PRECIS C4072 - 114

AUTHOR AND TITLE

Stelfox, John G., and David M. Poll, 1978. Weights, measurements and tooth replacement of Rocky Mountain Bighorn Sheep in Canadian national parks, 1967-71.

CONTRACT

This study was conducted by the Canadian Wildlife Service and supporting by Parks Canada in accordance with the EMS/Parks Canada Agreement.

PURPOSE AND OBJECTIVES

The purpose of this report is to compare body and skull measurements plus weights of Rocky Mountain bighorn sheep in Jasper, Banff, Kootenay and Waterton Lakes National Parks.

RESULTS

The report provides information on live weights and body measurements plus tooth replacement of wild sheep in Jasper, Banff, Waterton Lakes and Kootenay National Parks. Results are compared with those reported for Desert and Dall's sheep. Detailed results may be found on pages 13-31.

CONCLUSIONS

Measurements of Jasper rams compared with those in Waterton support the principle that with increasing latitude there is a decrease in the mass-to-surface-area ratio. Horn measurement and skull weight data indicate that Waterton rams have shorter but more massive horns than Jasper rams with Banff rams having the smallest horn measurements.

David Reynolds
Assist. Resource Studies Manager
July 4, 1978

Weights, Measurements and Tooth Replacement of Rocky Mountain Bighorn Sheep in Canadian National Parks, 1967-1971

by

John G. Stelfox

and

David M. Poll

Prepared for Parks Canada

by the

Canadian Wildlife Service

Edmonton, 1978

Your file Votre dossier

Environment Canada | Environnement Canada
Environmental Management | Gestion de l'environnement

Our file Notre dossier WLU 200 - Sheep

1110, 10025 - Jasper Avenue
Edmonton, Alberta
T5J 1S6

Canadian Wildlife Service | Service canadien de la faune

March 8, 1978

Mr. W.C. Turnbull
Director, Parks Canada
Western Regional Office
131 Customs Building
134 - 11th Avenue S.E.
CALGARY, Alberta
T2G 0X5

Dear Sir:

Attached herewith, is a report "Weights, Measurements and Tooth Replacement of Rocky Mountain Bighorn Sheep in Canadian National Parks, 1967-1971" by John G. Stelfox and David M. Poll. This study was part of the CWS Parks Research function, funded by Parks Canada.

The report provides information on live weights and body measurements plus tooth replacement of wild sheep (*Ovis canadensis canadensis*) in Jasper, Banff, Waterton Lakes and Kootenay National Parks. Results are compared with those reported for Desert *(Ovis canadensis nelsoni)* and Dall's *(Ovis dalli dalli)* sheep.

The senior author cooperated with the Warden Services of the above parks in the collection of data for this report during the period 1966-1971. The assistance of the Warden Service was invaluable and is gratefully acknowledged.

Information provided in this report should be of value to Parks Canada Interpretive Service and academically to various research agencies.

Yours sincerely,

M.R. Robertson
Regional Director

Encl.

ABSTRACT

Live weights, body measurements and tooth replacement by Rocky Mountain bighorn sheep (*Ovis canadensis canadensis* Shaw) were obtained from Jasper, Banff, Waterton Lakes and Kootenay National Parks for the period 1966-1971. The study was a cooperative project between the Canadian Wildlife Service and the Warden Service of each park. Information was obtained seasonally and the results compared to those reported for Desert (*Ovis canadensis nelsoni)* and Dall's *(Ovis dalli dalli)* sheep

Prime mature rams (6.5 yrs.+) in fall averaged 125.4 kg live weight and 127.4 cm chest girth. There was an average overwinter weight loss of 16.8% and a 7.1% decrease in chest girth. Mature ewes (4.5 yrs.+) in prime fall condition averaged 71.9 kg (57.3% as heavy as rams) with a chest girth of 115.3 cm. Jasper ewes were heavier in fall than ewes in Banff and Waterton Lakes but lighter in spring, indicating a greater overwinter weight loss due to high stocking rates on less-productive ranges and higher endoparasite loads.

Mean fall weights of Rocky Mountain bighorn rams and ewes were 66.9% and 50.7% greater, respectively, than fall weights of desert rams and ewes and 58.4% and 35.2% greater, respectively, than Dall's rams and ewes.

Waterton Lakes rams have shorter but more massive horns than Jasper rams with Banff rams having the smallest horn measurements. Jasper sheep attained a full complement of permanent incisors at an earlier age than sheep in Waterton.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION AND LITERATURE REVIEW

The purpose of this report is to compare body and skull measurements plus weights of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis* Shaw) hereafter referred to as bighorn sheep, among the National Parks of Jasper, Banff, Waterton Lakes and Kootenay, hereafter referred to as Jasper, Banff, Waterton and Kootenay (Figure 1). A second objective is to present information on tooth replacement to enhance the limited information presented in other references.

Previously, data on weights and growth of bighorn sheep in Alberta were presented by Cowan (1940), and Blood *et al.* (1970) while a few horn measurements for Banff were presented by Green (1949). Correlations among body weights, winter range forage production, ungulate stocking rates, lungworm loads and winter weight losses of sheep in western Alberta were discussed by Stelfox and McGillis (1970). Shackleton (1973) compared horn and skull growth rates for an expanding population in Kootenay compared to a static population in Banff.

Weights and measurements of desert sheep (*Ovis canadensis nelsoni)* were presented earlier by Aldous *et al.* (1958), Baker and Bradley (1965) and for Dall's sheep (*Ovis dalli dalli)* by Bunnell and Olsen (1976), Heimer and Smith (1975). Information on weights and measurements of snow sheep *(Ovis nivicola)* in Russia was presented by Cherniavski (1962).

Reports on tooth replacement and incisiform development have been presented by Deming (1952), Blood (1966) and Hemming (1967).

Although the above reports contain considerable information on skull and body weights and measurements plus tooth replacement, sample sizes for bighorn sheep reports were generally small, while variability among age classes was high. It is hoped that this report adds substantially to existing knowledge, especially in the comparison of results among the four national parks.

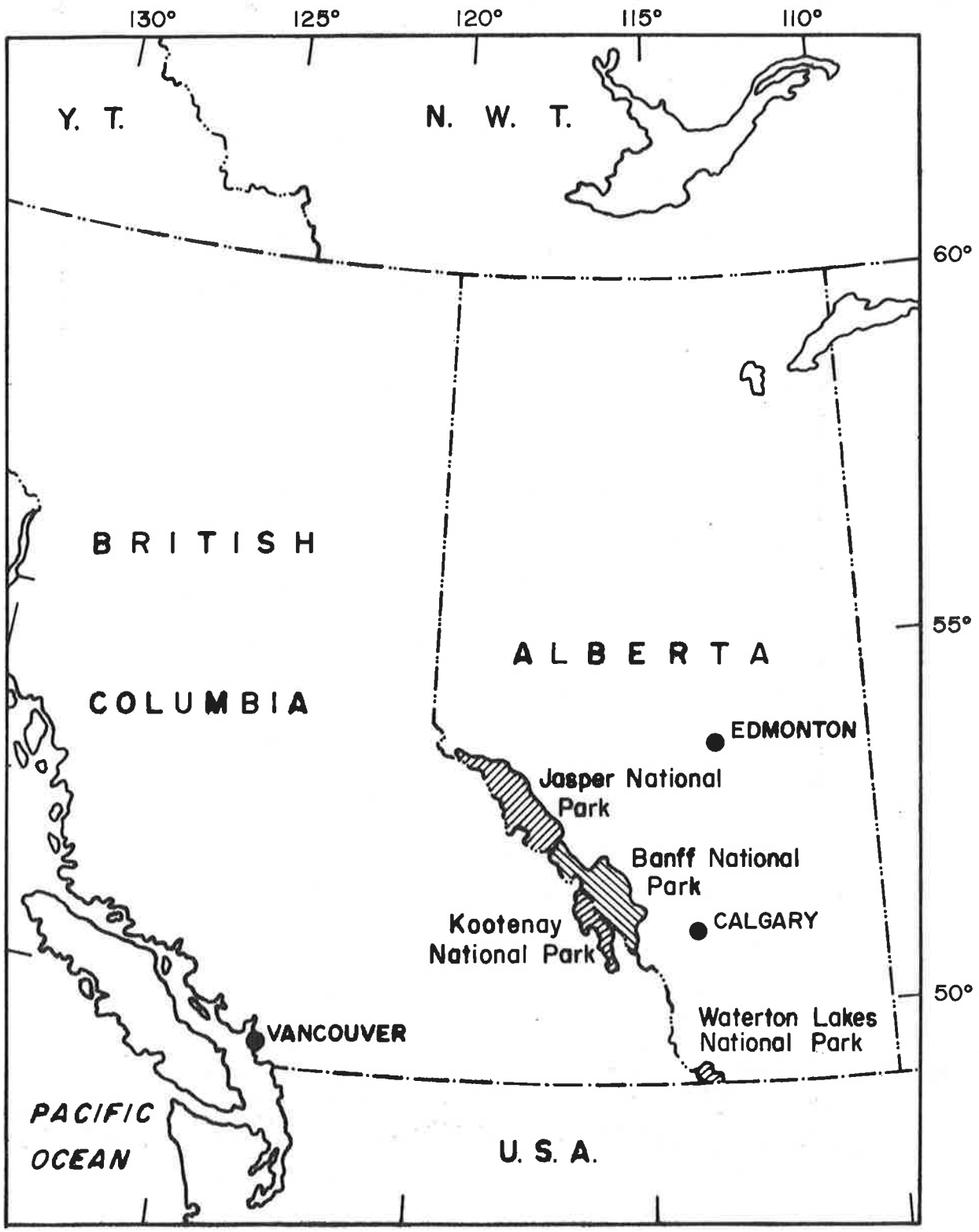


Figure 1. Locations of Jasper, Banff, Kootenay, and Waterton Lakes National Parks within the northern Rocky Mountains.

2.0 METHODS

2.1 Weights and Measurements

Body weights and external measurements were taken of corral-trapped sheep at Mt. Galwey in Waterton Lakes, Radium in Kootenay, Flint's Park and Mile 5 in Banff, and Windy Point in Jasper national parks. Similar data were obtained from sheep immobilized with drugs (Figure 2), from road and railway-killed cadavers, and from specimens sacrificed for the disease-parasite study (Stelfox 1976).

Body measurements included chest girth, horn length and base, total body length, shoulder height, hind foot, ear and tail lengths (Figure 3). Body weight and chest girth data were classified according to the seasons of Fall (Oct-Dec), Winter (Jan-Mar), Spring (Apr-Jun), and Summer (Jul-Sept).

The date used to separate the age classes of bighorn sheep was June 1 which was the peak of parturition.

2.2 Skeletal Measurements

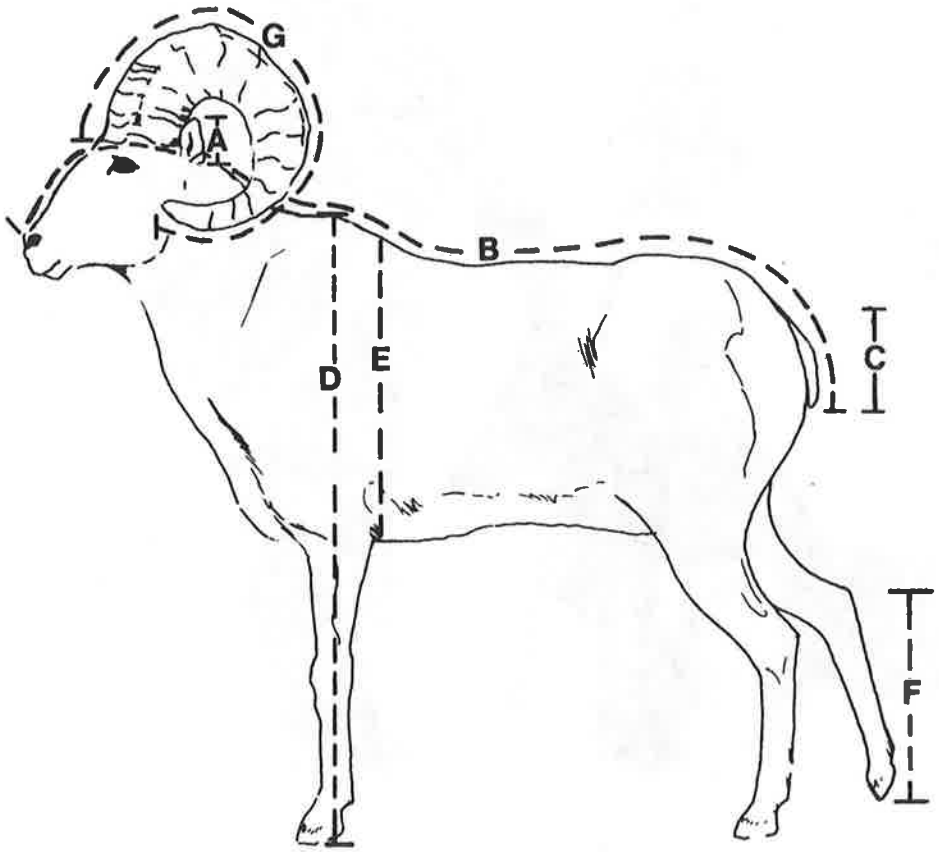
Skull measurements were taken of cleaned skulls according to Cowan (1940) and Shackleton (1973). Measurements taken were:

- Basilar length
- Nasal length
- Orbital width
- Zygomatic width
- Maxillary width
- Mastoid width
- Palatal breadth (M^3)
- Palatal breadth (Pm^2)
- Upper Molar series (length)
- Prealveolar length
- Postdental length

In addition to these skull measurements in millimetres (mm), the following horn measurements were taken:

1. Length of outside curve
2. Basal circumference
3. Annual increments
4. Tip to tip distance

Figure 2. Weighing bighorn sheep, Jasper National Park, February 1969.



A Ear length
B Total length
C Tail length
D Height at shoulder
E Chest girth: circumference of chest taken behind shoulder
F Hind leg
G Horn length and base

Figure 3. Body measurements taken on bighorn sheep.

Figures 4 and 5 illustrate how skull measurements were taken.

Skull and body weights were also taken. The field sheet used to record this data is shown in Figure 6.

Definitions for various skull measurements are as follows (Cowan, 1940):

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

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

Width of nasals: Greatest combined width of nasals.

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

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

Maxillary width: Least distance across rostrum behind maxillary protuberances.

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

Palatal breadth at M^3: Greatest distance across palate with calipers resting in re-entrant notch on lingual side of M_3.

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

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

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

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

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

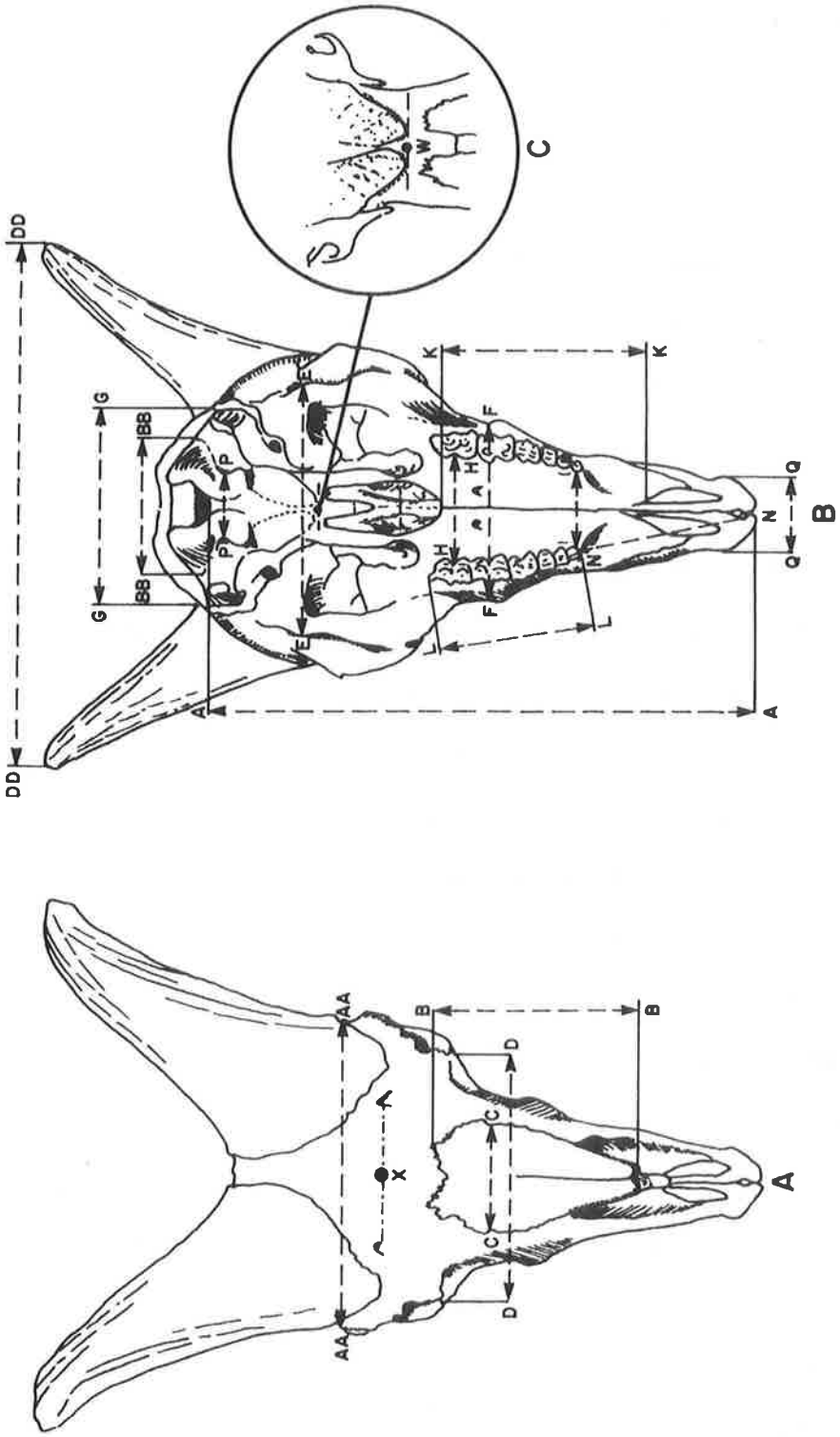


Figure 4. Skull measurements taken on bighorn sheep (from Shackleton 1973).

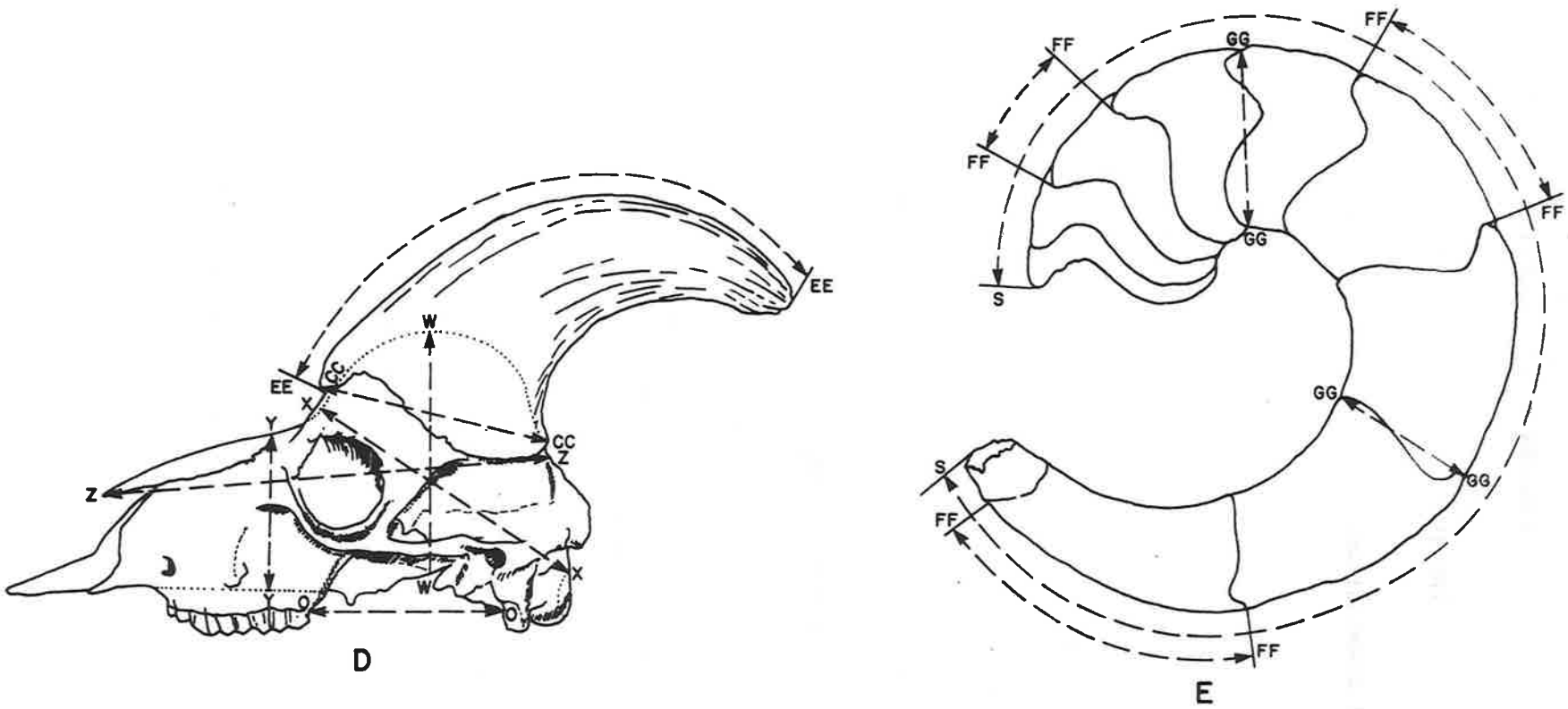


Figure 5. Points of reference for taking skull and horn measurements (from Shackleton 1973).

BIGHORN AUTOPSY SHEET

No. Species: Sex: Age:

Date of examination: ♀ Lamb at heel: Yes No
Lactating: Yes No
Length of teats:

Owner: Date of death:

Address: Cover type:

A. Condition

Kidney weight: Kidney fat: Fat/kidney ratio:

Femur marrow (% fat): Condition rating:

B. Weights and measurements (kg. & mm.)

Live weight: Bled weight: Eviscerated weight:

Dressed weight: Total length: Heart girth:

Height at shoulder: Hind leg: Ear: Tail bone:

Horn length (outer curvature): Basal circumference: Tip-to-tip:

Maximum spread: Horn increments: Burl:

Rump fat depth: Lens weight:

Figure 6. Field taxonomic sheet for recording body, skull and horn data.

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

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

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

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

Circumference of horn: Least circumference of base of right and left horns measured on an even plane touching the part of the margin farthest removed from the skull.

Length of horn: Measured round the spiral from orbital corner to tip of horn unless it is malformed.

Spread of horns (Tip to tip): Greatest distance between tips of horns.

Specimens were aged by examining tooth replacement up to the age of 3.5 years, after which ewes were classed as 4.5+ years.

Rams 3.0 years and older were aged by counting the horn annuli (Geist 1966).

Skull measurements were taken to the nearest millimetre using lock-joint outside calipers and steel rules. Horn measurements were taken to the nearest mm using a 0.25 cm wide steel tape. Skull weights were taken to the nearest milligram (mg) whereas body weights were taken to the nearest gram (gm).

2.3 Tooth Replacement

Dentition and tooth replacement data were recorded for the mandibular teeth only. The dental formula is:

$$I - \frac{0}{3},\ C - \frac{0}{1},\ Pm\ \frac{3}{3},\ M\ \frac{3}{3} \times 2 = 32.$$

The pattern of tooth replacement was determined by observing the sequence of events by which deciduous incisors and premolars were replaced by permanent teeth plus the successive eruption of the molars.

Bighorn sheep have a typical bovid dental pattern with no upper incisiform teeth. The upper maxillary bone contains 6 premolars and 6 molar teeth when mature. The lower mandible consists of 6 incisors, 2 canines, 6 premolars, and 6 molar teeth when mature.

Ages were also determined by counting cementum layers of the

3.0 RESULTS

3.1 Body Weights and Measurements; Banff, Jasper, Kootenay, and Waterton Lakes national parks

Fall and spring body weights and chest girths of rams and ewes for the four parks indicate that mature rams (6.5 yrs.+) in fall averaged 125.4 kg live weight and 127.4 cm chest girth (Table 1). By spring, these values declined to 104.3 kg and 118.4 cm indicating an overwinter weight loss of 16.8% and a 7.1% decrease in chest girth. Banff fall weights were slightly, but not consistently, larger than Jasper weights with an inadequate sample size from Banff to permit statistical analysis. No mature fall ram weights were available from Waterton and Kootenay.

Mature ewes (4.5 yrs.+) in fall averaged 71.9 kg live weight and 115.3 cm chest girth or 57.3% as heavy as rams (Table 1). Jasper ewes were heavier than ewes from Banff and Waterton in fall.

Aldous *et al.* (1958) compared with live weights of bighorn sheep from Canadian National Parks in Alberta to the desert sheep in Nevada and found bighorn rams and ewes to be consistently larger than their counterparts. The live weights and girth measurements of Aldous (1958) compare closely with those from this study. Blood *et al.* (1970) compared live weights of bighorn sheep with California (*O. c. california*), desert and Mexican (*O. c. mexicana*) sheep. They did not compare seasonal weights of mature sheep but did examine monthly weight and hind foot values for lambs up to 1 year of age. They concluded that bighorn lambs grew rapidly from

Table 1. Seasonal weights of 235 bighorn sheep in Banff, Jasper, Kootenay and Waterton Lakes national parks, October 1966 to January 1972.

Age	Whole Weights (kg) & Chest Girth (cm)									
	Jasper		Waterton		Banff		Kootenay*		Averages	
	Wt.	Girth	Wt.	Girth	Wt.	Girth	Wt.	Girth	Wt.	Girth
					RAMS					
	**		Fall - early Winter (October-January)							
Lambs (<0.5)	$13.9\surd^{2}$	-	-	-	-	-	$6.8\surd\surd^{1}$	-	-	-
Lambs (0.5)	31.4^{5}	82.0	33.1^{2}	78.0	35.4^{3}	90.4	17.0^{2}	-	29.3	93.2
1.5	58.2^{5}	105.2	-	-	61.4^{3}	106.7	42.4^{2}	-	54.6	106.0
2.5	80.4^{6}	111.8	-	-	78.5^{1}	116.8	61.1^{4}	113.03^{2}	72.7	114.3
3.5	97.5^{1}	115.6	-	-	90.3^{1}	124.5	-	-	93.9	120.1
5.5	101.4^{2}	121.4	-	-	-	-	-	-	101.4	121.4
6.5+	122.4^{5}	127.8	-	-	128.4^{2}	127.0	-	-	125.4	127.4
					Spring (February-May)					
Lambs (0.9)	34.7^{1}	82.6	33.8^{6}	77.0	40.8^{1}	89.9	$(36.3^{2})\Omega$	(84.2)	36.4	83.2
1.8	50.1^{4}	96.0	49.5^{7}	84.6	60.3^{1}	-	56.7^{1}	109.2	54.2	96.6
2.8	-	-	72.6^{4}	104.9	-	-	69.2^{2}	113.0	70.9	109.0
3.8	-	-	87.6^{6}	112.0	83.5^{1}	-	-	-	85.6	112.0
4.8	-	-	87.5^{3}	110.5	-	-	-	-	87.5	110.5
5.8	-	-	103.6^{3}	114.1	100.2^{2}	115.6	-	-	101.9	114.9
6.8+	-	-	104.3^{6}	118.4	-	-	-	-	104.3	118.4
					EWES					
Lambs			Fall - early Winter (October-January)							
(20-30 days)	10.8^{2}	-	-	-	-	-	-	-	-	-
Lambs (0.5 yr)	30.0^{6}	84.3	-	-	28.4^{2}	83.1	22.7^{4}	85.1	27.7	84.2
1.5	51.1^{3}	92.9	-	-	48.9^{1}	102.9	47.6^{1}	-	49.2	97.9
2.5	-	-	-	-	65.3^{1}	106.7	53.1^{2}	-	58.8	106.7
3.5	69.9^{3}	112.3	65.3^{3}	101.7	-	-	57.9^{4}	107.7	60.8	103.7
4.5+	$76.6^{1\,2}$	115.3	75.3^{6}	110.8	71.6^{8}	118.4	60.1^{16}	113.2	71.9	115.3
					Spring (February-May)					
Lambs (0.9)	27.8^{3}	81.8	33.5^{8}	85.1	-	-	(28.6^{3})	(78.1)	30.0	83.5
1.8	39.2^{2}	87.1	52.6^{7}	94.7	52.2^{4}	99.3	-	-	48.0	93.7
2.8	59.8^{2}	99.3	59.9^{5}	100.6	-	-	-	-	59.9	99.95
3.8	61.1^{8}	104.6	68.5^{3}	104.9	-	-	54.9^{5}	107.9	63.8	104.8
4.8+	61.9^{3}	101.9	$64.4^{1\,3}$	102.1	-	-	$(66.3)^{6}$	(107.7)	62.0	101.96

* 1966-67
**Sample size
$\surd$ 20-30 days
$\surd\surd$75 days (Aug. 67)
Ω ( ) Weights taken in 1972

birth to a weight of 70 lb (31.8 kg) in October with little increase during their first winter. Our results indicated that ram lambs averaged 29.3 kg compared to 27.7 kg for ewe lambs in late fall (Table 1). By spring, ram lambs weighed 36.4 kg and ewe lambs 30.0 kg, an increase of 24.3% for ram lambs and 8.3% for ewe lambs.

Their average spring weight of 207 lb (94.0 kg) for 54 bighorn rams (4 yrs.+) for the period 1955 to 1965 is 6.1% less than the average spring weight (220.4 lb, 100.1 kg) we obtained for 12 comparable rams from the same area (Waterton) during 1966 to 1970. However, their average spring weight of 159 lb (72.2 kg) for bighorn ewes is 14.6% greater than our average of 138.6 lb (63.0 kg) for 42 ewes.

Maximum weights of rams and ewes were 301 lb (136.7 kg) and 191 lb (86.7 kg) respectively for Jasper bighorn sheep in November.

Standard body measurements of rams and ewes for Jasper, Banff, Waterton and Kootenay are presented in Tables 2a and 2b, while a comparison of live weights among the parks and with other subspecies is presented in Table 3.

The mean fall weight for 39 bighorn rams of 118.2 kg (our study plus Aldous *et al.* 1958) WAS 66.9% greater than that reported for desert rams (Aldous *et al.* 1958) and 58.4% greater than for Dall's rams (Bunnell and Olsen 1976). The mean yearlong weight for 108 mature bighorn ewes of 66.0 kg was 50.7% greater than for desert ewes and 35.2% greater than for Dall's ewes (Table 3). It was not possible to conduct standard deviation and analysis of variance tests on these differences as individual weights were not available from the other references.

Table 2a. Body measurements of bighorn rams in Jasper, Banff, Waterton Lakes and Kootenay national parks (1967-1970).

Park	Sample size	Measurements (cm)						
		Horn length	Horn base	Total length	Shoulder height	Hind foot	Ear length	Tail length
				Lambs (0-0.5 yr)				
Jasper	5	8.6	9.4	130.3	71.6	36.6	9.4	5.8
Banff	1	1.3	-	107.95	62.9	27.9	8.9	6.1
Waterton	2	9.4	8.4	135.4	-	35.3	-	-
Kootenay	1 (2-3 wks)	0.0	0.0	72.4	48.9	24.8	-	-
				Lambs (0.5-1.0 yr)				
Jasper	1	15.0	12.2	124.5	79.5	37.6	8.9	7.1
Banff	-	-	-	-	-	-	-	-
Waterton	6	13.2	11.2	134.9	77.5	37.3	10.7	5.1
Kootenay	-	-	-	-	-	-	-	-
				Yearlings (1.0-2.0 yr)				
Jasper	4	34.0	18.5	153.2	83.6	41.4	10.2	7.4
Banff	-	-	-	-	-	-	-	-
Waterton	7	30.7	20.8	155.7	91.2	41.9	10.9	7.6
Kootenay	-	-	-	-	-	-	-	-
				Two-year olds (2.0-2.5 yr)				
Jasper	-	-	-	-	-	-	-	-
Banff	1	24.8	16.5	152.4	91.4	41.9	10.8	12.7
Waterton	-	-	-	-	-	-	-	-
Kootenay	-	-	-	-	-	-	-	-
				2.5 to 3.0 yr				
Jasper	5	52.1	31.8	162.6	94.0	44.2	10.4	9.9
Banff	1	57.5	30.5	172.7	94.6	41.3	10.8	-
Waterton	4	45.0	28.2	169.4	90.4	45.2	10.9	8.9
Kootenay	3	48.1	-	172.9	103.3	44.0	-	-
				3.0 to 3.5 yr				
Jasper	-	-	-	-	-	-	-	-
Banff	2	39.7	25.4	162.6	94.7	43.5	11.1	-
Waterton	-	-	-	-	-	-	-	-
Kootenay	2	46.2	-	173.7	104.8	44.5	-	-

Table 2a. Continued.

Park	Sample size	Horn length	Horn base	Total length	Shoulder height	Hind foot	Ear length	Tail length
				3.5 to 4.0 yr				
Jasper	1	66.3	38.9	181.6	94.0	43.9	11.4	10.9
Banff	-	-	-	-	-	-	-	-
Waterton	6	63.8	36.8	178.6	98.8	43.9	10.2	8.9
Kootenay	-	-	-	-	-	-	-	-
				4.0 to 5.0 yr				
Jasper	-	-	-	-	-	-	-	-
Banff	1	68.9	35.6	172.7	102.9	44.5	10.8	-
Waterton	3	73.2	39.4	164.3	102.9	44.7	10.9	7.6
Kootenay	-	-	-	-	-	-	-	-
				5.0 yr +				
Jasper	9	89.9	38.6	180.8	98.3	44.2	10.4	8.6
Banff	3	82.6	36.5	182.5	110.5	44.3	10.8	-
Waterton	9	90.2	40.1	185.7	105.4	45.2	11.2	9.1
Kootenay	-	-	-	-	-	-	-	-

Table 2b. Body measurements of bighorn ewes in Jasper, Banff, Waterton Lakes and Kootenay national parks, 1967-1970.

Location	Sample size	Horn length	Horn base	Total length	Shoulder height	Hind foot	Ear length	Tail length
				Lambs (0-0.5 yr)				
Jasper	5	6.1	6.9	122.9	71.9	34.5	8.6	6.4
Banff	1	0.8	-	111.8	57.7	30.5	8.9	6.1*
Waterton	0	-	-	-	-	-	-	-
Kootenay	0	-	-	-	-	-	-	-
				Lambs (0.5 to 1.0 yr)				
Jasper	3	6.9	7.1	133.1	70.9	36.1	9.9	7.1
Banff	0	-	-	-	-	-	-	-
Waterton	6	9.1	8.1	136.9	75.2	37.3	10.4	7.1
Kootenay	1	3.8	-	124.5	79.4	34.3	-	-
				Yearlings (1.0 to 1.5 yr)				
Jasper	0	-	-	-	-	-	-	-
Banff	6	12.6	10.1	136.0	76.1	37.5	9.7	9.3
Waterton	0	-	-	-	-	-	-	-
Kootenay	-	-	-	-	-	-	-	-
				Yearlings (1.5 to 2.0 yr)				
Jasper	2	18.03	11.2	136.4	80.5	36.6	10.2	8.6
Banff	-	-	-	-	-	-	-	-
Waterton	7	16.8	11.7	153.4	88.4	40.6	10.9	8.1
Kootenay	-	-	-	-	-	-	-	-
				Two-year-olds (2.0 to 3.0 yr)				
Jasper	2	21.1	13.2	147.6	84.6	39.4	9.9	7.4
Banff	4	16.1	11.1	148.6	81.3	39.2	10.8	-
Waterton	5	21.1	13.0	158.2	82.6	40.4	10.9	-
Kootenay	1	23.2	-	156.8	-	40.6	-	-
				Adults (3.0 + yr)				
Jasper	11	23.4	12.4	160.8	87.6	40.1	10.7	7.1
Banff	10	23.0	13.2	157.9	85.4	39.5	11.1	-
Waterton	16	23.4	12.7	162.6	87.6	41.2	10.9	7.4
Kootenay	11	21.9	12.1	163.1	92.8	40.0	-	-

*(0.1 year)

Table 3. Weights and measurements of mature rams (5 yrs.+) and mature ewes (3 yrs.+) of *O. c. canadensis* in national parks in Alberta, *O. c. dalli* in Kluane National Park, and *O. c. nelsoni* in Nevada.

Sex	Season	Subspecies	Sample size	Live wt (kg)	Chest girth (cm)	Shoulder ht. (cm)	Hind foot (cm)	Total length (cm)
Rams	Fall	*O.c.nelsoni**	33	70.8	100.3	91.9	37.3	145.0
Rams	"	*O.c.canad.**	18	119.1	124.2	101.6	44.7	183.1
Rams	"	*O.c.canad.***	21	117.4	125.4	104.7	44.6	183.0
Rams	Yearlong	*O.d.dalli****	6	74.6	115.9	102.6	39.9	163.3
Ewes	"	*O.c.nelsoni**	15	43.8	90.7	84.8	34.3	-
Ewes	"	*O.c.canad.**	60	66.7	107.2	87.6	40.6	162.1
Ewes	"	*O.c.canad.***	48	65.2	107.6	88.4	40.2	161.1
Ewes	"	*O.d.dalli****	9	48.8	108.5	-	37.1	152.6

* from Aldous *et al.* 1958
** this study
***from Bunnell and Olsen 1976.

Table 4. Statistical comparisons by season of bighorn ewe (3.5 yr.+) weights, total lengths and chest girths among Jasper, Banff and Waterton.

Park	n	Live weights (kg) $\bar{X}$	SD	t	p	Total length (cm) $\bar{X}$	SD	t	p	Chest girth (cm) $\bar{X}$	SD	t	p
						FALL (Oct.-Dec.)							
Jasper	15	75.95	±5.27	2.05*	0.5	160.1	±10.4	0.68*	0.5	115.2	±5.27	1.53*	<0.1
Banff	8	71.6	±3.99	0.22**	<0.5	157.5	±3.05	0.77**	<0.1	118.4	±3.83	3.26**	>0.01
Waterton	9	72.3	±8.56	1.30√	<0.1	154.1	±12.2	0.79√	<0.1	107.8	±8.52	2.65√	>0.02
Averages	32	73.3				157.2				113.8			
						SPRING (Mar.-May)							
Jasper	11	61.3	±3.46	1.62√	<0.1	160.3	±7.48	0.15√	<0.5	103.9	±3.66	0.54√	<0.5
Waterton	16	65.1	±7.28			160.9	±10.01			102.5	±7.82		
Averages		63.2				160.6				103.2			

*Jasper and Banff
**Banff and Waterton
√Waterton and Jasper

Mean age-class weights of rams and ewes were 29.3 and 27.7 kg respectively at 0.5 yrs, 54.6 and 49.2 kg at 1.5 yrs, 72.7 and 58.8 kg at 2.5 yrs, 93.9 and 60.8 kg at 3.5 yrs, 71.9 kg for ewes at 4.5+ yrs, 101.4 kg for rams at 5.5 yrs and 125.4 kg for rams 6.5 years and older.

3.1.1 Seasonal weights and measurements; Jasper and Waterton Lakes national parks

Fall weights of mature ewes along the Athabasca Valley in Jasper and the Blakiston Valley in Waterton were similar (76.6 kg and 75.2 kg respectively). However, in spring, ewe (4.8 yrs.+) weights were significantly heavier in Waterton ($p = 0.1$) than in Jasper--just the reverse of the fall situation (Tables 1, 4 and Figure 7). Lower spring weights and a corresponding higher overwinter weight loss of ewes in Jasper was shown to be correlated to a less-productive winter range, higher ungulate stocking rate, and a higher lungworm load in Jasper compared to Waterton (Stelfox and McGillis 1970). They showed that mature ewes in Jasper sustained a 20% overwinter weight loss while foraging on an unproductive range (133 lbs/acre or 149 kg/ha), under a high stocking rate (71 days-use/acre or 175.4 days-use/ha) and while supporting a high lungworm load (2 375 larvae/gm of feces). Conversely, in Waterton where the range was over 3 times as productive, the stocking rate only 41% as heavy, and the lungworm load only 25% as great, mature ewes lost only 13%

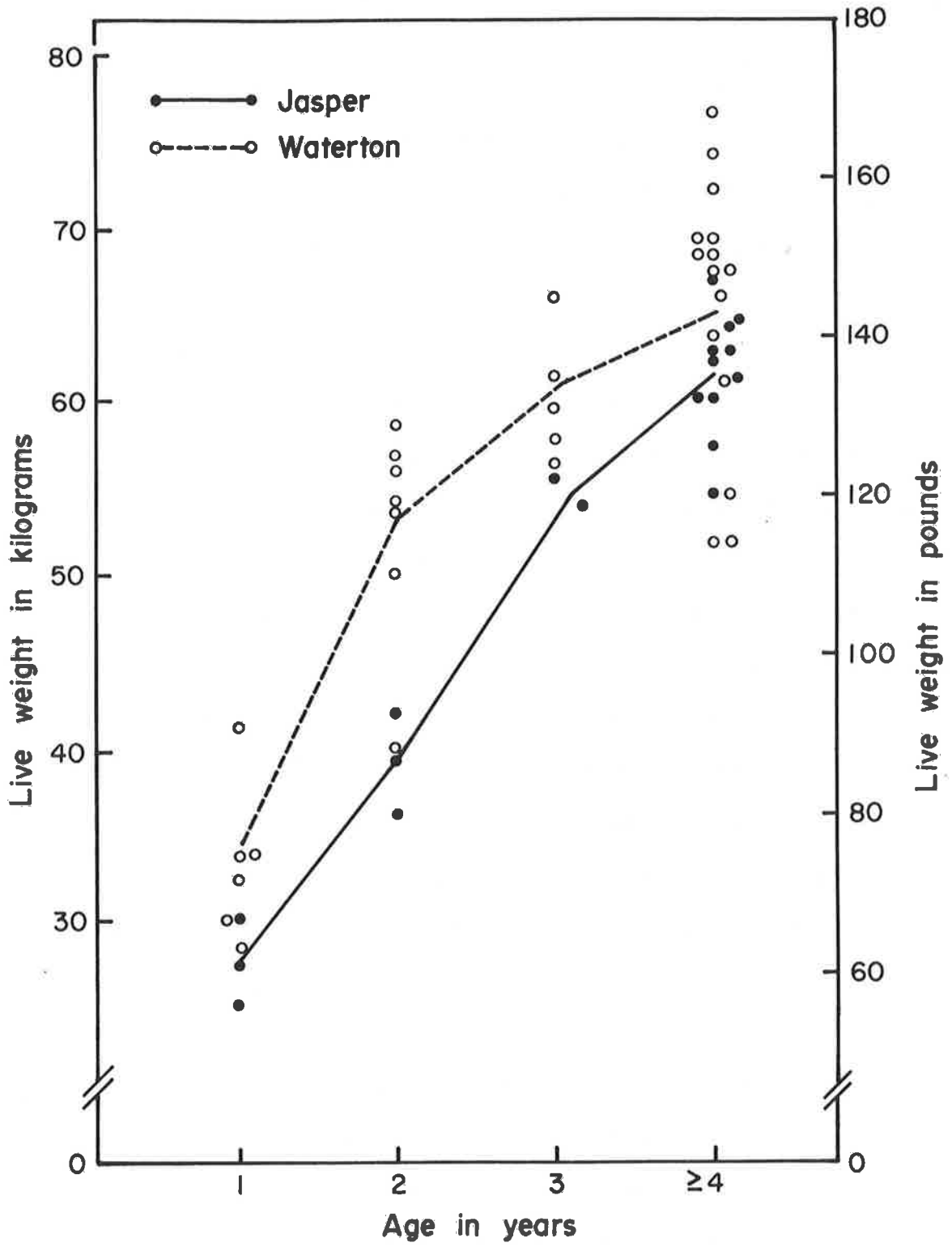


Figure 7. Weights of bighorn ewes in spring (April & May) in Jasper and Waterton Lakes national parks, 1966-69.

of their fall weight. In Banff, where the stocking rate was similar to Jasper but forage production greater and lungworm load only 25% as great as Jasper, ewes lost only 11% of their fall weight.

The best sample of spring weights (273) was obtained from Waterton during the period 1957 to 1968 (Figure 8). Weights and body measurements of foetuses and newborn lambs have been deficient for the parks. Table 5 presents weights and measurements of 15 of them from Jasper. Newborn lambs averaged 9.76 kg (21.5 lb) on June 6 and increased in weight to 16.2 kg (35.7 lb) when 5-6 weeks old on July 8.

As mentioned above, overwinter weight losses ranged from 11 to 20% of fall weight, on the average. Some individuals undoubtedly sustained greater overwinter weight losses. Weight increases by age as well as overwinter weight losses are depicted in Figure 9. Some large mature rams probably attained 159 kg (350 lb) in late October. The heaviest one the authors weighed was 137 kg (301 lb) in Jasper on November 14 after two weeks of fighting (Figure 10). This is in contrast to a ram in poor condition weighing almost 79 kg (175 lb) on July 8 after a severe winter (Figure 11).

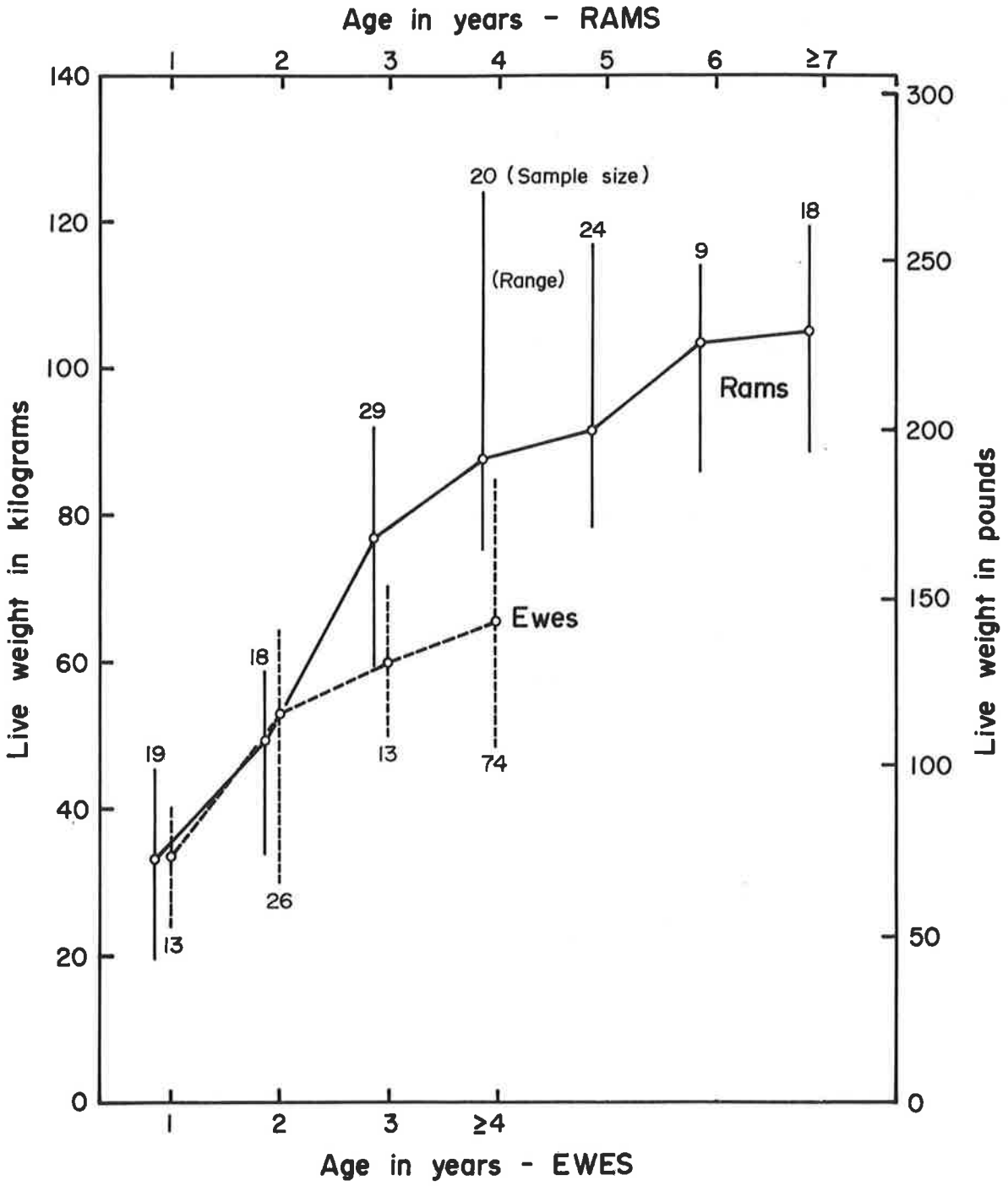


Figure 8. Spring weights of 273 bighorn sheep in Waterton Lakes National Park, 1957-68, showing the mean, range, and sample size.

Table 5. Weights and measurements of foetuses and lambs less than two months of age, Jasper National Park, 1957-1969.

Sex	Sample size	Age	Date	Wt. (kg)	Measurements (cm)				
					Chest girth	Total length	Shoulder height	Hind foot	Tail
♀	(2)	Foetus (130 days)	Apr. 1-12/69	1.4	24.1	45.5	26.2	13.2	2.3
♂	(2)	Foetus (157 days)	May 8/69	3.4	30.7	58.7	37.3	21.3	3.8
♀	(2)	Newborn	June 6/57	9.6	49.5	-	-	27.9	-
♂	(1)	Newborn	June 6/57	10.8	52.1	-	-	28.7	-
♀	(2)	3 - 4 wks.	June 25/64	10.8	-	-	-	-	-
♂	(2)	3 - 4 wks.	June 25/64	13.9	-	-	-	-	-
♀	(3)	5 - 6 wks.	July 8/57	15.6	58.2	-	-	30.2	-
♂	(1)	5 - 6 wks.	July 8/57	18.1	62.2	-	-	31.0	-

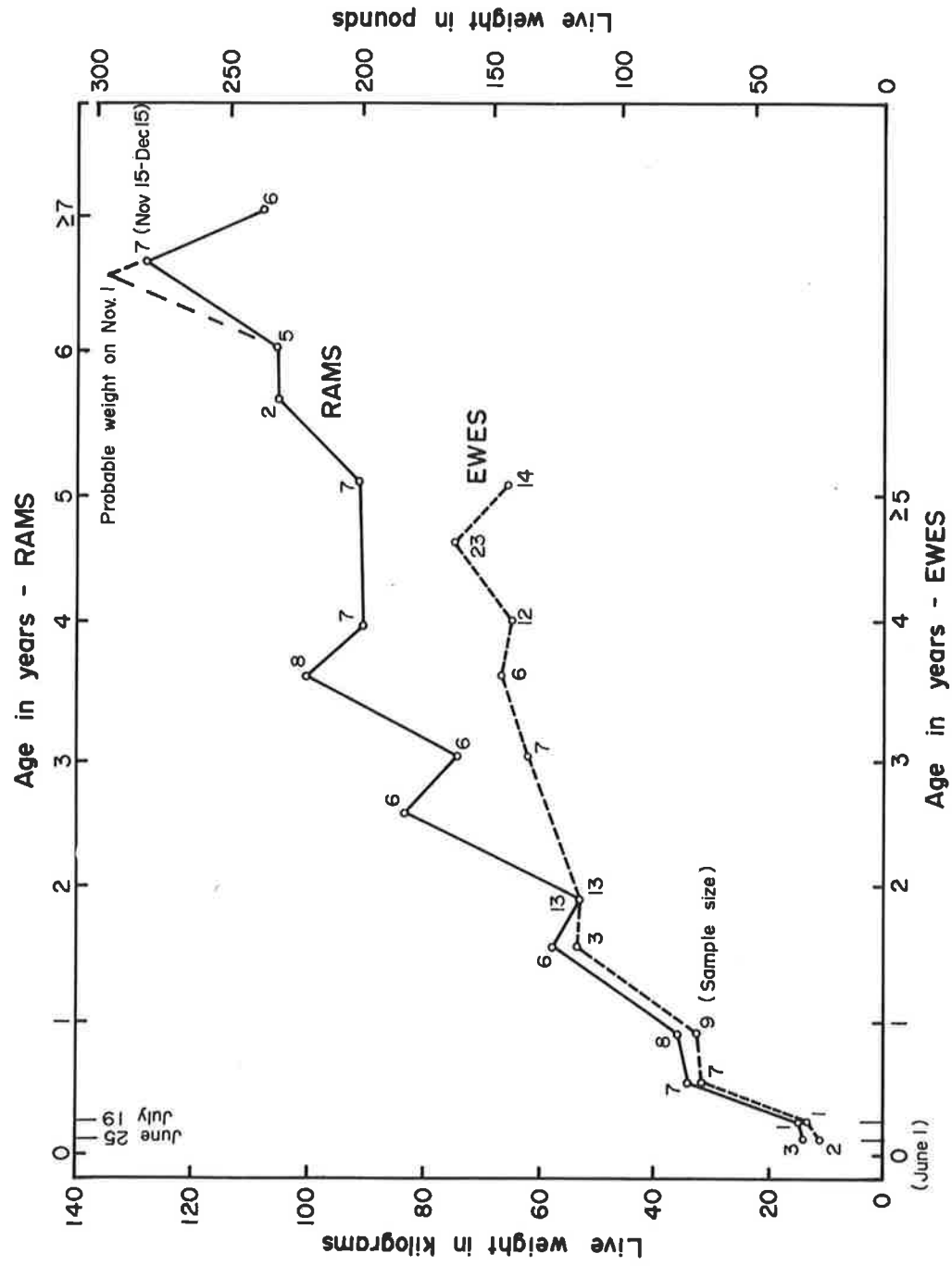


Figure 9. Weight gains and over-winter weight losses of bighorn sheep in the Canadian Rocky Mountain national parks, 1966-69.

Figure 10. Ram in prime condition (136.7 kg.(301 lb.)) at Windy Trap, Jasper National Park, 14 November 1968.

Figure 11. Ram in poor condition (approx. 80 kg.(176 lb.)) at Mt. Bourgeau, Banff National Park, 8 July 1967.

3.1.2 Pre and post die-off weights and measurements for Kootenay National Park

Kootenay sheep were suffering from a pneumonia-lungworm disease during 1966-67 which is reflected in lower body weights compared to those obtained in 1972, five years after the disease die-off (Table 1, 6 and Figure 12).

Mature ewes were 20.8% ($p = >0.01$) heavier in the spring of 1972 when the population was low and healthy compared to 1967 during the die-off.

During the fall and winter of 1966-67 at the initiation of the die-off, Kootenay ewes averaged only 60.1 kg compared to 71.5 kg for Banff, 75.3 kg for Waterton and 76.6 kg for Jasper ewes (Table 1).

The pronounced weight variations associated with healthy versus sick sheep and fall versus spring seasons indicate the importance of using comparable specimens from different parks or from different subspecies when trying to draw conclusions about phylogenetic weight differences.

3.2 Skull Weights and Measurements

3.2.1 Canadian national parks

Skull weights, including horns, were significantly heavier for Waterton rams and ewes than for corresponding skulls from Jasper and Banff (Table 7 and Appendices I, II). For rams (5 yrs.+), they averaged 10 076 gm in Jasper, 9 521 gm in Banff and 11 627 gm in Waterton. Comparable skull plus horn weights for ewes were 871, 790, and 1 029 gm for Jasper, Banff and Waterton respectively.

3.2.2 Bighorn rams compared to Dall's and Stone rams

Mean weights of horns plus skull plate of mature rams (7.5+yrs) were significantly greater for bighorn sheep from Alberta (12 334 gm), compared to stone sheep from British Columbia (9 526 gm) and Dall's sheep from the Yukon and Northwest Territories (7 097 gm).

The greatest horns plus skull plate weight for a bighorn ram was 17 237 gm, compared to 12 928 gm for a stone ram and 8 528 gm for a Dall's ram (Appendix I).

3.3 Horn Development: Ewes and Rams

3.3.1 All parks

Horn development of rams in Banff from 1.5 to 6.6 years is illustrated in Figure 13 while a 12-year-old ram skull from Jasper is compared with that of a 10-year-old ram from Waterton in Figure 14. The trend towards greater horn divergence in rams further south is illustrated in Figure 15 comparing rams from Jasper, Banff and Montana.

Horn length and base measurements for 53 sheep (34♂ + 19♀) in Jasper, 42 in Banff (25♂ + 17♀) and 21 in Waterton (14♂ + 7♀) are presented in Appendix II. Mean horn length and base values for adult ewes (3 yrs.+) were 24.7 and 12.9 cm in Jasper, 23.4 and 12.5 cm in Banff, 26.8 and 13.0 cm in Waterton. Corresponding values for adult rams were 90.3 and 37.3 cm in Jasper, 88.5 and 36.9 in Banff, 87.1 and 40.8 cm in Waterton (Table 7). These results indicate that adult ewes in Waterton had significantly greater horn measurements than their counterparts in Jasper or

Table 6. Average body weights of bighorn sheep in Kootenay National Park during the die-off (1966-67) compared to five years later (1972).

Age Class (yrs)	Sex	Sample (n)	Weight (kg) $\bar{X}$	Weight (kg) Range
		FALL 1966 (Oct. 1 - Dec. 10)		
0.5	♀	3	22.3	13.6-27.2
"	♂	2	17.0	-
1.5	♀	1	47.6	-
"	♂	2	42.4	-
2.5	♀	1	52.2	-
"	♂	4	61.1	53.9-65.3
3.5+	♀	16	60.5	34.5-67.1
		WINTER 1967 (Jan. 25 - Feb. 10)		
<0.7	♀	1	23.1	-
2.7	♀	1	53.9	-
3.7+	♀	5	55.8	49.9-59.9
		SPRING 1967 (April 6)		
1.8	♂	1	56.7	-
2.8	♂	2	69.2	67.1-71.2
3.8+	♀	5	54.9*	54.4-55.8
		SPRING 1972 (March 22-28)		
0.8	♀	3	28.6	27.7-29.0
"	♂	2	36.3	32.2-39.9
3.8+	♀	6	66.3*	56.2-69.9

*p = >0.01

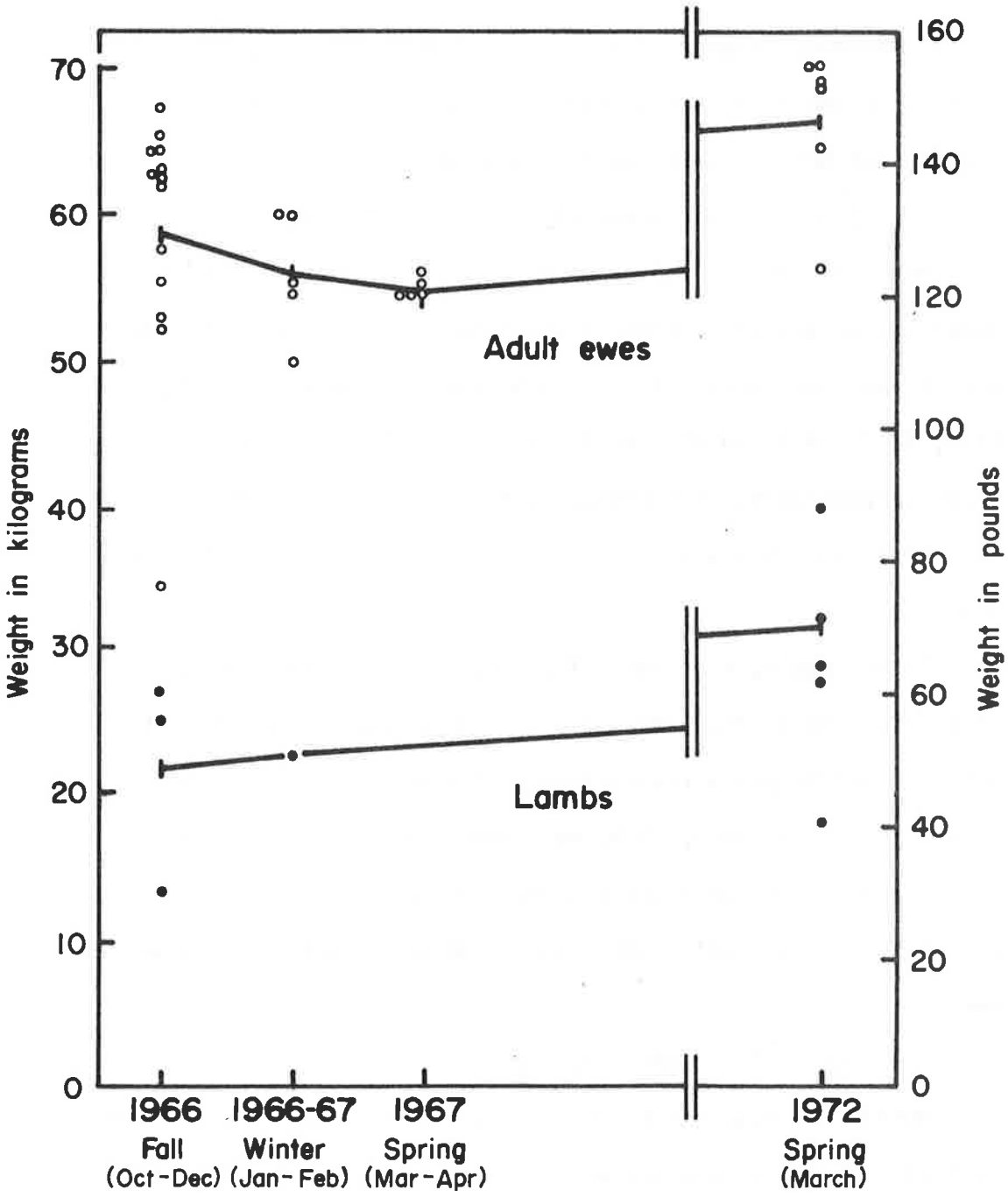


Figure 12. Weights of bighorn sheep during, and 5 years after, a 75 % population decline in Kootenay National Park.

Banff. However, Jasper ewes and rams had greater mean horn measurements than those in Banff, with Jasper rams having longer horn lengths but smaller bases than rams in Waterton.

3.3.2 Jasper compared to Waterton Lakes

Mean horn length and base values for rams from <1 year to 6+ years are presented in Table 8 and Figure 16. For Jasper rams, horn lengths averaged 8.9 cm at 0.5 years, compared to 31.2, 46.0, 65.9, 63.0, 78.7 and 90.3 cm for 1-2, 2-3, 3-4, 4-5, 5-6 and 6+ years respectively. Corresponding horn lengths for Waterton rams were 11.8 cm at 0.9 yrs, compared to 33.5, 51.7, 59.5, 70.7, 74.3 and 87.1 cm.

Corresponding horn bases for Jasper rams averaged 11.2, 20.8, 28.5, 36.3, 33.3, 36.8, and 37.3 cm for ages 0.5, 1-2, 2-3, 3-4, 4-5, 5-6 and 6+ years respectively. For Waterton rams they were 11.4, 23.5, 32.3, 35.9, 39.6, 40.6 and 40.8 cm respectively.

These results indicate that mature Jasper rams (6+) had longer horns but smaller horn bases than their Waterton counterparts.

3.4 Mandibular Tooth Eruption

Dental formulas for sheep from 0.5 to 4.0 years are presented in Table 9. The appearance of incisor, canine, premolar and molar teeth at ages 1.8, 2.2 and 3.5 years are shown in Figure 17.

The most important features of tooth replacement and eruption are the sequence of replacement for incisors and premolars

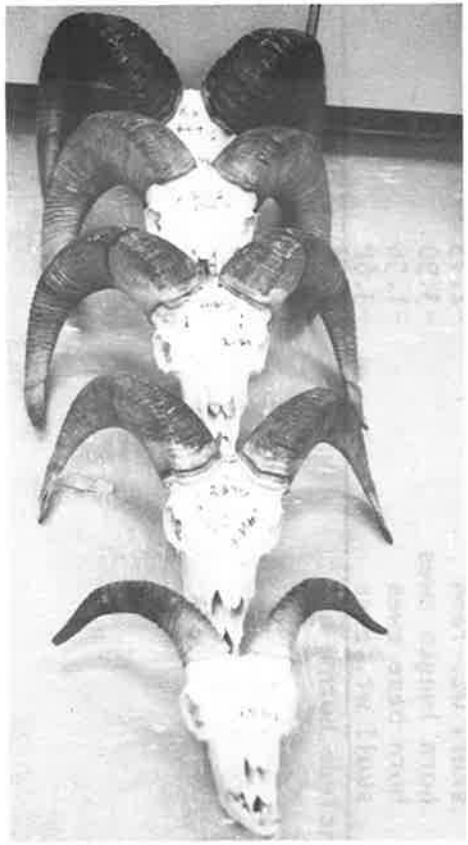


Figure 13. Horn development in rams 1.5 to 6.6 years.

Figure 14. Mature rams from Jasper (lower) and Waterton (upper).

Figure 15. Latitudinal variation in horn development; Jasper (upper), Banff (centre) and Montana (lower).

Table 7. Summary of horn measurements and skull weights of rams (6 yrs.+) and ewes (3 yrs.+).

Park	Horn length (cm)					Horn base (cm)					Skull wt*(gm)	
	n	X	s	Min	Max	n	X	s	Min	Max	n	X
Jasper ♂	20	90.3	6.54	82.8	102.9	20	37.3	1.91	33.0	40.9	15	10 076
♀	15	24.7	4.26	10.2	34.5	15	12.9	0.98	10.8	15.8	12	871
Banff ♂	18	88.5	7.39	69.0	99.3	18	36.9	4.16	33.3	57.0	15	9 521
♀	9	23.4	1.20	21.9	25.0	9	12.5	0.65	11.0	13.3	7	790
Waterton ♂	17	87.1	5.34	76.2	100.3	17	40.8	1.73	37.5	44.5	6	11 627
♀	5	26.8	3.26	20.9	29.9	5	13.0	0.79	11.7	14.0	5	1 029

t-test		t	df**	p
Jasper vs Waterton	horn length rams	-1.58	29	0.10
	horn base rams	-2.99	29	0.01
	skull wt. rams	-1.76	19	0.10
	horn length ewes	-1.31	18	>0.10
	horn base ewes	-0.25	18	>0.50
	skull wt. ewes	-2.07	15	>0.05
Jasper vs Banff	horn length rams	+1.27	36	>0.10
	horn base rams	+0.34	36	>0.50
	skull wt. rams	+0.70	28	>0.10
	horn length ewes	+1.30	22	>0.10
	horn base ewes	+1.44	22	>0.10
	skull wt. ewes	+1.27	17	>0.10
Banff vs Waterton	horn length rams	-2.56	27	<0.02
	horn base rams	-1.86	27	<0.10
	skull wt. rams	-2.73	19	<0.02
	horn length ewes	-3.90	12	>0.01
	horn base ewes	-1.56	12	>0.10
	skull wt. ewes	-3.60	10	<0.01

* Skull weights include horns
**df = $n_1 + n_2 - 2$

Table 8. Horn sizes by age class for Jasper and Waterton rams, 1957-1969.

Age	Park	Sample (n)	HORN LENGTH [in (cm)] Mean	Max.	Min.	HORN BASE [in (cm)] Mean	Max.	Min.
0.5	J	12	3.5 (8.9)	5.8 (14.7)	0.0	4.4 (11.2)	5.5 (14.0)	2.1 (5.3)
0.9	W	21	4.6 (11.8)	7.0 (17.8)	2.5 (6.4)	4.5 (11.4)	6.0 (15.2)	3.2 (8.3)
1-2	J	12	12.3 (31.2)	16.5 (41.9)	8.1 (20.5)	8.2 (20.8)	10.5 (26.7)	5.4 (13.7)
"	W	27	13.2 (33.5)	16.5 (41.9)	9.0 (22.9)	9.3 (23.5)	10.7 (27.3)	7.0 (17.8)
2-3	J	10	18.1 (46.0)	23.8 (60.5)	15.8 (40.1)	11.2 (28.5)	13.9 (35.3)	9.5 (24.1)
"	W	22	20.3 (51.7)	25.0 (63.5)	15.7 (40.0)	12.7 (32.3)	15.7 (40.0)	11.0 (27.9)
3-4	J	4	25.9 (65.9)	26.5 (67.3)	21.5 (54.6)	14.3 (36.3)	15.3 (38.9)	13.0 (33.0)
"	W	20	23.4 (59.5)	28.2 (71.8)	18.0 (45.7)	14.1 (35.9)	18.0 (45.7)	11.0 (27.9)
4-5	J	6	24.8 (63.0)	29.3 (74.4)	17.5 (44.5)	13.1 (33.3)	14.0 (35.6)	10.6 (26.9)
"	W	26	27.8 (70.7)	34.0 (86.4)	22.0 (55.9)	15.6 (39.6)	17.0 (43.2)	13.5 (34.3)
5-6	J	5	31.0 (78.7)	33.3 (84.6)	28.8 (73.2)	14.5 (36.8)	15.6 (39.6)	13.8 (35.1)
"	W	8	29.2 (74.3)	33.0 (83.8)	24.0 (61.0)	16.0 (40.6)	17.0 (43.2)	15.0 (38.1)
6+	J	20	35.7 (90.3)	38.9(102.9)	32.6 (82.8)	14.7 (37.3)	16.1 (40.9)	13.0 (33.0)
	W	17	34.3 (87.1)	39.5(100.3)	30.0 (76.2)	16.1 (40.8)	17.5 (44.5)	14.7 (37.5)

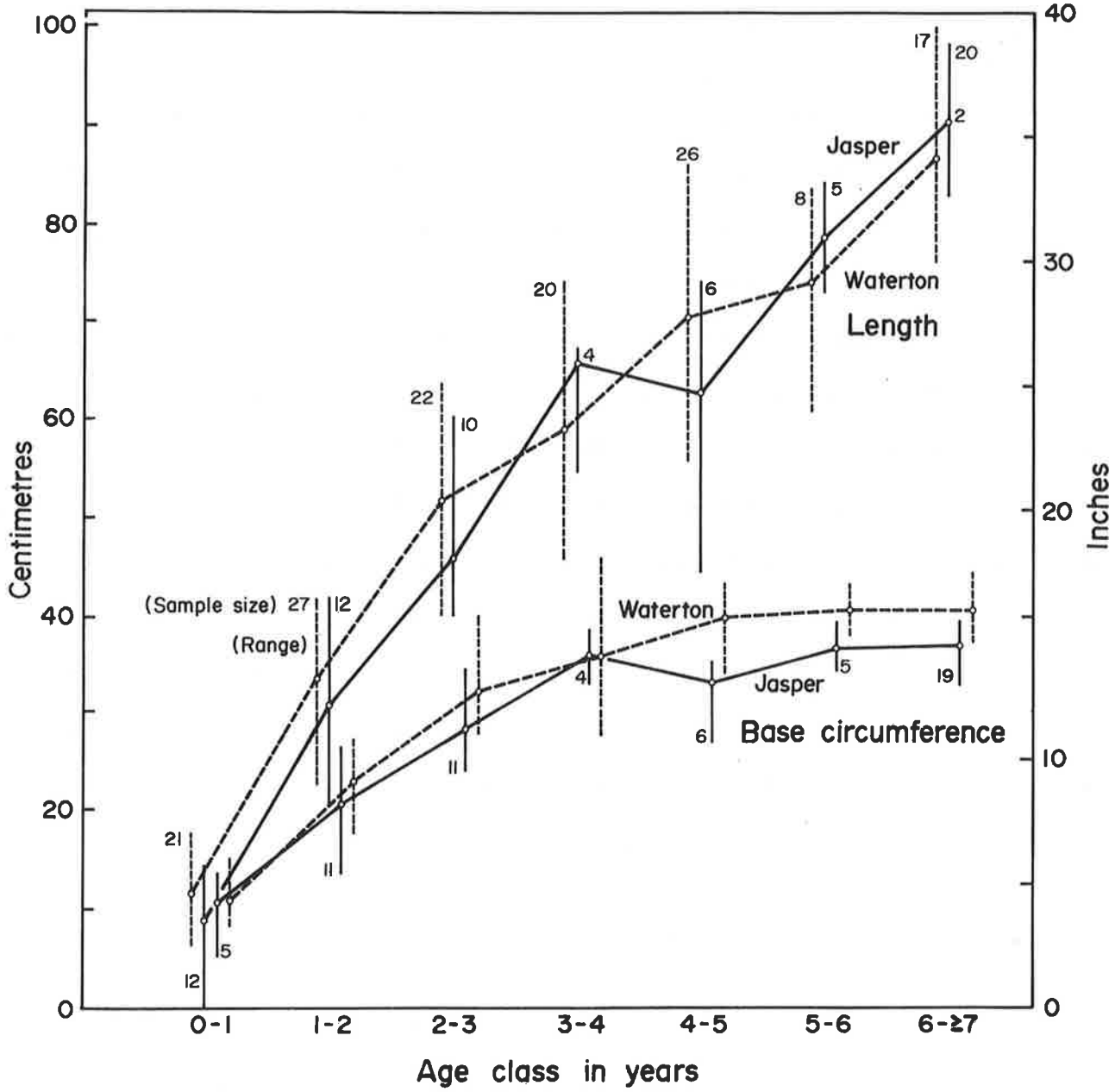


Figure 16. Horn sizes by age class of Jasper and Waterton rams, 1957-1969.

Table 9. Tooth development of bighorn sheep, Canadian national parks.

Age	Dental Formula				Remarks
	Incisors	Canines	Premolars	Molars	
at birth	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	
0.5	$\frac{0}{3}$	$\frac{0}{1}$	$\frac{3}{3}$	$\frac{1}{1}$	Incisors, canines and premolars all deciduous; M_1 erupted, alveoli of M_2 present
1.0	$\frac{0}{3}$	$\frac{0}{1}$	$\frac{3}{3}$	$\frac{2}{2}$	I_1 permanent, I_2 and I_3 deciduous; C_1 and premolars deciduous; M_2 erupted
2.0	$\frac{0}{3}$	$\frac{0}{1}$	$\frac{3}{3}$	$\frac{3}{3}$	I_2 permanent; C_1 deciduous; Pm_1 becoming permanent; M_3 erupting
2.5	$\frac{0}{3}$	$\frac{0}{1}$	$\frac{3}{3}$	$\frac{3}{3}$	I_3 deciduous, C_1 deciduous; Pm_2 becoming permanent; M_3 one-half erupted
3.0	$\frac{0}{3}$	$\frac{0}{1}$	$\frac{3}{3}$	$\frac{3}{3}$	I_3 permanent; permanent C_1 erupting or absent; Pm_2 permanent M_3 three-fourths erupted
3.5	$\frac{0}{3}$	$\frac{0}{1}$	$\frac{3}{3}$	$\frac{3}{3}$	Incisors complete or C_1 erupting; permanent Pm erupting; M_3 fully erupted
4.0	$\frac{0}{3}$	$\frac{0}{1}$	$\frac{3}{3}$	$\frac{3}{3}$	Pm_3 developed; permanent dentition complete

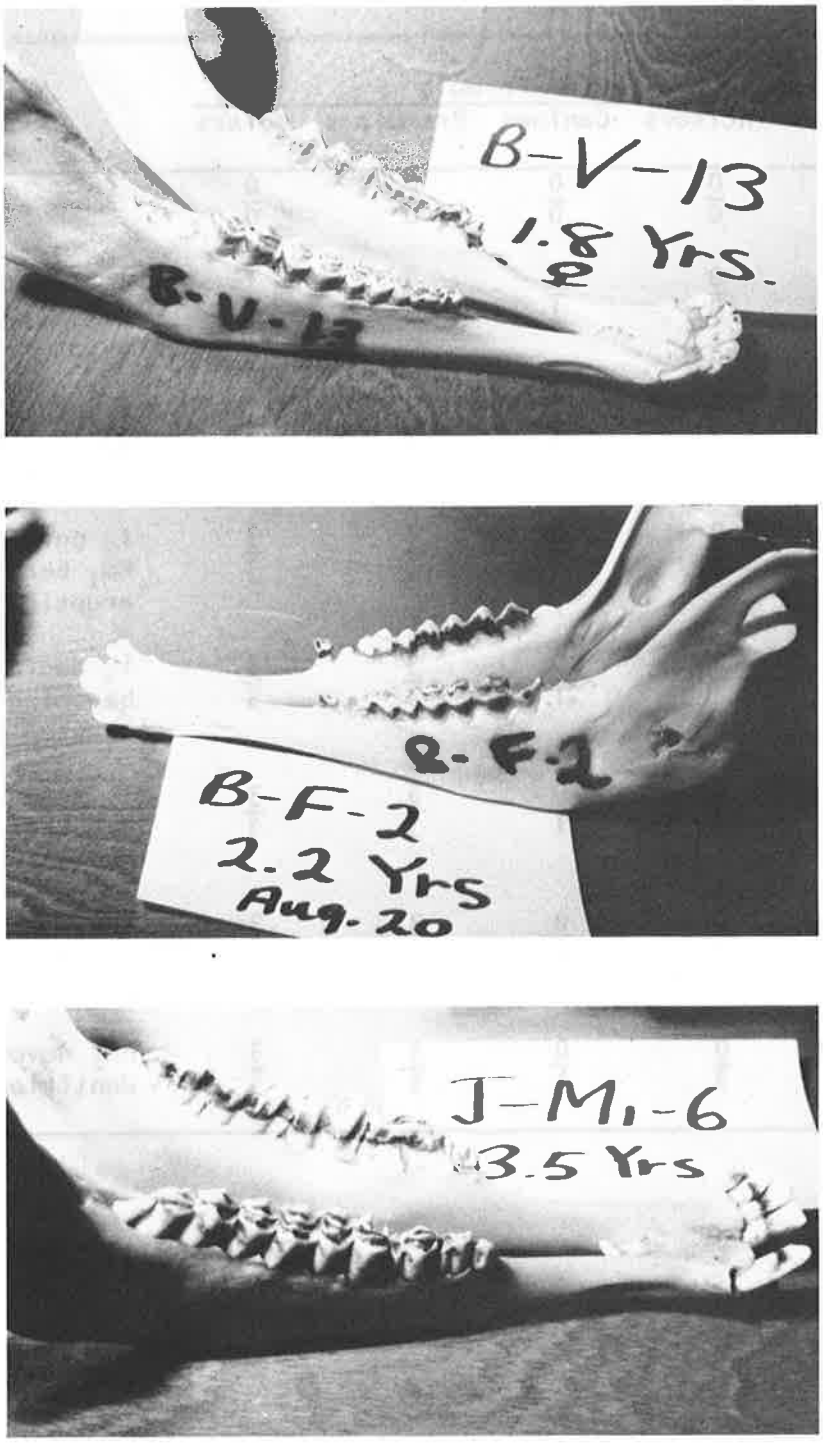


Figure 17. Dentition of bighorn sheep at 1.8, 2.2 and 3.5 years.

plus the eruption of molars.

The four incisiform teeth are replaced in the following order:

(a) during the first year all the incisors are deciduous (immature);

(b) at about 1 year, the two middle incisors (nippers) (I_1) are replaced by permanent ones;

(c) during the second year, the 1st pair of deciduous intermediates (I_2) next to the nippers are replaced by permanent ones, while the 2nd pair (I_3) are replaced at about 2.5 years;

(d) at 3.0 to 3.5 years, the deciduous canine (C_1) is lost and the permanent canine is fully erupted by 4.0 years and the replacement pattern is complete.

Premolars consist of three teeth (Pm_2, Pm_3 and Pm_4) as Pm_1 was lost in evolutionary development but occasionally is present. At about 2.0 years, Pm_2 (deciduous) is being replaced by the larger permanent Pm_2. At about 2.5 years, the deciduous Pm_3 is being pushed out by permanent Pm_3. At about 3.5 years, the 3 cuspid deciduous Pm_4 is replaced by the 2 cuspid Pm_4.

The first molar (M_1) was fully erupted in lambs at 0.5 years, while M_2 was just visible in the alveoli at that time. At 1.0 year, M_2 was one-half erupted and by 1.8 years was fully erupted. By 2.5 years, M_3 was one-half erupted and by 3.5 years it was fully erupted.

Comparisons of our results with those of Cowan (1940) for

Ovis sp. are:

Cowan	This Study
M_2 perm. at 18 mos.	M_2 perm. at 12 mos.
I_1 perm. at 18 mos.	I_1 perm. at 12 mos.
Pm_3 and Pm_2 perm. at 36 mos.	Pm_2 and Pm_3 perm. at 30 mos.
Pm_4 replaced at 42 mos.	Pm_2 and Pm_3 perm. at 30 mos.
I_2 replaced at 42 mos.	I_2 replaced at 24-30 mos.
I_3 and C_1 replaced at 42-48 mos.	I_3 perm. at 36 mos., C_1 erupting at 42 mos.

Comparisons of tooth replacement of bighorn sheep from our study with that for snow sheep by Cherniavski (1962) are:

Snow sheep (Cherniavski)	Bighorn sheep (this study)
M_1 fully developed at 7-8 mos.	M_1 fully developed at 6 mos.
C_1 not yet dropped out at 3.5 yrs.	C_1 erupting at 3.5 yrs.
C_1 protruding slightly above level of alveoli at 4.0 yrs.	C_1 developed at 4.0 yrs.

The tooth replacement sequence of bighorn sheep from this study agrees closely with that described for desert sheep by Deming (1952).

We found considerable individual variation in the age at which deciduous incisiform teeth were replaced by permanent teeth. The typical incisiform dentition of 4-year-old bighorn sheep (93.1%) consisted of eight permanent teeth, whereas about 7% had only six permanent incisors. A comparison of incisor replacement for bighorn sheep in Jasper (Table 1, Appendix III) and Waterton (Table 2, Appendix III, Blood 1966) shows

that Jasper sheep were more advanced in incisor replacement with 63.6% having eight permanent incisors by age 2.9 years whereas only 57% of Waterton sheep had permanent incisiform dentition by age 4.0 years.

4.0 DISCUSSION

It is beyond the scope and intent of this report to attempt a detailed analysis of taxonomic variations between the various races of North American sheep and the Rocky Mountain bighorn sheep. However, the weights and measurements of bighorn sheep presented here support the statements on geographical variation in North American sheep by Cowan (1940). He states that "Apparently *canadensis* rams average larger than do those of any other race. The females of *canadensis* however, differ very little from those of the more southerly races, it follows therefore that in the Rocky Mountain range generally, there is an increase in size of males toward the north and a resulting increase in sexual disparity from south to north."

Our data indicates that adult rams in Jasper are shorter, chunkier and heavier with shorter appendages than their counterparts in Waterton some 500 km to the south. This relationship is less pronounced in mature ewes except that Jasper ewes in the fall are heavier than those in Waterton. This tends to support the Bergmann Principle (Clarke 1954) which states that animals further north have a greater torso mass in relation to surface area than animals to the south. Allen's Rule, (Clarke 1954) which applies to a decrease in length of extremities, such as the tail and ears, of mammals living in colder climates is also supported by measurements from Jasper and Waterton of both ewes and rams. Ear and tail lengths were shorter in Jasper than in Waterton and shoulder

heights were shorter for Jasper rams, but similar for Jasper ewes compared to their Waterton counterparts.

Skull measurements and weights of bighorn sheep are presented here for Jasper, Banff, and Waterton primarily for the purpose of enlarging the small data base that presently exists. However, a cursory comparison of measurements among the three parks indicates that there is an increase in horn length in adult rams between Waterton and Jasper, with a corresponding decrease in horn basal circumference. Interestingly, Banff rams have the shortest horns and smallest basal circumference. The converse is apparent for adult ewes which show a decrease in horn length between Waterton and Jasper while the basal circumference remains relatively similar. Again, Banff ewes have the smallest horn measurements. There is also a greater horn divergence in rams from north to south. These latitudinal differences in horn development also support the findings of Cowan (1940).

Comparison of the tooth development sequence in bighorn sheep from Canadian national parks with that reported for *Ovis* sp. (Cowan 1940), desert sheep (Deming 1952) and snow sheep (Cherniavski 1962) indicates a great similarity in tooth replacement patterns. However, there is apparent variation in the timing of tooth replacement which is most probably due to differences in sample size. The variation in incisor replacement between Jasper sheep from this study and Waterton sheep from Blood (1966) indicates a possible latitudinal difference in the timing of incisor replacement with Jasper sheep attaining a full complement of permanent

incisors at an earlier age than sheep in Waterton. However, further study would be necessary in order to demonstrate whether such a relationship actually exists.

5.0 SUMMARY AND CONCLUSIONS

Body weights and external measurements, skull weights and measurements, plus tooth replacement information were collected from Rocky Mountain bighorn sheep in Jasper, Banff, Waterton Lakes and Kootenay national parks during the period 1967 to 1971. Results were compared with those obtained earlier from this subspecies (Cowan 1940, Blood *et al.* 1970, Shackleton 1973) and for desert sheep (Aldous *et al.* 1958) and Dall's sheep (Bunnell and Olsen 1976).

Body weight and measurement values for bighorn sheep indicated that mature rams (6.5 yrs.+) in prime fall condition averaged 125.4 kg live weight and 127.4 cm chest girth. By spring, these values declined to 104.3 kg and 118.4 cm, an overwinter weight loss of 16.8% and 7.1% decrease in chest girth. Mature ewes (4.5 yrs.+) in prime fall condition averaged 71.9 kg (57.3% as heavy as rams) with a chest girth of 115.3 cm. Jasper ewes were heavier than ewes from Banff and Waterton in fall but lighter in spring, indicating a greater overwinter weight loss due to high stocking rates on less-productive ranges and higher lungworm loads.

Mean fall weights of bighorn rams and ewes from this study and Aldous *et al.* (1958) were 66.9% and 50.7% greater, respectively,

than fall weights of desert rams and ewes from Nevada (Aldous 1958) and 58.4% and 35.2% greater respectively than Dall's rams and ewes in Kluane National Park (Bunnell and Olsen 1976).

Newborn lambs in Jasper averaged 9.76 kg on June 6 and increased to 16.2 kg by July 8.

Both measurements of Jasper rams compared to those in Waterton support the principle that with increasing latitude there is a decrease in the mass-to-surface-area ratio. Jasper rams are generally shorter of body and appendages and heavier than Waterton rams. Ewes do not demonstrate as clear a relationship except that in the fall, Jasper ewes are heavier than those in Waterton.

Mature ewes in Kootenay National Park were 20.8% heavier in spring of 1972 when the population was low and healthy compared to 1967 during the die-off.

Horn measurement and skull weight data indicate that Waterton rams have shorter but more massive horns than Jasper rams with Banff rams having the smallest horn measurements. Waterton ewes averaged longer and slightly stockier horns than Jasper and Banff ewes, respectively.

Tooth replacement in bighorn sheep from this study was somewhat more rapid than that demonstrated by Cowan (1940) for *Ovis* sp. and by Cherniavski (1962) for snow sheep in the U.S.S.R. Jasper sheep had a more advanced incisor replacement schedule than did sheep examined by Blood (1966) in Waterton.

REFERENCES

Aldous, M.C., F.C. Craighead Jr., and G.A. Devan. 1958. Some weights and measurements of desert bighorn sheep (*Ovis canadensis nelsoni*). J. Wildl. Manage. 22:444-445.

Baker, L. and W.G. Bradley. 1965. Skull measurements of desert bighorn sheep from the Desert Game Range. Trans. Desert Bighorn Council. 9:90-74.

Blood, D.A. 1966. Progress report on bighorn sheep investigations in the Rocky Mountain National Parks. Unpubl. typescript report to Can. Wildl. Serv., Edmonton.

Blood, D.A., D.R. Flook and W.D. Wishart. 1970. Weights and growth of Rocky Mountain bighorn sheep in western Alberta. J. Wildl. Manage. 34:451-455.

Bunnell, F.L. and N.A. Olsen. 1976. Weights and growth of Dall's sheep in Kluane Park Reserve, Yukon Territory. Can. Field-Nat. 90:157-162.

Cherniavski, F.B. 1962. On the reproduction and growth of the snow sheep (*Ovis nivicola* Esch). Zod. Institit., Academy of Sciences of the U.S.S.R., Leningrad. Transl. from Zoologicheskii Zhurnal XLI(10):1556-1566.

Clarke, G.L. 1954. Elements of ecology. John Wiley & Sons, Inc. New York. 534.p.

Cowan, I. McT. 1940. Distribution and variation in the native sheep of North America. Amer. Mid. Nat. 24:505-580.

Deming, O.V. 1952. Tooth development of the Nelson bighorn sheep. Calif. Fish & Game. 38:523-530.

Geist, V. 1966. Validity of horn segment counts in aging bighorn sheep. J. Wildl. Manage. 30:634-635.

Green, H.V. 1949. The bighorn sheep of Banff National Park. Can. Dept. of Resources and Development, National Parks and Historic Sites Service, Ottawa.

Heimer, W.E. and A.C. Smith III. 1975. Ram horn growth and population quality--their significance to Dall's sheep management in Alaska. Alaska Dept. of Fish and Game, Wildl. Tech. Bull. 5.

Hemming, J.E. 1967. Mandibular dentition and horn development as criteria of age in the Dall sheep, *Ovis dalli* Nelson. M.S. Thesis, Univ. of Montana, Missoula.

Shackleton, D.M. 1973. Population quality and bighorn sheep (*Ovis canadensis canadensis* Shaw). PhD. thesis, Univ. of Calgary, Calgary.

Stelfox, J.G. and J.R. McGillis. 1970. Seasonal growth patterns of bighorns correlated with range conditions and endo-parasite loads. Trans. Northern Wild Sheep Council, Williams Lake, B.C. May 1970:35-38.

Stelfox, J.G. 1976. Diseases and parasites of bighorn sheep in Canadian National Parks, 1966 to 1972. Prepared for Parks Canada by Can. Wildl. Serv., Edmonton.

APPENDIX I

Ram Skull and Horn Measurements and Weights of Rocky Mountain Bighorn, Stone and Dall's Sheep

Table 1. Skull measurements in mm of bighorn rams, Canadian National Parks 1966-71.

Age (Years)	Basilar Length	Nasal Length	Nasal Width	Orbital Width	Zygomatic Width	Maxillary Width	Mastoid Width	Palatal Breadth (M^3)	Palatal Breadth (Pm^2)	Upper Molar Series	Prealveolar Length	Postdental Length
< 1 yr.	84.0 204.5	26.5	18.0 16.2	45.0 83.0	58.0 99.0	20.0 66.0	43.3 75.0	NOT	16.0	39.5 to posterior of M_1	35.8	44.1 from posterior of M_1
	97.0 180.0	34.2	22.5	58.9 84.0	71.7 93.0	51.4 62.0	58.0 72.0		28.8 28.0		66.9	
	119.6 194.0	69.8	34.6	93.8 86.5	118.7 100.1	68.5 66.9	74.5 71.8	POSSIBLE	27.0		57.6	
Average	146.5	43.5	22.8	75.2	90.1	55.8	65.8		25.0		53.4	
Range	84.0 - 204.5	26.5 - 69.8	16.2 - 34.6	45.0 - 93.8	58.0 -118.7	20.0 - 66.9	43.3 - 75.0		16.0 - 28.8		35.8 - 66.9	
1 - 2	218.0	71.3	34.4	98.7	108.3	74.8	79.9	43.4	27.0	70.0	67.4	76.6
2 - 3	242.0	100.7	41.7	104.3	114.5	79.1	81.7	45.4	28.3	84.8	77.6	75.5
	246.0	99.0	44.8	107.5 106.7	117.2 117.5	81.7 77.3	87.8 91.5	46.6 52.7	28.2 25.4	90.0 81.5	78.1	76.1 78.9
	241.1	91.0	26.1	91.9	110.7	76.8	84.6	50.8	30.4	74.0	47.0	73.0
Average	243.0	96.9	37.5	102.6	115.0	78.7	86.4	48.9	28.1	82.6	66.6	75.9
Range	241.1 - 246.0	91.0 -100.7	26.1 - 44.8	91.9 -107.5	110.7 -117.5	76.8 - 81.7	81.7 - 91.5	45.4 - 52.7	25.4 - 30.4	74.0 - 90.0	47.0 - 78.1	73.0 - 78.9
3 - 4	245.0 266.0	105.0	43.0	111.0	121.5	78.5	92.4	53.5	35.3	87.0	87.9	86.4
	279.0 264.5	115.5 101.3	47.4 45.0	118.0 105.5	124.5 122.0	94.0 87.4	102.0 92.8	50.9 48.7	30.3 28.9	90.8 94.0	87.8 86.8	88.0 87.0
	267.0 262.0	113.5 93.0	47.0 49.7	114.8 111.5	121.0 122.2	78.0 88.2	91.7 104.5	50.6 51.3	36.3 30.3	85.0 82.9	81.7 83.7	90.6 89.5
	258.0 258.0	105.5	52.0 44.6	112.0 125.0	123.3 120.0	81.4 82.0	96.4 100.4	50.9 51.6	30.4 37.8	85.3 86.7	81.0 78.0	86.4 87.3
	262.0	93.0	46.8 43.1	117.0	121.0 121.8	88.0 78.0	98.0 96.0	54.0 53.9	33.0 28.9	87.0 94.9	80.0	84.0 81.5
Average	262.4	103.8	46.5	114.4	121.9	83.9	97.1	51.7	32.4	88.2	83.4	86.7
Range	245.0 - 279.0	93.0 -115.5	43.0 - 52.0	105.5 -125.0	120.0 -124.5	78.0 - 94.0	91.7 -104.5	48.7 - 54.0	28.9 - 37.8	82.9 - 94.9	78.0 - 87.9	81.5 - 90.6
4 - 5	273.0	109.5	47.0	123.5	127.5	80.4	99.3	56.0	38.0	85.5	87.0	91.0
	267.5	109.8	43.9 49.0	109.5 113.0	126.0	89.5	106.0 97.0	50.8 55.0	34.5	85.0	82.7	87.2 89.0
			47.0	120.5 120.0	122.0	85.0	104.0	51.5	29.0	83.0		93.1
Average	270.3	109.7	46.7	117.1	125.2	85.0	101.6	53.3	33.8	84.5	84.9	90.1
Range	267.5 - 273.0	109.5 -109.8	43.9 - 49.0	109.5 -123.0	122.0 -127.5	80.4 - 89.5	97.0 -106.0	51.5 - 56.0	29.0 - 38.0	83.0 - 85.5	82.7 - 87.0	87.2 - 91.0
5 - 6	268.5	112.6	50.8	122.5	123.0	93.0	100.9	51.8	34.6	89.6	84.3	86.7
	281.0 266.0	112.6 114.2	51.4 49.9	119.5 122.5	129.0 125.0	87.5 93.0	107.0 105.7	50.3 55.2	33.0 34.5	83.3 89.9	82.4 82.8	99.4 96.5
	252.0	123.0 103.5	54.0	120.0 202.8	134.0	92.0 92.3	99.5 109.7	50.0 50.2	32.0 32.6	90.0 84.8	54.3	89.0 101.8
	279.0	105.8	54.3	123.0 114.0	126.0	83.0 82.5	106.0 103.5	55.0	32.5 34.9	87.4 83.0	86.4	92.8 92.0
Average	269.3	112.0	52.1	132.0	127.4	89.0	104.6	52.1	33.4	86.9	78.0	94.0
Range	252.0 - 281.0	103.5 -123.0	49.9 - 54.3	114.0 -202.8	123.0 -134.0	82.5 - 93.0	99.5 -109.7	50.0 - 55.2	32.0 - 34.9	83.0 - 90.0	54.3 - 86.4	86.7 -101.8
6 - 7	273.0	117.7	56.9	144.2	129.0	84.0	98.5	51.8	35.1	82.7	86.9	95.3
	278.0	113.6	59.0	126.0	129.0	90.0	104.3	54.5	38.5	81.0	90.0	95.0
Average	275.5	115.7	58.0	135.1	129.0	87.0	101.4	53.2	36.8	81.9	88.5	95.2
Range	273.0 - 278.0	113.6 -117.7	56.9 - 59.0	126.0 -144.2	129.0	84.0 - 90.0	98.5 -104.3	51.8 - 54.5	35.1 - 38.5	81.0 - 82.7	86.9 - 90.0	95.0 - 95.3
7 - 8	274.0	111.4	51.1	121.5	129.0	91.0	103.0	53.3	35.0	87.3	83.1	91.9
	245.0	117.2 119.0	49.0 63.7	125.0 124.5	124.6 127.0	84.5 96.9	98.4 110.4	49.7 54.0	33.1 38.4	84.8 84.4	52.3	98.0 103.0
	286.0	107.5	55.2 57.5	118.0 124.5	134.0	90.9 92.0	97.9 99.3	46.8 50.0	34.8 35.5	87.8 83.0	89.0	97.3
Average	268.3	113.8	55.3	122.7	128.7	91.9	101.8	50.8	35.4	85.5	74.8	97.6
Range	245.0 - 286.0	107.5 -119.0	49.0 - 63.7	118.0 -125.0	124.6 -134.0	84.5 - 96.9	97.9 -110.4	46.8 - 54.0	33.1 - 38.4	83.0 - 87.8	52.3 - 89.0	91.9 -103.0

Table 1. Continued

Age (Years)	Basilar Length	Nasal Length	Nasal Width	Orbital Width	Zygomatic Width	Maxillary Width	Mastoid Width	Palatal Breadth (M^3)	Palatal Breadth (Pm^2)	Upper Molar Series	Prealveolar Length	Postdental Length
8 - 9	273.0	112.5	57.5 68.2	129.0 130.0	133.0 129.5	93.0 95.0	111.0 107.0	52.5 53.7	37.0 38.5	84.0 90.7	88.4	95.8 96.2
	272.0 280.0	116.5 111.3	53.0 61.0	124.5 128.0	126.0 127.5	91.5 96.8	94.3 103.6	51.0 51.6	35.0 37.8	82.5 87.2	83.0 82.3	98.0 97.9
	281.0 275.0	103.5 120.4	52.0 53.0	121.0 130.0	125.0 125.0	82.5 83.5	95.8 103.9	47.5 48.5	33.0 33.5	79.0 85.2	81.0 84.1	100.5 94.2
	294.0 282.0	116.4 94.0	57.5 54.0	125.5 125.0	126.0 140.0	92.5 93.3	105.0 102.9	50.3 53.4	31.5 36.8	88.8 83.0	87.3 85.6	94.6 97.0
	279.0 277.0	114.6 113.5	78.3 47.0	126.0 123.0	135.5 127.0	93.0 90.0	117.7 103.0	49.7 51.5	37.2 39.0	87.0 90.0	52.8 89.5	96.9 94.5
Average	279.2	111.4	58.2	126.2	129.5	91.4	104.4	51.0	35.9	85.7	81.6	96.6
Range	272.0 -294.0	94.0 - 120.4	47.0 - 78.3	121.0 - 130.0	125.0 - 140.0	82.5 - 96.8	94.3 - 117.7	48.5 - 53.4	31.5 - 39.0	79.0 - 90.7	52.8 - 89.0	94.5 -100.5
9 - 10	287.0	108.8	56.9	122.6	136.0	89.2	109.0	52.6	35.7	82.8	94.2	94.8
	280.0	121.2	59.8 54.6	122.5 129.5	126.0 131.3	90.0 103.2	102.7 104.3	48.4 54.9	36.5 37.9	86.7 87.1	87.5	88.5 95.8
	269.0	117.6	57.9	129.1 121.5	134.0 132.0	107.9 87.7	112.8	52.1 50.9	39.6 32.2	85.5 85.4	85.2	97.4 88.5
Average	278.7	115.9	57.3	125.0	131.9	95.6	107.2	51.8	36.4	85.5	89.0	93.0
Range	269.0 -287.0	108.8 - 121.2	54.6 - 59.8	121.5 - 129.5	126.0 - 136.0	87.7 -107.9	102.7 - 112.8	48.4 - 54.9	32.2 - 39.6	82.8 - 86.7	85.2 - 94.2	88.5 - 97.4
10 - 15	277.0	102.5	56.8	139.0	137.0	97.1	113.5	57.6	43.6	83.2	88.0	106.6
	273.0	110.2	60.7	131.0 131.0	131.0 136.0	91.8 95.7	114.0 110.3	58.0 51.0	36.3 36.6	82.8 90.0	84.3 87.5	85.5 94.3
	279.0	121.3	54.3	118.0 131.3	124.8 135.5	83.4 95.5	97.0 103.7	48.0 58.1	34.0 44.3	80.0 79.1	86.0 92.3	92.9 102.3
	289.3 278.0	117.2	61.3 53.1	123.8 133.0	128.5 129.0	90.3 94.0	107.0 96.5	55.2 52.2	35.0 36.0	84.4 85.5	92.3 90.7	97.7 93.1
	281.0 288.0	119.1	30.5 58.3	136.3 126.0	133.0 123.8	94.8 88.9	100.9 102.4	57.0 52.2	41.7 37.1	85.4 83.2	84.1	103.3 96.3
	276.0 288.3	117.5	52.0 54.4	128.0 136.0	134.0 138.0	94.0 93.7	113.0 115.0	47.8 53.3	36.7 39.2	90.0 81.5	89.3	89.2 102.3
	278.0	99.8	31.3 57.9	138.0 119.0	132.0 126.1	94.8 92.2	105.0 92.5	48.7 45.3	42.0 32.3	86.7 85.3	84.8	94.8 97.0
	283.1	129.3	55.5	134.0 135.0	137.0 136.0	93.5 101.9	104.0 100.8	50.5 54.2	36.5 35.4	85.7 92.0	90.2	93.9 98.9
Average	281.0	114.6	52.2	131.0	132.1	93.4	105.0	52.6	37.8	85.0	88.1	96.5
Range	273.0 -289.3	99.8 - 129.3	30.5 - 61.3	118.0 - 139.0	123.8 - 138.0	83.4 -101.9	92.5 - 115.0	45.3 - 58.1	32.3 - 44.3	79.1 - 92.0	84.3 - 92.3	85.5 -106.6
Mature but weathered ram skulls	272.0	108.3	58.7	127.0 115.5	128.0	97.2 92.1	110.7	50.7	40.4	87.2	81.5	95.3
	273.0	117.2	58.3	125.0 130.0	129.0 127.0	90.1 87.6	100.7 107.6	52.3 50.2	34.0	83.2 81.0	83.1	85.3 94.6
			60.5	130.0 122.0	127.0 128.0	98.5 92.6	108.7 112.0	47.6 51.5	33.0	81.2		97.5 95.3
				128.0 121.0	126.5	90.0 87.8	104.0 109.7	50.7 54.2	34.5	81.0		90.6
Average	272.5	112.8	59.2	124.8	127.5	92.0	107.6	51.0	35.5	82.7	82.3	93.1
Range	272.0 -273.0	108.3 - 117.2	58.3 - 60.5	115.5 - 130.0	126.5 - 129.0	87.6 - 97.2	100.7 - 112.0	47.6 - 54.2	33.0 - 40.4	33.0 - 40.4	81.5 - 83.1	85.3 - 97.5

Table 2a. Bighorn ram horn and skull weights and measurements 1965-1972.

Location	Date	Length R	Length L	Base R	Base L	tip to tip (inches)	Amt tip broken	HORN MEASUREMENTS (INCHES) Increment by Years 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	Skull weights (lbs) Horns and Plate	Skull less Lower Jaw	Body Weights Carcass 4 Quarters	Live	Hog Dressed
								4.5 YEARS																
Pincher Creek	1972	33.5	32.3	16.2	16.1	19.5	0	6.0	9.5	6.9	6.6	4.1								16.4				
								5.5 YEARS																
Sulfur River, Alta	1970	29.4	27.7	13.3	13.3	19.3	1.0														10.0			
								6.5 YEARS																
Sulfur River, Alta	1970	31.7	31.4	13.7	13.8	20.0	1.0														13.0			
Sheep Cr																								
Smoky River, Alta	1965	34.2	33.9	14.5	14.5	17.5	1.0													13.5		219.0	116.5	176.0
Cadomin, Alta	1972	30.8	30.4	14.0	14.0	12.0	1.0	2.5	6.0	5.0	5.2	4.7	4.7	1.9						12.0				
								7.5 YEARS																
Berland River, Alta	1969	34.8	34.8	14.8	14.8	19.0	2.0																19.0	
Sulfur River	1970	34.6	34.3	15.6	14.5		2.0														19.0			
Sulfur River	1969	28.2	28.2	13.5	13.5	14.7	2.0													13.0				
Sulfur River	1970	32.5	34.2	13.5	14.0		3.0													17.0				
								8.5 YEARS																
Sulfur River	1969	28.4	28.4	14.3	14.3		7.0													17.0				
Clearwater River	1970	30.4	30.8	14.5	14.5	19.2	1.0													16.0				
								9.5 YEARS																
Clearwater River	1970	32.4	34.6	15.4	15.5	20.6	1.0														19.0			
Clearwater River	1969	35.0	35.0	15.3	15.3		1.0														20.5			
								11.5 YEARS																
Cadomin, Alta	1972	35.7	35.7	15.2	15.3		6.0	0	2.7	7.0	6.3	5.2	3.5	2.5	2.4	1.6	1.2	1.1	1.0	22.6				
Cardinal River, Alta	1966	38.8	38.0	14.6	14.6															34.0				
Cadomin	1966	39.4	37.0	15.3	15.3															34.5				
Pincher Creek, Alta	1965	41.8	40.6	16.6	16.6	18.7														36.5				
								12.5 YEARS																
Waterton Park	1965	39.4	39.3	15.2	15.5	18.4														38.0				
								13.5 YEARS																
Cadomin	1955	40.5	41.4	16.4	16.4	18.6	7.0													35.0				
Clearwater River	1966	39.3	41.2	14.8	15.2	17.7														35.5				

Table 2B. Dall's sheep ram horn and skull weights and measurements, 1966-72.

Location	Date	Length R	Length L	Base R	Base L	tip to tip	Amt tip Broken Off	HORN MEASUREMENTS (INCHES) Increments by Years (inches) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	Skull weights (lbs.) Horn and Plate
							7.5 YEARS												
NWT Mackenzie Mtns.	1972	32.3	30.1	10.6	10.6	16.0	0	5.0	5.0	4.4	3.7	3.8	4.5	5.6					7:6
							8.5 YEARS												
Yukon Dezadeash Lake	1972	32.5	34.6	13.2	13,2	23.0	-	1.7	5.0	6.0	6.2	4.7	3.5	3.2	2.2				14.6
" "	1972	32.2	36.5	13.2	13.2	22.5	-	1.4	6.3	5.5	6.8	5.8	4.3	3.0	2.3	1.6			14.0
" "	1972	37.8	37.2	14.0	14.0	28.0	-	1.9	6.5	7.8	6.7	5.2	3.1	2.2	1.7	1.2			17.4
							9.5 YEARS												
Yukon Carcross	1970	42.0	42.0	13.6	13.6		1.0												17.5
Callison Area	1970	41.6	41.4	13.7	13.7	32.0	0												--
" "	1970	34.2	36.4	12.6	12.6	22.7	0												15.0
" "	1970	36.4	36.8	13.0	13.0	21.0	0												14.0
							10.5 YEARS												
Dezedeash Lake	1972	38.5	38.5	14.3	14.3	23.7	-	0.5	9.0	7.7	6.9	3.8	4.0	2.5	1.6	1.2	1.0	0.7	18.8
" "	1972	37.6	42.8	13.6	13.6	24.5	-	1.0	7.2	7.2	7.3	5.8	4.6	3.2	2.3	1.3	1.2	0.7	18.7
" "	1972	40.0	40.5	13.3	13.3	24.5	-	1.5	8.4	6.7	5.6	4.1	4.0	2.6	2.1	1.8	1.6	1.1	17.5
" "	1970	39.2	39.5	13.5	13.5	27.0	0												17.0

Table 2c. Stone sheep ram horn and skull weights and measurements in British Columbia 1970-71.

Location	Date	HORN MEASUREMENTS (INCHES) Length R	Length L	Base R	Base L	tip to tip	Amt tip Broken Off	Increments By Years (Tip to Base) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	Skull weights (lbs.) Horns and Plate
							7.5 YEARS									
Pink Mtn, B.C.	1970	35.3		12.6			1.0									13.0
Watson Lake, B.C.	1970	37.2		14.0			0									17.0
Watson Lake, B.C. (K. Brown)	1971	44.2	44.0	16.0	16.1	26.4	1.0	3.0	10.8	9.5	6.5	5.6	4.5	2.7	1.2	28.5
							8.5 YEARS									
Hudson Hope, B.C.	1970	37.7		13.7			0									16.0
Pink Mtn, B.C.	1970	39.2		13.4			2.0									18.0
Gary Lowells area Hudson Hope, B.C.	1970	45.5	44.8	14.4	14.3	24.0	0									24.0
							9.5 YEARS									
Gary Lowells area Hudson Hope, B.C.	1970	39.5	39.7	13.5	13.5	26.7	0									18.0
							10.5 YEARS									
Muskwa River, B.C.	1970	38.7	38.5	15.0	15.2	19.5	3.0									24.5
							11.0 YEARS									
B.C.	1970	38.7	39.4	13.5	13.5	--	--									20.0
							12.5 YEARS									
Pink Mtn, B.C.	1970	42.8	--	14.7	--		3.0									26.0
Pink Mtn, B.C.	1970	43.3	39.4	14.7	14.6	21.4	--									26.0

APPENDIX II

Horn Measurements, Skull and Live Weights,

Jasper, Banff and Waterton Lakes National Parks

Table 1a. Bighorn ram horn measurements and skull weights, Jasper National Park, 164-71.

Location	Date	Age (yrs)	Length (cm) R	Length (cm) L	Base (cm) R	Base (cm) L	Annuli definable R	Annuli definable L	Tip to tip (cm)	Skull wt. (gm)	Live wt. (kg)
J-W-2	1967	0.9	14.5	14.5	12.3	12.0	Nil	Nil	-	357.0	34.70
J-Mo-1	1969	1.5	32.3	32.6	20.5	20.5	1.0	1.0	43.0	889.5	-
J-G-12	1969	2.8	44.5	44.2	26.6	26.2	2.0	2.0	35.5	-	-
J-T.L.-1	1971	2.8	48.5	48.5	29.5	29.2	2.0	2.0	-	2849.0	-
J-W-1	1964	3.0	55.0	55.0	33.2	32.5	2.0	2.0	-	1020.0	-
J-W-13	1969	3.5	72.4	71.4	47.0	46.5	3.0	3.0	-	-	-
J-G-6	1967	3.8	65.0	68.0	33.0	33.5	3.0	3.0	44.0	435.5	-
J-W-9	1969	3.8	66.0	62.5	33.6	34.8	3.0	3.0	50.0	5897.0	73.48
J-C-2	1964	4.0	-	45.0	-	27.3	-	4.0	-	1512.0	-
J-Di-10	1969	4.1	55.6	55.9	32.3	32.3	4.0	4.0	-	3685.0	-
J-G-8	1967	4.5	75.4	74.5	33.6	33.8	4.0	4.0	36.0	5942.0	106.60
J-B-1	1967	4.5	69.0	75.0	34.9	36.0	4.0	4.0	45.5	-	-
J-W-1	1964	5.0	79.0	79.5	36.8	37.3	4.0	5.0	-	6577.0	-
J-W-16	1968	5.0	78.0	74.5	39.5	40.5	5.0	5.0	36.0	6940.0	-
J-G-4	1967	5.5	83.5	83.0	35.0	35.5	5.0	5.0	43.5	8301.0	99.79
J-C-1	1968	5.9	77.5	78.0	37.8	37.8	5.0	5.0	40.0	7801.0	79.83
J-W-1	1964	7.0	86.0	81.0	37.7	36.8	7.0	6.0	-	5386.0	-
J-W-1	1964	7.5	87.5	91.0	36.3	33.0	7.0	7.0	-	-	-
J-Di-4	1967	7.5	99.1	94.6	40.9	40.9	7.0	6.0	50.8	-	-
J-W-8	1969	7.8	89.5	97.2	37.3	36.8	6.0	7.0	-	9979.0	112.49
J-W-1	1964	8.0	101.0	92.0	40.1	40.2	7.0	6.0	52.6	12 247.0	-
J-I-2	1967	8.5	85.0	94.5	36.0	36.0	7.0	8.0	44.5	8845.0	100.70
J-W-11	1969	8.5	87.6	80.0	34.3	34.5	9.0	8.0	49.0	-	-
J-Wil-1	1967	9.0	94.5	91.5	37.4	36.8	8.0	8.0	45.5	11 094.0	-
J-Mo-4	1967	9.5	88.5	-	38.2	-	8.0	-	-	-	-
J-W-1	1965	10.0	95.0	88.5	36.7	36.9	9.0	8.0	-	10 319.0	-
J-W-1	1967	10.0	89.0	82.5	33.5	33.0	8.0	8.0	45.0	8162.0	-
J-Mi-4	1967	10.5	88.0	89.0	38.0	38.0	9.0	9.0	55.0	10 885.0	-
J-I-3	1967	N.O.	86.5	85.5	37.5	37.5	9.0	9.0	40.0	9299.0	-
J-W-1	1967	11.9	98.3	102.9	38.9	38.9	-	-	-	-	-
J-W-1	1965	12.0	87.0	87.0	36.7	36.2	11.0	11.0	-	10 829.0	-
J-I-5	1971	12.5	94.7	96.0	36.8	37.6	12.0	11.0	-	12 134.0	90.27
J-I-4	1970	12.9	96.2	96.5	37.1	37.0	11.0	11.0	-	11 204.0	-
J-M-1	1967	13.0	102.3	93.0	39.0	39.0	11.0	11.0	49.0	13 653.0	-

Table 1b. Bighorn ewe horn measurements and skull weights, Jasper National Park, 1965-71.

Location	Date	Age (yrs)	Length(cm) R	Length(cm) L	Base(cm) R	Base(cm) L	Annuli definable R	Annuli definable L	Tip to tip (cm)	Skull wt. (gm)	Live wt. (kg)
J-W-6	1969	1.8	20.3	18.0	11.4	11.4	2.0	2.0	-	-	42.18
J-Vi-2	1968	2.1	19.7	-	11.0	-	2.0	2.0	-	680.0	-
J-G-15	1970	2.4	23.0	17.1	12.4	12.1	2.0	1.0	17.5	721.1	79.83
J-EG-4	1970	2.9	34.3	31.1	12.9	12.7	2.0	2.0	37.0	647.8	-
J-Mo-3	1965	4.5	28.0	25.5	12.1	12.2	4.0	4.0	-	604.0	-
J-W-10	1969	4.5	21.8	24.9	12.2	12.2	4.0	4.0	-	-	-
J-G-13	1969	4.5	18.4	22.9	13.0	13.3	2.0	3.0	27.0	782.5	-
J-Di-9	1969	4.5	27.7	24.3	12.3	12.6	5.0	5.0	26.5	725.8	-
J-W-7	1969	4.5	23.1	10.2	12.7	11.9	3.0	1.0	-	794.0	-
J-G-9	1969	4.5	24.0	-	12.2	-	3.0	-	-	-	-
J-Mo-6	1971	4.5	20.1	21.6	14.0	14.0	3.5	3.5	-	907.0	63.96
J-TL-2	1971	5.5	26.4	22.6	12.7	12.4	8.0	8.0	-	1020.0	-
J-Di-8	1969	6.5	26.0	24.3	12.8	12.7	6.0	6.0	33.0	880.8	-
J-EG-1	1970	6.5	34.5	28.4	13.2	12.9	5.0	5.0	35.8	837.2	-
J-G-4	1970	7.0	26.0	25.5	13.5	13.1	5.5	5.5	-	998.0	-
J-Mo-7	1971	8.0	28.4	26.9	13.2	13.0	7.0	7.0	-	1134.0	-
J-Mo-5	1969	9.0	24.2	24.6	14.1	13.9	5.0	5.0	33.3	766.7	-
J-G-14	1969	Mature	28.1	-	15.8	-	7.0	-	-	-	-
J-Mi-7	1970	Mature	24.9	29.5	11.2	10.8	7.0	7.0	-	998.0	59.87

Table 2a. Bighorn ram horn measurements and skull weights, Banff National Park 1966-1970.

Location	Date	Age (yr)	Length (cm) R	Length (cm) L	Base (cm) R	Base (cm) L	Annuli R	Annuli L	Tip to tip (cm)	Skull wt (gm)	Live wt (kg)
B-V-11	Sept. 1968	1.3	28.0	27.0	18.4	18.1	1	1	-	-	-
B-V-19	Dec. 1969	2.5	46.0	N/A	26.0	N/A	2	N/A	N/A	1130	-
B-V-10	May 1968	2.9	54.4	55.1	30.0	30.6	3	3	48.0	2720	-
B-H-6	Jan. 1968	3.6	57.0	N/A	34.5	N/A	3	N/A	N/A	N/A	-
B-V-5	Feb. 1968	3.8	60.5	59.0	32.5	32.5	3	3	40.5	3720	83.5
B-V-6	May 1968	4.0	67.0	66.3	35.3	35.3	3	3	49.5	-	73.9
B-V-12	Apr. 1969	4.9	86.0	81.3	37.9	37.5	5	5	-	7940	92.5
B-V-1	Nov. 1966	5.5	81.9	82.6	37.1	37.1	5	5	-	-	112.9
B-H-2	Dec. 1967	5.5	80.0	81.5	36.5	36.5	4	5	46.0	8160	-
UNK	Dec. 1968	5.5	69.0	70.5	34.0	34.0	5	5	44.0	6500	-
B-S-6	Jan. 1969	5.5	86.5	89.0	36.0	36.0	5	5	45.0	7710	-
B-V-14	Nov. 1969	6.4	86.0	86.0	37.0	37.0	6	6	52.0	8620	99.3
B-V-9	Jan. 1969	6.5	93.0	90.5	39.1	38.2	6	5	45.0	11570	-
B-S-4	Spring 1967	7.0	88.3	81.2	34.6	34.3	6	5	-	7580	-
B-H-9	May 1970	7.9	91.8	92.3	35.0	32.9	8	8	-	-	-
B-S-10	March 1970	7.9	86.7	92.0	38.0	38.6	7	7	-	10090	-
B-S-3	Spring 1967	8.0	79.7	73.0	34.3	34.5	7	6	39.0	7300	-
B-S-7	June 1969	8.0	89.5	85.7	35.6	36.8	9	8	-	9980	-
B-S-8	June 1969	8.0	94.0	95.3	36.2	36.2	8	8	-	11550	-
B-I-1	Dec. 1966	8.5	94.0	96.5	38.5	38.5	8	8	41.5	10980	110.2
B-S-1	Spring 1967	9.0	91.5	93.5	44.0	57.0	7	7	43.0	10300	-
B-V-20	Jan. 1970	9.6	93.1	95.2	38.7	38.1	8	8	-	-	-
B-S-2	Spring 1967	11.0+	97.5	86.0	35.5	36.0	10	9	40.0	11250	-
B-S-11	June 1970	13.0	94.0	92.4	33.5	33.3	12	12	-	10430	-
B-S-9	June 1970	14.0+	96.0	99.3	34.6	35.2	13	13	46.5	10800	-

Table 2b. Bighorn ewe horn measurements and skull weights, Banff National Park, 1966-1970.

Location	Date	Age (yr)	Horn Length(cm) R	Horn Length(cm) L	Base (cm) R	Base (cm) L	Annuli R	Annuli L	Tip to tip (cm)	Skull wt (gm)	Live wt (kg)
B-P-3	Dec. 1966	0.6	4.6	4.0	6.0	5.9	0	0	9.0	272.0	34.5
B-H-1	Mar. 1967	0.8	5.8	5.5	6.0	6.0	0	0	-	204.0	25.4
B-H-4	Apr. 1968	0.8	4.0	3.8	5.2	5.2	0	0	7.7	-	-
B-H-3	May 1968	0.9	3.5	-	5.0	5.0	-	-	-	-	23.1*
B-V-8	Sept. 1968	1.3	-	-	-	-	-	-	-	-	57.6
B-F-2	Aug. 1969	2.2	16.0	16.0	9.5	9.7	1	1	27.8	780.3	-
B-V-18	Aug. 1970	2.2	12.7	18.8	10.4	11.0	1	2	-	519.5	-
B-V-2	Apr. 1967	4.8									64.4
B-S-5	Mar. 1968	4.0+	22.5	23.1	12.2	12.6	4	4	29.0	612.0	-
B-F-1	Aug. 1969	5.3	21.9	22.0	12.9	12.9	5	5	27.8	780.3	-
B-R-1	Jan. 1970	5.0+	23.2	24.3	12.1	11.7	5	5	-	-	-
B-V-17	Mar. 1970	5.5	10.4Ω	25.0	11.0	12.0	2	3	-	841.0	-
B-P-1	Dec. 1966	7.5	24.2	24.5	13.1	13.2	8	-	22.5	862.0	64.4
B-V-16	Dec. 1969	7.5	22.3	23.2	12.0	12.0	3	3	28.0	844.0	-
B-H-10	Nov. 1970	7.5	24.8	25.0	12.8	13.3	5	6	25.5	894.0	77.1
B-V-3	May 1967	7.0	24.8	21.9	13.3	13.3	-	-	26.7	-	62.4
B-V-5	Jan. 1969	8.5	22.2	22.2	12.2	12.4	5	5	24.0	694.0	-

*bled weight
Ωbroken

Table 3a. Bighorn ram horn measurements and skull weights, Waterton Lakes National Park 1957-1971.

Location	Date	Age (yr)	Length (cm) R	Length (cm) L	Base (cm) R	Base (cm) L	Annuli R	Annuli L	Tip to tip (cm)	Skull wt (gm)	Live wt (kg)
W-VR-5	May 1971	0.9	14.6	14.6	12.1	12.5	0	0	-	370	33.6
W-G-5	Mar. 1971	3.7	45.7	53.3	31.8	31.8	3	3	-	3450	75.3
	1957	7.5	83.0	84.5	38.5	39.0	6	6	41.5	10340	-
W-G-1	May 1968	7.9	98.5	100.0	37.5	37.9	7	7	50.5	12840	-
	Aug. 1968	8.0	88.3	87.7	39.7	39.0	8	8	-	-	-
	June 1965	8.0	100.0	101.5	40.2	39.2	7	8	-	12930	-
	1959	9.0	89.0	94.0	36.5	36.7	8	9	-	-	-
W-B-1	Apr. 1970	9.8	94.5	91.5	40.7	41.5	8	8	-	-	99.8
W-A-1	Apr. 1964	9.0	87.7	90.2	38.9	38.9	8	8	-	-	-
W-OB-1	Spr. 1970	9.9	95.0	98.5	39.0	39.0	8	8	-	-	-
	Aug. 1967	11.0	100.5	94.5	35.8	35.8	10	10	-	11790	-
	Oct. 1965	11.4	90.0	89.0	36.4	36.4	11	11	-	9980	-
W-VR-6	May 1971	11.0+	-	-	-	-	9	10	-	11880	114.8
W-A-1	May 1970	14.9	92.5	92.3	41.3	40.7	13	13	-	-	-

Table 3b. Bighorn ewe horn measurement and skull weights, Waterton Lakes National Park 1957-1971.

Location	Date	Age (yr)	Length (cm) R	Length (cm) L	Base (cm) R	Base (cm) L	Annuli R	Annuli L	Tip to tip (cm)	Skull wt (gm)	Live wt (kg)
W-IB-8	Apr. 1971	0.9	3.8	3.2	N/A	3.8	0	0	-	270	26.3
W-IB-7	Apr. 1971	1.9	16.5	17.8	10.8	10.8	1	1	-	540	35.4
W-G-4	Mar. 1971	7.0+	29.2	27.9	13.3	13.3	-	-	34.0	1020	73.5
W-VR-4	May 1971	7.0+	29.2	29.9	13.7	14.0	6	6	-	1179	76.7
W-G-9	Mar. 1971	10.0	23.5	20.9	12.1	11.7	8	7	32.0	862	-
W-G-8	Feb. 1971	Mature	26.7	-	13.3	-	8	-	-	953	-
W-G-2	May 1969	15.9	23.9	29.8	12.1	13.02	9	8		1132.6	54.4

APPENDIX III

Dental Composition of Rocky Mountain Bighorn Sheep at Ages 0.1 to 4.0 Years

Table 1. Replacement of incisiform teeth in bighorn sheep examined at Jasper National Park, 1960-1973.

Age (yrs)	Incisors					Percentage of total in age group
	Milk	Perm	Male	Female	Combined	
0.5-0.9	8	0	12	20	32	88.9
	6	2	3	1	4	11.1
			15	21	36	100.0
1.5-1.9	6	2	9	7	16	50.0
	5	3	0	2	2	6.3
	4	4	2	8	10	31.3
	4	2	2	0	2	6.3
	2	6	1	1	2	6.3
			14	18	32	100.0
2.5-2.9	6	2	0	1	1	9.1
	4	4	1	0	1	9.1
	3	5	1	0	1	9.1
	2	6	0	1	1	9.1
	0	8	2	5	7	63.6
			4	7	11	100.0
3.5-4.0+	2	6	0	1	1	3.4
	0	6	0	1	1	3.4
	0	8	2	25	27	93.1
			2	27	29	99.5

Table 2. Replacement of incisiform teeth in bighorn sheep examined at Waterton Lakes National Park, 1962-1965 (from Blood 1966)

Age (yrs.)	Incisors					Percentage of total in age group
	Milk	Perm	Male	Female	Combined	
0.8-1.0	8	0	10	3	13	100
1.8-2.0	2	4	0	1	1	4.3
	4	4	0	1	1	4.3
	6	2	11	10	21	91.3
			11	12	23	99.9
2.8-3.0	0	6	2	0	2	6.8
	2	6	8	7	15	51.7
	0	5	1	0	1	3.4
	3	4	1	1	2	6.8
	4	4	4	1	5	17.2
	5	3	1	0	1	3.4
	6	2	3	0	3	10.3
			20	9	29	99.6
3.8-4.0	0	8	9	4	13	56.5
	0	6	1	0	1	4.3
	2	6	4	3	7	30.4
	3	5	1	0	1	4.3
	2	4	0	1	1	4.3
			15	8	23	99.8