COMPARISON BETWEEN A HUNTED AND AN UNHUNTED DALL SHEEP POPULATION

-A PRELIMINARY ASSESSMENT OF THE IMPACT OF HUNTING-

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ABSTRACT

Compared are demographic characteristics and horn growth parameters of the Dall sheep population on Sheep Mountain (Kluane National Park) with those of the hunted population inhabiting the Ruby Range. The harvest rate has been limited to mature rams and has averaged 2 to 3% of the summer population over the past decade. Hunting at this rate has not led to a population decline, to a change in adult sex ratio, or to a lowering of life expectancy. The age specific mortality patterns of mature rams due to hunting and natural causes were similar. Hunter-caused mortality is, therefore, considered compensatory and sustainable and not additive. The hunted population had a significantly higher natality rate and a significantly lower rate of horn brooming. However, hunters selectively removed from the population rams with the best horn development, and there is reason for concern that this may lead in the long run to deterioration of horn growth qualities. Lastly, attempts to relegate these two populations to different "quality" classes as proposed by Geist (1974) were not successful.

INTRODUCTION

Game Management agencies are coming under increasing pressure to justify hunting, particularly hunting for sport. Sheep are an example in case, because they are almost exclusively managed for trophy harvest. There is the added factor that 70% to 80% of the sheep harvest in Yukon is by non-resident hunters, guided by local outfitters, which has led to a negative attitude toward outfitters as well as government by many local hunters. Even among professionals, opinions vary widely, as to the value of large protected areas where hunting should not be allowed as well as when hunting is allowed, whether full-curl, 3/4 curl ram harvest or a "both sex" harvest is the most appropriate sheep management strategy. Little information exists about sheep hunting on such issues as the additive or compensatory nature of hunter harvest or on the long-term impact on a population through the constant removal of rams with the best developed horns.

By comparing demographic characteristics and horn growth parameters of an unhunted (Kluane National Park) and a hunted (Ruby Range) population, we tried to address some of these questions. The ranges of these two populations in southwest Yukon are adjacent to each other. Therefore, environmental parameters such as weather pattern, predator pressure, and vegetation cover are similar. The study was not designed to address the question whether hunting has had an impact on the hunted population. However, both populations have been monitored in connection with other investigations and some of the data obtained lend themselves to such a comparison.

Specifically this analysis was meant to address the following topics:

1. Is hunting mortality at the rate carried out on the hunted population additive or compensatory?

   While this question can not be directly dealt with with the data on hand, one can reason that hunting can be considered additive, if it leads to a reduction in population size, to a change in the adult sex ratio, to a change in the age-specific mortality pattern or to a reduction in maximum life expectancy of rams. On the other hand, if these demographic parameters remain the same as in the unhunted population, then hunting can be considered compensatory and sustainable.

2. Is brooming of horn tips, which is known to be brought about by fighting and is a common characteristic of horns of old rams on Sheep Mountain, less common in the hunted population, where hunting continually removes rams and thereby lowers fighting opportunities?

3. Do hunters selectively remove those rams with the best horn growth characteristics? If so, does this lead in the long-term to a reduction in the horn growth qualities of the population? And, lastly

4. Do the characteristics documented for these two populations support the "quality" hypothesis advanced by Geist (1971) and co-workers (Shackleton 1973, Horejsi 1976)?

   In summary, Geist (1966, 1971) found that physical attributes of Stone Sheep and Bighorn Sheep were related to demographic processes and behaviour patterns. Expanding (better quality) populations were characterized by individuals with larger bodies, rapid horn growth early in life, high fecundity, and low life expectancy. By contrast, stable or declining (poorer quality) populations were characterized by individuals with smaller bodies, slower horn growth rates early in life but above average growth rates in the older age classes, lower fecundity, and longer life expectancy. To this can be added that poorer quality populations are generally more prone to diseases, and are often characterized by a higher density (Heimer and Smith 1975).

METHODS AND MATERIALS

Annual, detailed, aerial and ground surveys have been conducted for the Sheep Mountain population since 1969, and its demographic characteristics, range size, mortality patterns and horn growth characteristics are known (Hoefs 1975, Bunnell 1978, Bunnell and Olsen 1976, Hoefs and Bayer 1983). From 1969 to 1983, 118 skulls of rams that died from natural causes were inspected. The age at death was determined by the horn annulus technique (Hemming 1969) and various horn growth parameters were measured as outlined in Heimer and Smith (1975) and Shackleton (1973). These included the determination of annual growth increments and horn circumferences at the annuli.

In the Ruby Range, 4 complete aerial surveys have been conducted between 1974 and 1983, and during 7 years an assessment was made of lamb production by counting nursery bands. During these aerial surveys it is not possible to separate yearlings and young rams from ewes, and "productivity", as used in the paper, is defined as the number of lambs per 100 adult sheep in nursery bands. The Ruby Range sheep population is subject to hunting and over the past decade 168 trophies taken by hunters were measured by the wildlife branch as outlined by Merchant et al. (1982). In all these horn measurements, the longest or less damaged of the two horns of a skull was used, and measurements were to the nearest 1 mm since 1975 and to the nearest 1/8 of one inch prior to 1975.

An index of horn volume was calculated by assuming that a horn is a regular cone and applying the formula $V=h/3\ (d/2)^2\pi$, where V is the index of volume, h is the length of the horn, d is the horn diameter, which can be estimated by dividing the horn circumference by 3.14(π), and π is 3.14. A similar method was applied by Heimer and Smith (1975) in their assessment of horn growth qualities of Alaskan Dall Sheep populations.

It is emphasized that the value derived is an index only and not the actual horn volume, because of a number of assumptions made, which have been elaborated on by König and Hoefs (1982). However, volume determinations using water displacement of 24 horns indicated that this index predicts reasonable well ($r = 0.899$), and that the mean error was an over-estimation of the true horn volume by only 2.9%. It can therefore be used to make comparisons between populations.

Statistical tests used in the assessments consisted of t-test, Chi square test, and regression analyses.

STUDY AREA

The two study areas are shown in Fig. 1. The Sheep Mountain population inhabits part of the Kluane Range, in the newly established Kluane National Park in southwestern Yukon. The geographic coordinates of this population's range, which is approximately 165 km^2 in size, are 61°-00'to 61°-10' N, and 138°-30' to 138° 50" W. The physiography is rugged. The altitudinal limits are 755 m (the level of Kluane Lake)

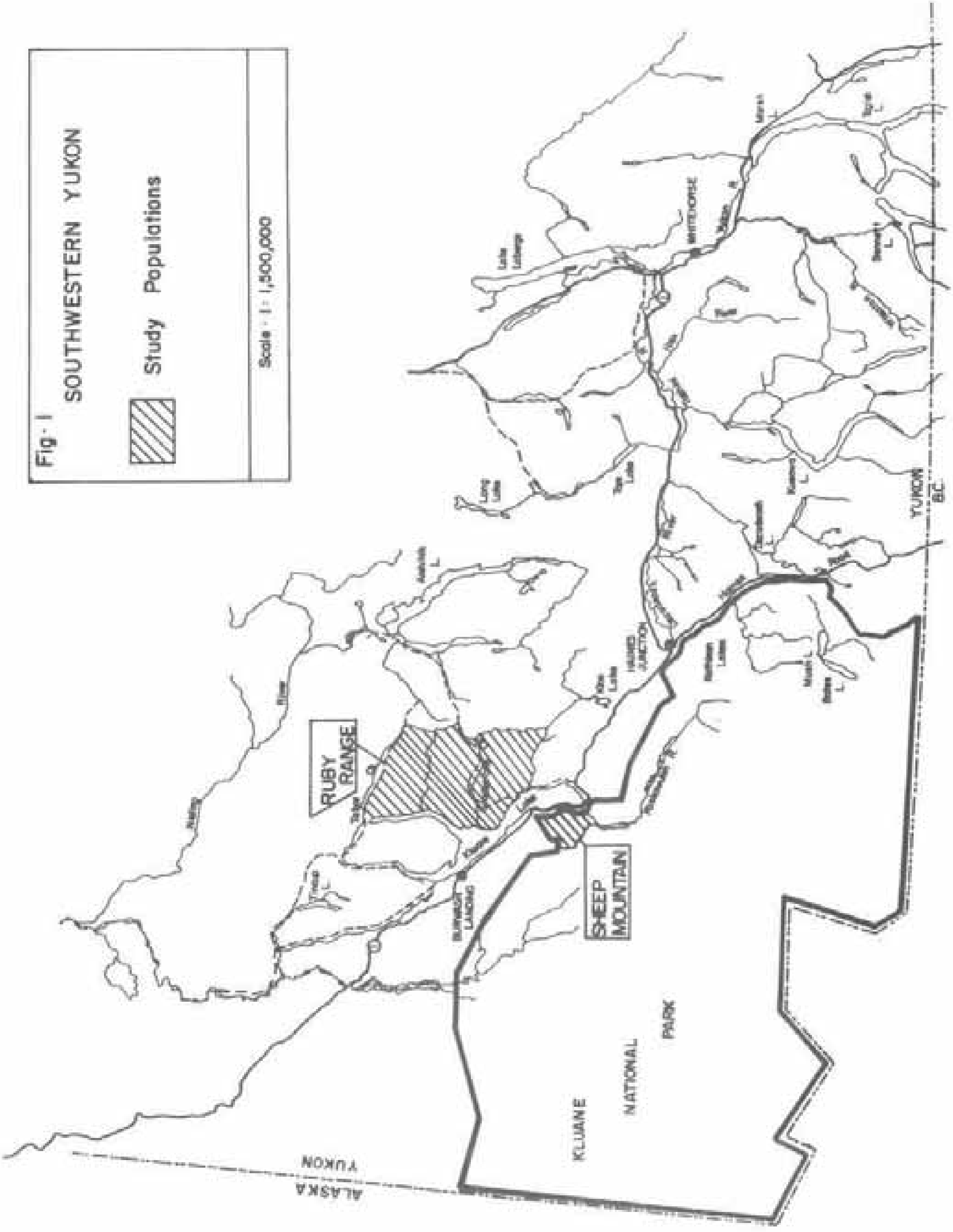


Fig. 1
SOUTHWESTERN YUKON
Study Populations
Scale · 1 : 1,500,000
RUBY RANGE
SHEEP MOUNTAIN
KLUANE
NATIONAL
PARK
YUKON
B.C.
ALASKA
YUKON
WHITEHORSE
HAINES JUNCTION
BURWASH LANDING

and 2400 m (the peak of Mount Wallace). The bedrock in the area consist mainly of metamorphic and sedimentary deposits of Triassic, Permian, and Cretaceous ages. Three glacial periods modified the topography and left a thick layer of glacial till around the base of mountains. The soils are juvenile and azonal. They are characterized, particularly at lower elevations, by recent loess deposits. The loess deposition continues to this date, whenever strong, down-glacier winds stir up the silt of the Slims River floodplain at times of low water. Most soils are characterized by high alkalinity (Muller 1967).

Three altitudinal vegetation zones are recognized. The forested zone, consisting mainly of white spruce (Picea glauca) stands, extends to an elevation of about 1200 m, where it gives way to the "sub-alpine shrub zone", in which dwarf birch (Betula glandulosa) and several willow species (Salix spp.) dominate. This vegetation belt may reach an elevation of 1550 m in favourable sites. Dry, south-facing, exposed slopes in the forested as well as the sub-alpine zones, are usually occupied by grassland vegetation. Dominant plants here are Artemisia frigida, Carex filifolia, Agropyron yukonense, and Calamagrostis purpurescens. It is these grasslands that make up the winter range of the local sheep populations. The alpine zone is the most extensive vegetation type in the area. Dryas integrifolia, Festuca altaica, and Cassiope tetragona are dominant plants here. The altitudinal limit of vascular vegetation is reached at an elevation of 2150 to 2300 m. Permanent snow is encountered at 2500 m (Hoefs et al. 1975).

The Kluane area lies in the rainshadow of the St. Elias Mountains, and the climate is semi-arid and continental. Annual precipitation is usually less than 250 mm. Summer temperatures hardly ever reach 25°C, and winter temperatures of -40°C to -50°C are not uncommon. The annual mean temperature is -2.5°C. Local modifications of the regional climate are brought about by the proximity of Kluane Lake and the funnelling effects of the Slims River valley on "down-glacier" winds. The former results in a moderation of the local temperatures, when the water is not frozen and the latter adds to the dryness of the region and is responsible for creating snow-free areas in winter, which are heavily grazed by sheep (Hoefs 1975). Detailed descriptions of the local climate and weather patterns are found in Taylor-Barge (1969).

The Ruby Range is located northeast of Sheep Mountain at the opposite side of Kluane Lake. The closest distance between these two study areas is less than 8 km. The geographic coordinates of that part of the Ruby Range under consideration here, are 61°-10' to 61°-40' N and 138°-07' to 138°-40' W. The size of the range is estimated at 1330 km^2 and takes in game management subzones 5-31, 5-34 and 5-36. This area has a similar physiography and bedrock geology as Sheep Mountain, it also has been subjected to 3 glacial periods.

Because of the proximity to Sheep Moutain it is reasonable to assume that the vegetation and the general weather patterns are comparable; however, no studies have been conducted to verify these claims.

RESULTS

A. Demographic parameters

Based on annual counts over the past 15 years, the size of the Sheep Mountain population has averaged 222, with the following composition: 79 rams, 93 ewes, 23 yearlings and 27 lambs (Table 1). However, considerable variations have been documented between years, primarily because of changing lamb crops (Hoefs and Bayer 1983) (Table 2). In the most recent past, the population has declined because of heavy mortality in the severe winter of 1981/82 followed by 2 years of lamb failures. The adult sex ratio in this population averaged 85 males:100 females. Based on a year-round range of 165 km^2, the density of this population is 1.34 sheep/km^2, which is one of the highest in the Yukon. Based on 4 complete surveys of the Ruby Range population between 1974 and 1983, the average population size amounted to 862, consisting of 309 rams, 349 ewes, 91 yearlings and 113 lambs (Table 1). The adult sex ratio is similar to that of the Sheep Mountain population with 88 males:100 females; however, its range extends over 1300 km^2, giving a density of only 0.66 sheep/km^2. Productivity estimates were conducted during 7 years (Table 2). During these years the Ruby Range population had a significantly better lamb production than the Sheep Mountain population, amounting to 29% respectively ($X^2 = 35$; d.f. = 6, $P < 0.005$). The size of the Ruby Range population has also fluctuated among years. But it has not declined by 25% in recent years as the Sheep Mountain population did, because lamb production was not quite as low, nor was adult winter mortality quite as high.

B. Hunting

Over the past decade the mean annual harvest in the Ruby Range has been around 20 rams (Table 3), of which 14 were taken by non-resident hunters guided by outfitters and 6 were taken by resident hunters. There are indications that resident hunting pressure is increasing in recent years. This harvest constitutes 2 to 3% of the local sheep population which is presently estimated at 862. Considering the observed sex ratio among adult sheep and the fact that rams under existing hunting legislation become legal (on the average) between the 8th and the 9th year, it can be estimated that about 25 to 30 rams are recruited into the legal cohort per year, and the present harvest of about 20 translates into a removal rate of 66% to 80% of the legal rams. Over the past decade the trophy quality of the rams taken has improved, both in respect to average age of harvested rams as well as in mean horn length. Trends in these two trophy quality parameters are shown in Fig. 2.

C. Comparison of natural and hunter caused mortality patterns

The frequency distributions of age-specific mortalities of rams are shown in Fig. 3. Over the past 15 years 139 known age natural mortalities of adult rams were documented for the Sheep Mountain population, while 192 hunter-caused mortalities were registered for the

Table: 1 COMPARISON OF POPULATION STATISTICS

Population	Observation period	Years of observation (complete counts)	Rams	Ewes	Yearlings	Lambs	Total	Sex ratio	Size of range	Density sheep. km^{-2}
Sheep Mtn.	1969-83	15	79	93	23	27	222	85:100	165 km	1.34
Ruby Mtn.	1974-83	4	309	349	91	113	862	88:100	1300 km	0.66

Table 2: COMPARISON OF PRODUCTIVITY (lambs per 100 nursery sheep*)

Year	1974	1977	1978	1979	1980	1982	1983	$\bar{X}$
Sheep Mtn.	12%	18%	40%	31%	23%	4%	11%	20%
Ruby Range	34%	36%	35%	36%	32%	15%	15%	29%

Table: 3 SHEEP HARVEST IN RUBY RANGE (GMZ 5-31, -34, -36)

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	$\bar{X}$	%
Resident Hunters	6	8	1	3	4	9	3	8	6	7	5.5	28.1
Non-resident Hunters	18	12	9	13	16	16	17	11	16	13	14.1	71.9
Total Harvest	24	20	10	16	20	25	20	19	22	20	19.6	100.0

FIG. 2 TREND IN TROPHY QUALITY OF RAMS TAKEN IN RUBY RANGE

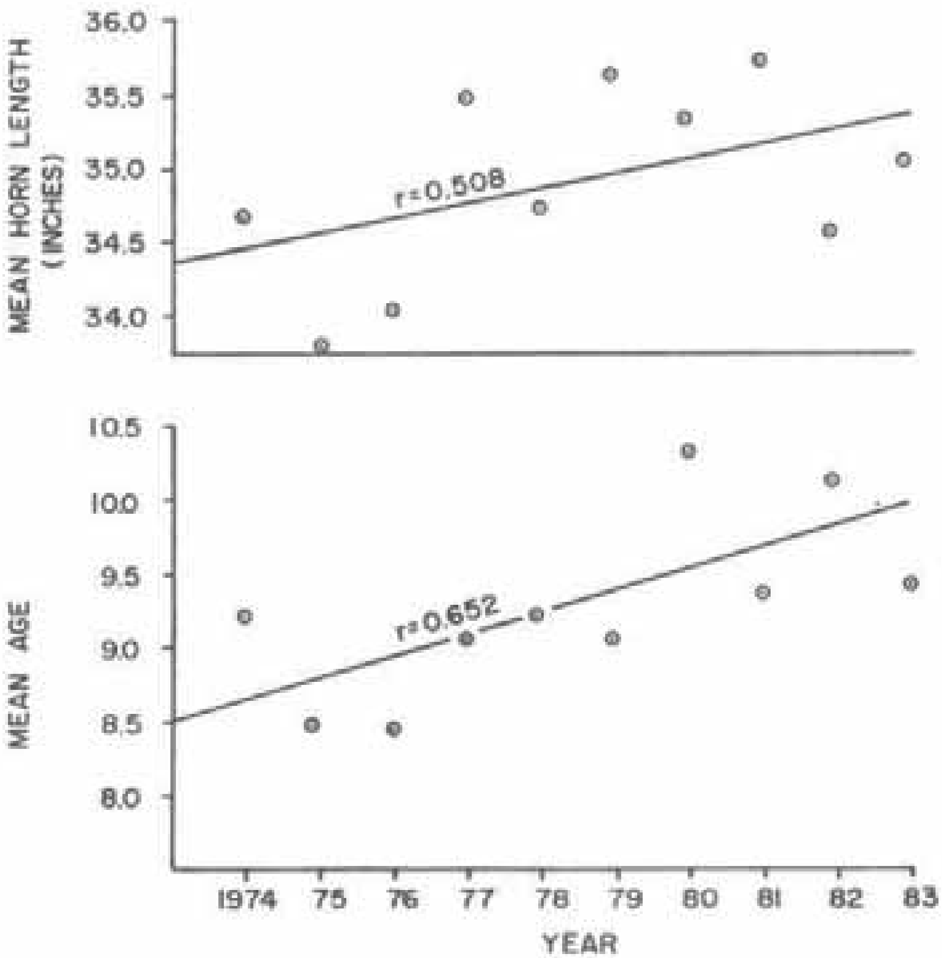
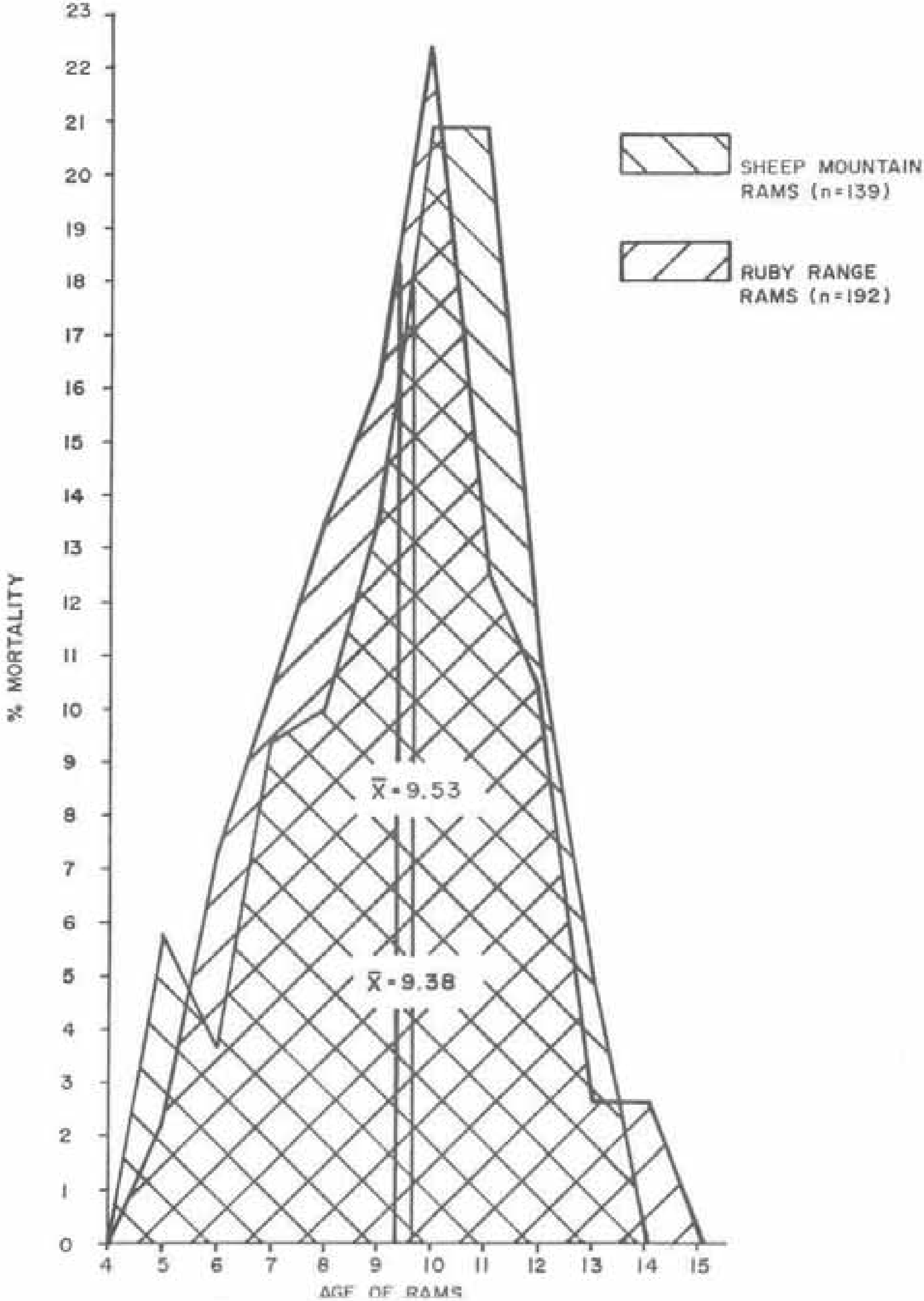


FIG.3 COMPARISON OF NATURAL AND HUNTER-CAUSED MORTALITY PATTERNS



Ruby Range. For the Sheep Mountain population the mean age of adult mortality was 9.53 years, most rams died in the 10- and 11-year age cohorts and the maximum life expectancy was 12 to 13 years. The mean age of ram mortality in the Ruby Range was 9.38 years, most rams were shot in their 10th year, and the maximum life expectancy was 14 to 15 years. There is no statistically significant difference in the age-specific adult ram mortality distributions between these two populations ($X^2 = 7.14$, d.f. 7, $p > .50$). Hunter-caused mortality had a similar age distribution as natural mortality and has not led to a lowering of the life expectancy of affected rams.

D. Horn growth parameters

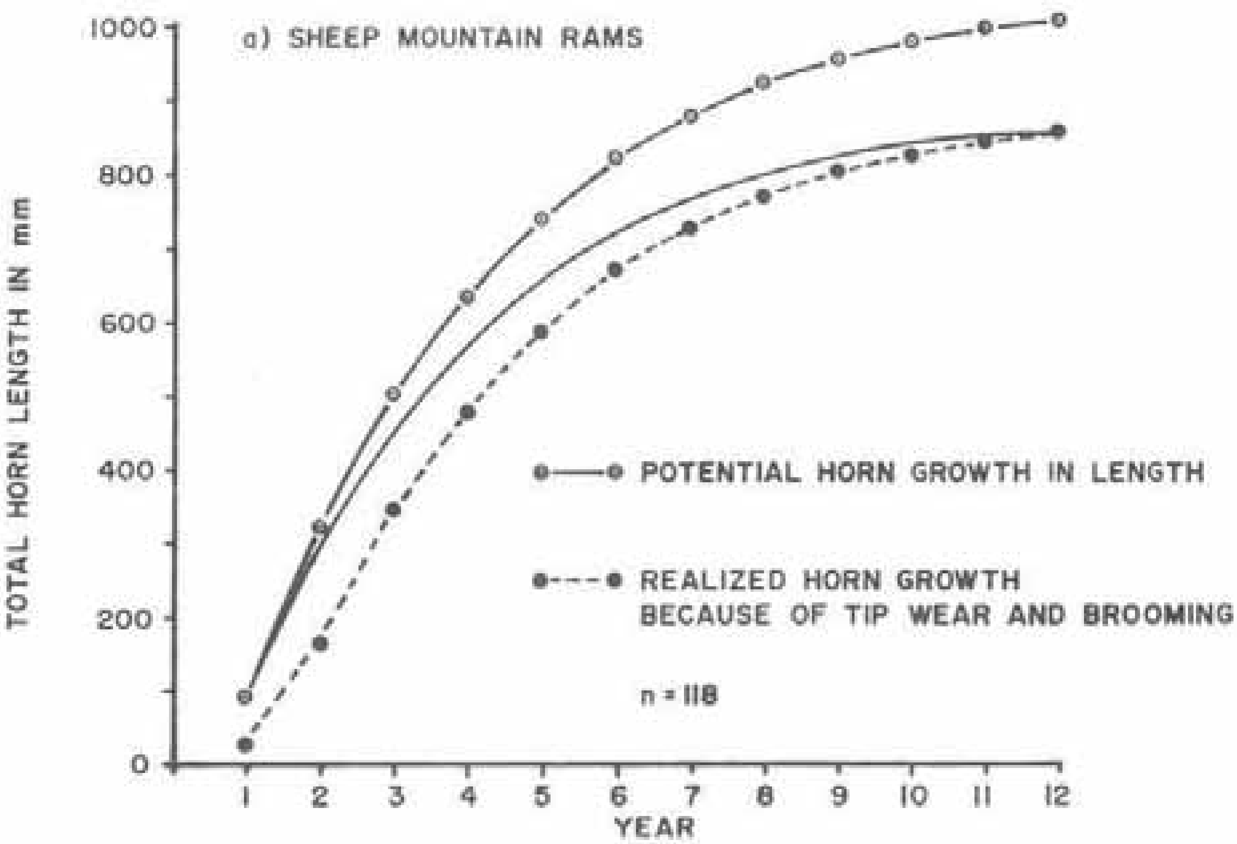
When comparing horn growth characteristics among populations it is essential to point out how data were derived. Horns not only grow with age, they also wear down with age (Hoefs and Nette 1982). Considerable differences exist between population in horn wear rate and brooming, and lack of recognition of this fact can lead to errors in comparisons. Unfortunately very few publications on horn growth in sheep make reference to how this problem was addressed.

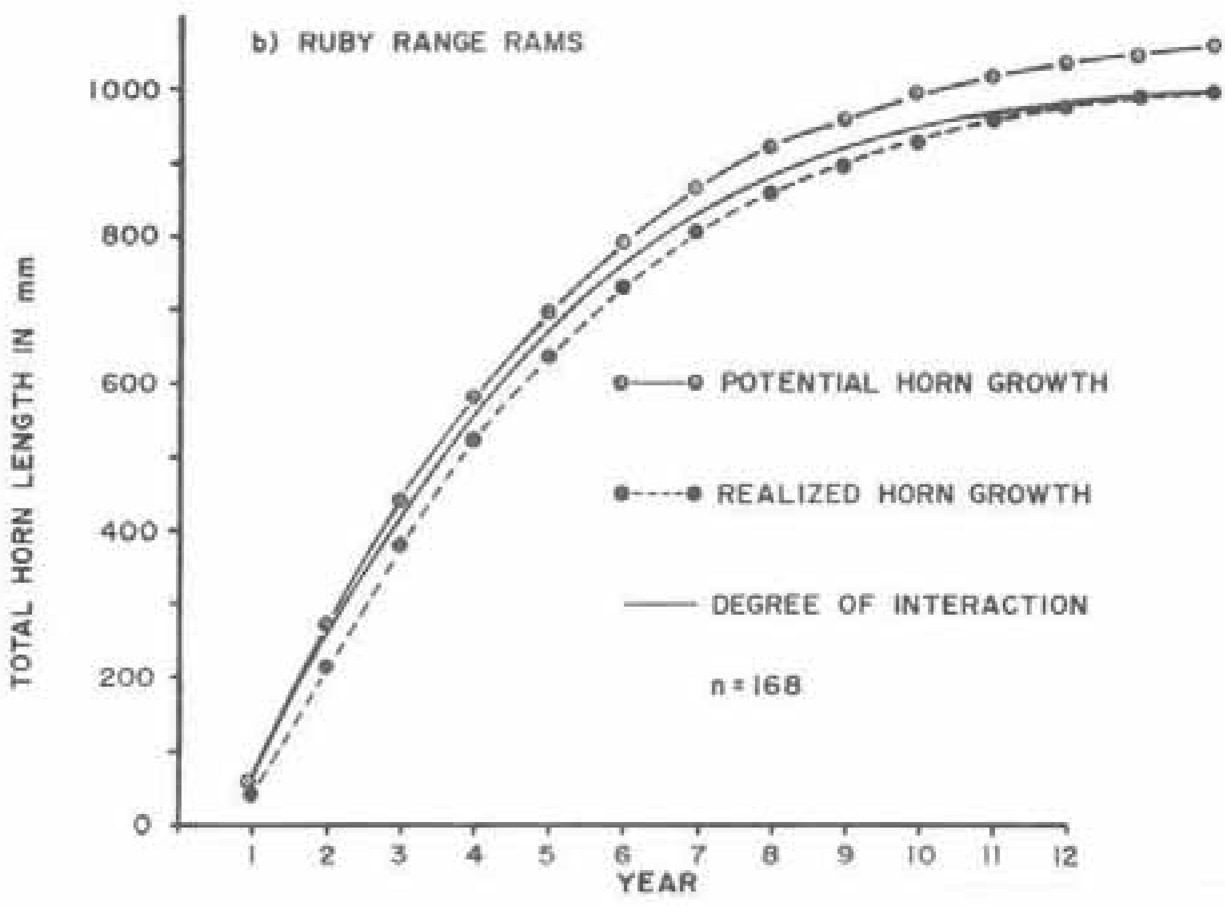
Figure 4 presents two types of horn growth curves, one referred to as "potential" horn growth and the other one as "realized" horn growth for each sheep population. "Realized" horn growth data are the ones usually found in the relevant literature. They treat annual increments that are affected by tip wear and brooming, which are usually the first and the second years' increments, as part of the sample size and use these reduced values in computing mean increment lengths. In the calculations of "potential" horn growth, increments affected by wear and brooming are ignored. This means that for the determination of mean lengths of the first and second annual increments, the horns of younger rams primarily are being used. By means of the regression technique a good estimation of the full length of the first increment (lamb tip) is possible, because the relation of horn tip wear with years appears to be linear (Bunnell 1978, Hoefs and Nette 1982).

The term "potential" is actually misleading, since this growth was at one time also realized. However because skulls are usually not available for measurements until an advanced age is reached, horn tip wear in all and horn brooming in many have reduced the lengths of the lamb tip and often the second year increment also.

In Figure 4 potential and realized horn growth curves are shown for the Sheep Mountain rams as well as for those from the Ruby Range. The difference between potential and realized horn growth is remarkable particularly for the Sheep Mountain population, where horn tip wear and brooming rates are higher than for the Ruby Range rams (Fig. 4). In old rams on Sheep Mountain observed horn lengths are 15 to 17% shorter than potential growth, while in the Ruby Range a reduction of only about 5% could be documented.

FIG. 4 POTENTIAL AND REALIZED HORN GROWTH IN DALL RAMS





Since it is at this time not known why brooming and horn tip wear rates differ among populations, comparisons in horn growth should be made by using "potential" growth. Wear rates may be affected by population density or the presence of many superior rams (because of lack of hunting) both of which will increase the frequency of contacts between rams. Shackleton and Hutton (1971) have shown that horn length reduction by brooming is caused by fighting of rams.

In Fig. 5 and Fig. 6 Sheep Mountain ram horn growth is compared to that of the Ruby Range rams, firstly in respect to potential horn growth and secondly in relation to realized horn growth, to demonstrate the concerns raised in relation to methods of assessment. Fig. 5 shows that the Sheep Mountain rams have superior horn growth during the first, second and third years; starting with the 4th year, however, Ruby Range rams put on more growth. In Fig. 5a these annual increments are added up to show cumulative potential horn growth with age. Better horn growth early in life allows Sheep Mountain rams to have longer horns until their 7th year. They are then passed by Ruby Range rams. Sheep Mountain rams can potentially reach a horn length of 1020 cm (40.2 in.) on the average in their 12th year, if there were no brooming, and about 10% do so. The Ruby Range rams can obtain a horn length of 1060 cm (41.6 in.) in their 14th year and about 33% reaching that age, do so because brooming is less important in this population.

Fig. 5b shows the type of relationship in horn growth rates that a number of investigators have used to distinguish between better and poorer quality populations (Geist 1971, Shackleton 1973, Taylor 1962). In the definition by Geist (1971) these horn growth characteristics would relegate the Sheep Mountain population to one of better quality than the Ruby Range population. The relevant parameters are good initial horn growth, poorer horn growth after the 4th year and a shorter life expectancy.

However, a different type of picture emerges, when "realized" horn growth is used for the comparison (Fig. 6). As already pointed out, here the annual growth increments are computed from a sample size consisting primarily of old rams' horns (mean age 10 years), which show a considerable amount of horn tip wear and brooming. Because of substantially higher rates of brooming in the Sheep Mountain population truly accomplished higher growth rates in the first and second years are masked. In all but the third annual increment, the computed annual horn growth rates of the Sheep Mountain rams are now lower than those of Ruby Range rams, and the Sheep Mountain population has a lower total, cumulative horn growth from the very beginning. At an age of 12 years, Sheep Mountain rams reach a mean horn length of 860 mm (33.9 in.). At the same age Ruby Range rams have obtained a mean horn length of 970 mm (38.2 in.) and they can reach a mean of 990 mm (39.0 in.) in their 14th year.

The assessment of growth in horn mass by determinations of circumference measurements at the annuli is not affected by problems caused by brooming. Circumference measurements are discrete variables not continuous as is growth in length. A given annulus is either present or absent. If a horn tip is broomed and the first and second

FIG. 5 COMPARISON OF POTENTIAL HORN GROWTH RATES

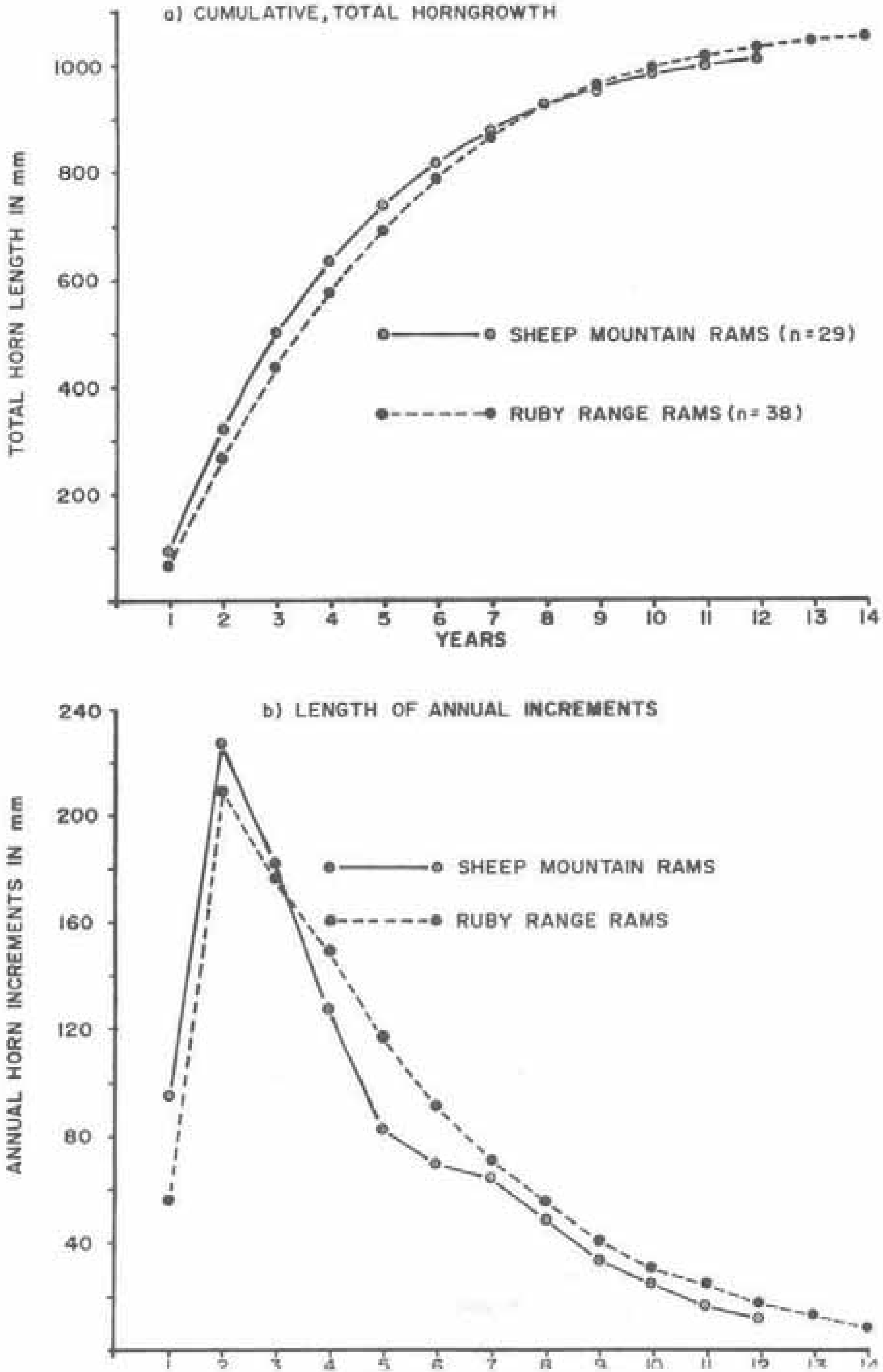
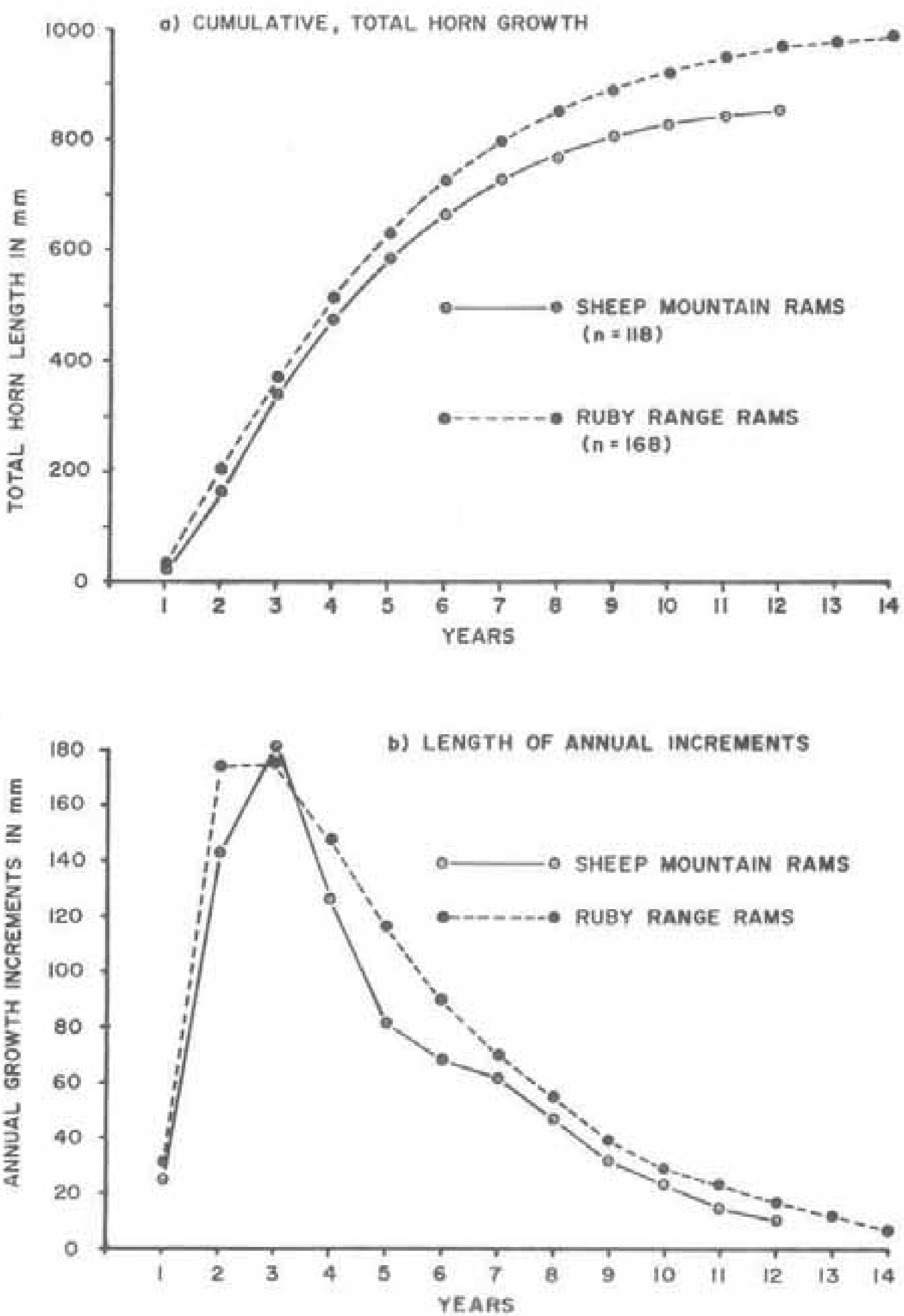


FIG. 6 COMPARISON OF REALIZED HORN GROWTH RATES



annuli are missing, their absence will not affect the mean value obtained, as is the case in horn length assessments, since the sample size will be accordingly reduced. Fig. 7 shows the growth in horn circumference of these two populations. Sheep Mountain rams have bigger horns at the 2nd, 3rd and 4th annuli; however, these differences are not significant.

Since the differences in horn length observed between these two populations, are primarily the result of differential rates of brooming we have analyzed in more detail horn tip wear rates and brooming rates. Table 4 lists for both populations the lengths of the first and second annual increments per age cohort as well as the percentage per age cohort in which these two increments are entirely missing. While in the rams of both populations the reduction in lengths of the first and second horns increments are significantly correlated with age (Sheep Mountain, $r = -0.821$; Ruby Range, $r = -0.991$ for first increment: Sheep Mountain $r = -0.768$; Ruby Range $r = -0.941$ for second increment), the rate of horn reduction is higher for the Sheep Mountain rams and it is also more "erratic". This indicates that brooming as opposed to gradual wear is more prominent here. This is primarily obvious from analyses of the second increment, since gradual horn tip wear affects essentially the first increment only (Hoefs and Nette 1982). In Sheep Mountain rams, 36% of the rams older than 5 years have no 2nd horn increments left, but this was observed in only 3% of the rams from the Ruby Range. These differential rates of horn length reduction are shown graphically in Fig. 8. Here the assessment is based on reduction in length of the sum of the first plus second horn growth increments. From the 5th year to the 12th or 14th year, respectively, horn reduction appears to be linearly related to age. We have no data for the younger age classes, but we know from extrapolation with first year increment data only (Hoefs and Nette 1982), that the sum of the first plus second increment can not be greater than about 326 mm for Sheep Mountain rams and about 308 mm for Ruby Range rams. This would indicate that during the first 4 or 5 years of life, horn length reduction is primarily brought about by gradual tip wear, and that this wear rate is relatively slow. Starting with the 5th and 6th year horn length reduction is brought about by the additive impacts of horn tip wear and brooming; and this combined rate is much greater, as is obvious from Fig. 8. This interpretation appears to be reasonable in light of the fact that brooming is brought about by fighting (Shackleton and Hutton 1971) and rams do not usually engage in severe fighting until they have reached maturity, which according to Geist (1971) is about the 6th year.

This affect of brooming on total horn lengths realized in mature rams has management implication, if trophy harvest is the management objective. In Fig. 9 we have shown the mean horn lengths obtained by rams dying at different ages for both populations. For Sheep Mountain rams, the longest horns were documented for the 9- to 10-year age group. In older rams brooming exceeded new growth put on at the horn base; and there was, therefore, a reduction in horn length in older rams. For Ruby Range rams, on the other hand, horn lengths obtained were greater in all age classes and remained relatively stable from the 9th to the 13th year age classes.

FIG. 7 COMPARISON OF HORN GROWTH IN CIRCUMFERENCE

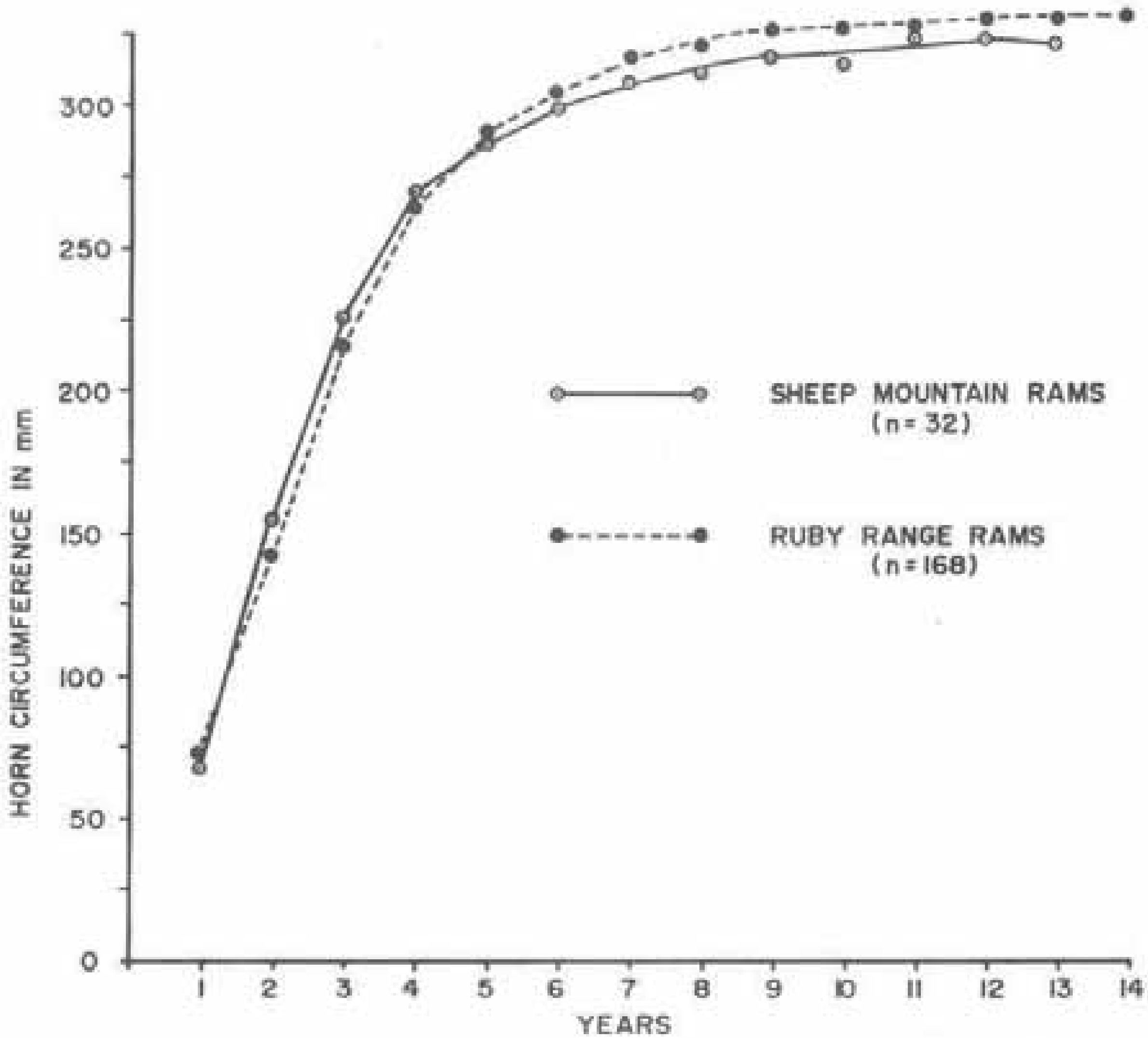


Table: 4

ASSESSMENT OF HORN TIP WEAR AND BROOMING

Age	n	$\bar{X}$ length of 1st increment	percent with 1st increment missing	$\bar{X}$ length of 2nd increment	percent with 2nd increment missing
		mm	%	mm	%
A) Sheep Mountain rams					
4	4	95.8	0	227.3	0
5	5	55.6	40	170.2	20
6	4	25.0	50	169.5	25
7	9	38.4	44	126.0	33
8	11	21.0	73	114.1	36
9	17	12.6	76	120.6	47
10	29	27.8	58	171.2	17
11	25	15.4	52	135.7	36
12	10	16.2	70	110.7	50
13	4	0.0	100	0.0	100
B) Ruby Range rams					
6	17	57.2	0	211.7	0
7	16	53.4	6	210.4	0
8	22	43.7	18	176.7	0
9	31	33.1	29	184.5	0
10	38	27.6	32	168.3	5
11	19	23.5	53	166.9	5
12	16	7.9	69	127.6	0
13	6	7.7	66	128.0	17
14	3	0.0	100	136.7	0

FIG. 8 RELATIONSHIP OF HORNWEAR AND BROOMING TO AGE OF RAMS

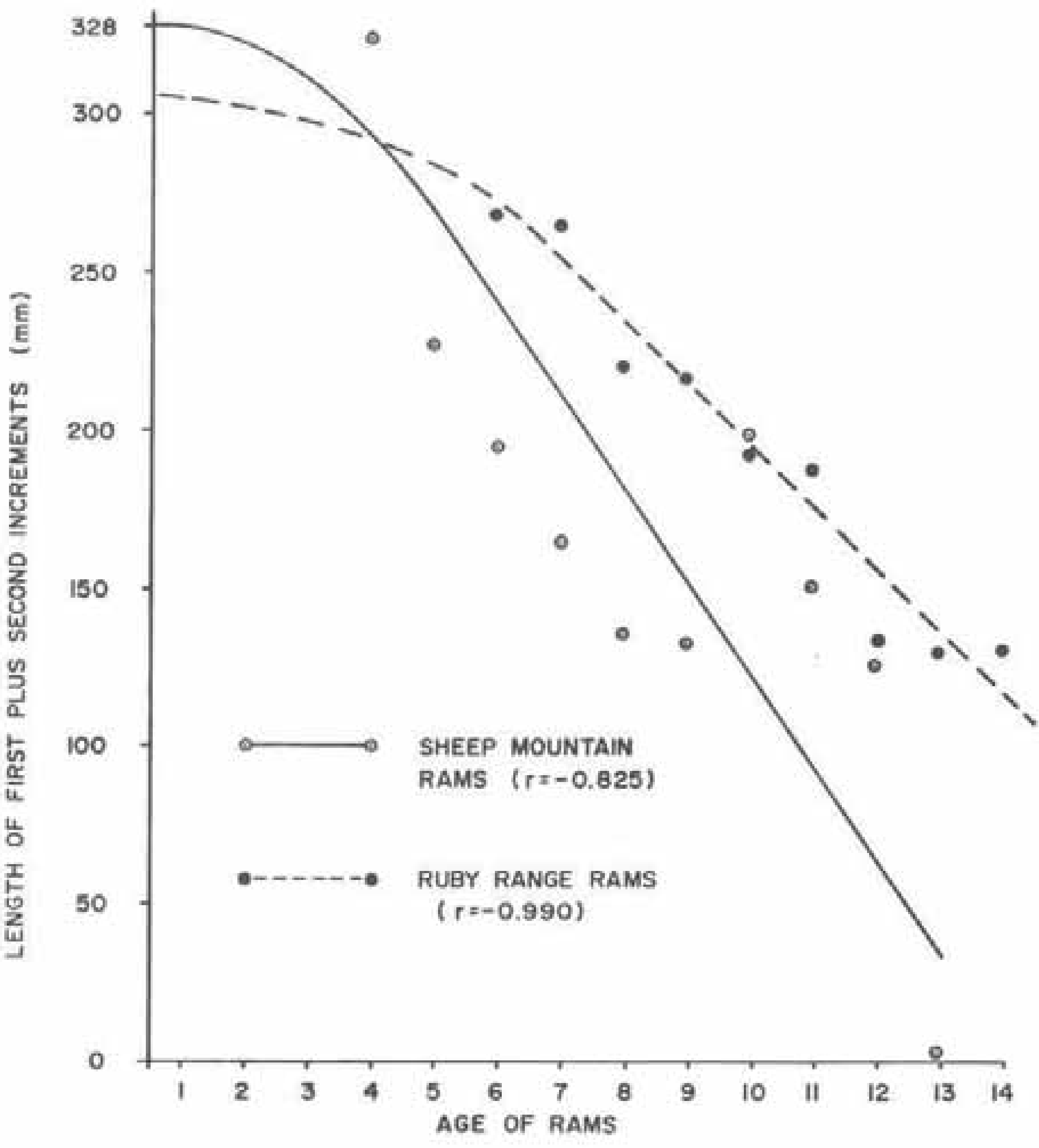
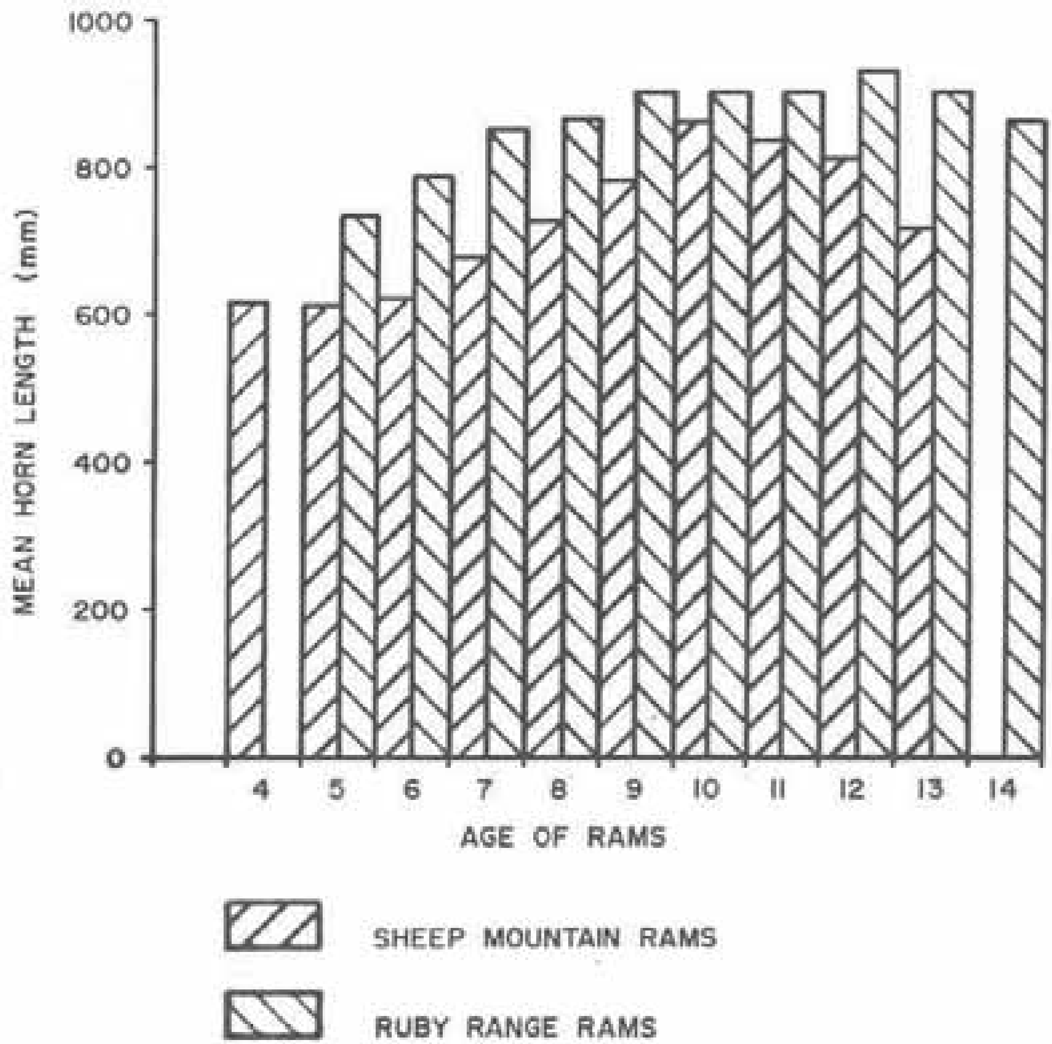


FIG. 9 MEAN HORN LENGTH OBTAINED BY RAMS ON SHEEP MOUNTAIN AND ON RUBY RANGE



During these years new growth put on at the horn base and brooming of the horn tip were more or less in balance. Only in very old rams, 13 and 14 years of age, did brooming exceed new growth and there was a slight reduction in total horn length. Since horn length is the single most important parameter in trophy evaluations, rams in a population with horn characteristics comparable to those of the Sheep Mountain herd should be harvested at an average age of 9 to 10 years, while Ruby Range rams should be allowed to live longer. However, to strive for an average harvest age of 12 to 13 years is unrealistic. Many rams will have died from natural mortality causes by then, and asymmetrical brooming lowers the trophy quality, even if a few points may have been gained for the longer of the two horns. Our assessments, throughout this analysis have only considered the longer of the two horns on a given skull, differential rates of brooming are therefore not apparent in our tables and diagrams.

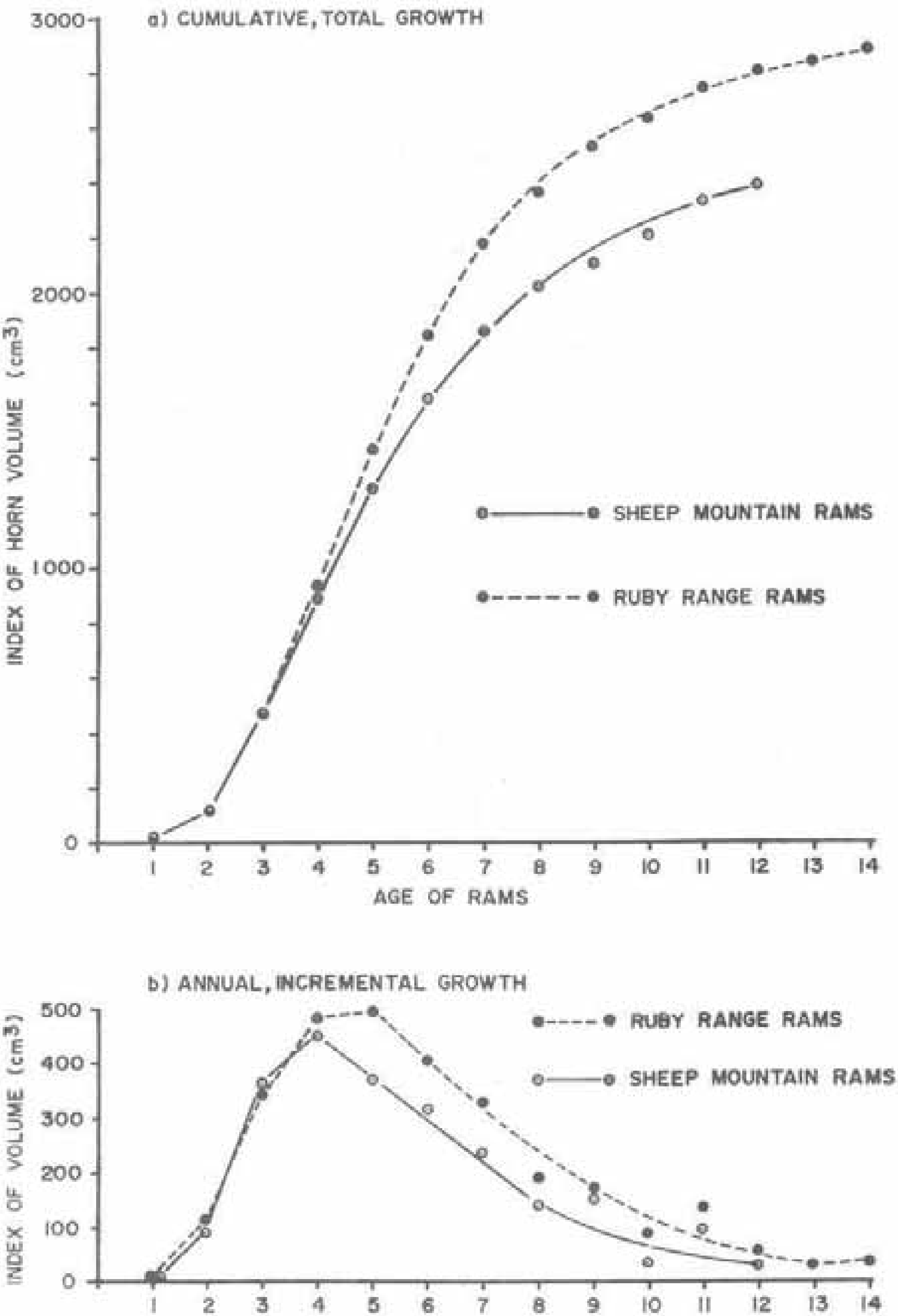
There are many advantages in assessing horn growth in volume. It more appropriately reflects accumulation of mass or tissue than either length or circumference measurements. However, volume determinations are difficult and few attempts have been made (Heimer and Smith 1975, König and Hoefs 1982, Stewart and Butts 1982). We have used here an index of volume, applying Heimer and Smith's (1975) methodology. In Fig. 10 the incremental and annual horn volumes as well as the total cumulative volumes are shown for both ram groups and Table 5 shows the horn length and circumference data from which they were derived. Here, data for "realized" growth were used. However, this makes little difference, since the presence or absence of the first plus second horn growth increments would only introduce an error of less than 5% in the total horn volume of a mature ram (> 8 years old). Horn volume growth is not significantly different in the first 4 years, but after that growth in horn volume of the Ruby Range rams exceeded that of the Sheep Mountain rams, and at the age of 12 years it was on the average 18% greater. In contrast to growth in horn length, which for both populations was highest during the second year, most volume growth was accomplished by Sheep Mountain rams during their 4th growing season and by Ruby Range rams during their 4th and 5th growing season. Even during the 9th growing season was volume accumulation still higher than during the 2nd year. The pattern of horn volume growth is therefore very different from that of growth in horn length, and it may question many of the hypothesis that have been advanced in relation to population quality, based on the latter (Geist 1971, Shackleton 1973, Bunnell 1978).

The possibility exists that the differences observed in horn parameters of these two populations may be a reflection of a biased sample. In the Sheep Mountain population the rams died from natural causes and all were included in the sample. Particularly in recent years, the skulls of most rams that died were recovered and measured. There is also no reason to assume that skulls that were not recovered should have different horn growth characteristics. In the Ruby Range, the sample

Table: 5 COMPARISONS OF HORN GROWTH PARAMETERS

Age	Cumulative horn length (mm)	Horn circumference at annuli (mm)	Cumulative volume index cm^3	incremental volume index cm^3
A. Sheep Mountain Rams				
1	25.4	68.7	3.0	3.0
2	168.7	155.1	107.7	104.7
3	348.2	226.8	475.2	368.0
4	483.5	269.3	931.2	456.0
5	589.8	288.4	1299.6	368.4
6	669.0	302.5	1625.9	326.3
7	728.0	311.3	1824.2	248.3
8	772.6	313.5	2022.6	148.2
9	806.0	320.5	2195.7	173.1
10	830.2	317.8	2225.0	30.0
11	848.2	325.0	2379.3	154.3
12	861.1	325.0	2415.8	36.5
B. Ruby Range Rams				
1	32.7	71.4	4.5	4.5
2	207.6	148.5	121.5	116.7
3	377.2	215.1	463.9	342.0
4	517.3	263.2	950.8	486.9
5	635.1	292.8	1444.5	493.7
6	728.4	309.3	1847.3	402.8
7	801.8	319.8	2175.3	328.0
8	857.8	322.7	2370.3	195.0
9	899.7	326.7	2547.3	177.0
10	932.3	329.0	2639.3	93.3
11	957.4	329.1	2750.7	111.1
12	973.4	330.1	2817.1	67.0
13	987.3	330.4	2858.5	41.1
14	995.3	331.7	2903.5	45.0

FIG. 10 ESTIMATED HORN GROWTH IN VOLUME OF DALL RAMS



was obtained entirely from hunter-killed rams. Hunting pressure varied between years, amounting to 66% to 80% of the legal rams. The other 20 to 34% of the rams died from natural causes. None of their skulls were recovered and assessed.

Although supporting statistics are not available in the literature, it is known that hunters select the biggest trophies. We have used two analyses to address the hypotheses that hunters take the best trophies, and that rams with more inferior horn development live longer. Firstly, horn growth parameters for rams that were shot at an age of less than 9 years were compared with those rams living longer than 9 years. The relevant statistics are given in Tables 6a, b, and in Fig. 11. It is obvious, that rams shot at an age of less than 9 years show generally better horn development than those harvested at a greater age. For linear horn growth the difference is significant for the first, second and third annual increments. For the first increment, it may reflect different rates of tip wear, but for the 2nd and 3rd increments the differences are real. In general, the younger rams also had larger horn circumferences, however, only the one at the 5- to 6-year annulus was significantly different. As a practical example, it can be said, that a ram shot by hunters in his 9th growing season had an average horn length of 904 mm with an average circumference at the horn base of 323 mm, while those rams of the same age that remained alive and an average horn length of 826 mm with a circumference at base of 315 mm.

Secondly, we applied these procedures to all hunted age classes, and the results are shown in Fig. 12. It is obvious that for each cohort shot at a given age the horn growth is superior to those of rams living longer. Detailed statistics are given in Table 7a and b. These tables show that these differences are derived primarily from horn growth rates during the first 6 years, which show in general a negative correlation between age at death of a ram, and increment length during the first 6 years. For circumference measurements this negative correlation is found in all age classes except for 4th (Table 7a). From these analyses it becomes obvious that hunters take indeed the biggest trophies for a given age class.

A similar analysis for the Sheep Mountain rams, does not show this trend. Tables 8a and 8b give the relevant statistics. Here the pattern of mortality is more random, with rams with both well developed and less well developed horns dying in a given age cohort. Correlations between horn increment length or circumference and age at death are generally positive, and where they are negative, they are less significantly so than for Ruby Range rams.

Having established that hunters select the rams with the best horn development, the question whether this selective removal of superior animals will not over time lead to a deterioration of trophy quality in the population needs to be addressed. By selectively removing inferior animals, European wildlife managers have over many years been able to considerably improve the trophy quality in herds of red deer, roe deer, chamois and muffIon sheep. It is therefore not unrealistic to suggest that the reverse could come into being here. Unfortunately, the Yukon

Table 6a Comparison of horn growth in length (mm) of rams shot before and after 9 years of age

Age	n		1	2	3	4	5	6	7	8	9	10	11
> 9	42	$\bar{x}$	32	168	157	137	115	92	72	53	41	29	30
		$\sum \bar{x}$	32	200	357	494	609	701	773	826	867	896	926
≤ 9	38	$\bar{x}$	59	192	174	142	115	94	74	54			
		$\sum \bar{x}$	59	251	425	567	682	776	850	904			

Table 6b Comparison of horn growth in circumference (mm) of rams shot before and after 9 years of age

Age		4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
> 9	$\bar{x}$	264	291	306	315	320	325	330	331
	n	17	17	17	17	17	17	32	9
≤ 9	$\bar{x}$	262	315	310	323	330			
	n	14	15	16	18	16			

FIG. II DIFFERENTIAL HORN GROWTH RATES OF RAMS SHOT OF AN AGE LESS THAN 9 YEARS OLD AND THOSE LIVING LONGER

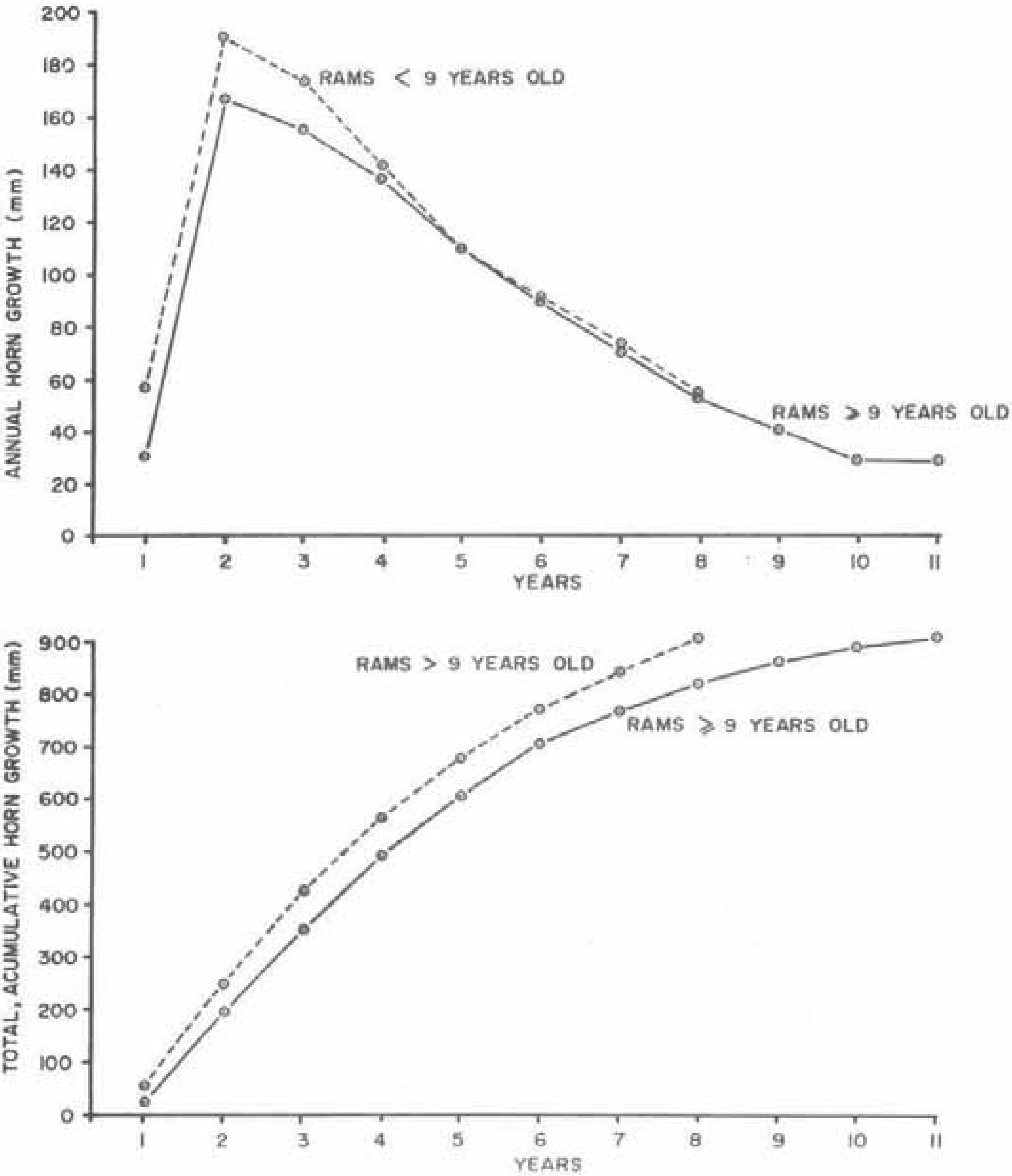


FIG. 12 DIFFERENCES IN HORNGROWTH RATES OF RAMS SHOT AT A GIVEN AGE COMPARED TO THOSE THAT LIVED LONGER

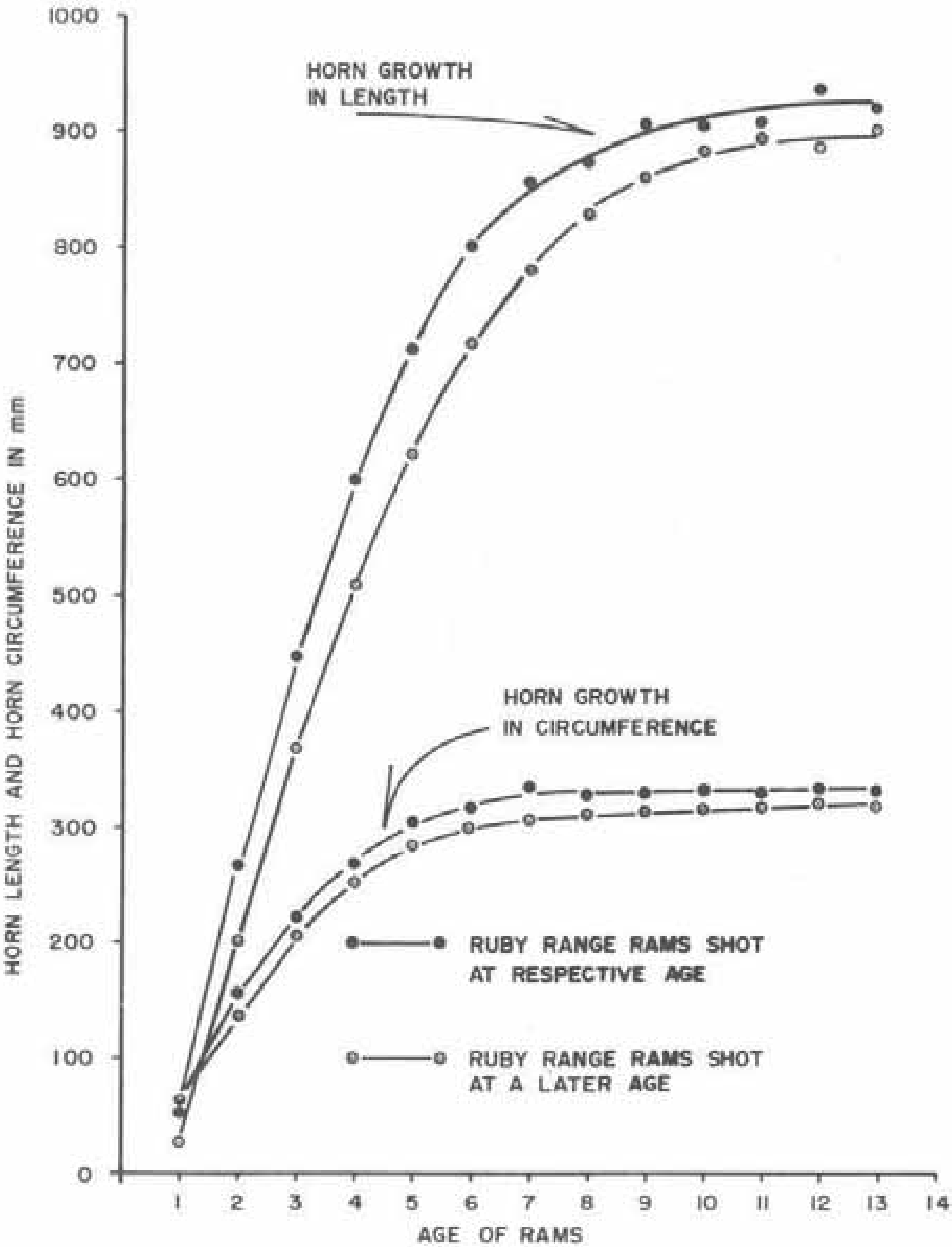


Table: 7a

RELATION OF AGE AT DEATH OF RAMS IN RUBY RANGE AND THEIR ANNUAL HORN GROWTH RATES IN CIRCUMFERENCE.

CIRCUMFERENCE AT HORN ANNULI IN mm

Age of death of Rams	2	3	4	5	6	7	8	9	10	11	12	13	14
6	148.0	217.9	262.4	303.8	319.3								
7	160.5	233.2	278.8	306.7	319.6	336.7							
8	137.5	207.6	257.8	287.1	304.4	318.1	327.1						
9	150.5	215.3	264.3	291.4	307.7	317.5	324.5	330.0					
10	150.4	217.5	267.5	293.5	306.5	316.6	320.8	324.3	330.4				
11	151.8	212.8	258.2	289.9	305.8	315.4	320.5	324.9	327.9	329.0			
12	130.5	197.6	253.6	284.5	302.3	311.8	319.4	325.8	327.4	330.3	331.5		
13	141.7	216.4	266.2	294.0	309.5	316.3	320.8	326.0	328.4	327.3	328.3	332.1	
14	140.0	205.7	258.0	288.0	304.0	311.0	318.5	322.0	324.5	322.5	323.0	324.0	331.7
r =	-.51	-.56	.16	-.66	-.70	-.76	-.88	-.69	-.85	-.88	-.99	-	-

(Last increments are often not complete at time of hunting season)

Table: 7b

RELATION OF AGE AT DEATH OF RAMS IN RUBY RANGE AND THEIR ANNUAL HORN GROWTH RATES IN LENGTH.

LENGTH OF ANNUAL HORN INCREMENT IN mm

Age of death of Rams	1	2	3	4	5	6	7	8	9	10	11	12	13	14
6	57.2	211.7	178.7	150.5	118.5	84.4								
7	53.4	210.4	182.1	139.1	112.8	90.6	69.1							
8	53.4	183.1	175.6	142.8	117.8	98.3	71.4	47.5						
9	46.7	195.5	168.1	136.1	117.7	96.5	74.5	56.5	40.7					
10	40.3	188.2	168.9	138.3	116.4	93.6	72.8	53.1	40.1	28.1				
11	44.7	202.1	151.0	136.0	121.0	90.8	73.7	54.5	43.9	30.2	18.7			
12	25.2	172.1	167.9	140.8	124.6	93.4	81.0	63.9	52.8	35.8	26.1	16.9		
13	23.0	179.3	181.5	161.3	114.5	85.0	64.5	49.2	43.0	33.0	21.8	16.8	15.2	
14	-	-	136.7	106.7	104.0	113.0	74.0	62.3	39.7	36.0	21.3	12.7	11.3	8.0
r =	-.94	-.74	-.61	-.35	-.30	-.33	.12	.51	.14	.85	.15	-.88	-	-

(Last increment is often not fully grown during hunting season)

Table: 8a

RELATION OF AGE AT DEATH OF RAMS ON SHEEP MOUNTAIN AND THEIR ANNUAL HORN GROWTH RATE IN CIRCUMFERENCE.

CIRCUMFERENCE AT HORN ANNULI IN mm

Age of death of Rams	2	3	4	5	6	7	8	9	10	11	12	13
6	169.0	234.0	275.0	284.0	322.0							
7	128.0	200.5	246.5	266.5	275.5	316.4						
8	135.5	207.0					318.7					
9	167.2	237.5						327.8				
10	157.1	228.4	275.1	296.6	310.3	313.7	316.4	318.6	320.6			
11	149.7	230.4	265.1	285.3	294.6	300.4	301.9	303.9	305.9	324.9		
12	170.0	243.0	280.0	296.0	307.0	317.0	322.0	325.0	327.0	327.0	325.0	
13	170.0	245.0	285.0	305.0	314.0	318.0	320.0	321.0	322.0	326.0	327.0	322.0
r =	.44	.63	.58	.76	.17	-.01	.09	.03	.36	.52	-	-

Table: 8b

RELATION OF AGE AT DEATH OF RAMS ON SHEEP MOUNTAIN AND THEIR ANNUAL HORN GROWTH RATE IN LENGTH.

LENGTH OF ANNUAL HORN INCREMENT IN mm

Age of death of Rams	1	2	3	4	5	6	7	8	9	10	11	12	13
5	95.8	227.3	181.0	127.2	94.5								
6	50.8	226.0	189.5	112.8	82.3	64.0							
7	69.2	189.0	170.3	134.0	90.8	70.2	52.9						
8	77.0	179.3	165.6	128.2	110.6	84.5	65.1	46.9					
9	53.5	227.9	174.1	137.1	109.9	85.9	63.1	48.0	33.5				
10	47.4	171.2	180.2	136.2	112.2	77.1	57.4	42.9	32.9	26.0			
11	51.3	212.0	188.7	139.5	103.5	75.7	56.0	44.5	33.2	24.3	16.8		
12	54.0	221.4	189.0	131.2	109.4	82.7	58.0	41.0	33.4	21.4	17.1	11.9	
13	-	-	178.8	142.0	104.8	83.3	60.8	47.8	37.3	30.8	20.5	12.8	10.5
r =	-.42	-.15	-.52	.79	-.13	.61	.56	.33	.70	.38	.90	-	-

Wildlife Branch has only taken trophy measurements for about 10 years; the data base is therefore insufficient to address this issue.

Nevertheless, we have made an assessment of horn growth parameters of rams in the Ruby Range that were shot during the years 1973 and 1974 and compared them with data of rams shot between 1981 and 1983. The data are given in Table 9 and in Fig. 13. While the differences observed are not significant, they do show a trend, which forces us to be cautious with our present sheep management scheme and to closely monitor the situation. The horn growth pattern of rams shot during 1973-74 is characteristic of a better quality population (as defined by Geist, 1971), in that better horn growth increments were obtained during the first, second and third years. Circumference measurements were also higher. A period of 8 to 10 years is insufficient to document a genetic change, however, these data warrant further future assessment of the indicated trend.

E. Assessment of population quality

Characteristics we used as indicator of population quality are summarized in Table 10. By comparing the two populations in relation to each of these indicators they were then rated as being of better (+) or of a poorer (-) quality than the other. It is apparent from Table 10 that there is no distinct trend. The Sheep Mountain population can be considered of superior quality in relation to heavier body sizes of rams, horn growth pattern, and a shorter life expectancy. However, it is of poorer quality in relation to its low fecundity, high incidence rate of various mandibular diseases and its high density. The characteristics described, therefore do not allow a relegation of these two populations into different quality classes, as hypothesized by Geist (1971).

SUMMARY AND CONCLUSION

Hunting carried out on the Ruby Range sheep population, which translates into a harvest rate of 2 to 3% of the summer population, must be considered compensatory and sustainable and not additive. It did not cause population decline, it did not change the adult sex ratio, it did not lower the maximum life expectancy, and the age specific mortality pattern was not different from the natural mortality pattern observed in the unhunted population of Sheep Mountain. Hunting, therefore, has had no negative impact over the past decade in a quantitative sense.

The rate of horn brooming was significantly lower in the hunted population, which resulted in longer average horn sizes in the older age classes of rams. While we have no evidence of this, it is not unreasonable to assume, that the lower density and the removal of superior rams in the hunted population lowered the frequency of contacts between rams and therefore the potential for fighting. Brooming of horns is thought to be primarily caused by fighting (Shackleton and Hutton 1971).

Table 9: Comparison of horn growth rates of rams shot in 1973 and 1974 with those shot in 1981 to 1983

Horn length (mm)

1973-74	1	2	3	4	5	6	7	8	9	10	11	12	13	14	n
$\bar{x}$	55.6	204.4	177.4	143.9	115.6	86.0	66.7	48.3	35.7	24.7	20.6	12.0	17.0		22
$\sum \bar{x}$	55.6	260.0	437.4	581.3	696.9	782.9	849.6	897.9	933.6	958.3	978.9	990.9	1007.9		
1981-83															
$\bar{x}$	35.7	191.3	174.3	142.8	121.0	94.7	75.0	58.4	44.7	32.2	20.3	16.5	12.7	10.0	51
$\sum \bar{x}$	35.7	227.0	401.3	544.1	665.1	759.8	834.8	893.2	937.9	970.1	990.4	1006.9	1029.6		

Horn circumference (mm)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	n
1973-74															
$\bar{x}$		153.2	221.9		318.0		326.0		328.0			327.0			
1981-83															
$\bar{x}$		142.9	214.9		300.4		320.7		326.6			331.2			

FIG. 13 HORN GROWTH RATES OF RAMS SHOT IN 1973-74 AND IN 1981-83 IN RUBY RANGE

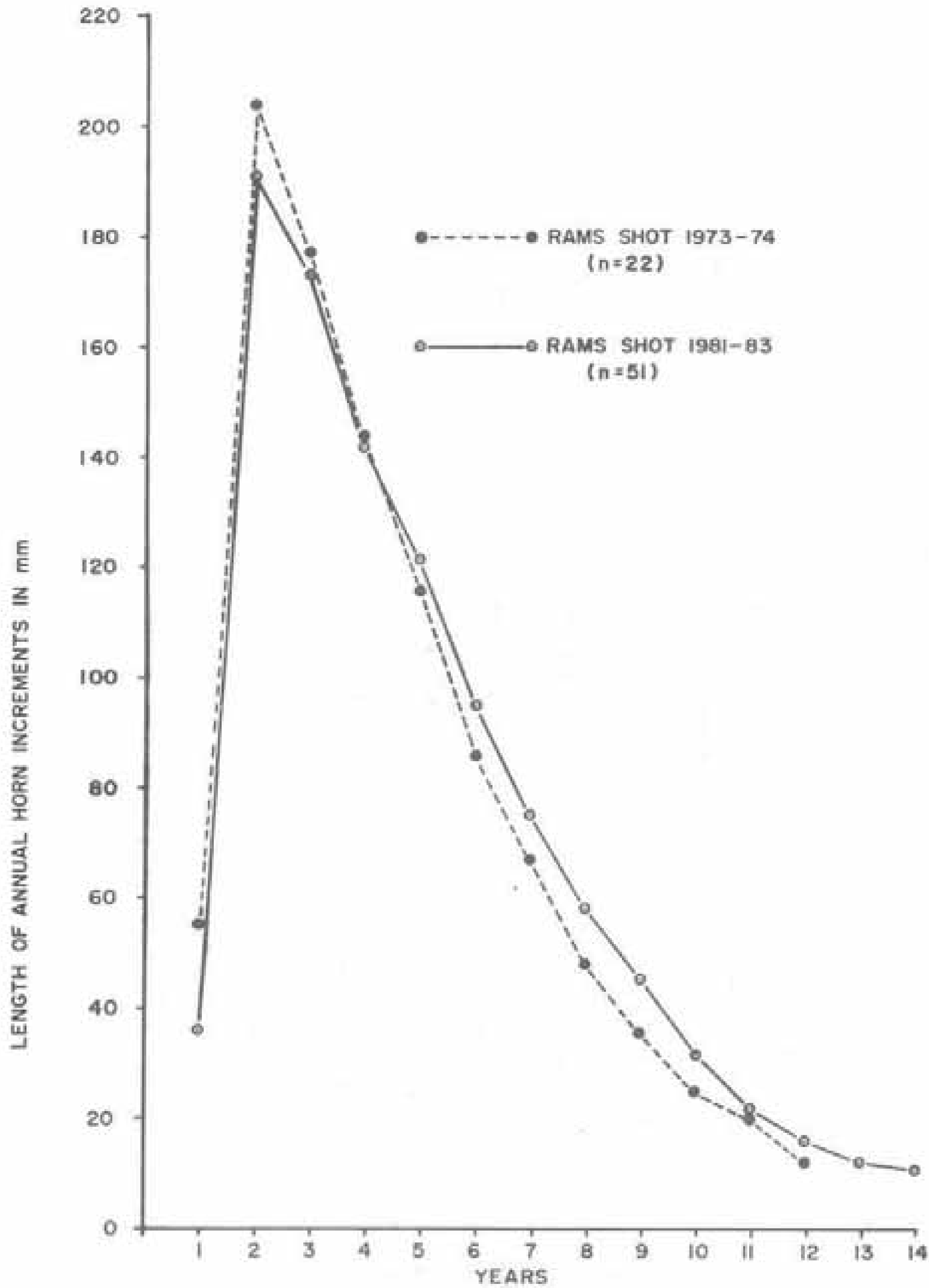


Table 10: Characteristics of population quality

Quality indicator	Sheep Mountain population		Ruby Range population	
	Value	Rating	Value	Rating
Mandibular diseases (incidence rate)	63% (n=33)	-	38% (n=77)	+
Density	1.34 sheep/km²	-	0.66 sheep/km²	+
Productivity	20 lbs/100 ewes	-	29 lbs/100 ewes	+
Longevity	12-13 years	+	14-15 years	-
Male weight (max.)	230 lbs. (n=10)	+	214 lbs. (n=13)	-
Horn growth pattern		+		-

Hunters selectively remove those rams with the best horn development. There are indications that this may lead in the long term to a deterioration in horn growth quality of the population and it is, therefore, imperative that the trend is carefully monitored. Should this concern be substantiated, it will be necessary to modify our harvesting strategy, allowing a ram component with a more natural composition in the population to perpetuate its genes.

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