HORN GROWTH AND *QUALITY* MANAGEMENT FOR MOUNTAIN GOATS

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ABSTRACT

Population quality concepts in Caprinae are assessed for application in mountain goat management. Individual and population horn growth data were obtained from both my study area in west-central British Columbia and from the first year (1976/77) of a Compulsory Inspection Data (CID) reporting system introducted in this Province. Analyses of the CID returns mainly demonstrated a lack of data quality (94%), with respect to recording errors of horn measure, and incorrect age analyses determined by both horn keratin and tooth cementum annuli. Of the usable CID, opposing characteristics of male and female horn growth are described in terms of rate of horn growth. Male goat horn growth simulates *high quality* concepts whereas female horn growth is more representative of *low quality* regimes. Analyses of variance of both male and female subadult horn growth were conducted on a number of variables (mountain systems, their geological description, predominant biogeoclimatic zone, soil type and crude density, game management regions and their respective subunits, and other geographic areas of British Columbia (north vs. south and coastal vs. interior)). Some significant horn growth relationships were apparent, but their biological meanings are uncertain. Based upon the data presented, population quality concepts are the premise of a discussion on horn growth and socio-biological models of high and low population density and levels of harvest.

INTRODUCTION

Due to the lack of information available on mountain goats, they have historically been managed throughout western North America by implementing traditional biological principles appropriate for other ungulates (Eastman 1977, Hebert and Turnbull 1977). This has resulted in detrimental effects on the status of many mountain goat populations (British Columbia Fish and Wildlife Branch 1976, Foster 1977(a), Kuck 1977, Pendergast and Bindernagel 1977, and Phelps et al. 1976 this Proceedings). An additive effect of these management practices has been a decrease in recreational value of mountain goat sport hunting (Foster 1977(a), Pearse and Bowden 1972).

Subsequently, many game management agencies have implemented more restrictive goat hunting regulations in order to promote better management of the species (Foster 1977(a), Johnson 1977). However, much more research is required of this species. Past studies should be used to quantify aspects of goat ecology described by the many researchers listed in Foster (1977(b)), and more importantly, to determine the factors distinguishing *regional* ecology as discussed by Foster (1976) and documented by Hebert and Turnbull (1977).

It may be possible to assess variability in mountain goat range, demography and ecology, from the analysis of variation in horn growth. The structure of such a concept is based upon the plane of nutrition of individuals from differing ranges (Klein 1964, Lambert and Bathgate 1977, and Nievergelt 1966). Bunnell (1978) correlated annual rate of Dall ram horn growth to climatic variation, which ultimately controls energy availability to any given system and individual. The concept of *population quality* for Bovids (Table 1 - MODEL I) has also been examined in North American mountain sheep by Geist (1971), Heimer and Smith (1975) and Shackleton (1973).

The objectives of this paper are (i) to determine the feasibility of handling and analysing goat horn data collected by the British Columbia Fish and Wildlife Branch during the 1976/77 hunting season, (ii) to examine characteristics of mountain goat horn growth, and (iii) to assess the concept of mountain goat annual horn growth as a range condition indicator.

I thank D. Eastman, L. Friis and P. Haley of the British Columbia Fish and Wildlife Branch for their contributions of large portions of the data base. Partial funding for this study was supplied to Dr. D.M. Shackleton and myself by the Canadian Wildlife Service, National Research Council of Canada and the University of British Columbia. Computer analyses were funded by the Department of Animal Science. E. Rahs helped with much of the data handling.

METHODS

Data Sources

Interpopulation horn growth and age data were extracted from records of the first year (1976/77) of a mountain goat Compulsory Inspection Data (CID) retrieval system, a management technique instituted in British Columbia by the Fish and Wildlife Branch (Figure 1(a)). The omitted portions of the CID form describe hunter effort and kill and location data, in addition to hunter and guide identification.

Intrapopulation information was extracted from data of my current study on Maroon Mountain in west-central British Columbia.

Data of the left horn only were utilized throughout this paper.

CID Recorder Precision

Recording errors in the CID were due primarily to the variety of trained and untrained personnel completing the records. The following list is a summary of the more common problems and sources of error which were recognized and corrected, *a priori*:

I. INTERPOPULATION MODEL

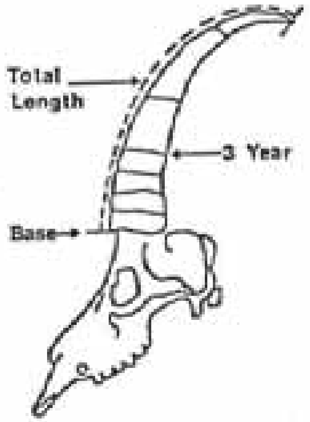
High Quality (optimal habitat)	Quality characteristics	Low Quality (marginal habitat)
larger	skull and horn size	smaller
more	lamb(or kid)-play	less
longer (and self terminating)	" " suckles	shorter
rapid	yearling maturation	delayed
larger	body size	smaller
higher	population density	lower
higher	productivity	lower
shorter	life expectancy	longer

II. INTRAPOPULATION MODEL

Optimal Habitat (mixed types)	Marginal Habitat (little mixture)
dominant and quality reproductive individuals (females)	subordinate and more promiscuous individuals (males and subadults)
seasonally regulated grazing and browsing food habits	predominantly browsing food habit
social animals with larger group sizes	less social animals with smaller group sizes
reduced resource competition	increased resource competition

TABLE 1. Hypothetical bioenergetic models inferring individual and population quality concepts for both Caprini and Rupicaprini. The interpopulation model (I) is structured from data collected from Geist (1971), Neivergelt (1966) and Shackleton (1973). The intrapopulation model is based on the author's studies on mountain goat in West-Central British Columbia.

A.



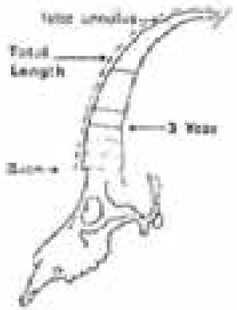
HORN CIRCUMFERENCE MEASUREMENTS

Point of Measurement	Horn	
	R	L
Base		

HORN LENGTH MEASUREMENTS

	Horn	
	R	L
Total length of horn		
Established length of horn broomed portion		
Tip to 1st annulus		
Tip to 2nd annulus		
Tip to 3rd annulus		
Tip to 4th annulus		
Tip to 5th annulus		
Tip to 6th annulus		

B.



Mountain Goat:

Age (from annuli)..............................

Goat tooth extracted: Yes ☐ No ☐

Vial No..................

AGE SUMMARY (all species)

Aging Method	Code	Age (yr)	Aged by
Horn annuli	4		
Tooth annuli			
Wear, staining, eruption	3		
Other (specify)			

Tooth extracted Yes ☐ 1 No ☐ 2

Recorder's name ______________________

Location ______________________

Check Date		
D	M	Y

FIGURE 1. Portions of Compulsory Inspection Data (CID) formats for measuring horns and aging mountain goats, implemented by the British Columbia Fish and Wildlife Branch. Inadequacies in the 1976/77 format (A) have been accomodated in the 1977/78 format (B).

(i) Ages determined by the horn annulus method were incorrectly assessed where recorders thought that the absolute number of horn annuli corresponded to the true age of the animal. The CID skull diagram was erroneously labelled in the 1976/77 format and misleading in the 1977/78 format (Figure 1(a) and (b)).

(ii) The 'false annulus' (formed during the first winter of life) was frequently recognized because of the diagrams in Figure 1(a) and (b). Therefore, based upon recorder judgement of (i), horn age estimates ranged from minus two to plus one years about the true age of the animal.

(iii) Some recorders obviously over-estimated the number of true horn annuli on adult horns, counting superannulations and incomplete annuli in their age determination.

(iv) Conversely, rapid horn growth of the first 1.5 years of life was not recognized as such and conservative ages were assigned.

(v) Consecutive horn measurements frequently did not correspond; (a) the measure of the last annulus (from the tip of the horn) sometimes exceeded the total horn length as a result of non-systematic measuring, and/or (b) consecutive annuli measurements were often less than or equal to a previous annulus measure.

(vi) The Table for Horn Measurement was often completed to the 7th annulus, as room permitted only (Figure 1(a)), but the animal was assigned an older age. Recorder accuracy was next to impossible to check on these records as no recorder identification was required on the form.

Pertinent CID Compensations

Aging errors associated with the inclusion of the 'false annulus' during the first 1.5 years of horn growth were reduced by examining 60 horns representing both high and low quality growth. I defined the 'false annulus' upper limit (i.e. the maximum growth of the first year of life) and the first annulus lower limit at 95mm.

A lack of correlation between the length of horn recorded and the age assigned to that animal by Matson's[1] was observed. Therefore complimentary sets of horn and jaws were examined from my study area. It was concluded that no cementum annulus was formed in the lower medial incisor until after it had erupted in the milk and permanent forms and experienced one winter in that state (Foster et al. in prog.). Resultantly, all ages assigned to the teeth by Matson's were wanting one year.

All age determinations by horn annuli and tooth cementum analysis were corrected on the CID accordingly.

[1] Tooth extractions were sent to Matson's Commercial Microtechnique (Montana) for cementum analysis.

Inter-Regional Horn Quality

Because of the lack of population-specific data, horn growth of the first two years of life could only be compared on geographic bases or with other independent variables. I compared male and female subadult horn growth to mountain systems and to descriptions of their geological elements (Douglas 1976), to biogeoclimatic zones (Krajine 1969), to regions of Britsh Columbia defined as 'North' and 'South' (Foster 1976) and to Coastal vs. Interior regions, to game management regions and to their subunits, and to predominant soil types (Valentine et al. 1978) and mountain goat distribution abundance (Blower 1976).

Twleve mountain systems in British Columbia were compared; St. Elias, Coast (north of Prince Rupert), Coast (south of Prince Rupert), Cassiar, Omineca, Skeena, Hazelton, Rocky (north of Prince George), Rocky (south of Prince George) and Columbia Mountains, Rocky Mountain Foothills and the Fraser Plateau.

Six geological elements are defined. Crystalline rocks of the St. Elias Fold Belt make up the St. Elias Mountains. Granitic rock of the Coast Plutonic Complex make up the Coast Mountains north and south of Prince Rupert. Metamorphic rocks of the Omineca Crystalline Belt compose the Cassiar, Omineca and Columbia Mountains and Sedimentary volcanic rock of the Columbian Zwischengebirge comprise the Skeena and Hazelton Mountains. The carbonates of the Rocky Mountain Thrust Belt make up the Rocky Mountains (north and south of Prince George) and the Rocky Mountain Foothills, and the Cascade Fold Belt constitutes the Fraser Plateau.

Biogeoclimatic zones compared were the Alpine Tundra (AT), Engelmann Spruce - Subalpine Fir (ESSF), Boreal White and Black Spruce (BWBS), Sub-boreal Spruce (SBS), Subalpine Mountain Hemlock (SHH), Coastal Western Hemlock (CWH), Interior Douglas Fir (IDF) and Interior Western Hemlock (IWH) zones. Only the predominant zone within each mountain system was compared.

Geographic regions of British Columbia are compared as follows; 'North' contains Game Management Regions 6 and 7 and 'South' contains Regions 1 through 5. Coastal British Columbia contains Regions 1, 2, 5 and 6 and the Interior area is made up of Regions 3, 4 and 7. Consult Fish and Wildlife Branch game regulations or see Foster (1976) for more complete descriptions of these Regions.

Each game management Region comprises a number of smaller game management units (MU's). In all, 70 MU's had goats harvested from them in the 1976/77 hunting season. 43 different MU's had both male and female goats taken within their boundaries.

Predominant soil types for each MU were defined from the recently compiled soil map of British Columbia by Valentine et al. (1978). The nine soil classifications compared were; brunisolic, chernozemic, cryosolic, gleysolic, luvisolic, organic, podzolic, regosolic and lithic soils.

A mountain goat density index was obtained from Blower's (1976) mountain goat distribution and abundance map. Prevalent densities for each MU were ranked from very sparse to plentiful in eight categories.

Volumetric Determination of Horns

Mountain goat horn volumes were calculated assuming the horn to represent a straight cone. The following formulae were used;

$$V = \frac{(\pi) \cdot (r^2) \cdot (L)}{3} \qquad\qquad r = \frac{C}{2(\pi)}$$

where V = horn volume, π = 3.1416, r = the radius of the cone base, and L = the total length of the horn along the outside curve. Substituting r^2 with the mathematically appropriate function to the right, where C = the circumference about the base of the horn cone, I simplified the horn volume equation into the following workable form;

$$V = \frac{C}{6.2832}^{\,2} \cdot (1.0472) \cdot (L)$$

Horn volume, in this context, is only a relative volume index.

Variation in Horn Growth

To quantify the variation in horn growth between individuals of the same age, the total (vertical) length of the horn was visually examined and expressed as a ratio of ear length (measured on the sagittal side of the ear). This field technique, which I term Horn-to-Ear Ratio (HER), is a guide to the variation in horn growth among subadults specifically, before their horns grow excessively long and curved (male horn curvature especially, creates artifacts within the HER criteria).

RESULTS

INTRASPECIFIC CID ANALYSES

Accuracy of Aging Mountain Goats

To check accuracy of age determination in the CID, a matrix was constructed comparing corrected ages of mountain goats calculated by the number of horn annuli, to those ages assigned by tooth cementum analysis. From a total sample size of 710 CID records collected in 1976/77, 150 forms (21%) had accompanying tooth extractions for the purpose of aging. The matrix clearly gives evidence that 69.3% (n=104) of the CID records were incorrect, with 41.3% (n=61) of the records overestimating the corresponding tooth age, using the horn annuli method. I refer to tooth age in the absolute sense assuming that the corrected tooth cementum analyses represent chronologic age.

The immediate implication of the age matrix thus far in the analysis is the dismissal of 93.5% or 664 records of questionable information on incremental horn measure and age assessment from the CID retrieval system. From the remainder of the data, normalized frequency age distributions suggest that younger cohorts (½ to 4½ years old) were given conservative age estimates using the horn annulus method whereas adults (5½ to 8½ years old) were aged liberally. No directional bias was apparent in the aging of very old animals (≥ 9 years old), suggesting even higher recorder subjectivity.

It is apparent from Figure 2, however, that male horns are nearly twice (1.81 X) as easy to assess ages from than are female horns, which are over-aged proportionately more due to their presence of superannulations and other pseudoannuli.

Precision of CID

Analyses of data collected from specialized Wildlife personnel support the source of variation in recorder precision of horn measures. Ten biologists examined a pair of male horns and eleven examined female horns. Horn measurements required in the CID forms (Figure 1(a)) were requested. Analyses of these data showed that the only significant growth data available were; (i) total horn length (S.E. = 1.5mm for ♂ horns and 2.4mm for ♀ horns), (ii) basal circumference (S.E. = 0.8mm for ♂ horns and 1.6mm for ♀ horns), and (iii) horn growth for the first two years ('tip-to-first annulus') of life (S.E. = 0.9mm for ♂ horns and 1.7mm for ♀ horns). Attempts to measure the second annulus (from the tip of the horn) resulted in unacceptable standard errors of 10.1 and 14.5 millimeters for male and female horns respectively.

Characteristics of Horn Growth

The precision maintained in measuring the three former characteristics allows limited horn growth analysis. Where analyses occur in this paper, I chose to use the left horn measures. There were no statistically significant differences from the right horn, with respect to total horn length ($U = 217$, $P > 0.20$, $N = 20$) or basal circumference ($U = 210$, $P > 0.30$, $N = 20$).

Horn growth characteristic of the first two years of life differs between sexes (♂: $\bar{x}$ = 153mm, S.E. = 21mm, N = 381; ♀ : $\bar{x}$ = 141mm, S.E. = 19mm, N = 252; $t = 7.43$, $P < .001$). Frequency distributions are portrayed in Figure 3 showing how male horn growth is negatively skewed towards more rapid growth. Indications from only a few horns examined are that both males and females exhibit the greatest horn growth rates during their second growing season (Figure 4). It was also discovered that female horn growth during the third growing season ($\bar{x}$ = 28mm, S.E. = 11mm, N = 11) is significantly greater than male horn growth ($\bar{x}$ = 16mm,

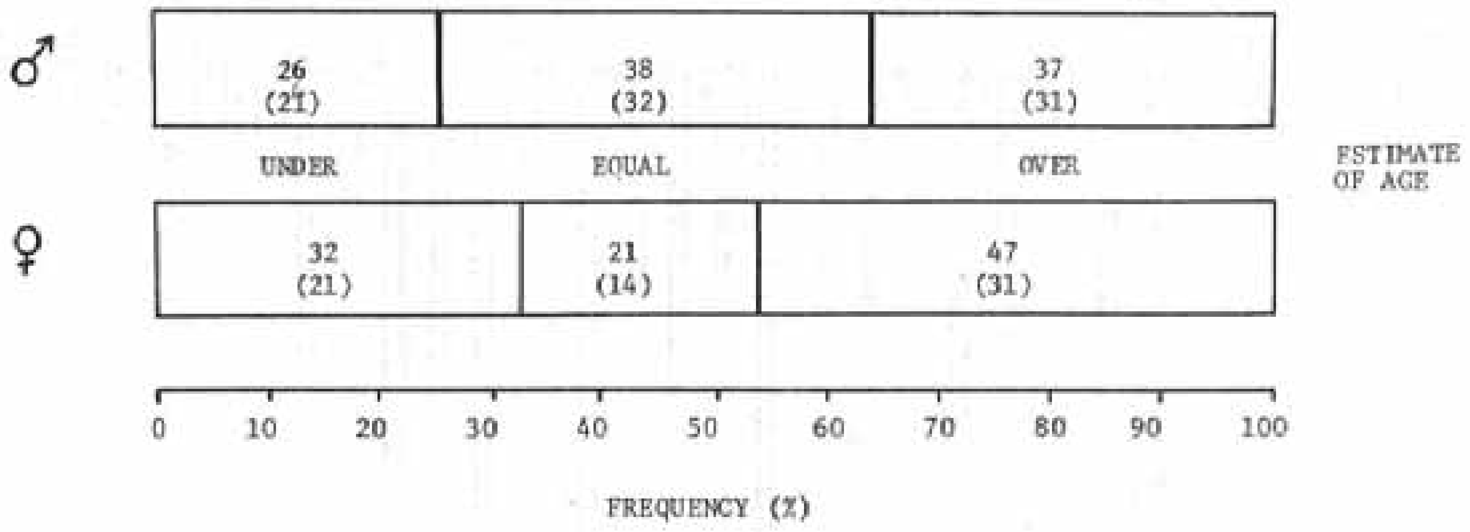


FIGURE 2. Accuracy in age estimation of male and female mountain goat horns. The data are extracted from the 1976/77 mountain goat CID forms having corresponding age analyses from both the horn and tooth cementum annuli methods. The bracketed values reflect sample size.

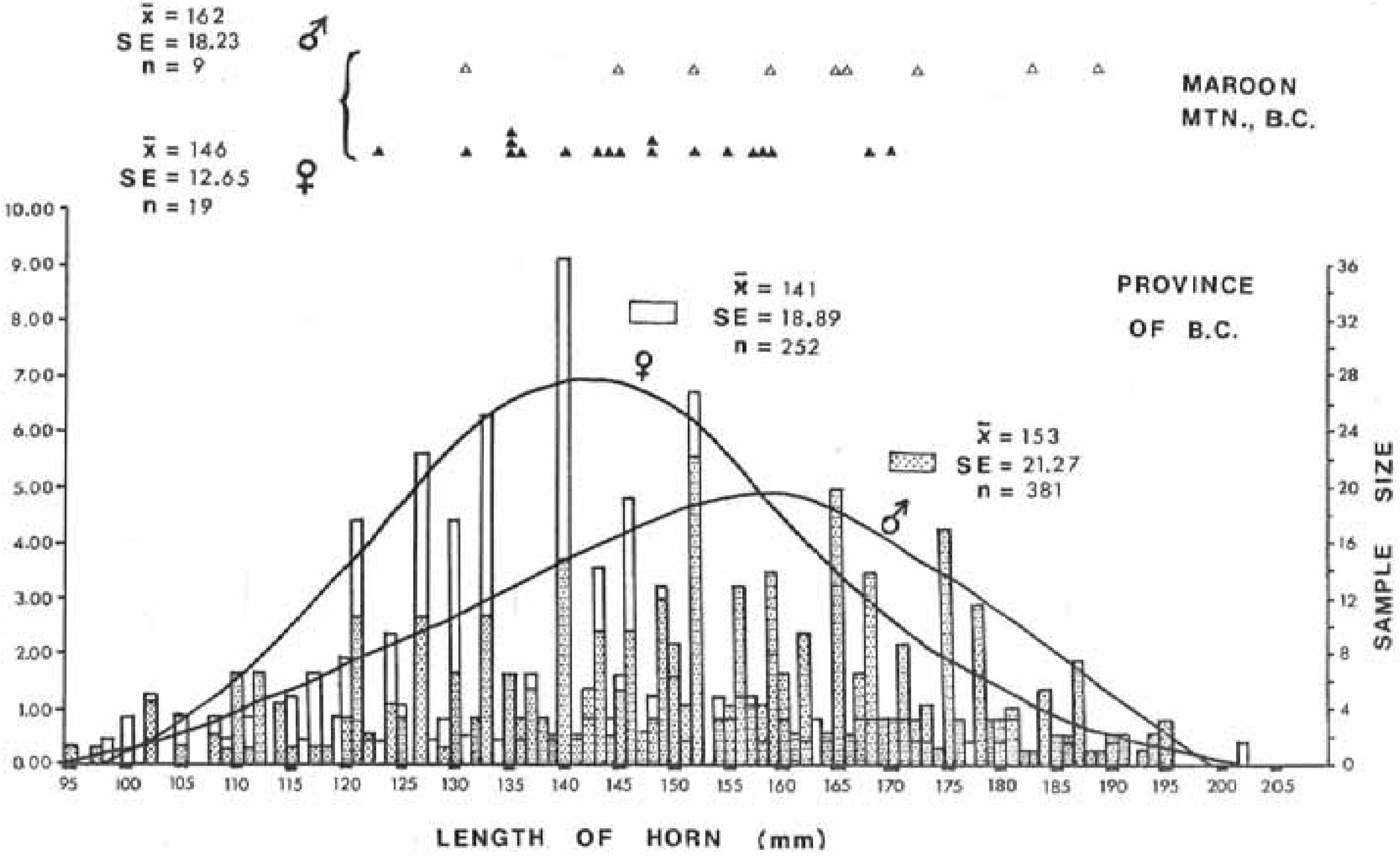
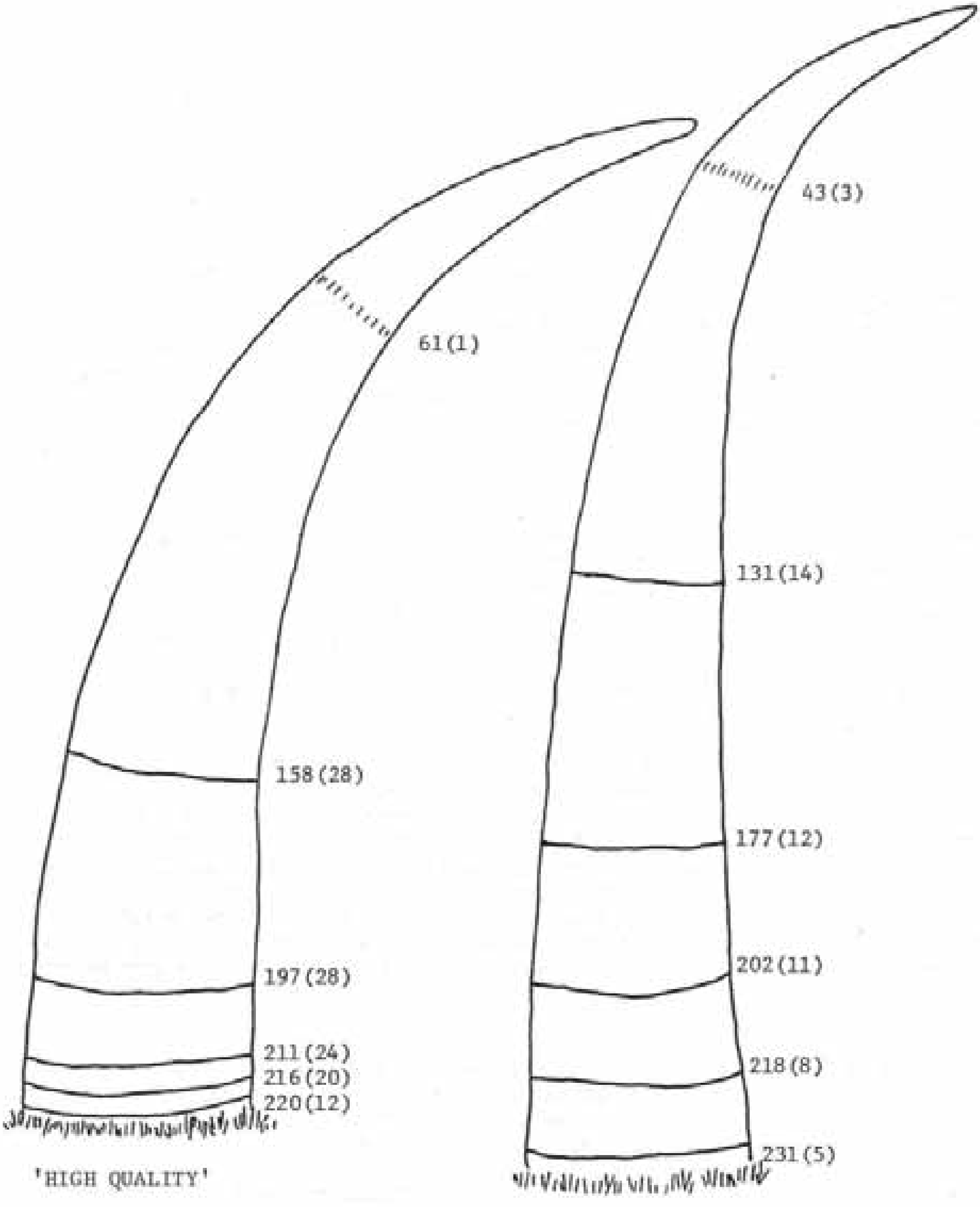


Figure 3. Comparison of both male and female linear subadult horn growth of the first two years of life (measured along the outside curve of the horn). The Provincial data are taken from the 1976/77 CID and the data from Maroon Mountain were gathered from the author's study area. Where the male frequency column exceeds the female frequency, the latt is expressed by a bar within the male data. Horn measures 132, 135, 138 and 170 represent equal male and female frequency data.



6.5 YEARS

FIGURE 4. Mean incremental horn growth rates for both male and female mountain goats. Male horn growth implies a high quality concept which relates to the ecology of billies, in contrast to female horn growth which represents low quality concepts underlying the ecology of nannies. The horns are drawn to scale. Open figures indicate mean horn length in mm. Bracketed values reflect sample sizes.

S.E. = 6mm, N = 24). Hoefs (1977) concluded similar growth trends for mountain goats in the Yukon Territory.

Age-specific analyses of total horn lengths and basal circumferences were not included due to the lack of data. However, additional incremental analyses of mountain goat horns are discussed to describe a more complete scenario of male and female horn growth regimes. Total horn length, in addition to annual rates of growth, were found to vary significantly between males and females for most age-specific categories (Figure 4), but the data are limited. The disparity of the sexes frequently increases with age.

Sex and Interpopulation Horn Quality

Above the Provincial frequency distributions of horn growth represented in Figure 3 are data plotted from the Maroon Mountain goat herd only. These intrapopulation growth means fall in accordance with the Provincial averages for each sex. Unfortunately, data were adequate only from this one population. The Maroon Mountain goat herd is characteristic of a productivity rate of 55 kids per 100 adult females. Crude planimetric density approximates 5.5 goats/km^2 (1976 - 1978 data) and the herd apparently sustains a harvest level of 10% (Foster, in prep.).

Although interpopulation data are not available for comparison, horn growth of the first two years of life were compared on larger geographic levels and with several independent variables (Table 2). One-way analysis of variance tests show no significant relationships for male and for female subadult horn growth with variables relating to mountain systems or their geological elements. There is also no relationship between biogeoclimatic zones, Coastal and Interior British Columbia, game management units, or distribution density or predominant soil types based upon these latter geographic units. However, male horn growth is found to be significantly different between the larger game management Regions ($P = 0.04$) and also between North and South British Columbia ($P = .01$), whereas female horn growth is not.

Further investigation was undertaken with two-way analysis of variance testing, comparing each of the above variables with sex and with the interaction of each sex with all variable categories. As expected, contrasts with each sex showed significant differences within each of the variables ($P = 0.001$).

The higher power offered by two-way analysis of variance tests resulted in significance ($P = 0.040$) between certain areas described by geological elements, where the one-way analysis of variance did not ($P = 0.120$). Interpretation of a Duncan's multiple range test is that lower horn growth characterized by those populations living within the St. Elias Fold Belt of the St. Elias Mountains (♂ : $\bar{x}$ = 136mm, N = 8; ♀ : $\bar{x}$ = 133mm, N = 5) vary significantly from measures of higher growth rates characterized by mountain goats living within the Cassiar, Omineca and Columbia Mountains (Omineca Crystalline Belt) and also within the Skeena and Hazelton Mountains (Columbian Swischengebirge complex) (♂ : $\bar{x}$ = 155mm, N = 226; ♀ : $\bar{x}$ = 143mm, N = 107). In other words, rates of mountain goat subadult

Mountain Range [Biogeoclimatic Zone][1]	Geological Element[2]	Density[3]	M.U.	MALE				FEMALE			
				$\bar{X}$	Standard Error	Range	N	$\bar{X}$	Standard Error	Range	N
Hazelton [AT/ESSF/CWH SMH	Columbian Zwischengebirge	f	6-02	122		121 - 122	2	140			1
		f	6-04	149		110 - 184	5	143		120 - 163	4
		m	6-09	148		110 - 182	12	148		123 - 181	5
		p	6-15(A-E)	165		132 - 189	11	143		135 - 152	5
				152	23.04	110 - 189	30	145	16.04	120 - 181	15
Coast (S. of Prince Rupert) [AT/SMH/CWH]	Coast Plutonic Complex	m(p)	1-15	151		143 - 159	2	-		-	-
		f((m))	2-05	127			1	-		-	-
		m(f)	2-06	131		114 - 146	4	-		-	-
		f(m)	2-08	143		136 - 150	2	132		111 - 149	3
		p(m)	2-09	148		127 - 169	3	133		121 - 146	3
		m	2-15	133		114 - 156	3	-		-	-
		f(m)	5-04	157		146 - 167	2	128		98 - 168	3
		m(f)	5-05	141		102 - 156	6	144		121 - 178	8
		m(f)((p))	5-06	178		178 - 181	2	159			1
		m(f)	5-08	168			1	140			1
		m((f))	5-09	121			1	149		133 - 165	2
		m	6-03	102			1	-		-	-
		m	6-10	172			1	160		143 - 177	2
		m(f)	6-11	168			1	-		-	-
				144	21.48	102 - 181	30	141	20.58	98 - 178	23
Rocky (N. of Prince George) (MUSKWA) [AT/ESSF/BWBS]	Rocky Mountain Thrust Belt	m(f)	7-37	176		172 - 181	3	161		140 - 187	4
		m	7-41	146		124 - 171	11	150		140 - 165	3
		m(f)	7-51	152		102 - 195	26	136		108 - 165	19
				152	22.17	102 - 195	40	141	19.39	98 - 187	26
Rocky Mountain Foothills [AT/ESSF/BWBS]	Rocky Mountain Thrust Belt	m(p)((f))	7-19	132			1	122		117 - 127	3
		m((f))	7-21	138		121 - 152	3	-		-	-
		f	7-23	146			1	-		-	-
		f	7-31	140			1	142		140 - 146	4
		f	7-36	170		165 - 175	3	134		121 - 143	7
		f(m)	7-42	160		140 - 191	10	144		127 - 181	4
		f	7-43	153		121 - 187	5	125		105 - 152	4
		f	7-47	155			1	-		-	-
		f	7-49	160		155 - 165	2	-		-	-
		m(f)	7-50	158		124 - 184	8	131		114 - 146	5
		f	7-53	157			1	-		-	-
		f(m)	7-54	132		95 - 152	4	102		-	1
				153	20.15	95 - 191	40	132	15.62	102 - 181	28

TABLE 2. Some aspects of regional variation in mountain goat linear horn length of the first two years of life (measured along the outside curve of the horn). Each mountain system is summarized by lined rows. The following symbolic abbreviations are used: (i) M.U. = game management unit, (ii) X = arithmetic mean of linear subadult horn growth, and (iii) n = sample size.

Mountain Range [Biogeoclimatic Zone][1]	Geological Element[2]	Density[3]	M.U.	MALE				FEMALE			
				$\bar{X}$	Standard Error	Range	n	$\bar{X}$	Standard Error	Range	N
St. Elias [AT/ESSF]	St. Elias Fold Belt	m	6-28	143		121-160	5	133		117-152	5
		p((f))	6-29	125		115-140	3	-		-	-
				136	17.93	115 - 160	8	133	12.51	117-152	5
Coast (N. of Prince Rupert) [AT/ESSF/BWBS]	Coast Plutonic Complex	f(m)	6-14	169		157 - 187	5	141		127-152	5
		m(f)	6-15[4]	162		158 - 165	2	-		127-152	-
	Coast Plutonic Complex	m(p)(f)	6-21	162		152 - 175	3	136		124-140	4
		m((f))-((p))	6-22	-		-	-	130		124-140	1
		m(f)	6-25	155		135 - 193	9	131		121-141	3
		p(m)	6-26	156		110 - 194	20	142		105-170	3
		p(m)(f)	6-27	134		97 - 165	10	133		100-160	11
				153	24.20	97 - 194	49	136	16.93	100-170	27
Cassiar [AT/ESSF/BWBS]	Omineca Crystalline Belt	f((m))	6-19	149		111 - 186	7	134		121-155	5
		f(m)	6-23	160		124 - 191	18	143		124-155	8
		m	6-24	152			1	-		-	-
		m((f))	7-52	155		102 - 194	49	143		95-178	39
				156	18.08	102 - 194	75	142	17.92	95-178	52
Omineca (Swannell) [AT/ESSF/SBS]	Omineca Crystalline Belt	p(m)	6-18	156		117 - 178	10	141		124-162	4
		f	7-27	160			1	-		-	-
		f	7-28	-		-	-	150		-	1
		f(m)	7-38	163		159 - 167	3	140		119-150	3
		m(p)	7-39	153		117 - 180	11	148		108-190	25
		m	7-40	148		121 - 175	2	114		102-125	2
				155	19.83	117 - 180	27	145	21.76	102-190	35
Skeena (Babine) [AT/ESSF/SBS]	Columbian Zwischengebirge	m(p)	6-17 (A&B)	167		156 - 179	3	164		145-190	3
		p	6-20	156		120 - 190	27	134		114-172	18
		m(p)	6-08	162	17.88	140 - 181	6	157	30.23	150-202	5
				158	19.72	120 - 190	36	142	22.92	102-202	26

Mountain Range [Biogeoclimatic Zone][1]	Geological Element[2]	Density[3]	M.U.	MALE				FEMALE			
				$\bar{x}$	Standard Error	Range	N	$\bar{x}$	Standard Error	Range	N
Rocky (S. of Prince George [AT/ESSF/IDF]	Rocky Mountain Thrust Belt	p	4-23	146		108 - 185	5	153		152 - 154	2
		p	4-24	151		133 - 168	2	-			-
		m(f)	7-02	144		132 - 151	3	-			-
		f(m)	7-03	162		148 - 178	3	144			1
				150	20.76	108 - 185	13	150	5.29	144 - 154	3
Columbia (Monashee Mts.) [AT/ESSF/IWH]	Omineca Crystalline Belt	m	3-36	186			1	-		-	-
		m	3-43	126		121 - 130	2	127			1
		m	4-38	108			1	-		-	-
				136	34.37	108 - 130	4	127			1
(Cariboo Mts) [AT/ESSF/IWH]		m	3-44	139		110 - 154	4	127		102 - 157	5
		m	3-46	-		-	-	140			1
		m(f)	5-15(A&B)	146		121 - 178	5	160		146 - 178	5
		m	7-04	157		124 - 195	8	137			1
		f(m)	7-05(A&B)	180		170 - 195	3	-		-	-
				154	23.86	110 - 195	20	143	21.57	102 - 178	12
				151	25.87	108 - 195	24	141	21.11	102 - 178	13
Fraser Plateau [AT/ESSF/IDF]	Cascade Fold Belt	m(p)	3-15	156		149 - 162	2	-		-	-
		p	3-16	148		114 - 175	10	135		125 - 140	4
		f	3-32	121			1	153		146 - 159	2
		p((m))	3-33	154		133 - 175	2	145		133 - 152	3
				148	19.38	114 - 175	15	142	10.68	125 - 159	9
PROVINCE OF BRITISH COLUMBIA				153	21.27	92 - 194	387	141	18.89	95 - 202	262

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[1] see Krajina (1969) for descriptions of B.C.'s biogeoclimatic zones. The underscored zones are those that predominate. Abbreviations are explained in METHODS.

[2] see Douglas (1976) for descriptive details of geological elements.

[3] Density ratings are taken from Blower (1977): 'p' = plentiful, 'm' = moderate and 'f' = few. Those designations without brackets predominate for the given area. Single brackets represent a significant representation of that density, however it does not predominate. Double brackets signify insignificant areas of the designated density.

[4] Management Unit (MU) 6-15 excludes subunits A - E in this designation.

horn growth do not vary significantly between the Coast Mountains, the Fraser Plateau, the Rocky Mountains or the Rocky Mountain Foothills.

Additionally, two-way analysis of variance shows a significant difference between MU's, in terms of rate of subadult horn growth ($P = 0.004$). Duncan's multiple range test separated the 47 MU's with contrasting male and female data into three subsets. However, significant differences in mean horn growth are obvious between MU's 7-37 ($\bar{x} = 167$mm, $N = 7$) and 7-54 ($\bar{x} = 126$mm, $N = 5$) only.

An investigation into the differences of horn growth between game management Regions, using two-way analysis of variance testing, shows that the mean horn growth for Region 2 ($\bar{x} = 136$mm, $N = 19$) is significantly different from growth rates exhibited in Regions 5, 6 and 7 ($\bar{x} = 148$mm, $N = 580$). Regions 3 and 4 do not vary significantly in their characteristic horn growth, as determined by horn measures from harvested animals.

Unfortunately, significance in horn growth appears to be relative to geographic size of the variable in question. Horn growth is significantly different between northern and southern British Columbia ($P = 0.04$). Analyses from Duncan's multiple range test show that male subadult horn growth is higher in northern British Columbia ($\bar{x} = 154$ mm, $N = 325$) than of males in the South ($\bar{x} = 145$mm, $N = 218$), but male horn growth in the South is not significantly different from female growth in either the South ($\bar{x} = 141$, $N = 44$) or in the North ($\bar{x} = 140$, $N = 218$).

Horn volume is an alternative horn quality index, however, sample sizes are small due to lack of age-specific data. Unlike the initial results of subadult linear horn growth, no significant relationship is observed between age and horn volume with the Provincial CID. However, significance is evident within the Maroon Mountain goat data (Table 3). Heimer and Smith (1975) multiplied this volume index by a constant, determined by water displacement of the horns, in their measurements.

INTRAPOPULATION HORN QUALITY

Rates of Horn Growth in Subadults

The occurrence of intrapopulation variation in subadult linear horn growth is presented in Figure 5. HER values composing the frequency distributions are representative of six months of kid horn growth and eighteen months of yearling growth. Kids average a 0.53 HER in November whereas yearlings average 1.37. Disparities in linear horn growth between and within males and females are not accounted for in these data.

	MALE		FEMALE	
	Province	Maroon	Province	Maroon
slope	4.56	4.62	3.52	4.40
Y-intercept	83.94	71.07	52.48	39.83
r	.39	.87	.37	.91
P	0.02	0.01	0.2>p>0.1	<0.001
n	33	5	16	9

Table 3. Linear regression analyses on relative volumes of mountain goat horns with respect to age. The data are comparatively summarized for Provincial CID and for Maroon Mountain (the author's study area). r = regression coefficient, P = significance probability and n = sample size.

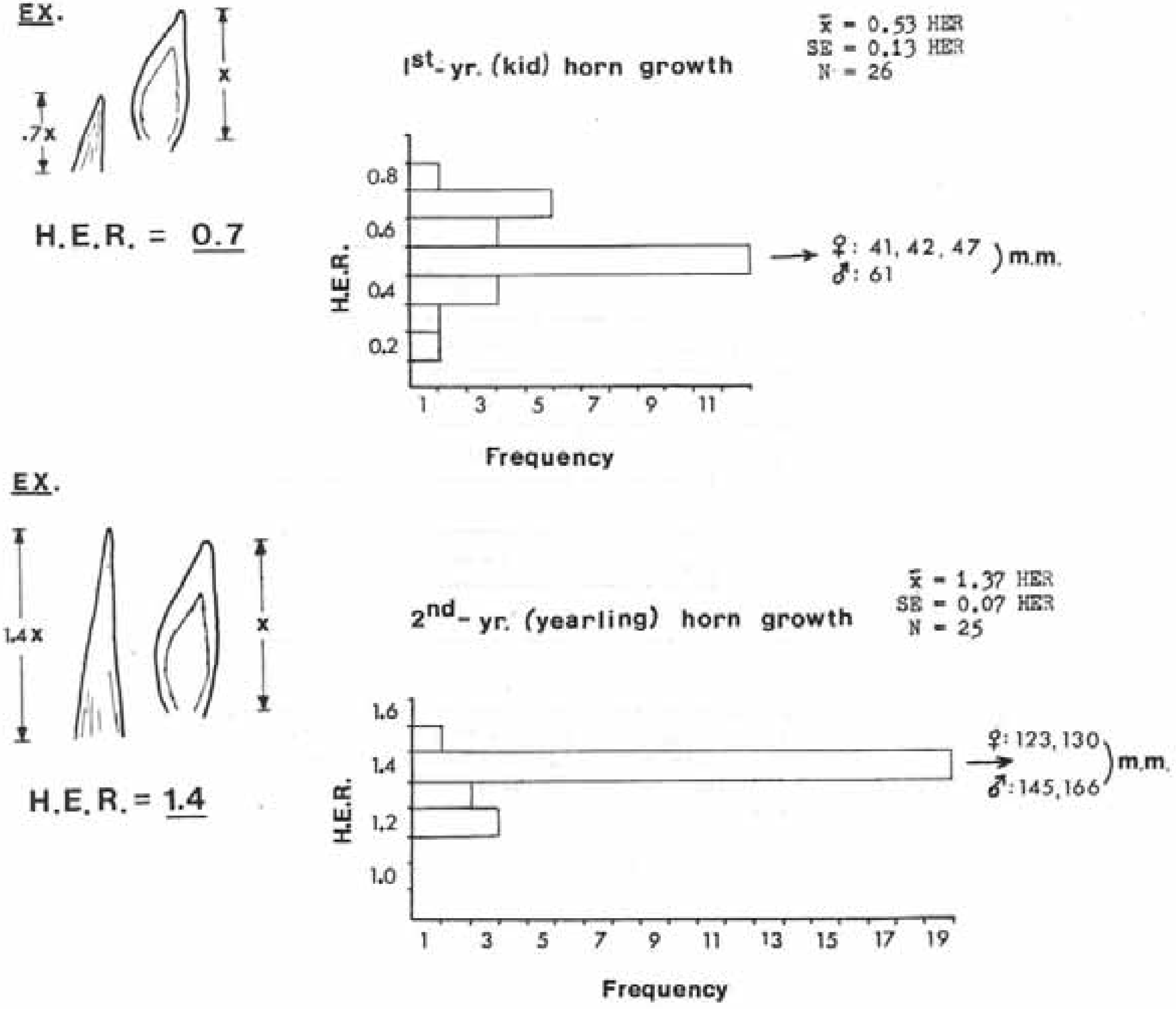

Figure 5. Occurrence of intrapopulation variation in linear horn growth. The horn variation is measured as a ratio of the vertical rise of the horn to the sagittal length of the ear and is termed Horn-to-Ear Ratio (HER). These data were collected in November on Maroon Mountain, B. C. from the author's study area.

DISCUSSION

Utility of the CID Retrieval System for Horn Growth and Age Assessment

The initial 1976/77 CID retrieval system for mountain goat was plagued with erroneous horn measures and age determinations due to imprecise data entries from a large number of recorders. Concomitantly, horn and age data losses accrued 94%. Many form errors were accommodated for in the following year's (1977/78) format (Figure 1(b)). Longer Table lengths (to twelve annulations) were included on the CID sheets and the skull diagram was relabelled to reduce ambiguity (i.e. to recognize but not record the 'false annulus'). Unfortunately, the indicator for age still confused recorders. Measurements were instructed to be recorded in Metric units (millimeters) and steel measuring tapes were provided to a more standardized list of recording personnel who were now to identify, with their name, the records they completed. Space was provided for the assessment of age by tooth annuli and by their eruption pattern also.

One response to this attempt at standarization of CID recording was a 300% increase in the number of incisor teeth extracted for age analysis (N = 483) in 1977/78 compared to 164 in 1976/77. The 1978/79 CID format has changed in only a few minor details. Inclusion of Provincial Park harvest data has been made and the skull diagram has once again been relabelled, this time correctly.

Unfortunately, the CID retrieval system lacks the required data precision factor - namely, quality data control workshops for the recording field personnel. This lack of guidance has resulted in the loss of horn growth and aging statistics of more than 2000 harvested goats over a three year period.

Ultimately, a quick, yet objective aging criteria should be used. Horn sectioning is time consuming and a highly impractical request for a trophy animal. X-ray diagnoses are unproductive due to the absence of horn annuli being highlighted. Ultrasound techniques might be considered as a means to identify internal interfaces of annual horn growth in the future.

Regardless of the method of horn annulus determination, a system should be devised to at least maintain constant sytematic bias, if it occurs. For example, if horns are to be visually examined, recognition of annuli should be confirmed by one or two other biologists as well. Such a system could be made possible by organizing a centralized 'horn depot' where horns would be inspected and returned to the hunter.

Characteristics of Horn Growth

The only large-sample horn data usable of the 1976/77 CID are total horn length, basal circumference and horn growth of the first two years of life ('tip-to-first-annulus').

The frequency distributions of subadult linear horn growth of the first two years of life show significant differences in rate of horn growth when stratified into male and female components (Figure 3). Female horn growth maintains the familiar bell-shaped curve of a normal distribution, however the negatively skewed distribution of male horn growth strongly relates to their more vigorous growth early in life. During the third growing season, however, it appears that the bioenergetic regime reverses and female horn growth becomes larger than male horn growth. Such a response to increased horn growth rate by females at this age coincides with increasing individual health in preparation for their first gestation period, which normally commences during the third autumn of life. Hoefs *et al.* (1977) found similar linear horn growth trends for male and female goats in the Yukon Territory. After the shift in rate of male and female horn growth occurs between the second and third growing season, I have often noticed the disparity to increase with age (Figure 4). A four year old nanny can have the equivalent horn length of a three year old billy. A six year old female may have horns averaging more than one centimeter larger in total length than male horns of the same age. This discrepancy may seem insignificant until one realizes that a centimeter of horn growth in late adulthood may have taken four years on the average to grow.

Caprini species and mountain goats maintain similar physiological horn growth processes and most of these species occupy seasonally harsh climates. Therefore, concepts of *population quality* (Geist 1971) should be appropriate for mountain goats also. Shackleton (pers. comm.) believes the first several years of rapid horn growth in bighorn sheep may be an adequate indicator of individual and population quality. An annulus at the end of a goat kid's first year of growth, however, is seldom distinct, so only the first two years of linear horn growth could be considered in any type of *quality* analysis for mountain goats.

A comparison of subadult horn growth in stratified portions of British Columbia, on the basis of mountain systems, geological elements, biogeoclimatic zones, soil types, game management and other geographic areas and crude population density, showed a limited number of significant differences. Many of the variables assessed are probably too crude and the sample sizes small, due to the intense levels of stratification required. Significances in the analysis of variance contrasts appear to relate to increasing geographic area in addition to crudeness of the variable. Therefore, these results probably warrant little if any biological interpretation. It is important not to confuse phenotypic expression with small samples taken from a normal distribution. Wishart (1969) recognizes the *combined* affects of climate, soil and vegetation in horn growth differences of bighorn sheep.

Probably the most important component missing in the last analyses (aside from sample size) is rate of age-specific horn growth for individual years and for regions characterized by varying climatic influences. More data on successive annual growth rates would be of great interest. The ages determined by tooth cementum analysis on past CID may enlarge samples sizes sufficiently to test this theory (providing one wishes to rely solely on cementum deposits as true indications of age). Similarly, if the known age sample of animals were increased, comparative horn volume analyses could be conducted (Heimer and Smith 1975). Collation of several years' CID, however, may produce ambiguous or misleading *population quality* trends, due to annual fluctuation in individual nutrition planes, unless annual climatic variables can be quantified.

Variation in Horn Growth

One important aspect of *population quality* often ignored when studying Bovids is the myriad of factors that may influencethe rate of horn growth. Extensive studies have only been conducted with Cervid antlers and now many growth regulating determinants have been recognized for species belonging to this Family (Chapman 1975).

Figure 6 portrays a mosaic of mostly hypothetical factors affecting Bovid horn growth. Geist (1971) discusses several biogeoclimatic factors regulating maternal weight loss of domestic ewes and reindeer, which in turn affects the development of progeny. Maternal winter weight losses may result in an undernourished fetus and/or neonate (Preobrazhenskii 1971, in Geist). Maternal weight losses may also increase the probability of under-sized neonates being produced and of their increased mortality due to postpartum hypothermy (Alexander 1968). These and other biogeoclimatic effects are ultimately linked to winter severity (Robinson et al. 1961, and Preobrazhenskii 1961 - both cited in Geist 1971), the intensity of which is proportional to the amount of stress experienced by an animal.

Stress developed from heavy hunting pressure may retard horn growth due to poor pre-winter conditioning. Also, the abnormal and unresponsive behaviour of lambs towards their mothers (as discussed by Alexander and Peterson 1961, in Geist) is suggested by Geist (1971) to be attributed to maternal psychological stress during the gestation period. Wishart (1976) documented a small percentage (4%) of orphaned bighorn lambs to be stunted in their growth upon yearling maturation.

Other factors affecting individual health (which precipitates the rate of horn growth) may be numerous (Figure 6). Geist (1966) and Shackleton (1973) believe horn growth is related in part to the annual cycle of sex hormone production. Genetic influences are also probable. Bunnell (1978) emphasises range condition as a factor for horn growth in Dall sheep. He states that a small horn core, laid down initially by a year of poor forage, results in an adult individual having small horns. Bunnell (1978) believes that traumatic periods are recorded in the pattern of horn growth. Both Bunnell (1978), and Lambert and Bathgate (1977) show that horn growth and body size are not correlated, as an animal can easily regain its weight after a nutritional hardship.

Elliott (this Proceedings) states that past burning practices stimulate better forage and hence more rapid ram horn growth, after recolonization of these burned areas. I have observed eleven month old 'orphaned' mountain goat kids, fed a diet of alfalfa, to have HER's of 0.9, 1.0 and 1.1 whereas kids on Maroon Mountain averaged just over a 0.6 HER (N = 35) at the same age. I would estimate this difference in HER's to represent a little more than twenty millimeters of linear horn growth.

HYPOTHETICAL HORN GROWTH REGULATORS IN CAPRINAE

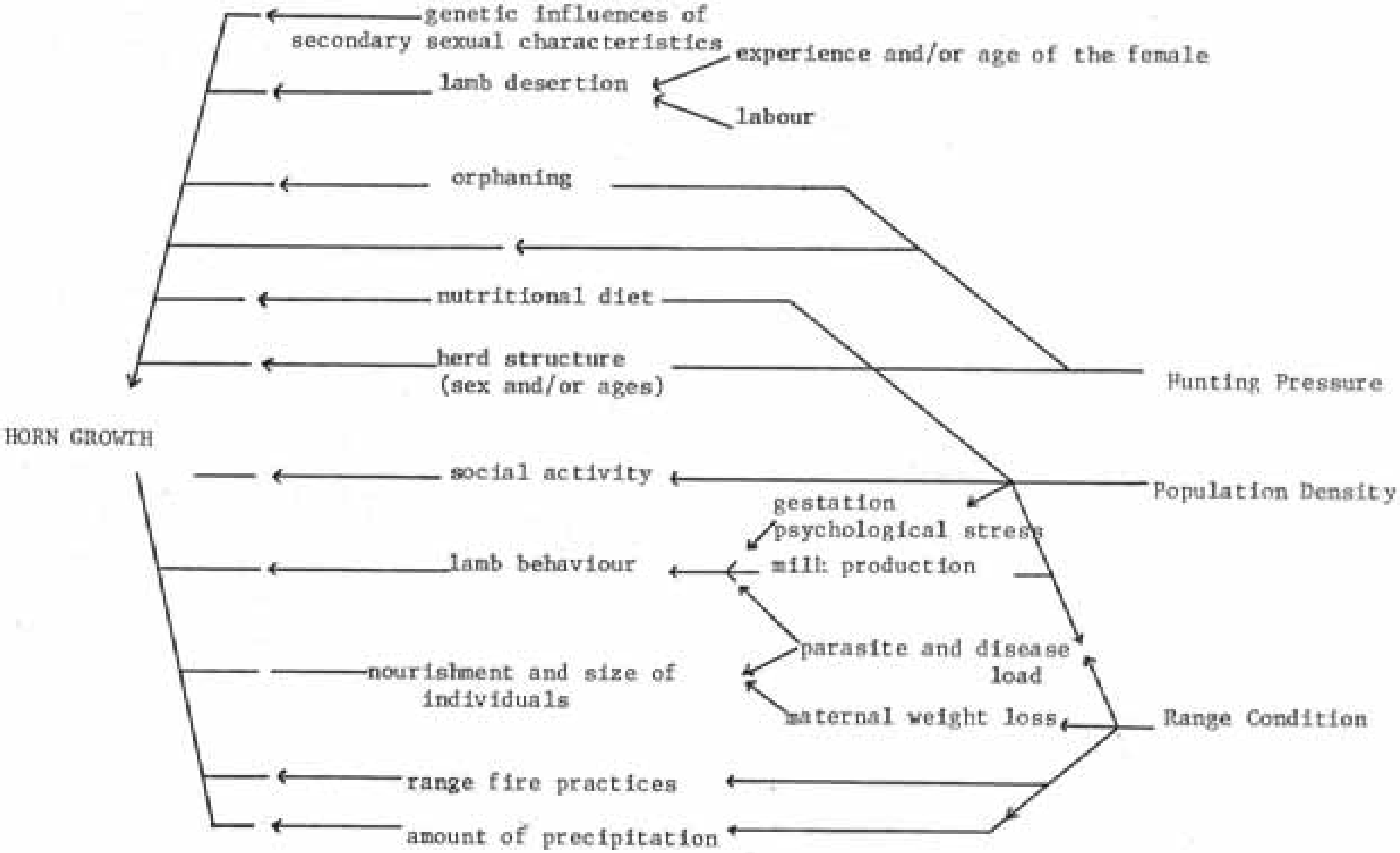

FIGURE 6. General synopsis of factors affecting the regulation of Caprini and Rupicaprini horn growth. Some determinants are documented while others are hypothetical.

The effect of factors outlined in Figure 6 (in addition to others yet unrecognized) is portrayed in Figure 5. Variation in the horn growth of conspecifics from the same population is significantly variable.

Horn Growth and Mountain Goat Sociobiology

I would hypothesize that mountain goat social organization reflects habitat occupancy. Hence, elicited behavioural patterns, individual sociability (as it pertains to dominance status), activity patterns, and food habits would resemble MODEL II of Table 1. This intrapopulation model is defined on the basis of habitat value, but probably involves high population densities only (>5 goats/km^2). Heimer and Smith (1975) stipulate that population density is inversely proportional to horn growth in Dall sheep, although exceptions to this rule have been discovered (Heimer, pers. comm.).

It appears that during subadult life, male horn growth and development potential resembles the *high quality* interpopulation concept (Table I - MODEL I), in preparation for conversion later in life (throughout their asocial years) to the *low quality* intrapopulation model (Table 1 - MODEL 1). Because nannies are dominant over billies and subadults (Chadwick 1973, Foster in prep., Kuck 1977), it would seem most advantageous in goat society for the young males to utilize abundant resources much more efficiently than females, such that when males mature and become subordinate, they are better suited to survive in marginal habitats which they occupy, particularly when population densities are high. The beneficial process becomes apparent when one learns how reproductive females (the dominants later in life) justifiably occupy optimal habitats because of their energy-consuming maternal and behavioural characteristics.

Populations which contain animals of differing *quality* (on a male/female basis, in mountain goat) allow genotypes to find expression and maintenance. Schaller (1977) states that urial and wild goats of the Himalays represent such a model. Such genetic variation is desirable in a population for in effect it preadapts some individuals (males) to new conditions and enables them to colonize unoccupied terrain successfully. This model will seem appropriate to those of you who have encountered or heard of 'wandering billies' found at low elevations crossing rivers, lakes, valleys or roads.

Under situations of low population density, billies are believed to be more social, occupying less marginal areas, and having higher rates of horn growth. Resultantly, life expectancy is increased (at least for bighorn sheep - Geist 1971, Shackleton 1973) resulting in greater fitness for enhancement of colonization status. However, a population of low density, yet sustaining a harvest of 'heavy' hunting pressure (i.e. >10%), or habituating to environmental disturbances produced by human activity, may be knocked out of balance, reverting the herd to characteristics described of high density populations with heavy harvest levels.

The models are potentially complex and require more comparative data from populations of differing density and hunting pressure. The Maroon Mountain goat data have been made available in some of the Figures and Tables bearing this purpose in mind.

CONCLUSIONS

It has been shown by one compulsory inspection data (CID) system that accurate horn growth and age data are difficult to obtain for mountain goats. In addition to the variety of a number of trained and untrained personnel completing CID records, inadequacies of the CID system, specifically relating to interpopulation data analyses, are compounded by the continuing low levels of Provincial goat harvest, in comparison to total numbers, the heterogeneity of goat ranges and their influencing characteristics, and the fluctuation of hunting pressure and harvest distribution based on road access.

The available CID and data from the Maroon Mountain Goat herd have shown that horn growth is variable both between and within populations. The data in this paper recognizes and highlights both intrapopulation variation and also sexual disparities of horn growth. Both factors are believed to be inherent in mountain goat sociobiology.

Unfortunately, the inadequate aging methods for adult mountain goats negate any type of current analysis on rate of horn growth for similar-aged animals under specific climatic regimes. The small sample variations discussed are probably the result of the effects of selection from a random distribution rather than range condition.

At present, biological aids are required more than ever, to supplement management devices to date - namely, control of harvest in hindsight. The discussion addressed during this Workshop as to whether mountain goats can ever be scientifically managed must await future data considerations.

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