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# AN EVALUATION OF HORN AND SKULL CHARACTERS AS A MEASURE OF POPULATION QUALITY IN ALBERTA BIGHORNS

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## ABSTRACT

Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) in southern Alberta have several skull characters which exceed those of bighorns north of the Bow River. In the south, both sexes have longer rostra, tooth rows, and higher crowns than northern bighorns. Southern rams have more massive horns than northern rams. Although brain case volume was significantly larger ($p<0.05$) in southern rams, that measure did not differ between southern and northern ewes.

## INTRODUCTION

Bubenik and Bellhouse (1980) cite several references that indicate undernourishment during pregnancy and/or during the nursing period are major causes of a small and under-developed brain. They measured 53 moose skulls (*Alces alces*) from north central Ontario and proposed that brain case volume could be a valuable tool for measuring population quality. We tested brain case volume as a measure of population quality in Rocky Mountain bighorn sheep from high quality and low quality populations from southern and northern Alberta respectively. In southern Alberta there is an optimum combination of climate, soil and vegetation that produces large bighorns (Blood et al. 1970) with the southern rams growing significantly larger horns than rams north of the Bow River (Wishart 1969). Since high quality mountain sheep populations are characterized by more massive horns and skulls than lower quality populations (Geist 1971, Shackleton 1973, Heimer and Smith 1975), comparison of bighorn skulls from northern and southern Alberta appeared appropriate for the brain case volume test.

## METHODS

After plugging foramina with modeling clay, brain case volume was measured by filling the cavity with #6 lead shot and then pouring the shot into a calibrated cylinder. Measurements were recorded to the nearest 5 cc.

Skull measurements were made to the nearest millimeter using a steel tape, lock-joint outside calipers and a Vernier caliper. Standard skull measurements described by Cowan (1940) were taken on 17 characters. We measured six additional characters after Shackleton (1973) to describe the rostral cranial relationships of each skull. The skull measurements are defined in the Appendix and illustrated in Figure 1. Comparison of interpopulation skull dimensions were restricted to age classes 5 years and older (Cowan 1940, Baker and Bradley, 1965).

Horn measurements were made to the nearest millimeter using a cloth tape. Measurements included the base circumference from animals aged 5 years and older and the lengths of annual increments for each horn from all ages. Annual increments were measured for only the first three years in ewes, since annuli were not accurately discernible thereafter.

A "t-test" for samples of unequal size and unequal variances was used to compare population sample means. The level of five per cent probability had been selected *a priori* for tests of hypotheses. A total of 90 ewe skulls and 70 ram skulls was measured.

## RESULTS

### 1. Ewe Skulls

Southern specimens were almost invariably larger. Differences ($P<0.05$) between southern and northern ewes were found in the basilar length, naso-cranial length, molar lengths, maxillary width and rostral depth (Tables 1 and 2). In the cranial region significant differences were found in the basisphenoid crown height, occiput-frontal length, supraorbital width and occiput width, however, there was no difference in brain case volumes (Table 2).

### 2. Ram Skulls

As with the ewes the southern specimens were almost invariably larger. Significant differences were found in the naso-cranial length, palatal length, molar lengths, occiput frontal length and basisphenoid crown height (Tables 3 and 4). Brain case volumes were significantly larger in southern Alberta rams (Table 4).

Table 1. Skull measurements of bighorn ewes, 5 years and older from northern (N) and southern (S) Alberta.

| Measurement | Pop. | $x_n$ | | $\overline{X}$ | $SE\overline{X}$ | SD | CV | R |
|---|---|---|---|---|---|---|---|---|
| A. Basilar length | N | 23 | * | 246.2 | 1.37 | 6.58 | 2.67 | 232-256 |
| | S | 22 | | 252.4 | 1.08 | 5.06 | 2.00 | 241-260 |
| B. Nasal length | N | 24 | | 94.7 | 1.09 | 5.35 | 5.65 | 86-106 |
| | S | 22 | | 97.5 | 1.12 | 5.29 | 5.42 | 92-109 |
| C. Nasal width | N | 22 | | 37.4 | 0.56 | 2.63 | 7.03 | 32-41 |
| | S | 21 | | 37.4 | 0.58 | 2.69 | 7.20 | 32-41 |
| D. Orbital width | N | 23 | | 108.3 | 0.56 | 2.70 | 2.49 | 102-114 |
| | S | 22 | | 108.1 | 0.82 | 3.84 | 3.55 | 101-117 |
| E. Zyomatic width | N | 23 | | 114.6 | 0.64 | 3.08 | 2.69 | 108-119 |
| | S | 21 | | 115.1 | 0.55 | 2.53 | 2.19 | 108-119 |
| F. Maxillary width | N | 26 | | 80.8 | 0.51 | 2.60 | 3.22 | 77-84 |
| | S | 23 | * | 82.8 | 0.60 | 2.89 | 3.49 | 78-88 |
| G. Mastoid width | N | 19 | | 79.7 | 0.53 | 2.30 | 2.89 | 76-83 |
| | S | 20 | | 80.1 | 0.59 | 2.64 | 3.29 | 76-86 |
| H. Palatal br. $M_3$ | N | 26 | | 47.3 | 0.53 | 2.72 | 5.76 | 43-51 |
| | S | 23 | | 47.3 | 0.52 | 2.48 | 5.24 | 42-52 |
| I. Palatal br. $Pm_2$ | N | 26 | | 29.5 | 0.54 | 2.76 | 9.34 | 23-35 |
| | S | 23 | | 29.9 | 0.41 | 1.96 | 6.56 | 27-34 |
| J. Post-palatal width | N | 22 | | 26.1 | 0.29 | 1.39 | 5.32 | 23-28 |
| | S | 22 | | 25.8 | 0.22 | 1.05 | 4.07 | 23-38 |
| K. Palatal length | N | 23 | | 90.8 | 0.90 | 4.32 | 4.76 | 84-99 |
| | S | 22 | | 90.9 | 1.37 | 6.45 | 7.09 | 71-100 |
| L. Upper Molar length | N | 26 | | 81.9 | 0.65 | 3.30 | 4.03 | 75-87 |
| | S | 23 | * | 85.2 | 0.62 | 2.98 | 3.50 | 79-91 |
| M. Lower Molar length | N | 29 | | 82.4 | 0.55 | 2.95 | 3.59 | 78-88 |
| | S | 15 | * | 86.2 | 0.96 | 3.72 | 4.32 | 81-91 |
| N. Prealveolar length | N | 25 | | 78.1 | 0.63 | 3.18 | 4.07 | 74-84 |
| | S | 23 | | 79.3 | 0.50 | 2.38 | 3.00 | 75-83 |
| O. Postdental length | N | 25 | | 82.2 | 0.81 | 4.08 | 4.96 | 71-89 |
| | S | 22 | | 83.6 | 0.65 | 3.06 | 3.67 | 79-89 |
| P. Basioccipital width | N | 23 | | 30.2 | 0.31 | 1.50 | 5.26 | 28-33 |
| | S | 22 | | 30.7 | 0.34 | 1.61 | 4.96 | 27-34 |
| Q. Premaxilla width | N | 21 | | 29.5 | 0.35 | 1.63 | 5.53 | 27-31 |
| | S | 23 | | 29.2 | 0.41 | 1.95 | 6.68 | 25-33 |

$x_n$- sample size
$\overline{X}$- mean
$SE\overline{X}$- standard error of mean
SD- standard deviation
CV- coefficient of variation
R- range
*- $p<0.05$

Table 2. Rostral and cranial measurements and brain case volume of bighorn ewes, 5 years and older from northern (N) and southern (S) Alberta.

| Measurement | | Pop. | $x_n$ | $\overline{X}$ | $SE\overline{X}$ | SD | CV | R |
|---|---|---|---|---|---|---|---|---|
| W. | Basisphenoid-crown height | N | 25 | 88.1 | 0.74 | 3.71 | 4.21 | 82-94 |
| | | S | 22 | *92.9 | 0.88 | 4.14 | 4.45 | 86-103 |
| X. | Occiput-frontal length | N | 24 | 121.2 | 0.71 | 3.47 | 2.84 | 118-128 |
| | | S | 21 | *125.9 | 0.91 | 4.19 | 3.33 | 120-134 |
| Y. | Rostral depth | N | 24 | 65.8 | 0.56 | 2.76 | 4.20 | 61-71 |
| | | S | 22 | *68.6 | 0.62 | 2.92 | 4.26 | 65-76 |
| Z. | Naso-cranial length | N | 24 | 198.2 | 1.38 | 6.75 | 3.41 | 184-209 |
| | | S | 21 | *203.5 | 1.37 | 6.26 | 3.08 | 192-215 |
| AA. | Supraorbital width | N | 25 | 105.0 | 0.84 | 4.18 | 3.98 | 98-112 |
| | | S | 23 | *107.4 | 0.73 | 3.48 | 3.25 | 101-113 |
| BB. | Occiput width | N | 23 | 61.9 | 0.66 | 3.15 | 5.09 | 56-68 |
| | | S | 21 | *64.1 | 0.56 | 2.57 | 4.01 | 61-69 |
| | Brain case volume | N | 23 | 213.9 | 3.09 | 14.84 | 6.94 | 190-250 |
| | | S | 22 | 216.6 | 2.89 | 13.57 | 6.26 | 190-245 |

$x_n$- sample size
$\overline{X}$- mean
$SE\overline{X}$- standard error of mean
SD- standard deviation
CV- coefficient of variation
R- range
*- $p<0.05$

Table 3. Skull measurements of bighorn rams; 5 years and older from northern (N) and southern (S) Alberta.

| Measurement | Pop. | *n | | $\overline{X}$ | SE$\overline{X}$ | SD | CV | R |
|---|---|---|---|---|---|---|---|---|
| A. Basilar length | N | 6 | | 271.2 | 2.96 | 7.25 | 2.67 | 259-278 |
| | S | 9 | | 278.4 | 3.57 | 10.71 | 3.84 | 266-295 |
| B. Nasal length | N | 7 | | 104.3 | 2.99 | 7.91 | 7.58 | 92-114 |
| | S | 7 | | 108.8 | 2.15 | 5.70 | 5.23 | 103-118 |
| C. Nasal width | N | 10 | | 51.8 | 1.20 | 3.79 | 7.32 | 46-59 |
| | S | 10 | | 53.2 | 1.50 | 4.75 | 8.94 | 46-60 |
| D. Orbital width | N | 10 | | 121.3 | 1.55 | 4.90 | 4.04 | 115-128 |
| | S | 10 | | 123.3 | 2.27 | 7.19 | 5.84 | 115-135 |
| E. Zygomatic width | N | 10 | | 126.1 | 1.36 | 4.30 | 3.41 | 116-131 |
| | S | 10 | | 128.5 | 1.01 | 3.21 | 2.49 | 124-133 |
| F. Maxillary width | N | 11 | | 89.4 | 0.98 | 3.27 | 3.65 | 85-94 |
| | S | 10 | | 92.2 | 1.38 | 4.37 | 4.73 | 86-98 |
| G. Mastoid width | N | 9 | | 93.4 | 0.62 | 1.88 | 2.01 | 91-96 |
| | S | 10 | | 96.1 | 1.42 | 4.51 | 4.69 | 90-103 |
| H. Palatal br. $M_3$ | N | 11 | | 50.9 | 0.97 | 3.24 | 6.36 | 45-57 |
| | S | 10 | | 51.6 | 0.60 | 1.89 | 3.68 | 49-54 |
| I. Palatal br. $P_{m2}$ | N | 12 | | 32.2 | 0.42 | 1.47 | 4.56 | 30-35 |
| | S | 10 | | 32.9 | 0.69 | 2.18 | 6.64 | 29-37 |
| J. Post-palatal width | N | 11 | | 30.4 | 0.43 | 1.44 | 4.73 | 28-33 |
| | S | 10 | | 31.8 | 0.51 | 1.62 | 5.09 | 29-34 |
| K. Palatal length | N | 8 | | 85.9 | 1.51 | 4.29 | 4.99 | 81-91 |
| | S | 10 | * | 99.3 | 2.08 | 6.58 | 6.63 | 93-108 |
| L. Upper molar length | N | 12 | | 86.0 | 1.17 | 4.07 | 4.73 | 79-94 |
| | S | 10 | * | 91.2 | 0.95 | 3.01 | 3.30 | 88-96 |
| M. Lower molar length | N | 8 | | 87.6 | 1.66 | 4.69 | 5.35 | 80-95 |
| | S | 9 | * | 92.8 | 1.38 | 4.13 | 4.45 | 87-100 |
| N. Prealveolar length | N | 6 | | 83.7 | 1.02 | 2.50 | 2.99 | 79-86 |
| | S | 9 | | 85.3 | 1.16 | 3.50 | 4.10 | 80-93 |
| O. Postdental length | N | 10 | | 92.8 | 1.50 | 4.76 | 5.12 | 87-102 |
| | S | 10 | | 90.8 | 2.35 | 7.45 | 8.21 | 84-102 |
| P. Basioccipital width | N | 12 | | 32.6 | 0.50 | 1.73 | 5.31 | 30-36 |
| | S | 10 | | 34.0 | 0.71 | 2.26 | 6.65 | 29-37 |
| Q. Premaxilla width | N | 6 | | 34.6 | 0.87 | 1.95 | 5.64 | 32-40 |
| | S | 9 | | 35.1 | 0.76 | 2.24 | 6.78 | 32-38 |

*n- sample size
$\overline{X}$- mean
SE$\overline{X}$- standard error of mean
SD- standard devoation
CV- coefficient of variation
R- range
*- $p<0.05$

Table 4. Rostral and cranial measurements and brain case volume of bighorn rams, 5 years and older from northern (N) and southern (S) Alberta.

| Measurement | Pop. | ^x^n | $\overline{X}$ | SE$\overline{X}$ | SD | CV | R |
|---|---|---|---|---|---|---|---|
| W. Basisphenoid-crown height | N | 12 | 132.9 | 1.14 | 3.96 | 2.98 | 172-141 |
| | S | 10 | *142.1 | 3.04 | 9.63 | 6.78 | 125-156 |
| X. Occiput-frontal length | N | 12 | 150.6 | 1.09 | 3.80 | 2.52 | 144-155 |
| | S | 10 | *157.0 | 2.73 | 8.65 | 5.51 | 147-171 |
| Y. Rostral depth | N | 12 | 80.1 | 0.96 | 3.34 | 4.17 | 75-86 |
| | A | 10 | 82.5 | 1.14 | 3.60 | 4.36 | 78-88 |
| Z. Naso-cranial length | N | 10 | 228.0 | 1.62 | 5.12 | 2.24 | 220-235 |
| | S | 10 | *239.6 | 4.21 | 13.31 | 5.55 | 226-265 |
| AA. Supraorbital width | N | 12 | 156.3 | 1.00 | 3.47 | 2.22 | 152-162 |
| | S | 10 | 159.3 | 2.91 | 9.19 | 5.77 | 149-180 |
| BB. Occiput width | N | 12 | 67.6 | 0.95 | 3.29 | 4.86 | 63-74 |
| | S | 10 | 67.5 | 1.51 | 4.76 | 7.06 | 62-78 |
| Brain case volume | N | 14 | 223.2 | 3.04 | 11.37 | 5.09 | 205-240 |
| | S | 10 | *234.5 | 4.18 | 13.22 | 5.63 | 210-250 |

^x^n- sample size
$\overline{X}$- mean
SE$\overline{X}$- standard error of mean
SD- standard deviation
CV- coefficient of variation
R- range
*- $p<0.05$

3. Ewe Horns

The horn base circumference of southern ewes is notably larger than northern ewes, however, the difference is not significant at $P<0.05$ (Table 5). The annual increment length of southern ewes is longer in the first year ($P<0.05$) and shorter ($P<0.05$) in the third year compared to northern ewes (Table 6). This initial rapid growth followed by a reversal and vice versa has been noted by Shackleton (1973) in high and low quality ewe populations from Kootenay National Park and Banff National Park respectively.

4. Ram Horns

Horn bases of southern rams are larger ($p<0.05$) than northern rams (Table 5) as previously noted by Wishart (1969). Annual increment lengths are longer ($p<0.05$) in southern rams during the first four years (Table 7). However, a significant reversal in increment length compared to the northern rams occurs during the sixth and seventh years. This increment growth phenomenon between high and low quality populations in bighorn rams has also been noted by Taylor (1962), Geist (1971) and Shackleton (1973).

Table 5. Horn base circumferences of ewe and ram horns 5 years and older from northern (N) and southern (S) Alberta.

| Ewes | Pop. | [x]n | $\overline{X}$ | SE$\overline{X}$ | SD | CV | R |
|---|---|---|---|---|---|---|---|
| Left horn | N | 25 | 129.8 | 1.79 | 8.95 | 6.90 | 113-145 |
| | S | 21 | 134.8 | 2.23 | 10.25 | 7.60 | 116-153 |
| Right horn | N | 27 | 129.2 | 2.03 | 10.57 | 8.18 | 108-146 |
| | S | 19 | 133.3 | 2.18 | 9.53 | 7.15 | 115-151 |
| Rams | | | | | | | |
| Left horn | N | 15 | 365.3 | 3.44 | 13.32 | 3.65 | 345-400 |
| | S | 11 | *386.4 | 7.32 | 24.28 | 6.28 | 349-431 |
| Right horn | N | 14 | 365.5 | 2.94 | 10.99 | 3.01 | 345-390 |
| | S | 11 | *386.2 | 6.80 | 22.55 | 5.84 | 354-430 |

[x]Symbols as in previous tables.

Table 6. Mean lengths of the first three annual increments of ewe horns (left and right sides) from northern (N) and southern (S) Alberta.

| Increment | Pop. | $^{x}n$ | $\overline{X}$ | SE$\overline{X}$ | SD | CV | R |
|---|---|---|---|---|---|---|---|
| 1 | N | 57 | 46.1 | 2.24 | 16.91 | 36.68 | 20-80 |
| | S | 30 | *61.2 | 2.28 | 12.51 | 20.44 | 33-87 |
| 2 | N | 72 | 101.7 | 2.00 | 16.96 | 16.67 | 60-133 |
| | S | 34 | 103.4 | 3.11 | 18.11 | 17.52 | 74-143 |
| 3 | N | 81 | 61.7 | 1.28 | 11.50 | 18.64 | 28-86 |
| | S | 34 | *51.5 | 2.74 | 15.96 | 31.00 | 30-75 |

$^{x}$Symbols as in previous tables.

Table 7. Mean lengths of the first eight annual increments of ram horns (left and right sides) from northern (N) and southern (S) Alberta.

| Age | Pop. | $^{x}n$ | $\overline{X}$ | SE$\overline{X}$ | SD | CV | R |
|---|---|---|---|---|---|---|---|
| 1 | N | 36 | 82.2 | 4.84 | 20.53 | 24.99 | 50-130 |
| | S | 42 | *105.9 | 5.37 | 24.62 | 23.23 | 57-150 |
| 2 | N | 60 | 185.5 | 5.23 | 40.49 | 21.83 | 90-274 |
| | S | 49 | *206.5 | 5.24 | 36.71 | 17.78 | 130-295 |
| 3 | N | 68 | 176.8 | 2.52 | 20.80 | 11.78 | 133-213 |
| | S | 50 | *187.1 | 3.11 | 21.97 | 11.74 | 145-246 |
| 4 | N | 46 | 147.0 | 2.79 | 18.96 | 12.90 | 123-196 |
| | S | 32 | *156.5 | 2.89 | 16.35 | 10.44 | 136-188 |
| 5 | N | 29 | 119.7 | 3.11 | 16.75 | 14.00 | 91-163 |
| | S | 26 | 118.7 | 3.10 | 15.81 | 13.32 | 98-163 |
| 6 | N | 30 | 99.2 | 2.71 | 14.85 | 14.97 | 71-121 |
| | S | 18 | *88.4 | 4.02 | 17.05 | 19.29 | 71-130 |
| 7 | N | 22 | 80.3 | 3.26 | 15.31 | 19.11 | 54-108 |
| | S | 12 | *64.8 | 4.89 | 16.94 | 26.13 | 31-87 |
| 8 | N | 19 | 59.9 | 4.16 | 18.16 | 30.29 | 28-90 |
| | S | 8 | 50.4 | 4.32 | 12.21 | 24.24 | 37-67 |

$^{x}$Symbols as in previous tables.

Table 8. Summary table of skull and horn measurements that show significant difference (*p<0.05) between northern (N) and southern (S) Alberta bighorns. S>N unless otherwise noted by (N).

| | Ewes | Rams |
|---|---|---|
| A. Basilar length | * | n.s. (not significant) |
| F. Maxillary width | * | n.s. |
| K. Palatal length | n.s. | * |
| L. Upper molar length | * | * |
| M. Lower molar length | * | * |
| W. Basisphenoid-crown height | * | * |
| X. Occiput-frontal length | * | * |
| Y. Rostral depth | * | n.s. |
| Z. Naso-cranial length | * | * |
| AA. Supraorbital width | * | n.s |
| BB. Occiput width | * | n.s |
| Brain case volume | n.s. | * |
| Horn base circum. | n.s. | * |
| Horn increment length | | |
| 1 | * | * |
| 2 | n.s. | * |
| 3 | * (N) | * |
| 4 | - | * |
| 6 | - | * (N) |
| 7 | - | * (N) |

## DISCUSSION

In mountain sheep, population quality has been defined in terms of horn size of rams by various authors (op. cit). This study has shown that in addition to horn size there are a number of skull characters in bighorns that can be used to note differences in population quality (Table 8). Skull features that are significantly larger in both sexes of southern Alberta bighorns are the upper and lower molar series, occiput-frontal length, basisphenoid crown height and naso-cranial length. The ewes have five additional skull characters that are significantly larger than the northern group: basilar length, maxillary width, rostral depth, supraorbital width and occiput width. Rams have significantly longer palates; there was no overlap in this measurement between the two population samples. The results of this study are similar to a population quality study of bighorn skulls by Shackleton (1973). He noted that cranial and facial development are correlated with prepartum and postpartum nutrition respectively. Rapid cranial development and delayed facial development are characteristic of most mammalian species. This skull growth sequence has been described by Cowan (1936) in deer (Odocoileus) and by Hutton (1972) in wapiti (Cervus). In this study, several anterior and posterior measurements of the skull were found to be larger in southern Alberta bighorns. Five of these measurements are significantly larger and common to both sexes (Table 8) and they provide a better measure of population quality than brain case volume which differed only in rams.

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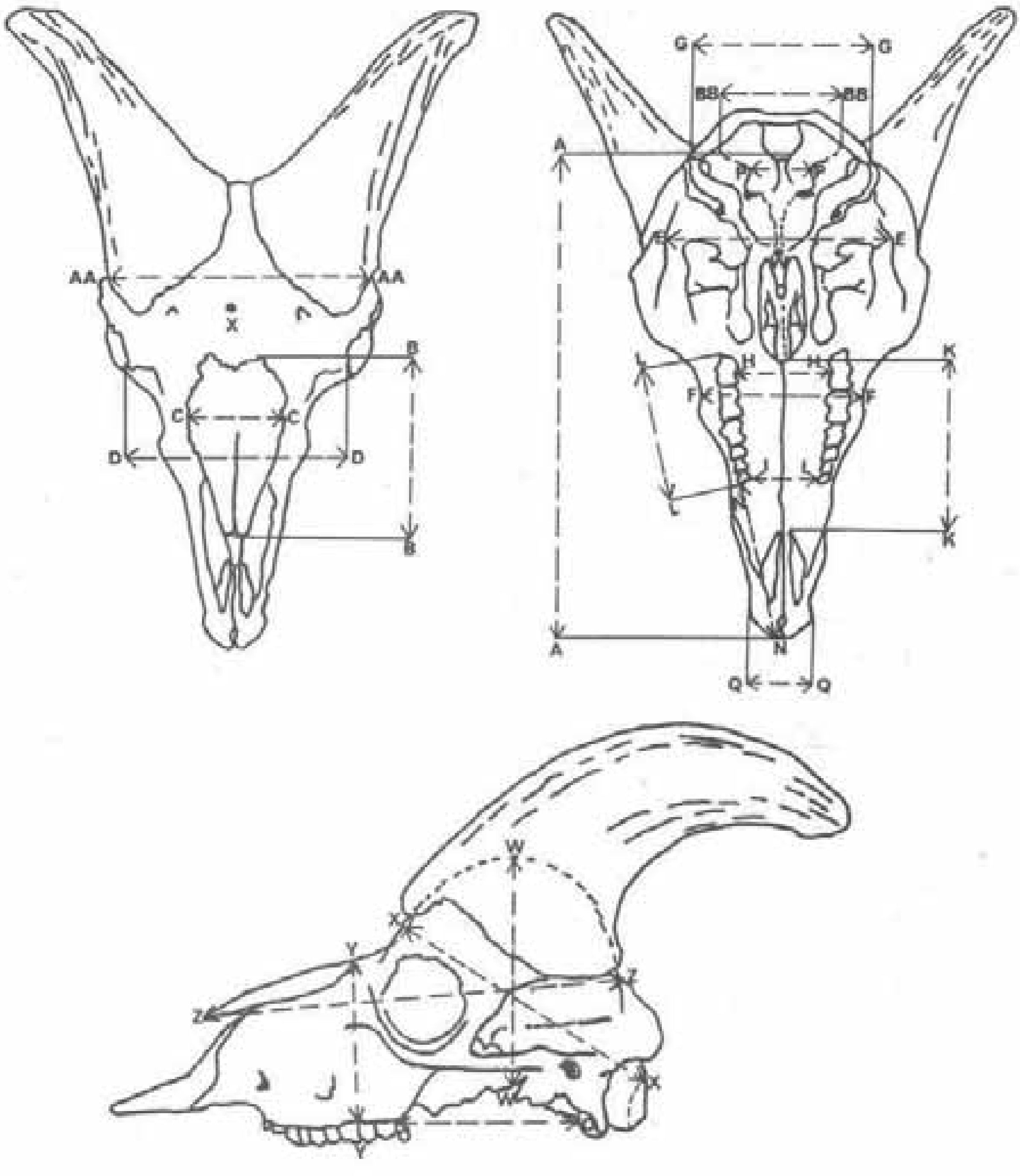


Figure 1. Reference points for 21 measurements taken of bighorn skulls (after Shackleton 1973).

## APPENDIX I

### Definition of Skull Measurements from Cowan (1940)

A Basilar length: Greatest distance between inferior lip of foramen magnum and tip of premaxillae on mid-line.

B Greatest length of nasals: Greatest distance from anterior margin to posterior margin of left nasal unless this is broken or otherwise malformed.

C Width of nasals: Greatest combined width of nasals.

D Orbital width: Least distance in straight line taken with calipers resting in notch on orbital rim at lower edge of lachrymal bone.

E Zygomatic width: Greatest distance between external margins of zygomatic arches taken on jugo-squamosal suture.

F Maxillary width: Least distance across rostrum behind maxillary protuberances.

G Mastoid width: Greatest distance across occiput with calipers resting on external (lateral) surfaces of paroccipital processes.

H Palatal breadth at $M^3$: Greatest distance across palate with calipers resting in re-entrant notch on lingual side of $M^3$.

I Palatal breadth at $Pm^2$: Least distance across palate between alveoli of first premolar.

J Post-palatal width: Least palatal width posterior to third upper molars.

K Palatal length: Least distance from posterior margin of anterior palatine foramen to posterior margin of palate.

L Upper molar series or upper tooth row: Greatest alveolar length of combined upper molars and premolars.

M Lower molar series: Greatest alveolar length of combined lower molars and premolars.

N Prealvolar length: Least distance between alveolus of second upper premolar (first tooth of upper series) and gnathion.

O Post dental length: Least distance between alveolus of third upper molar and anterior margin of paroccipital process on same side.

P Width of basioccipital: Least width of this element between foramina ovale.

Q Width of premaxillae: Greatest width of combined premaxillae opposite anterior end of anterior palatine foramina.

Definition of Rostral Cranial Measurements from Schackleton (1973)

(W) Basisphenoid - crown height: Greatest distance between the highest point of the crown between the horn cores, and the point on the basisphenoid near its junciton with the presphenoid.

(X) Occiput - frontal length: Least distance between the superior lip of the foramen magnum and the center of the frontals in line with the two frontal foramina.

(Y) Rostral depth: Vertical distance between the point on the midline of the palatines, opposite to the junction of the second and third upper molars, and the mid-point of the nasal suture.

(Z) Naso - cranial length: Least distance between the midline of the anterior end of the nasals and the depression of the parieta parietals in adult males or to the parietal crest in females and juveniles.

(AA)Supraorbital width: The least width, superior to the orbits but inferior to the lip of the horn cores, across the cranium.

(BB)Occiput width: Greatest width across the occipital condyles at right angles to the longitudianl axis of the skull.

CONFERENCE DISCUSSION

Q. Do they have big horns because they have big brains or big brains because they have big horns?

ANS. It appears that big brains and big horns in rams are synonymous, they need that large brain area or cranial area to support large horns, so it follows that the brain capacity would also approach a large size.

Q. I liked your paper but can you really assure us that those differences are not genetic?

ANS. I guess what I would like to do to show that the differences are not entirely genetic is to bring northern bighorns down to the south as lambs and watch them grow. Actually, there is already that sort of evidence from captive flocks: for example, at the University of British Columbia and the Penticton Game Farm they brought in sheep from various parts of Alberta and B.C. and generally they all grew large on an ad libitum diet. However, there are enough individual differences in the species that some animals will respond differently to an unlimited forage supply. I tried to demonstrate that the growth rates, i.e., the chance to grow was much better in the chinook belt of southern Alberta. If you trap an animal down there in February or March you will find a 2-3 year old ram will have 2 to 3 inches in new horn growth. I can't believe that a northern ram under those circumstances wouldn't also have a 2 to 3 inch jump in horn growth vs. putting a southern ram up north, into a longer, colder winter in an alpine situation.

Q. I don't know if anybody has looked at this, and Ken, you may know that in Colorado we have a similar situation only it's tied to elevation. We have probably a dozen rams that could be found within a couple of days with horns better than full curl pushing 40 inches in low elevation herds around the states and the herds that tend to range above timberline in the alpine areas tend to have horns significantly shorter. In a similar situation relative to the amounts of growth at different times, the hypothesis which has been raised a number of times is that the lower elevation rams are growing horns for 2 to 3 to 4 months longer a year than are the rams at the higher elevation. Very commonly in some of the sheep areas in the southwest where rams from the high mountain areas and a lower elevation area have to be checked through the same game warden, animals of the same age will have 3 to 5 inches difference in horn length and body size differences as much as 30 or 40 or 50 pounds. Does elevation tie into what you are doing at all?

ANS. Elevation is tied in with latitude, right. In this study I have compared lower latitude sheep to higher latitude sheep. Meteorologically we use a 1,000 foot elevation as equivalent to about 150 miles in latitude so it ties in very well. In some situations we grow very large rams that have discovered new low elevation ranges that have been recently logged or burned.

Q. Bill, you have been threatening to transplant your northern and southern bighorns for about 10 years, I just wonder why you haven't done it yet?

ANS. Why haven't I done it? I don't think I have to, but I might have to for this group.

Q. We have been measuring horns for a number of years from the entire Yukon, and we cannot generalize that the horns are poorer in the north. There are populations which are very poor in the north but we also have very good populations in the north. What we did find, though, is that very often in the north the growth was delayed and very often the third increment was largest when in the south it was almost always the second increment.

ANS. That is similar to the growth-increment phenomenon between high-and low-quality populations in bighorns.