

# AGE, SEX, AND SEASONAL DIFFERENCES OF CARCASS WEIGHTS OF MOOSE FROM THE CENTRAL INTERIOR OF BRITISH COLUMBIA: A COMPARATIVE ANALYSIS

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**ABSTRACT:** Carcass weight (4 quarters without head, hide, lower legs, or internal organs) of moose (*Alces alces*) harvested in 1995-2007 in the Omineca sub-region of the Central Interior of British Columbia, Canada were obtained from meat cutters records submitted to the Conservation Officer Service, Prince George, British Columbia. Mean carcass weight of male calves (<1 year) was  $82 \pm 16$  (SD) kg and was not different ( $P = 0.629$ ) from that of female calves that was  $81 \pm 13$  kg. Mean carcass weight of juvenile bulls (spike/fork antlers) was  $162 \pm 21$  kg. The mean carcass weight ( $249 \pm 37$ ) of adult bulls (larger than spike/fork antlers) was heavier (25%,  $P < 0.001$ ) than that of adult cows ( $199 \pm 29$  kg). Mean carcass weight of adult bulls was heavier (14 kg or 5.9% of carcass weight,  $P = 0.002$ ) in the pre-rut (10-25 September) than post-rut period (16-31 October); a similar change did not occur in juvenile bulls ( $P = 0.244$ ). The mean carcass weights of calves ( $P = 0.651$ ) and adult cows ( $P = 0.142$ ) were not different between the October and late November-early December hunting seasons. Carcass weights and sexual size dimorphism for moose from the Omineca were mostly similar to those from European and North American ranges. We recommend increased collection of biological data at hunter check stations to provide more accurate body weight data and associated relationships.

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**Key words:** *Alces alces*, body mass, carcass, moose, body weight, sexual dimorphism.

Weights of moose (*Alces alces*) have been studied across their ranges in North America (Blood et al. 1967, Schladweiler and Stevens 1973, Peterson 1974, Schwartz et al. 1987, Quinn and Aho 1989, Adams and Pekins 1995, Lynch et al. 1995, review of calf and yearling weights in Broadfoot et al. 1996) and Europe (Sæther 1983, Sæther and Hagenrud 1983, 1985a, b, Sæther and Heim 1993, Ericsson et al. 2002, Solberg et al. 2007). Body size (mass or weight) and proportions change together (Franzmann et al. 1978, Sæther 1983, Bartosiewicz 1987, Wallin et al. 1996, but see Sand et al. 1995), and both are sensitive to the nutritional intake of the individual. Whatever an animal's genetic potential, its

body size is much influenced by its environment (Klein 1964, Geist 1999). Body mass and condition of male moose peak just before the breeding season, whereas female moose reach their maximum weight in early winter (Franzmann et al. 1978, Schwartz et al. 1987, Schwartz 1998). Maximum weight of calves in their first year occurs at about 5 months of age (Franzmann et al. 1978, Schwartz et al. 1987), some of which is lost during their first winter (Schwartz 1998). Female moose attain maximum body weight at 3.5-4.5 years, whereas male moose attain their maximum body weight at 5.5-6.5 years (Sand et al. 1995, Schwartz 1998).

Live weights have been measured by sus-

pending moose in a sling below a tripod (Franzmann et al. 1978, Haigh et al. 1980, Quinn and Aho 1989) or having captive moose stand on a scale (Lankester et al. 1993, Schwartz et al. 1994). Several different measures have been used to describe weights of dead moose. For example, Blood et al. (1967) defined whole weight as the weight immediately after death, not accounting for blood or tissue loss, and they defined carcass weight (or dressed weight) as the weight without viscera, head, lower legs, and hide. Field-dressed weight (hog-dressed weight or eviscerated weight) refers to weight after removal of all viscera (Schladweiler and Stevens 1973, Peterson 1974). For clarity, we use the terms live, whole, carcass, and eviscerated weights.

The purpose of this study was to establish a base-line understanding of carcass weights of hunter-harvested moose (*A. a. andersoni*) from the Omineca sub-region of British Columbia relative to moose throughout their North American and European ranges. Examining records from the Omineca for the period from 1995-2007, we documented the carcass weights and calculated sexual size dimorphism (SSD) specific to calves, juvenile bulls (spike/fork antlers), adult cows (older than calves), and adult bulls (antlers larger than spike/fork). We compared carcass weights of both juvenile bulls and adult bulls before and after the rut. We also compared carcass weights of calves and adult cows harvested throughout October (normal cow/calf season) with those harvested during the last week of November and the first week of December (a special late season that ran from 1977-1997).

### STUDY AREA

The Omineca sub-region as delineated by the British Columbia Ministry of Environment for game management purposes is located in the Central Interior of British Columbia, extending across the province from approximately 52°N, 118°W in the southeast to 57°N, 125°W in the northwest. This region is approxi-

mately 122,500 km<sup>2</sup> in total area representing about 13% of the total land mass of British Columbia (Fig. 1). Rugged mountainous terrain with deeply incised valleys is typical to the north and east of the sub-region (Child 1992). By contrast, the terrain is flat to rolling with hundreds of small lakes and wetlands to the south and west (Heard et al. 1997). The sub-region contains extensive areas of important moose habitat in the sub-boreal ecotype. This ecotype is a comparatively homogeneous unit, occurring on a drumlinized till plateau surrounding periglacial lake deposits, and dissected by many rivers, lakes, and wetlands (Child 1992). The landscape is dominated by coniferous forests of hybrid white spruce (*Picea engelmannii* x *glauca*) and subalpine fir (*Abies lasiocarpa*). Lodgepole pine (*Pinus contorta* var. *latifolia*) and trembling aspen (*Populus tremuloides*) pioneer secondary successional sites (Meidinger & Pojar 1991).

The climate is generally wet and cool, with precipitation evenly distributed throughout the year. The mean annual temperature at Prince George (54°N, 122°W) in the southern portion of the Omineca sub-region is 3.7°C, ranging from a monthly mean minimum of -10.3°C in January to a mean maximum of 15.2°C in July. By contrast, at Fort Saint James (56°N, 124°W) in the western portion, the mean annual temperature is 2.5°C with mean monthly minimum and maximum of -12.2°C in January and 14.8°C in July, respectively. Mean annual precipitation at Prince George is 636 mm with 200 mm of snowfall; at Fort Saint James the mean annual precipitation is 465 mm with 160 mm of snowfall (Environment Canada 2011).

Fires, logging, and forest pathogens have had major impacts on the forest landscapes in the region. Cut blocks created by commercial logging since the 1960s are common (Heard et al. 1997). Forest succession is characterized by an early shrub stage of 10-25 years duration providing important foods for moose such as willow (*Salix* spp.) and paper birch



Fig. 1. The Omineca sub-region (Region 7A) of the British Columbia Ministry of Environment in central British Columbia (reprinted from 2008 British Columbia Hunting and Trapping Regulations and Synopsis).

(*Betula papyrifera*) (Child 1992). An outbreak of mountain pine beetle (*Dendroctonus ponderosae*) has killed pine stands from the mid-1990s to the present (2009) throughout the study area and extensive salvage logging of these stands occurs (Ritchie 2008).

## METHODS

Information on the carcass weights and sex and age class of hunter-harvested moose from 1995-2007 was obtained from meat cutter records on file at the Prince George office of the British Columbia Conservation Officer Service. At weigh-in, carcass submissions were recorded as a whole carcass or portion thereof (i.e.,  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{3}{4}$ , whole carcass). Quantity

of meat submitted was recorded as weight on the hook or weight of deboned meat submitted. For this study, we only used records classified as a whole carcass (all 4 quarters): these were without head, hide, lower legs, or internal organs (dressed carcass as per Blood et al. 1967).

Information on sex and maturity class (calf, juvenile, or adult) was recorded by meat cutters during carcass submissions. The maturity class "calf" indicated moose of either sex, less than 6 months of age with carcass weight <115 kg (Blood et al. 1967, Sæther 1983, Cederlund et al. 1991, Herfindal et al. 2006a, b, but see Tiilikainen 2010) that were harvested by hunters during a general open

season in mid-October. The maturity class juvenile indicated bulls with spike/fork antlers harvested during a general open season (early September-early November). Adult bulls had antlers larger than spike/fork and were harvested during a limited entry season from early September-early November. Adult cows were females older than calves that were harvested during a limited entry season in mid-October. A small number of additional records for adult cows and calves were available from animals harvested during a limited entry season from the last week of November and first week of December in 1995-1997.

We only used individual data that were complete (those reporting date of kill within a legal hunting season, management unit (MU), whole carcass, sex, and maturity class) from records submitted by 5 meat cutter establishments. We reclassified the records of male calves ( $n = 57$ ) weighing  $>115$  kg as juvenile bulls, while juvenile bulls ( $n = 2$ ) weighing  $<115$  kg were reclassified as male calves, and juvenile bulls ( $n = 4$ ) weighing  $>230$  kg were reclassified as adult bulls. Finally, we reclassified juvenile females ( $n = 66$ ), a maturity class for which no season was advertised, as either female "calves" ( $n = 2$ ) with weights  $<115$  kg or female adults ( $n = 64$ ) with weights  $>115$  kg.

Carcass weights were described by mean  $\pm$  standard deviation (SD), range, and sample size. We report these statistics for the harvested sample and for 4 maturity classes: calves, juvenile bulls, adult bulls, and adult cows. Carcass weights for both juvenile and adult bulls harvested during the pre- (10-25 September) and post-rut (16-31 October) periods were compared by  $t$ -test to determine whether either class of bulls lost weight between periods; the rut period (26 September-15 October) was determined from conception dates (British Columbia Ministry of Environment, unpublished data). Carcass weights of both calves and adult females were compared by  $t$ -test between the October and

late November-early December seasons to determine whether their weights changed over the course of the hunting season. Because only a limited number of records were available from the late November-early December seasons in 1995-1997, records from those 3 years were pooled and compared with similarly pooled records from the October season.

Sexual dimorphism of carcass weights of calves and adults was tested using carcass weights of calves and of cows from all seasons, but only carcass weights of adult bulls from the pre-rut period. In each case, equality of variances was tested with Levene's test and then equality of means was compared using independent sample  $t$ -tests for equal or unequal variances as appropriate (Milliken and Johnson 1984). A lack of age information prevented us from identifying all yearlings of either sex. Consequently, adult SSD was calculated as the ratio of mean adult bull carcass weight to mean adult cow carcass weight.

Carcass weights from our study were compared with carcass weights reported in other studies. We assumed carcasses from all studies to be equivalent, even though carcass weight may be affected by loss of blood resulting from bullet wounds (Blood et al. 1967), additional losses following hanging and cooling (2.5% in the first 24 h; Ledger and Smith 1964), trimming of damaged tissues (e.g., blood-shot meat) and fat deposits (e.g., rump fat), as well as the exact location of removal of the head (at the atlas-occipital junction or along the cervical vertebrae) and lower legs prior to butchering. We did not correct for these losses; they may account for some of the differences between the carcass weights reported in this and other studies.

Comparison of live or whole weights reported by others with carcass weights reported in our study required us to convert their measurements to carcass weights. We assumed whole weights of dead moose to be equivalent to live weights. We used the average carcass yield (50% of whole weight,

$n = 35$ ) for moose (*A. a. andersoni*) from Alberta (Blood et al. 1967) to calculate carcass weights from live weights and whole weights given in a number of studies throughout North America for *A. a. andersoni* (Crichton 1980, Haigh et al. 1980, Lynch et al. 1995), *A. a. americana* (Quinn and Aho 1989, Addison et al. 1994), and *A. a. gigas* (Franzmann et al. 1978, Schwartz et al. 1994). We assumed the carcass yield reported by Blood et al. (1967) was applicable to all North American moose, but this probably requires substantiation. We did not use the carcass yields available in Sand et al. (1995), Wallin et al. (1996), or Solberg et al. (2007) because they were developed from moose (*A. a. alces*) in Sweden and Norway and we considered them less applicable to our study.

Comparison of eviscerated weights with carcass weights also required a conversion. Visceral weight reportedly varies with body weight, age, volume of food in the digestive tract, and the amount of visceral fat (Peterson 1974). First, we converted eviscerated weights to “whole” weights. Eviscerated and whole weights have been reported for *A. a. andersoni* (Crichton 1979, 1980) and *A. a. americana* (Peterson 1974, Broadfoot et al. 1996). We used the average visceral weight reported by Crichton (1979, 1980) for calves (38%,  $n = 4$ ), yearlings (31%,  $n = 4$ ), and adults (31%,  $n = 28$ ) to convert reported eviscerated weights of *A. a. andersoni* to whole weights. These visceral weights were also used to convert eviscerated weights of *A. a. shirasi* to whole weights. Similarly, to convert eviscerated weights of calf and yearling *A. a. americana* to whole weights, we used the average eviscerated weight (68% of live weight) for captive 11-month-old moose ( $n = 12$ ) from Broadfoot et al. (1996). The average visceral weight (28%,  $n = 9$ ) from Peterson (1974) was used to convert eviscerated weights (72% of live weight) to whole weights of adult moose. Second, we converted these “whole” weights to carcass weights using the conversion fac-

tor from Blood et al. (1967). The conversion factors for eviscerated weights reported in Peterson (1974) and Broadfoot et al. (1996) were determined for *A. a. americana*, while both the visceral weights reported by Crichton (1979, 1980) and the carcass yields reported by Blood et al. (1967) were based on measurements of *A. a. andersoni*; it is unknown whether these conversion factors are applicable to other subspecies of moose.

We calculated SSD for moose from various North American and European ranges by dividing reported mean weight of males by reported mean weight of females for calves, yearlings, and adults. Statistical procedures were performed with PASW's SPSS version 18. Significance of all statistical tests was set *a priori* at  $P = 0.05$ .

## RESULTS

### Carcass Weights

Carcass weights derived for 2,050 moose ranged from 36-375 kg (Fig. 1) with a mean weight of  $188 \pm 61$  (SD) kg. The mean carcass weight of all calves ( $n = 236$ ) was  $81 \pm 15$  kg (range = 36-114 kg); the mean weight of males ( $n = 143$ ) was  $82 \pm 16$  kg (range = 36-114 kg) and that of females ( $n = 93$ ),  $81 \pm 13$  kg (range = 4-110 kg). The mean carcass weight of juvenile bulls ( $n = 844$ ) was  $162 \pm 21$  kg (range = 117-214 kg). The mean carcass weight was  $249 \pm 37$  kg (range = 135-375 kg) for adult males ( $n = 747$ ), and  $199 \pm 29$  kg (range = 118-281 kg) for adult females ( $n = 223$ ) (Fig. 2a, 2b).

### In-Season Changes of Carcass Weight

Adult bulls were heavier ( $t = 3.241$ ,  $df = 181$ ,  $P = 0.001$ ) in the pre-rut ( $\bar{x} = 251 \pm 39$  kg,  $n = 204$ ) than post-rut period ( $\bar{x} = 237 \pm 30$  kg,  $n = 79$ ). Mean weight loss for adult bulls was 14 kg, or 5.6% of the mean weight at pre-rut. In contrast, weights of juvenile bulls were not different ( $t = 1.168$ ,  $df = 375$ ,  $P = 0.244$ ) between the pre-rut ( $\bar{x} = 162 \pm 20$  kg,  $n = 241$ ) and post-rut periods ( $\bar{x} = 160 \pm$

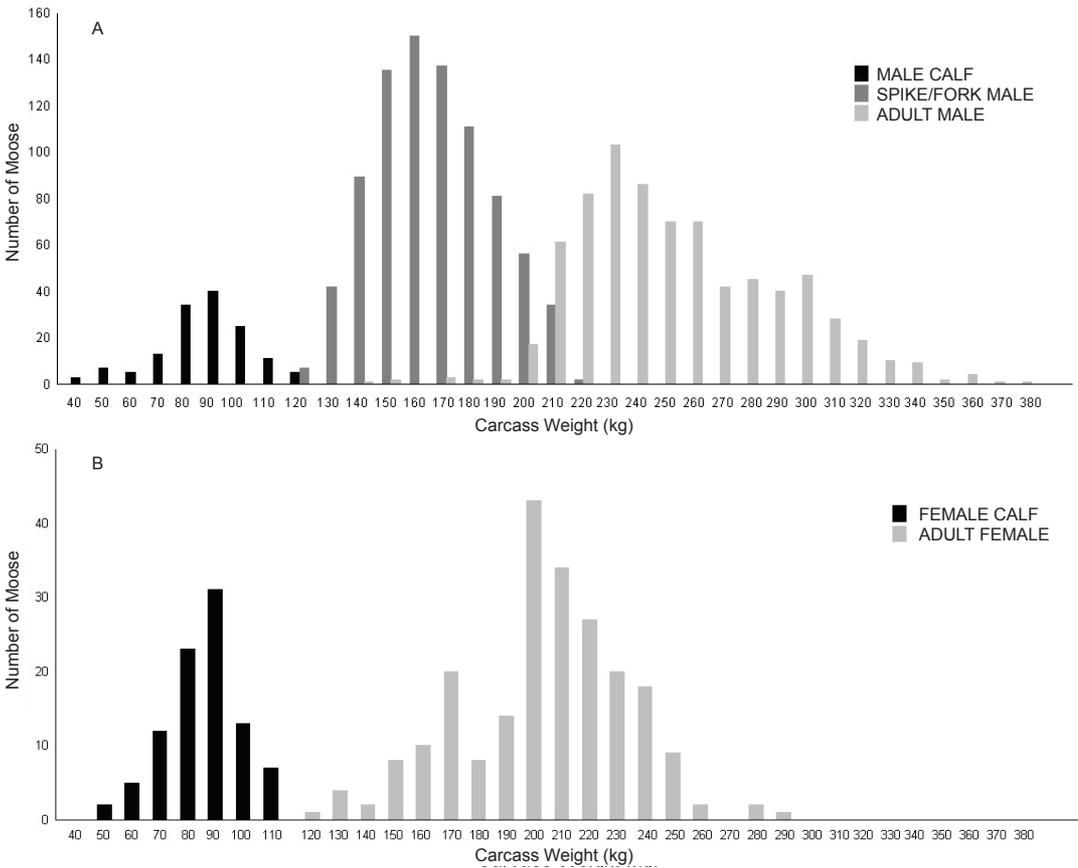


Fig. 2. Carcass weights of moose harvested in the Omineca region of British Columbia, 1995-2007. Weights (nearest 10 kg) and sample size are provided for 3 age classes of males (2a.) and 2 age classes of females (2b.).

21 kg, n = 136). Carcass weights of calves in October ( $x = 79 \pm 16$  kg, n = 87) were not different ( $t = 0.454$ ,  $df = 89$ ,  $P = 0.651$ ) from weights of a small sample of calves in late November-early December ( $x = 75 \pm 21$  kg, n = 4). Similarly, carcass weights of adult cows in October ( $x = 190 \pm 30$  kg, n = 48) were not different ( $t = -1.488$ ,  $df = 60$ ,  $P = 0.142$ ) from weights in late November-early December ( $x = 203 \pm 27$  kg, n = 14).

**Sexual Size Dimorphism**

The SSD for calves was 1.01 (Table 1) and the mean carcass weight of male calves was not different from that of female calves ( $t = 0.484$ ,  $df = 225$ ,  $P = 0.629$ ). In contrast, the SSD for adults was 1.25 with the mean carcass weight of adult males heavier than

that of adult females ( $t = 15.464$ ,  $df = 377$ ,  $P < 0.001$ ). We were unable to calculate the SSD for yearlings.

**Carcass Weights and SSD in North America and Europe**

Carcass weights of moose of all age and sex classes in the Omineca had more variation than in most other studies, with heavier maximum and lighter minimum carcass weights. Mean weights of moose of all age and sex classes from the Omineca were generally heavier than reported for moose elsewhere (Tables 2-4). Weights of male and female calves from the Omineca were not different (i.e., SSD = 1). Similarly, equivalent weights were reported for male and female calves in central Alberta (Blood et al. 1967). In

Table 1. Sexual size dimorphism (SSD) values calculated for calf, yearling, and adult moose of 5 subspecies found in North America and Europe. The SSD for each category was calculated as mean weight of males/mean weight of females; calf = 0.5 years, yearling = 1.5 years, adult = 2.5+ years; “-“ indicates no data available. Whole weight is for the entire animal immediately after death before evisceration (Blood et al. 1967); eviscerated (field dressed) weight is for an animal with all viscera removed (Schladweiler and Stevens 1973); carcass weight is for animals lacking viscera, head, lower legs, and hide (Blood et al. 1967).

Subspecies	Calf	Yearling	Adult	Weight Category	Source, location, time of collection
<i>andersoni</i>	1.01	-	1.25	Carcass	Present study, British Columbia, Sept.-Dec.
<i>andersoni</i>	1.01	0.94	1.02	Carcass	Blood et al. 1967, Alberta, 24 Nov.-6 Jan.
<i>andersoni</i>	-	-	1.25	Live	Haigh et al. 1980, Alberta & Saskatchewan, Oct.-Feb.
<i>andersoni</i>	0.68	-	1.14	Whole and eviscerated	Crichton 1979, 1980, Manitoba, Sept.-Dec.
<i>andersoni</i>	1.16	1.17	1.11	Whole	Lynch et al. 1995, Alberta, 1-12 Dec.
<i>americana</i>	0.9	1.1	1.17	Eviscerated	Timmermann 1972, Ontario, Autumn
<i>americana</i>	1.1	1	1.25	Eviscerated	Peterson 1974, Quebec, mid Sept-late Oct
<i>americana</i>	1.06	0.99	1.37	Eviscerated	Dunn and Morris 1981, Maine, 22-27 Sept.
<i>americana</i>	-	1.18	1.04	Live and whole	Quinn and Aho 1989, Ontario, Winter and summer
<i>americana</i>	1.13	-	-	Live	Addison et al. 1994, Ontario, mid Oct. (151 days)
<i>americana</i>	1.04	0.92	1.25	Eviscerated	Adams and Pekins 1995, New Hampshire, Autumn
<i>gigas</i>	-	-	1.18	Live and whole	Franzmann et al. 1978, Alaska, inside the MRC, unspecified
<i>gigas</i>	-	-	1.14	Live and whole	Franzmann et al. 1978, Alaska, outside the MRC, unspecified
<i>shirasi</i>	1.18	1.05	1.18	Eviscerated	Schladweiler and Stevens 1973, Montana, Oct.-Nov.
<i>alces</i>	1.06	1.05	1.23	Carcass	Sæther 1983, Sweden, 10 Sept.-20 Oct.
<i>alces</i>	1.05	-	-	Carcass	Cederlund et al. 1991, Norway, Oct.-Nov.
<i>alces</i>	1.07	1.07	-	Carcass	Lykke 2005, Norway, Sept.-Nov.
<i>alces</i>	1.06	1.08	-	Carcass	Herfindal et al. 2006a, Norway, Sept.-Oct.
<i>alces</i>	1.06	1.06	-	Carcass	Herfindal et al. 2006b, Norway, adjusted to 1 Oct.
<i>alces</i>	1.05	1	1.17	Carcass	Tiilikainen 2010, Finland, adjusted to 15 Oct.
<i>alces</i>	1.06	-	-	Carcass	Tiilikainen 2010, Norway, adjusted to 15 Oct.

contrast, SSD of calves favoured males in 13 of 17 studies from various North American and European jurisdictions, although SSD of calves favoured females in only 2 areas in North America (Table 1). Although we were unable to calculate SSD for yearlings in the Omineca, SSD favoured males in 8 of 13 studies across North America and Europe (Table 1).

No SSD was calculated for yearlings from 3 studies, and 2 studies found that SSD favoured female yearlings (Table 1). In adult moose, SSD favoured males by 25% in the Omineca. Adult male moose were heavier than adult female moose in 13 of 15 studies across North America and Europe, whereas no SSD was found in the other 2 studies (Table 1).

## DISCUSSION

### Carcass Weights

The trimodal distribution of carcass weights of males (Fig. 2a) and the bimodal distribution for females (Fig. 2b) likely reflects the harvest regime, with open seasons for calves of either sex and juvenile (spike/fork antlers) bulls complimented by restricted (limited entry) seasons for older bulls and cows; calves were <6 months old when harvested in October. Previous studies (Hatter 1993, Child et al. 2010a, b) showed that spike/fork antlered moose from the Omineca were principally yearlings (1.5 yr), and bulls with larger than spike/fork antlers comprised 55% of yearlings and more than 98% of bull moose  $\geq 2.5$  years old. Thus, for comparative purposes, we considered juvenile bulls (those with spike/fork antlers) from the Omineca to be yearlings (1.5 yr) and adult bulls (those with antlers larger than spike/fork) as  $\geq 2.5$  years old.

Lifelong growth patterns, monthly changes in body condition, and different methods of estimating weight of individual moose, coupled with population age and sex structure may introduce sources of bias that make it difficult to compare weights of moose between populations or different geographical areas (Franzmann et al. 1978). It is possible that the carcass weight statistics of both yearling and adult males were biased because we were unable to determine if yearlings with spike/fork antlers were of similar weight as yearlings with larger antlers. Specific aging through measurement of incisor teeth would address this potential bias. Consequently, caution should be exercised when comparing our results with other studies.

The carcass weights of moose of all age and sex classes from the Omineca had more variation than in most other studies (Table 2-4). This variation may reflect some combination of the large number of carcasses sampled ( $n = 2050$ ), the length of the study (15 yr), the

wide geographic area (53° N 122° W to 55° N 124° W), the range of habitat types (Child et al. 2010a, b) from low elevation riparian (700 m) to montane (2000 m), and differences in local densities and sex ratios (Heard et al. 1999a, b, Walker et al. 2006a, b). The comparatively heavy mean and maximum weights for moose of all age categories from the Omineca are suggestive of a population below carrying capacity, not limited by per capita food availability (Heard et al. 1997).

Weights of moose vary with climate (Sæther 1985, Solberg et al. 2004), latitude (Sæther 1985, Sand et al. 1995), altitude (Hjeljord and Histøl 1999, Ericsson et al. 2002), habitat quality (Sæther and Heim 1993, Selas et al. 2003, Herfindal et al. 2006a, b), density of moose (Sand et al. 1996, Hjeljord and Histøl 1999, Ferguson et al. 2000, Solberg et al. 2004), and population sex ratio (Garel et al. 2006). Also, winter ticks (*Dermacentor albipictus*) occur in north central British Columbia (Samuel 2004) and high density of winter ticks can cause reduction in weight of moose (Glines and Samuel 1989, Addison et al. 1994). The effect of each of these factors on carcass weight of moose from the Omineca is unknown.

The minimum weights of calves from the Omineca were generally lower than reported elsewhere (Tables 2-4). These minimum weights were similar to those from an extensive study in Finland and Norway (Tiilikainen 2010; Table 2), and weights of captive 3<sup>rd</sup> estrous calves in Alaska (Schwartz et al. 1994). The mean and maximum weights of calves from the Omineca were generally higher than reported elsewhere during similar time periods (Table 2-4). Interestingly, mean and maximum weights of captive 1<sup>st</sup> and 2<sup>nd</sup> estrous moose calves on a high quality diet (Schwartz et al. 1994) were similar to the weights we report. The mean carcass weights of calves reported by Blood et al. (1967; Table 2), Timmerman (1972; Table 4), and Lynch et al. (1995; Table 3) were heavier than those from the Omineca.

Table 2. Comparison of carcass weights (kg;  $\bar{x} \pm SD$ , n, [range]) of moose from the Omineca region of British Columbia with other jurisdictions. Carcass weight (dressed carcass) refers to animals lacking viscera, head, feet, and hide (Blood et al. 1967). The three age classes were calf (0.5 years), yearling (1.5 years), and adult (2.5+ years). Data sources were this study (1), Blood et al. 1967 (2), Saether 1983 (3), Cederlund et al. 1991 (4), Lykke 2005 (5), Herfindal et al. 2006a (6), Herfindal et al. 2006b (7), and Tiilikainen 2010 (8).

Subspecies	Calf		Yearling		Adult		Source, location, time
	Male	Female	Male	Female	Male	Female	
<i>andersoni</i>	82 ± 2, 143 [36-114]	81 ± 12, 93 [41-110]	162 ± 21, 844 [117-214]	- <sup>1</sup>	249 ± 37, 747 [135-375]	199 ± 29, 223 [118-281]	1, BC, Sept. 10 - Dec. 5
<i>andersoni</i>	95 ± -, 21 [70-110]	94 ± -, 27 [70-112]	153 ± -, 34 [115-193]	162 ± -, 28 [128-186]	205 ± -, 72 [151-258]	201 ± -, 79 [144-241]	2, Alberta, 24 Nov. - 6 Jan.
<i>alces</i>	71 ± 14, 63 [-]	67 ± 13, 53 [-]	152 ± 20, 211 [-]	145 ± 18, 123 [-]	222 ± 39, 681 [-]	181 ± 46, 380 [-]	3, Norway, 10 Sept. - 20 Oct.
<i>alces</i>	70 ± -, 161 [32-93]	67 ± -, 172 [32-93]	- -	- -	- -	- -	4, Sweden, Oct. - Nov.
<i>alces</i>	63 ± -, 511 [-]	59 ± -, 415 [-]	129 ± -, 461 [-]	121 ± -, 250 [-]	- -	- -	5, Norway, Sept. - Nov.
<i>alces</i>	67 ± 6, ? [-]	63 ± 6, ? [-]	140 ± 11, ? [-]	130 ± 9, ? [-]	- -	- -	6, Norway, Sept. - Oct.
<i>alces</i>	66 ± 13, 8268 [-]	62 ± 12, 7680 [-]	139 ± 20, 8629 [-]	131 ± 20, 5483 -	- -	- -	7, Norway, adjusted 1 Oct.
<i>alces</i>	67 ± 7, 489 [44-96]	63 ± 7, 488 [28-91]	- -	- -	- -	- -	8, Norway, adjusted 15 Oct.
<i>alces</i>	81 ± 7, 4264 [25-120]	77 ± 7, 4245 [40-107]	152 ± 19, 1639 [-]	151 ± 19, 982 [-]	227 ± 28, 374 [-]	188 ± 22, 198 [-]	8, Finland, adjusted 15 Oct.

<sup>1</sup> “-“ indicates no data available.

However, Blood et al. (1967) and Lynch et al. (1995) measured calves harvested later in December and January when heavier weights are expected due to continued growth into early winter (Schwartz 1998). The weights reported by Timmermann (1972) from calves harvested in September may reflect high quality habitat resulting from scattered logging for pulpwood production.

The minimum carcass weight of yearling males was generally lower, whereas both maximum and mean weights were generally higher than reported elsewhere (Tables 2-4). These findings were only for yearling bulls with spike/fork antlers and did not include yearlings with larger antlers. If larger antlers

are indicative of heavier bodies (Stewart et al. 2000), the mean and maximum carcass weights we report are presumably conservative; inclusion of yearlings with larger antlers might elevate our mean yearling weight to that of Timmermann (1972).

Carcass weights of both adult male and female moose included a lighter minimum as well as heavier maximum than reported elsewhere (Tables 2-4). The lighter minimum weight likely reflects the inclusion of yearlings in our sample of adult moose. In contrast, the maximum weights and mean weights that we report for both males and females are heavier than reported elsewhere, despite the inclusion of yearlings in both categories. It seems

Table 3. Carcass weights (kg;  $\bar{x} \pm SD$ , n, [range]) of moose calculated from live weights or whole carcass weights from North America. Reported live weights and whole weights were converted to carcass weights using the conversion of carcass weight = 50% of whole weight where whole weight represents the entire animal immediately after death, before evisceration (Blood et al. 1967). The three age classes were calf (0.5 years), yearling (1.5 years), and adult (2.5+ years). Data sources were Haigh et al. 1980 (9), Crichton 1979, 1980 (10), Addison et al. 1994 (11), Lynch et al. 1995 (12), Quinn and Aho 1989 (13), Franzmann et al. 1978 (14), and Schwartz et al. 1994 (15).

Subspecies	Calf		Yearling		Adult		Source, location, time
	Male	Female	Male	Female	Male	Female	
<i>andersoni</i>	- <sup>1</sup>	-	-	-	264 ± -, 6 [238-285]	211 ± -, 12 [163-258]	9, Alta. and Sask., Oct. - Feb.
<i>andersoni</i>	72 ± 30, 2 [51-93]	107 ± -, 1 [-]	146 ± 7, 3 [-]	-	225 ± 23, 12 [190-240]	197 ± 198, 9 [163-230]	10, Manitoba, 17 Sept. - 15 Dec.
<i>americana</i>	72 ± 8, 8 [-]	64 ± 3, 10 [-]	-	-	-	-	11, Ontario, mid Oct. (151 days)
<i>andersoni</i>	99 ± -, 13 [75-114]	85 ± -, 12 [66-114]	163 ± -, 6 [141-182]	139 ± -, 8 [89-166]	221 ± -, 40 [178-289]	200 ± -, 46 [136-261]	12, Alberta, 1-12 Dec.
<i>americana</i>	-	-	145 ± -, 4 [115-180]	123 ± -, 8 [100-165]	227 ± -, 29 [130-271]	218 ± -, 45 [155-265]	13, Ontario, winter and summer
<i>gigas</i>	-	-	-	-	201 ± -, 21 [-]	170 ± -, 81 [-]	14, Alaska inside MRC, unspecified
<i>gigas</i>	-	-	-	-	227 ± -, 5 [-]	200 ± -, 66 [-]	14, Alaska outside MRC, unspecified
<i>gigas</i>	85 ± 15, 12 [-]	-	166 ± 29, 8 [-]	-	-	-	15, Alaska 1 <sup>st</sup> estrous, Oct.
<i>gigas</i>	70 ± 15, 12 [-]	-	161 ± 22, 7 [-]	-	-	-	15, Alaska 2 <sup>nd</sup> estrous, Oct.
<i>gigas</i>	52 ± 9, 3 [-]	-	-	-	-	-	15, Alaska 3 <sup>rd</sup> estrous, Oct.

<sup>1</sup> “-” indicates no data available.

reasonable to speculate that the mean weights for adults would have been heavier had we identified and corrected for yearlings.

### In-Season Changes of Carcass Weights

Weight loss of bull moose over the course of the breeding season has been widely reported (Franzmann et al. 1978, Schwartz et al. 1987, Miquelle 1990, Mysterud et al. 2005) and has been used as a measure of reproductive effort (Mysterud et al. 2005). Yearling males lost little weight during the rut, while weight loss of adults ( $\geq 2$  years old) increased with

advancing age, but did not vary with either sex ratio or population density (Mysterud et al. 2005). Adults are involved in the majority of rutting behaviours including fighting, scent-urination, mounting, and copulation (Miquelle 1990, 1991, Van Ballenberghe and Miquelle 1993), fast for about 18 days (Schwartz et al. 1987, Miquelle 1990), and lose large amounts of body fat (Schwartz and Renecker 1998); their younger counterparts rarely fast, yet feed at reduced rates (Miquelle 1990, Mysterud et al. 2005). Lipid mobilization occurs simultaneously in the carcass

Table 4. Carcass weights (kg;  $\bar{x} \pm SD$ , n, [range]) of moose from across North America as calculated by converting eviscerated weights to carcass weights; eviscerated (field dressed) weight is for an animal with all viscera removed (Schladweiler and Stevens 1973). Eviscerated weights of calves and yearlings were converted to whole weights using 32% visceral weight (Broadfoot et al. 1996), and eviscerated weights of adults were converted using 28% visceral weight (Peterson 1974); whole weights were then converted to carcass weights using 50% carcass weight (Blood et al. 1967). The three age classes were calf (0.5 years), yearling (1.5 years), and adult (2.5+ years). Data sources were Timmermann 1972 (16), Schladweiler and Stevens 1973 (17), Peterson 1974 (18), Crichton 1980 (19), Dunn and Morris 1981 (20), Lankester et al. 1993 (21), and Adams and Pekins 1995 (22).

Subspecies	Calf		Yearling		Adult		Source, location, time
	Male	Female	Male	Female	Male	Female	
<i>americana</i>	103 $\pm$ -, 7 [80-125]	115 $\pm$ -, 3 [102-137]	187 $\pm$ -, 19 [147-247]	170 $\pm$ -, 7 [157-200]	248 $\pm$ -, 26 [178-331]	212 $\pm$ -, 8 [173-255]	16, Ontario, Autumn
<i>shirasi</i>	73 $\pm$ -, 9 [60-85]	62 $\pm$ -, 14 [40-75]	126 $\pm$ -, 28 [92-153]	120 $\pm$ -, 15 [93-137]	173 $\pm$ -, 97 [106-265]	147 $\pm$ -, 70 [96-230]	17, Montana, Oct. - Nov.
<i>americana</i>	88 $\pm$ -, 19 [-]	80 $\pm$ -, 26 [-]	150 $\pm$ -, 51 [-]	150 $\pm$ -, 34 [-]	228 $\pm$ -, 300 [-]	182 $\pm$ -, 194 [-]	18, Quebec, mid Sept. - late Oct.
<i>andersoni</i>	- <sup>1</sup>	-	151 $\pm$ 8, 4 [-]	120 $\pm$ 0, 2 [120-120]	-	-	19, Manitoba, 17 Sept. - 15 Dec.
<i>americana</i>	85 $\pm$ -, 15 [-]	79 $\pm$ -, 20 [-]	150 $\pm$ -, 48 [-]	151 $\pm$ -, 21 [-]	247 $\pm$ -, 342 [-]	180 $\pm$ -, 123 [-]	20, Maine, 22-27 Sept.
<i>americana</i>	78 $\pm$ 3, 5 [-]	-	-	-	-	-	21, Ontario, mid-Oct. (week 24)
<i>americana</i>	82 $\pm$ 14, 23 [-]	79 $\pm$ 17, 23 [-]	146 $\pm$ 30, 139 [-]	159 $\pm$ 24, 65 [-]	222 $\pm$ -, 476 [-]	178 $\pm$ -, 181 [-]	22, New Hampshire, Autumn
<i>americana</i>	-	-	156 $\pm$ -, 450 [-]	-	223 $\pm$ -, 2521 [-]	-	22, Maine, Autumn

<sup>1</sup> “-” indicates no data available.

(subcutaneous fat, intramuscular fat, and bone marrow) and visceral deposits (Stephenson et al. 1993, 1998).

Weight loss in captive bulls (n = 3) in Alaska increased from 12% of pre-rut body weight at age 2.5 years to 18-19% at age 4.5-5.5 years (Franzmann et al. 1978, Schwartz 1998). By comparison, maximum weight loss of harvested male moose (n=9,949) in Norway averaged 9-11% for bulls 6-12 years of age in several hunted populations (Myserud et al. 2005). Weight changes of carcasses should be considered conservative since they reflect loss of carcass fat but not loss of visceral fat; weight loss in live moose is larger because it reflects loss of both.

The average carcass weight for adult bulls declined significantly between the pre- and post-rut periods, with losses averaging 5.6%. This value is lower than reported elsewhere (Franzmann et al. 1978, Schwartz 1998, Myserud et al. 2005) and may indicate lower levels of rutting activity by adult bulls in our study area, or that yearlings with antlers larger than spike/fork were in the adult segment. Our lack of precision in estimating age prevented calculation of age-specific weight losses; subsequent comparison with data of Myserud et al. (2005) was also precluded.

It is unknown to what extent yearling bulls participate in the rut in the Omineca. Yearling males generally invest in growth

rather than reproductive effort, and lose less weight than older bulls; their weight loss is not influenced by sex ratio, but declines with increasing population density (Mysterud et al. 2005). We found that pre- and post-rut carcass weights were not different for spike/fork bulls, suggesting minimal involvement in the rut by these bulls (Child et al. 2010a, b).

Calves achieve maximum body size at or just after the rut, while cows continue to gain weight until early winter (Schwartz 1998, Cederlund et al. 1991). We found that carcass weights of calves and adult cows from the Omineca did not change between the October and late November-early December seasons; however, these findings were based on only 4 calves and 14 adult cows from the late season, and additional data are necessary to substantiate this finding.

### Sexual Size Dimorphism

Male moose at all stages of life are generally heavier (Franzmann et al. 1978, Schwartz et al. 1987, Adams and Pekins 1995, Lynch et al. 1995, Schwartz 1998, Loison et al. 1999, Mysterud 2000) and grow faster and for several more years than females (Schwartz 1998, Garel et al. 2006, Tiilikainen 2010). As a result, SSD favours males, increases with age (Geist 1998), and varies with adult sex ratio and length of growing season (Garel et al. 2006), as well as location (Tiilikainen 2010).

Male calves were heavier than female calves in 13 of 17 studies (Tables 2-4) from across North America and Europe, but the difference was not pronounced. In some European studies with large sample sizes ( $n > 500$ ), the SSD of calves favoured males and ranged from 1.04-1.07 (Table 1); however, we documented no SSD for calves from the Omineca and Blood et al. (1967) found no SSD for calves in central Alberta. No difference in weight was found (thus,  $SSD = 1.00$ ) in wild male and female calves in Alaska (Franzmann et al. 1978), or captive moose calves in Alaska (Schwartz et al. 1994) and Ontario (Lankester

et al. 1993). The only studies indicating SSD favouring female calves were based on sample sizes of 10 (Timmermann 1972) and 3 animals (Crichton 1979, 1980).

The differences in body size of yearlings (Tables 2-4) were similar to those of calves; SSD for yearlings favoured males in 8 of 13 studies in North America and Europe (Table 1). The SSD of yearlings in studies with large sample sizes ranged from 1.05-1.08 (Table 1). No SSD was calculated for yearlings from Quebec (Peterson 1974), Maine (Dunn and Morris 1981), or Finland (Tiilikainen 2010). Similarly, no SSD in yearling moose from Alaska was reported by Franzmann et al. (1978), but SSD of yearlings favoured females in Alberta (Blood et al. 1967) and New Hampshire (Adams and Pekins 1995).

Size differences favored males by an average of 24% for Norwegian moose. These SSDs were larger in areas of Norway with short, intense growing seasons that may provide very high forage quality (Garel et al. 2006). By contrast, SSDs were smaller in populations with an adult sex ratio biased to females (Solberg and Sæther 1994, Garel et al. 2006) which may reflect males diverting resources from growth to reproduction (Stearns 1992 in Milner et al. 2007), or an altered age distribution of males from harvest practices. In adult moose, SSD favoured males in 13 of 15 studies in North America and Europe (Table 4). The largest SSD (1.37, Table 4) we calculated was from weights of moose harvested 22-27 September, 1980 from a Maine population with a balanced sex ratio, an older age structure, and males in peak condition following a 45 year hunting closure (Dunn and Morris 1981); most SSD of adults were 1.15-1.25 (Table 4). The minimal SSD (1.02) in adult moose from Alberta (Blood et al. 1967) was attributed to the reduced condition of bulls harvested after the rut, as was the SSD (1.04) in Ontario (Quinn and Aho 1989) that was based on weights collected during summer and winter. No records were found indicating

SSD favouring adult females.

We found that adult bull moose were, on average, 25% heavier (SSD = 1.25) than adult cow moose, which is higher than in most jurisdictions (Table 4). Our value likely represents a maximum for this population as it was calculated with the presumed annual maximum weight of bulls when in prime condition at pre-rut (Schwartz 1998). However, potential bias in these data exists since the mean weight for adult males includes some yearlings (antlers larger than spike/fork), and the mean weight for adult females includes all female yearlings. Again, more accurate age information would better clarify differences. Also, the relationships between SSD and both density and sex ratio should be investigated since the density and sex ratios of moose varied within the study area (Heard et al. 1999a, b, Walker et al. 2006a, b).

### Record Reliability and Data Quality

Our examination of the butcher records revealed some obvious confusion with terminology for recording age categories, especially the terms “juvenile” and, to a lesser extent, “calf.” The records used “juvenile” to indicate a spike/fork antlered bull, whereas the hunting regulations currently advertise open seasons for spike/fork bulls, but have historically used either spike/fork or immature bull. Calf seasons, on the other hand, are advertised in mid-October for animals 6 months of age or younger. At this time, calf carcasses reportedly weigh <115 kg (Blood et al. 1967, Sæther 1983, Cederlund et al. 1991, Herfindal et al. 2006a, b, but see Tiilikainen 2010); therefore, weights of male calves >115 kg, particularly those recorded in September and November, suggest that some (~57 of 844) spike/fork (immature) bulls are probably recorded mistakenly as calves.

Interestingly, no records for female calves >115 kg were found, and only 2 of 66 records for juvenile females had a carcass <115 kg. Together, these observations suggest that hunt-

ers and/or butchers were accurately identifying female calves; 64 of 66 records for juvenile females were for animals weighing 115-210 kg. The weight distribution for these 64 juvenile females >115 kg parallels that for juvenile males (spike/fork antlers) in our study (117-214 kg), suggesting that hunters and/or butchers were correctly identifying yearling females and recording them as juveniles.

### CONCLUSIONS

Carcass weights of moose from the Omineca region in north central British Columbia were similar to carcass weights of moose reported for other jurisdictions. Our results were also similar to carcass weights we calculated by converting live weights, total weights, and eviscerated weights, even though we used published conversion factors based on small samples from a variety of locations and subspecies. Further research is needed to document the range of conversion factors between carcass weights, eviscerated weights, total weights, and live weights and the applicability of these conversion factors to different subspecies of moose.

Our data represent body mass measurements of a small portion (approximately 10%) of hunter-harvested moose taken in the study area from 1995-2007. Additional records would be beneficial and this could be achieved in two ways. First, the accuracy and reliability of the data obtained from the meat cutter records could be improved by employing consistent terminology in both the Hunting Regulations Synopsis and in butcher records. We recommend retaining the terms “calf”, “spike/fork” and “adult” as currently used in the Hunting Regulations Synopsis, while dropping the terms “immature” and “juvenile” on the butcher forms. Second, the use of in-season check stops would facilitate collection of additional carcass weights of harvested moose and provide a larger sample for analysis, particularly for calves, since butchers may preferentially accept adults

for butchering. In-season check stops could also provide the opportunity to collect related information including specific kill location coordinates (UTM or latitude and longitude), incisor teeth for aging, and tissue samples for analysis (e.g., DNA, toxins).

Despite the short comings of the data set, our findings suggest that butcher records have value because carcass weights were similar to weight records obtained with other methods. Without substantially increasing effort at hunter check stations, such records presumably represent the best high volume data available to managers. These data are important as baselines and in developing relationships between animal condition as measured by body mass (Adams and Pekins 1995, *sensu* Hjeljord and Histol 1999) to climate change (Sæther 1985, Solberg et al. 2004), habitat relationships (Sæther and Heim 1993, Hjeljord and Histol 1999, Selas et al. 2003, Herfindal et al. 2006a, b), and population structure in locally harvested populations (Sand et al. 1996, Ferguson et al. 2000, Solberg et al. 2004, Garel et al. 2006). And, enforcement personnel can use such records as supporting evidence during investigations and prosecutions. Information about kill location and habitat would help identify specific relationships between weight and a host of factors including age, geography, climate, forage availability, timing of conception, population health, and density of moose in British Columbia.

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