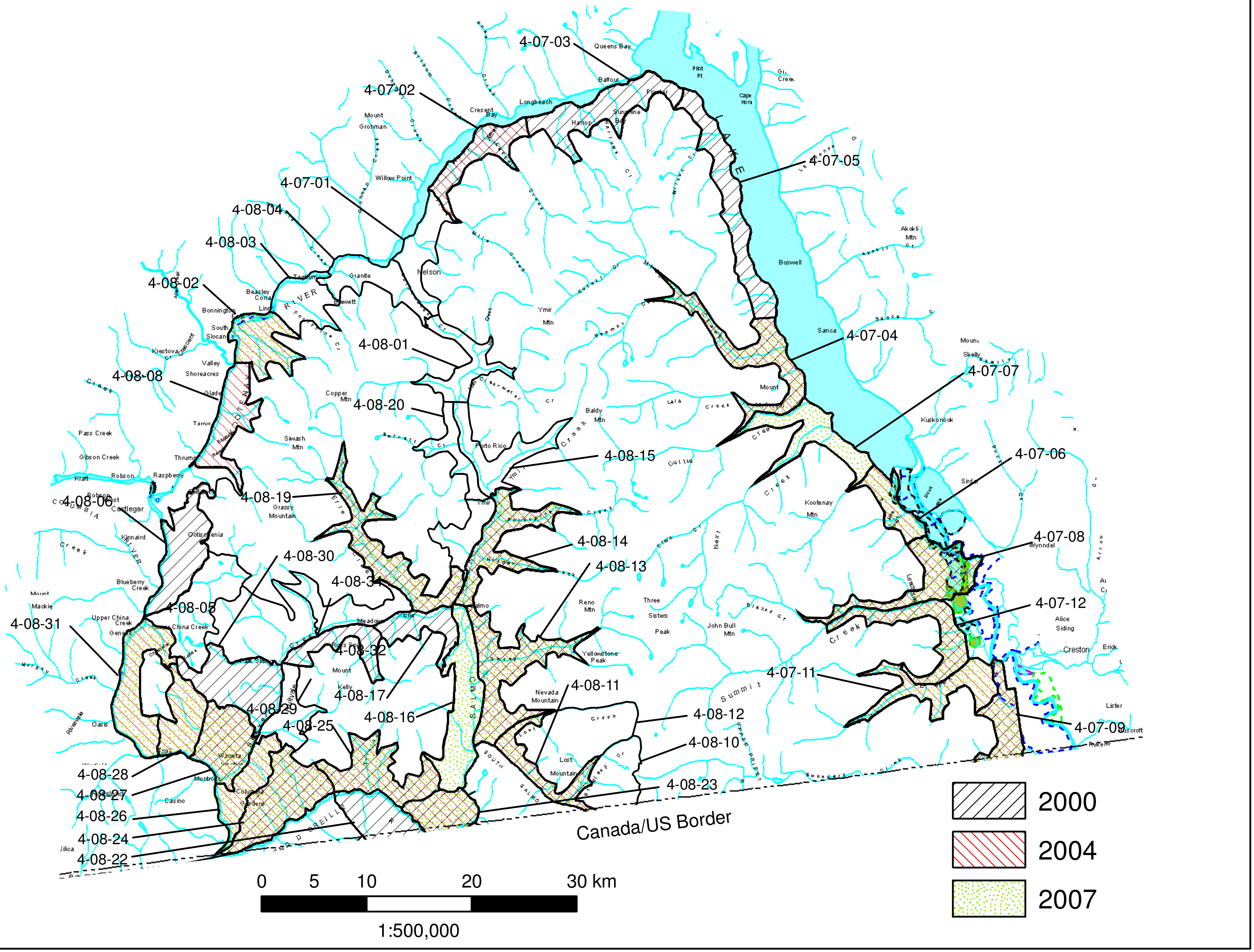
The study area is within two biogeoclimatic zones; the interior cedar - hemlock (ICH), and the Engelmann spruce – subalpine fir (ESSF) (Braumandl and Curran 1992). The ICH zone extends from the lowest elevations of the study area to approximately 1,200 m. Western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) are the dominant tree species in mature forests, with black cottonwood (*Populus balsamifera trichocarpa*) the climax in more moist areas. Open mixed stands of Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) are common on more xeric, south facing slopes (Ketcheson et al. 1991). The ESSF zone occurs from approximately 1,700 m to 2,100 m. Engelmann spruce (*Picea engelmannii*) dominates the climax forest, with subalpine fir (*Abies lasiocarpa*) composing the understory, and lodgepole pine (*Pinus contorta*) common following fire (Coupe et al. 1991).

In addition to deer, elk, and moose, bighorn sheep (*Ovis canadensis*), and mountain caribou (*Rangifer tarandus caribou*), were also present in the study area, roughly in that order of abundance. Common predators included coyotes (*Canis latrans*), black bears (*Ursus americanus*), bobcats (*Lynx rufus*), and cougars (*Puma concolor*). Low numbers of grizzly bears (*Ursus arctos*), lynx (*Lynx canadensis*), wolverines (Gulo gulo) and wolves (*Canis lupus*) were also present.

While mule deer populations have generally declined in recent decades, white-tailed deer have experienced substantial population increases in many parts of western North America (Crete and Daigle, 1999). In 1948, Dalquest summarized the relative abundance of the two deer species in Washington State as "…the whitetail of northeastern Washington is smaller than the mule deer and far less common". Today, white-tailed deer outnumber mule deer from 2:1 to 4:1 in large portions of northeast Washington and southern B.C. (Robinson et al. 2002, Cruickshank 2004).

Previous research has suggested that both white-tailed deer and mule deer populations declined in Northeast Washington and Southern British Columbia during the severe winters of 1993-1994 and 1996-1997. Following the winter of 1996-97 the white-tailed deer population remained stable or increased slightly while mule deer continued to decline (Robinson et al. 2002).

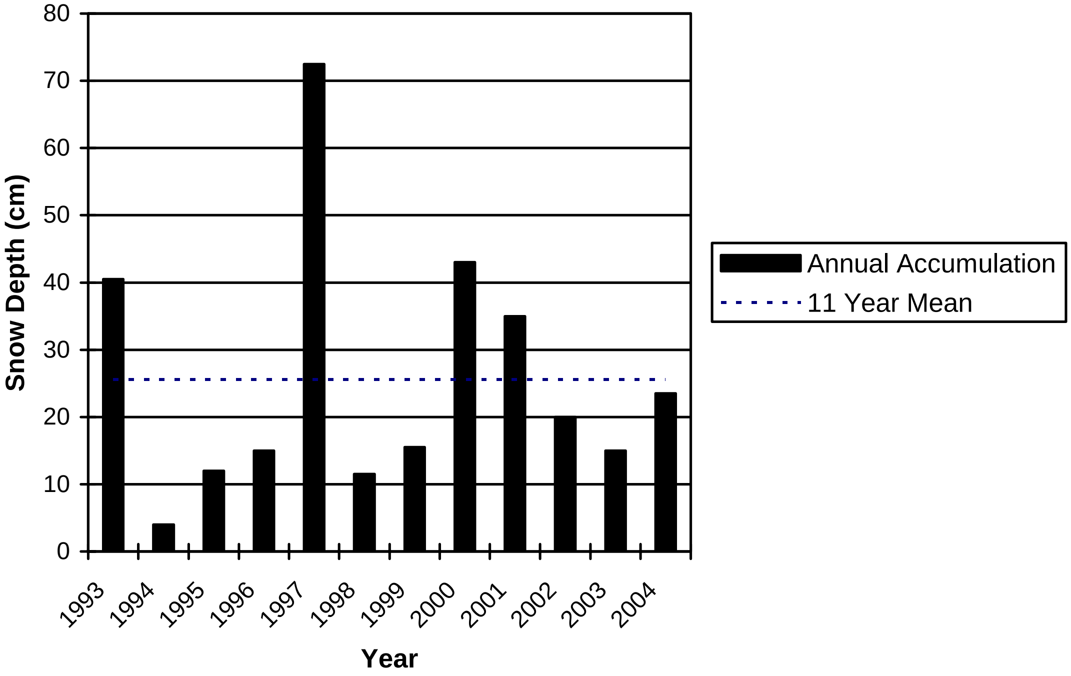
Figure 1. Mule deer and white-tailed deer winter range survey units in MUs 4-07 and 4-08



In the East Kootenay region, elk populations declined during the mid 1990's leading to hunting restrictions and a plan to promote recovery in that region (Raedeke 1998, Bircher et al. 2001). By 2004 elk populations had recovered substantially, perhaps in response to a succession of mild winters and decreased hunting pressure (Wilson and Morley 2004).

Moose populations vary throughout the Kootenay region and are thought to have generally increased in distribution and densities over the past 40-50 years (Shackleton 1999, Thompson and Stewart 1998). More recently however, Halko et al. (2000, from Poole 2007) suggested that moose numbers declined in southern portions of the Kootenays.

Figure 2. Annual accumulated snowfall (snow depth at months end, January to April) and ten year mean accumulated snowfall in south-central British Columbia 1993-2004* as measured at Creston and Castlegar A weather stations (Environment Canada, Vancouver B.C.).



* Data for years 2005-2007 were not available at the time of writing.

METHODS

Aerial surveys followed guidelines set forth by Unsworth et al. (1994). Surveys were flown in late winter when both species of deer and elk were concentrated on winter ranges. The study area was divided into 44 deer winter range subunits ranging from 15 km^2 to 53 km^2 (Heaven et al. 1999) (Figure 1.). Each subunit was classified into a high, medium, or low stratum for each deer species prior to each survey based on ground observations, a priori knowledge of regional biologists, and previous surveys. Twenty subunits were flown in each survey representing a mix of all three strata for each deer species. In 2004 and 2007, all high and medium units were flown for each species of deer. All units flown were included in the survey for both species. For instance, a unit that was flown as high for whitetails was considered low stratum for mule deer. Low stratum units that were not flown were included in the analysis in order to provide a study area wide population estimate.

In addition to deer, observations of elk and moose were recorded during the survey. Units should be stratified prior to a survey being conducted (Unsworth et al 1994), however as this survey was designed to enumerate deer and elk and moose sightings were collected opportunistically, units were stratified for elk and moose analysis post survey based on the mean raw counts of each species in all years. This method of stratification and survey design did not allow that the recommended minimum number of survey units (5) was sampled in each stratum in each year for elk and moose. However, the underrepresented stratum was always the lowest which contained no observations. This method of analysis assumes that moose and elk are only present in the zones that they were observed, producing a conservative population estimate for these two species in each year.

Subunits were flown in transects 100 m to 300 m apart at a speed of 60 to 80 km/hr as dictated by terrain and animal density (Unsworth et al. 1994). When animals were sighted, the location and total number observed in the group was recorded. Groups were then broken into sex age classes as doe/cow, fawn/calf, buck/bull (if antlers were visible, number of points were recorded), or unclassified. The animal's activity (bedded, standing, moving), as well as vegetation class (grassland, sagebrush, juniper, aspen/deciduous brush, conifer), percent snow cover (10% increments in immediate area surrounding the sighted animal), and percent canopy (10% increments above sighted area) cover were recorded at each observation (Unsworth et al. 1994). In areas where no animals were sighted, zeroes were entered in all fields. Sightability of white-tailed and mule deer was corrected using the Mule Deer Hiller 12-e Winter model, elk using the Elk Hiller 12-E Idaho model, and for moose using the Moose Hiller-Siloy Wyoming model. The moose model contains a covariate for terrain ruggedness which was considered important in early iterations of the aerial survey program (Unsworth et al 1994), but which has since been removed (Anderson and Lindzey 1996). Although it has no effect on the population estimate, the input still requires that this field contain some value therefore it was set to 0 for all observations. Differences in population estimates were tested using a chi-squared test of homogeneity at a significance level of 0.10 (Sauer and Williams 1989, Unsworth et al. 1994).

High, low, and mean population growth rate estimates were calculated for each species for each inter-survey period. Mean population growth rates were simply based on the difference between population estimates from each survey. High and low estimates were based on the greatest and least differences respectively in 90% confidence population estimates produced by Aerial Survey. For instance, the high population growth rate for mule deer between the 2000 and 2004 surveys was based on the mean estimate in 2000 minus 1 standard deviation and the 2004 estimate plus 1 standard deviation.

RESULTS

Surveys were conducted February 12th, 13th and 14th 2000, February 16th, 17th, 19th, 20th and 21st 2004, and February 17th, 18th, 21st, and 23rd 2007. Over the course of the three surveys a total of 687 mule deer, 1582 whitetails, 201 moose, and 717 elk were observed (Table 1). Observations of mule deer and moose were roughly equal between units 4-07 and 4-08 (Table 1) whereas elk and white-tailed deer observations were skewed towards unit 4-08. On average, twice as many elk were observed in 4-08 as in 4-07, and roughly 8 times as many whitetails were observed in 4-08 primarily due to high numbers in the Pend D'Orielle (units 4-08-24 and 4-08-25, Table 1). Sixty-five percent of the 44 survey units were flown at least once in the past 7 years. A total of 15 survey units, all low for all species, were never sampled (Table 1, and Table 2).

Deer

Total numbers of white-tailed deer increased significantly between the 2000 aerial survey (946) and the 2004 survey (1837) ($\chi^2 = 20.89$, $df = 1$, $P < 0.01$) but remained constant between the 2004 survey and 2007 survey (1675) ($\chi^2 = 0.22$, *df* = 1, $P = 0.64$) (Table 3). White-tailed deer fawn/doe ratios increased between 2000 and 2004 although not significantly ($\chi^2 = 2.07$, *df* = 1, $P = 0.15$) and declined in 2007 although again, not significantly ($\chi^2 = 1.36$, *df* = 1, $P = 0.24$) (Table 4).

Total numbers of mule deer increased significantly from the 2000 survey (376) to the 2004 survey (1001) ($\chi^2 = 3.71$, *df* = 1, $P = 0.05$) but not between the 2004 survey and the 2007 survey (1161) ($\chi^2 = 0.18$, *df* = 1, $P = 0.68$) (Table 3). Mule deer fawn/doe ratios increased between 2000 and 2004 although not significantly ($\chi^2 = 0.65$, *df* = 1, $P = 0.42$) and declined in 2007, although again not significantly ($\chi^2 = 0.40$, *df* = 1, $P = 0.53$) (Table 4).

Elk

Elk numbers increased significantly between 2000 (214) and 2004 (416) ($\chi^2 = 14.17$, *df* = 1, $P < 0.01$) and again between 2004 and 2007 (591) ($\chi^2 = 5.90$, *df* = 1, $P = 0.02$) (Table 5). Elk calf/cow ratios increased between 2000 and 2004 ($\chi^2 = 5.06$, *df* = 1, $P = 0.02$) and increased again in 2007 ($\chi^2 = 16.03$, *df* = 1, $P < 0.01$) (Table 4).

Moose

Like the other species, the number of moose increased significantly between 2000 (26) and 2004 (242) ($\chi^2 = 15.69$, *df* = 1, $P < 0.01$) but remained stable between 2004 and 2007 (284) ($\chi^2 = 0.29$, *df* = 1, $P = 0.59$) (Table 5). Moose calf/cow ratios increased between 2000 and 2004 although not significantly ($\chi^2 = 1.88$, *df* = 1, $P = 0.17$) and remained constant between 2004 and 2007 ($\chi^2 < 0.01$, *df* = 1, $P = 0.98$) (Table 4).

Table 1. Survey units sampled and raw counts of mule deer, white-tailed deer, elk and moose in regions 4-07 and 4-08 2000, 2004, 2007.

Survey	Mule Deer			White-tailed Deer			Elk			Moose		
Unit	2000	2004	2007	2000	2004	2007	2000	2004	2007	2000	2004	2007
4-07-01	-	-	-	-	-	-	-	-	-	-	-	-
4-07-02	0	0	-	2	0	-	0	0	-	0	0	-
4-07-03	0	-	-	0	-	-	0	-	-	0	-	-
4-07-04	17	29	4	7	25	16	18	62	54	4	3	2
4-07-05	0	-	-	0	-	-	0	-	-	0	-	-
4-07-06	-	0	0	-	4	1	-	0	3	-	0	0
4-07-07	-	-	0	-	-	2	-	-	3	-	-	0
4-07-08	4	5	30	7	36	8	0	1	0	1	5	9
4-07-09	10	11	3	14	15	3	0	0	9	2	3	7
4-07-11	-	23	8	-	0	11	-	0	5	-	4	12
4-07-12	44	61	47	4	5	3	28	35	52	2	15	15
4-07-13	-	-	-	-	-	-	-	-	-	-	-	-
4-08-01	-	-	-	-	-	-	-	-	-	-	-	-
4-08-02	-	3	9	-	6	13	-	1	1	-	0	5
4-08-03	-	-	-	-	-	-	-	-	-	-	-	-
4-08-04	-	-	-	-	-	-	-	-	-	-	-	-
4-08-05	-	-	-	-	-	-	-	-	-	-	-	-
4-08-06	0	-	-	0	-	-	0	-	-	1	-	-
4-08-07	-	-	-	-	-	-	-	-	-	-	-	-
4-08-08	-	0	-	-	0	-	-	25	-	-	2	-
4-08-09	-	-	-	-	-	-	-	-	-	-	-	-
4-08-11	32	37	57	0	3	9	29	46	69	2	0	5
4-08-13	1	6	64	0	0	18	5	2	47	0	6	14
4-08-14	11	9	20	0	0	0	10	4	28	0	8	5
4-08-15	-	-	-	-	-	-	-	-	-	-	-	-
4-08-16	-	-	0	-	-	16	-	-	30	-	-	2
4-08-17	0	-	-	0	-	-	0	-	-	0	-	-
4-08-18	-	-	-	-	-	-	-	-	-	-	-	-
4-08-19	0	12	9	9	19	24	1	5	26	0	0	1
4-08-20	-	-	-	-	-	-	-	-	-	-	-	-
4-08-21	-	-	-	-	-	-	-	-	-	-	-	-
4-08-22	0	-	-	0	-	-	0	-	-	0	-	-
4-08-23	0	0	1	20	46	9	0	4	0	0	1	6
4-08-24	0	0	2	208	231	43	18	14	11	0	4	1
4-08-25	11	10	2	174	398	93	10	17	8	1	10	12
4-08-26	-	6	10	-	0	0	-	3	7	-	0	0
4-08-27	7	32	16	29	17	11	0	5	4	0	2	3
4-08-28	-	5	2	-	2	0	-	0	0	-	10	13
4-08-29	-	-	-	-	-	-	-	-	-	-	-	-
4-08-30	0	-	-	0	-	-	17	-	-	0	-	-
4-08-31	-	3	0	-	10	11	-	0	0	-	2	0
4-08-32	0	-	-	0	-	-	0	-	-	1	-	-
4-08-33	-	-	-	-	-	-	-	-	-	-	-	-
4-08-34	-	-	-	-	-	-	-	-	-	-	-	-
Total Low	18	44	3	31	9	47	0	0	0	0	0	0
Total Med	15	51	115	9	99	37	0	14	32	10	25	37
Total High	104	157	166	431	709	207	136	210	325	4	50	75

Table 2. Region 4-07 and 4-08 survey units and species specific survey stratifications (low, medium, high) 2000, 2004, 2007.

Survey	Mule Deer			White-tailed Deer			Elk	Moose
Unit	2000	2004	2007	2000	2004	2007	All Years	All Years
4-07-01	L	L	L	L	L	L	L	L
4-07-02	M	L	L	L	L	L	L	L
4-07-03	M	L	L	L	L	L	L	L
4-07-04	H	H	H	M	M	H	H	M
4-07-05	M	L	L	L	L	L	L	L
4-07-06	M	M	L	M	M	M	M	L
4-07-07	L	L	L	L	L	L	M	L
4-07-08	M	M	M	M	M	H	M	H
4-07-09	H	H	H	L	H	H	M	M
4-07-11	L	L	H	M	M	L	M	H
4-07-12	H	H	H	M	M	M	H	H
4-07-13	L	L	L	L	L	L	L	L
4-08-01	L	L	L	L	L	L	L	L
4-08-02	M	M	M	L	L	M	M	M
4-08-03	L	L	L	L	L	L	L	L
4-08-04	L	L	L	L	L	L	L	L
4-08-05	L	L	L	L	L	L	L	L
4-08-06	L	L	L	H	L	L	L	M
4-08-07	L	L	L	L	L	L	L	L
4-08-08	M	M	L	M	M	L	H	M
4-08-09	L	L	L	L	L	L	L	L
4-08-11	H	H	H	L	L	M	H	M
4-08-13	H	M	M	L	L	L	H	H
4-08-14	M	H	H	L	L	L	H	M
4-08-15	L	L	L	L	L	L	L	L
4-08-16	L	L	L	L	L	L	H	M
4-08-17	L	L	L	M	L	L	L	L
4-08-18	L	L	L	L	L	L	L	L
4-08-19	L	L	H	M	M	H	H	M
4-08-20	L	L	L	L	L	L	L	L
4-08-21	L	L	L	L	L	L	L	L
4-08-22	L	L	L	M	L	L	L	L
4-08-23	L	L	L	H	H	H	M	M
4-08-24	L	L	L	H	H	H	H	M
4-08-25	L	H	H	H	H	H	H	H
4-08-26	L	L	M	M	M	L	M	L
4-08-27	M	M	H	H	H	H	M	M
4-08-28	M	M	M	L	H	M	L	H
4-08-29	L	L	L	L	L	L	L	L
4-08-30	L	L	L	M	L	L	H	L
4-08-31	L	L	M	M	M	M	L	M
4-08-32	L	L	L	M	L	L	L	M
4-08-33	L	L	L	L	L	L	L	L
4-08-34	L	L	L	L	L	L	L	L
Total Low	29	31	29	25	29	30	24	24
Total Med	10	7	6	14	9	6	9	14
Total High	5	6	9	5	6	8	11	6

Table 3. Mule deer and white-tailed deer raw counts, sightability corrected population estimates ± 90% confidence interval (standard error$^+$), and mean estimated population growth rates* for regions 4-07 and 4-08 2000, 2004, and 2007.

	White-tailed Deer Raw Count	White-tailed Deer Sightability Corrected (*SE*)	Mule Deer Raw Count	Mule Deer Sightability Corrected (*SE*)
2000	474	946±147 (89)	137	376±151 (91)
Low period annual growth (λ)		*1.09*		*0.98*
High period annual growth (λ)		*1.27*		*1.61*
Mean period annual growth (λ)		*1.18*		*1.28*
2004	817	1837±285 (173)	252	1001±522 (318)
Low period annual growth (λ)		*0.82*		*0.81*
High period annual growth (λ)		*1.12*		*1.47*
Mean period annual growth (λ)		*0.97*		*1.05*
2007	291	1675±492 (299)	285	1161±349 (212)

$^+$ SE = $\sqrt{\sum \sigma}$ * $\lambda = \left(\frac{N_t}{N_0}\right)^{1/t}$

Table 4. Fawns per 100 does of mule deer, and white-tailed deer, and calves per 100 cows of elk and moose in regions 4-07 and 4-08 2000, 2004, and 2007.

Year	Mule Deer (S.E.)	White-tailed Deer (S.E.)	Elk (S.E.)	Moose (S.E.)
2000	40 (16)	59 (12)	17 (3)	0 (0)
2004	105 (78)	136 (52)	26 (3)	86 (63)
2007	50 (36)	61 (38)	51 (5)	88 (44)

Table 5. Moose and elk raw counts, sightability corrected population estimates ± 90% confidence interval (standard error^{+}), and estimated population growth rates* for regions 4-07 and 4-08 2000, 2004, and 2007.

	Moose Raw Count	Moose Sightability Corrected (*SE*)	Elk Raw Count	Elk Sightability Corrected (*SE*)
2000	14	26±11 (7)	136	214±42 (25)
Low period annual growth (λ)		*1.42*		*1.07*
High period annual growth (λ)		*2.16*		*1.30*
Period mean annual growth (λ)		*1.75*		*1.18*
2004	75	242±89 (54)	224	416±78 (47)
Low period annual growth (λ)		*0.87*		*1.01*
High period annual growth (λ)		*1.34*		*1.26*
Period mean annual growth (λ)		*1.05*		*1.12*
2007	112	284±90 (55)	357	591±89 (54)

$^{+}$ SE = $\sqrt{\sum \sigma}$ * $\lambda = \left(\frac{N_t}{N_0}\right)^{1/t}$

DISCUSSION

Within the study area, white-tailed deer are the most common ungulate followed by mule deer, elk, and moose (Figure 3). According to these aerial survey data all four populations of ungulates have increased significantly since 2000. Since the 2004 survey, elk populations appear to have continued to grow while the populations of the other three species have stabilized. The estimated mean population growth rates from 2000 would seem to be within the biological constraints of mule deer, white-tailed deer, and elk. The moose growth rate between 2000 and 2004 of 1.75 appears to be unrealistically high. Maximum rates described by Van Ballenberghe (1983) showed that a female survival rate of 0.95 and calf survival of 0.8 would produce a mean population growth rate of 1.42 (interestingly this is very close to the total mean population growth rate of 1.41 for moose between 2000 and 2007). The moose growth rate between 2000 and 2004 may be biased due to a low count in the first year of the survey. It should be stressed that these surveys were conducted to quantify deer populations, more accurate estimates of moose and elk populations would likely be obtained through species-specific surveys.

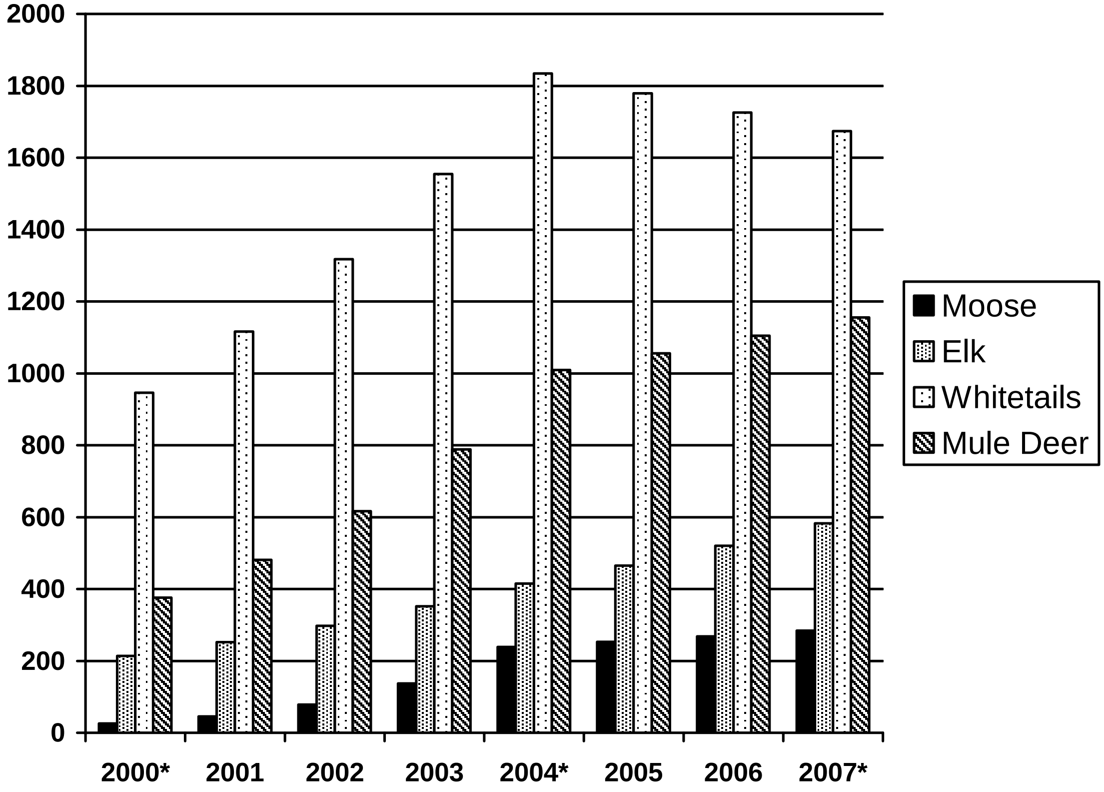
Although the surveys were conducted post antler-drop, the winter model was used to provide fawn/doe ratios that may be corroborative to population growth rates; however these "recruitment" estimates should be interpreted cautiously. Misclassification of antlerless bucks as does will bias fawn/doe ratios lower by over-counting the total number of females. Also, the statistical test used in the comparison between years is conservative and lacks power (Unsworth et al 1994). Large variances associated with low counts of juveniles will further prohibit detection of significant changes.

The fawn/doe and calf/cow ratios support the trends in growth observed in all populations. All ratios seemingly increased between 2000 and 2004 although only differences in elk ratios were statistically significant. Similar to population growth estimates, only elk calf/cow ratios increased significantly between 2004 and 2007. As stated above, statistical tests used here are conservative therefore statistical difference are likely indicative of real population changes.

Cougar populations in the Kootenay region of B.C. reached a peak in 1999 and began to decline in 2000 as a result of increased harvest (Lambert et al. 2006). Robinson (2007) suggested that mule deer and white-tailed deer increases between 2000 and 2004 were evidence that both species were limited by predators and not poor habitat or resource competition. Concomitant increases in populations of other ungulates during the same period may also be a result of relaxed predation by cougars.

It is difficult to predict how ungulate prey species will respond if/when the cougar population recovers. Messier (1994) suggested that, in ungulate/carnivore systems the primary prey will most likely revert to a low density predator/prey equilibrium. He doubted that the prey would escape the so-called predator pit, and remain at a high density, food-regulated equilibrium. Sinclair (1989) and Pech et al. (1995) on the other hand, suggested that prey could escape the predator pit and reach a high density, food-regulated equilibrium. Cougar harvest in the region has declined since 2000 however it is presently unclear if, or to what extent, cougar populations have recovered. The stabilization of mule deer, white-tailed deer, and moose population since 2004 could be either evidence that ungulates have reached a high equilibrium and have escaped the predator pit, or simply that cougar populations have not yet recovered to levels sufficient to again exert a limiting pressure. Continued monitoring of ungulate mortality and populations could provide valuable insight into predator-prey dynamics in large mammal systems.

Figure 3. Estimated population levels of moose, elk, white-tailed deer, and mule deer in MUs 4-07 and 4-08, 2000-2007. Estimates between survey years (*) are based on mean annual growth rates (see Table 3 and Table 5).



The aerial survey program corrects for missed animals using logistic regression models to quantify the probability that an animal or group of animals will be seen given a number of variables (i.e. group size, snow cover, vegetation cover, etc.). These corrected observations are then extrapolated to further account for survey units not flown. These calculations introduce two levels of possible bias into this population estimate: 1) models developed elsewhere are not suitable for use in this study area, and 2) that population densities are not consistent across all units within a single stratum.

The sightability models used by aerial survey were developed in different ecosystems than the Kootenays; the moose model in Wyoming, and the elk and deer models in Idaho. As the habitats of Idaho and the south Kootenay region do not vary greatly, deer and elk population estimates provided these models should be reliable. However due to the difference in habitat between Wyoming and the Kootenays, moose estimates provided here may better reflect trend in population rather than absolute number. For this analysis the models used throughout remained constant from year to year therefore any bias associated with sightability is also constant. The second source of bias mentioned above, that densities are not consistent across all units within a single stratum, is lessened by the increased variance associated with sampling a small number of available units. In essence the model takes into account the greater degree of uncertainty associated with predicting population levels outside of flown units, increasing the difficulty in detecting significant differences between survey years.

In 2007 the raw count of white-tailed deer was dramatically lower than in either previous survey, 291 vs 817 (2004) and 474 (2000), yet the estimated population was not significantly different from 2004 and was significantly higher than 2000. The explanation of the population's stability in the face of this dramatic decline in raw numbers lies in the higher counts in the lowest stratum. Unit stratification, and therefore the number of units in each strata, has varied from year to year as more surveys were conducted (see Methods) and should reduce overall variance as our stratifications become better. The number of whitetails observed in the low stratum in 2007 was the highest observed during the three surveys, 47 vs 9 (2004) and 31(2000), while the total number of survey units in this lowest level was also greater than any other year, 30 vs 29 (2004) and 25 (2000).

Sightability corrected estimates are better than regular index data as they account for variations in animal movements between years and within populations (i.e. differential habitat use from year to year and by differing age and sex classes). The raw counts of whitetails in 2007 may reflect a habitat shift by animals into traditionally lower density areas, in which case the population estimate should be sound. Support for the mean estimate (stable population) is provided by a fawn/doe ratio similar to that of 2000 (table 4) when more intensive population monitoring showed a stable to slightly declining population (Robinson et al. 2002). However, in future surveys FWCP may wish to sample fewer high and medium survey units in exchange for more in the lower stratum to further reduce sampling variance.

LITERATURE CITED

Anderson C. R. and F. G. Lindzey. 1996. Moose sightability model developed from helicopter surveys. Wildlife society bulletin 24:247-259.

Bircher, N., D. Janz, I. Hatter, and R. Forbes. 2001. East Kootenay elk management plan 2000-2004. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch.

Braumandl, T. F. and M. P. Curran 1992. A field guide for site identification for the Nelson Forest Region. B. C. Ministry of Forests, Victoria.

Cliff, G., M. D. Adnerson-Reade, A. P. Aitken, G. E. Charter, and V. M. Peddemors. 2007. Aerial census of whale sharks (*Rhinocondon typus*) on the northern KwaZulu-Natal coast, South Africa. Fisheries Research 84:41-46.

Coupe, R., Stewart, A.C., and Wikeem, B.M. 1991. Englemann spruce – subalpine fir zone. *In* Ecosystems of British Columbia. *Edited by* D. Meidinger and J. Pojar. Special Report Series 6, B.C. Ministry of Forests, Research Branch, Victoria, B.C. pp. 223-236

Crete, M., and C. Daigle. 1999. Management of indigenous North American deer at the end of the 20th century in relation to large predators and primary production. Acta Veterinaria Hungarica 47:1-16.

Cruickshank, H.S. 2004. Prey selection and kill rates of cougars in northeastern Washington. M.S. Thesis. Washington State University. Pullman, WA. USA.

Dalquest, Walter W. 1948. Mammals of Washington. University of Kansas Publications. Museum of Natural History, vol. 2. Kansas, USA.

Halko, R., K. Hebert, and D. Sam. 2000. 1999–2000 East Kootenay moose aerial survey. Unpublished report submitted to British Columbia Ministry of Environment Lands and Parks, Cranbrook, British Columbia, Canada.

Heaven, P. C., M. T. Tinker, and I. Adams. 1999. Columbia Basin Fish and Wildlife Compensation Program: Ungulate Monitoring Plan. Glenside Ecological Services. Canal Flats, B.C.

Ketcheson, M.V., Braumandl, T.F., Meidinger, D., Utzig, G., Demarchi, D.A, and Wikeem, B.M. 1991. Interior cedar – hemlock zone. *In* Ecosystems of British Columbia. *Edited by* D. Meidinger and J. Pojar. Special Report Series 6, B.C. Ministry of Forests, Research Branch, Victoria, B.C. pp. 167-181

Krebs, C.J. 1999. Ecological methodology, Second edition. Harper and Row, Publ., New York. USA.

Lambert, C. S., R. B. Wielgus, H. S. Robinson, D. D. Katnik, H. S. Cruickshank, R. Clarke, and J. Almack. 2006. Cougar population dynamics and viability in the Pacific Northwest. Journal of Wildlife Management 70:246-254.

Messier, F. 1994. Ungulate population models with predation: a case study with the North American moose. Ecology 75:478-488.

Msoffe, F., F. A. Mturi, V. Galanti, W. Tosi, L. A. Wauters, and G. Tosi. 2007. Comparing data of different survey methods for sustainable wildlife management in hunting areas: the case of Tarangire-Manyara ecosystem, northern Tansania. European Journal of Wildlife Research 53:112-124.

Pech, R.P., A.R.E. Sinclair, and A.E. Newsome. 1995. Predation models for primary and secondary prey species. Wildlife Research 22:55-64.

Poole, K. G. 2007. A population review of moose in the Kootenay region. Aurora Wildlife Research, Nelson. B.C. V1L 6K4.

Raedeke Associates, Inc. 1998. Assessment of harvest strategies for Rocky Mountain Elk. Prepared for: B.C. Ministry of Environment, Lands and Parks.

Robinson, H.S., R.B. Wielgus, and J.C. Gwilliam. 2002. Cougar predation and population growth of sympatric mule deer and white-tailed deer. Canadian Journal of Zoology 80:556-568.

Robinson, H. S. 2007. Cougar demographics and resource use in response to mule deer and white-tailed deer densities: a test of the apparent competition hypothesis. Dissertation. Washington State University, Pullman, WA. 99164.

Sauer, J. R. and B. K. Williams. 1989. General procedures for testing hypotheses about survival and recovery rates. Journal of Wildlife Management 53:137-142.

Shackleton, D. 1999. Hoofed mammals of British Columbia. The Mammals of British Columbia, Volume 3, Royal British Columbia Museum. UBC Press, Vancouver, British Columbia.

Sinclair, A.R.E. 1989. Population regulation in animals. Pp. 197-241. In J.M. Cherrett (ed), Ecological Concepts – The Contribution of Ecology to an Understanding of the Natural World. Blackwell Scientific Publications, Oxford UK.

Thompson, I.D., and R.W. Stewart. 1998. Management of moose habitat. Pages 377–401 *in* A.W. Franzmann and C.C. Schwartz, editors. Ecology and management of the North American moose. Smithsonian Institute Press, Washington, D.C., USA.

Udevitz, M. S., B. S. Shults, L. G. Adams, and C. Kleckner. 2006. Wildlife Society Bulletin 34:732-740.

Unsworth, J. W., F. L. Leban, D. J. Leptich, E. Garton, and P. Zager. 1994. Aerial survey: user's manual with practical tips for designing and conducting aerial big game surveys, second edition. Idaho Department of Fish and Game, Boise, Idaho.

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

Williams, B.K., J.D. Nichols, and M.J. Conroy. 2002. Analysis and management of animal populations: modeling, estimation, and decision making. Academic Press, San Diego, CA.

Wilson, S. F. and R. Morley. 2004. East Kootenay elk management plan 2005-2009. Prepared for: B.C. Ministry of Water, Land and Air Protection.