POTENTIAL VULNERABILITY OF BULL MOOSE IN CENTRAL BRITISH COLUMBIA TO THREE ANTLER-BASED HUNTING REGULATIONS

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ABSTRACT: Antlers from bull moose (*Alces alces andersoni*) harvested in the Omineca subregion of central British Columbia were submitted by hunters for inspection, measurement, and comparison by age in 1982-1989. After correcting for non-reporting bias, we examined the potential vulnerability of these moose (n = 1,886) to 3 antler-based hunting regulations currently advertised in British Columbia: spike/fork (S/F), tripalm (TP), and 10 point (10PT). The S/F regulation put 15.9% of all bulls at risk, and the TP and 10PT regulations put 11.1% and 12.0% at risk, respectively. Bulls with cervicorn antlers were at higher risk (41.3%) to the S/F regulation than the TP (1.4%) or 10PT (<1%) regulations. By contrast, bulls with palmicorn antlers were at low risk (5.4%) to the S/F regulation, but were at high risk to the TP (19.0%) and 10PT (17.1%) regulations. The S/F regulation focused harvest on yearlings, potentially exposing 46% of yearlings to harvest. The TP regulation exposed 20-40% of bulls older than 4.5 years of age; whereas, the 10PT regulation exposed 40-60% of bulls >7.5 years of age to harvest. Maximum spread and shaft circumferences of antlers were significantly smaller for yearlings at risk to the S/F regulation than for their same aged counterparts not at risk. Distance between the innermost points on the brow palm was significantly larger for yearlings at risk to the S/F regulation than for yearlings not at risk. Maximum spread, shaft circumference, palm height, and width were all significantly greater for bulls at risk to the TP and 10PT regulations than for those not at risk. Distance between the innermost points on the brow palms was significantly smaller for bulls at risk to TP and 10PT regulations than for those not at risk. These findings suggest that yearling bulls with smallest antlers are most at risk to harvest by the S/F regulation, whereas the largest antlered bulls are most at risk to harvest by the TP and 10 PT regulations. The consequences of this directed selection of bull moose by antler-based hunting regulations on the breeding biology, population genetics, and fitness of moose requires further study.

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Key words: *Alces alces*, harvest risk, hunting, social class, spike/fork, tripalm, yearling bull, 10 point.

Moose (*Alces alces andersoni*) hunting in British Columbia has traditionally been oriented toward the male segment of the population. In the long term, bull-only seasons may lead to age and sex imbalances that affect the growth, productivity, and ability of moose populations to sustain management and recreational objectives (Baker 1975, Demarchi and Hartwig 2008). Consequently, restrictive hunting seasons with increasing complexity of regulations and hunter dissatisfaction result (Hatter 1994, Child 1996, Hatter 1999).

Traditional practices of harvesting may act as an evolutionary force that can challenge conservation goals for wildlife and may impair both the health and genetic diversity of a species (Boer 1991, Darimont et al. 2009). Selective harvesting of large antlered males over the long term can alter genetics (Laurian et al. 2000) by negatively impacting those alleles that underpin fitness (Hundertmark and Bowyer 2004). Such changes can be irreversible if harvesting systems continue to target the larger individuals in a population (Van Ballenberghe 2004, Paquet 2009).

In this study we examined the potential vulnerability of bull moose harvested in the 1980s from the Omineca sub-region of the central interior of British Columbia (Fig. 1) to 3 antler-based hunting regulations (Fig. 2) practiced in the province: spike/fork (S/F), tripalm (TP), and 10 point (10PT). We evaluated the potential vulnerability of these bull moose specific to age class, social class, and antler characteristics.

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

METHODS

Morphometry of moose antlers in the Omineca sub-region of British Columbia was described by Child et al. (2010). Our data set was comprised of 1,686 sets of antlers from moose harvested in 1982-1989. Of these, 1,586 sets were submitted by successful limited entry hunters (LEH) for mandatory inspection; another 100 sets were submitted voluntarily by non-LEH hunters (i.e., hunters not possessing an LEH authorization who hunted in an open season for S/F bulls). We assumed that the LEH harvest was taken randomly from the population (Schwartz et al. 1992), whereas the non-LEH harvest of S/F bulls was taken primarily from the yearling component (Hatter and Child 1992).

Concerns regarding harvest bias against S/F bulls by LEH hunters, as well as under reporting by non-LEH hunters (Hatter and Child 1992, Hatter 1993), are reflected in the lack of yearling bulls in the reported age distribution (Child et al. 2010). To correct for non-reporting bias, we increased the number of S/F bulls until their vulnerability to the S/F regulation was 46%. This adjustment matched the vulnerability reported by Hatter (1993) and resulted in a hypothetical sample (hereafter considered to be the population) of 1,886 bull moose for study.

From the population (n = 1,886), we reported age of bulls potentially at risk to harvest when subjected to S/F, TP, and 10PT regulations (Fig. 2). We also report the proportions of bulls at risk by age class, social class, and antler form. For the analysis, we used the social classes described by Bubenik (1971): yearlings (1.5 years), teens (2.5-3.5 years), primes (4.5-11.5 years), and seniors (>12.5 years). Antler forms were described by Child et al. (2010) as cervicorn (pole type) and palmicorn (split palm or full palm). We separated those with palmicorm antlers as split palm and full palm antlers, and analyzed harvest risk to the regulations for each group. Proportions were calculated only if there were at least 5 bull moose in any age class, social class, or category of antler form.

The maximum spread, maximum height,

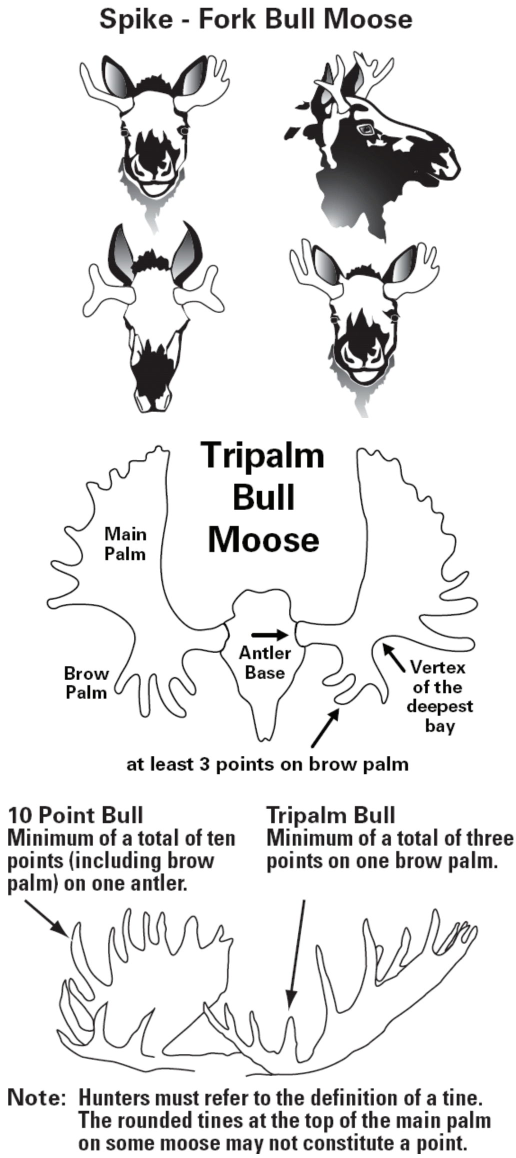

Fig. 2. Antler-based regulations for bull moose in British Columbia (from British Columbia Ministry of Environment Hunting and Trapping Regulations and Synopsis, 2008).

palm width, shaft circumference, and distance between the inner most points on the brow palms (Child et al. 2010) of yearling bulls at risk under the S/F regulation were compared (*t*-test, $P = 0.05$) with the same morphometrics for yearlings not at risk. Similarly, we compared the same morphometrics of antlers from bulls ≥2.5 years old at risk to the TP and 10PT regulations to bulls of similar age not at risk. We treated yearlings separately because this is the only age class subject to high harvest risk when exposed to the S/F regulation. Conversely, we separated all bulls >2.5 years old because they are at risk when exposed to the TP and 10PT regulations. We used Levene's test (Milliken and Johnson 1984) for equality of variances and then used the *t*-test for equal or unequal variances as appropriate.

Age-specific mean maximum antler spreads of bulls in the population were compared graphically with mean maximum antler spreads of bulls at risk to each of the regulations. Age-specific mean maximum spreads were calculated if there were at least 5 bull moose in the age class.

RESULTS

Harvest risk of bull moose exposed to S/F regulation

Bulls in our study (n = 1,886) ranged from 1.5-19.5 years with a mean of 3.9 ± 2.7 years (Fig. 3); nearly 16% were at risk to the S/F regulation. The mean age of bulls at risk was 1.9 ± 1.2 years of age (n = 100); 81% were yearlings and the oldest was 9.5 years. Age-specific vulnerability declined from 46.0% for yearlings to <5.0% for moose >2.5 years (Fig. 4). By social class, 46.2% of yearlings, 6.0% of teens, and 2.4% of primes were at risk. Sample size was insufficient to determine the

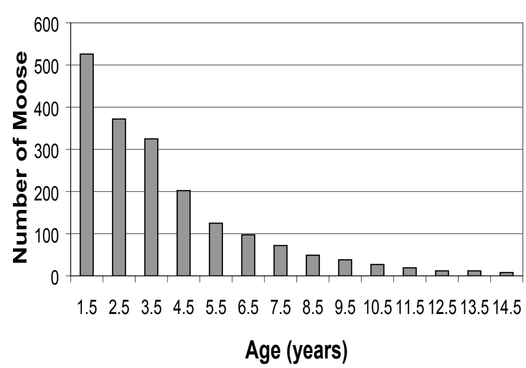

Fig. 3. Age distribution of the adjusted population of bull moose corrected for yearling reporting bias. Note: due to sample size (n <5) no data were plotted for bulls >15.5 years old.

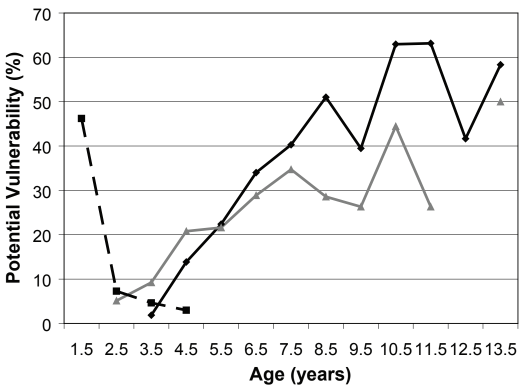

Fig. 4. Potential vulnerability of bull moose by age to 3 antler-based regulations. Broken line = S/F, gray line = TP, and black line = 10PT. Note: No data points were plotted for S/F regulation ages >5.5 years old, for TP regulation ages 1.5, 12.5, and 14.5 years and older, and for the 10PT regulation ages 1.5, 2.5, and 14.5 years and older due to insufficient sample size (n <5).

proportion of senior bulls at risk. Additionally, when considering antler form, 41.3% of bulls with cervicorn antlers and 5.4% of bulls with palmicorn antlers, including both split palm (5.4%) and full palm antlers (5.3%), were at risk (Table 1).

Both yearling and 2.5 year old bulls at risk had mean maximum antler spreads that were smaller than the mean maximum antler spread calculated for all bulls of similar age (Fig. 5). The maximum spread and shaft circumferences of antlers for yearling bulls at risk were smaller (*P* <0.001) than those of yearlings not at risk. Maximum antler height, palm width, and distance between the inner most points on the brow palms of yearlings were not different (*P* >0.05) between those yearlings at risk and those not at risk (Table 2).

Harvest risk of bull moose exposed to TP regulation

Of the 1,886 bull moose in the sample population, 12% were at risk to the TP regulation. The mean age of bulls exposed to the TP regulation was 6.3 ± 3.0 years (n = 227); bulls 1.5-19.5 years old were at risk. Vulnerability increased linearly from 5% at 2.5 years to 35% at 7.5 years, then fluctuated between 25-45% to 13.5 years (Fig. 4). Sample size was insufficient to determine the proportion of yearlings at risk, but 7.0% of teens, 25.9% of primes, and 38.2% of seniors were at risk. By antler form, 1.4% with cervicorn antlers and 19.0% with palmicorn antlers were at risk, including both split palm (18.3%) and full palm antlers (25.4%, Table 1). Mean maximum antler spread for each age class at risk was generally larger than the mean maximum antler spread calculated for the same age class in the population (Fig. 5). Antlers of bulls at risk had larger (*P* <0.001) maximum spread, height, palm width, and shaft circumference, and smaller (*P* <0.001) distance between the inner most points on the brow than bulls not at risk (Table 2).

Table 1. Potential vulnerability (%) of bull moose subjected to 3 antler-based regulations (S/F, TP, and 10PT) by social class and antler form for the population. Note: NC = % not calculated (n <5).

Regulation	Social class	%	Antler form	%
S/F	Population	15.9	Cervicorn	41.3
	Yearling	46.2	Palmicorn	5.4
	Teen	6.0	Split palm	5.4
	Prime	2.4	Full palm	5.3
	Senior	NC		
TP	Population	12.0	Cervicorn	1.4
	Yearling	NC	Palmicorn	19.0
	Teen	7.0	Split palm	18.3
	Prime	25.9	Full palm	25.4
	Senior	38.2		
10PT	Population	11.1	Cervicorn	NC
	Yearling	NC	Palmicorn	17.1
	Teen	1.1	Split palm	17.5
	Prime	29.7	Full palm	14.0
	Senior	44.1		

Harvest risk of bull moose exposed to 10PT regulation

Of the 1,886 bull moose in the sample population, 11% were at risk to the 10PT regulation. The mean age of bulls at risk was 7.7 ± 2.7 years (n = 210), ranging from 2.5-15.5 years old. Age-specific vulnerability increased linearly from <5% for bulls 3.5 years old, to about 50% at 8.5 years, then fluctuated between 40-65% to 13.5 years (Fig. 4). Sample size was insufficient to determine the proportion of bulls at risk that were <2.5 years or >13.5 years old. By social class, 1.1% of teens, 29.7% of primes, and 44.1% of seniors were at risk. By antler form, 17.1% with palmicorn antlers were at risk, including both split palm (17.5%) and full palm (14.0%, Table 1). Sample size was insufficient to determine the proportion of bulls with cervicorn antlers that were vulnerable to the 10PT regulation.

The age-specific, mean maximum antler spread for each age class at risk was generally larger than the mean maximum antler spread calculated for the same age class in the

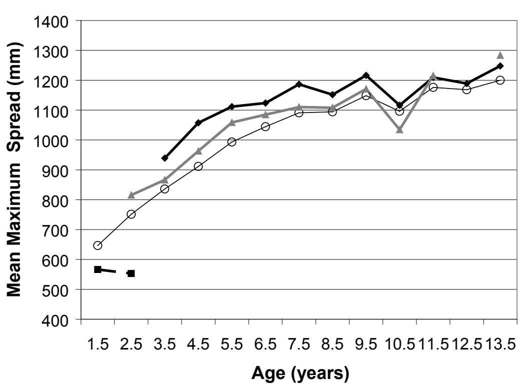

Fig. 5. Age-specific, mean maximum spread of antlers of bull moose in the population compared to those subjected to the 3 antler-based regulations. Thin solid line with open circles = population, broken line = S/F, gray line = TP, and thick black line = 10PT. No data points were plotted for S/F regulation for ages 3.5 years and older, for TP regulation ages 1.5, 12.5, and 14.5 years and older, and for the 10PT regulation for ages 1.5, 2.5, and 14.5 years and older due to insufficient samples (n <5).

population (Fig. 5). Bulls at risk had larger (P <0.001) sized antlers by maximum spread, height, palm width, and shaft circumference, and a smaller (P <0.001) distance between the inner most points on the brow palms than bulls not at risk (Table 2).

DISCUSSION

Assessment of the harvest risk of bull moose revealed that most bulls at risk to the S/F regulation were yearlings and those yearlings at risk had smaller antlers than yearlings not at risk. On the other hand, when subjected to the TP regulation, a large proportion of prime and senior bulls were at risk; when subjected to the 10PT regulation, risk to prime and senior bulls was higher still. Importantly, bulls at risk to either the TP or 10PT regulations had larger antlers (i.e., greater spread, width, height, number of points) and narrower distance between the innermost points on the brow palms than bulls not at risk to these regulations. Generally, bull moose with cervicorn antlers were at greatest risk to harvest under the S/F regulation, and bulls with palmicorn antlers were at high risk to both the TP and 10PT regulations. Bull moose with split palm antlers were similarly vulnerable to the TP and 10PT regulations, whereas bulls with full palm antlers were at higher risk to the TP regulation.

Antler size and symmetry reflects social status and fitness in cervids (Markusson and Folstad 1997, Pelabon and van Breukelen 1998, Ditchkof et al. 2001, Malo et al. 2005, Vanpé et al. 2007) including moose (Bubenik 1983, Solberg and Saether 1993, 1994, Bubenik 1998). Prime bulls carry the largest antlers (Gasaway et al. 1987) and their high numbers on rutting areas are required for optimal breeding and productivity (Bubenik 1983, Aitken and Child 1991, 1992, Solberg et al. 2002, Saether et al. 2003). The combination of antler size, form, and symmetry that cows recognize when selecting mates is not fully understood (Solberg and Saether 1993, Bowyer

Table 2. Summary of morphometric measurements (mean ± SD, n) and statistical significance of differences between bull moose at risk and those not at risk to the 3 antler-based regulations. Comparisons (t-tests) for the S/F regulation were only made for 1.5 year-old bulls, whereas comparisons for both the TP and 10PT regulation were made for bulls 2.5 years and older (see Methods).

Regulation	Morphometric	Mean value		*P*
		At risk	Not at risk	
S/F	MS	569 ± 122, 241	667 ± 95, 65	<0.001
	MHL	289 ± 140, 116	324 ± 97, 27	0.122
	MHR	287 ± 143, 98	302 ± 102, 24	0.567
	PWL	111 ± 63, 199	104 ± 39, 22	0.610
	PWR	114 ± 67, 203	102 ± 37, 22	0.442
	SCL	110 ± 16, 270	124 ± 17, 75	<0.001
	SCR	110 ± 18, 266	125 ± 18, 75	<0.001
	DIPB	431 ± 60, 189	414 ± 82, 28	0.295
TP	MS	1030 ± 181, 244	831 ± 194, 1536	<0.001
	MHL	676 ± 161, 154	489 ± 187, 769	<0.001
	MHR	658 ± 160, 146	474 ± 183, 670	<0.001
	PWL	227 ± 63, 241	149 ± 61, 1118	<0.001
	PWR	222 ± 57, 242	149 ± 61, 1113	<0.001
	SCL	168 ± 21, 251	144 ± 26, 1634	<0.001
	SCR	167 ± 21, 250	144 ± 26, 1566	<0.001
	DIPB	323 ± 86, 216	383 ± 85, 1303	<0.001
10PT	MS	1142 ± 154, 235	815 ± 174, 1545	<0.001
	MHL	771 ± 123, 124	481 ± 175, 799	<0.001
	MHR	756 ± 109, 107	469 ± 173, 709	<0.001
	PWL	259 ± 52, 196	147 ± 56, 1163	<0.001
	PWR	254 ± 46, 197	146 ± 56, 1158	<0.001
	SCL	180 ± 18, 241	142 ± 24, 1644	<0.001
	SCR	179 ± 18, 238	142 ± 24, 1578	<0.001
	DIPB	319 ± 92, 213	384 ± 84, 1306	<0.001

MS = maximum spread, MHL = maximum height left side, MHR = maximum height ride side, PWL = palm width left side, PWR = palm width right side, SCL = shaft circumference left side, SCR = shaft circumference right side, and DIPB = distance between the innermost points on brow.

et al. 2001). However, prolonged harvests of large antlered bulls and/or those with palmated brow structures may, over time, reduce genetic variability and cause an irreversible loss of alleles specific to antler features (Hundertmark et al. 1993, Hundertmark and Bowyer 1998, Bowyer et al. 2002, Hundertmark and Bowyer 2004, Van Ballenberghe 2004).

Moose hunting focused on bulls often results in age and sex imbalances that can lead to a scarcity of mature breeding bulls. Hunting regimes should ideally produce sex- and age-specific mortality patterns similar to those occurring naturally, and should maintain demographic structures conducive to natural breeding patterns (Harris et al. 2002) in order to ensure social well-being (Bubenik 1971, 1983), genetic variability (Ryman et al. 1981, Hartl et al. 1991, Hundertmark et al. 1993, Coltman et al. 2003), and high productivity

(Aitken and Child 1991, Timmerman 1991, Aitken and Child 1992, Schwartz 1998). Moreover, since a high proportion of mature breeders in the population prevents declines in population fitness (Ferer et al. 2003), a harvest strategy that reduces pressure on older, larger antlered males may be the most prudent. Open seasons or limited entry hunting (LEH) systems without antler restrictions are generally thought to randomize bull harvests (Child and Aitken 1989, Schwartz et al. 1992) and thereby ensure a normal age distribution. Antler-based regulations, on the other hand, direct hunters to selectively harvest bulls by antler characteristics that may have either beneficial or harmful consequences depending on the particular antler restriction (Harris et al. 2002).

The results of this study suggest that the S/F regulation targets mainly young bulls with the smallest antlers whereas the TP and 10PT antler regulations target bulls with the largest antlers across all age classes. It is important to understand the harvest risk of bull moose to antler-based regulations because genetic effects are suspected, if not likely (Hartl et al. 1991, Hundertmark et al. 1993, Coltman et al. 2003), and normal behavior (Bubenik 1987, 1998) and reproductive patterns (Schwartz 1998, Timmermann 1991) may be disrupted. Because of these negative consequences associated with over harvest of the largest bulls in a population, we advocate further monitoring and study of harvest impacts associated with antler-based hunting regulations.

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