MORPHOMETRY OF MOOSE ANTLERS IN CENTRAL BRITISH COLUMBIA

Kenneth N. Child[1], Daniel A. Aitken[2], and Roy V. Rea[3]

[1]6372 Cornell Place, Prince George, British Columbia V2N 2N7, Canada; [2]College of New Caledonia, 3330 22nd Avenue, Prince George, British Columbia V2N 1P8, Canada; [3]Natural Resources and Environmental Studies Institute, University of Northern British Columbia, 3333 University Way, Prince George, British Columbia V2N 4Z9, Canada.

ABSTRACT: We analyzed the morphometry of 1,965 sets of antlers from hunter-harvested moose (*Alces alces andersoni*) taken in the central interior of British Columbia. We describe the variation and age-related changes in antler and brow palm form, number of points on both main and brow palms, maximum spread, height and width of palmations, distance between innermost points on the brow palms, and shaft circumference. Architecturally, 25% were cervicorn pole type (PT); 75% were palmicorn with 67% split palm (SP) and 8% full palm (FP). Palmicorn antlers were most common in all age classes. Cervicorn antlers were most common in younger moose (1.5-3.5 years), and rare in moose >4.5 years. Of all antlers collected, 30% had forked brows and 12% had palmated brows. Forked brow palms increased with age; they occurred in 10% of moose 1.5 years old and 40-50% of moose ≥4.5 years old. The frequency of palmated brow palms increased quickly from 1.5 (2.5%) to 5.5 years (25%), peaked at 13.5 years (40%), before declining in later years. The number of points generally increased from 1.5-7.5 years, and remained stable thereafter. Maximum spread and shaft circumference generally increased from 1.5-13.5 years and decreased thereafter. Maximum antler height and width of main palms increased from 1.5-9.5 years; the first remained stable and the latter declined thereafter. Distance between the inner most points on the brow palms narrowed from 1.5-4.5 years, remained constant to 11.5 years, and then widened thereafter. Antler point counts were the most variable, whereas shaft circumference was the least variable character.

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Key words: *Alces alces*, brow palm, full palm, main palm, morphometrics, pole type, split palm, sociobiology.

Antlers are physiologically and behaviorally significant to members of the Cervidae, first developing as perennial, but later as deciduous protuberances of the skull (Bubenik 1982). Antlers appear to be luxury appendages that grow on males (and some females) only when other nutritional needs are satisfied (Heffelfinger 2006). The diversity of antler shapes and sizes provides convincing evidence that multiple factors were involved in shaping antlers over time - if antlers served only one purpose, then a single antler shape should have prevailed (Heffelfinger 2006).

Antlers are important in sparring and for defense, parading reproductive fitness, condition, and genetic superiority (Bubenik 1982, Heffelfinger 2006), to deflect and amplify sound (Bubenik and Bubenik 2008), and in thermoregulation (Stonehouse 1968). Bubenik et al. (1978) described a pattern of change in antler architecture and complexity relative to design, shape, and size that mirrored 3 life stages described by Gaillard et al. (2000) as juvenile, prime, and a senescent stage in seniors.

The growth and architecture of antler types varies among individuals of a species and between geographically distinct populations, and has been thoroughly described for moose (*Alces alces*) populations in North

America (Cringan 1955, Timmermann 1971, Bubenik 1973, Bubenik 1982, Child 1982, Van Ballenberghe 1982, Gasaway et al. 1987) and Fennoscandia (Solberg and Saether 1993a, Engan 2001, Nygrén et al. 2007). Antler size is influenced by age, genetic factors, health status, and nutrition (Hibler and Adcock 1971, Wolf 1980, Harmel 1983, Ullrey 1982). For example, Ullrey (1982) indicated that dietary energy restrictions reduce antler volume, shaft diameter, main shaft length, and number of shaft points in 1.5-year old white-tailed deer (*Odocoileus virginianus*). Therefore, understanding variation in antler types and morphometry in moose populations helps determine evolutionary history, sub-speciation, population fitness, and the influence of climatic conditions and habitat quality on antler growth. We describe the age-related morphometry of antler forms and changes in antler architectures of moose (*A. a. andersoni*) from central interior British Columbia.

Fig. 1. The Omineca sub-region (Zone A) in central British Columbia.

STUDY AREA

The Omineca sub-region of the central interior is approximately 122,500 km^2 in total area representing ~13% of the total land mass of British Columbia (Fig. 1). Rugged mountainous terrain with deeply incised valleys is typical on the northern and eastern sides (Child 1992); in contrast, the terrain is flat to rolling with hundreds of small lakes and wetlands in the southern and western areas (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, located on an extensive drumlinized till plateau surrounding periglacial lake deposits and dissected by many rivers, lakes, and wetlands. Dominant tree species are lodgepole pine (*Pinus contorta*), white spruce (*Picea glauca*), and subalpine fir (*Abies lasiocarpa*). Fires, logging, and insect outbreaks have had major impacts on the forests. Extensive 80-100 year old pine stands were typical of the area during the period in which antlers were collected, and were the result of historical widespread forest fires followed by decades of fire suppression (Child 1992). Clear-cuts created mostly since the 1960s are common throughout the area. Forest succession is characterized by an early shrub stage of 10-25 year duration, and many shrub species are important foods of moose (Heard et al. 1997).

The climate is generally wet and cool, with precipitation evenly distributed throughout the year. Mean daily average temperature in the southern portion of the Omineca at Prince George is 4.0^{o}C, ranging from a monthly mean of -9.6^{o}C in January to 15.5^{o}C in July; the mean annual precipitation is 600.8 mm, with 216 cm as snow. In contrast, to the west at Fort Saint James the mean daily average temperature is 3.0^{o}C, ranging from a monthly mean of -11.3^{o}C in January and 15.3^{o}C in July; mean annual precipitation is 487 mm, with 192 cm as snow (Environment Canada 2010).

Annual harvest of moose has ranged from 946-1691 animals, averaging of 1340 ± 44 (SD) over 19 years of record. The moose population is considered stable and below carrying capacity; intraspecific competition does not limit per capita food consumption

(Heard et al. 1997).

METHODS

From 1982-1989, successful limited entry hunters (LEH, selected by lottery) in central British Columbia were required to submit moose antlers for inspection to study age-related growth and developmental characteristics (Child and Aitken 1989); non-LEH hunters (those not selected by lottery) voluntarily submitted antlers for inspection (Hatter and Child 1992). On each set of antlers the following were measured by one Ministry of Environment technician: antler form - either full palm (FP), split palm (SP), or pole type (PT; Fig. 2), brow palm form (palm, fork, or unclassified palm), and numbers of points on each antler, main palm, and brow form according to Bubenik (1982). An antler tine is defined by regulation (British Columbia Ministry of Environment, 2008-2009 Hunting Regulations) to be a branch of an antler longer than its breadth, at least 2.5 cm in length, and is also called a point (Fig. 3). Number of points on each main palm was calculated to be the difference between the number of points on each antler and the number of points on the corresponding brow. Additionally, maximum spread, maximum antler height (left and right sides), maximum palm width (left and right sides), shaft circumference (left and right sides), and distance between the innermost brow points were measured to the nearest mm (Fig. 4).

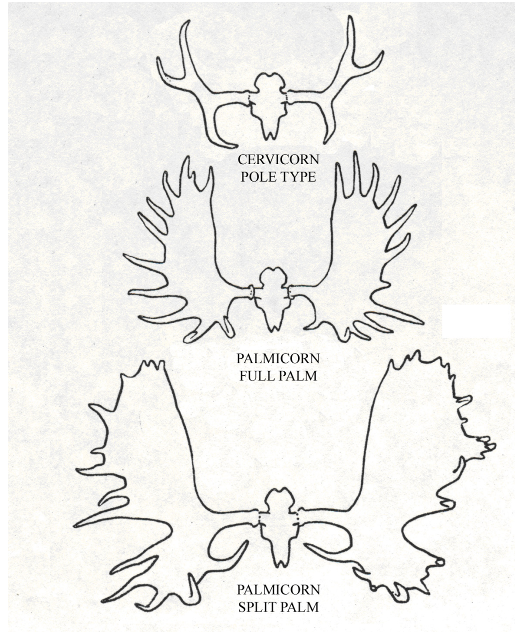

Fig. 2. Typical antler forms of moose in the central interior of British Columbia.

Incisor teeth were collected by hunters and submitted to the Ministry of Environment in Victoria, British Columbia. Tooth samples were analyzed by 2 Ministry of Environment technicians. Age was determined by counts of cementum annuli (Sergeant and Pimlott 1969) and stated as calendar age (e.g., 1.5 years).

We plotted frequency distributions for all variables in order to identify outliers. We then examined the records for each outlier and deleted those records that were clearly erroneous due to typographical errors; i.e., where measurements were in error by orders of magnitude or errors in transposition of data. After deletions, 1,965 records were available for analysis; we pooled all available data to describe antler morphometrics by age. The

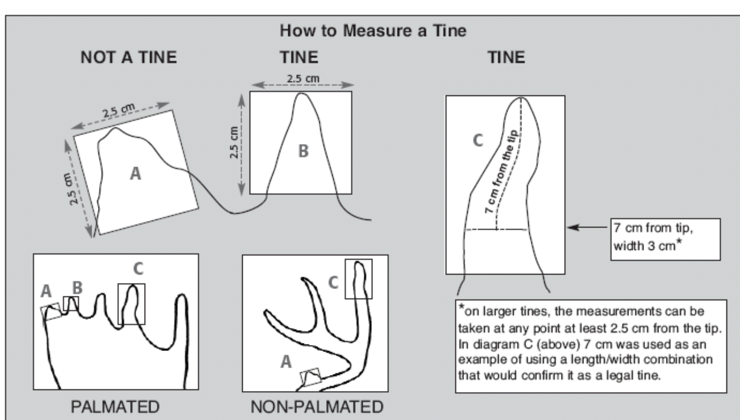

Fig. 3. Definition of a legal antler point (from British Columbia Ministry of Environment Hunting Regulations Synopsis 2007-2008).

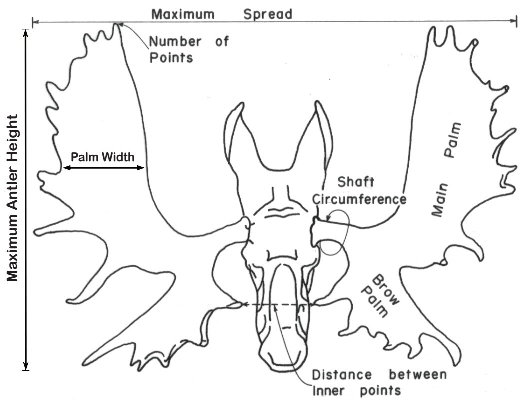

Fig. 4. Morphometrics recorded for moose antlers (Bubenik 1982).

effects of year and area of harvest on antler morphometrics in the same population are being investigated separately.

Antlers of SP and FP were tabulated as palmicorn type and antlers of PT were tabulated as cervicorn type (*sensu* Bubenik 1997). Antler form was tabulated for the entire sample; proportional changes of each form were plotted against age. Similarly, the form of brow palm was tabulated for the entire sample; proportional changes in brow palm were plotted against age.

We report the range, mean, and standard deviation (SD) for each variable (i.e., point counts, maximum spread, left and right maximum palm height, left and right maximum palm width, left and right shaft circumference, and distance between the inner most brow points). Paired sample *t*-tests ($P = 0.05$) were used to compare the variables from the left and right sides of each set of antlers. Sample sizes for age-specific means are in Table 1.

Left and right antlers in moose are generally symmetrical (Solberg and Saether 1993b, Bowyer et al. 2001). Therefore, we arbitrarily chose to plot only the forms and variables for the left antler. Changes in age-specific means ± 1 SD for each variable on the left side of the antlers were plotted to demonstrate changes in antler architectures with age.

Correlations between all of the variables were determined in order to show relationships between the various architectural features. Coefficients of Variation (CV) were calculated for each variable to compare variation amongst all variables.

RESULTS

Age Distribution

The mean age of moose was 4.1 ± 2.7 (SD) years (n = 1,686); age ranged from 1.5-19.5 years (Fig. 5). Since only 2 moose >14.5 years were inspected, we combined the 14.5 (n = 8), 15.5 (n = 1), and 19.5 (n = 1) year old moose into a single ≥14.5 year old group. Yearling bulls might be under-represented in the sample because of the voluntary requirement by non-LEH hunters to submit antlers for inspection (Hatter 1999).

Antler Form

Antler form was recorded for 1,597 sets of antlers; 75% were palmicorn type (67% SP type, 8% FP type) and 25% were cervicorn type (PT). Palmicorn antlers were most common in all age classes except yearlings. The majority of palmicorn antlers in each age class were SP type, whereas <10% in each age class were FP type (Fig. 6). Cervicorn (PT) antlers were the most common type in yearling moose (65%) and decreased in abundance to <10% in moose >3.5 years old.

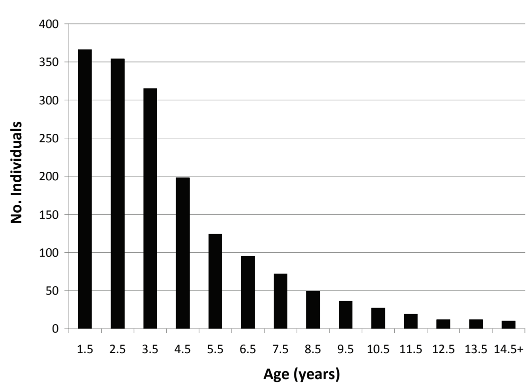

Fig. 5. Age distribution of hunter-killed bull moose (n = 1,965) from the Omineca sub-region of British Columbia, 1982-1989.

Table 1. Sample sizes for antler form, brow form, and the 8 variables examined on the left antler. AF = antler form, BF = brow form, NPL = number of points on left antler, MPL = main palm points left antler, BPL = brow points left antler, MS = maximum spread, MHL = maximum height left antler, SCL = shaft circumference left antler, PWL = palm width left antler, and DIBP = distance between innermost points on the brow palm.

Age	AF	BF	NPL	MPL	BPL	MS	MHL	SCL	PWL	DIBP
1.5	309	47	360	206	207	306	145	345	221	217
2.5	290	111	346	232	233	323	162	343	249	266
3.5	268	156	312	213	213	295	161	311	238	261
4.5	167	116	197	133	133	190	107	191	152	169
5.5	103	85	122	74	74	118	58	120	80	105
6.5	84	71	94	66	67	92	48	93	78	86
7.5	51	46	70	42	43	70	45	71	53	67
8.5	45	34	49	28	28	47	27	49	41	45
9.5	32	26	34	21	22	33	15	35	26	26
10.5	23	21	26	16	16	24	23	26	20	22
11.5	17	14	18	11	11	17	7	18	14	15
12.5	11	9	12	6	6	11	4	11	7	11
13.5	11	10	11	10	10	11	6	11	10	9
14.5+	8	7	10	6	6	10	6	10	7	10
Total aged	1419	753	1661	1064	1069	1547	814	1634	1196	1309
Recorded, but not aged	178	110	235	118	119	233	111	251	163	210
Not recorded	368	1102	41	783	777	185	1040	80	606	446
Total Sample	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965

Brow Palm Form

Brow palm form was recorded on 863 left antlers and 811 right antlers of the 1,965 antlers examined; palmation occurred on 13.1% and 12.4% of the left and right sides, respectively. Forked architectures were about twice as common as palmations; 30.8 % (n = 605) on the left and 28.9% (n = 567) on the right side. The remainder was unclassified, being neither forked nor palmated. The frequency of palmated brow palms increased linearly to approximately 25% at 5.5 years, and continued to increase at a slower rate to about 35% at 13.5 years, before decreasing to 10% thereafter. The frequency of forked brows also increased linearly to approximately 45% at 5.5 years, remaining relatively constant to 13.5 years, before increasing to 60% thereafter (Fig. 7).

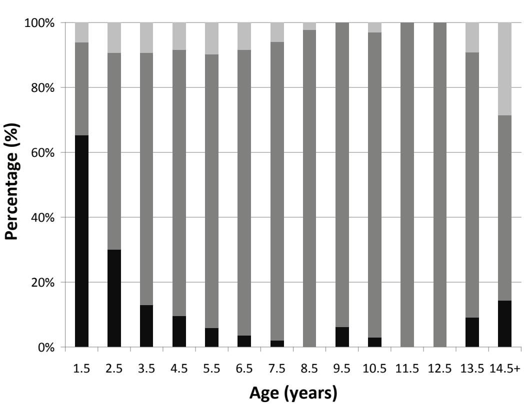

Fig. 6. Changes in antler form with age for hunter-killed moose from the Omineca sub-region of British Columbia, 1982-1989. Note: Black = Pole Type, Dark gray = Split Palm, and Light Gray = Full Palm.

Number of Points on Antlers

The number of points on the left side

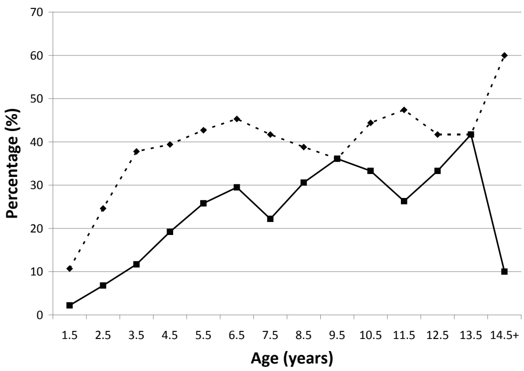

Fig. 7. Changes in brow form with age for hunter-killed moose from the Omineca sub-region of British Columbia, 1982-1989. Values are age-specific mean proportion of each type on left antlers. Dashed line is forked brow, solid line is palmated brow.

ranged from 0-18, averaging 5.90 ± 2.62 (SD) (n = 1,924; points on the right side ranged from 1-15, averaging 5.81 ± 2.49 (SD) (n = 1,913). There were more points (t = 3.011, df = 1,906, P = 0.003) on the left (mean = 5.90 ± 2.63, n = 1,907) than right side (mean = 5.81 ± 2.49, n = 1907), although the number of points on the left correlated (r = 0.866, n = 1,907, P<0.001) with the number on the right side. Generally, the number of antler points on both sides increased from 1.5-7.5 years, then remained relatively stable thereafter (Fig. 8).

Number of Points on Main Palms

The number of points on the left main palm ranged from 1-13, averaging 4.23 ± 2.01 points (SD) (n = 1,182); similarly, points on the right main palm ranged from 1-14, averaging 4.17 ± 1.89 (SD) (n = 1,175). There was no difference (t = 1.797, df = 1,138, P = 0.073) between the numbers of points on the left (mean = 4.24 ± 2.02, n = 1,139) and right main palms (mean = 4.18 ± 1.90, n = 1,139); the number of points on paired left and right main palms were correlated (r = 0.798, n = 1,139, P<0.001). Generally, the number of points on both palms increased from 1.5-7.5 years, then remained relatively constant thereafter (Fig. 8).

Number of Points on Brow Palms

The number of points on the left brow palm ranged from 0-7, averaging 1.75 ± 0.88 (SD) (n = 1,188); 0.3% had no measurable points, 46.7% were single points (spikes), 36.4% were 2 points (forks), and 16.7% had ≥3 points. On the right, points ranged from 0-8, averaging 1.72 ± 0.87 (SD) (n = 1,184); 0.1 % had no measureable points, 48.2% were spikes, 36.5% were forks, and 15.2% had ≥3 points. There was no difference (t =1.744, df = 1146, P = 0.081) between the number of points on the right (mean = 1.73 ± 0.87, n = 1,147) and left brow palms (mean = 1.76 ± 0.88, n = 1,147); the number of points on the left and right brows were correlated (r = 0.742, n = 1,147, P<0.001). Generally, the number of points on both brow palms increased from 1.5-7.5 years, and remained relatively constant thereafter (Fig. 8).

Maximum Spread of Antlers

The maximum spread of 1,780 sets of antlers ranged from 322-1,613 mm, averaging 858 ± 204 (SD) mm. Maximum spread generally increased annually with age (Fig. 9).

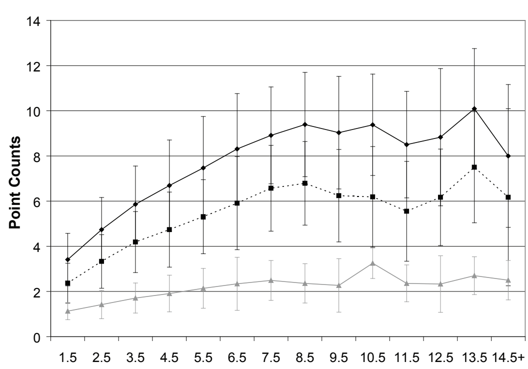

Fig. 8. Changes in age-specific means of total points, main palm points, and brow points for hunter-killed moose from the Omineca sub-region in British Columbia, 1982-1989. Values are means of the age-specific mean point counts ± 1 SD for the left side. Solid line is total points, dashed line is main palm points, and gray line is brow palm points.

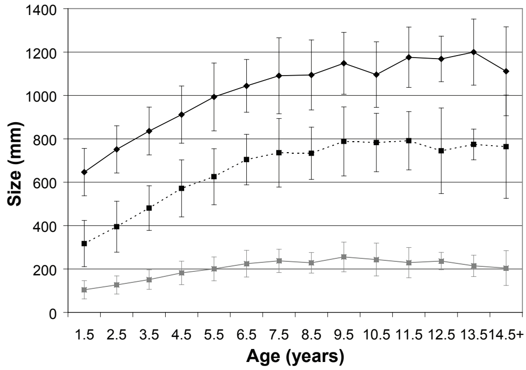

Fig. 9. Changes in age-specific mean values for antler attributes maximum spread, maximum height, and maximum palm width of hunter-killed moose from the Omineca sub-region of British Columbia, 1982-1989. Values are age-specific mean point counts ± 1 SD for the left side. Solid line is maximum spread, dashed line is maximum height of antler, and gray line is maximum width of palm.

Maximum Height of Antlers

The maximum antler height ranged from 49-1,194 mm. The mean maximum height on the left (519 ± 196 mm, n = 925) and right side (mean = 507 ± 192, n = 817) were similar. The maximum height of the left side (mean = 512 ± 188 mm, n =798) was not different (t = 1.858, df = 797, P = 0.063) from the right side (mean = 508 ± 192 mm, n = 798) on each set of paired antlers; the height on the left was positively correlated (r = 0.950, n = 798, P<0.001) with height on the right side. Maximum height of both sides generally increased from 1.5-9.5 years, and remained relatively unchanged thereafter (Fig. 9).

Maximum Width of the Main Palm

The maximum width of the main palm ranged from 12-436 mm. Palm widths on the left (mean = 163 ± 68 mm, n = 1,359) were similar to those on the right side (mean = 162 ± 66, n = 1,357). The width of the main palm on the left (mean = 163 ± 68 mm) was not different (t =1.111, df = 1336, P = 0.267) from the width on the right (mean = 162 ± 66 mm) in paired sets of antlers (n = 1337); width of the main palm on the left was positively correlated (r = 0.889, n = 1,337, P < 0.001) with width on the right side. Palm width of both sides generally increased with age from 1.5-9.5 years, and declined thereafter (Fig. 9).

Circumference of Antler Shaft

The shaft circumference of antlers ranged from 55-281 mm. Shaft circumference on the left side (mean = 147 ± 26 mm, n = 1,885) was similar to that on the right (mean = 147 ± 27, n = 1,819). There was no difference (t = 0.596, df = 1,805, P = 0.551) in shaft circumference on the left (mean = 147 ± 26 mm) and right sides (mean = 147 ± 26 mm) for paired sets of antlers (n = 1,806); shaft circumference on the left and right sides were positively correlated (r = 0.913, n = 1,806, P<0.001) for paired sets of antlers. Shaft circumference on both sides slowly increased with age (Fig. 10).

Distance between Innermost Points on Brow Palms

The distance between the innermost points on the brow ranged from 102-800 mm, averaging 375 ± 88 (SD) mm (n = 1,519). Average distance between the brow points narrowed from 417 mm at 1.5 year to 375 mm at 3.5 years.

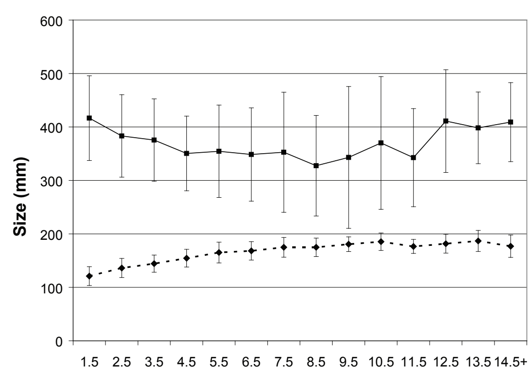

Fig. 10. Changes in age-specific mean values of distance between brow points and shaft circumference for hunter-killed moose from the Omineca sub-region of British Columbia, 1982-1989. Values are age-specific mean point counts ± 1 SD for the left side. Solid line is innermost distance between the brow points, and the dashed line is shaft circumference.

This distance remained relatively constant at ~350 mm from 4.5-11.5 years, then widened to >400 mm thereafter (Fig. 10).

Correlations between Antler Variables

Correlations between each variable on each side of a set of paired antlers (Table 1) were significant ($P<0.001$). Highest correlation coefficients (r) were found for antler height (r = 0.950) and shaft circumference (r = 0.914). Maximum spread, often the measurement of choice by hunters, was highly correlated with all other measures. The distance between innermost points on the brow palms and all other variables had the lowest correlation coefficients.

Variability in Antler Measurements

The least variable measure was shaft circumference (CV = 18% for both left and right sides); the most variable was number of points on the brow palms (CV = 51% for both left and right sides). Generally, the number of points had most variability (Table 2).

DISCUSSION

We found that form and morphometrics of antlers of bull moose changed with age in the central interior of British Columbia. These changes progressed through the juvenile and prime stages, ended in the senior/senescent stage (Gaillard et al. 2000), and were similar to those described for moose in North America (Timmermann 1971, Bubenik et al. 1978, Van Ballenberghe 1982, Erling et al. 1987, Gasaway et al. 1987). Prime moose (approximately 5-12 years) have near maximal antler size and antler growth plateaus at this stage (Gasaway et al. 1987). Antler size in juveniles (approximately 1-4 years) rapidly increases toward full development, whereas antlers of seniors (>12 years) gradually regress from full development. The mean maximum spread of antlers from our sample was similar to that of *A. a. andersoni* and *A. a. americana*, but smaller than that of *A. a. gigas* (Gasaway et al. 1987).

Gasaway et al. (1987) found that both palmicorn and cervicorn (pole type) antler forms occur throughout North America with palmicorn antlers being the predominant form for moose ≥2 years old; our findings are similar. Furthermore, Bubenik (1997) subdivided palmicorn into full palm (shell type) and split palm (butterfly type) forms; both were documented in the Omineca. Split palm antlers were the most common type in all age classes of moose ≥2.5 years old, whereas full palm antlers were infrequent in most age classes. We were unable to compare the variation of SP and FP types across North America. The proportion (65%) of yearlings in the Omineca with cervicorn antlers was higher than that documented throughout North America (30-40%; Gasaway et al. 1987). It is unknown whether this higher percentage reflects difference in range condition (Nygrén et al. 2007) and hunting regulations between the Omineca and other jurisdictions, and/or other factors.

The pattern of antler architecture and their increasing complexity in design, shape, and size in the central interior of British Columbia was similar to that described in other regions of North America (Timmermann 1971, Bubenik et al. 1978, Gasaway et al. 1987). There was, however, a great deal of variation in antler size and shape among moose of the same age, and between males of different age classes. Given that genetics, location (e.g., range quality), and other factors influence the growth and final design of antlers (Hundertmark and Bowyer 2004), variation in antler morphometry is not surprising. Knowledge of the age-related growth and development of antlers is important because harvest regulations increasingly define "legal" bulls by form and growth characteristics (Child and Aitken 1989, Hatter 1999, Demarchi and Hartwig 2008). It follows then that field collection and measurement of moose antlers is needed to best describe and understand standards,

Table 2. Pearson correlation coefficients between all measurements for moose antlers. All correlations were significant at $P<0.001$. Sample sizes are shown below the correlation coefficient.

	NPL	NPR	MPL	MPR	BPL	BPR	MS	MHL	MHR	SCL	SCR	PWL	PWR	DIBP
NPL	--	0.866	0.953	0.793	0.715	0.651	0.77	0.764	0.74	0.721	0.708	0.802	0.76	-0.351
	1924	1907	1182	1175	1182	1178	1767	917	809	1873	1803	1351	1347	1513
NPR	0.866	--	0.808	0.947	0.649	0.714	0.767	0.75	0.762	0.702	0.724	0.773	0.811	-0.361
	1907	1913	1170	1175	1171	1175	1762	911	807	1859	1803	1340	1346	1510
MPL	0.953	0.808	--	0.798	0.468	0.506	0.719	0.739	0.709	0.688	0.661	0.762	0.723	-0.279
	1182	1170	1182	1139	1182	1142	1093	649	619	1171	1163	1047	1041	941
MPR	0.793	0.947	0.798	--	0.494	0.452	0.699	0.72	0.748	0.652	0.662	0.741	0.778	-0.318
	1175	1175	1139	1175	1139	1175	1094	644	618	1162	1165	1040	1045	947
BPL	0.715	0.649	0.468	0.494	--	0.742	0.561	0.595	0.593	0.553	0.54	0.608	0.593	-0.405
	1182	1171	1182	1139	1188	1147	1097	652	621	1177	1167	1052	1045	944
BPR	0.651	0.714	0.506	0.452	0.742	--	0.572	0.596	0.598	0.562	0.559	0.605	0.604	-0.377
	1178	1175	1142	1175	1147	1184	1102	648	622	1171	1173	1047	1052	953
MS	0.77	0.767	0.719	0.699	0.561	0.572	--	0.806	0.805	0.765	0.769	0.73	0.724	-0.162
	1767	1762	1093	1094	1097	1102	1780	855	756	1749	1686	1272	1276	1498
MHL	0.764	0.75	0.739	0.72	0.595	0.596	0.806	--	0.95	0.782	0.788	0.762	0.731	-0.271
	917	911	649	644	652	648	855	925	798	913	905	753	747	756
MHR	0.74	0.762	0.709	0.748	0.593	0.598	0.805	0.95	--	0.752	0.78	0.776	0.76	-0.26
	809	807	619	618	621	622	756	798	817	808	809	658	660	663
SCL	0.721	0.702	0.688	0.652	0.553	0.562	0.765	0.782	0.752	--	0.913	0.694	0.692	-0.262
	1873	1859	1171	1162	1177	1171	1749	913	808	1885	1806	1349	1340	1507
SCR	0.708	0.724	0.661	0.661	0.54	0.559	0.769	0.788	0.78	0.913	--	0.701	0.715	-0.259
	1803	1803	1163	1165	1167	1173	1686	905	809	1806	1819	1339	1347	1455
PWL	0.802	0.773	0.762	0.741	0.608	0.605	0.73	0.762	0.776	0.694	0.701	--	0.889	-0.314
	1351	1340	1047	1040	1052	1047	1272	753	658	1349	1339	1359	1337	1097
PWR	0.76	0.811	0.723	0.778	0.593	0.604	0.724	0.731	0.76	0.692	0.716	0.889	--	-0.306
	1347	1346	1041	1045	1045	1052	1276	747	660	1340	1347	1337	1357	1102
DIBP	-0.351	-0.361	-0.279	-0.318	-0.405	-0.377	-0.162	-0.271	-0.26	-0.262	-0.259	-0.314	-0.306	--
	1513	1510	941	947	944	953	1498	756	663	1507	1455	1097	1102	1519

Note: NPL = number of points on left antler, NPR = number of points on right antler, MPL = main palm points left antler, MPR = main palm points right antler, BPL = brow points left antler, BPR = brow points right antler, MS = maximum spread, MHL = maximum height left antler, MHR = maximum height right antler, SCL = shaft circumference left antler, SCR = shaft circumference right antler, PWL = palm width left antler, PWR = palm width right antler, and DIBP = distance between innermost points on the brow palm.

Table 3. Coefficient of variation for each antler variable.

Antler Measurement	Coefficient of Variation (%)	n
Shaft circumference left	18	1885
Shaft circumference right	18	1816
Distance between innermost points on brow palms	23	1519
Maximum spread	24	1780
Maximum height left antler	38	923
Maximum height right antler	38	816
Palm width right antler	41	1355
Palm width left antler	42	1359
Total number points right antler	43	1910
Total number points left antler	44	1921
Main palm points right antler	45	1173
Main palm points left antler	48	1182
Brow points right antler	51	1182
Brow points left antler	51	1188

variation, and change amongst managed populations, especially where and if antler-based hunting regulations are planned or practiced (Child et al. 2010).

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