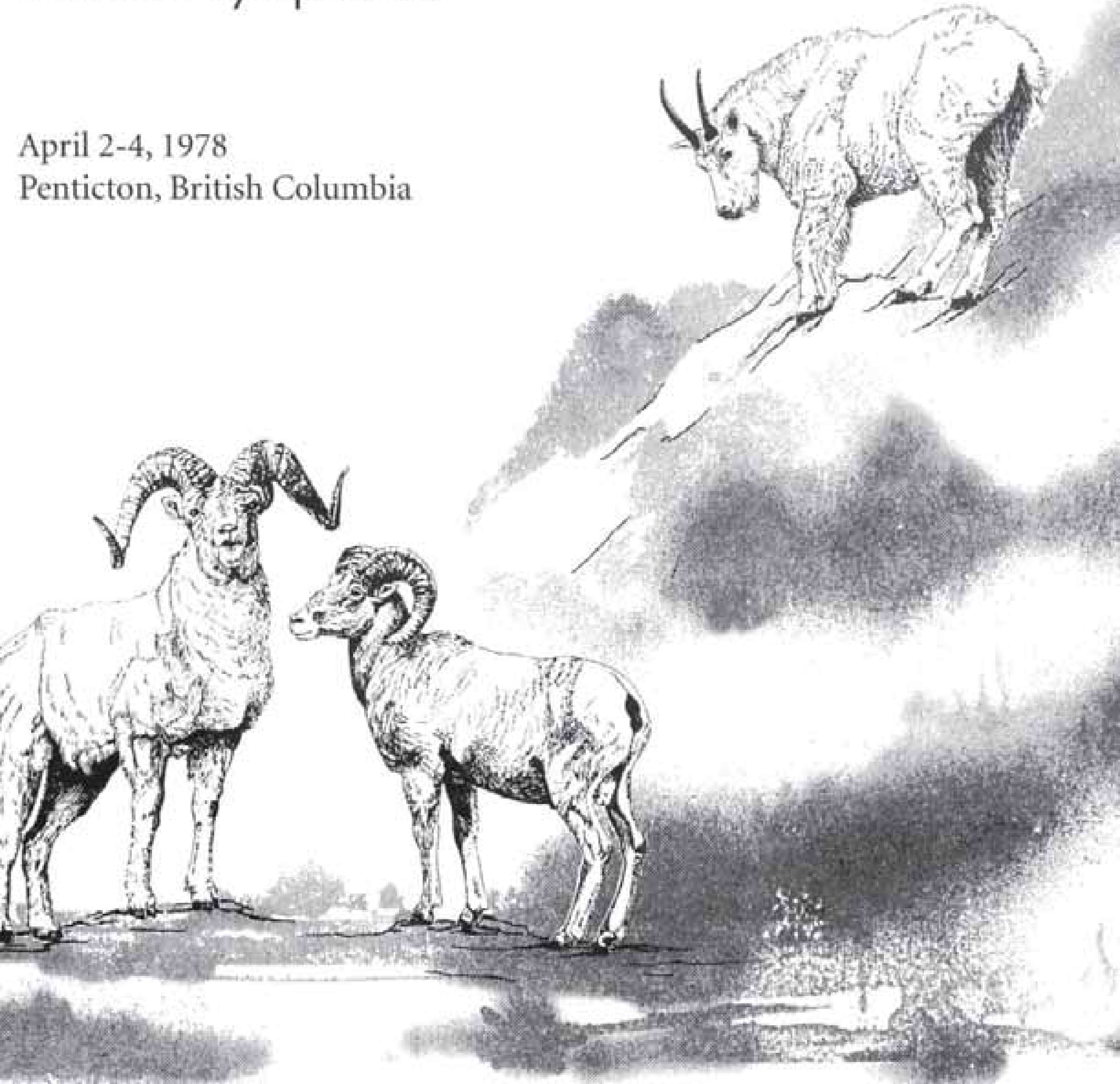
Northern Wild Sheep and Goat Council

Proceedings of the First Biennial Symposium

April 2-4, 1978
Penticton, British Columbia



PROCEEDINGS OF THE BIENNIAL SYMPOSIUM OF THE NORTHERN WILD SHEEP AND GOAT COUNCIL

Penticton, British Columbia
April 11 - 14, 1978

CHAIRMEN: D.M. Hebert and M. Nation

SPONSORED BY: B.C. FISH and WILDLIFE BRANCH
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REPROGRAPHICS

A special thanks is due Mr. Clarence Tillenius for his contribution of the Bighorn painting and the after-dinner address describing his experience in northern Canada. Ms. Stephanie Allan completed the retyping of all manuscripts and Ms. Holly Cleator completed the preparation, organization and much of the drafting contained in the Proceedings. Mr. John Youds prepared some of the diagrams.

Cover Artwork by Ms. Laura Friis, B.C. Fish and Wildlife Branch, Victoria

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SEASONAL DISTRIBUTION PATTERNS OF WHISKEY MOUNTAIN

BIGHORN SHEEP[1]

Kurt Becker[2], Tom Varcalli[3],
E. Tom Thorne[4], and Gary B. Butler[5]

INTRODUCTION

Mountain sheep have been shown to use distinct seasonal home ranges and well defined migration routes. Knowledge of home ranges and migration routes is passed on from generation to generation and is a function of tradition. Previous studies have indicated that sheep are very loyal to their ranges and use them during the same season year after year (Geist 1971, Morgan 1971). During three years of intensive study on Wyoming's Whiskey Mountain bighorn sheep (Ovis canadensis canadensis) populations, information substantiating and possibly broadening these concepts was gathered.

STUDY AREA

The Whiskey Mountain bighorn sheep winter range lies on the northern fringe of the Wind River Mountains near Dubois, Wyoming. The topography is characterized by steep mountainous slopes of up to 13,000 feet in elevation interspersed with numerous cliffs. The mountains rise over 6,000 feet above the adjacent Wind River drainage. Lower slopes are semi-arid with coniferous vegetation limited primarily to north and east exposures; sagebrush and bunch grasses grow on the other exposures. Timberline is approximately 11,500 feet above which only grasses and forbs persist. In the early 1950's the Wyoming Game and Fish Department became concerned about poor lamb production among bighorn sheep wintering in the area and established the Whiskey Basin Game Winter Range, primarily to benefit sheep. Pittman-Roberston funds were used to purchase land and Federal land management agencies removed or reduced domestic livestock grazing allotments on neighboring Federal lands. Through cooperative and intensive management, the forage available for wintering sheep increased and

1 This work was supported by Federal Aid in Wildlife Restoration, Wyoming Project FW-3-R.
2 Current address: U.S. Forest Service, Salmon, Idaho
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5 Wyoming Game and Fish Department, Whiskey Basin Winter Range, Dubois, WY

sheep responded by increasing in numbers from an estimated 400 sheep to the 800-1,000 animals present now. During the same interval, a greater number of sheep has been removed by trapping and transplanting or hunting (Crump 1976).

Prior to initiation of the study reported here, Game and Fish Department reports and discussions with personnel associated with the winter range revealed that three key winter ranges were present. These were Trail Lake Meadows and Torrey Rim on the east side of Whiskey Mountain, BLM Ridge on the north side of Whiskey Mountain, and Sheep Ridge which is north of BLM Ridge. Three lambing areas, one near each key wintering area, had also been located. Sheep wintering on Whiskey Mountain and Sheep Ridge were generally considered to be a single population and they were believed to inhabit a large portion of the northern Wind River Mountains. It is the purpose of this paper to present additional bighorn sheep distribution knowledge gained as a part of an extensive three-year study of the Whiskey Mountain sheep which was initiated during the winter of 1974-1975.

METHODS

During the winters of 1974-75, 1975-76, and 1976-77, 50 to 75 color coded and individually numbered neckbands were placed on yearling and mature ewes. In addition, between five and eight radio transmitter collars were placed on mature ewes each winter. Sheep were captured for neckbanding using a drop-net trap baited with apple pulp and alfalfa hay (Schmidt 1976). Those that received radio transmitters were chemically immobilized (Thorne 1974). Approximate equal numbers of neckbands and transmitters were placed on sheep from each of the three key wintering areas each winter.

Biweekly fixed-wing aircraft flights were made from May through September each summer to locate as many sheep as possible. During the same period each summer, continual ground observations were made which concentrated on sheep from one of the three key wintering areas with occasional observations on sheep from the other areas. Winter observations were made by management and research personnel assigned to the Whiskey Basin Unit, to trapping operations, or the research project.

A mapping system based upon U.S.G.S. topographic maps and legal land descriptions was devised which allowed locating and recording sheep observed to within a quarter of a quarter-section (40 acres). Since all neckbands and transmitters were on ewes, the data presented here deals primarily with the ewe-lamb segments of the populations.

RESULTS

Seasonal Movements of BLM-Sheep Ridge Sheep.

Sheep wintering on BLM Ridge and Sheep Ridge intermingled freely on both winter and summer ranges and were identified as the same sheep population with two sub-units.

Sheep wintering on BLM Ridge and Sheep Ridge were present on the winter ranges from late November to mid-May. Key wintering ranges for BLM-Sheep Ridge bighorn sheep are presented and average percent of annual forage production utilized by sheep is shown in Figure 1. These areas had been accurately described in earlier Department records. The precipitous slopes of Jakey's Fork Canyon and the rocky slope on the west of BLM Ridge seemed to serve as important bedding grounds and escape areas. There was a frequent and free interchange between sheep on BLM and Sheep Ridge as they crossed Jakey's Fork Canyon in a day or less.

Pregnant ewes began to leave the winter ranges in mid-May. Those leaving from BLM Ridge traveled in small scattered groups to the Wasson Fork (1)[1], Rollie Brown (2), or Ross Lake (3) lambing grounds and those leaving from Sheep Ridge traveled to the Sheep Ridge (4) or Jakey's Fork (5) lambing grounds (our location names, Figure 2). During a late May peak, large numbers of ewes had their lambs in isolation in the relatively small lambing grounds. After several days in isolation, ewes and their lambs moved to adjacent nursery areas (6) where they remained for several weeks. Barren ewes, yearlings and two year olds left the winter ranges later and remained in herds separate from ewes and lambs, but near nursery areas. Areas used by the barren groups were generally more open, more productive, and less precipitous and were classified as spring-fall range (7). Rams were frequently seen during this period in scattered bands near nursery areas and below the Wasson Fork spring-fall range in more precipitous and wooded habitat.

1 Numbers in parenthesis correspond with the same numbers showing locations in the various figures.

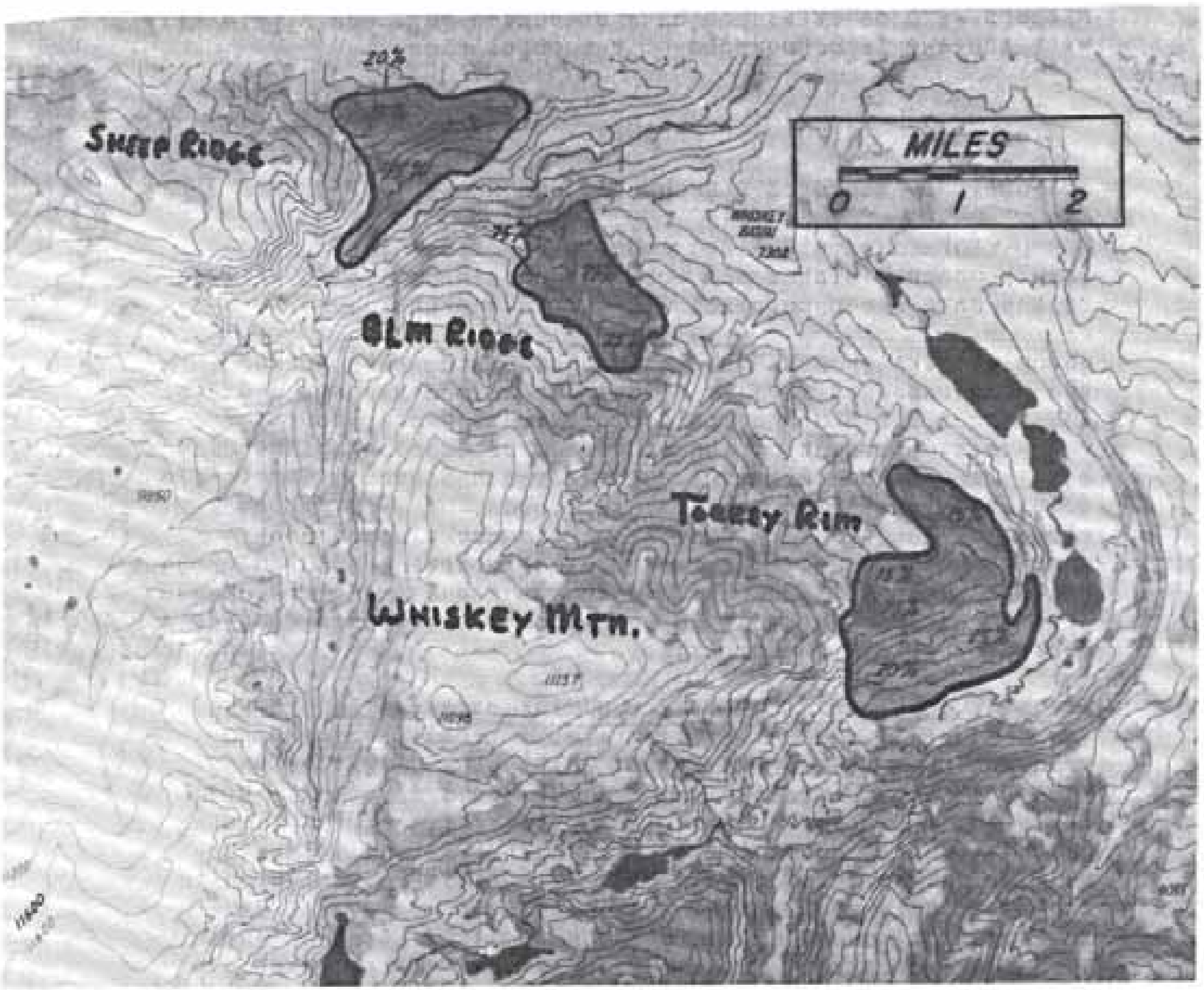

Figure 1. Sheep Ridge, BLM Ridge, and Torrey Rim bighorn sheep winter ranges.

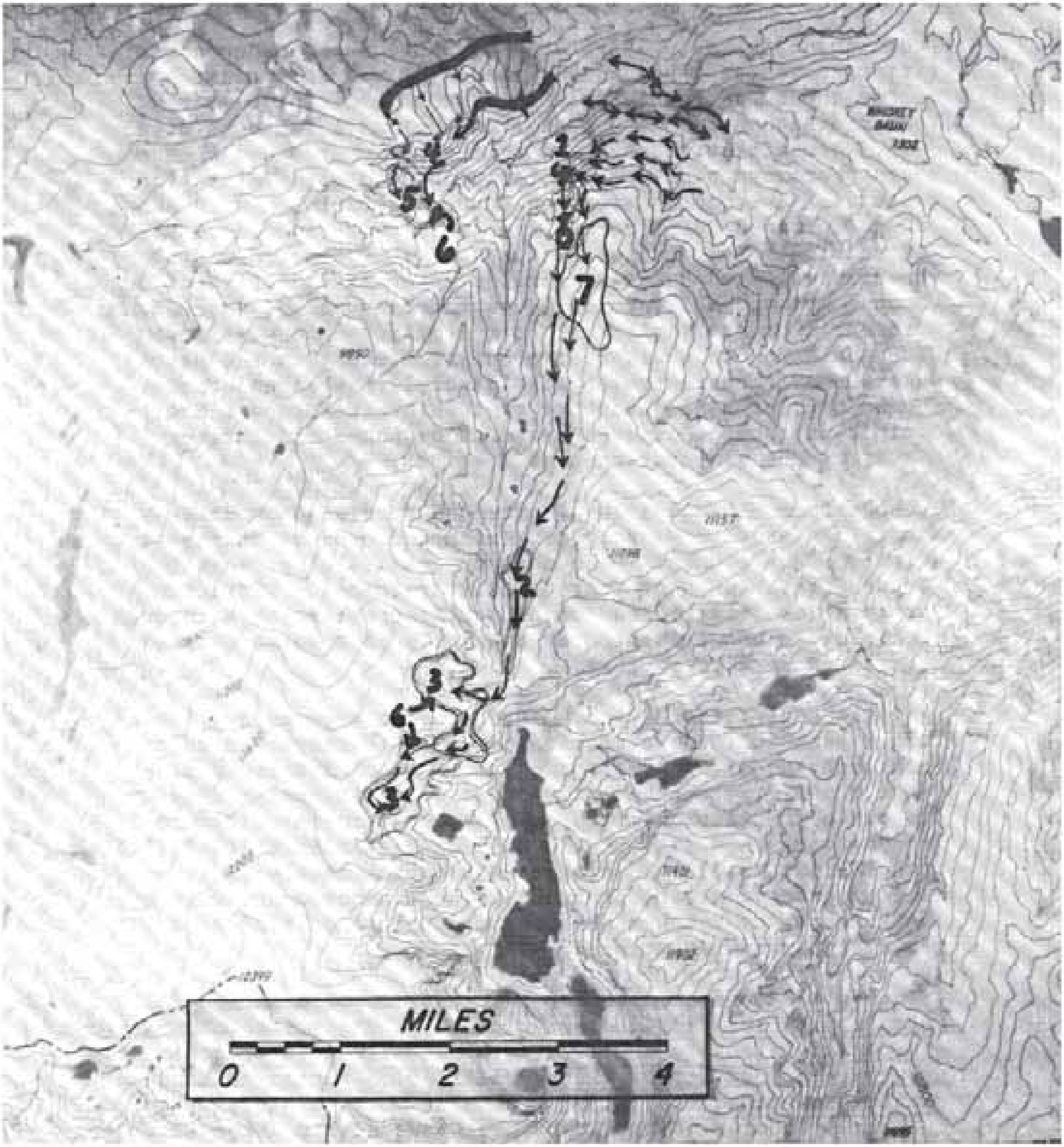

Figure 2. Lambing grounds of BLM-Sheep Ridge bighorn sheep and travel routes to them from winter ranges.

Beginning in early July, BLM-Sheep Ridge sheep began migrating to summer range. This range (8) was an extensive area across the Continental Divide at the head of the Roaring Fork drainage and around Bear and Faler (13) Lakes (Figure 3). Two migration routes led to the summer range with some sheep summering at various locations along the migration routes. Sheep using lambing grounds associated with Sheep Ridge crossed Jakey's Fork Creek (9) and traveled to Shale Mountain on the west side of Wasson Fork Creek. Crossing run-off swollen Jakey's Fork was apparently difficult for young lambs which were observed to cross on log jams. The movement from Jakey's Fork to the cliffs on the west side of Shale Mountain was rapid; but from there to the Bear Lake summer range travel was leisurely. Ewes and lambs seemed to be taking advantage of lush new forage and precipitous escape cover as they moved higher and further away from the winter ranges.

Sheep from BLM Ridge lambing grounds traveled on Whiskey Mountain east of Wasson Fork Creek and crossed to the east side of Shale Mountain on a narrow pass (10) between the Wasson Fork and West Torrey Creek drainages. Migration routes were limited and used by almost every sheep through the Rollie Brown lambing area and the pass between Wasson Fork and West Torrey Creek.

By late July, the BLM-Sheep Ridge sheep had reached the full extent of their summer range. This range was used through August. Sheep formed small bands and moved frequently during the time they were on their summer range. One ewe with a transmitter was observed to move (Figure 3) from Bear Basin (11) to the head of Wasson Fork Creek (12) to Faler Lake (13) (a distance of approximately 15 air miles) during a period of 5 days. Most movements were not as extensive, but the sheep seemed not to be tied to any restricted summering area.

In early September, the sheep returned to the spring-fall range over the same migration routes. These movements were slow and leisurely and seemed to be influenced predominantly by weather conditions. They remained on spring-fall ranges until snow conditions forced them to move to winter ranges in late October or early November. Rams joined the ewes and rut took place on winter ranges.

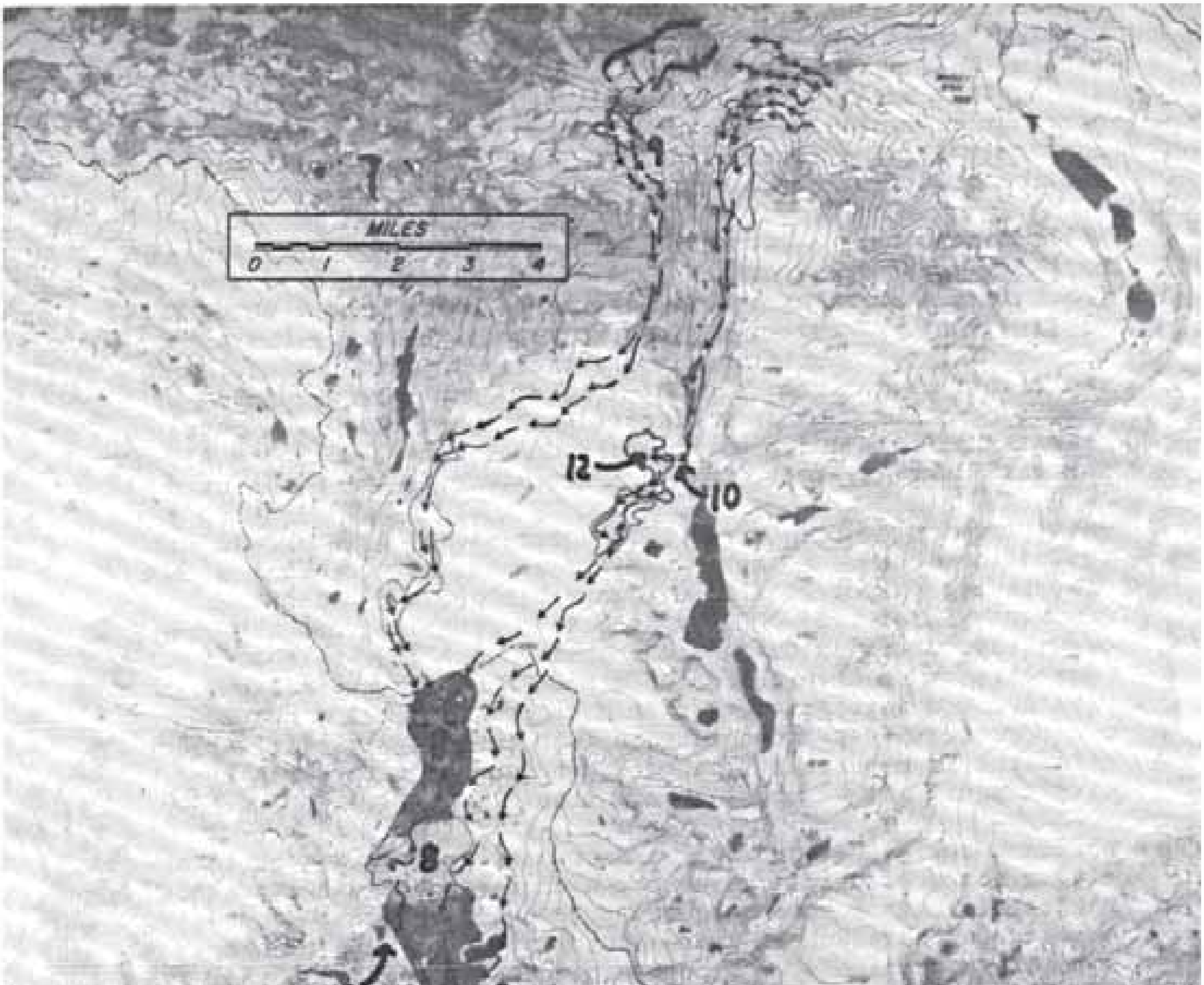

Figure 3. BLM-Sheep Ridge bighorn sheep summer range and migration routes.

Seasonal Movements of Torrey Rim Sheep.

The Torrey Rim sheep remained on winter range (Figure 1) until mid-May at which time they traveled up the southeast side of Whiskey Mountain to spring-fall range (14) (Figure 4). This travel route was very limited and followed the corridor above the steep rocky bluffs that connect the two ranges (15). The strip of timber along the top of the bluffs and the bluffs themselves provide for maximum security.

While most barren ewes, yearlings and two year olds remained on the spring-fall range until mid-June, pregnant ewes stayed for only a short time before continuing to lambing grounds (Figure 5). The rugged granite outcrops (16) on the south side of Whiskey Mountain in the vicinity of Lake Louise and the west-facing cliffs (17) of Middle Mountain were used as lambing grounds. Bands of rams were frequently seen on or near spring-fall range until mid-June, but as with BLM Ridge-Sheep Ridge rams, they did not associate with ewe bands.

Sheep from the barren group left spring range in mid-June and, following the same route as did pregnant ewes, traveled to the west-facing slopes of Middle Mountain above the lambing grounds (Figure 6). During the latter part of June, barren ewe groups utilized the broad open slopes (18) with lush vegetation on the west side of Middle Mountain while ewes with lambs were restricted to a nursery area (19) which was a narrower, less productive zone just above the cliffs which offered more security. They did not venture far from the cliffs until lambs became more mobile.

During early July, nursery and barren groups began to intermingle and gradually move to the higher south end of Middle Mountain. This movement seemed to be in response to decreased forage supplies and scarcity of water on the lower northern portion of the mountain. They remained on the higher nursery areas through mid-July and occasionally moved back to the north end of the range in response to severe weather (high winds, hail storms, high intensity rainstorms) and returned when the weather improved.

By late July the sheep had reached summer range (20) which was primarily on the high south end of Middle Mountain (Figure 6). Approximately 10-20 percent of the ewes and lambs from the Torrey Rim herd traveled on from Middle Mountain to Goat Flat (21). They followed a well defined route (22) between these two ranges. Like BLM-Sheep Ridge

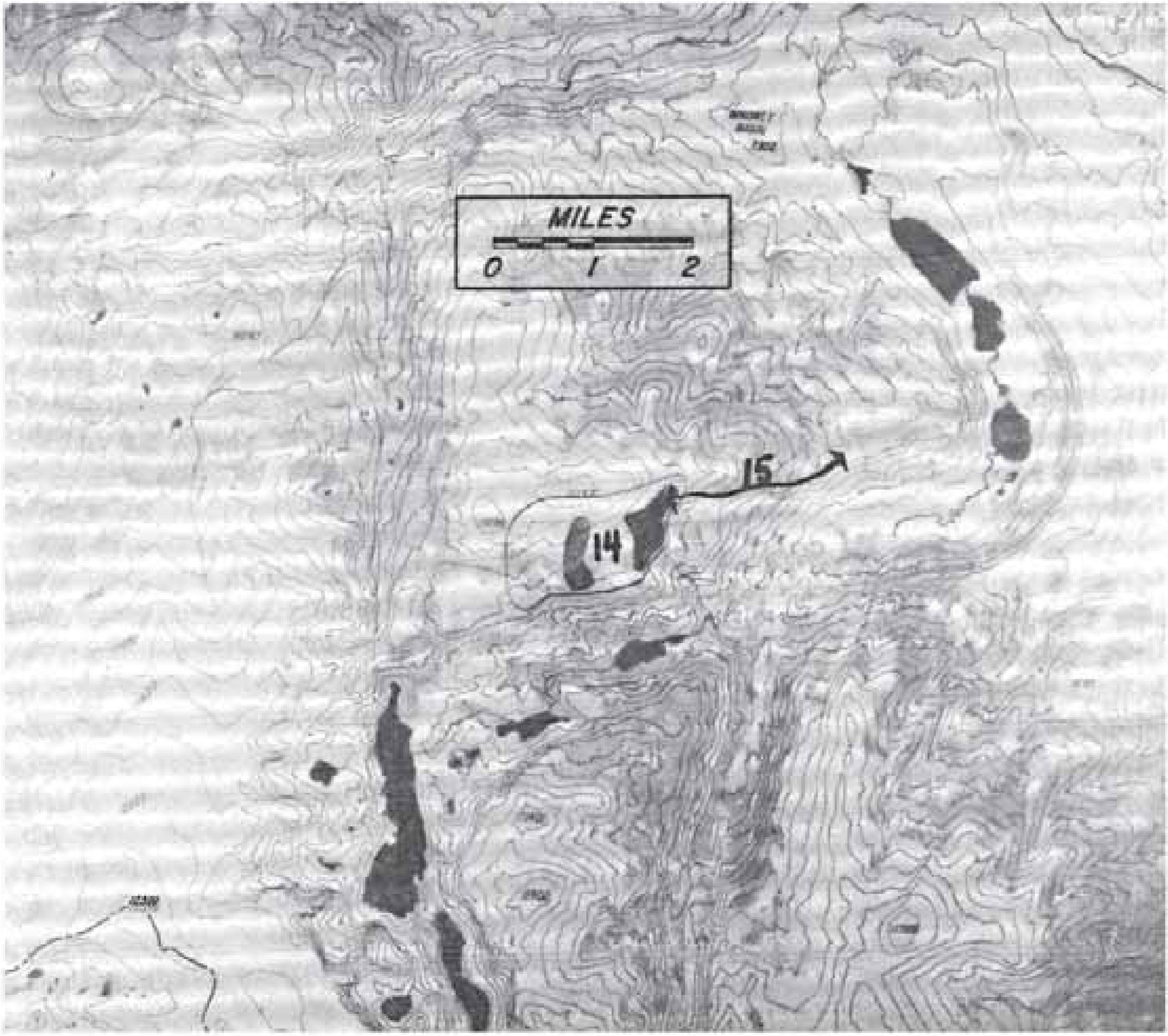

Figure 4. Spring-fall range of Torrey Rim bighorn sheep and migration route to and from the winter range.

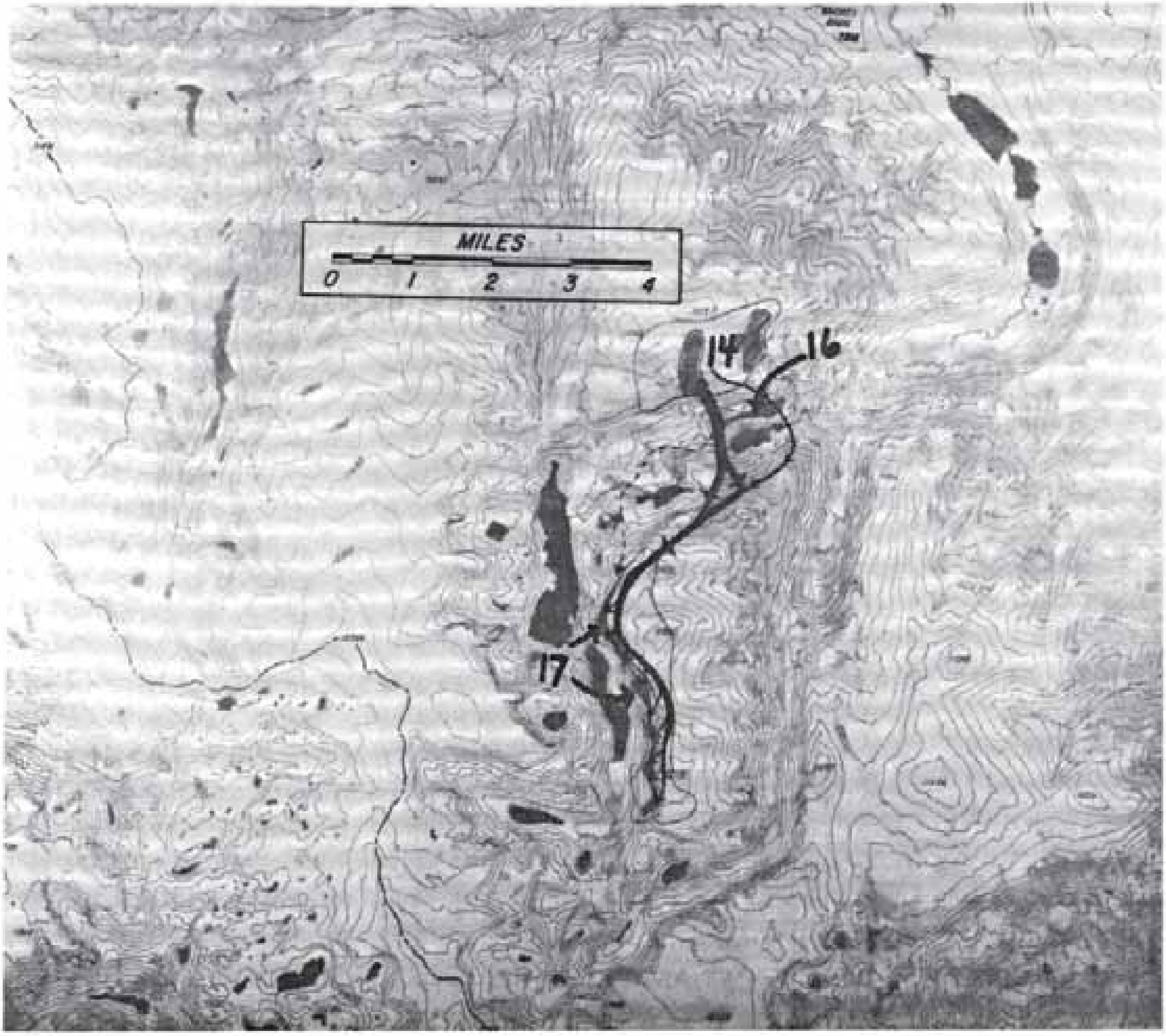

Figure 5. Torrey Rim bighorn sheep lambing grounds and migration routes to and from spring-fall range.

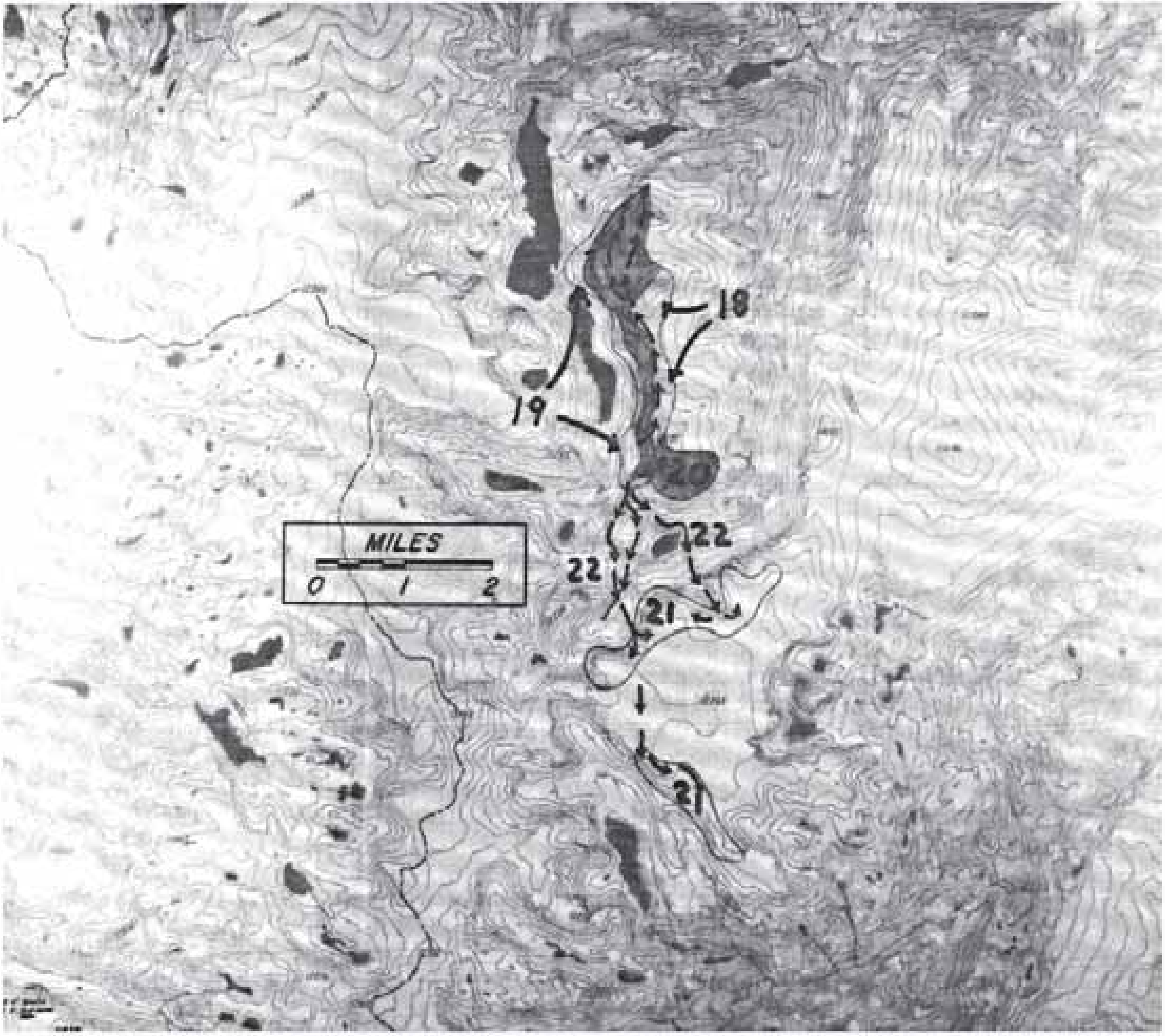

Figure 6. Areas used by Torrey Rim bighorn sheep nursery and barren groups, summer ranges, and migration routes.

sheep, Torrey Rim sheep also scattered into small mobile bands, but they did not travel as extensively because their summer range was much smaller.

During August, and generally earlier than BLM-Sheep Ridge sheep, Torrey Rim sheep began migrating back to spring-fall range (14) on Whiskey Mountain. We felt that utilization by sheep of much of the summer forage may have precipitated the earlier return to spring-fall range. During the year these sheep were observed closely there were two occasions when the majority of the sheep moved down to the Torrey Rim winter range because of periods of inclement weather and moved back up after the storms receded and snow melted. They used the same route (15) for these movements as they did during the spring. These movements were made in a matter of hours and on one occasion the trip from spring-fall range to winter range was made at night. The permanent migration to winter range occurred in late November and was also in response to snow storms which resulted in continuous snow cover at higher elevations.

DISCUSSION

Frequent intermingling of BLM Ridge and Sheep Ridge sheep on both winter and summer range showed these animals to be a single population utilizing two migration routes to the same destinations (Figure 7). Torrey Rim sheep, on the other hand, did not intermingle with the BLM-Sheep Ridge population. During three years of study, only one ewe marked on Torrey Rim was seen to join BLM-Sheep Ridge sheep and then only for one day (September 1976).

Torrey Rim sheep summer in a completely separate area and have different migration routes than the BLM-Sheep Ridge population. This summer time isolation is probably due to steep topographical barriers which effectively separate the two populations. Steep walled gorges (23), partially filled by extensive lakes, prevent the two populations from intermingling during summer. To cross the single readily traversable route between the two summering populations (No Man's Pass (24) and Downs Mountain (25)) would mean traveling for many miles through an area which is almost completely devoid of vegetation (Figure 7).

During winter the two populations are not separated by great distances, lakes or remarkable cliffs. However, to intermingle they would have to pass through extensive stands of

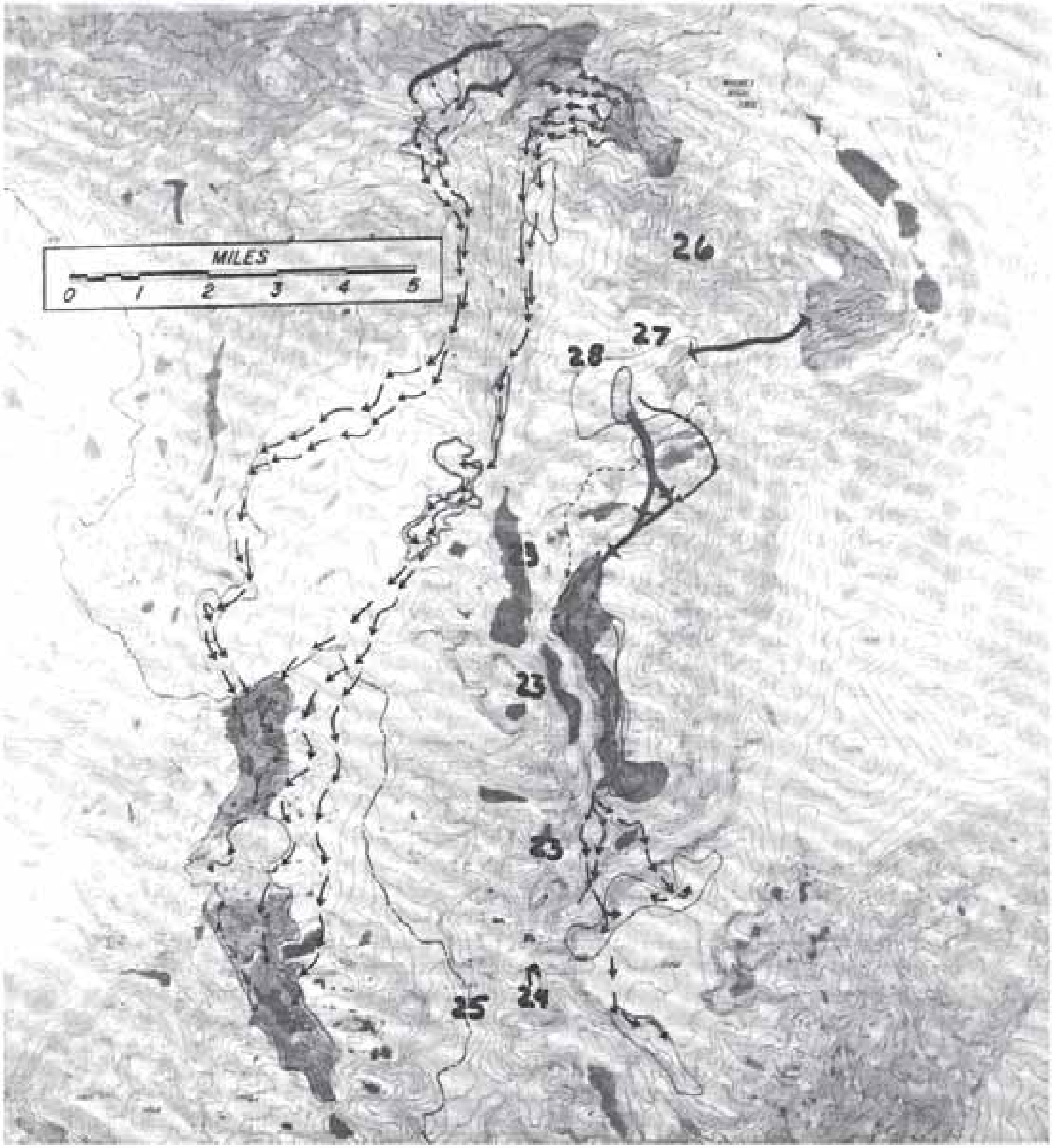

Figure 7. Year round distribution of the BLM-Sheep Ridge and Torrey Rim sheep herds.

timber (26) with their accumulated snow and/or cross extensive open wind-blown slopes (27) far from precipitous escape cover. During the rut, movement of a few rams from one population to another was documented, but no ewes made such movements.

Only on the spring-fall ranges are the two herds not separated by inhospitable terrain or habitat. Here, there is an open easily traversed saddle (28) on the southwest side of Whiskey Mountain where sheep from the two herds could intermingle with no difficulty. In fact, on several occasions during fall, large herds from both populations were observed within less than one-half mile and within visual contact of each other, yet there was no significant interchange.

These two populations seemed reluctant to stray from their own home ranges which agrees with the research conducted by Geist (1971). This trait may keep the two herds isolated from one another and strongly suggests that the two herds should be managed as separate populations.

There was an obvious difference in the size of the total home ranges of the two populations. This was most evident in the summer range of the Torrey Rim herd which was much smaller than that of the BLM Ridge-Sheep Ridge herd. The topography surrounding the migration routes and summer ranges of the Torrey Rim herd was thought to be the main factor limiting their range. Those few sheep which ventured from Middle Mountain to Goat Flat crossed deep precipitous canyons four times enroute to and from their summer range.

The movement of this small number (30-40) of sheep from Middle Mountain eased slightly the utilization of the limited amount of forage on Middle Mountain to the benefit of those which remain. Care should be taken to protect this segment of the herd and their migration route. There are other routes which, although difficult, would allow the Torrey Rim sheep to expand their summer range, but they are reluctant to use them, or, as Geist (1971) has suggested, they are unaware of them.

Our observations on the fidelity of Whiskey Mountain bighorn sheep to migration routes agreed with those of other researchers (Geist 1971, Morgan 1970). The sheep observed used the same migration routes each year while traveling to and from seasonal home ranges. Many of the routes have well worn sheep trails indicating generations of repeated heavy use. Even rocks and tree roots are polished where they have been crossed by sheep. Geist (1971) has stated that sheep learn migration routes and seasonal ranges from their elders.

Although Whiskey Mountain sheep demonstrated a high degree of fidelity to migration routes, they did not demonstrate this high degree of loyalty to certain of the seasonal ranges along the routes, especially lambing and nursery areas. The choice of lambing grounds and associated nursery areas appeared to be more a function of prevailing environmental conditions, such as snow melt and vegetation growth, and not previous years' usage or inheritance. It seemed that the migration routes were of the most importance and any of several lambing grounds along the routes were suitable for use, depending upon year to year circumstances. Lambing and nursery areas which were used extensively during one year were frequently unused the following year.

Lambing grounds and nursery areas were characterized by precipitous terrain as described by Geist (1971). Each migration route passed through several such areas, and areas suitable for lambing were probably an important consideration during establishment of migration routes long ago. Management implications point to the need to recognize the possibility of more than one lambing area existing for each herd of sheep and to protect those areas and their inter-connecting routes.

Spring-fall ranges, as the name suggests, were used twice each year. Because of their double use, these areas seem to be of great importance. They were susceptible to excessive grazing by bighorn sheep and are areas which should be protected from livestock grazing. Although we have no supporting data, it appears that spring-fall ranges may be some of the more important areas in which sheep could come in contact with or acquire parasites. They spend more total time on these ranges when it is warm enough for parasite intermediate stages or their intermediate hosts to be active than on any other ranges. There were some areas on spring-fall ranges which had the physical characteristics of *Protostrongylus* spp. laden snail hotspots as described by Lange (1974).

SUMMARY

The use of radio transmitters and neckbands on large numbers of sheep and almost continual spring, summer, and fall field observations allowed us to better describe and define the distribution of the Whiskey Mountain bighorn sheep population. Many of the concepts of previous investigators regarding seasonal home ranges and migration routes of bighorn sheep were confirmed and knowledge was added to that known about the distribution of the Whiskey Mountain bighorn sheep populations.

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EVOLUTION OF MOUNTAIN SHEEP HORN CURL REGULATIONS IN BRITISH COLUMBIA

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INTRODUCTION

MOUNTAIN SHEEP IN B.C.

Two species including four subspecies of mountain sheep are native to British Columbia: thinhorn (*Ovis dalli*) in the north including Dall sheep (*O.d. dalli* Nelson) and Stone sheep (*O.d. stonei* Allen): and bighorn (*Ovis canadensis*) in the south including Rocky Mountain bighorn (*O.c. canadensis* Shaw) and California bighorn (*O.c. californiana* Douglas). (Cowan and Guiguet, 1965). All four subspecies occur as viable populations and all are hunted annually.

RESULTS AND DISCUSSION

MANAGEMENT OBJECTIVES

British Columbia's Mountain Sheep Management Plan (Draft) developed the basic objectives: to protect and manage mountain sheep for consumptive uses through recreational hunting and non-consumptive uses for the general public (Demarchi, *et al*, 1977). The policy statement reads, "The Fish and Wildlife Branch will maintain the mountain sheep resources (the animals and their habitat) on the principle that their perpetuation is compatible with the management of related wildlife and is of benefit to the people of British Columbia." Management for non-consumptive uses is recognized as an important objective. However, as the purpose here is to examine the various alternatives employed by the B.C. Fish and Wildlife Branch to improve recreational hunting management, this objective will not be discussed.

OBJECTIVES OF MOUNTAIN SHEEP REGULATIONS

Mountain sheep have been managed as basically three distinct groups in B. C.: 1) northern thinhorns (comprising Dalls, Stones and a small native population of Rocky Mountain bighorns in the northern Rockies): 2) southern and central Interior California bighorns (comprising several native populations of California bighorns and two small introduced herds of Rocky Mountain bighorns) and 3) Rocky Mountain bighorns in south eastern B. C.

Beginning with any age rams and an annual bag limit of five, in the early 1900's, mountain sheep regulations have gradually become more restrictive particularly from 1966 to 1976. Basically the regulations take into account: 1) the trophy status afforded mountain sheep by the majority of hunters; 2) the limited supply of mountain sheep in relation to the demand; 3) the biological attributes including: the relatively low rate of recruitment to yearling age and poorer compensating mechanisms (compared to whitetailed deer for example) and the apparent importance of maintaining a relatively normal age-class distribution among males (Geist 1971 and 1975); and 4) the importance that the public places upon the maintenance of viable mountain sheep populations.

MOUNTAIN SHEEP REGULATIONS IN NORTH AMERICA

A generalized summary of mountain sheep regulations in North America is shown in Table 1 (from Trefethern, 1975).

Several management options are available to meet the four conditions listed above as follows:

a) Closed Seasons:

Season closures were imposted on most Rocky Mountain, California and Desert bighorn populations in southern British Columbia and the western American states in the late 1800's or early 1900's. Some attempts were made to restore populations which were depleted by overhunting and/or habitat deterioration but active conservation programs were minimal until at least the mid-1950's. Reopening seasons increased public awareness of the significant problems affecting bighorns and added a consumptive value factor to the hunted populations. Protection from hunting may be necessary or desirable in special instances but is not a viable alternative in most situations because of the loss of interest among the primary conservation agencies and organizations which often follows such closures.

b) Shortened Seasons:

Shortening seasons at either the beginning or the end is a useful method for reducing harvests and has been employed in most southern British Columbia California bighorn and Rocky Mountain bighorn populations. However, while some reduction of hunter effort usually occurs, shortening seasons beyond a certain point tends to concentrate hunters. The adverse effects include: 1) increase competion between hunters which tends to reduce the value of the recreational experience, 2) increased harassment of mountain sheep (Geist, 1975) and 3) a reduction in non-resident revenues to both the guide-outfitter industry and the government.

c) Increased Tag-Licence Fees:

Current big game species tag-licence fees for residents in British Columbia reflect approximately the amount that hunters expressed as their willingness-to-pay for a day's hunting for each species in 1970-71 (see Pearse-Bowden, 1972) while non-resident hunters are charged ten times the resident fee (for mountain sheep the tag licence fees are $25.00 for residents and $250.00 for non-residents). Using licence fees to limit resident hunters does not appear to be a viable alternative given the traditional common property ethic of most North Americans. However, pricing non-residents is another matter which should be given more consideration. Mountain Sheep hunting, including fees and guiding costs for non-residents in countries such as Mexico and Mongolia vary from about $5,000* to $16,000** for example. In British Columbia, the mandatory

* one desert sheep

** one Argali sheep and one ibex.

TABLE 1. Summary of the historical and present mountain sheep regulations in North America to 1973 from: Trefethen (1975)

A. Thinhorns and Rocky Mountain Bighorns

SPECIES & LOCALE	SEASON CLOSED	MALES ONLY	LIMITED ENTRY	1/2 CURL	3/4 CURL	4/5 CURL	7/8 CURL	B.& C. POINTS
THINHORNS								
Alaska	-	1900±	No	-	1950±	-	-	-
B. C.	-	1900±	No*	-	1969	-	1973& 1974a.	-
N.W.T.	-	1900±	No	-	1966	-	-	-
Yukon	-	1900±	No	-	1960s?	-	-	-
ROCKY MOUNTAIN BIGHORN								
Alberta	-	1922	Some	-	1956	1968	-	-
B. C.	-	1900±	No	-	1966	-	1972a.	-
Colorado	1890±	-	Yes	1953	1971	-	1970	-
Idaho	1900±	-	Yes	-	1953	-	-	-
Montana	1912	-	Some	-	1953	-	-	-
New Mex.	1900±	-	Yes	-	1959b.	-	-	-
Oregon	1900±	-	-	-	-	-	-	-
Utah	1899	-	-	-	-	-	-	-
Wash.	1900±	-	-	-	-	-	-	-
Wyoming		-	Yes	1965	1930 1969	-	-	-
S. Dakota	No information							

a. 7/8 curl or 8 years plus
b. 3/4 curl or 144 Boone and Crockett points
* Two thinhorn sheep herds placed under limited entry hunting in 1977

TABLE 1. (continued)

B. California and desert bighorns

SPECIES & LOCALE	SEASON CLOSED	MALES ONLY	LIMITED ENTRY	1/2 CURL	3/4 CURL	4/5 CURL	7/8 CURL	B.&C. POINTS
CALIFORNIA BIGHORNS								
B. C.	1909	-	Some	-	1954	-	1975a.	-
Calif.	1873	-	-	-	-	-	-	-
Idaho	1900±	-	-	-	-	-	-	-
Nevada	1900±	-	-	-	-	-	-	-
N.Dakota	1905	-	*	*	-	-	-	-
Oregon	1900±	-	Yes	1974	1965	-	-	-
Wash.	1900±	-	Yes	-	1966	-	-	-
DESERT BIGHORN								
Arizona	1900±	-	Yes	-	1953b.	-	-	-
Calif.	1873	-	-	-	-	-	-	-
New Mex.	1900±	-	Yes	-	1954c.			
Mexico	?	-	Yes	-	1963?	-	-	1974
Nevada	1917	-	Yes	-	1952	-	-	1965d.
Texas	1903	-	-	-	-	-	-	-
Utah	1900±	-	Yes	-	-	-	-	1967d.

a. 7/8 curl or 8 years plus
b. 3/4 curl and a minimum horn length of 26 inches in 1965 and 28 inches in 1972
c. 3/4 curl or 144 Boone and Crockett points
d. 144 Boone and Crockett points or 7 years plus
* Limited entry season introduced for 1/2 curl rams in 1975

guide requirement is more of a limiting factor to non-residents than is the sheep tag licence fee (most guide outfitters in B. C. charge between $250-$500 per hunter per day for sheep hunting).

d) Limited Entry Hunting:

Limited entry hunting has been imposed on almost all hunted sheep populations in the contigous U. S. and Mexico, on three California bighorn herds in British Columbia, on two herds of Stone Sheep in northern B.C., and on non-trophy sheep for residents and trophy sheep for non-residents in Alberta (Table 1). Limiting licences to a predetermined number provides for both an increased measure of control over the harvest and the reduction or elimination of over-crowded hunting conditions. However, limited entry significantly reduces recreational hunting opportunities. For most but not all of B. C.'s sheep herds, the extraction of rams by hunters can still be effectively controlled by other means such as shortened seasons, non-resident quotas, and more definitive horn-curl regulations.

e) Non-resident Quotas:

Most provinces and states provide non-resident sheep hunting. Nevada and Wyoming set aside 25 and 10 per cent, respectively, of bighorn permits for non-residents for example, while the Yukon, Alaska, and Northwest Territories have unlimited non-resident hunting, like B.C., impose a compulsory guiding restriction.

Competition between resident hunters while increasing in B.C. is apparently not a significant problem as yet because of the ruggedness and/or relative inaccessibility of most late summer-early fall bighorn habitats. (Exceptions to this occur primarily in the less rugged and/or more accessible sheep ranges of the interior of B.C. and accessible areas in northern B.C.) Competition between residents and non-residents, however, is a problem which has increased in significance in recent years. In addition, some guide-outfitters tend to over-exploit the mature ram component. Concern among resident hunters is expressed in a variety of ways but the most commonly suggested solution made by resident hunters is to eliminate or severely limit non-resident hunting. Considering the international interest in mountain sheep, the opportunities of British Columbians to hunt in other countries, including the U.S., the international exchange of research and management information (which flows mostly from the U.S. to Canada), the revenue from non-resident hunters which benefits all British Columbians and the dependence of the guiding industry on non-resident sheep hunters, total exclusion on non-residents is not a desirable alternative. In 1976 guide-outfitter quotas were established in the East Kootenay on Rocky Mountain bighorn. Individual area quotas were based on the population estimates of mountain sheep in each guide-outfitter territory and the degree of use by resident hunters. In this manner, resident-non-resident competition was reduced and overexploitation of sheep by a minority of opportunistic guide-outfitters was eliminated while maintaining non-resident hunting. The institution of non-resident quotas has been expanded to other regions and now includes grizzly bear and mountain goat as well as mountain sheep in the Kootenay Region.

Reduced numbers of non-resident big game hunters need not result in a concomitant reduction in revenues to either the government or the guide-outfitter, providing that the licence fees and guiding fees are increased to more closely reflect market values. To date, only the guide-outfitter sector has attempted to capitalize on the increased demand and decreased supply in British Columbia as licence fees for non-residents have remained unchanged since 1974, while guiding fees have more than doubled since 1975.

f) Horn Curl/Age Restrictions:

According to Cowan (1940) and Clark (1964) male mountain sheep possess three basic horn forms - convergent (tight curl); parallel (medium or average curl); and divergent (open or flaring curl). The three basic horn curl forms are shown in Figure 1.

Although the various subspecies may possess uniform horn shapes, considerable variability often exists both between and within herds of the same subspecies. Furthermore, horn size, if not shape, is often influenced by habitat influences such as fire, overgrazing, overpopulation, etc. (Shackleton, 1973). The difficulty encountered in attempting to standardize horn characteristics for purposes of defining a legal ram is compounded in British Columbia by the presence of four subspecies covering a greater physiographic range than any other area in North America.

Mountain Sheep have been managed under a variety of horn curl restrictions throughout North America (Table 1). As an historical note, the first horn curl restriction appears to have been instituted as a three-quarter curl law in Wyoming in the early 1930's (Trefethen, 1975). Since then, many attempts have been made to devise systems of enabling hunters to identify specific age/horn class rams in the field by employing horn curl, varying from one-half to full curl, establishing minimum horn lengths, setting minimum ages of rams, and establishing minimum total points according to the Boone and Crockett horn scoring system. Within reasonable limits, horn curl restrictions have proven to be a valuable tool in Mountain sheep management.

HORN CURL/AGE RESTRICTIONS IN BRITISH COLUMBIA: 1956 - 1975.

In the early 1900's, B.C.'s mountain sheep were managed under an Any Age Ram Regulation with a bag limit of five. The bag limit was gradually reduced to one, and beginning in 1954 several California bighorn herds which were closed to hunting were reopened under a three-quarter horn curl regulation. Rocky Mountain bighorn herds were placed under the three-quarter curl restriction in 1966 and the thinhorn herds were added in 1969. Figure 2 depicts the diagram used between 1954 and 1971 in B.C. The definition in the hunting regulations read as follows:

3/4 - CURL HORN means the horn of a mature mountain sheep, the tip of which has grown through 270 degrees of the circle described by the outer surface of the horn, as seen from the side.

With increasing demands for more stringent sheep hunting regulations from resident sheep hunters and guide-outfitters, the Fish and Wildlife

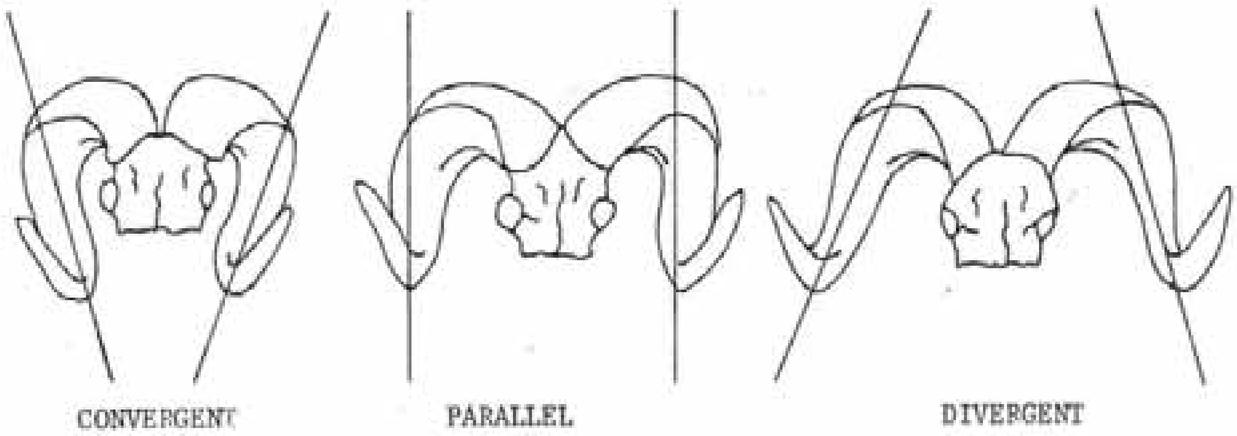


FIGURE 1. The basic forms of mountain sheep horns after Clark (1964).

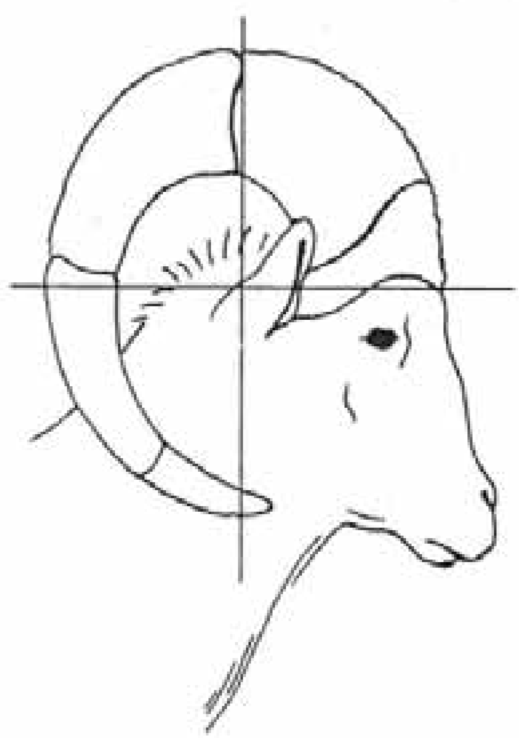


FIGURE 2. Diagram used in B.C. Hunting Regulations Synopses to depict a legal three-quarter curl ram from 1954 to 1971.

Branch attempted to increase the minimum legal horn curl by devising a seven-eighths curl for Rocky Mountain bighorns in 1972 (Figure 3). The definition involved three separate lines plus a circle, but did not accurately define a focal point. A minimum age was added to the definition for the first time in the province:

MATURE RAM is a male mountain sheep which has attained the age of eight years as determined by the horn growth (annuli): Or whose longest horn has grown through a minimum of 7/8 of a circle (315 degrees) described by the outer surface of the horn as seen from the side and including any broomed portion.

The province's remaining mountain sheep populations were progressively placed under the new regulation until 1975, when all mountain sheep, including California bighorns, came under the seven-eighths curl restriction. Although the diagram was improved somewhat (Figure 4), the complex definition was retained. In 1975, with the initiation of compulsory reporting of hunter-killed rams and after four hunting seasons under seven-eighths curl restrictions, 11 charges were laid for undersized rams in the East Kootenays out of a total of 23 Rocky Mountain bighorn rams inspected.

The B.C. Provincial Court decided the regulation was ambiguous in that it did not define a focal point (B.C. Provincial Court Judge H. Swayze in: Regina Vs. Ray Larson, 1975). The issue was sensationalized in the local press and resulted in considerable public controversy.

REDEFINING THE MATURE RAM REGULATION

Following the Provincial Court's criticism of the seven-eighths curl regulation, the Fish and Wildlife Branch established a committee to develop and test an improved mature ram regulation comprised of:

Odd W. AASLAND, Taxidermist
Dennis A. DEMARCHI, Wildlife Biologist
Raymond A. DEMARCHI, Wildlife Biologist
Cecil G. ELLIS, Animal Control Officer
Ross R. FARQUHARSON, Conservation Officer
David J. LUNN, District Judge
William J. WARKENTIN, Wildlife Techician

Diagrams and/or written descriptions were developed for the following: three-quarter, four-fifths, seven-eighths, and full curl rams. A series of scale line diagrams of male sheep heads were prepared by Dr. Val Geist. The diagrams and definitions thus developed were tested on mountain sheep museum specimens, color transparencies, and in the field. In addition, numerous sheep hunters were questioned as to their understanding of the various descriptions of ram horns in common use (i.e., half curl, three-quarter curl, four-fifths and full curl).

Ideally, the regulation would be one which could be easily understood, was readily applicable in the field, was enforceable, and which restricted the kill to the mature ram component. No regulation then in effect in North America adequately covered the wide range of horn forms

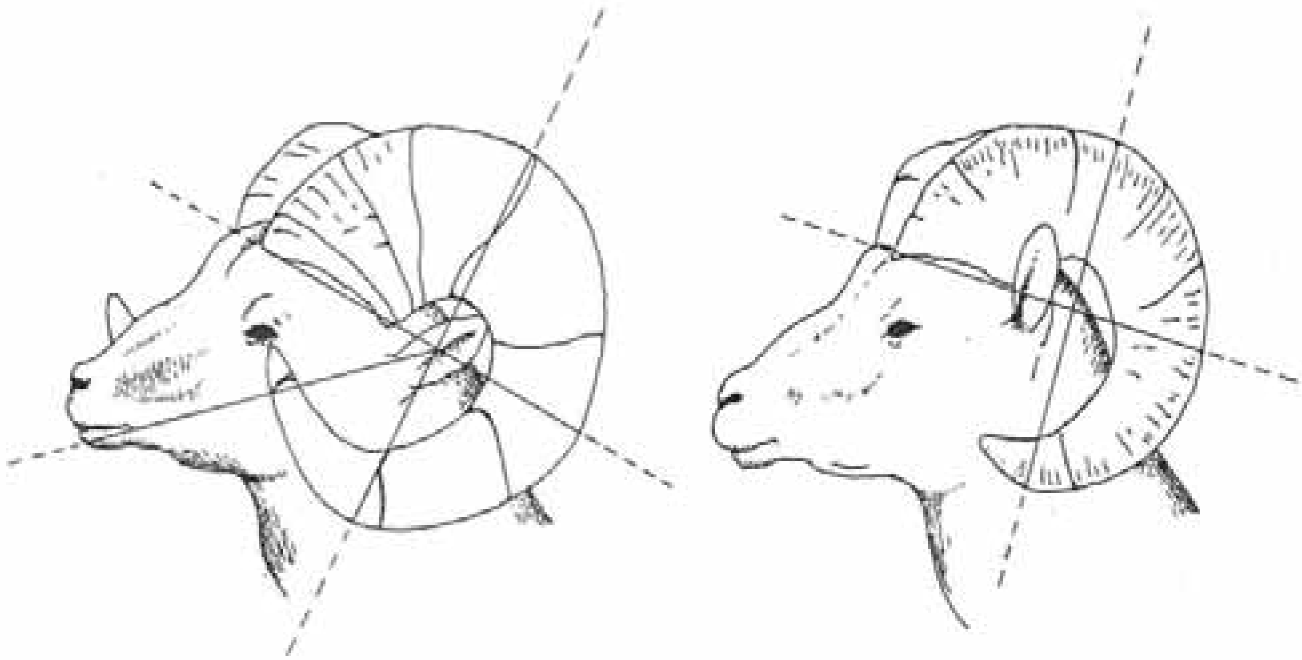


FIGURE 3. Diagram used in B.C. Hunting Regulations Synopses to depict a legal seven-eighths curl ram from 1972 to 1974.

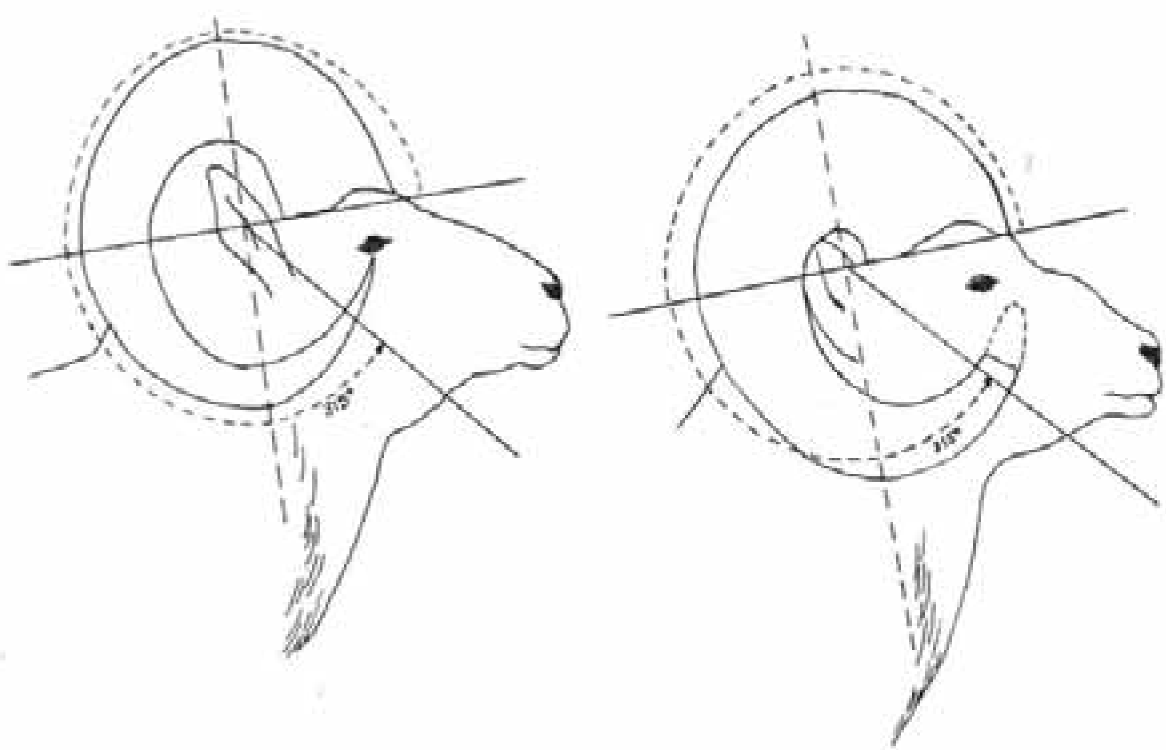


FIGURE 4. Diagram used in B.C. Hunting Regulations Synopses in 1975 to depict a legal seven-eighths curl ram.

found in the province with the possible exception of the Boone and Crockett trophy point system. However, the regulation requires considerable hunter education and training and is perhaps best applied in strictly controlled limited entry hunts.

A relatively simple system, involving a base line between two relatively distant descernible points, the nostril and the lowest hindmost portion of the horn, can be applied in the field to describe a "full curl" horn.* As the ventral posteriormost portion of the horn base, the eye socket and the nostril can be disected by a straight line and, as the nostril is often removed from a hunter-killed ram, the legal definition need only refer to a straight line drawn through the eye socket and ventral posteriormost portion of the horn base. By describing a line drawn through the ventral anteriormost portion of the eye socket remaining with the skull, and the ventral posteriormost portion of the horn base, the legal definition is slightly less stringent than the field definition, thus allowing the hunter a margin of error.

CONCLUSIONS

The improved 3/4 curl regulation was applied to most California bighorn herds while all Rocky Mountain bighorn, Stone, and Dall sheep herds were managed under the new Full Curl Regulation beginning in 1976.

The field definitions read as follows:

3/4 CURL RAM is any male Mountain Sheep which has attained the age of six years as determined by the horn annuli or whose horn tip, when viewed from the side, extends beyond a straight line drawn through the center of the eye and at right angles through a line drawn between the center of the nostril and the lowest hindmost portion of the base of the horn.

FULL CURL RAM is any male Mountain Sheep which has attained the age of six years as determined by the horn annuli or whose horn tip extends upwards beyond a straight line drawn between the center of the nostril and the lowest hindmost portion of the base of the horn.

LEGAL RAMS cannot be identified unless viewed from the side. These field definitions adequately conform to legal definitions, copies of which are available at Fish & Wildlife Branch and Government offices.

The legal definitions read:

FULL CURL RAM means any ram (male) Mountain Sheep which has attained the age of six (6) years as determined by horn annuli, or whose horn tip, when viewed from the side parallel to the horizontal plane

* The addition of a right angle extending below the baseline and passing through the eye provides a definition of a 3/4 curl horn.

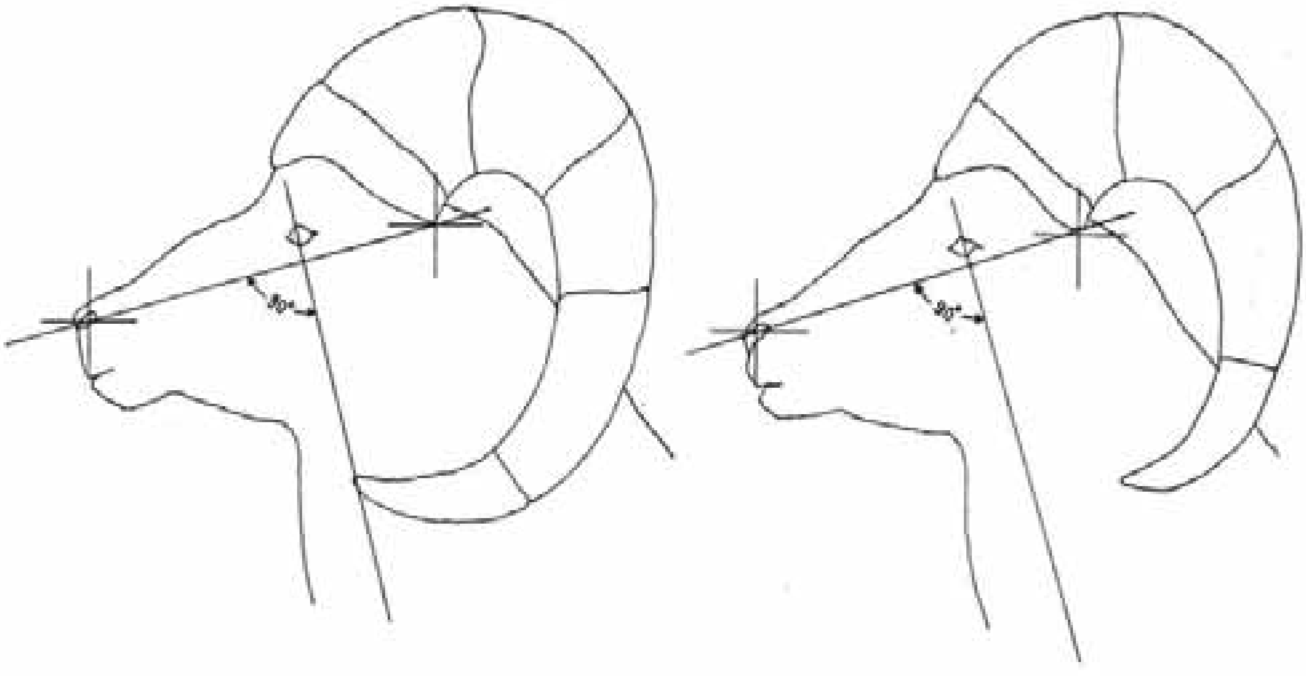
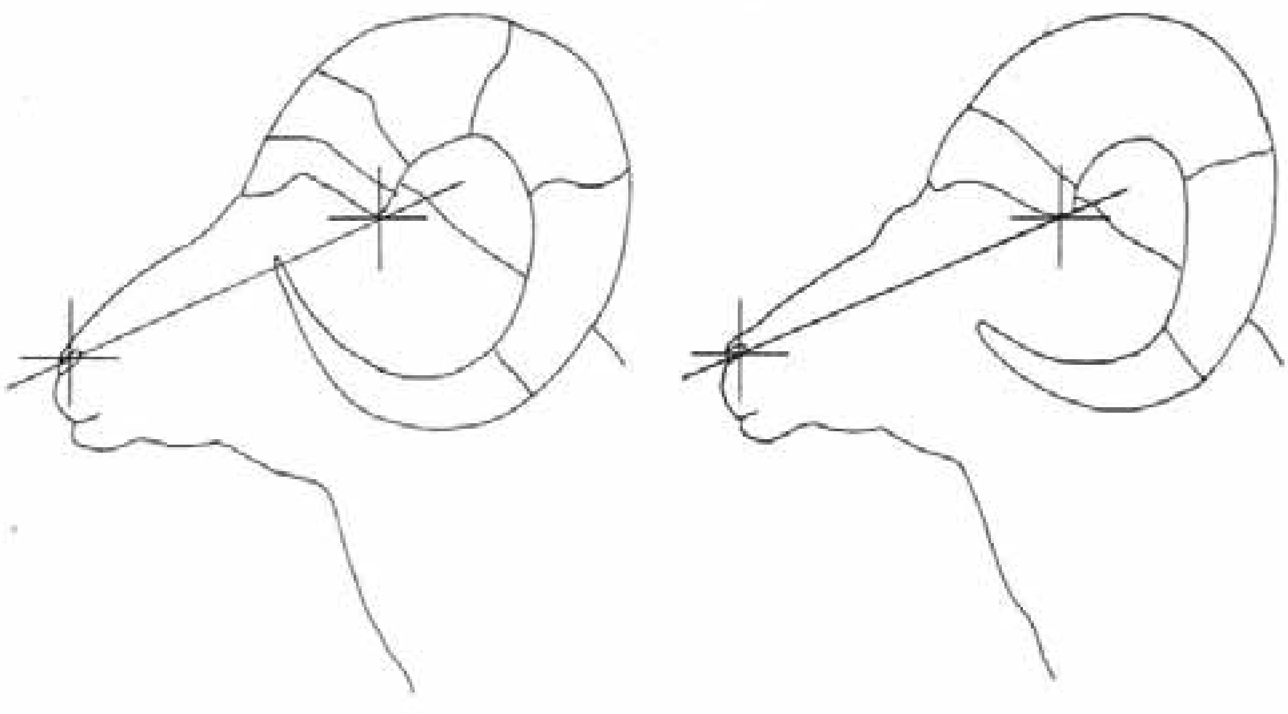


Figure 5. Diagram used in B.C. Hunting Regulations Synopses in 1976 and 1977 to depict three-quarter curl and full curl mountain sheep.



and at right angles to the sagittal plane of the skull, extends upwards beyond a straight line drawn between the ventralmost portion of the eye-socket retained with the skull and the ventral posteriormost portion of the base of the horn.

THREE QUARTER (3/4) CURL RAM means any ram (male) Mountain Sheep which has attained the age of six (6) years as determined by horn annuli, or whose horn tip, when viewed from the side parallel to the horizontal plane, and at right angles to the sagittal plane of the skull, extends beyond a straight line drawn vertically from the ventral anteriormost portion of the eye-socket remaining with the skull and which is at right angles to a line drawn between the ventral anteriormost portion of the eye-socket remaining with the skull and the ventral posteriormost portion of the base of the horn.

(a) The SAGITTAL PLANE is the surface by which the skull is divided equally into left and right sides;
(b) The HORIZONTAL PLANE is the surface intersecting the ventral posteriormost portion of the base of the left and right horns, the ventral portion of the left and right eye-sockets retained with the skull and which is at right angles to the sagittal plane:
(c) PLANE is a surface such that the straight line that joins any two if its points lies wholly in that surface.

The "improved" 3/4 curl regulation and the "new" full curl regulation have proven to be considerably more applicable in the field and enforceable in the courtroom than other previous regulations employed in British Columbia. The number of undersized Rocky Mountain bighorn rams taken in 1976 and 1977 was significantly reduced over previous years, particularly 1975, and convictions were readily obtained for the two rams which did not meet the minimum curl/age restriction. Because thinhorn sheep horns usually form a circle when viewed broadside at a younger age than bighorn sheep, and because the change in the age class distribution of the thinhorn ram kill did not meet expectations after the institution of the full curl regulation in 1976, the minimum age for a full curl thinhorn ram was raised from six to eight years in 1977.

The improved (1976) horn curl regulations have received general acceptance from sheep hunters, guide-outfitters, enforcement officers, and staff of the provincial courts. Although it is too soon to determine the effect on the sheep populations and the harvest, it appears, from the results of the 1976 and 1977 seasons, that an improvement is to be expected in both the sheep populations (viz. improved ram age class distributions and sex ratios) and the kill (viz. increased horn quality without a significant decline in the number of mature rams harvested) without sacrificing recreational hunting and commercial guiding opportunities.

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ALTERNATE YEAR REPRODUCTION IN A LOW QUALITY, DECLINING DALL SHEEP POPULATION: MANAGEMENT CONSIDERATIONS

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INTRODUCTION

Alaska Department of Fish and Game research efforts in the Dry Creek area of the eastern Alaska Range (Heimer 1973) required marking individaul Dall sheep. These studies resulted in close monitoring of herd numbers, initial lamb production by individual ewes, and survival of lambs to yearling age. Reproductive frequency of marked individual ewes was also observable. This paper reports on the reproductive interval of ewes in the Dry Creek study area in the early 1970's while the population was in a slow but steady decline, and discusses some theoretical aspects of alternate year reproduction in Dall sheep.

MATERIALS AND METHODS

Dall sheep were trapped as reported by Erickson (1970) and marked with permanent collars (Heimer 1973). Subsequently, marked ewes were observed each year as they utilized the main mineral lick on Dry Creek. Observation schedules varied from year to year (Heimer 1976), and population estimates were based on the return frequency of collared sheep at mineral licks (Heimer 1973). Population size was also estimated in 1970 and 1975 from aerial censuses (Heimer 1976) once movements were known. During periods of mineral lick observation, all collared ewes were carefully observed to determine whether they were leading a lamb. The criterion for defining a ewe with a lamb was the observation of suckling. This criterion is admittedly strict, but was necessary because some observers were unable to accurately recognize a ewe-lamb pair on the basis of behavioral displays and contact patterns. In all years except 1975, the number of collared ewes with lambs determined, using this restrictive criterion, was in substantial agreement with that determined by traditional composition counts at the mineral lick. Data gathered since 1975 were valid only for ewes definitely confirmed to have a lamb in 1975. Also, the mean lamb:ewe ratio of 33 lambs:100 ewes among the marked ewes from 1972 through 1974 corresponds exactly to the mean lamb:ewe ratio observed for the total population for those years from Table 1. Hence, use of this strict criterion did not underestimate lamb production.

RESULTS

Lamb:ewe ratios, survival of lambs through the first winter, and total numbers of sheep using the Dry Creek mineral lick suggest that sheep populations in the Dry Creek study area were declining through 1975 (Table 1). The total population estimates of 1970 and 1975 are

Table 1. Productivity, survival and estimated number of Dall sheep influenced by the Dry Creek mineral lick from 1970 through 1975.

Year	Lambs per 100 ewes	Yearlings per 100 ewes	% of lambs surviving 1st winter	Estimated population
1968*	63	13	--	--
1969*	64	31	49	--
1970*	55	31	48	1500
1971*	50	51	93	--
1972	15	16	32	1473
1973	38	11	73	1315
1974	28	25	66	1270
1975	28	23	82	1150
1976	36	16	57	1240
1977	58	17	47	1400

*Data gathered at mineral lick using observation schedules not described in procedures (see Heimer 1975).

based on aerial censuses; data for 1972-1975 are based on mineral lick use. The magnitude of this decline has totaled about 20 per cent since 1970, although some populations within the study area have declined more than others.

All instances of successive annual sightings of individual ewes with known reproductive history, where the presence or absence of a lamb could be definitely determined, are summarized in Table 2. In only seven per cent of the paired observations were ewes seen to lead a lamb in two successive summers. In 53 per cent of the observations, ewes were seen to lead a lamb only in alternate summers, and in 40 per cent of the observations, ewes were observed not leading lambs in two successive years.

Throughout the period of population decline, predator densities were high in the study area. Wolf (Canis lupus) densities in the Game Management Unit 20A are known to have been high (1 wolf per 30 square miles) and prey densities were relatively low for Alaska (45 ungulates per wolf; at least half of these ungulates were sheep) (Stephenson 1978). Wolves were reduced by aerial shooting and trapping during 1976 and 1977 to a density of 1 wolf/100 mi^2 causing a relative prey density increase to 130 ungulates/wolf.

DISCUSSION

Two possible causes for the observed decline may be insufficient production to compensate for "normal" mortality or unusually high mortality. The latter possibility might result from predator pressure. Murie (1944) concluded that wolves mainly utilized the old or weak (diseased or young) classes of Dall sheep in McKinley Park. This conclusion was based on the assumption that sheep with skulls having evidence of lump jaw were diseased and consequently weak. Murie's conclusion that wolf predation is concentrated on diseased sheep may be spurious. The frequency of lump jaw in Dry Creek sheep has been higher (N=35) in living sheep than in Murie's death assemblage (Nielsen and Neiland 1974) and survival of lambs through their first winter has been high (Table 1). Hence, a more correct interpretation of Murie's death assemblage data may be that the "diseased" and young sheep were represented as they occurred in the population. The influence of wolves as a factor in the decline of these sheep populations is probably directed at adults as well as lambs.

Predators were abundant in the area during the recent past, but removal of 40 wolves from the study area by trapping and aerial shooting left a minimum of 10 wolves in the area as of spring 1977 (Buchholtz, pers.comm.). Evidence of Dall sheep was seen in the stomach of only one wolf killed in the area. Primary prey species for these wolves are moose (Alces alces) and caribou (Rangifer tarandus).

Although predators have certainly contributed to the decline, evidence indicates that the decline is due primarily to lamb production below that necessary to compensate for "normal" adult mortality. During the population decline, 15 adult ewes were collected after the rut when a fetus would be visible (Heimer 1973). Of these 15 ewes, 7 were pregnant. Of the eight nonpregnant ewes, six were lactating strongly and two showed evidence of having resorbed a fetus. The low pregnancy rate in this admittedly small sample of ewes, frequent observations of 10-month-old lambs nursing in April, chronically low initial production, and observations of yearlings nursing at the mineral lick, indicate that the lowered rate of re-production and prolonged lactation may be adaptations favouring enhanced survival of lambs through their first winter.

The low percentage of ewes reproducing in successive years (7%), the low pregnancy rate (in our small collection), and the high incidence of extended lactation by nonpregnant ewes in this same sample, raise the possibility that when a ewe leads lambs in two successive years, early summer mortality may have occurred during the first year. Certainly, annual production of lambs in Dry Creek is the exception rather than the rule, and the most common pattern is biennial reproduction. That is, a lamb is born in June, the ewe does not breed during the rut of the following December or she may breed and then resorb the fetus, the lamb is weaned at about one year of age, and the ewe regains her decreased energy reserves before breeding again in December. The mean reproductive interval in the paired observations (Table 2) calculates to be one lamb every 4 years (65 lambs per 260 ewe-years or 0.25 lambs per ewe year). If this were indeed the average reproductive rate, the maximum number of lambs would be 25 per 100 ewes. This figure is, of course, unreasonably low since the observed mean is about 30 lambs per 100 ewes. It is obvious, then, that some ewes do produce lambs annually. Any ewe which did not participate in extended lactation could probably produce a lamb each year.

Table 2. Successive annual resightings of 69 collared ewes with and without lambs in subsequent years at the Dry Creek mineral lick.

Total successive sightings	Total with-with	Total with-without	Total without-with	Total without-without
98	7 (7%)	28 (28%)	25 (26%)	39(40%)
		52(53%)		

98 total observation pairs
69 ewes

Some theoretical calculations may be based on this alternate year reproductive strategy. The average initial production, observed over the last 6 years in Dry Creek, has been about 30 lambs per 100 ewes. Hence, the percentage of ewes presumed capable of reproduction in December (those without a lamb in summer) was 70 per cent. If all of these animals breed and produce a lamb, and the observable production is 30 lambs: 100 ewes, mean mortality associated with parturition or shortly thereafter was 57 per cent. (100 minus 30% with observable lambs + 70% giving birth). This is the maximum possible parturition-associated mortality, since it assumes that all breeding ewes will carry their lambs to delivery. However, severe winters, as well as other factors, probably result in some _in utero_ mortality.

In the small sample of collected ewes, fetal death occurred in 2 of 8, or in 25 per cent, of the ewes taken near term. If this figure is incorporated into the above calculation, 70 per cent of the ewes breed each year, minus 25 per cent of this number or 45 per cent of the ewes carry lambs to term. This calculates to a parturition-associated mortality of 33 per cent.

Throughout the last six years, harsh weather conditions were recorded during the lambing seasons of 1972, 1973, 1974 and 1975. Here harsh weather is defined as a 24 to 36-hour period of snow, freezing rain, rain accompanied by wind, or subfreezing temperatures. The effects of this weather on parturition mortality are unknown for Dall sheep, but are highly significant in domestic sheep neonate death (Watson _et al._, 1968). In winters of 1975-76 and 1976-77, snow was minimal, temperatures were generally mild, and no adverse weather was measured during the lambing seasons. Still, the production was well below the theoretical maximum of 72 lambs per 100 ewes in 1976 (100%-28% lambs in 1975) and 64 lambs per 100 ewes for 1977. One case of fetal resorption was documented from five ewes collected in late May, 1976. If fetal death in winter of 1975-76 is assumed to have been 38 per cent (given 28% with countable lambs in 1975 or 72% of the ewes capable of breeding; 20% fetal death; 36% of the ewes seen with lambs in 1976). Using the same assumptions for 1977, the calculation is: 64 per cent capable of breeding (100 - 1976 production) minus 13 per cent (.20 x 64) for fetal death, or 51 per cent giving birth. Production in 1977 was 58 lambs per 100 ewes, so fetal death must have been reduced, parturition-associated mortality nil,or there was consecutive year breeding by a significant proportion of ewes. Observations in 1977 indicated no increase in reproductive frequency. Hoefs (1975) observed mortalities of 15 and 20 per cent in 1971 and 1972 under favorable conditions in Kluane Park, Yukon. Pitzman (1970) documented no early neonate mortality in births observed on Alaska's Kenai Peninsula.

Consequently, lambing mortality, associated with parturition when unfavorable weather conditons occur, may range between 40 or 60 per cent. Under favorable weather conditons, it may range from 0 per cent to 40 per cent.

In summary, data indicate that rates of initial lamb production in the Dry Creek populations may be sacrificed as an adaptation favoring enhanced survival of lambs. This is accomplished by extended lactation which leads to reproduction in alternate years. Weather probably influences initial production by affecting _in utero_ and neonate mortality.

The decline in numbers of sheep in Dry Creek is thought to be due to relatively low reproductive rates, rather than high yearling and adult mortality. Parasitic fauna and burdens have been described (Neilsen and Neiland 1974), but their actual effects on condition and reproduction of Dall sheep are unknown.

Reasons for low, alternate year reproduction and the decline of Dry Creek sheep populations are unclear. One suspected cause is lack of sufficient energy availability in winter. Comparative studies of rumen fermentation (unpubl. data), high sheep population densities, slow horn growth rates for rams, small body size of ewes, and subjective determinations of range utilization made in numerous field trips, suggest that range conditions are relatively poor. Further work will be needed to test this hypothesis.

Recognition of alternate year breeding in these low-quality populations, resulting from a seeming energy insufficiency, immediately suggests that a profitable management strategy may be herd reduction. To evaluate the possible benefits of herd reduction on initial lamb production, a review of the responses of Dall sheep populations, which have been reduced, is in order. Nichols (1976) has seen an increase in initial production (lambs:100 ewes) following population reductions by ewe hunting on Crescent Mountain, Kenai peninsula, Alaska. Data relating subsequent initial production (lambs:100 ewes) to population reductions are also available from natural population fluctuations on Cooper Landing and Surprise Mountain (Nichols 1976), Kluane Park, Yukon (Hoefs 1975), and Dry Creek, Alaska (Table 1). These data are presented in Table 3. The population trends in Table 3 represent year-to-year changes in competing adults (ewes and yearlings) on the winter range during gestation. For purposes of this analysis, rams were excluded from the calculation as suggested by Geist and Petocz (1977). The maximum observed population of ewes and yearlings was taken as 100 per cent, and reductions were expressed as a per cent of this maximum figure. A winter-severity index was derived by multiplying snow depth by hardness from Nichols (1976) for the Kenai and using recorded snowfall in Fairbanks as an index of severity in Dry Creek. Winters having severity indices greater than the mean for the years sampled were arbitrarily classed as "harsh". Winters when the severity index was less than the mean were termed "mild".

Analysis of data in Table 3 shows that two trends are evident. First, when winters are harsh, populations of competing adults on winter range are reduced, and this is followed by low initial production the following spring. Second, when winters are mild, the number of competing adults is increased, and this is followed by increased initial production the following spring. These two situations account for 14 of the 21 data years available. The mean increase in competing adults, following mild winters, has been 10 per cent, and the mean decrease in competing adults, due to harsh winters, has been 16 per cent.

In the remaining seven data years, for which winter sevrity can be assigned, the winters were classified as mild.

Table 3. Trends and percent reduction of competing "adults" (ewes and yearlings) on winter ranges during gestation and initial relative production of lambs the following spring.

	Ewe and yearling population trend (%)	Production trend (%)	Winter severity
Kluane			
1970-71	(+6%)	(+27%)	
1971-72	(+1%)	(-11%)	
1972-73	(-2%)	(-28%)	
Cooper			
1970-71	(+5%)	(+39%)	
1971-72	(-10%)	(+18%)	harsh
1972-73	(+15%)	(+11%)	mild
1973-74	(+8%)	(-46%)	mild
1974-75	(-3%)	(-15%)	harsh
1975-76	(-5%)	(+48%)	mild
1976-77	(-7%)	(-65%)	harsh
Crescent			
1970-71	(-29%)	(-35%)	
1971-72	(-4%)	(+70%)	mild
1972-73	(+16%)	(+29%)	mild
1973-74	(-8%)	(+7%)	mild
1974-75	(-27%)	(-19%)	harsh
1975-76	(-9%)	(+46%)	mild
1976-77	(-15%)	(-57%)	harsh
Surprise			
1970-71	(-12%)	(+29%)	
1971-72	(+2%)	(+111%)	mild
1972-73	(+8%)	(+3%)	mild
1973-74	(-7%)	(-31%)	harsh
1974-75	(-14%)	(-37%)	harsh
1975-76	(-15%)	(+171%)	mild
1976-77	(-26%)	(-100%)	harsh
Dry Creek			
1973-74	(-3%)	(-26%)	mild
1974-75	(-8%)	(0%)	harsh
1975-76	(+12%)	(+29%)	mild
1976-77	(+5%)	(+61%)	mild

In six of these years, populations of competing adults declined by a mean of 8.5 per cent. One of these declines was attributable to hunting, and had a magnitude of 8 per cent. The remaining 5 years range in population reduction from 4 per cent to 15 per cent. It is possible that changes in this range, from one aerial survey to the next, are inherent error in the technique, particularly when no general trend is evident. It should also be noted that these declines also coincide with generally increased wolf abundance on the Kenai.

Whatever the causes, the apparent beneficial effects of ewe hunting on initial production of lambs the following spring can be plausibly rationalized in terms of the effects of weather; i.e., following the ewe hunt, a mild winter occurred which was subsequently followed by increased initial production (lambs:100 ewes). This predictably results in an increased lamb production because of decreases in fetal and adult death; hence, the observed result is explainable as a phenomenon of weather rather than hunting-stimulated reproduction.

If weather effects are neglected, it is possible, through the use of statistical correlation coefficient, to test the relationship predicted by the hypotheses that reduction of animals on the range stimulates initial production. The hypotheses predicts that a plot of initial production, as a function of the per cent of maximum observed competing adults, should give a line having negative slope and a high value for the correlation coefficeint. Figure 1 shows this plot. It can be seen that there is no significant correlation between the two variables, and the sign of the coefficent is opposite to that predicted by the hypotheses. Consequently, ignoring the possible effects of weather appears to force the conclusion that many population reductions, of the magnitude practiced on Dall sheep by man and nature in Alaska, have not resulted in increased initial production. Hence, population reductions, even in populations judged to be near carrying capacity, have had no beneficial effects on relative initial production (increased lamb ; ewe ratios), when the reductions have been as high as 25-30 per cent.

As the magnitude of population reduction, necessary to evoke an increase in relative production (improved lamb : ewe ratio), approaches 50 per cent in populations where alternate year reproduction occurs, the possibility of beneficial effects of this management tool diminish. It may be impossible to evoke a doubling in reproductive frequency, with a 50 per cent reduction in the number of ewes. If so, the levels of absolute production will never be as great as they were before the herd control was begun, even through increases in relative production (lamb : ewe ratio)might occur.

Figure 2 shows the increases in realtive production, which would be required to meet an absolute production of 30 lambs by a population of 100 ewes initially having a relative production of 30 lambs : 100 ewes, if the population were reduced. This example demonstrates that a reduction of 50 per cent would have to elicit a relative production of 60 lambs per 100 ewes to meet the initial level of absolute production. Individual lamb productions of this magnitude have been observed in

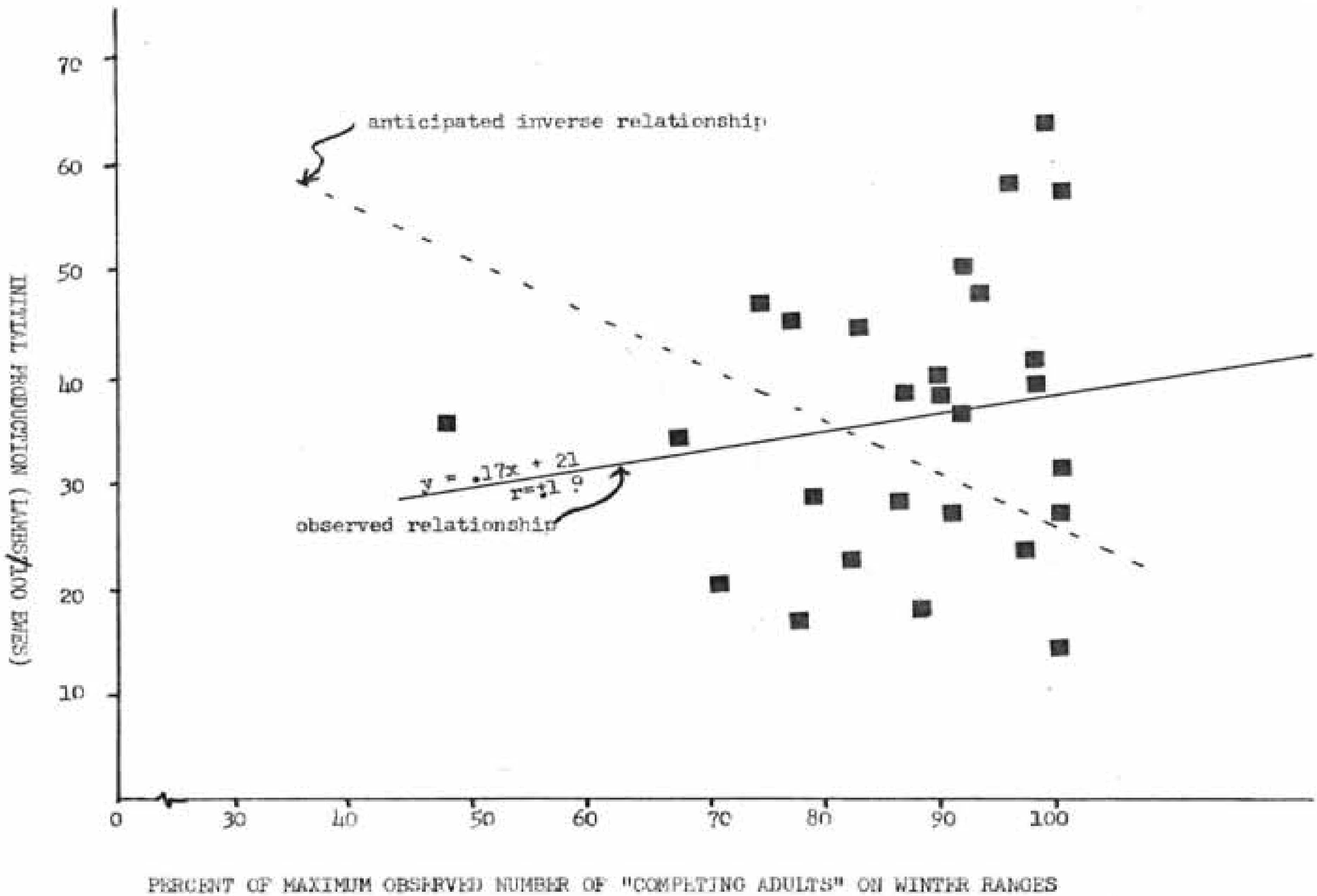

Figure 1. Relationship of percent of "competing adult" reduction and relative initial production of lambs in the following spring.for Dall sheep.

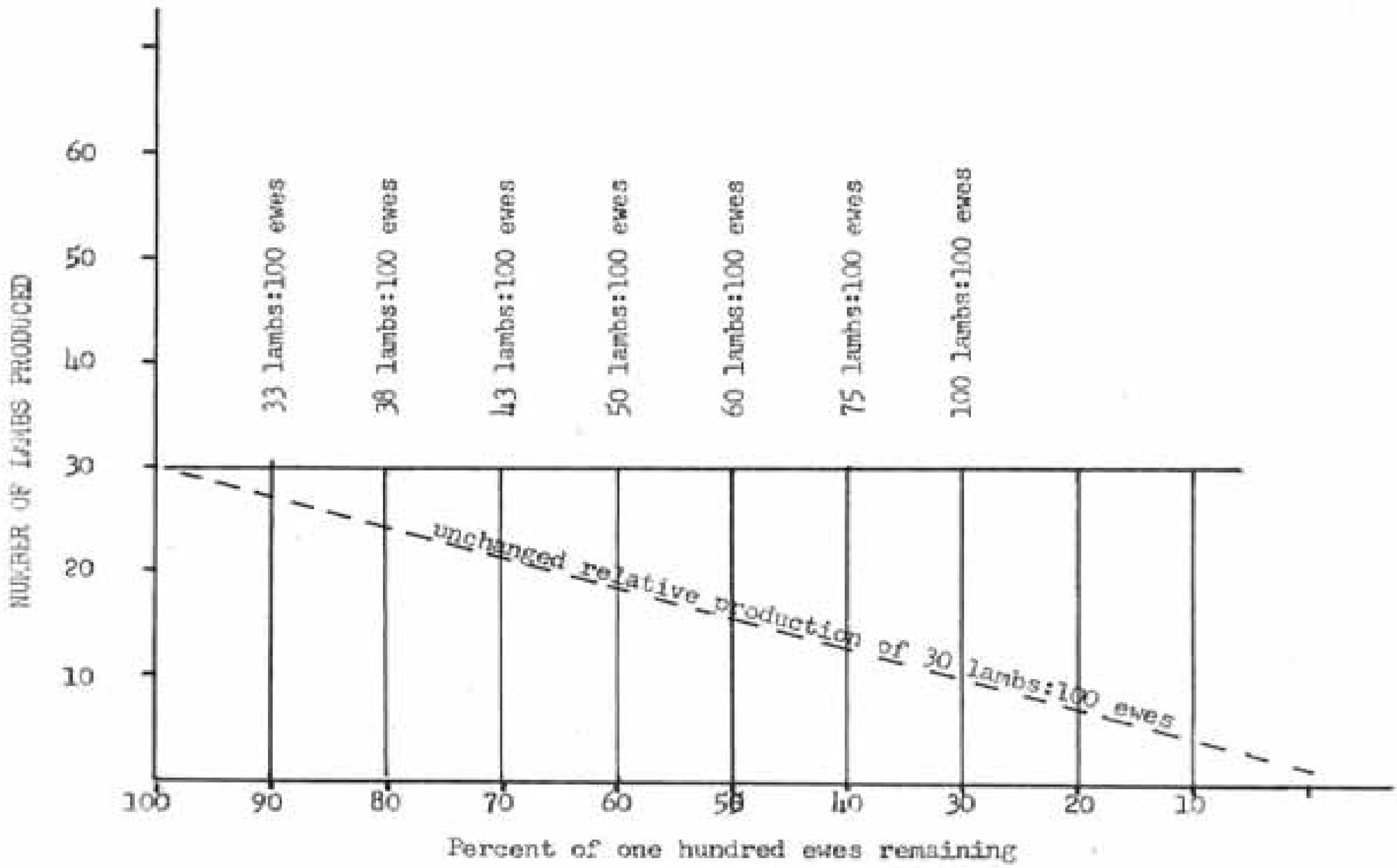

Figure 2. Necessary adjustments in relative production required to maintain initial lamb production of 30 lambs in a hypothetical population of 100 ewes, and the decrease in absolute production of lambs if relative production is unchanged when the number of breeding ewes is reduced.

Alaska, but the maximum attainable mean appears to be in the low 40's of lambs per 100 ewes. The dashed line on Figure 2 demonstrates the decreased absolute production of lambs resulting from herd reduction, if there is no stimulatory effect on initial production.

If there is a demand for trophy rams which equals or exceeds the supply, or if trophy management is the primary management goal, it should be understood that herd reduction will, in all likelihood, decrease the absolute supply of trophy rams and compromise the primary management goal. In herds where alternate year reproduction is not the case, there is even less possibility of benefit, and either sex sheep hunting should be clearly understood to result in reduced availability of trophy rams for harvest with no assurance that compensatory reproduction will result.

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SOME THOUGHTS ON THE CONSEQUENCES OF NON-TROPHY SHEEP HUNTING IN THE WIND RIVER MOUNTAINS OF WYOMING

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INTRODUCTION

The Whiskey Mountain wintering bighorn sheep (Ovis canadensis canadensis) population has recently been shown to consist of two herds which total between 900 and 1,200 animals. They winter in three relatively small areas on Whiskey Mountain and Sheep Ridge which are near Dubois, Wyoming. During summer they migrate to the south and inhabit large areas on either side of the Continental Divide in the northern Wind River Mountains.

Ewes, lambs, yearlings, and 2-year olds (ewe-lamb bands) of these populations are accessible and often quite visible to human visitors throughout most of the year. Wintering populations may readily be viewed from motor vehicles and can be approached on foot. These animals are quite popular as a source of nonconsumptive wildlife recreation for many people, and during 1976 an estimated minimum of 5,350 people using motor vehicles viewed and photographed sheep on their winter range. On summer ranges the same animals are heavily exposed to fishermen, backpackers, mountaineers, and, especially, amateur photographers. The number of people who seek sheep is increasing rapidly. Summer ranges are almost entirely above timberline, and, although the terrain is quite precipitous and rugged, sheep and man are highly visible to each other over considerable distances. During fall, ewe-lamb bands return to areas near winter ranges which are also frequented by sheep hunters. These sheep return to the various wintering areas during the rutting period.

Mature rams from the Whiskey Mountain populations are wild and timid during all seasons as far as their reactions to humans are concerned, but there is some variation in degree of wildness with different seasons. They are readily visible only during rutting season on the winter range and again for a short period coinciding with grass green-up on winter and spring ranges. However, our experiences indicate that even during these periods not all or even most rams are readily visible. During summer and fall months, mature rams are rarely viewed by the backpacker or mountain recreationist, and our observations have demonstrated that these animals will go to great means to avoid human contact.

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RESULTS AND DISCUSSION

Beginning in the early 1900's, sheep were hunted in Wyoming by anyone possessing a combination elk-deer tag. Since the 1930's, hunting has generally been on a limited basis and usually for rams with three-quarter curl or larger horns. Either sex or one-half curl or larger ram hunting on a permit basis was allowed between 1965 and 1968, but the harvest of ewes and smaller rams was very limited. Approximately 394 mature rams have been harvested from the Whiskey Mountain populations through hunting between 1968 and 1978. The harvest of three-quarter curl or larger rams during this time period has not significantly regulated population size. Between 1958 and 1978, 847 sheep, consisting primarily of ewes, yearlings, lambs, and young rams have been removed from the population by trapping for transplant or research purposes. Trapping and transplanting, in combination with limited hunting of mature rams, has served as the primary management means of population control. Even though techniques (Schmidt 1976) adopted in recent years have greatly increased the success and efficiency of trapping, this remains an expensive means of population control. Reduction through hunting ewes and young rams (non-trophy sheep) has been adopted in some areas and has been deemed to be biologically sound and an effective management tool (Morris 1976, Nichols 1976). It has been our observation that, although hunting non-trophy sheep may be biologically sound and the management tool of choice in many situations, behaviorally it could be destructive to populations such as the one we studied. We developed the following thoughts regarding possible consequences of non-trophy sheep hunting during an intensive 3-year study of the Whiskey Mountain bighorn population. These thoughts are our own and do not necessarily reflect the philosophy of the management personnel responsible for season recommendations within the Wyoming Game and Fish Department.

All ungulates, including bighorn sheep, respond to environmental and management alterations in varying degrees ranging from imperceptible to obviously drastic changes in numbers and distribution. In speculating on the consequences of non-trophy sheep hunting, we will present what are, in our personal estimations, the more extreme responses. However, we do recognize that responses of such magnitude may not invariably occur. Also, the responses we predict could not be expected to occur rapidly and might require a number of years or sheep generations. Our observations and thoughts are limited to the Whiskey Mountain sheep populations and their habitat which we believe are rather unique as compared to most other North American ungulates and their habitats. This uniqueness is based upon the following facts: 1) these populations are utilized in both consumptive (trophy hunting and trapping for transplant) and non-consumptive (viewing, photography, etc.) ways; 2) in most of their habitat they are highly visible to human visitors over great distances; and 3) they share large portions of their habitat with numerous recreationists.

Mountain sheep are relatively intelligent animals (Geist 1975) and their response to man is largely a result of previous experiences, pleasant or unpleasant (Geist 1971a), which may have occurred over many generations. In some national parks, all members of sheep populations including mature rams are unafraid of man (Geist 1971a). Their experience with man and those of their predecessors have been neutral or in some cases pleasant. Hence they have not learned to fear man. The fact that disturbance by man in the form of hunting will result in wild or wary sheep populations has been discussed (Horejsi 1976) and documented (Geist 1971a, 1971b) and is common knowledge to most sheep hunters. This avoidance response to humans has also been noted among other species such as elk (Cervus canadensis)controlled by hunting in national parks (Houston 1976, Schultz and Bailey 1978) and red deer (Cervus elaphus) controlled by hunting (Batcheler 1968). Discussions of wildness in hunted mountain sheep have often been generalized in the sense that ewes are expected to react much the same as rams (Horejsi 1976). However, we have observed vast behavioural and distribution differences between mature rams (the hunted segment) and immature rams, ewes, and lambs (the unhunted segment). It is recognized that behavioral and distribution differences exist among mature males, females, and juveniles in sheep and many other ungulates which are undisturbed by man, but we believe that among Whiskey Mountain sheep these differences are exaggerated due to differing degrees of unpleasantness associated with man that have resulted in differing responses to man.

Almost all sheep we encountered or that we observed encountering other people, such as backpackers, reacted in a negative way. Rams 2-3 years of age and older reacted by increased alertness, attention, and usually a strong flight response (Calef et al. 1976, Horejsi 1976). They inhabited areas right at or just below timberline where they were not visible for great distances. Those rams which ventured above timberline seemed to inhabit the most inhospitable mountain tops. Ewe-lamb bands almost always reacted to human presence, but much less strongly than rams. A number of observations indicated they reacted to man in a slightly more negative way than they did to coyotes, their chief predator. They usually responded with increased attention, sometimes walked to cover, and occasionally took flight, but flight distances were usually short. It appeared that young rams learned to react strongly to man when they joined ram bands and associated with older animals which had previously experienced unpleaseant encounters with man. This has been suggested by Geist (1971a). Very seldom are rams legally shot while in close association with ewe-lamb bands; therefore, ewes and lambs have not experienced being hunted.

Control of the Whiskey Mountain sheep population through hunting of non-trophy sheep would result in a great deal of disturbance. In the past 10 years an average of 92 permits for three-quarter curl rams have been granted with an average hunter success of approximately 40 per cent. It is probable that non-trophy hunters would initially experience a success rate approaching 100 per cent. But it could be predicted that as non-trophy sheep were hunted, they would become more wary and hunter success would drop as it did with Dall sheep ewes on Crescent Mountain, Alaska, where they are hunted rather intensively with only 25-44 per cent success (Nichols 1976). At the present time, an average minimum of 40 non-trophy sheep are being or should be removed yearly from each of the two Whiskey Mountain populations by trapping for transplant. To effect this level of population control through hunting of non-trophy sheep at a hunter success rate of 60 per cent would require 140 hunters in addition to 92 three-quarter curl ram hunters. This could result in a great deal of disturbance especially on Whiskey Mountain and other more accessible areas. Control of hunter opportunity and access could reduce this harassment of non-trophy sheep as it might for trophy rams.

Sheep should not be expected and certainly are unable to distinguish between hunters, hikers, fishermen, biologists, geologists, and photographers (Geist 1975, Horejsi 1976). Sheep which encounter an unpleasant experience when hunted might expect the same unpleasant experience each time they encounter man and react accordingly (Geist 1971 a). Thus, for hunted sheep any form of sheep-man encounter during any time of the year might be interpreted as a form of harassment or disturbance similar to that of being hunted.

Three categories of deleterious effects which human activity may have upon caribou (*Rangifer tarandus*) have been described. We feel these same categories would also be applicable to Whiskey Mountain bighorns once they learned to fear man:

"1. Those causing immediate physical injury or death.
2. Those resulting in increased expenditures of energy, or changes in the physiological condition of the animals, which reduce their rate of survival or reproduction.
3. Those resulting in long-term changes in behavior, including especially, the traditional use of ranges." (Calef *et al*. 1976)

Probably the least important deleterious effect induced by man-sheep encounters would be immediate physical injury or death. We never witnessed the "panic response" described for caribou reacting to aircraft (Calef *et al*.1976), but we did witness strong escape responses among rams fleeing from people at high speed into and through extremely precipitous escape cover, but they were usually more deliberate in their actions. Rams and ewe-lamb bands both usually fled farther into precipitous escape cover when escaping man than when escaping coyotes and this was especially pronounced among rams. We did not witness any injuries or deaths as a result of these flights. However, injuries such as dislocated shoulders and broken bones of the legs were relatively common and falls have been cited as causes of sheep mortalities (Smith 1954, Geist 1971b). It is not difficult to imagine that more frequent and stronger flight reactions among hunted non-trophy sheep could result in more injuries.

A possible consequence of stronger flight reactions by ewes with young lambs would be the loss of lambs either through injury or the ewe being unable to relocate the lamb later. Ewes responded most strongly to disturbance when relatively young lambs were travelling with them and this has been observed elsewhere (Light 1971). Disturbance of a nursery band of sheep by a coyote or backpacker resulted in prolonged periods during which ewes and their lambs searched for one another. If ewes responded as strongly to human presence as do rams at this time of year, the result might be injuries among those lambs which tried to follow and increased separation from their dam with greater susceptibility to predation among those lambs left behind.

One of the more severe consequences of human encounters among non-trophy sheep which fear man because of hunting would be increased energy expenditures. Man-sheep encounters occur most frequently during summer, when ewes are lactating and lambs and yearlings are growing, and during winter when energy demands are great.

In August, 1976, near the Continental Divide and only slightly above a very important ewe-lamb summering area, we witnessed seven rams, including one Class IV and three Class III individuals, which were disturbed by two backpackers. The backpackers never appeared to see the rams which were approximately 1.7 km (1.1 mi) distant. The sheep immediately fled from the backpackers at a run interspersed with short periods of walking or trotting. They were still running when they disappeared from our view over a glacier after fleeing for 2.6 km (1.6 mi). This seemed to be an example of an extremely strong flight reaction to man, but it may have been so only because we were in a position to observe much of their escape. It was marked in contrast to the flight of a similar group of rams fleeing a closely pursuing coyote in June, 1975. That flight covered onl 172 m. (189 yd.) and terminated once the sheep reached the edge of escape cover. We observed many other flight reactions, mostly from man, which we were unable to follow to completion.

Members of ewe-lamb bands encountered man frequently and were not observed to react as strongly. If these sheep learned to fear man as mature rams do, it would be difficult or impossible for them to utilize the larger and more productive summer and winter ranges which are places of high human contact. If they did not abandon these ranges, they would encounter and flee from man frequently, in some areas several times daily. The energy expenditure of excitement and flight would interfere with, and might prohibit, growth of lambs or winter survival of ewes, lambs, and young rams. The energy costs of this type of excitement or of a strong flight reaction are extremely high (Kleiber 1961, Coop and Hill 1962 , Blaxter 1967, Geist 1974, Geist 1975, Ledger 1977, Weiner 1977). A single incident might be of little consequence but numerous encounters would be detrimental. During summer months energy demands of lactating ewes are high and milk production would suffer with the result being impeded lamb growth and/or survival. At times during winter, sheep may be unable to consume sufficient food energy to meet body demands. Increased energy expenditure due to harassment at these times would result in greater nutritional deficiency. Nutritional deficiency and excessive weight loss have been shown to depress reproductive output in many ungulates including white-tailed deer (Odocoileus virginianus) (Verme 1965), elk (Thorne et al. 1976), and domestic sheep (Ovis aries) (Blaxter 1967) and would undoubtedly have the same influence on bighorn sheep. During severe winters or where winter ranges are especially deficient, increased energy demands induced by harassment of sheep preconditioned to strong flight tendencies might also result in increased mortalities due to malnutrition.

Frequent and excessive harassment may be expected to result in physiologic changes which might potentially be devastating to bighorn sheep. Increased energy expenditures predicted above may result in depleted energy reserves and a breakdown in the animal's immune system (McFarlane 1976, Sinclair 1977). Although they often present a calm outward appearance, wild sheep are easily stressed and stress may lead to disease (Thorne 1971, Fulton and Rosenquist 1976, Post 1976) and birth of unhealthy offspring (Stott 1977). The occurrences of extensive bighorn sheep die-offs due to various diseases or parasites have been well documented (Honess and Frost 1942, Buechner 1960, Forrester 1971, Woodward et al. 1972, Bear and Jones 1973, Post 1976) and most major pathogens which have been implicated as responsible for bighorn sheep mortalities have been found in Whiskey Mountain sheep (Thorne 1977, upublished data). The potential for loss of a major part of both herds due to stress-induced disease or exacerbation of existing disease and parasitic conditions in individuals is great.

Long term changes in distribution among the non-trophy sheep of Whiskey Mountain could be expected to occur if they were hunted. Rams in unhunted populations inhabit differing summer and winter ranges than do ewe-lamb bands (Geist 1971b). However, it is questionable that, if free from human harassment, Whiskey Mountain rams would select and use the habitat they do now in preference to much larger and more productive but less secure locations. Aged males of many ungulate species do not participate in breeding activities and lead a relatively solitary existence, and sheep which have adopted one range may ignore what seems to be more convenient and suitable ranges. Among sheep these ranges may be preferred as ancestral, because of safety from predators, or because of other criteria which have not been identified. Our inability to account for all rams on Whiskey Mountain and Sheep Ridge winter ranges and discovery of ram skulls in distant areas which appear to be small, harsh, marginal wintering areas confirms this and also suggests that some rams have abandoned more favorable winter ranges for secure but often inadequate wintering areas. We were not able to determine the extent to which these areas are used nor if rams return to them following rut or simply do not participate in the rut. Sheep have been shown to abandon areas where unpleasant experiences take place (Geist 1971b). Rams of the Whiskey Mountain herds are hunted on their summer, fall, and winter ranges and they also are hunted on or near the spring (including lambing and nursery areas) and fall ranges of ewes and lambs. These areas are close to the rutting and winter range, and it is no wonder that some rams are reluctant to use these areas especially when they are frequented by men who were hunting them only a month or two previously. Although rams have apparently adapted to hunting with few detrimental effects, a possible exception would be the use of marginal wintering areas which must occasionally result in the death of a few individuals. A quirk of ram-only hunting as practiced in this area is that it has probably benefited ewe-lamb bands by reducing intra-specific competition.

Rams are able to survive and perhaps prosper in marginal but secure spring, summer, and fall ranges because they are the only sheep using them and because during spring and summer they have nothing to do but build energy reserves in the form of stored fat. If ewe-lamb bands abandoned their vast productive summering areas because they were frequented by mountain recreationists and joined the rams or adopted similar smaller and more secretive ranges, survival potential for all members of the populations would be jeopardized by the resulting intraspecific competition. Ewe survival and productivity would be impeded because they must provide for a rapidly growing fetus, lactation, and regaining weight lost during the previous winter. All this must be done before fat reserves are restored. Rams have learned to fear man and appear to have responded to his presence by abandoning optimal ranges. Experience in other areas has suggested that ewe-lamb bands when either hunted (Nichols 1976) or subjected to excess pressure by hikers may abandon traditional ranges for more secure areas (Dunaway 1971, Light 1971, Horejsi 1976). It is predictable that ewe-lamb bands of Whiskey Mountain, if hunted as non-trophy sheep for population control, might also abandon current ranges to the detriment of the entire population. We recognize that dispersion to currently unused habitat niches might be beneficial, but the benefit would not replace abandoned habitat unless new niches were as large and productive as the abandoned habitat and were not frequented by human visitors.

The trade-off value of accepting consumptive use of non-trophy sheep in the form of hunting over nonconsumptive values warrants consideration. The nonconsumptive value of mature rams has been largely but not entirely lost. Were it not for the reproductive urge in early winter and desire for green grass in late spring, few rams would ever be enjoyed by the average nonconsumptive user. The nonconsumptive values of ewes, lambs, and the young rams which accompany them is very important. These animals are the most visible and most frequently enjoyed ungulate of the northern Wind River Mountains. We would question that the possible loss or reduced opportunity to participate in these nonconsumptive uses is justifiable in order to control the populations through non-trophy hunting when other means are available.

Geist (1975) has stated that consumptive and nonconsumptive uses of sheep are not compatible and should not be combined. We would qualify that and state that the two uses are compatible for the Whiskey Mountain sheep populations under present management policies and conditions. We recognize that these populations are rather intensely managed (three quarter curl ram hunting, trapping and transplanting, range acquisition for sheep, and habitat manipulation), that hunting is limited, and that nonconsumptive uses may not be as complete as one would wish for (unabailability of rams, especially during summer and fall), but current management practices do allow for acceptable levels of consumptive and nonconsumptive uses.

We recognize the necessity of population control and feel that the large numbers of Whiskey Mountain sheep are currently their own greatest threat. We have tried to express and support the reasons we believe these populations should be controlled by methods such as trapping, which minimize harassment and not through non-trophy sheep hunting. Our hypotheses have been suggested by some of the others we have cited,and they should also apply to other bighorn populations characterized by relatively tame animals which occupy open habitat with high visibility that are frequented by large numbers of nonconsumptive users. In these cases we would encourage increased acceptance of man by sheep rather than management practices which increase their fear of man.

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FURTHER OBSERVATIONS OF BIGHORN SHEEP NON-TROPHY SEASONS IN ALBERTA AND THEIR MANAGEMENT IMPLICATIONS

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Edmonton

ABSTRACT

A total of 31 bighorn lambs (Ovis canadensis) has been selectively orphaned on Ram Mountain during the hunting seasons of 1972-76. Survival rates of lambs of both sexes and growth rates of female orphans are not different from their non-orphan counterparts. However, there appears to be a tendency toward stunting of orphan rams. Another aspect of the selective non-trophy season on Ram Mountain is the development and/or maintenance of a moderately high-quality population suggested by rapid initial horn growth in males, early maturation in females, high lamb production, average suckle durations and low lungworm loads. Management implications of a non-trophy season are discussed on the basis of data from "ewe" seasons in Alberta since 1966 and the population dynamics of the Ram Mountain herd.

INTRODUCTION

In response to a bighorn die-off in British Columbia, Alberta instituted a non-trophy season in 1966 to avoid a similar catastrophe and to try and maintain bighorn populations below or near carrying capacities of critical winter ranges. The first two non-trophy seasons allowed the harvesting of any bighorn with horns less than 12 inches in length. However, the 1968 regulations were modified to include ewes and lambs only, as it had become apparent that hunters were starting to select yearling rams. Non-trophy seasons have run from the end of August to the latter part of October, except for 1971 when the season began September 25. Approximately 340 permittees have harvested about 110 non-trophy sheep per year resulting in an annual harvest rate of less than 3 per cent of the total estimated harvestable population of 4,500 Alberta bighorns (excluding National Parks). Since 1966, approximately 1,300 non-trophy sheep have been harvested.

Obvious questions concerning the non-trophy season are: 1. what effect does orphaning have on the survival and subsequent growth of lambs and 2. how does this influence the population dynamics of a bighorn herd. The Ram Mountain orphan study was initiated in 1972 to examine these questions.

STUDY AREA

Ram Mountain comprises the southernmost extent of the Brazeau Range, lying south of the North Saskatchewan River Gap approximately 160 kilometers west of Red Deer, Alberta (Figure 1). Elevation varies from 1082m.

on the North Saskatchewan River to 2173 m, at the summit of Ram Mountain. Several intermittent drainage basins jut irregularly into the mountains, interrupting the continuity of the range. The terrain is varied, with bare rock summits, talus slopes, wooded slopes, low relief alpine tundra and rugged escarpments and cliffs (Hoffman, 1971). Ram Mountain was chosen for the trapping and marking study because of its isolation. The mountain is bordered on three sides by heavily forested foothills and on the fourth side by the North Saskatchewan River.

METHODS

To date, approximately 90 per cent of the herd has been marked. It appears that movements of bighorns across the river to the north comprises less than 5 per cent of the herd. Animals were captured in a corral-like structure baited with salt. Horn measurements and weights were recorded and fecal samples were taken. All trapped sheep were marked. Subsequent observations of suckles confirmed ewe-lamb combinations. Survival rates were determined by observations of marked animals in ensuing years. Approximately half of the marked lambs were selectivley orphaned by hunting each year between the end of August and the end of October. Fecal samples were analyzed for lungworm infection by the Baermann technique as described by Uhazy et. al., (1973). An unpaired t-test or a t-test of a single observation versus a sample taken during the same time period was used to compare weights and measurements of non-orphans to orphans.

RESULTS

Thirty-one lambs have been selectively orphaned between 1972 and 1976 (Table 1). Lamb survival, since the orphaning program began, is indicated in Table 2. There was no significant difference of survival to one year between orphans and non-orphans (Table 3). Live weights of female orphans did not differ from their non-orphan counterparts (Figure 2). Although not statistically significant, there was some indication that orphan rams weighed less than non-orphans (Figure 3). The suggested size discrepancy between orphan and non-orphan rams becomes more pronounced when examining horn lengths (Figure 4) and horn base circumferences (Figure 5). Mean non-orphan ram horn lengths and base circumferences were statistically larger ($p<0.05$) than orphans in approximately 28 per cent and 11 per cent of the cases respectively, where statistical comparisons could be made.

DISCUSSION

Orphan rams appear to exhibit below average growth, especially in horn development. The following hypothesis attempts to explain this phenomenon. At the time of orphaning, the lamb drops to the bottom of the dominance hierarchy In this situation the energy budget of the lamb may be "taxed" because of its premature subordinate status, thus resulting in retarded growth. Perhaps the variation in size isn't as acute in female orphans compared to female non-orphans since they are paedomorphic (i.e. the adult female retains juvenile characteristics of males including horn size and weight) and therefore do not exhibit such a large discrepancy in size between juvenile and adult form.

J. 1. Location of bighorn sheep herds referred to in the text including Ram Mountain.

Table 1. Number of marked ewes and lambs that were matched and number of ewes collected on Ram Mountain. (1972-1977)

Year	Ewes and Lambs Marked and Matched	Number of Matched Ewes Collected
1972	9	6
1973	12	5
1974	9	7
1975	13	8
1976	14	5
1977	11	6
Total	68	37

Table 2. Ram Mountain lamb survival 1972-1977.

Year	Lambs	Yearlings	2 Years	3 Years	4 Years	5 Years
1972	24[a](6)[b]					
1973	25(5)	14(4)				
1974	15(7)	18(3)	13(3)			
1975	20(8)	11(3)	14(2)	9(3)		
1976	21(5)[c]	12(7)	10(3)	14(2)	7(2)[d]	
1977	16(6)	17(4)	11(7)	9(3)	9(1)[e]	7(2)

[a]total number of lambs

[b]number of orphans included in total

[c]one lamb not included - status unknown - may have died before the ewe was collected.

[d]one non-orphan ewe collected in 1976.
one orphan ram found dead in trap (spring 1976)

[e]one orphan ewe collected in 1976.
one non-orphan ewe collected in 1976.

Table 3. Chi-square test for independence on survival to 1-year of non-orphan lambs versus orphaned lambs (1972-1977).

Status	Non-Orphan Lambs	Orphan Lambs	Total
Survived	51(51)	21(21)	72
Died	23(23)	10(10)	33
Total	74	31	105

( ) = expected values with the Chi-square Test for Independence.

(x^2 1df = 0.00, N.S. at $p < 0.005$)

Table 4. Chi-square test for independence on 289 observations of bands sighted with 2-year-old orphan males vs. 2-year-old non-orphan males(1975-1977).

Band Type	Number of observations(Expected)		Total
	Non-orphan 2-Year-Old Males (n=10)	Orphan 2-Year-Old Males (n=3)	
Ewe-lamb-juvenile ram bands.	97(121)	81(57)	178
Ram only bands.	100(76)	11(35)	111
Total of all bands.	197	92	289

x^2 1df = 38.90 It is significant at $P<0.005$. The hypothesis that the number of observations of 2-year-old non-orphan males with female-lamb-juvenile ram bands is equal to the number of observations of 2-year-old orphan males with the same is rejected.

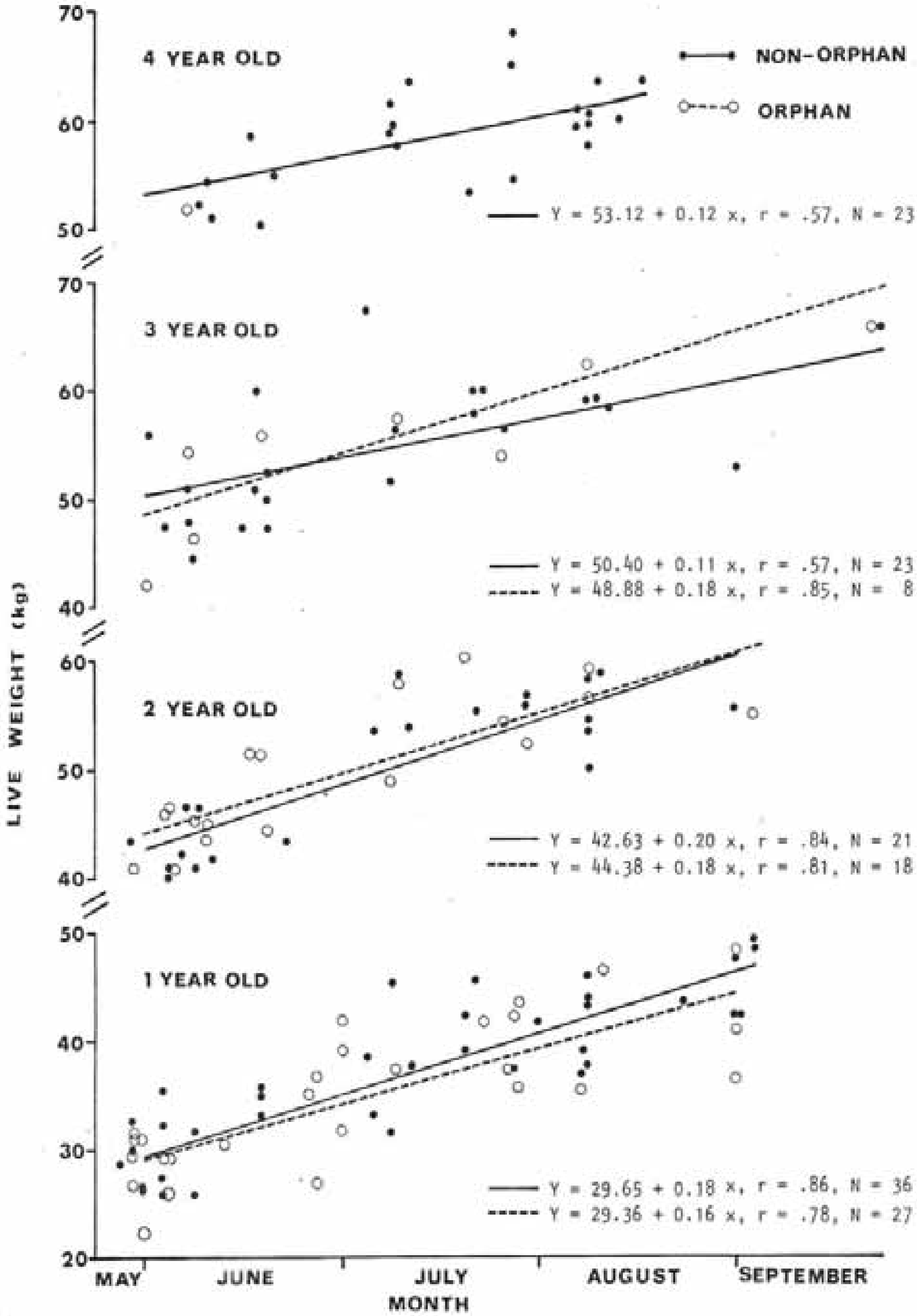

Fig. 2 Live weights of non-orphan vs orphan bighorn ewes from Ram Mountain 1975-1977. (June 1 = x_1 for regression lines)

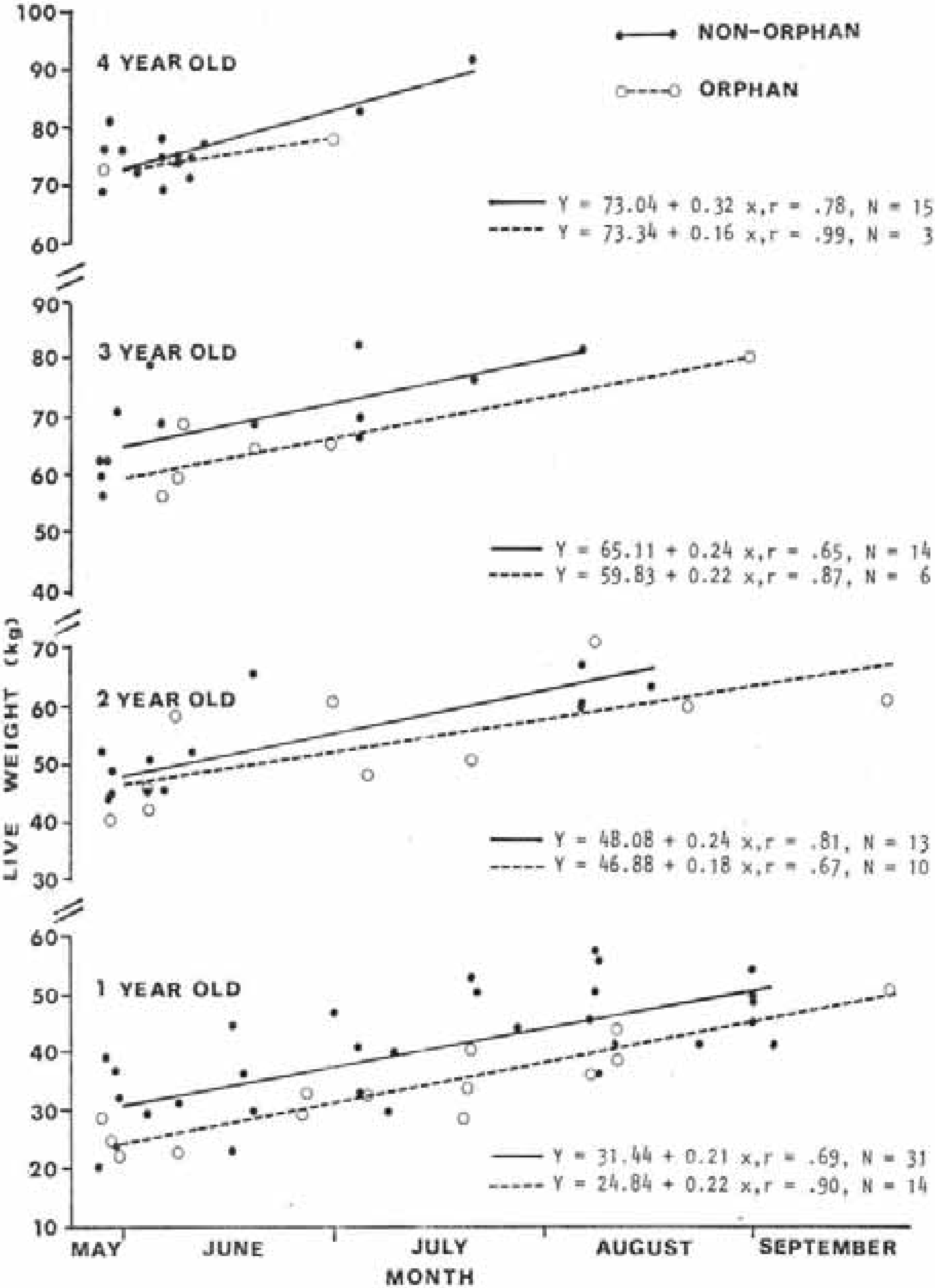

Fig. 3 Live weights of non-orphan vs orphan bighorn rams from Ram Mountain 1975-1977. (June 1 = x_1 for regression lines)

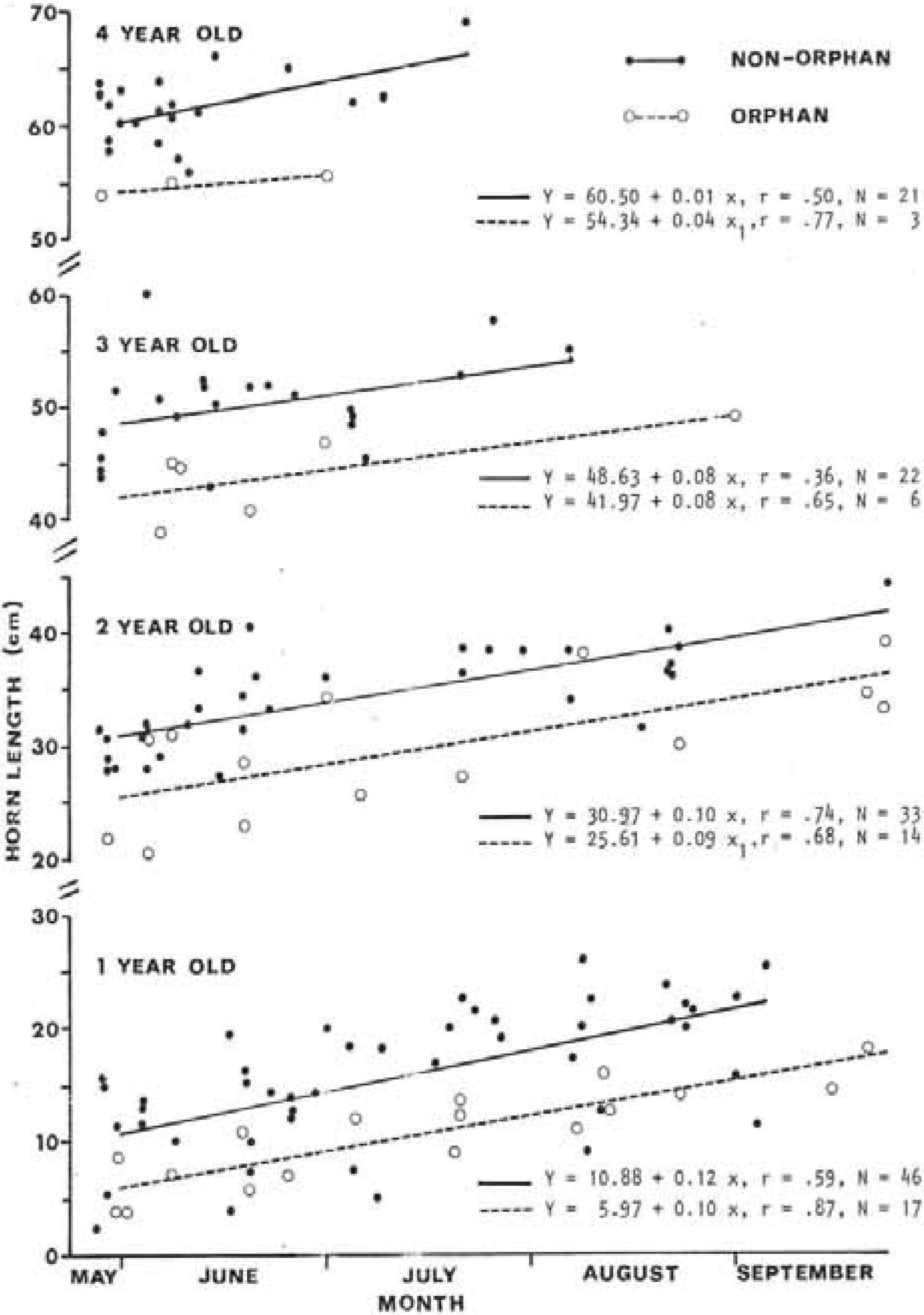

Fig. 4 Horn length measurements of non-orphan vs orphan bighorn rams from Ram Mountain 1971-1977. (June 1 = x_1 for regression lines)

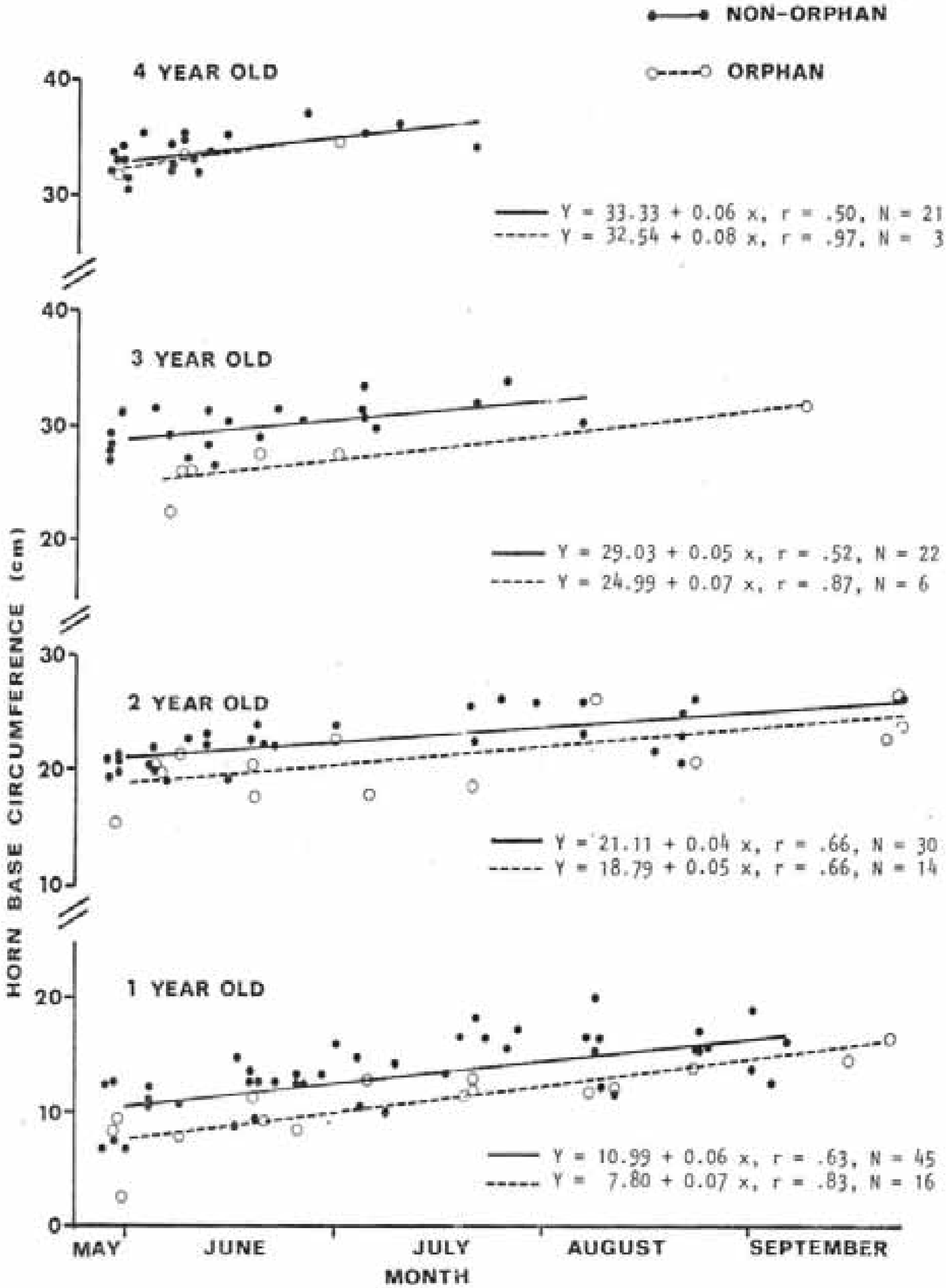

Fig. 5 Horn base circumference measurements of non-orphan vs orphan bighorn rams from Ram Mountain 1971-1977. (June 1 = x_1 for regression line)

Geist (1971) has demonstrated that the female generally remains on the home range of the maternal female group; whereas, the male leaves the group sometime after his second birthday, once he thoroughly dominates females. One would expect large young rams to dominate females and assimilate into ram bands much earlier than smaller rams. Therefore, orphan rams would remain with female groups longer than non-orphans. Table 4 supports this theory based on a comparison of three orphan rams and ten non-orphan rams.

Population Quality and Condition

Geist (1971) and Shackleton (1973) have examined the concept of population quality in bighorns and have indicated certain attributes characteristic of high quality populations such as increased productivity and growth rates. Bighorn ewes usually are not reproductively mature until they are 2½ years old. Two 2-year-old females in the high quality herd (Kootenay) studied by Shackleton were accompanied by lambs in 1970. Horesji (1976) observed 2 year old ewes with lambs in the Sheep River herd and demonstrated that herd to be a high-quality population. This reproductive phenomenon has also been reported by Woodgerd (1964) for an expanding population. One out of six 2 year old ewes on ram mountain had lambs in 1975 and 1976(Table 5). Five out of eight 2-year-old ewes were lactating, but only three were observed with lambs in 1977. The other two lambs suffered mortality before, during, or shortly after parturition. Of the five mothers, three were orphans. Of the three ewes with lambs surviving, one was an orphan.

High lamb production is indicative of a high quality population even though lamb production fluctuates greatly between years (Geist 1971). Over a 7 year period on Ram Mountain, an average ratio of 67 lambs:100 adult ewes (includes 2-year-old ewes with lambs) was realized (Table 6). This is comparable to a ratio of 68 lambs:100 adult ewes (includes 2-year-old ewes with lambs)found at Kootenay by Shackleton (1973) Horesji (1976) indicated a maximum ratio of 87 lambs:100 adult ewes (includes 2-year-old ewes with lambs) at Sheep River in 1972. The low quality herd (Banff) studied by Shackleton (1973) had a ratio of 33 lambs:100 adult ewes. None of the 2-year-old ewes were observed with lambs.

Shackleton (1973) also demonstrated that above-average annual horn increments in high-quality populations, were followed by below-average annual increments later in horn development. The Ram Mountain herd initially grew the second largest annual horn increments of the four populations examined, followed by the smallest increments by the fifth and sixth year (Figure 6);these data support Shackleton's findings. The Redcap herd, which hasn't been hunted since 1972, demonstrates the reverse of that previously described (Figure 6), suggesting that it is in a stable or declining state.

Mean suckle durations on Ram Mountain were comparable to those observed by Horesji (1976) in a high-quality population in southern Alberta (Table 7), and intermediate between the high and low quality populations studied by Shackleton (1973) (Table 8).

Uhazy <u>et.al</u>., (1973) examined fecal samples from six bighorn herds

Table 5. Age-specific lactation rates of bighorn ewes on Ram Mountain (1975-1977).

Age (years)	Percent Lactating (n)		
	1975	1976	1977
2	17(6)	17(6)	63(8)
3	50(4)	83(6)	80(5)
4	57(7)	100(3)	100(4)
5	66(3)	100(6)	66(3)
6	75(4)	100(2)	80(5)
7	75(4)	0(1)	100(1)
≥8	100(5)	100(5)	75(4)
$\bar{x}$	61(33)	76(29)	77(30)

Table 6. Lamb production on Ram Mountain (1971-1977).

Year	Number of Lambs	Number of Reproductively Mature Ewes	Lambs per 100 females (3 years and older)
1971	24	33	73
1972	24	38	63
1973	25	32	78
1974	15	36	42
1975	20	28[a]	71
1976	22	25[a]	88
1977[d]	16	25[b]	64
Total	146	217[c]	67

[a] Includes one 2-year-old ewe which had a lamb.

[b] Includes three 2-year-old ewes which had lambs.

[c] Includes five 2-year-old ewes which had lambs.

d In 1977, 24 of 27 reproductively mature ewes captured were lactating (including five 2-year-olds). Of those 24, only 16 were observed with lambs.

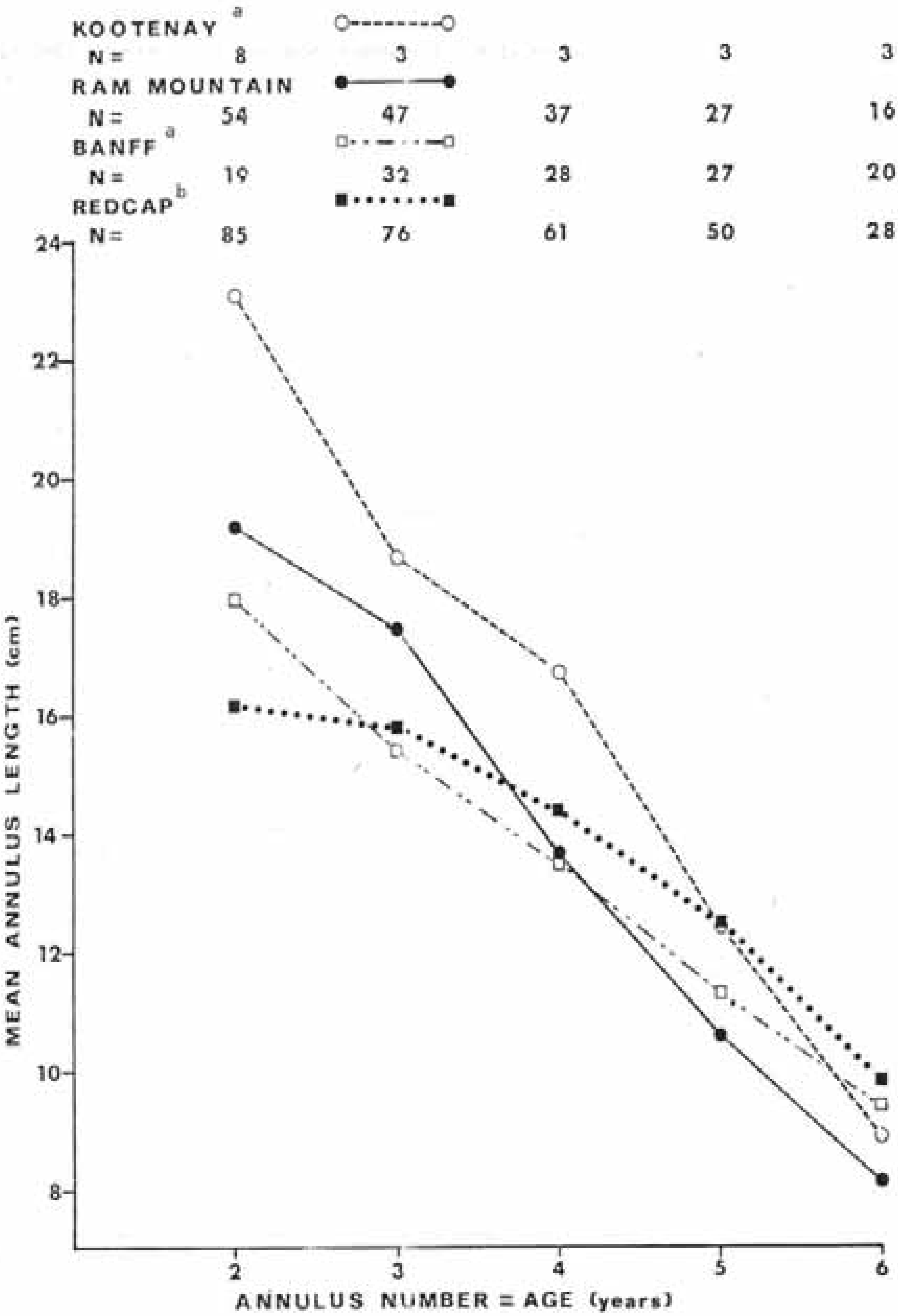

Fig. 6 Mean annual increments (cm) of ram horns from four bighorn sheep populations. By the sixth year of age increments in those populations which had initially shown the longest increments now become the smallest.

[a] Shackleton 1973.

[b] Data from Redcap sheep study - Alberta Fish and Wildlife Div. files.

Table 7. Monthly mean suckle durations from two herds.[a]

Herd	Year	Suckle Durations (Seconds) June	July	August
Sheep River[b]	1969	20.36 ±.513 149	15.9 ±.368 98	14.00 ±.543 22
Sheep River[b]	1970	21.54 ±.583 157	17.25 ± .45 129	14.56 ±.852 9
Sheep River[b]	1972	23.17 ±.981 169	17.43 ±.553 118	15.50 ±1.067 10
Sheep River[b]	1973	20.75 ±1.352 24		
Ram Mountain	1973	17.5 32	16.7 75	
Ram Mountain	1974	22.2 8	13.4 32	
Ram Mountain	1975	24.8 ±1.474 10	18.0 ±1.061 30	
Ram Mountain	1976	19.36 ±1.183 11	15.71 ±.686 18	14.09 ±1.245 11
Ram Mountain	1977	18.00 ±.769 36	15.32 ±.564 31	14.87 ±1.329 8

[a] In seconds, ± standard error and number timed.

[b] Modified from Horesji 1976.

Table 8. Comparison of suckle durations from three bighorn populations.

Population	Observation period	Mean suckle duration (sec)	n	Standard deviation
Kootenay Nat'l Park[a] (high quality)	3/6-25/07/71	28.0	70	13.54
Ram Mountain	21/6-30/07/75	19.7	40	6.25
	6/6-26/07/76	17.1	29	3.73
	1/6-22/07/77	16.7	69	4.21
Banff Nat'l Park[a] (low quality)	4/6-27/07/71	14.1	74	8.22

[a]Modified from Shackleton (1973).

Table 9. Estimates of herd sizes on Ram Mountain (1971-1977).

Year	Estimated Herd Size
1971	96
1972	115
1973	104
1974	106
1975	100
1976	100
1977	95

in Western Canada for lungworm larvae and indicated that fecal examination could provide an index to the proportion of heavy infections in the herd, given a sufficiently large sample size. They demonstrated a significant seasonal variation, with high numbers of larvae shed by bighorns on winter range. Figure 7 illustrates the "spring rise" phenomenon on Ram Mountain (supplemented by data from Sheep River). It appears that larval counts from Ram Mountain are well below the conservative estimate of a heavy infection (1400+ larvae per gram) given by Uhazy et.al., (1973) although conclusions are tentative due to the lack of samples during the spring peak of larval output (sometime between mid-March and mid-May).

Population Dynamics and Harvest

The Ram Mountain herd has remained around 100 animals since 1971 (Table 9). An average of approximately 8.4 per cent of the herd has been harvested annually since 1972 (Table 10). The harvest is comprised of reproductive ewes and rams 4/5 curl or larger. This has resulted in a herd composed of predominantly young age classes (Figure 8). Survival rates are quite high once an animal has lived one year (Table 11). The herd appears to be able to maintain itself under the imposed harvest by increased productivity and high survival rates.

Climatic conditions have been correlated with lamb production and survival (Cowan and Geist, 1971). A negative correlation between cumulative precipitation and lamb production is suggested in Figure 9. Shackleton (1973) has indicated that during the last months of pregnancy the development of the fetus and mammary tissues impose increasingly greater nutritional demands upon the ewe. Deep snow, combined with low temperatures, retard the start of continuous spring growth of vegetation and impose greater energy expenditures on the ewe. This would in turn result in smaller lambs at birth or pre-parturition mortality. Small lambs with poor fat reserves have a reduced chance of surviving inclement weather because of an inability to thermoregulate and gain sufficient nutrition from ewes under such conditions (Shackleton 1973, Horesji 1976).

If one makes the assumption that there is no difference in the chance of trapping a male or female lamb, then the sex ratio of captured lambs can be used as an index to the actual sex ratio. High lamb production appears to result in a sex ratio favoring female lambs (Figure 10). Verme (1969) discussed sex ratio changes of white-tailed deer fawns in relation to the nutritional plane experienced by the doe. He found that 70 per cent of the fawns, born to mothers on restricted rations when bred, were males; whereas, males comprised 47 per cent of the offspring from well-fed deer. He suggested that since deer are polygamous, limited production coupled with a disproportionately large number of male births would markedly depress the herd's annual increment when the range carrying capacity is seriously depleted. But if the habitat is capable of supporting a greater density, high productivity and more female births would result in a rapidly expanding population. The mechanisms which might account for changes in primary sex ratio are at best poorly understood (Nalbandor 1958, cited from Verme 1969). The bighorn situation may be analagous to the above description of sex ratio changes in white-

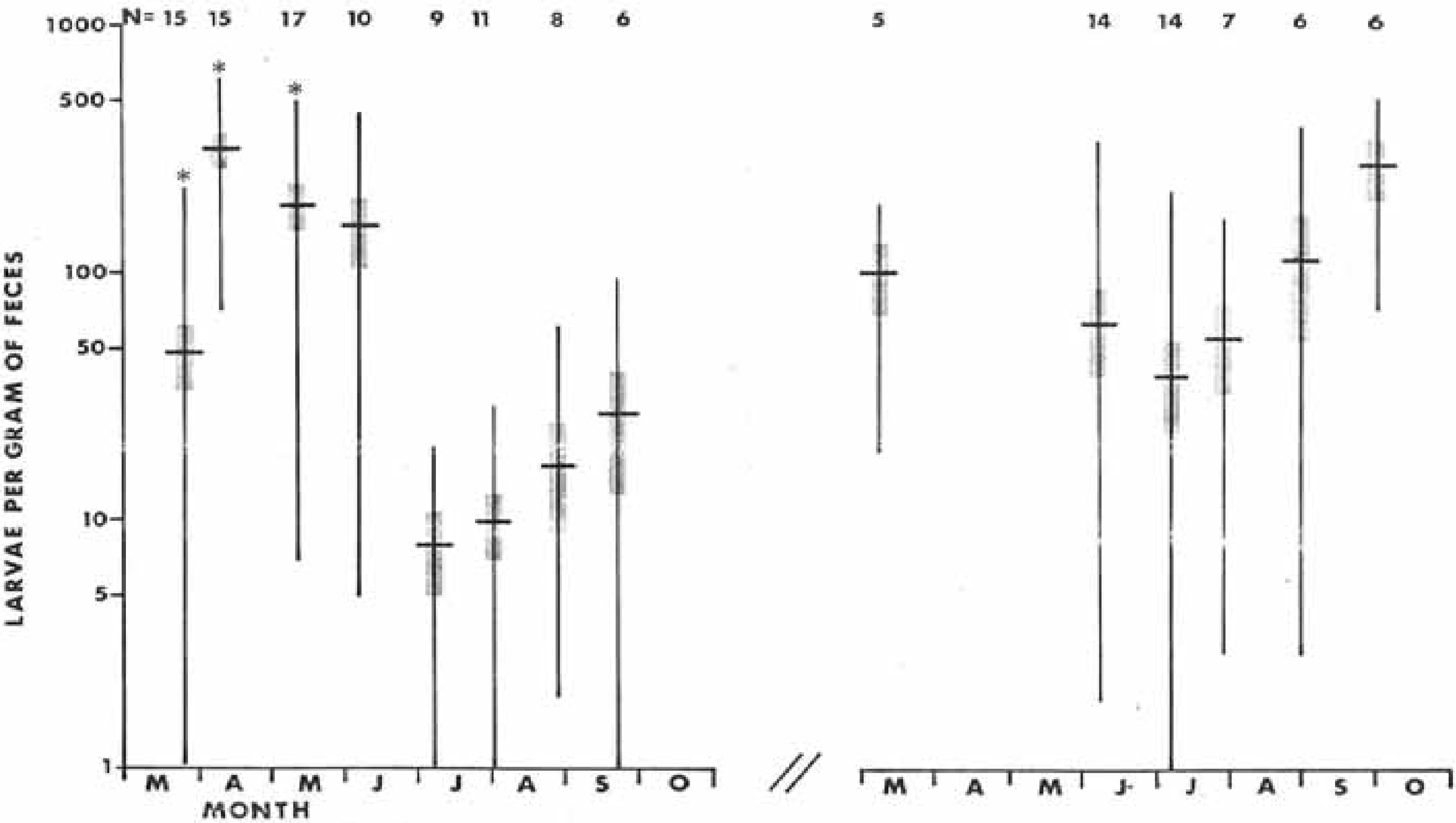

Fig. 7 Mean counts of protostrongylid larvae in bighorn sheep feces from Ram Mountain and Sheep River 1976-77. Means, ranges and ± one standard error are indicated by horizontal lines, vertical lines and shaded boxes respectively.

* Sheep River

Table 10. Number of bighorn sheep harvested on Ram Mountain 1972-77.

Year	Number of Ewes Collected	Number of Rams Harvested	Total Population	Percent of Total Population Harvested
1972	6	3	115	8%
1973	5	2	104	7%
1974	7	0	106	7%
1975	9	1	100	10%
1976	6	4	100	10%
1977	7	2	95	9%
Total	40	12	620	8.4%

Table 11. Survival Rates of Bighorn Sheep from Ram Mountain 1974-77. N = 278.

	Survival Rates (%)							
Cohort	0-1	1-2	2-3	3-4	4-5	5-6	6-7	≥8 years
Rams		.78	.94	.78	.89	.88	.90	.89
			$\bar{x}$ = .86					
	.71							
Ewes		.86	.80	.93	1.00	.92	.87	.93
			$\bar{x}$ = .89					

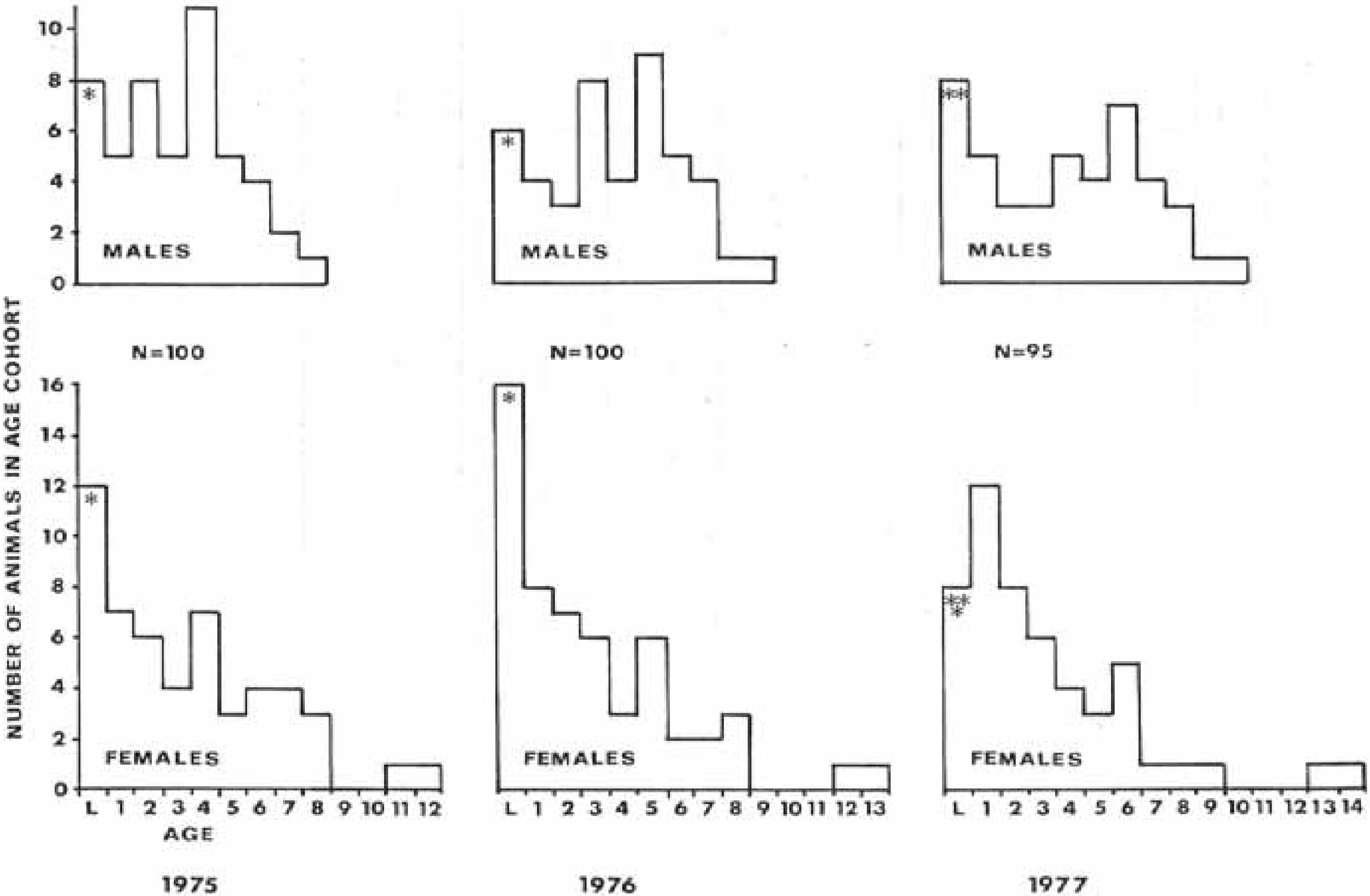

Fig. 8 Sex and age composition of the Ram Mountain bighorn sheep population (1975-77)
* Includes one lamb of unknown sex.
** Includes two lambs of unknown sex.
*** Includes three lambs of unknown sex.

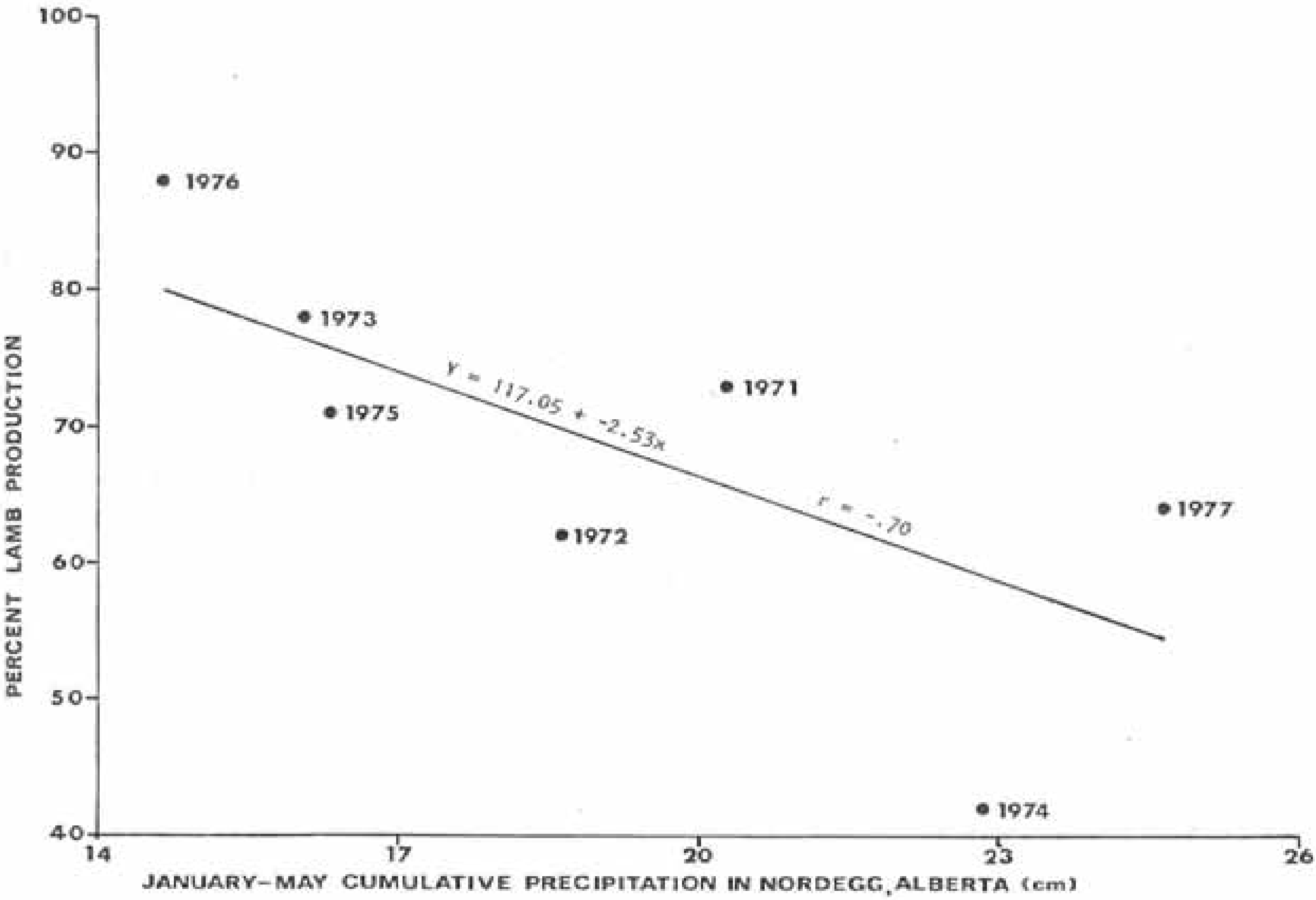

Fig. 9 Comparison of January-May cumulative precipitation in Nordegg, Alberta to lamb production on Ram Mountain 1971-1977. (Nordegg is approximately 25 km north-west of Ram Mountain, and precipitation values are not representative of higher altitudes on Ram Mountain. 1 cm of precipitation roughly equal 10 cm of snow).

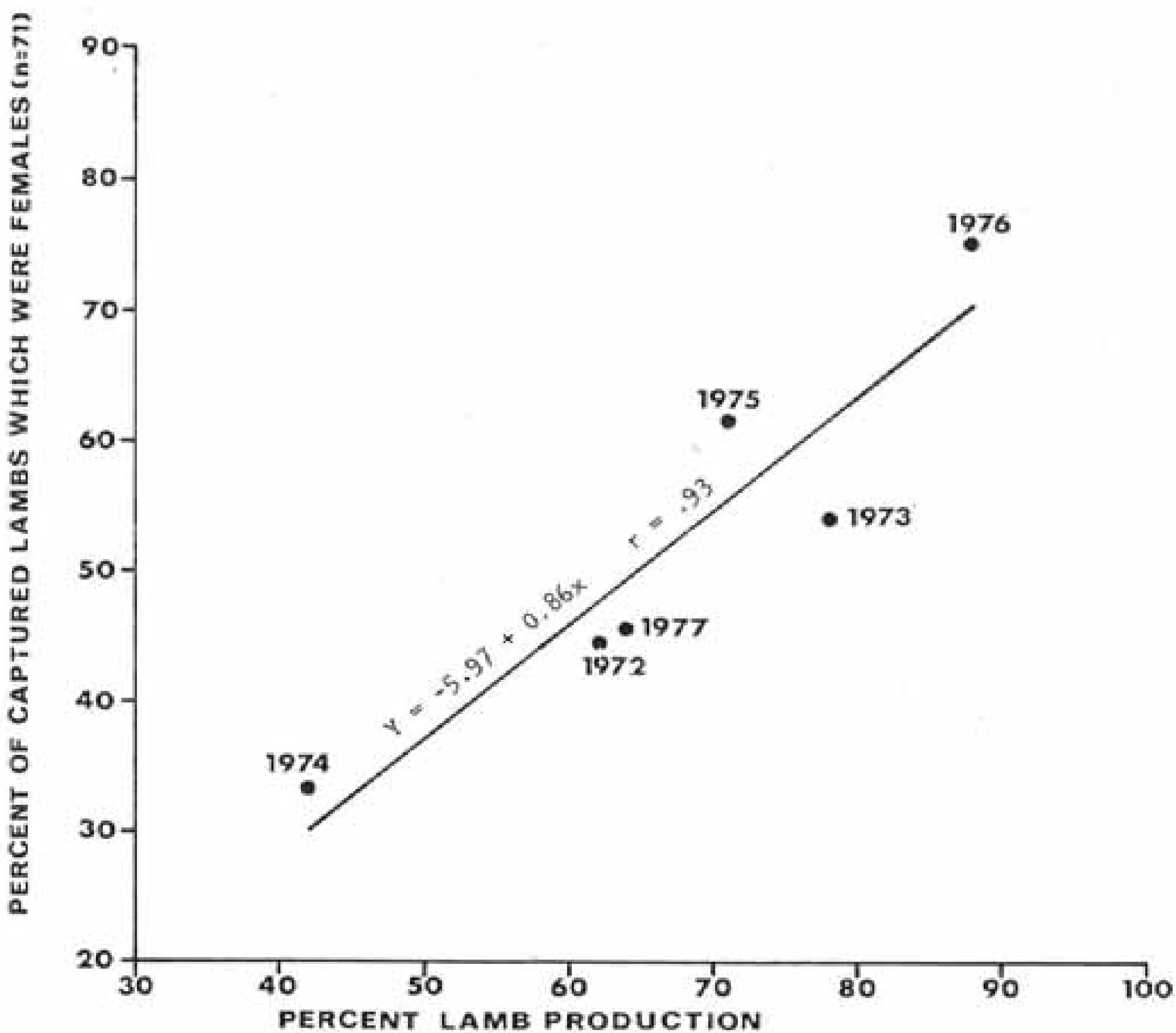

Fig. 10 Comparison of sex ratio of captured lambs to lamb production on Ram Mountain 1972-1977.

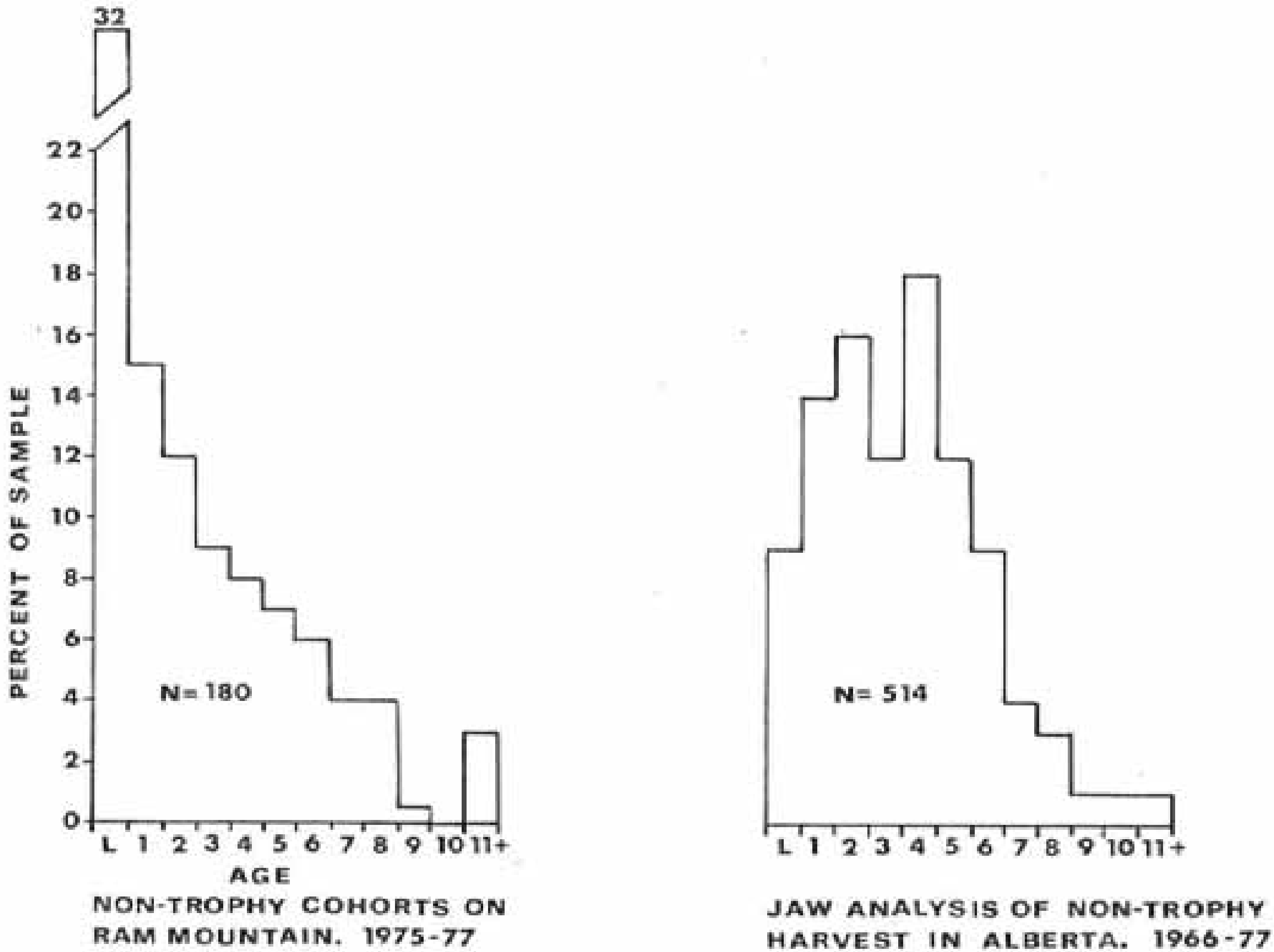

Fig.11 Age composition of non-trophy cohorts on Ram Mtn. (1975-1977) vs non-trophy harvest in Alberta (1966-1977).

tails. The condition of the ewe during the early winter rut would reflect the condition of the summer range, which would influence lamb production and the sex ratio the following year.

PROVINCIAL HARVEST

Certain factors become apparent after imposing provincial harvest rates on the non-trophy age structure of Ram Mountain (Figure11). Hunters are harvesting lambs, yearlings and 2 year old ewes in reverse to their normal occurrence in nature. This would indicate hunter selection against lambs and a slight selection for ewes without lambs as previously reported by Wishart (1976). A harvest rate of about 12 per cent (7 non-trophies and 5 trophies) could be applied to a population such as Ram Mountain on a sustained-yield basis by including lambs, yearlings and 2 year old ewes in the annual harvest of adult ewes and rams.

SUMMARY

The non-trophy season on Ram Mountain has resulted in physical and behavioral stunting of some orphan rams. Rapid horn growth by males in initial years, high lamb production, average suckle durations, low lungworm loads and early maturation indicate the population has developed into and/or maintained itself as a moderately high-quality population. Early maturation has been the most pronounced response, with the number of 2 year old mothers increasing dramatically in 1977.

The herd has stabilized around 100 under an annual harvest rate of 8.4 per cent (the harvest being comprised of reproductive females and rams 4/5 curl or larger). The Ram Mountain sheep herd can sustain an annual harvest rate of 12 per cent when sub adult non-trophy cohorts are included in the harvest as is the case in the provincial harvest. Monitoring climatological information on a yearly basis will assist the wildlife manager in predicting subsequent lamb production and sex ratios.

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WILD SHEEP MANAGEMENT - Chairman: H.B. Mitchell.

K. Becker, Tom Varcalli, E.T. Thorne, and G.B. Butler - Seasonal distribution patterns of Whiskey Mountain sheep.

Bob Jamieson: I was curious if you found:
1) any indications that the rams were moving between the two groups?
2) that there was any impact on the summer ranges?

Tom Thorne: The only ram interchange that we documented was a very few rams on winter ranges during the rutting period, which did move from the BLM ridge area to the Tory Rim. We did not feel that there was a lot of interchange between rams on summer ranges.

With regards to your second question, yes, the Tory Mountain sheep did have an impact on Middle Mountain. I think that that was probably the reason they left in the early summer.

Dave Shackleton: Do you plan to follow up with some of the particularly young rams to see, as they leave the female groups, where they go, which ram groups they go to, to see if this interchange between different areas does occur?

Tom Thorne: Probably the best we'll be able to do on that is follow ear tag returns. We put on an average of about 50-75 neck bands a winter, primarily on ewes.

Tim Baumann: Tom, at what elevations were the summer and winter ranges?

Tom Thorne: Summer range occurred between 10 to 12 thousand feet; winter range occurred around 8 thousand feet.

R.A. Demarchi - Evolution of Mountain Sheep Horn Curl Regulations in British Columbia.

Tim Baumann: In the field you use the cross-hairs to determine whether or not the animal was 7/8 curl. How does the hunter determine with regularity whether or not the animal is six years of age or over?

Ray Demarchi: It has been suggested that we shouldn't be using the horn curl regulation; we should just use a minimum age. The hunter should be educated to determine a class 4 ram from a class 3. Most hunters pass up rams that are of doubtful size and we haven't noticed a major shift in the age class distribution of our kill.

Bill Wishart: What do you do with rams that have been caped out?

Ray Demarchi: We have not explained to the hunter why they should keep the eye socket intact. According to the definition, the less eye socket they leave, the higher the line. If they cut the eye socket right up to the skull plate the horn must be about an inch longer.

Bill Wishart: From actual photos of Bighorns, I get the impression that it does go through the bottom of the eye.

Ray Demarchi: No, it doesn't go through the open eye ball, because once you take the eye out of the socket and expose it then it does go through the eye socket.

Gene Schoonveld: In Colorado's regulations, half the state goes 3/4 curl, the other half is 1/2 curl. Do you feel we have significant mortality on 1/2 curl animals, and is it justifiable to remain at 3/4 curl?

Ray Demarchi: Mortality is fairly low in yearlings compared to other ungulate populations, such as elk. The lower you set your limits when you are hunting these things the more animals you make available to the hunters and the greater chance you have of over-exploitation of whatever class you are shooting for in your population. These are the kinds of safety factors built into game management that we should exploit.

Clarence Tillenius: What was the precise number of rams taken last year in B.C.?

Ray Demarchi: I don't have it at my finger tips, but we have compulsory reporting now, and I think we are checking about 95% of the sheep.

W.E. Heimer - Alternate year production in low quality, declining Dall sheep populations: management considerations.

Dave Shackleton: Have you looked at the condition of the summer range as it affects lactation or fat deposition?

Wayne Heimer: In a classical sense, no. Under summer conditions in Dry Creek there seems to be no shortage of vegetation. However, Dry Creek is a small drainage, and there is little to be gained by chasing emerging vegetation altitudinally or up the valley because it happens all in two weeks, at the most. So that is probably limiting to an extent.

John Gibson: In your 30% lamb production, what is the ratio between ewes and rams? On the farm we get nine rams for every ewe in the newborn, in our Dall sheep.

Wayne Heimer: The ratio of rams to ewes in the population is very much skewed in favour of ewes. We have 65 or 70% ewes.

Rick Ellis: You seem to consider the alternate year production as fixed. It seems to me that the strategy is probably linked somehow to the amount of available food per female, and could change with range conditions fixed.

Wayne Heimer: No, I don't have any reason for assuming that it is fixed. It appears, in higher quality populations, that annual reproduction is probably the key.

E. T. Thorne, T. Varcalli, K. Becker and G.B. Butler - Some thoughts on the consequences of non-trophy sheep hunting in the Wind River Mountains of Wyoming.

Bill Wishart: At some point you will no longer be able to transplant sheep. What do you anticipate?

Tom Thorne: We don't really know. My suggestion would be that we could trap ewes and lambs and slaughter them if we had to. Tom Varcalli suggested that we have a two day season in the winter, when they are all on the winter ranges, or have a season every two years and kill more sheep each time.

Bill Wishart: Possibly your winter ranges could be a sanctuary in the sense that nobody hunts there.

Tom Thorne: There would be a danger that, in time, using the winter range as a sanctuary, we would end up with a non-migratory herd.

THE PROBABLE EFFECTS OF
THE ALASKA NATIONAL INTEREST LANDS CONSERVATION ACT
ON DALL SHEEP MANAGEMENT IN ALASKA

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INTRODUCTION

In 1867, the United States of America purchased Alaska from Russia. The land area purchased at that time was the same as today, 370 million acres. Alaska was then held as a territorial possession until 1959 when it was granted statehood. Under the terms of the Statehood Act, 104.5 million acres were to be granted to the State of Alaska with the balance remaining in Federal ownership. Of this 267 million acres of Federal land, 73 million acres were classified as National Parks, Monuments, Wildlife Refuges, National Forests, and a Petroleum Reserve. The Federal lands not specifically classified in this manner were administered by the Bureau of Land Management. At this time, B.L.M. had no organic act, and procedures were dictated by a "no management" or land disposal philosophy. Almost any human activity was permitted. The scope of human activities ranged from "living off the land" by hunting, fishing, and trapping, through recreational hunting, camping, hiking, logging, and both large and small scale mining.

In 1968, a vast petroleum field was discovered on the North Slope of Alaska at Prudhoe Bay. Prior to this discovery, the State of Alaska had been slowly selecting the 104.5 million acres to which it was entitled under the Alaska Statehood Act. Also, Alaska's Native peoples had made various claims based on their aboriginal rights and needs pursuant to continuing a "subsistence" lifestyle. The discovery of the Prudhoe Bay oil field changed the pattern of land claim settlements. The Natives saw that the oil would have to be transported to market, and that this could not happen until their aboriginal claims were settled. Consequently, they greatly expanded their claims, and filed them formally. When this happened, the Secretary of the Interior placed a "land freeze" on all Federal lands in Alaska. This meant there could be only limited land selection by the State of Alaska and virtually no disposition of Federal land until the Alaska Native Land Claims were settled. Hence, no pipeline could be built.

Given the necessity of transporting Prudhoe Bay oil to market, the so-called "energy crisis" which arose about that time and the hard winters in the midwestern United States, the Congress was readily convinced by the Native lobby, the oil lobby, the Alaska development lobby, and cold constituents throughout the country to make a rapid, generous settlement of the Alaska Native claims. The result was the passage of the Alaska Native Claims Settlement Act (ANCSA) on December 18th of 1971.

Roughly the terms of ANCSA were: (1) The Native peoples of Alaska were to receive $462,500,000 from the Federal government and $500,000,000 from the State of Alaska to be generated by leasing or production of leasable minerals (e.g. oil); (2) The Native peoples were to be granted title to 44,000,000 acres of land; (3) The State of Alaska was to be allowed to complete selection of its 104.5 million acres; (4) The Secretary of the Interior was directed to withdraw up to 80 million acres of the approximately 227 million remaining acres of Federal land for inclusion in the National Park, National Forest, Wildlife Refuge, and Wild and Scenic River systems (the "Four Systems"). In 1973, the Secretary of Interior made recommendations to Congress fulfilling this directive. Congress was to act on these recommendations within five years, that is by December 1978. Obviously, the Secretary of the Interior had little experience and expertise in deciding which Alaska Federal lands should be placed in which system of land management. Consequently, his recommendations reflected input by the Federal Alaska Planning team as well as many conservation and environmental groups. These recommendations represented long-term goals which had been defined for years by the National Park Service and the Federal Refuge System as well as the groups advising the Secretary. These groups also influenced the Secretary to expand on the 80 million acres stipulated in the ANCSA by adding areas of "ecological concern" around the lands designated for classification into the "Four Systems." These lands, an additional 45 million acres, were designated as "Public Interest" lands, and their inclusion was justified by a stated need for "ecosystem management." This was the situation at the end of 1973.

The lack of Congressional action upon the recommendations offered by the Secretary of the Interior in 1973 began to concern the conservation and environmentally oriented groups which had supplied the recommendations to the Secretary. As a result, several of these groups formed an umbrella group called the Alaska Coalition in April of 1976. The goals of the Alaska Coalition were initially the protection of wilderness, wildlife habitat and the subsistence lifestyle (Matz, pers. comm.). The operational plan of the Coalition was to write a bill detailing land classifications consistent with their views and have it submitted in Congress by a sympathetic legislator.

George Matz, an executive board member, said that the Coalition initially viewed the entire National Interest Lands question as one in which all user groups would co-operate to achieve mutual goals. That is, the Coalition envisioned that subsistence users, recreational hunters, and nonconsumptive wilderness users would work together for habitat preservation, a goal the Coalition construed to be in the best interests of all concerned. Matz has indicated (pers. comm.) that the Coalition approached all three groups for recommendations. The subsistence users, rural Alaskans most of which are Native, were very co-operative because they saw in this legislation a final opportunity to gain legal recognition of their subsistence lifestyle. Also, the legislation appears to be a means of gaining exclusive unregulated use of publicly-owned fish and game resources. This perception probably resulted from their experience with the Marine Mammal Protection Act under which the Federal government preempted control of marine mammal management from the State of Alaska which had enforced a conservative set of regulations. Under Federal control Natives were allowed exclusive and virtually unregulated use of marine mammals.

Another group, the nonconsumptive users (particularly the Park Service), eagerly co-operated with the Alaska Coalition. They provided data with which to justify the inclusion of much Alaska land within the National Park System.

According to Mr. Matz, the third user group, recreational or sport hunters, was contacted. Local sportsmen's clubs were invited to participate, but the response was negative. Generally, sportsmen viewed the Alaska Coalition as a group opposed to recreational hunting. This impression probably resulted from the participation of several members of the Alaska Coalition in various lawsuits related to wolf control programs by the Alaska Department of Fish and Game and their support for the Marine Mammal Protection Act. These activities were viewed by sportsmen as attempts to preempt or interfere with State management of resident wildlife species. Mr. Matz has stated this inference is contrary to the overall goals of the Alaska Coalition which favors State management of resident species if it acceptably meets the Coalition's goals.

Sportsmen, unlike the others providing input for the purposes of writing the land classification bill, did not see that they had anything to gain from the association. On the contrary, it appeared they had a good deal to lose. First, they viewed the Alaska Coalition as an anti-hunting group; secondly, they seemed unaware that despite almost 20 years of "traditional" use of the Federally-owned lands, these lands were the Federal government's to do with as it wished. Apparently, sportsmen believed that because they live in Alaska and have a history of using the land in question, their views should carry more weight than those of environmentalists, most of whom reside in the conterminous 48 states.

Partly because of the rejection of their initial invitation to hunters to participate and partly because of the anti-sport hunting bias of many of the members of the Alaska Coalition, the Coalition made no effort to include the needs of the recreational hunters in drafting its bill (HR 39), the Alaska National Interest Lands Conservation Act. Also, it should be understood that the Alaska Coalition favored the Park Service among the "Four Systems" because it had the most protective policy of land management, i.e. no hunting and no economic development. The Coalition did not view the State of Alaska as a good steward of wildlife habitat because of the developmental stance often endorsed by the State. The Federal Refuge system was the second choice because, even though it allows recreational hunting, it exists for the protection of wildlife habitat. The Forest Service was third and last choice because of its "unacceptable environmental record" in timber sales. Consequently, the National Park Service, because of its co-operation with the Alaska Coalition, its long-standing efforts to acquire more Alaska land, and the fact that it has the most restrictive policy on development and hunting, was nominated as the major recipient of lands when the Alaska Coalition wrote the Alaska National Interest Lands Conservation Act. This bill was subsequently introduced in the House of Representatives by Senator Morris Udall of Arizona and titled House Resolution 39. This bill is currently being debated in committee, and may be changed somewhat, but it seems certain that many of the recommendations of the Alaska Coalition are going to become law.

The influence of the National Park Service in the authorship of this bill is particularly important to Dall sheep and their management in Alaska. Because of the attractiveness of mountains to the Park Service, as well as for Dall Sheep, the Park Service may eventually control about 15 per cent of Alaska's land and more than half of Alaska's Dall sheep. In view of the National Park Service's policy and philosophy regarding hunting, and the "instant wilderness" designations in HR 39, it appears that more than half of Alaska's Dall sheep will become unavailable to hunters when the legislation is passed. The purpose of this paper is to detail traditional use patterns by Dall sheep hunters and to predict the impact of the impending land classification changes on Dall sheep hunting, management and research in Alaska. Future management options will also be discussed.

MATERIALS AND METHODS

Several assumptions are necessary in predicting the effect of the changes in land classifications. They are listed below:

1. The final boundaries for proposed additions to the National Park Service and Federal Refuge System will be drawn as a compromise between the Udall bill (HR 39) and the position taken by Alaska Governor Jay Hammond, Senator Ted Stevens, and Congressman Don Young. I have <u>arbitrarily</u> assigned such boundaries for purposes of this paper. An unanswered question is whether there will be an appreciable sheep harvest in the Wrangells-Saint Elias National Park/Preserve. Preserves are open to recreational hunting and mineral exploration. For purposes of simplicity I have assumed there will not be a significant opportunity to hunt Dall sheep in this area. This assumption follows the boundary lines of the original House Resolution. A committee substitute offered in January 1978 would greatly ameliorate the reductions expected. It is currently impossible to predict the outcome with any certainty. Murphy and Dean (1978) deal with these possiblilities.

2. Lands entering the Federal Wildlife Refuge System will continue to be open to hunting as they have been in the past.

3. Hunting will not be allowed in National Parks and Monuments but will be allowed in Preserves.

4. Wilderness area management will continue to allow traditional motorized access.

5. Hunter composition by residency, distribution and intensity for

the year 1976 was typical of traditional Dall sheep hunter patterns. There has been a small year-to-year variation in hunting pressure among mountain ranges and habitats, but 1976, being the most recent year for which reliable data are available, will be used. There is little chance that significant changes will result even if this assumption is not correct.

Levels of harvest, hunter use and the cost in dollars were determined by tabulation of information furnished on hunter report cards required by the Alaska Department of Fish and Game. In 1976, there were 497 non-resident sheep hunters in Alaska. The cost of a non-resident license was $60 and a Dall sheep tag was $250. This produced a license and tag sale of $154,000 which, when matched by Federal funds under terms of the Pittman-Robertson Act, provided the Department of Fish and Game $616,000 for management purposes in Alaska. A non-resident Dall sheep hunter usually spends about $250 per day hunting, and most guides book 10-day hunts. Hence, non-resident sheep hunters pay approximately $1,240,000 per year to guides for hunting sheep. In 1976, there were 2,667 resident sheep hunters who averaged 5 days per hunt. A conservative estimate of the cost of resident sheep hunting is $60 per day; therefore, residents spent about $800,000 on sheep hunting. Of course, each of these residents purchased a $12 license for a total license sale of $32,000, making possible an additional $128,000 of Pittman-Robertson money to be spent in Alaska. Also, Alaska Department of Fish and Game estimates of the number of sheep processed into trophy mounts in Alaska is about 500 rams per year. At a price of $300 per head this comes to another $150,000 generated by recreational hunting of Dall sheep each year. Adding these figures gives the following:

Non-resident license and tag fees plus potential matching Pittman-Robertson funds	=	$ 616,000
Resident license fees plus potential P.R. funds	=	128,000
Money paid to guides by non-resident clients	=	1,240,000
Money spent by resident Alaskans hunting sheep	=	800,000
Money spent on taxidermy of sheep in Alaska	=	150,000
Total money spent in Alaska on Dall sheep hunting	=	$2,934,000

Dall sheep hunting in Alaska is a $3,000,000 per year industry.

RESULTS

Table 1 shows the estimated sheep population (Heimer and Smith, 1975), normal harvest, and hunter use in each of the proposed additions to National Parks, Monuments, Preserves, National Wildlife Refuges and Ecological Preserves.

This table also gives the absolute magnitude and relative percentages of the normal Alaskawide harvest for each area. If National Interest Lands withdrawal and classification occur as anticipated, the reduction in harvest of Dall rams in Alaska will be 450 to 500 animals and the number of displaced hunters will be about 1000. This translates to

Table 1.

Location	Harvest (1976)	Hunters (1976)	% Statewide harvest	% Statewide hunters	Sheep population (estimated)
Wrangell-St. Elias Park	322	954	29	23	12,000
McKinley Park extension	40	60	4	2	1,000
Lake Clark Park	30	63	3	2	1,000
Noatak Ecological Preserve	38	68	4	2	1,000
Gates of the Arctic Park	52	110	5	3	3,000
Total expected reductions	482	1055	45	32	18,000
Arctic National Wildlife Range	79	118	7	4	8,000

about 40 per cent decrease in harvest and a disruption of about one-third of the hunter effort. Table 1 also shows that approximately 18,000 of Alaska's estimated 40,000 (Heimer and Smith, 1975) sheep will be unavailable to sheep hunters.

DISCUSSION

It is apparent that there will be a drastic reduction in hunting opportunity for Dall sheep in Alaska when the withdrawal of lands slated for nonconsumptive management is completed. The effects may be a reduction in hunter effort, an increase in hunter pressure on remaining habitat, or a combination of the two. It is impossible to predict what sort of mix might occur so I shall discuss each situation individually.

Decreased Hunter effort: If, as shown in Table 1, there is a decrease of one-third in hunting resulting from reclassification of sheep habitat into National Parks, a loss of revenue to the State of Alaska from sheep hunting will occur. If the approximately 1000 displaced sheep hunters do not hunt and do not purchase licenses and tags, a proportionate reduction in the amount of money spent on sheep hunting would occur. This might be as high as 33 per cent or an annual loss to the Alaskan economy of about $1,000,000 excluding commercial air fare.

If the possible maximum reduction in hunting opportunity discussed above should occur other losses would follow. Typically, the resident-non-resident composition of the 1000 displaced hunters would be 300 non-residents and 700 residents. A loss of 300 non-resident hunters would result in a loss of $93,000 annually to the Fish and Game License Fund. Because of the methods of allocating Pittman-Robertson monies for fish and wildlife restoration there would not be an immediate decrease in operating funds for the Alaska Department of Fish and Game. However, withdrawal of vast acreages from hunting will eventually limit the opportunity to participate in hunting so that the long-term effects are certain to be an erosion of the funding base for fish and wildlife restoration funding.

Sustained hunter effort: If hunter effort remains the same as it has for the last several years, another set of circumstances could arise. Alaska has been totally "discovered" by Dall ram hunters. That is, there are no longer any large unexploited areas which can absorb increased hunter pressure. This means that the 1000 displaced sheep hunters have no place to go that is not already hunted. Several areas have had low hunter pressure in the recent past, but these are included in the proposed withdrawals. With harvest already approaching or exceeding the annual increment of legal rams in many areas and the possibility of an approximate "increase" of 32 per cent which will have to be absorbed, something will have to be done to preserve the desirable human aspects of sheep hunting.

Presumably the biological aspects are being protected by harvesting only mature males. The only way to preserve the desirable human experience in sheep hunting will be to limit participation. This will probably take the form of more active and restrictive management practices.

It has been the experience of the Alaska Department of Fish and Game that attempts to limit hunter participation by any means other than permits have been notable failures. Consequently, the most productive approach will be to increase the number of special permit hunts offered, thereby reducing the number of people involved. The Alaska Dall sheep management plans (Alaska Department of Fish and Game, 1977) partially address this problem. These plans identify three different management goals. First, in areas having high-quality sheep populations which will still be available for hunting, very restrictive management is anticipated. In these areas the Department of Fish and Game is seeking to provide high-quality hunting experiences for trophy rams. Such areas will have a limited harvest and limited hunter participation with only large, old animals, usually full curl rams, defined as legal.

The management plans call for two such management areas having very high-quality populations of Dall sheep. One area, the Tok Management Area, is already under this system of management and has proven highly acceptable to the public. The other area, the southeast corner of the Wrangell Mountains, is unique among Dall sheep ranges, having by far the highest quality populations in Alaska (Heimer and Smith, 1975). This area, from the Nizina River to the Canadian border north of the Chitina River, is currently scheduled for inclusion in the Wrangells-Saint Elias National Park. Because of the extremely restrictive type of Dall sheep management planned here (a maximum harvest of 30 full curl rams per year taken by approximately 60 hunters - a mean maximum density of 1 hunter per 20 mi^2 - all of which would have to reach the area by aircraft) the biology of Dall sheep populations managed under this scheme would be indistinguishable from that of fully protected sheep within the Park; and the impact of Dall sheep hunters would be undetectable. Allowing sheep hunting in this section of the Park or including it in the Preserve with wilderness designation would allow limited numbers of Dall sheep hunters a unique experience in this area and the cost to the goals of the Alaska Coalition would be nothing except to gain the good will of sportsmen throughout the world. Of course, the same argument could be made for any area where restrictive management is enforced. Attention is directed to this area because of its ability to produce the largest - horned Dall rams in the world, the very restrictive management planned, and the scarcity of other big game species in the area.

The second management goal is that of providing for hunting under aesthetically pleasing conditions. This means that a limited number of hunters would be allowed to participate, but the number would be greater than in the scheme described above. Generally, legal rams would be defined at a lesser size than in the trophy management areas and harvest levels would approach annual increments of rams into legal age classes.

The third management goal described in the long-range plans is that of maximum opportunity to hunt. Generally areas where this goal will be in force are considered "sacrifice" areas where anyone may hunt for legal rams of designated minimum size. There would be no limit on human participation, and the virtue of these areas, if any, would be that anyone who desires to hunt sheep will always have the opportunity even under less than ideal conditions. We currently envision little in the way of transportation restrictions or limitations on means as long as they are traditional. These areas generally should contain high density, low-quality populations, and the possiblility of either sex hunting may be considered.

It is unlikely that hunter pressure will remain constant, or a decrease corresponding exactly to that of the decrease in available sheep habitat will occur exclusively. Should a combination of these occur, the problems of Dall sheep management in Alaska will be compounded. In all likelihood there will be some decrease in hunter effort (with the attendant decrease in funding) as well as increasing pressure requiring increasingly active sheep management programs which will be underfunded. In short, the Alaska Department of Fish and Game will have more responsibility and less money.

An additional irony involved in the Alaska National Interest Lands Act will be that the taking of Dall sheep allowed on the lands scheduled for inclusion in the in the National Park System will be only that allowed for subsistence. This is ironic because Dall sheep have never been able to sustain the intense level of harvest required for subsistence. Campbell (1974) argued that aboriginal subsistence use of Dall sheep resulted in their near extinction throughout the Brooks Range in the late 19th and early 20th centuries. Certainly, commercial market hunting has resulted in depletion of Dall sheep in the past, and recent accounts of diminishing Dall sheep populations in the western Brooks Range correlate closely with intense local use of Dall sheep in a subsistence lifestyle.

It may be argued that because Dall sheep are consumed as food they are used for subsistence; if this argument is valid all Dall sheep taken by sport hunters are by definition taken for subsistence.

The most common justification of present day "subsistence" Dall sheep use is that it is necessary for maintenance of the culture of the villagers of Kaktovik on Barter Island on Alaska's north coast. These villagers usually take large numbers of Dall sheep in late winter from the Arctic National Wildlife Range. These sheep are not required as food, but the hunt is a pleasant late winter diversion. This appears to be as much a matter of recreation as survival. Because Dall sheep are incapable of contributing significantly to human sustenance over the long haul, I think that their taking by rural Alaskans has always been a recreational venture as well as one of protein and skin acquisition. Consequently, I think it ironic that efforts to protect the subsistence lifestyle have classified an animal which has been "sport hunted" throughout history as a component reserved for present day "subsistence." Trophy management as described earlier would certainly have less impact on Dall sheep populations in the proposed National Parks than subsistence hunting.

Mr. Matz, in making the point that the Alaska Coalition is not anti-hunting, pointed to the Coalition's recognition of subsistence hunting in the proposed National Parks. This will require a substantial change in management philosophy on the part of the National Park Service in the name of "subsistence" which will be far more detrimental to Dall sheep than closely regulated recreational hunting. The question of why the National Park Service is willing to accept "subsistence" hunting which will have a far greater impact on the wildlife within the National Parks yet is unwilling to accept recreational hunting which can be regulated to have no effects remains to be answered.

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FORAGE PRODUCTION AND UTILIZATION OF A DALL SHEEP WINTER RANGE, SOUTHWEST YUKON TERRITORY

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ABSTRACT

Estimates of net primary productivity, amount of winter carry-over, and utilization rates are presented for "Sheep Mountain", a well-known Dall Sheep winter range in Kluane National Park, southwest Yukon Territory. Forage production is shown to be dependent on precipitation during the growing season, rather than on favourable temperatures. Soil moisture deficiencies determined the end of the growing season in all plots, except those established at alpine elevations. Forage production in the eight exclosure plots varied from 41.0g to 120.1g oven dry weight per square meter and utilization rates by sheep varied from 0.0% to 48.4%. Data based on 3 years observation indicate that the number of lambs born as well as the number of lambs surviving to yearling age are positively correlated with forage production on winter range. The adverse effects on range and sheep of recently introduced feral horses is commented on.

INTRODUCTION

The net productivity data and sheep utilization rates presented in this paper are portions of a larger investigation on Dall Sheep and their habitat, most of which is contained in a Ph.D. dissertation (Hoefs, 1975).

The study area is "Sheep Mountain", located near the center of the newly established Kluane National Park, southwestern Yukon Territory (Figure 1 & 2). For a long time this mountain has been known to support a high density of Dall Sheep during winter, and the unofficial name "Sheep Mountain" was given to it for that reason. During the period of our intensive research 1969 to 1973, the adult population of sheep remained fairly stable at about 200 during winter on this 23.6 square km area, of which less than 16.5 square km are actually sheep habitat. This entire project was meant to document some of the factors responsible for explaining this high carrying capacity in a sub-arctic location. Information on vegetative cover, climate and population dynamics of sheep are contained in Hoefs (1975) and Hoefs et al. (1975).

This paper deals specifically with the net productivity of this winter range and the utilization rates by sheep. It documents that this range is occupied at carrying capacity level, using accepted standards, that sheep adjust to fluctuations in forage production from one year to the next - which are most likely correlated to rainfall during the growing season - by varying their lamb crops and by suffering heavier lamb mortalities during winters of food shortage. Lastly, it explains the importance of competition of feral horses and predicts a decline in the sheep population if grazing by horses continues.

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METHODS AND MATERIAL

Eight exclosures were established on Sheep Mountain, Kluane National Park, Yukon Territory, at various altitudes and aspects of its large southeast facing slope. These exclosures were established on dry grassland sites, which were known to be important winter ranges of a Dall Sheep population of approximately 200 adults.

Each exclosure was about 15 meters by 15 meters in size. Beside it was established an equally large "check plot" with comparable vegetation cover. The exclosure was protected from grazing by sheep through a 6-foot high, 7-strand barbwire fence. The check plot was open to grazing.

The overall vegetation cover was determined through synecological methods of the Zurich-Montpellier school (Braun Blanquet, 1951), and after eight appropriate sites of sufficient size had been located, detailed foliage cover was determined by dividing a one meter square frame into 100 quadrats to compute foliage cover to the nearest 1%. This wooden frame was moved 1.2 meters at the time along the contour for 10 "replicates" and subsequently downhill for 10 "blocks" by 1.3 meters at a time. Each exclosure therefore contained 100 one meter square quadrats separated from each other by .2 and .3 meters respectively to avoid "border effects" and to leave room for walking. Each quadrat was marked with wooden stakes.

The same analytical method was used for the accompanying plot "outside" the exclosures. The exclosures were established during the summer of 1969 and net productivity was estimted 5 times subsequently to determine forage production, winter carry-over, and utilization rates of sheep on the following dates: a) during the last week of August or the first week of September in 1969, 1970 and 1971, to determine net productivity during those seasons and b) during the last week of April of 1970 and 1971, to determine winter carry-over from the previous season. At each harvesting date, 10 replicate quadrats were clipped to about one-half inch above ground level according to a "randomized block" design. This meant that it was predetermined that each of the 10 quadrats would fall into a different horizontal row, but within the rows the selection was random.

At each clipping date both plots of the pair (the exclosure and the open plot) were harvested. The forage was temporarily stored in paper bags and subsequently oven-dried to constant weight at 105°C. The utilization rate by sheep (minimum rate) was determined by calculating the differences between winter carry-over inside the exclosures and the open check plots. Prior to the harvest of September, 1970, and September, 1971, old vegetation matter inside the exclosures was removed.

In addition to floristic composition and foliage coverage, some physical parameters were determined for each plot. These were : altitude, aspect, slope, some characteristics of the soil as well as temperature and precipitation during the growing season.

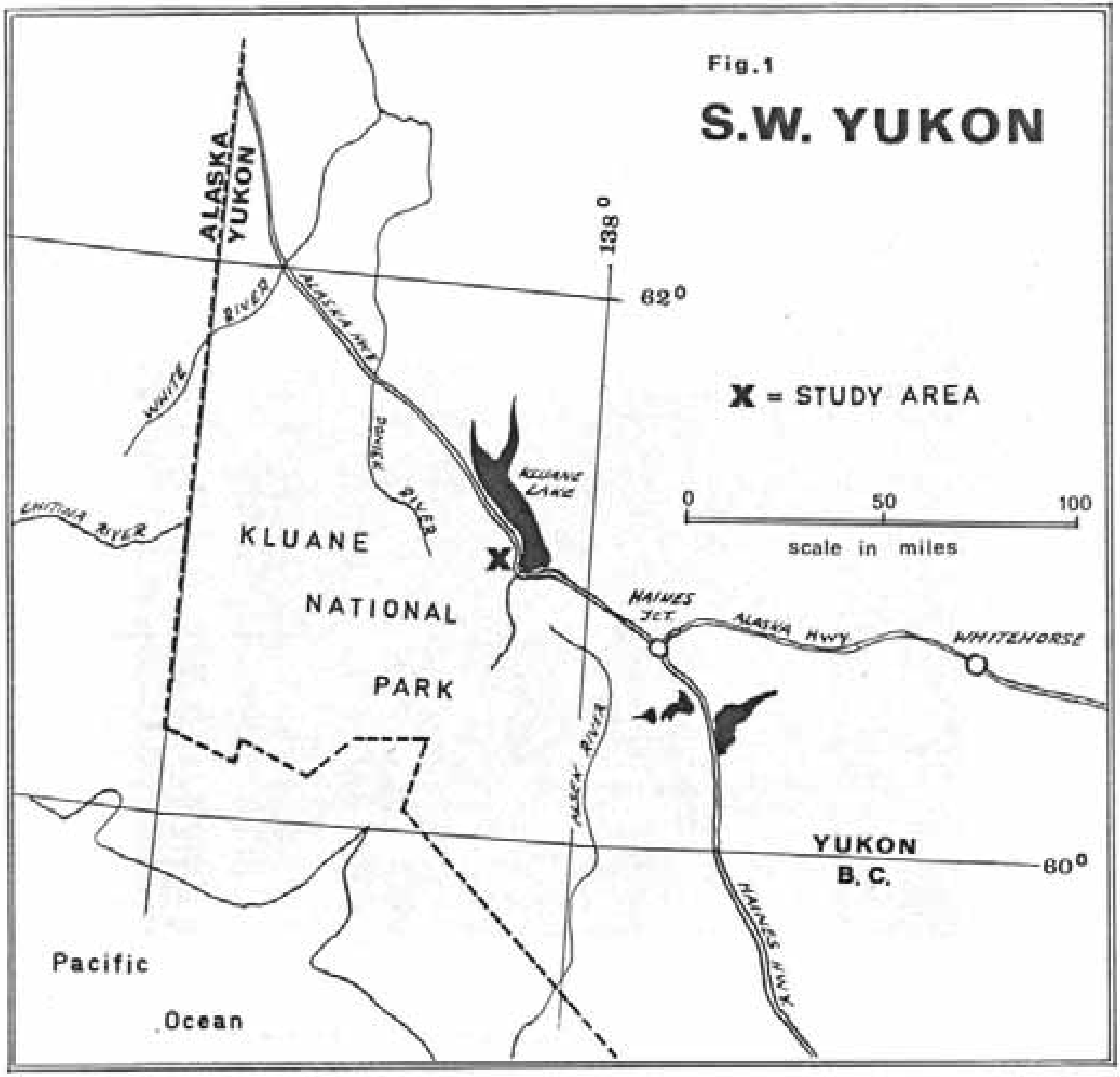

Figure 1: Map of the southwestern Yukon showing the study area at the southwest corner of Kluane Lake in the newly-established National Park.

Figure 2: Oblique aerial photograph of study area. Sheep Mountain, in centre of picture, is surrounded by areas of low relief, giving it high exposure to sunshine and wind. The locations where grazing plots were established are indicated by numbers.

Since these azonal soils have no profile development a composite soil sample was taken from four locations around each plot according to soil depths as follows: 0 - 20 cm, 21 - 40 cm, and 41 - 60 cm. Some physical and chemical analyses were done of these samples in the Department of Soil Science, University of British Columbia, according to standard procedures.

Each pair of plots was equipped with a thermograph (Cassela Inst. Ltd., London, England) and maximum and minimum thermometers set up in Stevenson screens according to D.O.T. regulations, as well as with two standard rain gauges. These instruments were maintained only during the 1970 and 1971 growing seasons and they were checked at weekly intervals.

RESULTS

a) Exclosure plots:

Even though it was intended to establish three plots each in the boreal, sub-alpine and alpine vegetation zones on sites with southeastern, southern, and southwestern aspects, such a systematic experiment was not possible for lack of suitable sites.

To be able to accommodate the exclosure and the test plot a site had to be at least 15 meters by 30 meters in size, and it had to be uniform in vegetative cover, aspect and slope, and could not contain large boulders, windfalls, and ground squirrel colonies. These restrictions considerably limited the number of potential sites.

Only 8 plots were established in the locations indicated on Figure 2. This photograph also gives a good impression of the physiography and general setting of the study areas on Sheep Mountain.

Table 1 lists some physical characteristics of these plots and summarizes their vegetation cover. All plots were established on exposed, windblown ridges, which are largely snow-free in winter and provide the bulk of the winter forage for the sheep population. Only two of the plots (#7, #8) were located at alpine elevations, and two others (#4, #5) were established at the transition zone between the boreal and subalpine vegetation zone. The remaining ones (#1, #2, #3, #6) were located at fairly low elevation in the boreal zones (Figure 2).

The species composition is similar in all plots, but there is a change in dominants as well as in total vascular vegetation cover with altitude which gave rise to the grouping of the vegetation in these plots into three different plant associations. With the exception of *Linum perenne* all of the abundant vascular plants in these plots are known to be eaten by sheep (Hoefs, 1975). On the other hand, intentional feeding on the few mosses and crustose lichens of the plots has not been observed.

With the exception of plot #2, all are characterized by a high percentage of bare soil. In plot #2, most of the bare soil is stabilized by an almost continuous cover of crustose lichens. These lichens

Table: 1

Physical characteristics and floristic composition of plots.

Plot Number	1		2		3		4		5		6		7		8	
Elevation (feet)	2640		2670		3080		3840		3610		3310		5320		5260	
Aspect	120°		176°		240°		168°		180°		236°		90°		226°	
Slope	-20°		-26°		-26°		-21°		-16°		-20°		-18°		-26°	
Treatment	a	b*	a*	b	a*	b	a*	b	a*	b	a*	b	a	b*	a	b*
Artemisia frigida	2.6**	3.5	7.8	9.7	5.7	6.6	15.1	13.3	4.1	5.8	10.1	8.1	14.9	6.6	5.1	3.0
Carex filifolia	8.9	9.9	3.6	4.3	7.2	6.8	4.3	2.4	9.3	7.3	1.3	4.0	6.7	11.0	20.7	13.0
Agropyron yukonense	3.0	3.3	0.6	0.9	0.5	0.7	4.4	3.2	1.8	4.7	3.4	2.5	-	-	P	-
Calamagrostis purpurascens	1.3	0.7	-	P	0.3	0.9	0.6	0.7	6.7	4.1	1.3	4.1	5.1	9.8	2.0	3.4
Oxytropis viscida	0.1	P	1.2	1.9	0.1	0.5	2.2	4.0	3.1	1.2	4.9	4.4	13.1	9.7	1.6	1.8
Erigeron caespitosus	0.3	P	1.5	1.4	1.7	1.7	0.6	0.3	0.6	1.3	0.6	1.1	-	P	0.7	0.4
Artemisia rupestris	-	-	0.4	-	-	-	6.3	10.4	5.9	3.9	-	-	-	-	4.4	9.2
Poa glauca	0.2	0.1	-	-	-	-	0.1	0.1	P	P	-	-	1.2	1.0	3.7	2.3
Pentstemon gormanii	-	-	1.5	1.8	0.2	0.1	0.7	0.5	-	P	-	-	-	-	-	-
Potentilla hookeriana	-	-	-	-	0.1	P	-	P	P	-	-	-	0.3	0.4	P	P
Aster alpinus	-	-	P	P	-	-	0.2	P	P	P	P	-	-	-	P	-
Linum perenne	-	-	0.2	0.5	0.5	0.3	-	-	-	-	-	-	-	-	-	-
Plantago canescens	5.2	4.4	-	-	-	-	P	P	-	-	-	-	-	-	-	-
Artemisia hyperborea	-	-	-	-	-	-	-	-	-	-	-	-	0.8	3.3	P	P
Pulsatilla patens	0.1	P	-	-	-	-	P	-	-	P	-	-	-	-	-	-
Minuartia rossii													0.2	2.4		
Eurotia lanata					0.3	0.4										
Lappula myosotis							P					P				
Chamaerhodos erecta					P			P								
Arabis holboellii				P		P										
Senecio conterminus						P										
Townsendia hookeri				P												
Antennaria rosea							P									
Comandra umbellata					P											
Orobanche fasciculata											P					
Total vascular vegetation cover (%)	21.7	22.0	16.8	20.5	17.5	18.0	34.5	34.9	31.5	28.6	21.6	24.2	42.3	44.2	38.2	33.1
Lichens ***	27.0	25.0	56.0	56.2	0.4	0.7	1.0	3.0	1.0	0.2	2.4	3.8	0.2	0.5	0.2	0.3
Mosses ****	0.5	0.1	0.6	0.5	0.5	0.4	3.0	4.0	P	P	1.3	5.7	P	2.3	P	0.1
Bare Soil	49.8	52.9	26.6	22.8	81.6	80.9	61.5	58.1	67.5	71.2	74.7	76.3	57.5	53.0	71.6	76.5
Association name after Hoefs et.al (1975)	Pentstemono (gormanii) - Artemisio (frigidae)-Agropyretum yukonensis		Pentstemono (gormanii) - Artemisio (frigidae)-Agropyretum yukonensis		Pentstemono (gormanii) - Artemisio (frigidae)-Agropyretum yukonensis		Agropyro (yukonensis) - Artemisietum frigidae-rupestris		Agropyro (yukonensis) - Artemisietum frigidae-rupestris		Pentstemono (gormanii) - Artemisio (frigidae)-Agropyretum yukonensis		Oxytropo (viscidae) - Artemisio (hyperboreae-frigidae) - Caricetum filifoliae		Agropyro (yukonensis) - Artemisietum frigidae-rupestris	

* enclosed plots

** foliage cover expressed as percent (P= present in insignificant amounts)

*** The following species contributed to lichen cover: Dermatocarpon hepaticum, Lecidea rubiformis, Lecanora lentigera Caloplaca cirrochroa, Lecidea decipiens, Buellia epigaea.

**** The following species contributed to moss cover: Tortula ruralis, Hypnum vaucheri, Barbula icmadophila.

are very fragile and brittle, particularly during dry conditions, and are easily destroyed by tramping. This is the reason why they occur only as remnant cover values in all the other plots which are heavily used by sheep. Plot #2 was not used by sheep, most likely because of lack of escape terrain nearby.

b) Weather and Climate:

In spite of its short distance of only eighty miles from the Pacific Ocean, the climate of the Kluane area is definitely continental. The St. Elias Mountains and the Coast Mountains serve as an effective barrier against the penetration of moist, warm air from the Pacific. Winters are cold and clear, while summers are pleasant, but short. The area lies in the rain shadow of the St. Elias Mountains and it has been classified as approaching semi-arid (Taylor-Barge, 1969; Kendrew and Kerr, 1955). The mean annual temperature is around -4 C and the total annual precipitation varies between 18 and 25 cm. Characteristic for this latitude are the long summer days and long winter nights. Most precipitation falls during the summer months. Snow depths in winter are one foot to two feet and drifting is prevalent. In winter the precipitation results from air movements across the St. Elias Mountains from the Gulf of Alaska. Summer rain storms, usually generated in interior Alaska or continental Canada, tend to track westward or southeastward and spend their moisture against the eastern flank of the St. Elias Mountains (Neilson, 1972). For this reason, exclosures established on the east side of the mountain (#1, #4, #7) get significantly more rain during the growing season than those established on the west side (#3, #6, #8).

Local modifications of this regional climate include temperature moderations because of the proximity of Kluane Lake, a high degree of direct insolation because of the areas of low relief surrounding Sheep Mountain, and exposure to strong west winds which often carry with them large amounts of airborn silt (loess) and have greatly affected the soils in the area (Hoefs et al., 1975).

Temperature and precipitation data measured during the 1970 and 1971 growing season in each of the eight exclosure plots are summarized in Table 2. This table gives the maximum, minimum and mean temperatures per plot per month, as well as the total precipitation values are also given for the entire season and for all plots per month.

As is obvious from the temperature data in both years, the expected negative correlation of temperature and altitude is not apparent except for the two alpine stations (#7, #8), which have significantly lower temperatures than the other stations. Of the remaining stations #3 and #5 have generally higher temperatures, in spite of the fact that they are located at greater altitudes than for instance #1 and #2. This can be explained by the fact that they were located on large, open areas with southern exposure, while stations #1, #2, #4, are subject to shading for a considerable portion of a day, because of aspect, local terrain type and proximity to forest stands.

Table 2: Temperatures (C°) and precipitation (cm) during the growing season.

Period	Monthly Temp. °C	Plot# 1	2	3	4	5	6	7	8	$\bar{\bar{x}}$ or Σ
May 1970	h	14.4	15.0	18.3	20.0	17.2	17.8	11.1	7.2	
	l	-2.8	-2.2	2.2	1.1	1.1	-1.7	-12.2	-10.0	
	$\bar{x}$	7.8	7.9	9.0	7.3	8.3	7.9	-2.3	-1.3	5.6
	ppt.	3.30	3.22	2.54	3.99	3.40	3.33	3.02	2.51	3.18
June	h	16.7	17.8	20.0	17.8	17.2	18.3	11.1	15.0	
	l	2.8	1.1	1.1	-0.6	2.8	-0.6	-5.0	-0.6	
	$\bar{x}$	9.0	9.1	10.3	7.7	10.2	7.8	1.9	5.6	7.6
	ppt.	1.35	1.80	1.09	2.18	2.06	1.96	1.88	1.32	1.70
July	h	22.8	23.3	22.2	21.7	22.2	23.3	18.3	17.8	
	l	2.8	3.9	3.9	0.0	5.6	1.1	-2.2	3.3	
	$\bar{x}$	10.4	10.9	11.2	8.9	12.9	9.9	6.4	4.9	10.6
	ppt.	3.71	3.78	3.91	4.64	4.90	3.83	4.52	3.83	4.14
August	h	20.0	20.6	19.4	18.9	21.1	20.0	16.1	18.3	
	l	1.7	1.7	5.0	0.6	3.9	2.8	0.6	-1.1	
	$\bar{x}$	9.9	9.8	10.3	8.0	11.6	9.2	6.5	5.8	8.9
	ppt.	1.04	0.66	0.28	1.14	1.02	0.64	1.55	1.12	0.94
average temperature		9.3	9.4	10.2	8.0	10.8	8.7	3.1	3.8	
total precipitation		9.39	9.47	7.82	11.96	11.38	9.75	10.97	8.79	9.96

		Plot# 1	2	3	4	5	6	7	8	$\bar{\bar{x}}$ or Σ
May 1971	h	13.9	15.0	12.8	13.3	12.2	14.4	8.9	7.2	
	l	-4.4	-3.9	-5.6	-7.8	-3.3	-6.7	-10.0	-11.1	
	$\bar{x}$	4.9	4.6	3.8	1.6	3.9	1.2	-1.4	-1.3	2.2
	ppt.	0.03	0.03	0.26	0.0	0.0	0.36	0.0	0.0	0.10
June	h	21.7	22.2	21.1	22.2	18.9	21.7	18.3	20.6	
	l	0.6	2.2	1.1	-3.3	3.9	-1.1	-2.8	-4.4	
	$\bar{x}$	12.1	11.7	11.9	9.4	12.3	11.0	7.7	6.4	10.3
	ppt.	3.75	3.75	3.30	5.46	5.21	4.50	4.90	4.93	4.47
July	h	26.1	26.1	25.0	23.9	24.4	25.0	21.7	20.0	
	l	4.4	3.9	3.3	2.2	2.8	3.3	1.7	-1.7	
	$\bar{x}$	13.9	14.2	13.6	11.6	14.6	13.9	10.5	9.1	12.7
	ppt.	0.46	1.09	0.41	0.96	1.35	0.61	1.32	1.12	0.91
August	h	25.6	27.2	25.6	24.4	25.6	26.7	22.2	23.3	
	l	3.3	4.4	6.7	3.3	5.0	5.6	0.0	0.0	
	$\bar{x}$	12.1	12.6	11.7	11.1	12.1	12.2	8.3	7.6	11.0
	ppt.	4.57	2.76	3.35	5.38	3.78	3.35	6.14	3.53	4.11
average temperature		10.8	10.8	10.3	8.4	10.7	9.6	6.3	5.4	
total precipitation		8.81	7.64	7.34	11.81	10.34	8.81	12.37	9.58	9.55

As is expected for a continental location, only stations in the boreal zone reach mean monthly temperatures of around 10°C during June, July and August. Maximum temperatures were generally between 20°C and 25°C and only reached 27°C once (#6 in August, 1971). Most stations are exposed to freezing nighttime temperatures during May, while the alpine stations can expect frost during any month. Also obvious is the fact that the temperatures throughout August were favourable for growth, in spite of the fact that many species have terminated their growing season before that time (Hoefs, 1975). Precipitation amounts approached 10 cm on the average but considerable differences were observed between the plots. Reference has already been made to the fact that those stations located at the eastern flank of the mountain (#1, #4, #7) received in both years more rain than those located at the west side (#3, #6, #8) because of the local weather patterns. Plots #2 and #5 are in an intermediate position in both respects.

The exclosure plots, except for #7, #8, derive their soil moisture almost entirely from rainfall during the growing season since they are located on exposed, dry ridges where wind removes the snow cover and where there is very little sub-surface seepage from above. It is, therefore, not surprising that there is a good correlation between biomass production and precipitation during the growing season not only between the different plots, but also on the same plot in different years with different rainfall.

The weather data for these two seasons show some distinct differences which appear to have affected the length of the growing season and the forage production.

While the total precipitation amounts are only slightly less in 1971 with 9.55 cm, compared to 9.96 cm in 1970, the distribution pattern was quite different. In May, 1970, the total rainfall averaged 3.18 cm and the temperature was very mild with a mean value of 5.6°C. In contrast, May, 1971, received only 0.10 cm precipitation and the mean temperature was fairly cool with 2.2°C. Investigation by the writer indicate (Hoefs, 1975), that almost 50% of the growth in the boreal zone takes place during May in an average year. The above-mentioned differences resulted in the growing season of 1971 being delayed by 10 to 14 days in a phenological sense compared to 1970 and revealed themselves in a decreased biomass production. This difference could not be compensated for by more favourable conditions during August, 1971, compared to 1970 (1971: temp. 11.0. C, ppt. 4.1 cm; 1970: temp. 8.9 C, ppt. 0.94 cm). The growing season is essentially terminated in the early part of August in most species, particularly at higher elevations, and favourable weather conditions at that time can only affect seed production and carbohydrate storage in the subsurface organs of plants.

c) Soils:

No soil survey has been done in the study area. Day (1962) did a reconnaissance in the Takhini and Dezadeash valleys, some 40 and more miles southeast of Sheep Mountain. Day (1962) states that because of the youth of the soil material and the dry, cool climate, most soil profiles are weakly developed. This applies even more to the study area where continuous loess deposition does not allow leaching and profile development. The soils can therefore be described as juvenile and azonal and they would be classified as Regosols.

Our study was not intended to be a detail soil reconnaissance; the composite samples taken were primarily meant to detect gross differences between plots, which could explain differences in vegetation cover and forage production. Such differences were not observed. All soils are loamy in texture and are characterized by lack of profile development. The pH is alkaline, the organic carbon content is very low and the calcium content is very high. Some differences exist between the soils of the boreal zone as compared to the alpine zone. The thickness of loess deposition is influenced by exposure to wind and altitude. Areas at low elevations facing the prevailing winds from the west may be covered by two to three feet of loess. With increasing altitude this loess layer decreases in thickness and the amount of coarse matter (mainly colluvial in nature) incorporated into the loess increases. This is very obvious in sub-alpine elevations (plots #4 and #5). Alpine soils (for instance plots #7 and #8) developed primarily from bedrock weathered in place or from thin drift deposits. But even at this altitude windblown material is being deposited and incorporated into the soils during strong dust storms.

d) Forage production and utilization:

Production is here limited to the "above-ground" portion of plants. Table 3 lists the production, expressed as grams oven-dry weight per square meter, for the three seasons (1969, 1970, 1971) and the winter carry-over after the 1969/70 and 1970/71 winters. As is obvious from Table 3 the production figures in 1969 from the exclosures and their check plots are comparable, while considerable differences were found between some of the plots. An error was introduced by the low production figure of 38.4 gr/m^2 for plot #8a in 1971. A band of sheep had returned to the winter range unexpectedly early and removed some forage before it was clipped. Since soil and temperature data in all but the alpine stations are very similar, it appears that rainfall during the growing season is an important factor in determining forage production. Plots with the highest rainfall (#4, #5) also had the highest production, while the plot with the least precipitation had the least production. That this assumption may be correct is borne out of the fact that all plots but one (#5) had a higher production in 1970 when the rainfall was higher and better distributed than in 1971 when total precipitation was less and concentrated toward the end of the growing season. No climatic data were collected in 1969, but nearby weather stations recorded "an average season", very similar to that in 1971.

These assumptions do not appear to apply to the alpine stations (plots #7, #8). Their growing season is considerably shorter, and moisture deficiency does not seem to be a limiting factor. Lower temperatures and higher humidity will result in a lower evaporation rate

Table: 3 __Forage production and utilization.__

Plot #		Treatment [1]	1969 Production [2]	Winter Carry-over [3]	Percentage Remaining [4]	Percentage used by Sheep [5]	1970 Production	Winter Carry-over	Percentage Remaining	Percentage used by Sheep	1971 Production
1	a	o	59.0 ± 19.0	28.6 ± 9.5	48.4%	32.3%	57.5 ± 6.9	29.3 ± 5.4	51.0%	13.9%	37.3 ± 9.8
	b	e	56.9 ± 6.5	45.9 ± 8.0	80.7%		70.4 ± 13.1	45.6 ± 11.1	64.9%		51.3 ± 10.0
2	a	e	65.9 ± 19.9	56.8 ± 17.6	86.2%	-0.2%	72.3 ± 19.7	57.5 ± 17.5	79.5%	-1.2%	49.8 ± 14.9
	b	o	58.8 ± 21.1	50.9 ± 25.3	86.4%		75.4 ± 18.4	60.8 ± 19.5	80.7%		48.5 ± 15.3
3	a	e	41.0 ± 9.4	30.6 ± 10.6	74.6%	48.4%	70.2 ± 16.2	51.9 ± 19.0	74.0%	34.8%	58.6 ± 35.8
	b	o	45.9 ± 12.9	12.0 ± 6.9	26.2%		61.1 ± 31.7	23.9 ± 14.3	39.2%		29.1 ± 9.4
4	a	e	83.2 ± 29.8	47.9 ± 28.9	57.6%	36.1%	110.5 ± 23.4	83.8 ± 41.2	75.7%	34.0%	97.1 ± 30.3
	b	o	88.5 ± 32.8	19.0 ± 16.0	21.5%		86.8 ± 27.7	34.3 ± 26.8	39.7%		105.2 ± 61.4
5	a	e	85.0 ± 32.2	51.8 ± 20.0	61.0%	42.6%	96.6 ± 29.8	65.3 ± 15.8	67.7%	39.7%	98.5 ± 42.3
	b	o	90.5 ± 43.8	16.6 ± 7.1	18.4%		58.9 ± 11.2	16.5 ± 11.9	28.0%		51.4 ± 14.7
6	a	e	59.7 ± 14.6	38.7 ± 9.7	65.0%	16.0%	99.3 ± 35.7	49.7 ± 17.6	50.1%	25.2%	62.0 ± 22.5
	b	o	45.5 ± 9.1	22.5 ± 7.8	49.0%		53.8 ± 9.2	13.4 ± 3.7	24.9%		37.5 ± 5.5
7	a	o	45.0 ± 5.1	3.1 ± 0.7	6.9%	22.5%	97.1 ± 12.8	7.1 ± 1.0	7.3%	30.4%	87.3 ± 13.5
	b	e	52.5 ± 9.4	15.4 ± 3.3	29.4%		103.2 ± 20.2	38.9 ± 6.5	37.7%		89.9 ± 21.9
8	a	o	115.2 ± 72.5	25.1 ± 23.3	21.8%	29.2%	86.3 ± 36.0	20.7 ± 13.2	24.0%	26.6%	38.4 ± 11.7
	b	e	120.1 ± 79.5	61.2 ± 39.8	51.0%		99.9 ± 20.4	50.1 ± 18.2	50.6%		104.5 ± 18.4

1 Treatment: o = open plot, e = enclosed plot.
2 Production is given as average value from 10 quadrats clipped in late August and is expressed as grams oven dry weight per square meter.
3 Winter carry-over is given as average value from 10 quadrats clipped in early May, before new growth started, and is expressed as grams/m^2.
4 Percentage remaining reveals winter carry-over as percentage of previous season's production.
5 "Percentage used by sheep" is the difference in winter carry-over between open and enclosed plots.

over the growing season, and the termination of growth is determined by frost in late summer, not by soil moisture deficiency as appears to be the case for the stations in the boreal zone.

Of importance to the sheep is the fact that the forage production from one year to the next may vary considerably. It is of interest to note that in locations that are heavily used by sheep (plots #3, #4, #5, #6, #7) the forage production increased after protection from grazing. This would indicate that the grazing pressure in those sites is so severe that the vegetation can not produce at capacity level.

The amount of winter carry-over left in the plots in late April just prior to the initiation of the new growing season varies greatly between plots. An important factor in this connection is the severity of ground squirrel activity in the area and exposure to the abrasive effects of wind. In low "protected" plots (for instance #2) 80 to 90% of the forage present in early September may still be there in late April. On the other extreme, plot #7 is exposed to great wind speeds and has considerable ground squirrel activity. Here, only 25 to 40% of the September standing crop is left by May next year.

The amount of forage taken by sheep as computed by the differences in winter carry-over of open and enclosed plots will be a minimum value, since some of the grazing takes place throughout the winter, and some of the forage lost for instance by wind action inside the enclosures, is used by sheep before it is lost on the check plots outside. However, most of the over-winter loss will be caused by ground squirrels which are very abundant on the grassy slopes of Sheep Mountain, and their grazing takes place in September and early October before they go into hibernation and before most sheep return to the winter range.

These minimum removal rates by sheep vary between sites. During the study period no use was made of exclosure site #2, while #3 and #5 received the greatest pressure with 40 to 50% in 1969/70 and 30 to 40% in 1970/71, when considerably more forage was available. The percentages given for sheep grazing do not take into consideration the grazing by horses, since these were prevented from entering certain areas by special horse fences.

DISCUSSION AND CONCLUSION

a) Range Productivity:

The dependence of forage production on available moisture in arid and semi-arid rangeland has been well documented (Blaisdell, 1958; Campbell and Rich, 1961; Craddock and Forsling, 1938; Dahl, 1953; Harper, 1969; Hutchinson and Stewart, 1938; Rogle and Hass, 1947). While our data cover too short a period to be conclusive, it is reasonable to assume that this relationship also applies here.

As was mentioned, a good correlation was found in all plots except the alpine ones between the forage production and the moisture during the growing season, and all but one plot had a higher production in 1970 when the moisture conditions were more favourable. There is no doubt that available moisture is very much influenced by physical characteristics of the soils, which were not determined in our investigation. However, since all the soils in the boreal zone are developed from loess deposits, it is reasonable to assume that moisture-holding capacity will be comparable under the different plots, and therefore the dependence of forage production on rainfall will still apply.

Experiments by the writer on plant phenological phenomena also support this assumption (Hoefs, 1975). It was found that growth of important Dall Sheep forage plants (Carex filifolia, Agropyron yukonense, Calamagrostis purpurascens, Artemisia frigida and Oxytropis viscida) terminated before the end of July in spite of the fact that temperatures at that elevation were still favourable for growth for another 4 to 6 weeks after and that shallow-rooted plants (for instance Carex filifolia) dried up much earlier than species with deep tap roots (Artemisia frigida, Oxytropis viscida).

b) Range use and condition:

That the production and utilization values as determined from exclosure plots are fairly reliable is revealed by the following computations which take into consideration the size of this winter range, its forage production and the observed grazing pressure by sheep (Hoefs, 1975).

From range studies in the area we know that during 1970/71 the average number of sheep on the mountain per day over the annual cycle was 93.2. We also know that during that year the dry grassland associations, which are represented in the exclosure plots, provided 54.5% of the grazing sites. The total acreage of these grassland sites amounts to 900 acres.

Computations using weighted means for forage production (these take into account not only the production of a plot but also the total acreage of the plant association it represents) reveal the following total production figures for this winter range: 1969: 495,000 lbs.; 1970: 603,000 lbs.; and 1971: 446,000 lbs. It has to be taken into account that this computation of total forage produced for the 900 acres, using that of the 8 exclosures as the base line is "optimistic", since the exclosures were established in ideal sites, where no large boulders, windfalls, and excessive ground squirrel activity interfered with the sampling. It is difficult to estimate how great an error was introduced here, but an over-estimation of forage production by 5 to 10% appears reasonable.

In 1970/71, 34,018 sheep days (365 days x 93.2 sheep/day) accounted for the total grazing pressure. Of these, 54.5% or 18,540 sheep days were spent on the dry grassland associations under consideration here.

Palmer (1944) who did considerable work on captive Dall Sheep in Alaska determined the average required forage need for these sheep to be about 6 lbs dry weight per day. The 18,540 sheep days spent on these grasslands in 1970/71 therefore resulted in the removal of 111, 240 lbs. (18,540 sheep days x 6 lbs. per sheep day) forage from this range.

In 1970, 603,000 lbs. were available in mid-August, but by the following May 37.4% or 225,522 lbs. were lost through natural causes primarily by ground squirrel activity, breakage and removal by wind, and decomposition, etc. Of the 377,478 lbs. remaining sheep used 111,240 lbs., which works out to be 29.5%. The average utilization rate for 1970/71 as determined by exclosure plots (Table 4) amounted to 25.6%. These two figures are remarkably similar if one considers that the exclosure plots were established before much was known about the distribution of grazing pressure over the mountain. It is also reasonable to assume that the utilization figure as revealed from exclosure plots will be minimum values, since some of the natural winter loss will outside the exclosures have contributed to the sheep's diet. In addition, no use was made of exclosure site #2, which lowered the average utilization rate considerably. Sites on the mountain which are not used by sheep, most likely because of lack of escape terrain nearby, are rare and certainly do not comprise 1/8 of the total grassland acreage, which was assumed in compiling the average utilization rate. The true rate will, therefore, be somewhat higher and may be similar to the one determined by the first compilation method using sheep days and range size.

While a utilization rate of around 30% may be a safe rate by ordinry range use standards, we must be reminded of the assumptions made, the fact that the 1970 season was exceptionally good in forage production, and that there are horses on certain areas of the mountain which utilize essentially the same forage species and whose impact has not been evaluated by the exclosure plots.

Let us consider the horses first. During the investigation 6 of them were in the area from October to May, inclusive, and utilized the eastern side of the study area. This is the area around exclosure plot #1, but horses were prevented from interfering with the experiment by a special fence, which allowed only sheep to walk under it. The utilization rates given for plot #1 (Table 3) are therefore only those of the sheep.

If we assume that 6 horses were on the mountain for 180 days and that each horse eats as much as 6 sheep on the average, then an additional 51,840 lbs. will have been removed from the area, bringing the total to 163,080 lbs. (111,240 lbs. sheep use + 51,840 lbs. horse use). This total forage removal increases the removal rate from the original 29.5% based on sheep use only to 43.2%. This rate approaches the limit of a "safe" range use. The situation is worse for 1971/72 when the forage production was lower. Only 446,000 lbs. were available in mid-August and only 279,196 lbs. after over-winter losses if these losses were around 37.4% as in the previous winter. There are indications that this rate is fairly constant, since it was 36.8% in the 1969/70 winter.

Even though the grazing pressure was not determined for the 1971 /72 winter, it is reasonable to assume that it was at least as high as in 1970/71, because of the good lamb crop in spring of 1971 (Hoefs, 1975).

If we consider a removal rate of 111,240 lbs. - as established for 1970/71 - we are looking at a utilization by sheep only of 39.8% (111,240 lbs. /279,196 lbs.) and if we add the forage consumption by horses (6 horses for 180 days each) of 51,840 lbs., the range use rate goes up to 58.4% (1111240 lbs. + 51,840 lbs. / 279,196 lbs.) which is beyond a safe range use practice by accepted standards.

It must be emphasized that the sheep grazing remained below a level which would adversely affect the range, and it is only the relatively recent introduction of horses which brings about an over -utilization on certain sites in certain years, and could eventually result in a decrease of the sheep population.

It is unfortunate that experience gained in other areas, where the introduction of horses adversely affected wild sheep populations, is not put to good use here.

It is known that the drastic population die-offs of Bighorns in the Rocky Mountain National Parks through Lungworm-Pneumonia infections can largely be explained by over-grazing of the winter ranges, to which domestic horses made a substantial contribution (Stelfox, 1974), and it is also known that the decline of Desert Bighorns in the south-western U.S.A. can be partly explained by the competition introduced through feral burros (Summer, 1975, 1959; McKnight, 1958, and St. Johns, 1965).

The following observations lead to the conclusion that this winter range is occupied at carrying capacity level by the sheep and that continued competition by horses will eventually result in a decline of the sheep population.

(1) The sheep population has maintained itself at a level of 200 adults in late winter during our research from 1969 to 1973 and an evaluation of historical information by the writer (Hoefs, 1975) revealed that this is the level they have always built up to after declines were brought about by mans' activity. They did not build up to higher levels even in years of intensive predator control.
(2) If we assume that 50% forage removal is a safe range use practice - as established in the western U.S.A. - then sheep population - before the introduction of horses - executed good range use. While the utilization rates of sheep calculated above for 1970 with 29.5% and for 1971 with 39.8% will be minimum values because of various assumptions made, it is reasonable to say that the true values will be below 50%.
(3) The fact that all exclosure plots except #2 (which is not used by sheep) improved their productivity after protection from grazing

indicate that presently the combined effects of grazing by sheep and horses prevent the grassland vegetation from producing at capacity levels.

(4) Even though it may be premature to draw any conclusion from only 3 years of data, it appears that a very sensitive correlation exists between forage production in a given season, the reproductive performance of the sheep herd during the following spring as well as the survival of lambs over their first winter. These correlations again point to a capacity-filled winter range. The relationships are summarized in Table 4. Forage production was similar in 1969 and 1971 and so were the lamb crops and the survival rates. The 1970 season was exceptional, with 17% more forage produced than in 1969, resulting in a 17.5% increase in the number of lambs born and in a 18.3% improvement of over-winter survival.

These data, as well as the observation that these sheep maintain themselves at a relatively stable level over many years, suggest that this sheep population is "regulated" and that their number is adjusted to the carrying capacity of their winter range, primarily through variation in the lamb crops and lamb survival rates. This observation is in opposition to claims made by Stelfox (1974) that sheep populations build up to levels well beyond the carrying capacity of their range and are therefore subject to periodic, severe die-offs of 25 to 30 year intervals.

Table 4

Correlation between forage production and vital statistics of sheep population.

Season	Forage Production*	Spring	Lamb Crop**	Winter	Lamb Survival***
1969	69.5	1970	41:100	1969/70	60%
1970	81.2	1971	47:100	1970/71	71%
1971	65.4****	1972	41:100	1971/72	61%

* Forage production is the average value for all plots expressed as grams oven-dry weight per square metre.

** Lamb crop is expressed as number of lambs born per 100 ewes in reproductive age.

*** Lamb survival refers to the percentage of lambs born the previous spring that survived to yearling age.

**** This average value includes the error introduced for plot #8a in 1971 by grazing sheep. A more realistic value for an average forage production for 1971 would be 70.0 gr/m^2.

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PROVINCIAL PARKS AND STONE SHEEP: "AFFINITY THROUGH DEFAULT"

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ABSTRACT

Seven Provincial Parks in British Columbia contain populations of Stone Sheep and their habitat. Of the 3½ million acres in these Parks, 870,000 acres is considered to be sheep habitat. Management policy of the Parks Branch is slowly evolving from people priorities to a more balanced attitude, including wilderness and wildlife habitat needs. Wildlife management responsibilities are a dual role between two Branches of Government. The seven parks discussed are Stone Mountian, Muncho lake, Kwadacha, Tatlatui, Spatsizi Wilderness, Atlin and Mount Edziza Provincial Parks. Short comments on boundaries, hunting harvest, population estimates, and general character of each Park are included.

INTRODUCTION

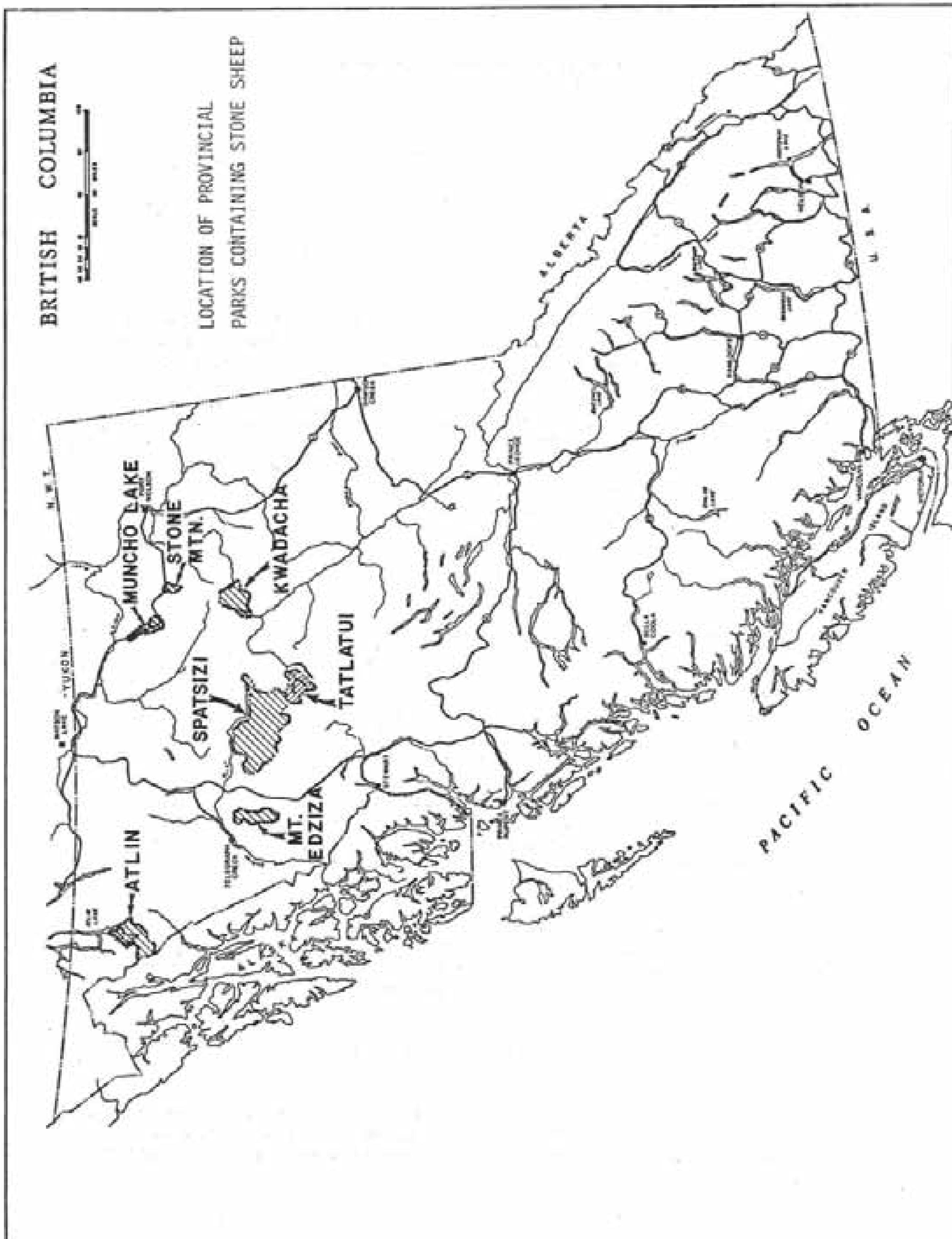
In the Province of British Columbia there are approximately 11½ million acres of recreational parklands. The working pattern for establishment of new Parks is laid down by park planners and basically constitues high scenic terrain providing vistas of majestic inspiring mountains, or conversely, are oriented around lowland water bodies and aquatic or shoreline recreations. Other reasons for establishing parks include geological or vegetationally significant parts of the Province. These concepts are not only aesthetically appealing to the public but are also based on avoidance of valley bottom alienations and the conflicts so often associated with these areas of high value to developers or other resource users. It is obvious, given the above mandates, that mountain sheep ranges in Parks are there by accident rather than design (Figure 1).

Exceptions to the above concepts are White Pelican Park in the Chilcotin, created to preserve the only known breeding colony of these birds in B.C.: Ballingall Islets and Mitlenatch Islands Parks also created for preservation of bird colonies and Spatsizi Wilderness Park created for wilderness and wildlife values in northern B.C.

RESULTS AND DISCUSSION

POLICY

A slogan that has stood the test of time and strife in Park management is that "Parks are for People" first and foremost. This concept is now changing slowly in the light of better knowledge about the wildlife


BRITISH COLUMBIA
LOCATION OF PROVINCIAL
PARKS CONTAINING STONE SHEEP
ATLIN
MT. EDZIZA
SPATSIZI
TATLATUI
KWADACHA
MUNCHO LAKE
STONE MTN.
YUKON
N.W.T.
ALBERTA
U.S.A.
PACIFIC OCEAN

habitat role in the preservation of natural places. A public desire to retain these natural areas in the face of modern technology has led Parks Branch into placing an equal mandate on restraint of human use and abuse in some of our more congested Parks. A new concept of restricted use in some of our more fragile ecosystems has also evolved as a natural extension in our planning concepts.

Parks Branch policy is to manage all species and their habitats within Parks under the total Provincial wildlife management program. Provincial Parks are dedicated to the provision of a variety of outdoor recreational experiences including the provision of a range of wildlife related opportunities in both the consumptive and non-consumptive categories.

Specific wildlife policies are as follows:

1. Hunting may be allowed in a Provincial Park where this activity is consistent with Park objectives and where species populations will support a harvest.
2. Endangered wildlife and their habitat will be afforded full protection under the Park Act.
3. Conditioning or taming of wildlife will be discouraged.
4. Scientific studies will be encouraged under Letter of Authority.
5. Mineral licks and other species wildlife areas will be fully protected.
6. Non-resident species introductions will not be encouraged in Provincial Parks.

RESPONSIBILITY

Management of wildlife resources within Provincial Parks is the joint responsibility of the Parks Branch and the Fish And Wildlife Branch. By legislative mandate Parks Branch is responsible for establishing policy for wildlife management practices in Parks.

Due to the dual management responsibility, the system runs into technical and bureaucratic difficulties. Parks Branch wants more intensive management and Fish And Wildlife Branch is often unable to provide this service. The Fish And Wildlife Branch collectively must priorize their limited funds and manpower to deal with constant crises of new dams, new open pit mines, new logging impacts and new access roads.

Parks Branch through limited funding can and does enlist extra input to crucial management situations involving wildlife in Parks but only sporadically. The system simply does not allow for funding preventive measures to avoid wildlife crises but only to react after the situation has often deteriorated to the point of habitat salvage.

This then is the background against which management of wildlife including Stone Sheep in our northern Provincial Parks is conducted.

NORTHERN PARKS

We have 7 major parks in northern B.C. (Figure 1) that contain Stone Sheep habitat. They contain approximately three and a half million acres, of which 870,000 acres of 25% are Stone Sheep range (Table 1). For The purposes of this paper I am including the Gladys Lake Ecoreserve (82,000 acres) in the above figures. Some of these ranges are contigous with more Stone sheep habitat adjacent to the park boundaries when heights-of-land are followed by the boundary.

Table 1.

Park	Total Area (Acres)	Sheep Range (Acres)	Population Estimate Stone Sheep	Harvest/ Rams 1977
Stone Mountain	64,000	36,970	80	5
Muncho Lake	218,460	97,590	110	3
Kwadacha	414,000	46,080	40	3
Atlin	575,000	22,940	70	0
Tatlatui	261,500	60,820	80	1
Spatsizi	1,740,000 (includes Ecoreserve)	412,470	500	3
Mount Edziza	326,000	193,220	220	15
TOTAL	3,526,960	870,000	1,100	30

There are estimated to be about 12,000 Stone Sheep in B.C., 1,100 or roughly 9% of which are ranging on Provincial Parklands.

Individually the Parks are well separated except for Spatsizi and Tatlatui which share 15 miles of common boundary.

STONE MOUNTAIN PARK

The smallest northern park contains 64,000 acres of Stone sheep range. Over 37,000 acres or half of the entire park is utilized by Stone sheep sometime during the year. Most of the range is seasonal summer habitat. The Park boundaries follow heights-of-land in most cases and thus cut across habitat occupied by local bands of sheep.

Several mineral licks are found within the Park where these animals often concentrate. There is a "one kilometre no shooting zone" along the Alaska Highway which bisects the Park. In 1977 five full curl rams were harvested (Table 3) within the Park from a population estimated at 80 animals. All hunters were unguided residents of B.C.

MUNCHO LAKE PARK

This park is a lake oriented subalpine setting in the northern Rocky Mountains. It is 218,460 acres in size and 97,590 acres are alpine sheep habitat. The boundaries tend to follow heights-of-land wherever possible. This park is famous for its mineral licks where Stone sheep are often photographed by tourists on the Alaska Highway. The licks along Trout Creek are heavily utilized by sheep during the summer and a band of sheep crossing or on the road is always a traffic stopper.

A "one kilometre no shooting" area extends along the highway through the Park. Three rams out of an estimated sheep population of 110 were harvested by guided hunters in 1977 within the Park boundaries.

KWADACHA PARK

This Park is one of the most remote in the entire Park system. It contains 414,000 acres, of which 46,080 acres are considered to be Stone sheep range. The terrain is high precipitious country dominated by ice-fields and glaciers. The bulk of the park is on the wetter west side of the Rocky Mountains which precludes good sheep habitat through climatic extremes. Summer and early fall ranges on the headwaters of the Gataga and Tuchodi rivers are the main sheep areas.

Access to the park is by float plane, helicopter or horse-back. No mineral licks for sheep are know to be in the Park. Three rams were harvested by guided hunters in 1977 (Table 3). The estimated population of sheep utilizing Kwadacha Park is 40 animals.

TATLATUI PARK

The park contains 261,500 acres, with only 60,820 acres considered to be Stone sheep range. It is located on the extreme southern edge of the Stone sheep range. Like Kwadacha Park it is located in the heart of the Cassiar-Omineca Mountains and harsh climatic extremes limit the resident population of sheep. The marginal habitat along the northwest boundary are mostly maternity ranges and several important mineral licks are found here as well. Heights-of-land boundaries also constitute much of this lake-oriented Park on the headwaters of Findlay River.

Guided fishing parties can also become keen sheep photographers in "lick valley". One ram was harvested by a guided hunter in 1977 (Table 3). The resident sheep population is estimated to be 80 animals, of which 11 were ewes and lambs (Table 2).

SPATSIZI WILDERNESS PARK

Immediately adjacent to the northern boundary of Tatlatui lies Spatsizi Park, the second largest Park, which contains 1,740,000 acres. This area includes the 82,000 acre Gladys Lake Ecoreserve created for the preservation of Stone sheep and Mountain Goat range.

The Park contains 412,470 acres of prime sheep range. It was created along with the ecoreserve in 1975 with wildlife conservation as one of its prime mandates. Its rainshadow location creates ideal winter conditions with shallow fluffy snow and windswept plateau habitats. The park contains many entire distinct sheep ranges which are geographically separated. The Eaglenest Range of mountains contains excellent sheep habitat and many mineral licks.

Spatsizi is now under special management for sheep hunting and currently is the only Park thus far controlled by quota and limited entry regulations. An intensive inventory of sheep populations and their range is an essential future project for this park (Table 2). Two guided hunters and one resident hunter harvested rams out of a population estimated to be 500 animals in 1977 (Table 3). A total of 10 sheep permits were issued for the Park in 1977.

Table 2. Classified counts.

	Ewes/ Class 1 Rams	Lambs	Rams Class 11, 111, 1V	Unclassified	Total
Mount Edziza					
1972 (January)	40	25	34	53	152
1973 (March)	-	-	14	102	116
1975 (August)	78	13	48	-	139
1976 (March)	56	8	36	10	110
Atlin					
1975 (August)	4	1	4	-	9
Spatsizi					
1972 (January)	23	15	50	67	155
1976 (Summer)	110	36	18	22	186
1976 (September)	2	2	-	40	44
Tatlatui					
1976 (Summer)	7	4	-	-	11
Total Observations	320	104	204	294	922

Table 3. 1977 Stone sheep harvest in Provincial Parks.

Park	Resident Hunter	Guided Hunter	Park Total
Atlin	0	0	0
Kwadacha	0	3	3
Mount Edziza	9	6	15
Muncho Lake	0	3	3
Spatsizi	1	2	3
Stone Mountain	5	0	5
Tatlatui	0	1	1
	15	15	30

ATLIN PARK

Atlin Park in the northwest corner of B.C. is mainly ice and water. The Llewellyn glacier and Atlin Lake dominate the Park's 575,000 acres. Only 22,940 acres are suitable for Stone sheep populations on a year-round basis. The rounded mountains east of the lake in the Sloko Range form a rainshadow area that supports a small population of sheep.

One major mineral lick is located above Sloko Lake and is utilized by sheep. Historically Teresa Island supported Stone sheep but the influx of gold seekers at Atlin terminated any sheep presence on the alpine areas of the island. Apparently Indian meat hunters utilized rock barricades to drive sheep and goats past hidden marksmen near escape terrain. Restoration of this range through local transplant is a project for the future consideration of Parks Branch. Hunting closures along the Atlin Lake shoreline and the islands in 1978 would serve to protect any restored sheep population.

No rams were harvested out of the population of 70 sheep in 1977.

MOUNT EDZIZA PARK

This park is a biological "island" of 326,000 acres of which 193,220 acres is alpine and subalpine sheep range. Again the bunchgrass-oriented habitat is a product of rainshadow conditions east of the Coast Range. The volcanic origins of this unique area are among the most recent in B.C. It is a classic alpine study area being isolated from all other mountainous alpine areas by deep timbered valleys and turbulent rivers.

The steep escarpments on the west side are adjacent to the windswept bunchgrass plateau where access to winter food is easy and provides most of the winter escape terrain. Summer and early fall sheep ranges on the east side of the Park combined with lake access result in a high harvest within the Park (Table 3).

Quota and limited entry hunting regulations should be instituted as soon as possible. The 1977 harvest of 9 rams to resident hunters and 6 rams to guided hunters from an estimated population of 220 sheep is too high to be maintained in an "island" population with no outside recruitment (Table 2). One interesting mineral lick currently utilized by sheep is a hotsprings seep area.

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RANGE ENHANCEMENT AND TROPHY PRODUCTION IN STONE SHEEP

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INTRODUCTION

Mountain sheep in British Columbia are, as a matter of policy, managed as a trophy species. Indeed, to assure that hunting does not unduly truncate the age distribution of the males, hunting harvest is to be restricted to two per cent of the total fall population. This increased emphasis towards the trophy aspect has highlighted a deteriorating supply/demand ratio. While the intention is not to stabilize this value indefinitely, it was recognized that the supply component was open to some increase. Thus, as part of regular wildlife management activities, information was gathered relative to range and mountain sheep dynamics with a view to identifying features which could facilitate increasing the number of trophy Stone sheep (*Ovis dalli*).

STUDY AREA

The data used in this analysis came from those Stone sheep on ranges in British Columbia primarily designated by the drainages of the Kechika-Turnagain, Trout, Toad, Dunedin, Muskwa-Prophet, Sikanni, Halfway, and Nabesche Rivers. This corresponds to about 75 per cent of British Columbia's Stone sheep.

Unaltered subalpine forest in the area is dominated by various ratios of white spruce (*Picea glauca*), black spruce (*Picea mariana*), and alpine fir (*Abies lasiocarpa*). Fire and other altered subalpine sites, where forested, are dominated by balsam poplar (*Populus balsamifera*), aspen (*Populus tremuloides*), and various willows (*Salix* spp.). The transition between forest and alpine is dominated by alpine fir and various willows. The alpine communities themselves vary considerably in composition.

A typical annual cycle for mountain sheep in an unaltered area would be wintering in the alpine, spending the spring in the transition alpine to forest brush zone (first to green), and then spending the summer and fall in the forest zone or the lusher alpine and transition areas. Mountain sheep in a location where the subalpine forest is suitably altered to open decidous forest (the location of these sites must, of course, be satisfactory relative to escape terrain, alpine areas, and so forth) typically spend winter and spring in the altered sites (at various elevations) and summer and fall in lusher sites - altered, unaltered forest, transition, or alpine.

METHODS

Sheep population sizes and recruitments were estimated on several ranges utilizing winter aerial surveys of ewes and young. Horn growth in male sheep was calculated from measurements (250 per year in the study area) of the horns of hunter-killed animals. Contact with hunter kill was achieved through a compulsory reporting system.

Sheep ranges were grossly evaluated in the course of regular work, plus site-specific forage abundance estimates were made in various areas. These forage estimates were restricted to the number of grass or sedge plants (plus the mean number of blades per plant) in rectangular plots (13.5 square feet).

It should be noted that the somewhat superficial procedures adopted were necessitated by the low financial and time budgets allotted to the project. The author realizes the shortcomings, but feels the major points are still valid.

RESULTS

The first feature to emerge was the striking difference between ranges. While the abundance of available alpine vegetation was certainly a significant feature, it was also apparent that the presence of suitable subalpine altered vegetation had a marked enhancement effect. Indeed, for otherwise comparable ranges, those with suitably altered subalpine winter range achieved five times the density and absolute population size of sheep. Not only was the population size greater, but sheep on the suitably altered ranges averaged 75 per cent more lambs in late winter than those on unaltered ranges (although this recruitment lead at the equilibrium population size is lost by the second or third year).

It was also apparent that the main suitable alterer of range was fire. Mud slumping, snow sliding, and blowing down was less significant. While it may require a second or third burning to clear the litter associated with the initial fire, even a primary burn is effective. Although the burn sites may require a couple of years to stabilize (forb to grass and sedge ratio is higher initially than in later years), both primary and subsequently burned sites show a marked increase in available forage for sheep with transect plots indicating up to 10 times the amount of grass on fire-opened sites. The quality (such as protein) of the vegetation likely also changes on these sites but this has not been investigated to date. Certainly the lower elevation of these sites would tend to favour this feature and sheep do move into a burnt areas as soon as new grass pushes through the ashes suggesting a preference for this forage.

A further feature which varied between unaltered and suitably fire altered ranges was horn growth in rams (ewes were not examined). Figure 1 illustrates the average difference. It can be seen that rams on the fire-altered ranges show an average accelerated horn growth in the first three years of life. In subsequent years, rams on both range types show roughly similar growth (this differs from that found by Shackleton, 1973). The significance of this differential growth on trophy quality

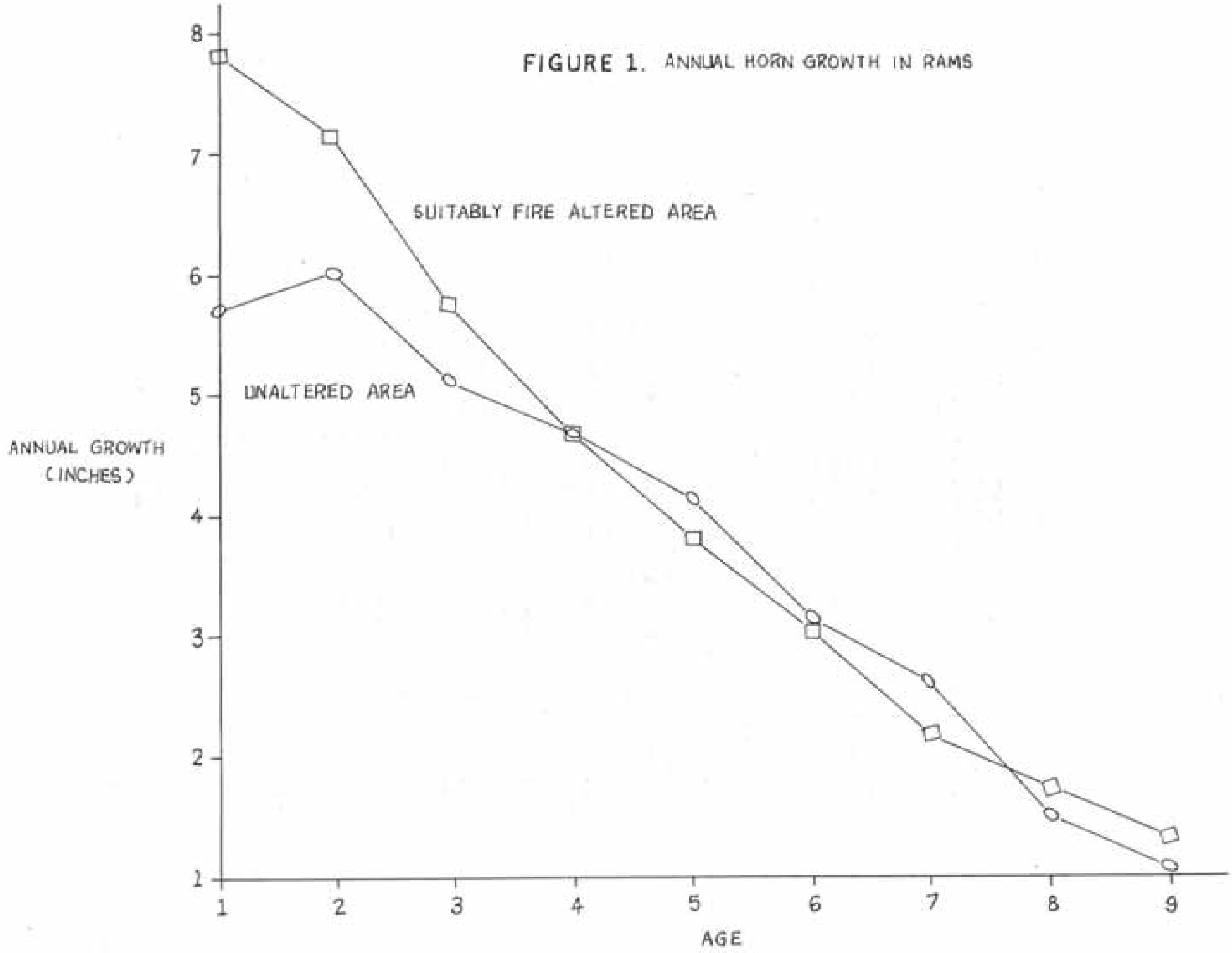


FIGURE 1. ANNUAL HORN GROWTH IN RAMS

can be seen in Figure 2 which illustrates total horn length against age. It can be seen that rams on suitably fire-altered ranges have, for a given age, horns about three inches longer than those on unaltered ranges.

DISCUSSION

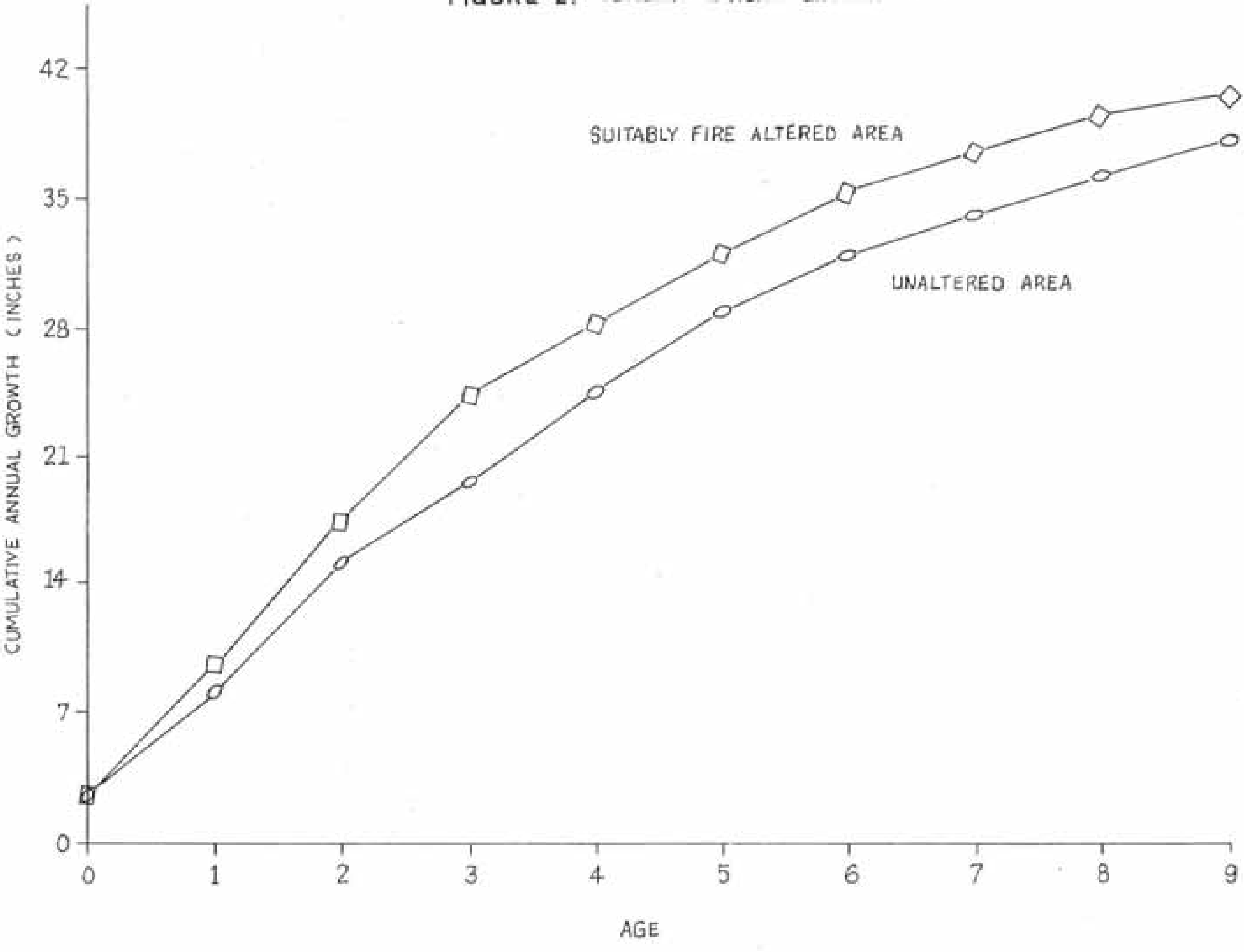
A number of studies have commented upon quality differences in sheep populations. Geist (1971) suggests nutrition to be the primary feature with there being two sheep types, one adapted to a higher plane of nutrition and the other to a low plane of nutrition. Hoefs (1975) and Erickson (1970) have noted a correlation (negative) between quality (horn growth) and latitude. Heimer and Smith (1975) found for Alaska that high-quality populations tended to be associated with low sheep densities. Shackleton (1973) corroborated Geist's (op. cit.) hypothesis on the role of nutrition, but did not elaborate upon the possible role of genetics.

The present work suggests that suitable alteration of sheep ranges by fire increases both sheep numbers and sheep quality (as evidenced by the proportion of late winter lambs and horn growth in rams). The improved forage on the fired sites is the probable factor responsible for the bettered status of the sheep. The improved forage does not, however, result simply from the increased supply which was observed; two other features are significant. First, the removal of tree cover allows winter winds to reach snow accumulated on the ground and disperse and/or sublimate it. The sheep are thus freer to move across the range and less pawing is necessary to expose forage. This openness may even have the secondary benefit of facilitating predator detection and maintaining herd contact. It is the feature of improved openness which makes it often desirable to reburn an area; clearing deadfall, stumps, and so forth. The second benefit of the fire alteration is the increased vertical displacement of year-round available range. The sheep are thus able to utilize forage of peak nutrient level (associated with "green-up") for a longer period each year.

Horn growth and lamb number responses are exhibited soon after a burn, suggesting that the genetic capability to respond exists in a large proportion of these sheep. Geist (1971) notes this is to be expected in such herds which are under the influence of predation, periodic severe winters, and so forth.

Considering the aesthetically pleasing effect of a fire-altered landscape (over heavy forest) and the benefits in species diversity and positive response by other ungulates, fire appears to be a viable tool in the enhancement of Stone sheep populations. Indeed, in 1978 a 10,000 acre controlled burn was instigated in this area with the aim of improving sheep numbers and production for one population.

FIGURE 2. CUMULATIVE HORN GROWTH IN RAMS



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THINHORN SHEEP MANAGEMENT - Chairman: Dr. D. F. Hatler.

W.E. Heimer - The effects of National Interest Lands with-drawal on Dall sheep Management in Alaska.

Ray Demarchi: You talked about the economic values of sheep hunting in Alaska. What people spend for something is not it's real value, it is what they are willing to spend. And there are two ways of looking at that: 1. what would you pay for access to it? and 2. what you would take if somebody was going to take it away from you.

Wayne Heimer: Two million dollars is a bare-bones conservative estimate.

Bill Wishart: Is this the only park in which hunting is allowed?

Wayne Heimer: There is hunting in Grand Teton National Park.

Bill Wishart: Is that subsistence hunting?

Tom Thorne: Right. Presently, this is the only National Park where - on a limited basis - hunting is allowed.

W.G. Hazelwood - Provincial Parks and Stone Sheep: "Affinity through default".

Brian Horejsi: Are the sheep completely protected in any of the seven areas you talked about? Is native hunting allowed?

Grant Hazelwood: The Ecoreserve in Spatzizi is completely closed to hunting. That area has 82,000 acres of prime sheep and mountain goat range. I believe the area is closed to native hunting as well.

Brain Horejsi: Do you see the day when you will phase hunting out of some of these areas and is there a different policy for northern and southern parks?

Grant Hazlewood: Looking down the road twenty to forty years or more, Parks policy probably will be gradually to phase it out of most of the parks. Generally, we close smaller southern parks when there is heavy public use.

John Elliot - Influence of Range on Horn growth in Stone Sheep in Northern B.C.

Wayne Heimer: I found that sheep from low quality populations are capable of growing horns every bit as long as sheep from high quality ones. But the pattern of growth throughout the life of a sheep will be different if you look at volume rather than length.

John Elliot: If you look at impact force (a function of horn mass), then you are assuming that the genetic change is something which occurs over a series of generations, where the animals with the big horns are doing all the breeding. With the S and T herds, no generations passed with the fire yet there is still larger horn growth.

If one could imagine long term selection for horns, then it makes sense to look at the clash force. But in this case it seemed to me that it was just a direct response to nutrition rather than being reproductively selective.

Tim Baumann: Can you comment on the ability of your sheep to inhabit those burnt ranges? Were these burns adjacent to your climax ranges? How quickly did they colonize them?

John Elliot: These sheep had already been using these areas in the summer prior to burning. Whether they could move with any rapidity into an area that they had not been using either in summer or winter, I do not know.

Bob Jamieson: John, are the Smokies up there serious about cutting down those little trees?

John Elliot: Yes, but there is no timber harvesting in those areas right now.

Bill Wishart: Does it seem conceivable that some rams could locate a burn, live there and grow big horns, then return to the inferior range and lead the sheep to the new-found range? It strikes me as being a pretty good strategy for expanding your range as it occurs.

Don Eastman: Have you given any thought to how much is enough, i.e., do you have to burn the whole slope off? And have you thought about the frequency of fire? How often will you have to reburn areas that have been burned before?

John Elliot: It is pretty hard to generalize. If you are aiming at the winter ranges, you can get away with burning just the west-facing slopes. So your main effort should be concentrated on the areas where the wind will take off snow.

The frequency varies a little bit on the site. It takes usually two to three burns to get rid of all the woody material unless you are really lucky and get a midsummer burn. For the first few years you have to burn quite regularly, perhaps every year for three years. After that, once every 10 years or so is probably adequate.

PANEL DISCUSSION: RESEARCH NEEDS FOR WILD SHEEP
CHAIRMAN: Dr. D. EASTMAN
W. D. WISHART, SECTION HEAD, WILDLIFE RESEARCH, ALBERTA

In order to gain some perspective of wildlife research we must recall the four basic steps of wildlife management, i.e.,

1. inventory: where are the animals and how many are there?
2. production: what is the annual production?
3. limiting factors (research): restrictions to population expansion.
4. management: based on the first three premises.

Research is devoted primarily to determining the factors that limit populations, while management procedures are generally based on those findings. The basic approach to sheep management is to "leave them alone and they will come home, wagging their tails behind them" provided of course that they have a home. Obviously then, the most important research need is to know the home range requirements of mountain sheep and these ranges must be protected. The second need is to know how to maintain or improve sheep habitat by fire management or any other reasonable means of maintaining a grassland community near escape terrain.

If home ranges are known, protected and managed, how then do you manage the sheep? Historically mountain sheep have been subject to die-offs from scabies, lungworm/pneumonia and now Johne's disease. Personally, I disagree with having the disease organisms spread or perpetuated using band-aid remedies like transplanting or treating the animals. What is required is a careful examination of what brought on the symptoms in the first place.

In Alberta, our strategy has been simply to regulate population numbers. Our objective has been to keep sheep populations in a perpetual state of recovery with either sex seasons. I believe sheep managers have been extremely cautious in managing a remarkably adaptable species.

R. E. KEISS, Wildlife Researcher, Colorado.

In the last 175 years, with increasing human exposure, bighorn sheep in Colorado have declined to their present day 'toe-hold'.

About 6 years ago, however, we were blessed with a "green light" and quite a bit of money to go ahead with a crash program on sheep research.

I'm not going to dwell on the details. We have raised a lot of dust and we have to wait until it all settles, before we evaluate what has been done and where we will go next.

W. E. HEIMER, Dall Sheep Biologist, Alaska

In Alaska we have had two different approaches. On the Kenai peninsula management-oriented research has produced a lot of good, basic biological information. In the interior we have been looking at biological parameters - population dynamics, movements, fidelity to home range, comparisons between low and high quality populations - and, by serendipity, stumbled onto useful management-oriented information.

Aside from long range planning, one of our greatest contributions has been to find an effective survey and inventory technique for the interior - through mineral licks. We feel that we know production, recruitment and population trends for the entire Alaska range.

But our research has to be management-oriented or it doesn't go anywhere. For the future, we are looking at the effects of resource exploration and development, particularly helicopter survey and its effects. We need research on the kind and quality of human experience people want from sheep. We need to find out consumptive user attitudes. Last, we need to be able to tell if hunting in a supposedly healthy eco system will lead to a decrease in stocks.

D. M. SHACKLETON, University of British Columbia

There seem to be two simple components to mountain sheep research: 1) plain biological interest, and 2) research for management of the species. The first is of boundless interest, but what are our goals for management research? Much of the time the answer seems to be that 'more is better'. Really, this is unacceptable to the hunter/photographer/backpacker/biologist kind of consumer we are dealing with because it is not clearly established exactly what this consumer really does want.

But let's assume we have the answer to that. Then, what are the goals of the manager for wild sheep? I think that managers first have to answer or develop some fairly specific management goals - quantitative, time-specific frameworks: how many sheep of what kind, over what time period, etc. A shopping list of research needs is the task of the manager, not the researcher.

Another important thing arising from symposia like this is the growing recognition of inter- and intra-population variability, of the complexity of these systems. We must recognize that there are some basic common factors under-lying this variability. We need to develop a sound conceptual framework against which we can evaluate the empirical confusion we are now faced with. One example is Geist's concept of population quality.

I would like to consider possible methods of improving our present knowledge of sheep, both academic and applied:

1. more compulsory game checks - morphometric data, etc.
2. select one or two representative sheep populations for intensive monitoring over time.
3. use management practises as bona fide research - there are several ways we can use management applications and learn directly from them in a much more rigorous, scientific way.
4. develop the co-operative wildlife unit concept - use a team research approach.
5. systems approach to management.
6. greater use of information and education departments of Fish and Game Branches.
7. If Game Branches want more applied research, you'll have to put your money where your mouth is - come up with some funds.

STATUS OF THE MOUNTAIN GOAT
(*Oreamnos americanus*)
OF THE SIMILKAMEEN RIVER
BRITISH COLUMBIA

J. N. Bone, Regional Wildlife Technician
Fish and Wildlife Branch, Penticton, B.C.

INTRODUCTION

Distribution

The mountain goat of the Similkameen River, British Columbia, inhabit the area: 1. north of the Similkameen River from Keremeos to Hedley, 2. south of the Similkameen River from the confluence of the Ashnola River east to Keremeos and south to the Canada/United States border, 3. the Cathedrals west of Ewart Creek and east of the upper Ashnola River and 4. west of the upper Ashnola River south of Young Creek (Figure 1.). These populations are more or less discrete but it is believed there is some inter-population movement.

In addition to these populations, individuals or small groups are occasionally seen on both sides of the Similkameen River as far west as Princeton.

History

The history of this mountain goat population parallels that of other goat populations in an area of proliferating access.

Access to the area was initiated with the presence of large numbers of gold miners in the Similkameen Valley during the mid-nineteenth century. Charles Wilson, in his August, 1860 diary (Stanley, 1970) mentioned 150 miners in the lower Similkameen. Wilson also mentioned goat sign on the

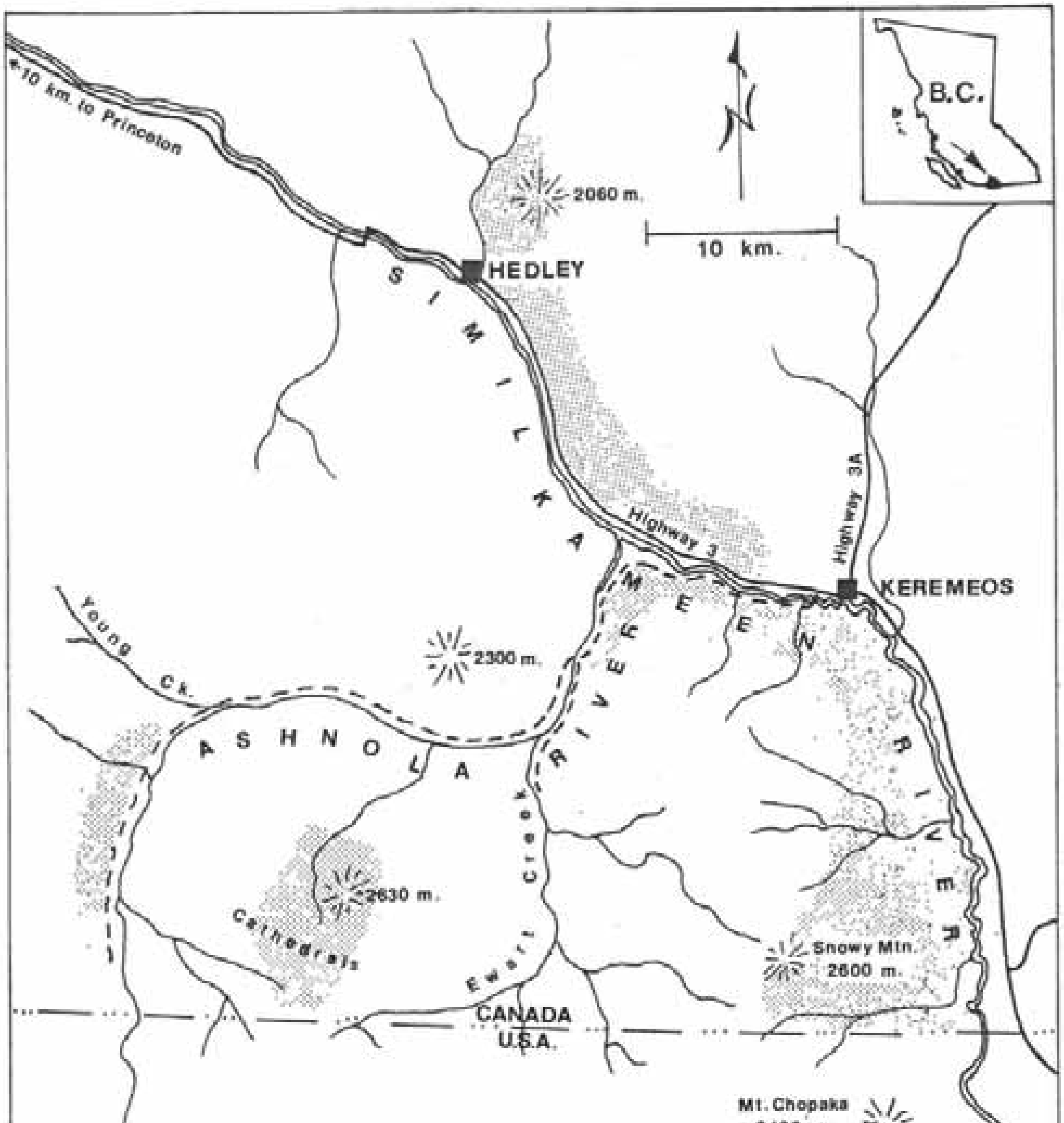

Fig. 1. Distribution of the Similkameen River Mountain goat (*Oreamnos americanus*) population in British Columbia, Canada.

west fork (upper Ashnola) of the Ashtnolen (sic) River. Gold fever in the interior resulted in the 1860/61 construction of the Mule road to the Similkameen (Dewdney Trail) over the Cascade Mountains from Fort Hope on the Fraser River. Mining in the Similkameen continues but the burgeoning permanent white population is primarily agricultural.

Access to the Similkameen and Ashnola became easier as the human population grew. By 1900, wagon roads from the east (Okanagan Valley) and the west (Princeton) were well used and the Ashnola Wagon Road was built beyond Ewart Creek. The area became famous for hunting (esp. Bighorn sheep and Mountain goat). Turn-of-the-century reporters in describing goat numbers used such words as "teeming" and "abounding" (Vernon News, 1891). By 1938, Game Warden Wilson, whose earlier annual reports described "plentiful" numbers of goats, began to warn, "the season should be closed as they are very easy prey to the hunters as they can be located from the town of Keremeos". Again in 1939 "there was a number killed on the Ashnola Range where the season should have been closed .. .. and unless the season is closed there will be no goat left to hunt" (Fish and Wildlife Branch files).

The season was closed until 1956 when short hunting seasons were instituted until 1967.

Habitat and seasonal migration

The Similkameen mountain goat seasonally occupy four biogeoclimatic zones: - Ponderosa pine-bunchgrass, Interior Douglas-fir, Englemann spruce-Subalpine fir and Alpine tundra (Krajina 1965). Their habitat is precipitous with many tallus slopes and is deeply cut with gorges.

North of the Similkameen River seasonal migration is minimal and

and mainly vertical (ca. 700 m. to 200 m.). The aspect here is south and the topography precipitous. Solar insolation plus nearly continous winds contrive to maintain a nearly snow-free habitat in winter.

Part of the population south of the Similkameen River (much of the population south of Keremeos to the border) seasonally migrate horizontally up to 10 km. and 1900 m. vertically. The band of goats west of the upper Ashnola are seen at all seasons and do not appear to migrate. Little is known of the seasonal movements of the Cathedrals group but some do winter in that area (pers. obs.).

RESULTS

Management

In 1956, a Similkameen mountain goat hunting season was again instituted (Table 1). The season length was conservative (3 days), hunter participation was low (20 hunters) and the hunter success ratio high (45 per cent).

In the years following, up to and including the 1962 hunting season, during which time the season was lengthened to 9 days and the area open to hunting reduced to the areas east of the Ashnola and south of the Similkameen, hunter participation remained low and hunter success generally high. Increased hunter participation in 1963 to 1965 reflected the increased ease of access provided by the construction of the Ashnola River Access Road (completed in 1964) and the lengthened season. Now, however, hunter success dropped severely and despite a season shortened once again in 1966 and 1967 to 3 days (which did curtail hunter participation) continued to drop. Following the 1967 season, hunting for Similkameen mountain goat was again discontinued.

Table 1. Season length, hunter participation and hunter kill from 1956 to 1967 for the Similkameen River population of Mountain goats.

Year	Season length (days)	Hunters (numbers)	Kill (numbers)	Areas open
1956	3	20	9	west and east of Ashnola and north of Similkameen.
1957	3	40	18	"
1958	3	35	8	east of Ashnola and south of Similkameen.
1959	3	27	4	"
1960	3	30	10	"
1961	8	41	3	"
1962	9	27	14	east of Ashnola and south of Similkameen plus west of Ashnola
1963	10	56	13	"
1964	9	156	27	"
1965	9	138	31	"
1966	3	67	4	"
1967	3	32	2	"

In 1958, an annual spring census (by helicopter) was instigated (Table 2). Initially only total animals censused were recorded but from 1970 to the present adults and juveniles were classified. Two transects are flown on this census. The north side of the Similkameen census includes the area from Hedley Creek canyon (at Hedley) to Keremeos. South of the river the census begins at the mouth of the Ashnola River valley, and continues easterly and southerly along the Similkameen River to Mt. Chopaka south of the Canada/United States border. The area covered by these transects is precipitous, broken and deeply dissected by gorges making censusing difficult. Timing of the census is critical. It must occur after the snow is gone, but while most of the goats are still using "greenup" plants. Despite the difficulty a large enough sample was obtained during most years to indicate a clearly declining population in the area east of the Ashnola and south of the Similkameen until about 1970. This area has been continuously open to hunting from 1956 to 1967. The 1978 census, after several years of poorly timed counts and one year in which the census was not taken (1977) indicates a population recovery at least exceeding 1958 numbers. Of equal significant management implications are the recruitment figures shown by the juvenile:adult ratio. The 1978 census shows a ratio of 30:100 on the south transect and 28:100 on the north transect. This compares with the East Kootenay recruitment of 9.5:100 and the coastal 5.4:100 (Hebert, D.M. and W.G. Turnbull, 1977)

Table 2. Annual spring census of the Similkammen Mountain goat population from 1958 to 1978.

	Asnola-Chopaka Transect					Hedley-Keremeos Transect				
Year	Tot.	Ad.	Juv.	U/C	Ratio Juv:Ad.	Tot.	Ad.	Juv.	U/C	Ratio Juv:Ad.
1958	107									
1959	104									
1964	94					46				
1965	64					24				
1966	68					37				
1967	74					55				
1968	45					62				
1969	32					50				
1970	19	11	2	5	18:100	50	38	3	9	8:100
1971	26	18	5	3	28:100	59	43	6	10	14:100
1972	34	23	6	5	26:100	57	34	7	16	21:100
1973	24	19	4	1	21:100	51	37	5	9	14:100
1974	11	7	4	-	57:100	15	13	2	-	15:100
1975	8	5	3	-	60:100	31	18	4	9	22:100
1976	28	20	8	0	40:100	41	37	4	-	11:100
1977	No census									
1978	102	60	18	24	30:100	49	25	7	17	28:100

Discussion and management proposals

Obviously we require more detailed population parameters and habitat characteristics that, with present manpower and fiscal restraints, must be relegated to low priority. Equally obviously the mountain goat of the Similkameen River have a satisfactory recruitment rate and appear to be increasing in numbers in the absence of hunting pressure. This indicates, at least, satisfactory quality of forage and herd productivity and a natural mortality below recruitment.

The Proposed Wildlife Management Plan for British Columbia (in draft) with respect to management of mountain goats (province wide) states as objectives; 1. to increase mountain goat populations on traditional ranges 2. to provide the opportunity to view goats in their natural habitat and 3. to provide 18,000 sport-hunting days of recreation and an annual sustained hunter kill of 1,500 animals. As a matter of policy the hunter kill is to be maintained at less than 5%.

Presently, the Similkameen mountain goat population appears to be increasing. With respect to objective 2. the British Columbia Ministry of Highways are rebuilding Highway 3 between Hedley and Keremeos and are providing for pullouts at several locations where travellers can often view mountain goat. Objective 3 is not presently being fulfilled by the Similkameen mountain goat population.

Hunter demand for goat hunting is high in British Columbia. In the 1977 season 2,185 resident and 838 non-resident licenses were sold (last figures available). Application for Limited Entry Hunts totaled 1071 in 1978 for only 224 licenses available.

Since British Columbia has introduced the enabling legislation to provide for Limited Entry Hunting (L.E.H.) and, with our present knowledge of the herd, I think the population can sustain a low level hunter harvest. I now estimate the total Similkameen goat population to be in excess of 270 animals. Conservatively 10 animals can be harvested. Regulations common to L.E.H. must be observed. Since it is proposed to be an L.E.H. area it is restricted to resident hunters. Indivividual hunters must be restricted spatially and in time. Only adult mountain goats should be harvested and hunters must be encouraged to take lone animals. In the special case of the animals north of the Similkameen hunters must be restricted to an area away from the highway.

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GOAT MANAGEMENT IN THE KOOTENAYS

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BOX 9
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ABSTRACT

The following discussion is based on an earlier extensive discussion of the subject (Phelps, Jamieson and Demarchi, 1975). This presentation is a short review of that paper and discusses the management cptions implemented since the original paper was written.

INTRODUCTION

Mountain goats are widely distributed in the East Kootenays of British Columbia and are relatively abundant. The area of major interest (i.e., the Rockies south of Banff and north of Fernie) support the largest goat herd in southern British Columbia. This area and other goat herds in the Kootenays became a management concern in the late 1960's when a drastic decline in population became apparent. The decline was coincident with the bighorn die-off of that era (Demarchi and Demarchi, 1969), and the discovery of white muscle disease in goats (capture myopathy) (Hebert and Cowan, 1971). Neither of these factors served, however, to explain the decline. Hunting seasons during this period were long and goat harvests high. The data available to the wildlife manager at that time (from the British Columbia Hunter Sample) were hunter numbers which showed a substantial increase from 1955 to 1965; harvest figures by Management Area (units of several thousand square miles each) which showed an increase in all units up to 1965 (Figure 1); and hunter success, which remained constant until the late 1960's (Figure 2). The sex ratio in the kill remained biased toward males, 138:100 through the same time period. Given these data, it was difficult to justify the closures demanded by hunters and guides, especially in view of the philosophy of maximum harvest found among managers and administrators of the time. However, based on local knowledge and an intuitive sense of the problem, closures were instituted beginning in 1963 and culminated in a full closure in 1972.

RESULTS

The first objective of the study, initiated in 1973, was to develop a more detailed description of the spatial distribution of the goat harvest using the hunter sample cards. This provided an entirely different view of the harvest that occurred in the 1959 to 1970 period than that obtained from the original analysis of the hunter sample data. Harvest data for management area 9 (Revelstoke-Golden) showed a gradual increase through to 1970.

Separation of these data into harvest by Management Unit (Figure 3) showed a severe decline in harvest in the Golden area (M.U.'s 4-36 and 4-40), the area which had the majority of road access at that time. This decline, however, was masked by a sharp increase in goat harvest in the Mica Dam area (M.U. 4-38), coincident with the influx of people into that area. In the East Kootenay (Figure 4) the situation, though more complex was essentially the same. A decline in goat harvest was discernible from

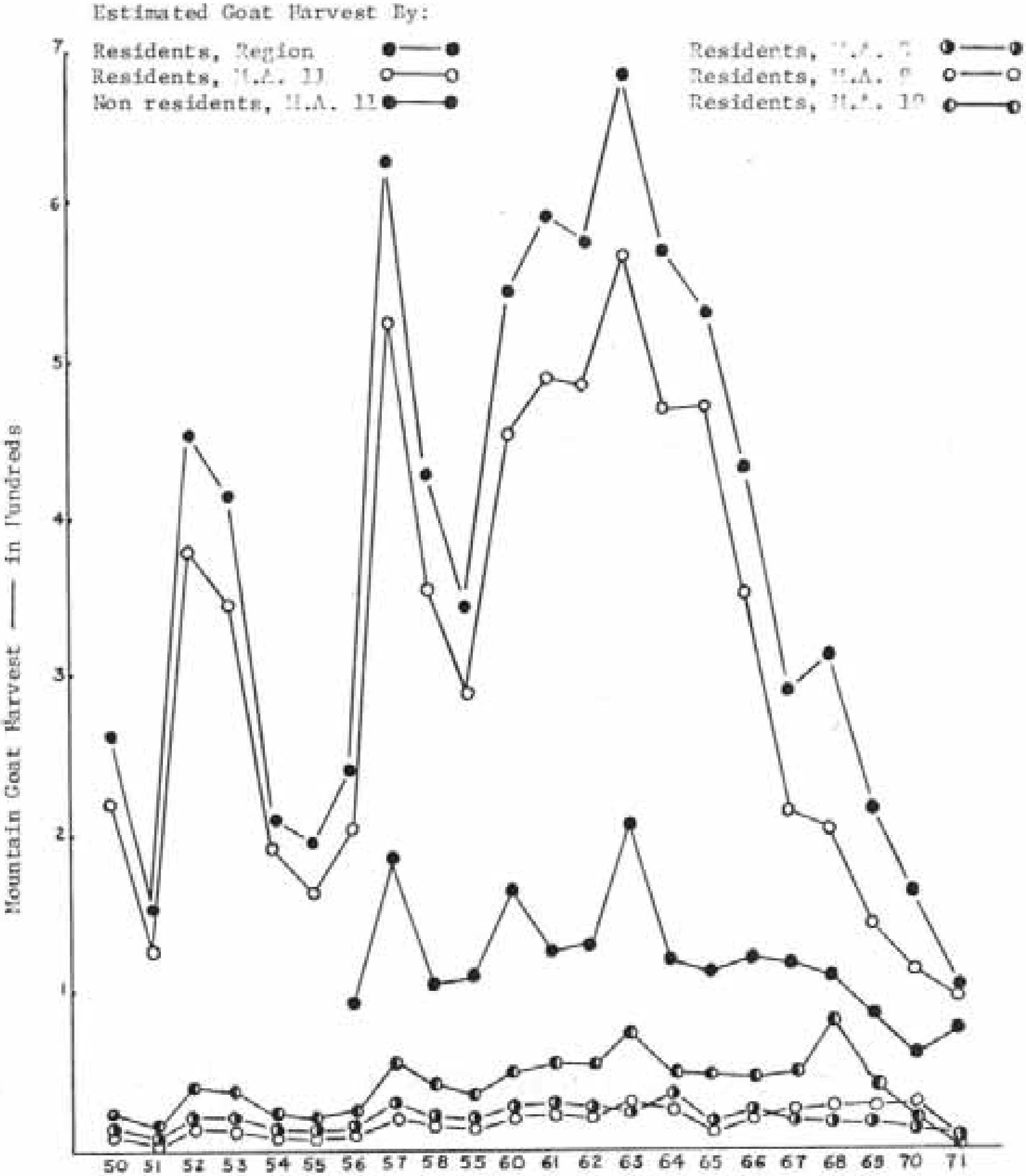

Fig 1. Goat harvests in the Kootenay Region, 1950 — 71

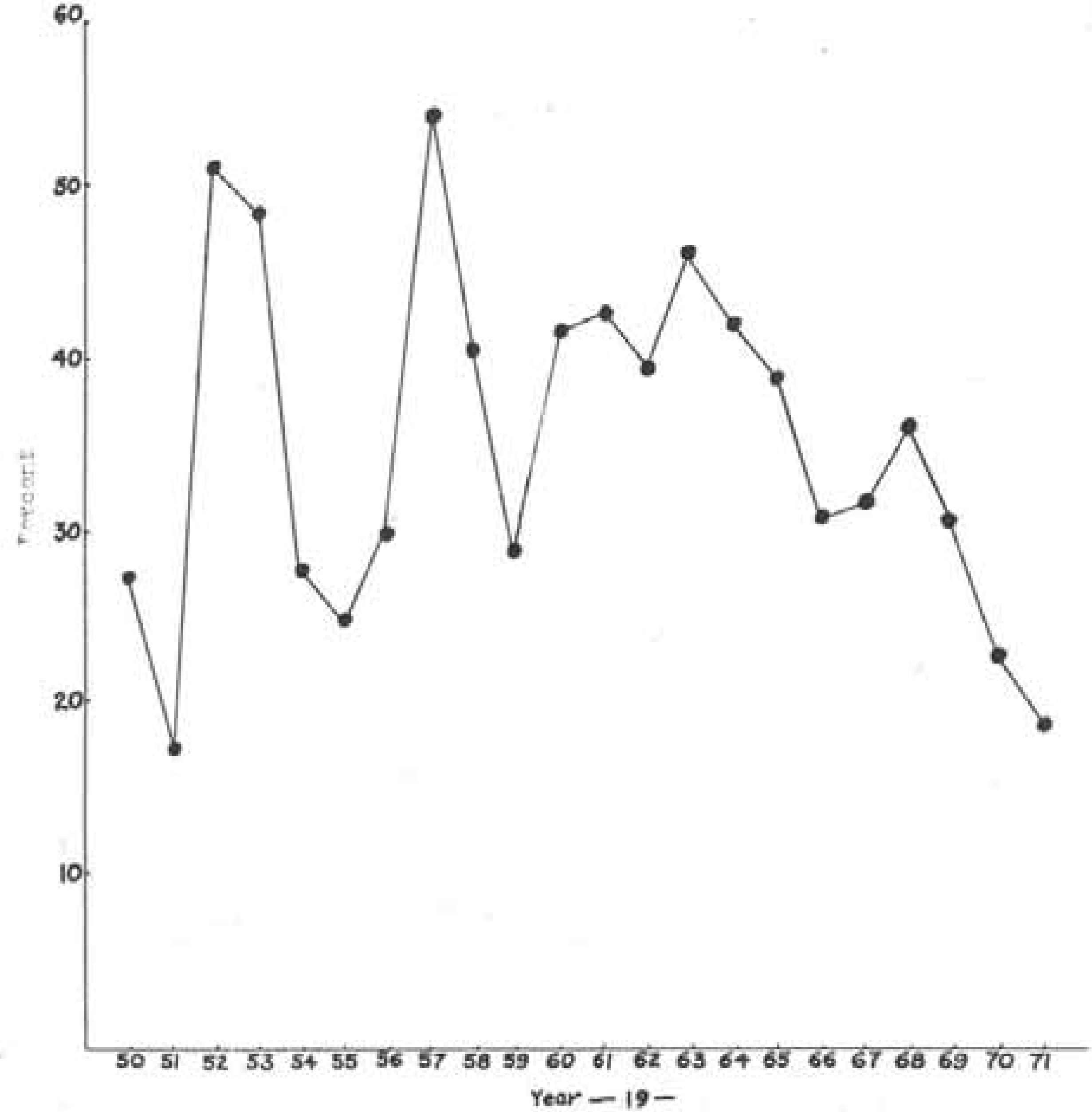

Fig. 2. Resident goat hunter success in the Kootenay Region, 1950 — 71

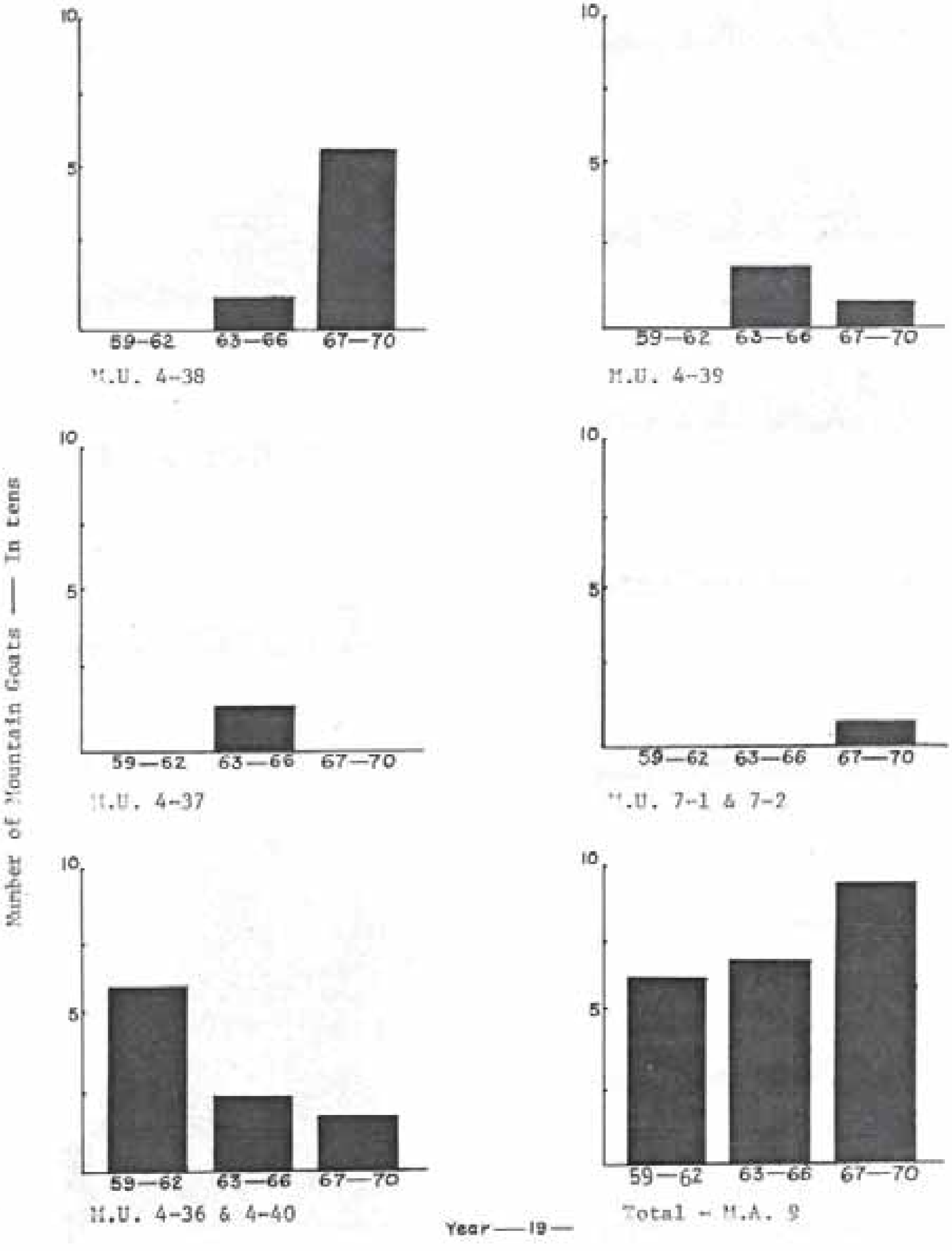

Fig. 3. The goat harvest distribution by Management Unit in Management Area 9, 1959 — 70

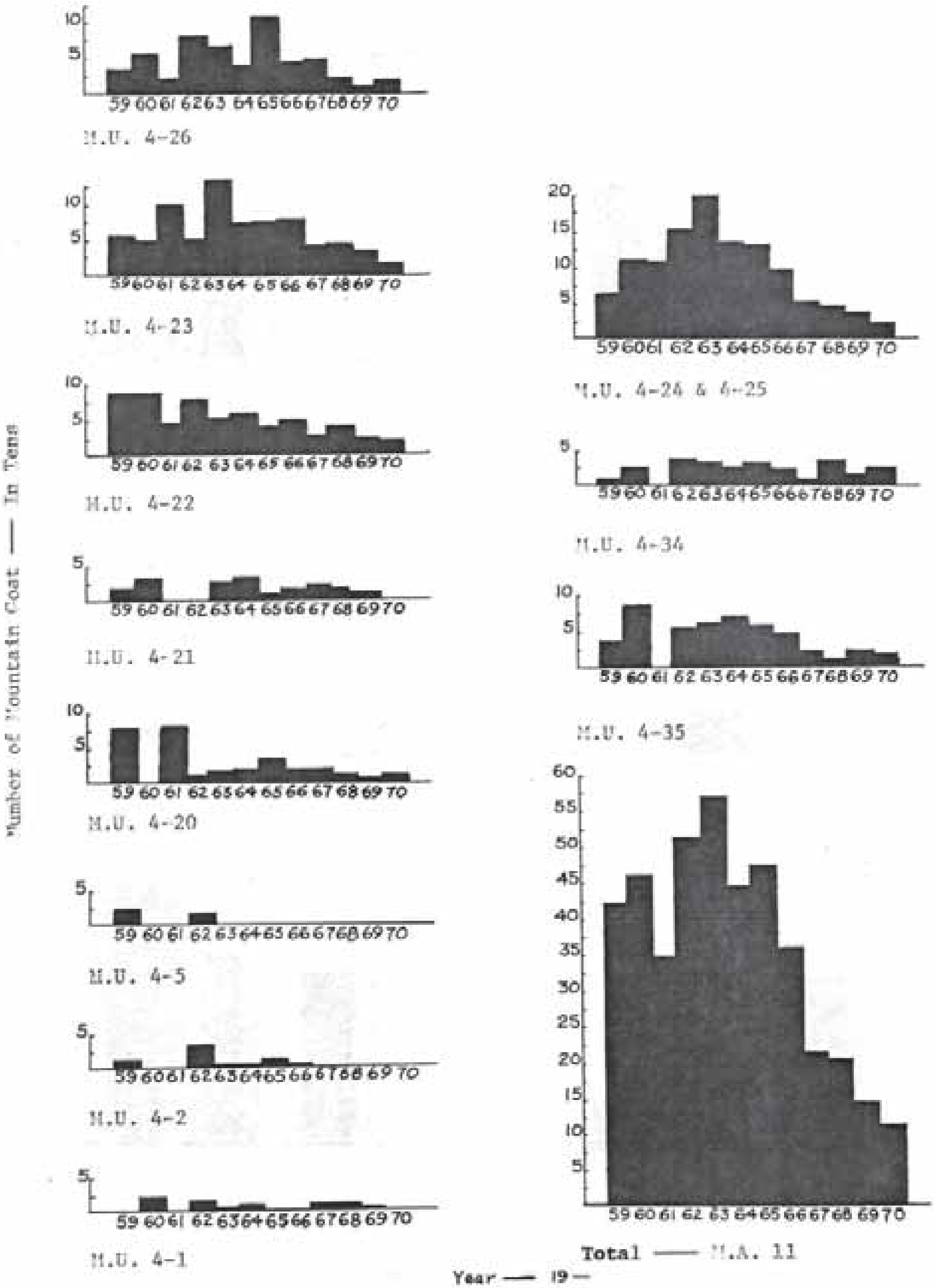

Fig. 4. The goat harvest distribution by Management Unit in Management Area 11, 1959 -- 70

1965 on, but this was made up of declines in harvest beginning as early as 1960 in the Flathead (M.U. 4-1), Bull River (M.U. 4-22)(as early as 1950 - 1955), and St. Mary's units (M.U. 4-20). These declines were masked by increasing harvests in the White River (M.U. 4-24), Upper Kootenay (M.U. 4-25), Horsethief (M.U. 4-26), and Beaverfoot (M.U. 4-35) units. These increases reflected the development of access into these units and subsequent increased goat harvest.

A game check specific to the Granby watershed provided data which indicated a severe decline in goat harvest and mean age of the kill within two years of opening (Figure 5). Harvest in the White River unit, after its status as a game reserve was dropped, and road access developed; showed a similar decline in harvest and a drastic decline in mean age of the kill (Figure 6). Similar examples of exploitation of goat populations are documented for the Highwood River (Jamieson, 1969) and Mt. Hamel (Kerr, 1965) areas in Alberta. These exploitations were attributable to insufficent management capability, a philosphy of maximum harvest and uncontrolled access development.

Based on this study, a management plan for the 1975 to 1985 period was developed and requirements for effective management of goats were laid out. A program of goat inventory was initiated in the summer of 1977 with helicopter flights by

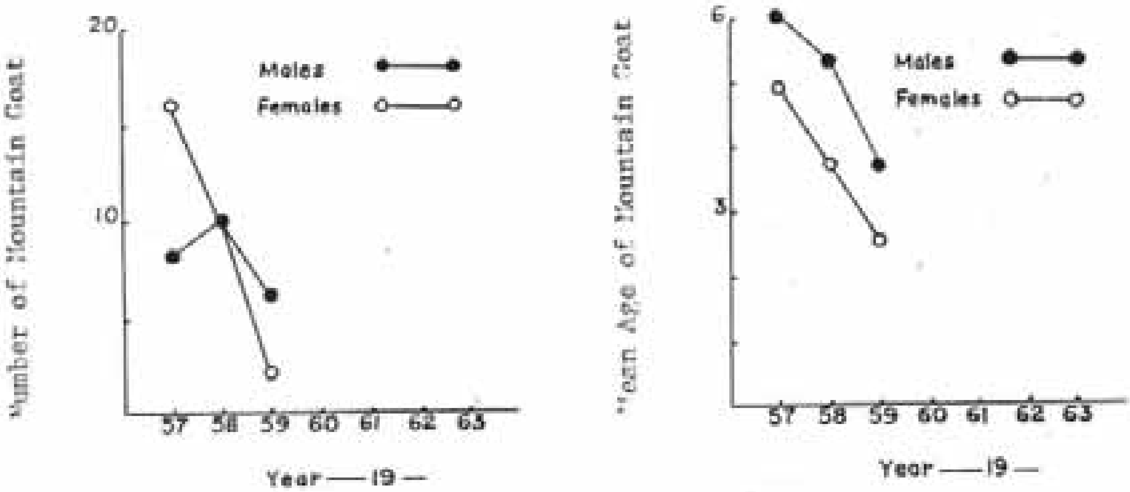

Fig. 5. The estimated resident goat harvest and the mean age of harvested goats in the Granby watershed, 1957 — 59

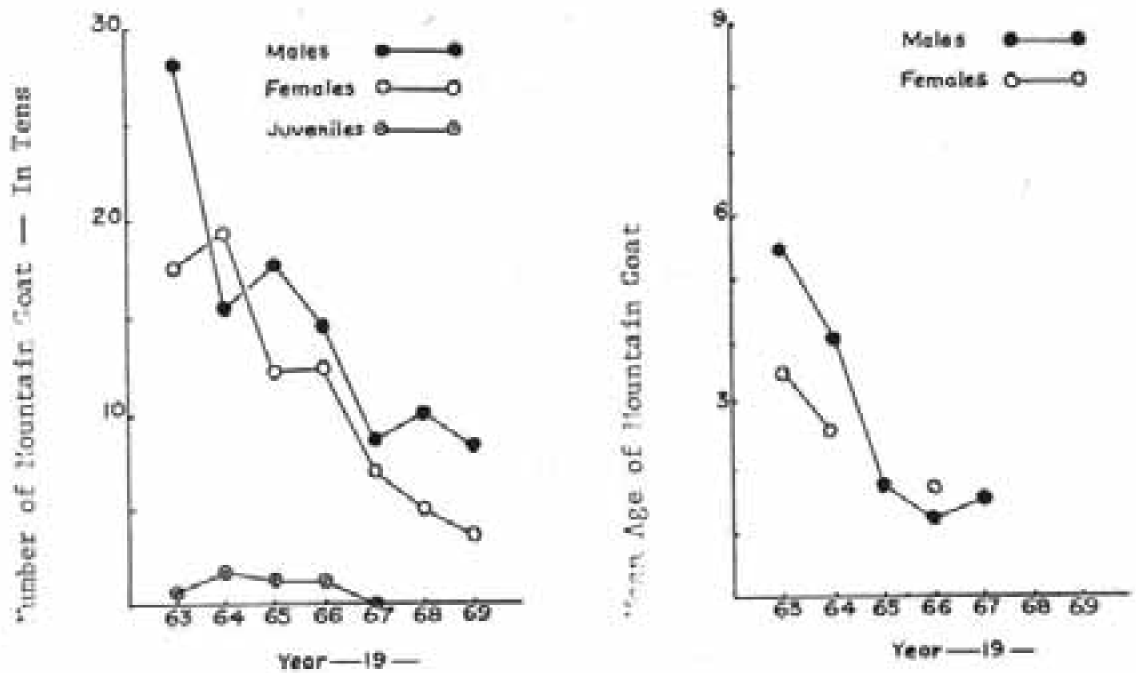

Fig. 6. The estimated resident goat harvest and the mean age of harvested goats in the Rocky Mountains (M.U. 4-21—25), 1963 — 69

W. Warkentin and G. Tipper of the Fish and Wildlife Branch and M. Burns, a consultant working in the area. A total of 503 goats were observed between Fernie and the Cross River, 83 of these were possible double counts, indicating a minimum population of 420 goats. However, within this survey area only 13 goats were seen in the Blackfoot Squaw drainage due to poor flying weather. I made 238 observations while guiding in that area in the fall of 1977. Based on these observations, I calculated a minimum population of 130 goats on one side of that unit. This, combined with the above data would indicate a minimum population of 537 goats. The actual population is probably closer to 1,000 goats.

Data from the helicopter flights indicated 50 kids per 100 adults, as did my data from the Blackfoot Squaw. These data are questionable for several reasons which will no be discussed in this presentation, but we did observe several family groups of a nannie, a two year old, a yearling and a kid, as well as two cases of twinning, indicating excellent recruitment.

No goat harvest occurred for the 1972 to 1975 period. In 1976 a limited entry season with 12 permits was initiated, as goat herds responded to protection. Eleven goats were killed; nine billies and two nannies. In 1977 the season was expanded to 20 permits, 15 goats were killed, ten billies and five nannies, with an average age of 6.2 years. In 1978 the season will be expanded to 100 permits and a quota of one goat for each guide (29 permits), based on a harvest rate of three to five goats harvested per 100 animals in the population. The length of the season will be increased from October 1 - 15 to September 15 - October 15. Expected success is 80 percent, the sex ratio of the kill is expected to change as billies are taken out of the population.

Major problems remain in goat management in the Kootenays. With the lack of effective tools for monitoring herds over the vast goat ranges of the Kootenays, there is no real guarantee that we won't repeat the errors of the 1960's. We may find that we are taking all the harvested goats out of the more accessible herds in each unit, and decimating these herds, as was found in the limited entry season in the Wilmore Wilderness Park in Alberta (Quaedvlieg, et al., 1973). Our major management concern for this species must be the development of some coherent program for access management. Access control is presently a major public issue in the Kootenays.

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GOATS AND THEIR MANAGEMENT IN ALBERTA

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INTRODUCTION

A federally commissioned big game survey conducted along the east slopes of the Rockies in Alberta (Millar, 1916), indicated that there were goats everywhere and in such numbers that it was difficult to estimate the total population which was certainly well up in the thousands. At this time, sheep and elk were in the midst of a major decline which apparently did not affect the goat population. Goats were held in low esteem as a source of meat or hides and escaped the harvest pressure attributed to elk and sheep.

In 1909, Alberta held its first mountain goat hunting season with no restrictions on age or size. However, a two bag limit was enforced. In 1923, the bag limit was changed to one animal and a 4" minimum horn length restriction was imposed. Season and horn length restriction stayed relatively the same until 1957 when some zone closures were enacted. From 1957 until the present, regulations entailed a change of season dates and zone closures. In 1969, only one area, the Willmore Park, was open, and in 1970 the entire province was closed until 1972 when a portion of the Willmore was reopened to permit hunting only (75 permits). In 1974, the Willmore area was organized into six zones containing a total of 50 permits.

In conjuction with the Willmore Park open season, an aerial survey system was developed for the purpose of monitoring goat numbers in the harvest. Successful goat hunters were asked to bring out a series of samples from their harvested goats.

The objective of these two systems were:

1) to gain information on goat density for the purpose of establishing numbers,

2) to provide preliminary data on kid production and mortality rates,

3) to provide distribution data on goats by area,

4) to provide an insight into food habits (rumen samples),

5) to provide a parasite list including number of parasites,

6) to provide data on reproductive history, and

7) to provide age structure data.

MATERIAL AND METHODS

Goat numbers were obtained by conducting aerial surveys during July when kidding was complete and the majority of goats were inhabiting alpine valleys.

Classified counts of herds of 10 or more animals were conducted by a ground crew. These animals were classified as adults, yearlings,or kids. Permits were set so that not more than a 10 per cent harvest could be realized per zone.

Hunter information was collected through the operation of three check stations. Successful hunters were asked to collect the jaw, part of a lung, and a rumen sample from all goats, and the uterus from females.

RESULTS AND DISCUSSION

The change from winter to summer surveys increased the total count by approximately 2.25 times. Similarly, kids and yearlings were easier to classify.

<u>Classified Counts and herd composition</u>

In July of 1973, 353 goats were classified as 282 adults (1+) and 71 kids. At that time, it was felt that yearlings could not be classified from the air. The adult class was broken down into 243 adults (2+) and 39 yearlings based on composition data collected between 1974 and 1977. Based on these figures, the herd composition would then be 69 per cent adults, 11 per cent yearlings, and 20 per cent kids. Herd composition data for the period 1974 - 1977 is shown in Table 1. The mean composition breakdown of the Willmore goat herd is 68 per cent adults, 11 per cent yearlings, and 21 per cent kids.

The data to date indicates that the population structure is stable. There has been no great fluctuation or change in the population structure over the four-year period, except in 1976

Table 1. Herd Composition by Year.

	1973		1974		1975		1976		1977		1974-77**	
	H	%	H	%	H	%	H	%	H	%	H	%
Adults	243*	68	224	69	224	63	235	74	254	68	1135	68
Yearlings	39*	11	43	13	47	13	20	6	38	10	183	11
Kids	71	20	58	18	84	24	62	20	84	22	361	21
Total	353		325		355		317		376		1679	

* Figures arrived at by using population composition data.

** Includes a survey conducted in June 1977 which was not considered in this paper.

when the yearling cohort accounted for only 6 per cent of the herd (the reason for this will be discussed later). This stable appearance may be caused by the limited sample size and should be reviewed with some reservations until more data can be collected.

Kid production appears to increase one year followed by a decrease the next year. This can be seen in Table 1 where 71 kids were recorded in 1973, 58 in 1974, 84 in 1975, 62 in 1976 and 84 in 1977. The data appears to indicate a yearly fluctuation, yet variation in the survey methodology may also account for this fluctuation. McFetridge (1977) shows a variation in the number of adult nannies bearing young between years, while working on Mt. Hamell and the Goat Cliffs in 1974 and 1975 (just north of Willmore Park). In 1974, he observed 23 adult nannies on his study area of which 12 had kids at heel and 11 did not. During 1975, 15 nannies were with kids and 8 were not. This type of reproduction would give a pulsating effect to the kid production.

Reproduction and Mortality

The July surveys may indicate that a certain percentage of adult nannies only bare young every second year. However, the data does not demonstrate the potential loss of kids between May and July. Examination of 50 pairs of ovaries from goats taken during the hunting season in late September and early October all show good follicle development. In addition, 38 pairs also showed follicle or corpus luteum degeneration taking place. Thus, goats would have to start follicle development sometime in August to have gone through follicle development, a rupture, a degeneration and follicle development again. Most follicle development was well advanced and in some cases rupture had occurred recently. In any case, we feel that all nannies were capable of producing eggs and had the potential of bearing kids yearly. (Those female goats coming through check stations were all classed as being in good physical condition.)

The relationship between kid production and mortality (yearly) is also unclear. Years of high kid production are followed by low yearling counts or high winter mortality of kids. In years of low kid production, yearling survival is high or kid mortality is low. In Table 2, kid production in 1973 was 30 kids per 100 adults in association with a yearling ratio of 19 per 100 adults in 1974. Yearly mortality between these age cohorts was 37 per cent. In 1974, kid production was 26 per 100 adults and yearling recruitment was 21 per 100 adults in 1975, producing a mortality rate of 19 per cent. During 1975, kid production was 38 per 100 adults while yearlings were 9 per 100 adults in 1976 (76 per cent mortality rate.) In 1977, the mortality rate was 42 per cent based on a

Table 2. Yearlings and Kids per 100 Adults by Year Plus Kid Mortality.

	1973			1974			1975			1976			1977		
	N	Y/A	K/A	N	Y/A	K/A	N	Y/A	K/A	N	Y/A	K/A	N	Y/A	K/A
A	243*			224			224			235			254		
Y	39*	16		43	19	(37%)	47	21	(19%)	20	9	(76%)	38	15	(42%)
K	71		30	58		26	84		38	62		26	84		33
Totals	353			325			355			317			376		

N - observations

Y/A - yearlings/100 adults

K/A - kids/100 adults

* Estimated by using composition data.

(37%) percent kid mortality

1976 production of 26 kids per 100 adults and 15 yearlings per 100 adults in 1977.

These data indicate that there is high mortality during high production years and low mortality during low production years. Considering the minor differences in total population, between years the fluctuating mortality rate may actually be providing a stabilizing effect. However, kid and yearling ratios per 100 adults can also fluctuate due to the incidence of males (sex ratio changes due to surveys) and barren females in the population.

The 1976 mortality rate of 76 per cent may have resulted from the heavy snowfall which occurred in the mountains that year.

Harvest and distribution of kill

Since 1972, 331 permits have been issued with 232 or 70 per cent of the hunters actually hunted.

Of the 122 goats taken, 67 were females and 55 were males, a ratio of 1.2 nannies/male. The breakdown by year is given in Table 3. Only 4 yearlings have been harvested to date. This may be due to the minimum four-inch horn measurement requirement or our emphasis on a trophy season. The important points are:

Table 3. Summary of Goat Hunting Seasons in Alberta 1972-77.

Year	No. of Permits Issued	No. of Hunters Hunting	Successful Hunters	Unsuccessful Hunters	F	M	F/M	Success Rate	
1972	75	40	22	18	12	10	1.2:1	22*	55**
1973	50	36	14	22	7	7	1:1	28	39
1974	53	32	13	19	6	7	0.85:1	25	41
1975	55	43	28	15	18	10	1.8:1	51	65
1976	48	44	29	15	13	16	0.8:1	60	66
1977	50	37	16	21	11	5	2.2:1	32	43
Total	331	232	122	110	67	55	1.2:1	37	53

M - Males in harvest
F - Females in harvest
F/M - ratio of females to males

* Based on total permits

** Based on those who hunted

1) The female kill was greatest during poor hunting years (e.g. 1975 and 1977) or when hunters were congregated in one area as in 1972.

2) The low rate of harvest on yearling animals.

The summary of harvest by area is shown in Table 4 and reflects the high rate of success that can be achieved.

Success rates between 1974 - 1977 were: A - 40 to 100 per cent, B - 10 to 64 per cent, C - 7 to 62 per cent, D - 0 to 66 per cent, E - 66 to 100 per cent, F - 0 to 17 per cent. The 1972 and 1973 success rate are low in comparison to other areas, but it is important to note that the harvest occurred in only two areas, resulting in a high harvest on the most accessible goats. This indicates that goats must be managed more conservatively or with more precise data.

Age Structure

According to tooth sectioning information, the age distribution of male and female goats harvested in the Willmore ranged from 1½ years to 9½ years (Table 5). A further breakdown shows that 35 per cent of the animals were between the age of 1½ and 3½, while 65 per cent were between 4½ and 9½ (Table 6). The mean age for males and females is 5½ years.

Table 4. Summary of Harvest by Area.

Area	1974			1975			1976			1977		
	P	H	%	P	H	%	P	H	%	P	H	%
A	10	4	40	5	3	60	5	5	100	7	3	43
B	10	1	10	14	8	57	14	9	64	13	7	54
C	12	4	33	13	3	23	13	8	62	14	1	7
D	10	-	-	12	8	66	5	3	60	5	-	-
E	6	4	66	5	4	80	5	2	40	5	5	100
F	5	-	-	6	2	33	6	2	33	6	1	17
TOTALS	53	13	25	55	28	51	48	29	60	50	17	34

	1972		
	P	H	%
C			
D	75	22	29
F			

	1973		
C			
D	50	14	28
F			

P - Number of permits issued

H - Number of goats harvested

% - Harvest rate

Table 5. Estimated Age of Males and Females by Incisor Annuli. (1972-1977)

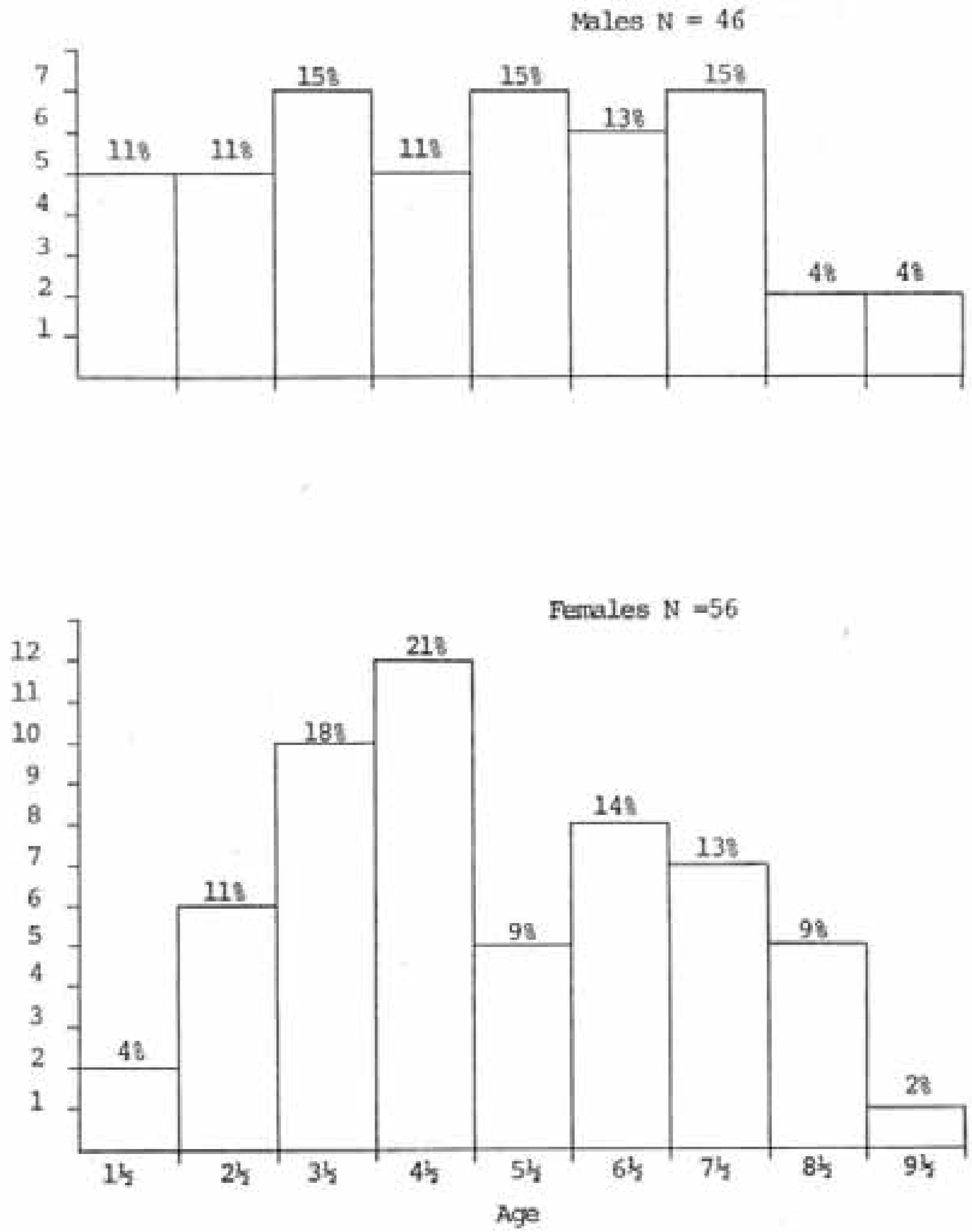
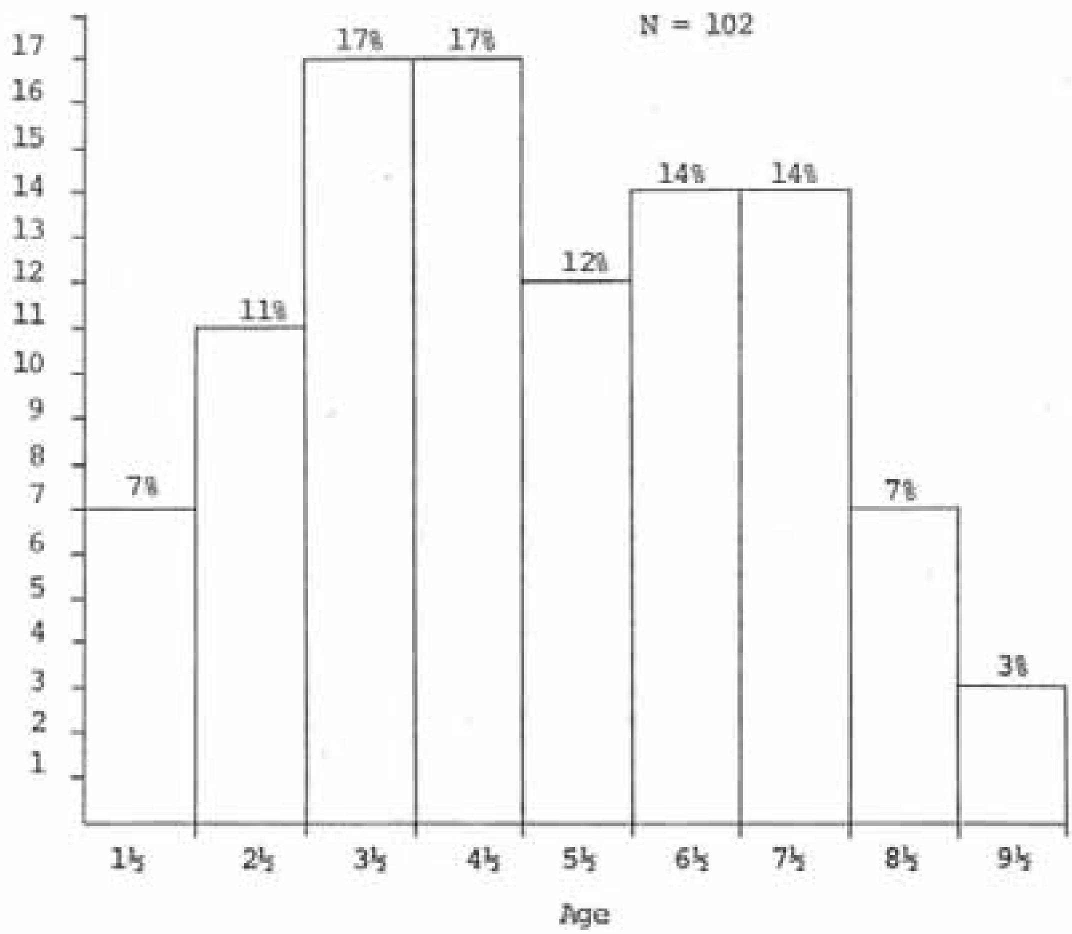


Table 6. Age Distribution of Goats from 1972-77 by Incisor Annuli.



Management Implications

The main objective of goat management in Alberta is to develop a management plan that will establish and sustain goat numbers which will supply recreational opportunity to both non-consumptive and consumptive users. This means that we must establish the level at which goats can be safely harvested.

A good monitoring system should provide information on all components of the population. Goat census work, however, is limited by time, experience of the observer, and restricted budgets. Therefore, it was decided to utilize an aerial classified count which would provide basic herd composition; kids, yearlings and adults annually by area. These aerial counts are supplemented by classified counts from the ground.

This classification system is presently supplying the following information:

(1) A classified count of 300+ goats per year,

(2) kid production and the number of yearlings,

(3) trend information on kid mortality, recruitment, population trends and composition,

(4) age of first breeding,

(5) establishment of recruitment ratios/100 females utilizing age of first breeding.

Adequate management can be undertaken utilizing the above information. However, it should be supplemented with information on:

(1) Natural and unnatural mortality,

(2) sex ratios, and

(3) production and recruitment ratios/100 females.

This information, combined with the following harvest data (1 - number of goats harvested by area, 2 - sex ratios, 3 - the success rate by area, 4 - the age structure), should allow us to establish a management plan. The above data has been used to build a model which will indicate the level of harvest of goats in Alberta and the safe level at which to harvest. Before designing the model, we made the following assumptions:

(1) Kid mortality (natural) is 50 per cent per year (4 - year mean for Alberta).

(2) No yearlings or kids are harvested (3 yearlings in the last 4 years - now have a 4" horn regulation).

(3) Harvest ratios are 100 per cent (10 permits - 10 goats harvested).

(4) Mortality is nil after 1½ years of age.

(5) Females do not breed until 2½ years of age.

(6) Reproduction based on number of adults in spring population.

Models one, two, and three are shown in Tables 7, 8, and 9. These models show what could happen when harvesting takes place at the 10 per cent level, the 5 per cent level, and at the present level of harvest in Alberta. All three models are based on data collected in the Willmore and are based on numbers per 100 adults.

Table 7. Effects of Harvesting at the 10% Level

1st year	1973 + 11 yearlings	100 adults
		111 spring population (1974)
	1974 + 26 kids	137 fall population
		- 11 permits (10% of spring population)
		126 breeding population
		11 - yrlg.
		26 - kids (assuming no yearling harvest)
		89 - adults
		- 13 kid mortality
2nd year		113 spring population
		11 - 2 year
		13 - yrlg.
		89 - adult
	1975 + 34 kids	147 fall population
		- 11 permits (10% of spring population)
		136 breeding population
		13 - yrlg.
		34 - kids
		89 - adults
		- 17 kid mortality
3rd year		119 spring population
		13 - 2 year
		17 - yrlg.
		89 - adult
	1976 + 23 kids	142 fall population
		- 12 permits (10% spring population)
		130 breeding population
		17 - yrlg.
		23 - kids
		90 - adult
		- 11 kid mortality
4th year		119 spring population
		17 - 2 year
		12 - yrlg.
		90 - adult
	1977 + 30 kids	149 fall popualtion
		- 11 permits
		138 breeding population
		12 - yrlg.
		30 - kids
		96 - adult
		- 15 mortality
		123 spring population
		12 - 2 year
		15 - yrlg.
		96 - adult

Table 8. The Effect of Harvesting at the 5% Level

1st year	1973 + 11 yearlings	100 adults
		111 spring population (1974)
	1974 + 26 kids	137 fall population
		- 6 permits (5% of spring population)
		131 breeding population
		11 yrlg.
		26 kids
		94 adults
		- 13 kid mortality
2nd year		118 spring
		11 - 2 year
		13 - yrlg.
		94 - adult
	1975 + 36 kids	154 fall population
		- 6 permits (5% of spring population)
		148 breeding population
		13 - yrlg.
		36 - kids
		99 - adult
		- 18 kid mortality
3rd year		130 spring population
		13 - 2 year
		18 - yrlg.
		99 - adult
	1976 + 26 kids	156 fall population
		- 7 permits (5% of spring population)
		149 breeding population
		18 - yrlg.
		26 - kids
		105 - adult
		- 13 kid mortality
4th year		136 spring population
		18 - 2 year
		13 - yrlg.
		105 - adult
	1977 + 35 kids	171 fall population
		- 7 permits (5% of spring population)
		164 breeding population
		13 - yrlg.
		35 - yr.
		116 - adult
		- 17 kid mortality
		147 spring population
		13 - 2 yr.
		18 - yrlg.
		116 - adults

Table 9. The Effect of Alberta Harvest (Permits based on 10% of spring population).

1st year	1973 + 11 yearlings	100 adults 111 spring population (1974)
	1974 + 26 kids	137 fall population - 3 (11 permit 25% harvest) 1974 134 breeding population 11 - yrlg. 26 - kids 97 - adult - 5 (19% of 26) kid mortality
2nd year		129 spring population 11 - 2 yr. 21 - yrlg. 97 - adult
	1975 + 37 kids	166 fall population - 7 (13 permits 51% harvest) 1975 159 breeding population 21 - yrlg. 37 - kids 101 - adult - 28 (76% of 37) kid mortality
3rd year		131 spring population 21 - 2 yr. 9 - yrlg. 101 - adult
	1976 + 26 kids	157 fall population - 8 (13 permits 60% harvest) 1976 149 breeding population 9 - yrlg. 26 - kids 114 - adult - 11 (42% of 26) kid mortality
4th year		138 spring population 9 - 2 yr. 15 - yrlg. 114 - adult
	1977 + 38 kids	176 fall population - 4 (14 permits 32% harvest) 1977 172 breeding population 15 - yrlg. 38 - kids 118 - adult

Results from Table 7. (Results from harvesting at the 10 per cent level)

1) Started with 100 adults and 11 yearlings

1st year	a. adults breeding dropped to 89 (100 - 11 permits) b. spring population shows increase of 2 animals - adult numbers still at 100
2nd year	c. adults breeding at 89 d. spring population of 119 up 6 animals - adult numbers at 102 (up 2)
3rd year	e. adults breeding 90 f. spring population at 119 (no increase) adults at 107 (up 5)
4th year	g. adults breeding 96 h. spring population 123 - 108 adults and 15 yearlings

Overall, the population has increased by 12 animals after four years, yet the breeding segment has decreased by 4 animals.

The population has increased by 8 per cent after four years, yet the adult or breeding segment has not yet recovered from its first season when 11 animals, or 10 per cent of the adult animals, were harvested.

This may indicate that harvesting at the 10 per cent level could be detrimental as the harvest is close to the maximum recruitment rate. Also herd expansion will be slow, if at all, and virtually no buffer zone is available to cover for unexpected mortality.

Results from Table 8. (Harvesting at the 5% level)

1) Started with 100 adults and 11 yearlings

1st year	a.	94 breeding adults
	b.	spring population up 7 animals (adults at 105, up five)
2nd year	c.	99 breeding adults
	d.	spring population up 12 animals (adults at 112, up 7)
3rd year	e.	105 breeding adults
	f.	spring population up 6 animals (adults at 123, up 11)
4th year	g.	116 breeding adults
	h.	spring population up 9 animals (adults at 129, up 6)

Overall the population has increased by 36 animals after four years and the production segment has increased by 16 animals. The population has increased by 32% while the breeding segment is up 16%.

This is a more desirable level of harvest, in that it is conservative enough to allow for growth and at the same time supplies a buffer zone.

Results From Table 9. (Effect of Alberta's present level of harvest)

1) Starts with 100 adults and 11 yearlings

1st year
- a. adult breeding stock at 97
- b. spring population up 18 animals (adults at 108, up 8)

2nd year
- c. adult breeding stock at 101
- d. spring population up 3 animals (adults at 122, up 14 animals)

3rd year
- e. adult breeding stock at 114
- f. spring population up 7 animals (adults at 123, up 1)

- g. adult breeding stock at 118 animals

The population has increased by 27 animals or 24 per cent after three years, with the breeding segment showing an increase of 14 per cent or 14 animals. In comparison to the other two models, it would appear that the present level of harvest in Alberta is taking place at the 5 per cent level.

Of the two theoretical models and the one natural model, the 5 per cent level is the safer level for actual harvest. Harvesting at this level allows for growth (at about 33 per cent over four years) and for unexpected mortality, such as that which took place during the winter of 1975 - 1976 when kid mortality was 76 per cent.

The 5 per cent level may be a safe level for harvest, but we feel the following areas should be looked at in order to substantiate this:

(1) What effect the reproduction fluctuations are having on production and on recruitment (if, in fact, fluctuations are taking place).

(2) What effect is the harvesting of adult females having on reproduction.

(3) What effect is the harvesting of adult males having on the breeding process.

(4) Herd composition should be clarified.

(5) Movement patterns.

In summary, until mountain goat biology is better understood, harvest should not exceed the 5 per cent level, and this harvest rate should be applied at the herd level or to drainages or mountain complexes, but not as a blanket policy.

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INITIAL OBSERVATIONS ON A TAGGED MOUNTAIN GOAT POPULATION IN THE OLYMPIC MOUNTAINS

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INTRODUCTION

The perspective on goats in Olympic National Park is contrary to that of many goat range managers. The Park has too many. In a National Park, one individual of a non-native species is theoretically too many, and mountain goats are a non-native species. By an accident of history, goats did not invade the Olympic Mountains. In 1926, in an effort to correct that oversight, state and federal officials introduced four individuals from the Selkirks in Alberta. During the next four years goats obtained from Alaska, in exchange for Roosevelt elk calves, provided animals for two more introductions, approximately 11. The hopes of establishing another big game species on the peninsula for hunting purposes were damped by the establishment of Olympic National Park in 1933 on at least 95% of the potential goat habitat.

In the 50 years since the introductions the goats have dispersed throughout the mountainous interior and eastern portion of the peninsula and the total population has grown to an estimated 1,000 individuals (Moorhead 1977, Figure 1). A few of these find their way out of the park each fall and there is a legal hunting season on the periphery. Of the 20 archery permits allotted each year, 3 to 8 goats are taken.

The Park Service has initiated the present study to assess the immediate and potential impact of goat use on the ecosystem. Their management policies state that "control or eradication of exotic species will be undertaken when their presence threatens the perpetuation of significant scientific features, ecological communities and native species ...." (Olympic National Park 1973). Of particular concern is the handful of endemic plants and their relationship with the goats with whom they now share their mountainous habitat. One species, Senecio neowebsterii has already been documented as goat forage (Olmsted 1977).

METHODS AND MATERIALS

Effective control is based on a sound understanding of the dynamics of the population and its habitat requirements. To begin an assessment of the former, a tagging operation was initiated in June, 1977, and by September, 1977, 68 animals were tagged with individually identifiable ear tags. The data collected to date is being used to monitor movements and to estimate population parameters.

The major focus during 1977 was on the largest, densest and most accessible herd in the park. Its range is the area on and around Mt. Angeles and Klahhane Ridge in the northeast section of the park. From 1972 to 1976 the Park Service and the Game Department cooperated on a tagging operation in this area. A total of 34 animals were tagged with colored ear ribbons of which 14 are estimated to be still in the population. Most of these tags are not individually identifiable. Last summer we tagged 54 goats on Klahhane Ridge with numbered tags that can be identified at approximately half a mile with a 60 x power scope. The remaining 14 were tagged in the Lake Constance area in the east-central area of the park. The goats on Klahhane Ridge were captured primarily by snaring at an artificial salt lick which was established several years

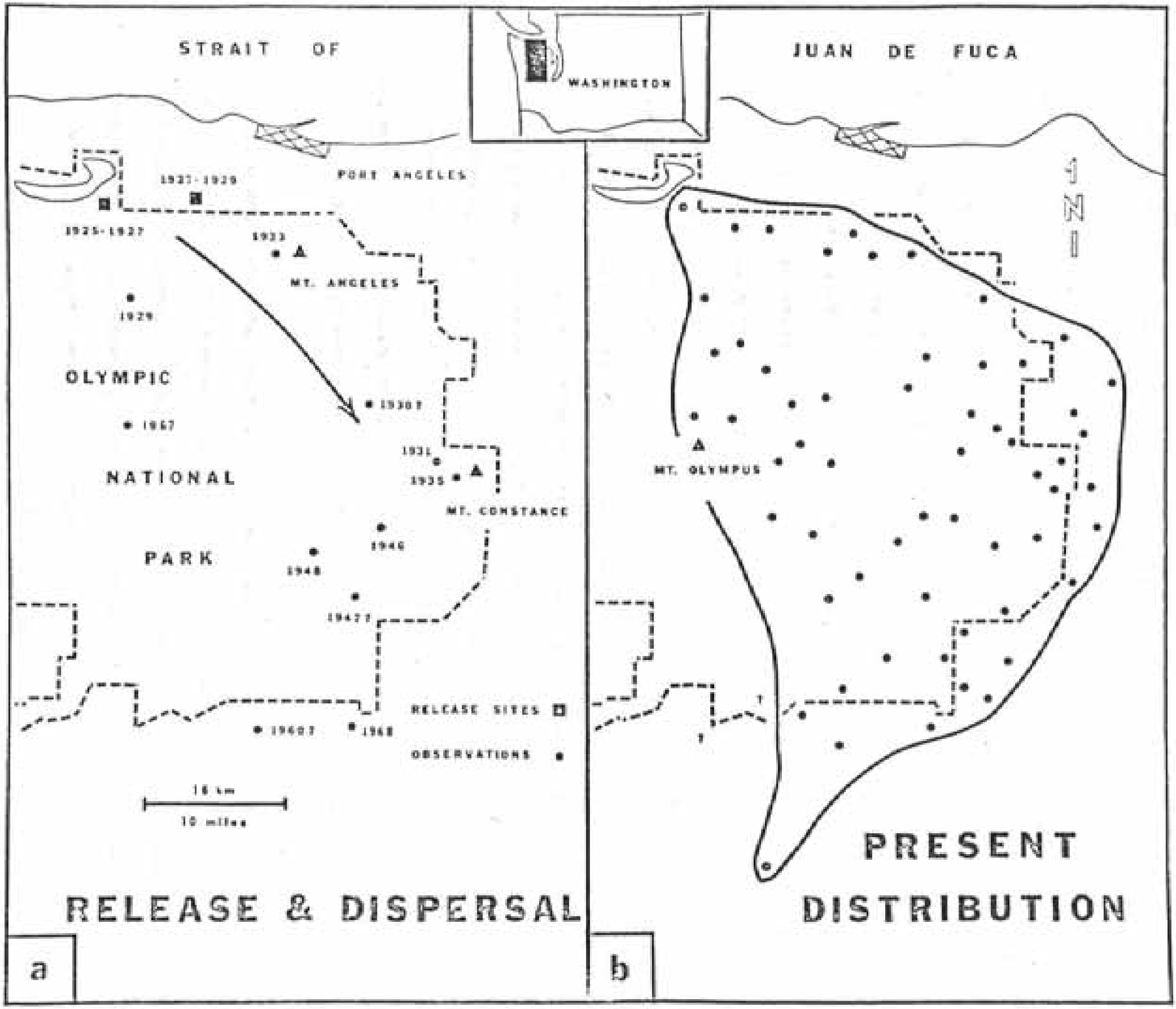

FIGURE 1. Distribution of mountain goats in Olympic National Park.

ago by the Park Service. The salting practice has been abandoned by the park, but the lick area is still sought by the goats in the spring and summer.

RESULTS

Population Parameters:

The composition of the newly tagged population on Klahhane Ridge is 61% adult females, 9% adult males, 13% yearling females, 7% yearling males,6% female kids and 4% male kids. The animals were aged by horn annuli. The presence of a known number of tagged individuals has permitted census estimates. From 16 to 60% of the estimated total population has been observed from the ground each month from September through March with the exception of November when weather precluded any observations. From a cummulative record of these censuses, the per cent of each cohort that is tagged was calculated to be 54% adult females, 15% adult males, 44% yearling females, 15% yearling males and 7% kids. The same data was used to estimate the adult male/female ratio at 56 males per 100 females. Due to the small percentage of males seen during the winter months, the confidence interval is large for the adult male estimate. The estimates for adult males and therefore the ratio of males to females will presumably be more accurate after the censuses of the spring and summer of 1978.

Total population of Klahhane Ridge has been estimated each month using Bailey's modification of the Petersen estimate (Seber, 1973). Estimates have ranged from 100 to 221. By using the cummulative data since September, 1977, and calculating each cohort separately, the assumption of equal catchability is more closely met, and the estimate is 256 with a 95% confidence interval of 164 to 344.

The first goat was seen in the Klahhane Ridge area in 1933. In the 45 years since that time the intrinsic rate of growth has been 11% based on a population estimate of 256. Caughley (1977) noted that in growing populations the age of fecundity is sometimes lower than in populations with no growth. Reports (Hibbs 1966, Hjeljord 1971, Rideout 1974) indicate that mountain goats usually begin breeding at 3½ and have their first kid at 4 years although they are capable of breeding at 2½ and kidding at 3. In the Olympic population we did not observe a single 3 year old without a kid and occasionally a 2 year old had a kid. Another indication of a healthy, growing population is the twinning rate. Last summer the twinning rate was 6% among the tagged adult females, which in part was responsible for the exceptionally high overall reproductive rate. Twinning is a rare occurrence in a native or long-established population. (Chackwick 1973, Rideout 1974). In September there were 97 kids per 100 adult females, an adult female being 2 years or older. This high rate was in spite of at least 2 kid deaths that were known prior to the date of the September census.

Another important aspect of population growth is kid survival during the first year. We have tried to monitor that aspect closely each month and have developed three regression lines based on different combinations of data (Figure 2). The first line is computed from the kid/nanny ratio each month using the tagged and untagged sample and estimates a mortality of 33% from September - March. The second line is computed from the ratio of kids to nannies using only the tagged nannies and estimates a kid loss of 26% from September to March. The third line was included only to show minimum known loss. It was computed from the known losses of the tagged adult females and shows a mimimum loss of 15% from Sept-

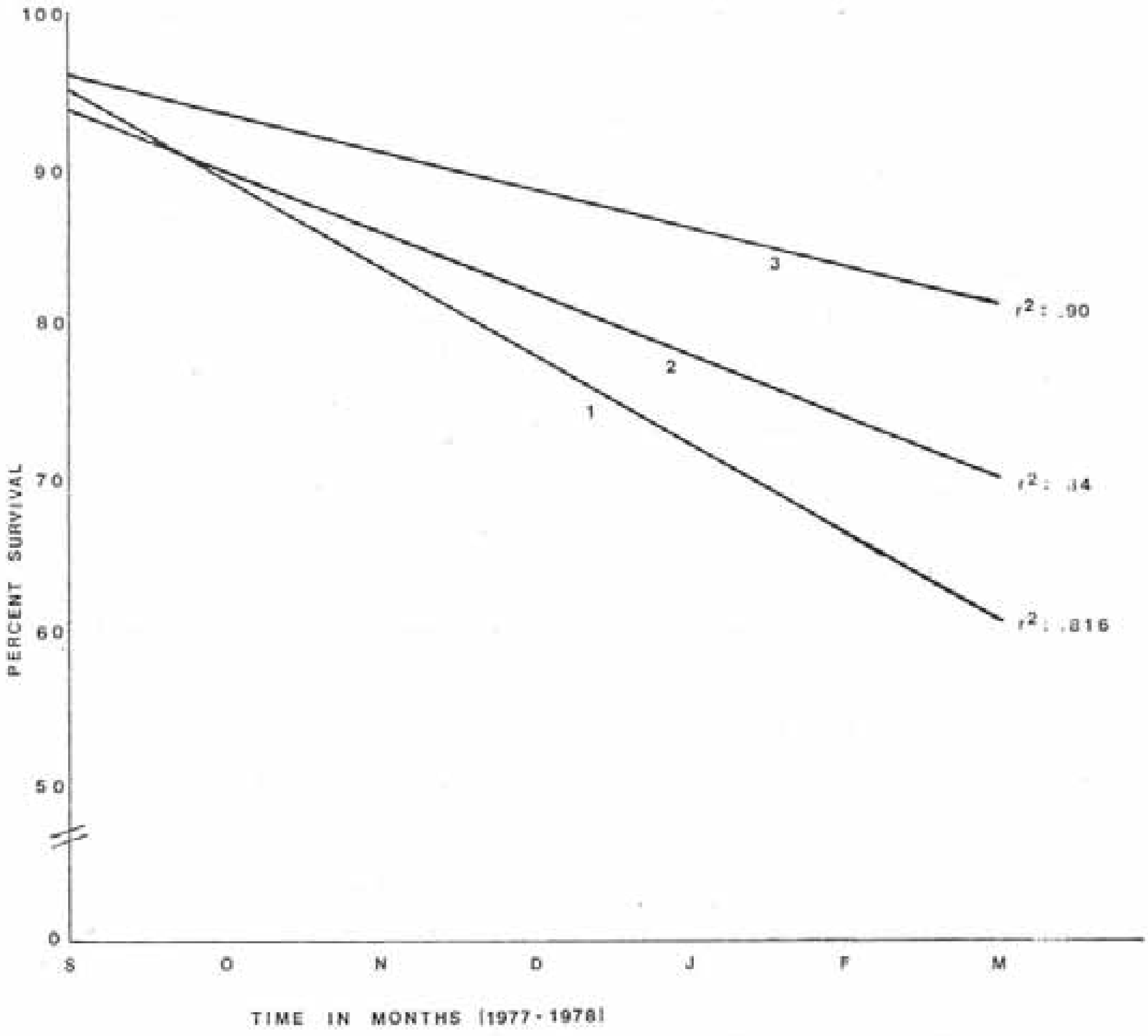

FIGURE 2. Regression of kid survival computed 1. using all individuals sampled, 2. using only tagged sample, 3. using cumulative known deaths.

ember to March.

Causes of kid mortality are rarely known. The remnants of one kid were found in mid-summer after being partially devoured by what appeared to be a bobcat. It was not known if the bobcat killed the kid or found it dead. Of the 6 tagged nannies that have lost kids, all were 3 or 4 years or younger and therefore could have been inexperienced and physiologically ill-prepared to support their offspring. In fact, of the tagged nannies that have been seen since September, 25% of those in the 4 year or younger group have lost kids as opposed to 12.5% in the older age group. This difference was significant at the 95% level. Growth and maturity of the nanny appears to be related to kid survival. Weight data collected by the park biologist suggests that full growth is not attained until at least 4 years. Of the three losses in the older age group, one was a twin and therefore had less parental investment than would a single kid.

Movements:

Social and spatial dynamics both within and between groups are also of importance to managers. With 20% of the population on Klahhane Ridge tagged, patterns of association and movement are developing. Close association appears to be limited to nanny and kid pairs, but fidelity to a winter home range was very apparent. The area sampled can be divided into three discrete portions. The goats within any one portion tend to be the same from month to month in spite of the fact that travel between areas does occur. It is significant that goats tagged during the same day are more likely to be in the same geographical area during the winter in spite of the opportunity to randomize during the summer. Since we used consecutively numbered tags and tagged in order, series of numbers in the same area indicate some group cohesion from summer to winter.

During the years of data collection the only difference that we have been able to detect was that adult females in the lower area around the tunnels are losing large patches of hair as early as February. Last year one animal with an acute example of this condition was found dead on the summer range. To date, we have not been able to diagnose the affliction. A difference in forage quality between the tunnels and the other areas is one possible reason for the geographical isolation of this condition, but it has not yet been tested.

The last thing to mention is our new ability to see dispersal with a large percentage of tagged animals. Until last summer, no tagged goats were ever seen outside of the Mt. Angeles - Klahhane Ridge area except for one reported sighting on the opposite boundary of the park which was discounted by the park biologist because of what seemed to be an impossible distance to cover in a matter of weeks. Last summer we had 4 sightings of tagged animals, all males, at least halfway across the park. One of these goats, a 2 year old billy, was tagged 3 weeks earlier on Klahhane Ridge. He had travelled approximately 35 airline kilometers by the next time he was observed. This billy stayed in the new area for approximately a week and then moved on and has not been reported since.

This type of movement has not been observed in the other cohorts. Only 6% of the tagged adult females have disappeared from the Klahhane Ridge area since September as opposed to 60% of the adult males. We would venture to guess that the majority of those not seen are either dead or are wintering in an unsampled area near Klahhane and will be back on the ridge in the summer.

The ease with which these goats can be individually marked and observed makes possible an analysis of movement, grouping and population dynamics not possible in most herds. It is anticipated that we will tag at least another 20% of the herd this summer and with careful and consistent observation will soon have an excellent opportunity to analyze fecundity and mortality by age class; kid and yearling survival related to the condition of the nanny; relatedness of individuals on a home range; productivity by home range and dispersal rate by age and sex class.

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STATUS OF INTRODUCED MOUNTAIN GOATS IN THE EAGLES NEST WILDERNESS AREA, COLORADO

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ABSTRACT

Mountain goats (*Oreamnos americanus*) were studied in the Eagles Nest Wilderness Area in Summit and Eagle Counties, Colorado, from June 8, 1977, to August 2, 1977, to determine population size, sex and age ratios, distribution, habitat utilization, mineral lick behavior, mortality, and interactions with predators, recreationists, and indigenous bighorn sheep (*Ovis canadensis*).

The minimum to maximum population of goats inhabiting the area was 77-110 goats. Sex and age ratios were 48 kids: 100 older animals, 57 kids and 18 yearlings: 100 adults, and 125 kids: 100 nannies. Summer distribution extended as far west as the West slope of Mt. Powell, as far north as the northern slope of Dora Mountain, and as far south and east as Slate Creek. This encompasses about 62.4 square kilometers within the Wilderness boundary.

Northern aspects were used in 56 per cent of the non-lick

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observations (n=50). Goats were observed within 0.4 kilometers of water in 80 per cent of the sightings. Observations of goats ranged in elevation from 3,414 meters to 3,840 meters. Grasses, sedges, and forbs comprised the vegetation type in 77 per cent of the accounts.

Mountain goats used mineral licks extensively. Soil analyses from two licks indicated that sodium was probably the attracting mineral while phosphorus was quite low. The dominance hierarchy at licks was, in decreasing order, nannies with kids, nannies, billies, and yearlings of either sex. Based on population estimates since introduction in 1966, the mountain goat population appears to be increasing exponentially.

INTRODUCTION

The Colorado Division of Wildlife introduced the Rocky Mountain goat (*Oreamnos americanus*) into Colorado in 1948 (Rutherford 1972). Since then, herds have been established in several areas of the state for consumptive and nonconsumptive use. Three male and five female mountain goats from South Dakota were transplanted into the Eagles Nest Welderness Area (then called the Gore Range-Eagles Nest Primitive Area) on June 13, 1968. This introduction was based on the migration of two billies into the range from either the Mt. Evans or Collegiate Range herds. Their persistence in the range indicated that the habitat was suitable for mountain goats. In 1970, one male and two females from British Columbia were released. The male was later found dead and another male from British Columbia was transplanted in

1971. During the summer of 1972, the Division of Wildlife released one male and four females from the Mt. Shavano herd in Colorado.

Bruce McCloskey, of the Colorado Division of Wildlife, sighted 53 different goats during a helicopter survey in 1976. The population was estimated at 75 mountain goats. Prior to the helicopter survey and this study, little was known about the dynamics and habitat utilization of this herd. There was some concern about the possibility of competition between the goats and bighorn sheep (*Ovis canadensis*) which have historically inhabited the Gore Range.

The Gore Range-Eagles Nest Primitive Area was designated the Eagles Nest Wilderness Area on July 12, 1976, and is managed under the Wilderness Act of September 3, 1964. Under the proposed management plan, non-indigenous species like the mountain goat may be allowed to maintain an equilibrium with carrying capacity provided that they are not detrimental to native species or the wilderness resource (USDA Forest Service, 1977).

The Colorado Division of Wildlife (1974) identified five problems in mountain goat management in the state:

1. There are not enough mountain goats to satisfy the demand for sport hunting.
2. Areas which should have mountain goats do not.
3. Existing mountain goat populations are not being maintained at proper levels.
4. Mountain goats may compete with bighorn sheep where they occur together.

5. Surplus mountain goats are not being harvested.

The demand for harvesting mountain goats exceeds the present supply. In 1976, 438 people applied for 48 licenses to harvest mountain goats in Colorado. This study area will be opened for mountain goat for the first time. Four permits will be issued for rifle hunting during the period from August 26 to October 9, 1978.

The primary objectives of this study were to (1) obtain minimum and maximum mountain goat population estimates, (2) estimate sex and age ratios for the population, (3) determine the summer goat distribution, (4) delineate habitat types frequented by goats, and (5) record information on mortality, mineral lick behavior, and interactions with predators, bighorn sheep, and recreationists. Data obtained during this study will assist both agencies in future management decisions.

This study was a cooperative project between the Dillon Ranger District of Arapaho National Forest, the Colorado Division of Wildlife, and the Department of Zoology and Physiology at the University of Wyoming. Support was provided by the Forest Service and the Division of Wildlife. We are grateful to personnel of both agencies, particularly Bruce McCloskey of the Colorado Division of Wildlife and Dennis Havig of the U.S. Forest Service for providing advice and logistical support. We also wish to thank Robert Keiss of the Colorado Division of Wildlife for the analysis of soil samples.

THE STUDY AREA

The study area is defined by the boundaries of the Eagles Nest Wilderness Area which contains the high peaks of the Gore Range. The Wilderness is located approximately 8 km. (5 miles) northeast of Vail, in Summit and Eagle Counties, Colorado (Figure 1). It encompasses 542 square km. (133,915 acres).

The range was formed by a Precambrian uplift of granite and gneisses and is characterized by a series of knife-edged peaks and ridges separated by deep glacial valleys (Tweto et al., 1970). Cirques, moraines, rock glaciers, and other glacial features dominate the topography. Maximum relief at the summit of Mt. Powell, 4,125 m. (13,534 ft.), to the Piney River, 2,393 m. (7,850 ft.), is approximately 1,737 m.(5,700 ft.). Annual precipitation varies from 51 cm. (20 in.) to over 102 cm. (40 in.) at higher elevations (mostly as snow) (U.S.D.A., Forest Service, 1977). Approximately one third (180 $km.^2$ or 44,640 acres) of the wilderness area is alpine tundra, craggy peaks, talus and boulder fields. This comprises the most suitable habitat for mountain goats.

Vegetation of the area varies with elevation. Dense stands of engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) dominate the subalpine zone. Lodgepole pine (*Pinus contorta*) and aspen (*Populus tremuloides*) also occur. Treeline occurs at about 3,505 m (11,500 ft.). Above timberline, the spruce-fir become dwarfed and give rise to alpine vegetation such as bluegrasses (*Poa* spp.), tufted hairgrass (*Deschampsia caespitosa*), spiked trisetum (*Trisetum spicatum*), kobresia

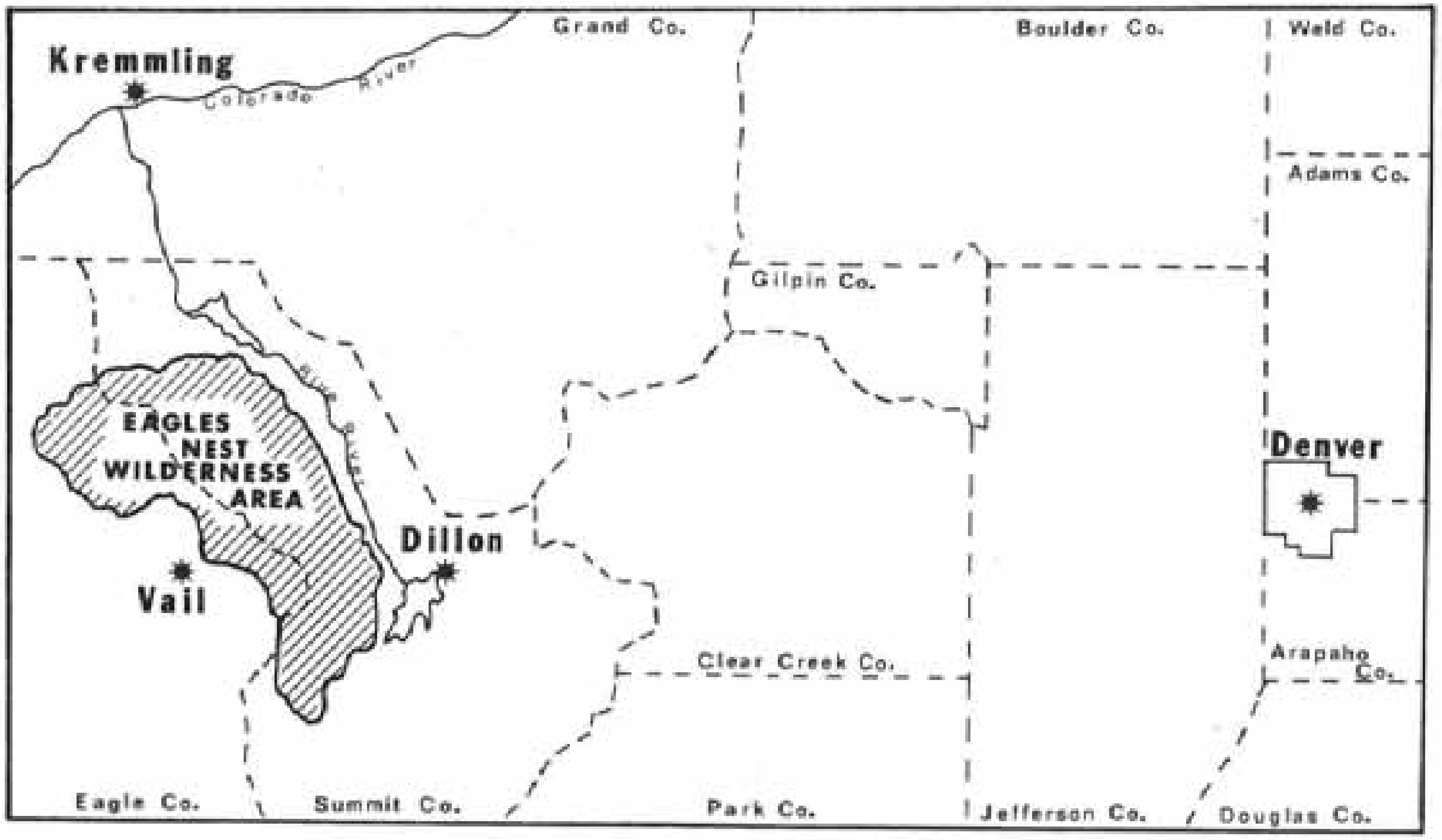

Figure 1. Map showing the location of the Eagles Nest Wilderness Study Area in relation to Denver, Colorado.

(*Kobresia* spp.), sedges (*Carex* spp.), and forbs such as alpine avens (*Geum rossii*), clovers (*Trifolium dasyphyllum*, *T. nanum*, *T. parryi*), green-leaved chiming bells (*Mertensia viridis*), mountain dryad (*Dryas octopetela*), and cinquefoil (*Potentilla* spp.). Willow (*Salix* spp.) and shrubby cinquefoil (*Potentilla fruticosa*) are the major shrubs in the alpine.

Three mineral licks occur on Dora Mountain where salt blocks were placed by Division of Wildlife personnel (Figure 2). The northeast licks, numbered one through three, northwest and southwest licks are designated by their positions on the mountain. None of the original salt is present aside from what has leached into the soil. Goats used these licks extensively and much of our research centered around them.

METHODS AND MATERIALS

From June 8 to August 9, 1977, approximately five days and four nights per week were spent in the field. We backpacked into most areas and established base camps. Over 384 km. (240 miles) were covered on foot.

Three flights were made over the area during the study. We flew on June 9 for orientation and preliminary observations using a Division of Wildlife single-engine plane. A Hughes 500C helicopter was used for census and classification flights on July 25 and 26.

Direct observations were aided by the use of 7 x 35 binoculars and a 20X spotting scope. Forms were used in the field to record observations of both mountain goats and bighorn sheep.

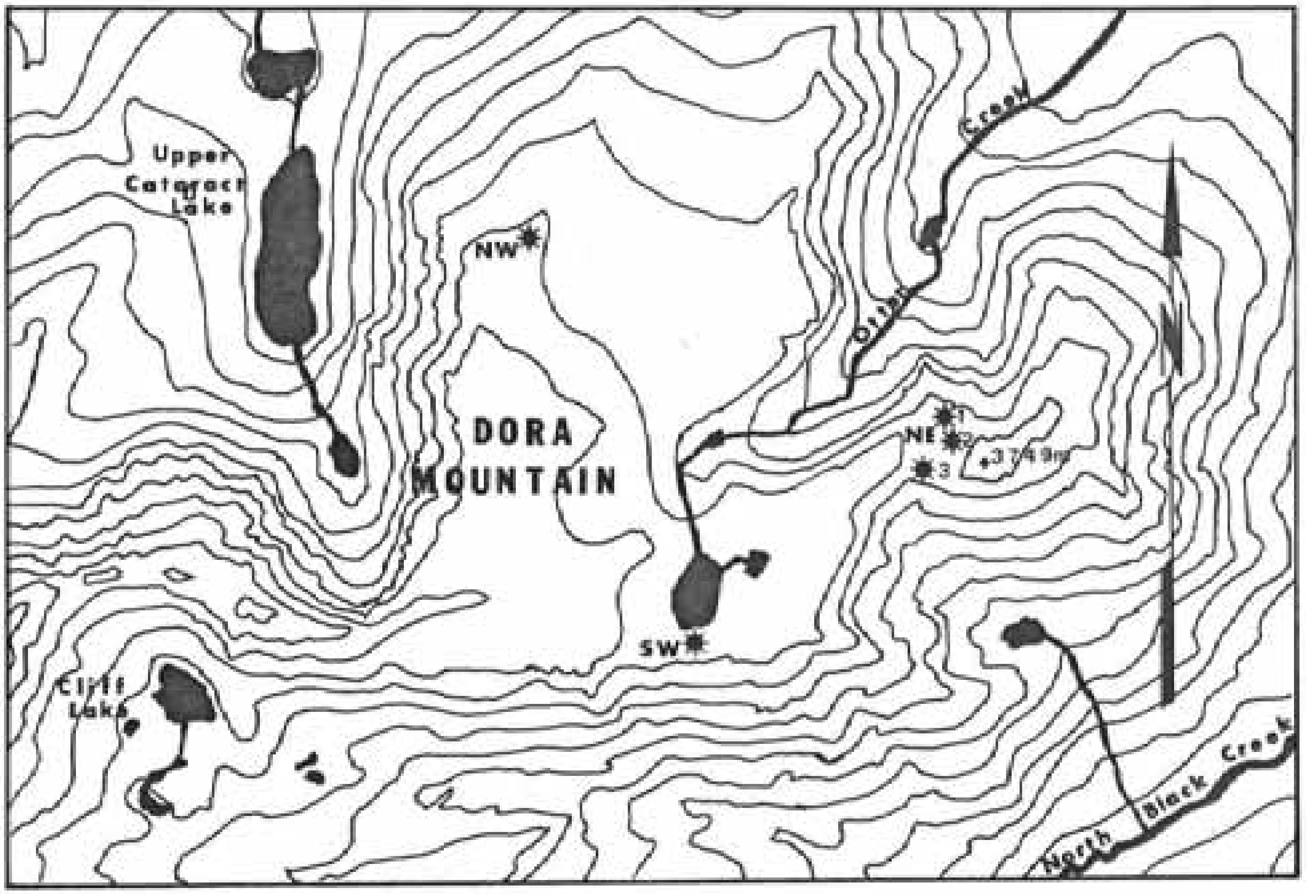

Figure 2. Map of the Dora Mountain area, Eagles Nest Wilderness, Arapaho National Forest, Summit County, Colorado. Asterisks indicate the locations of mineral licks used by mountain goats during the summer of 1977. Contour intervals are 61 m (200 ft.).

Observer, date, weather conditions, species, and time of day were noted. Codes were devised to facilitate recording information on location, elevation, vegetation, relative plant density, slope, substrate, aspect, proximity to water, classification by sex and age, and activity. Results were tabularized to determine the frequencies of occurrence.

Mountain goats were classified as adult males, adult females, yearlings, kids, unknown adults, and unknown subadults. Adults were considered to be animals two years old or older, while yearlings were considered to be animals between one and two years of age. Kids were considered as goats less than one year old. Unknown subadults were assumed to be less than two years old. Unknown adults, unknown sub-adults, yearlings, and kids were not classified by sex. Sex and age ratios were determined as kids: 100 older animals, kids and yearlings: 100 adults, and kids: 100 nannies. Sex determination followed criteria from Hibbs(1967).

We determined the estimate for the minimum population size as the highest number of goats observed without duplication. A maximum population estimate was based on observational data and accounted for the largest percentage of the population believed to have been overlooked. Locations of goats sighted were plotted on maps and recorded to quarter sections. The summer goat distribution was determined from the plotted goat locations.

Soil samples from all licks on Dora Mountain, as well as five meters away from licks, were collected for analysis of mineral composition. Twenty-four predator scats were gathered for determining whether or not mountain goats were consumed. Twenty-three fecal pellet samples were collected for determination of

endoparasites or food habits. All samples were taken to the Colorado Division of Wildlife Research Laboratory in Ft. Collins, Colorado, for analyses.
Additional notes and comments were recorded in a field notebook.

RESULTS AND DISCUSSION

Population Size

During the study, we classified 657 mountain goats from 93 observations including duplicate sightings. Approximately seven goats were seen per observation. Our highest one-day count without duplication was 44 goats. Our minimum population estimate was 77 which included 25 kids, 8 yearlings, 20 nannies, 8 billies, and 16 unknown adults. The maximum population size was estimated at 110 assuming 30 per cent of the population was overlooked. Based upon transplants (Rutherford, 1972) and population estimates for 1972 (Sandfort, 1973), 1976 (Bruce McCloskey, WCO, Colorado Division of Wildlife, Kremmling; personal communication), and 1977 (this study), the Gore Range goat population appears to be growing exponentially (Figure 3). The rate of increase for this herd is estimated at 30 per cent.

Sex and Age Ratios

Due to the difficulty of sexing goats, particularly at a distance, we feel our kid: older animal ratio of 48 : 100 to be the most reliable. Our kid and yearling : adult ratio was 57 and 18 : 100 which may be slightly biased by inadvertently class-

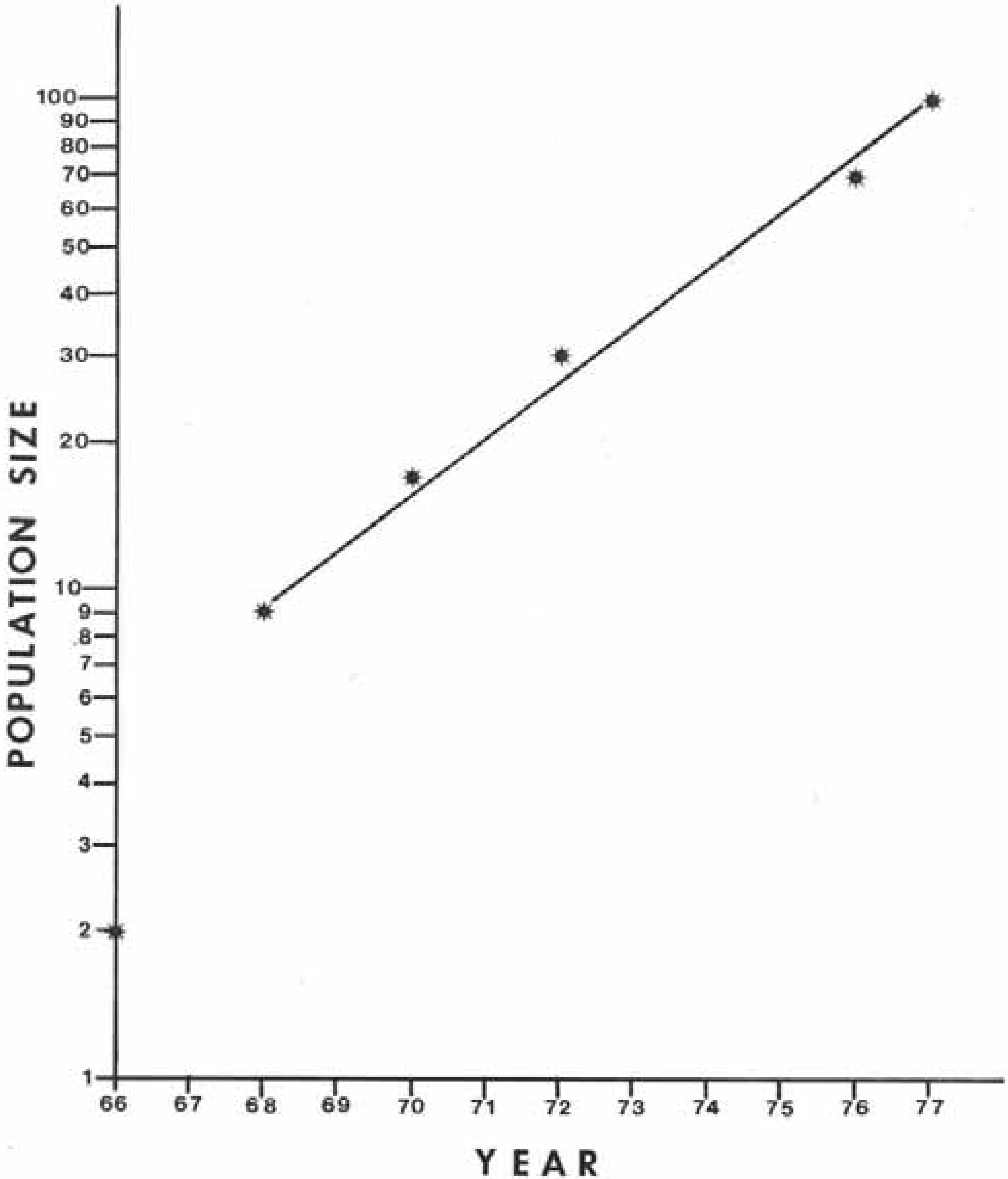

Figure 3. Graph showing the exponential growth of the mountain goat population in the Eagles Nest Wilderness Area, Colorado, based on population estimates from 1966 through 1977 (semi-logarithmic plot). In 1966, two billies were reported to occur in the area and were not believed to have contributed to the population growth prior to transplants which began in 1968.

ifying some yearlings as adults. We feel our calculated kid : nanny ratio of 125 : 100 under-represents nannies in the population based on the probable number classified as unknown adults. However, this value is within the range of values determined from other studies. Hibbs (1965) reported 150 kids : 100 nannies from the Collegiate Range in Colorado in 1963. Kid production in the Gore Range appeared to be high in 1977, possibly due to an unseasonably mild winter and lack of spring storms. Bailey et al., (1977) found a negative correlation between age ratios and snow depth. Brandborg (1955) found kid production to vary with winter conditions undergone by pregnant females prior to parturition, and indicated that rainy weather may lower kid survivorship during their first weeks of life.

Distribution

The 1977 summer distribution of mountain goats in the Gore Range is similar to that reported for 1976 (Bruce McCloskey, Wildlife Conservation Officer, Kremmling; personal communication). The goat distribution extends North to Dora Mountain, West to Mt. Powell, and South and East to the South Fork of the Slate Creek drainage (Figure 4). The occurrence of goats in Slate Creek appears to be an extension of their range. Prior to 1976, mountain goats were not known to occur there (Rutherford 1972). The Gore Range goat population seems to be staying in the same general area in which the releases occurred. The mineral licks on Dora Mountain may be holding the goats in the area. The southeastern extension of the goat range may have resulted from the

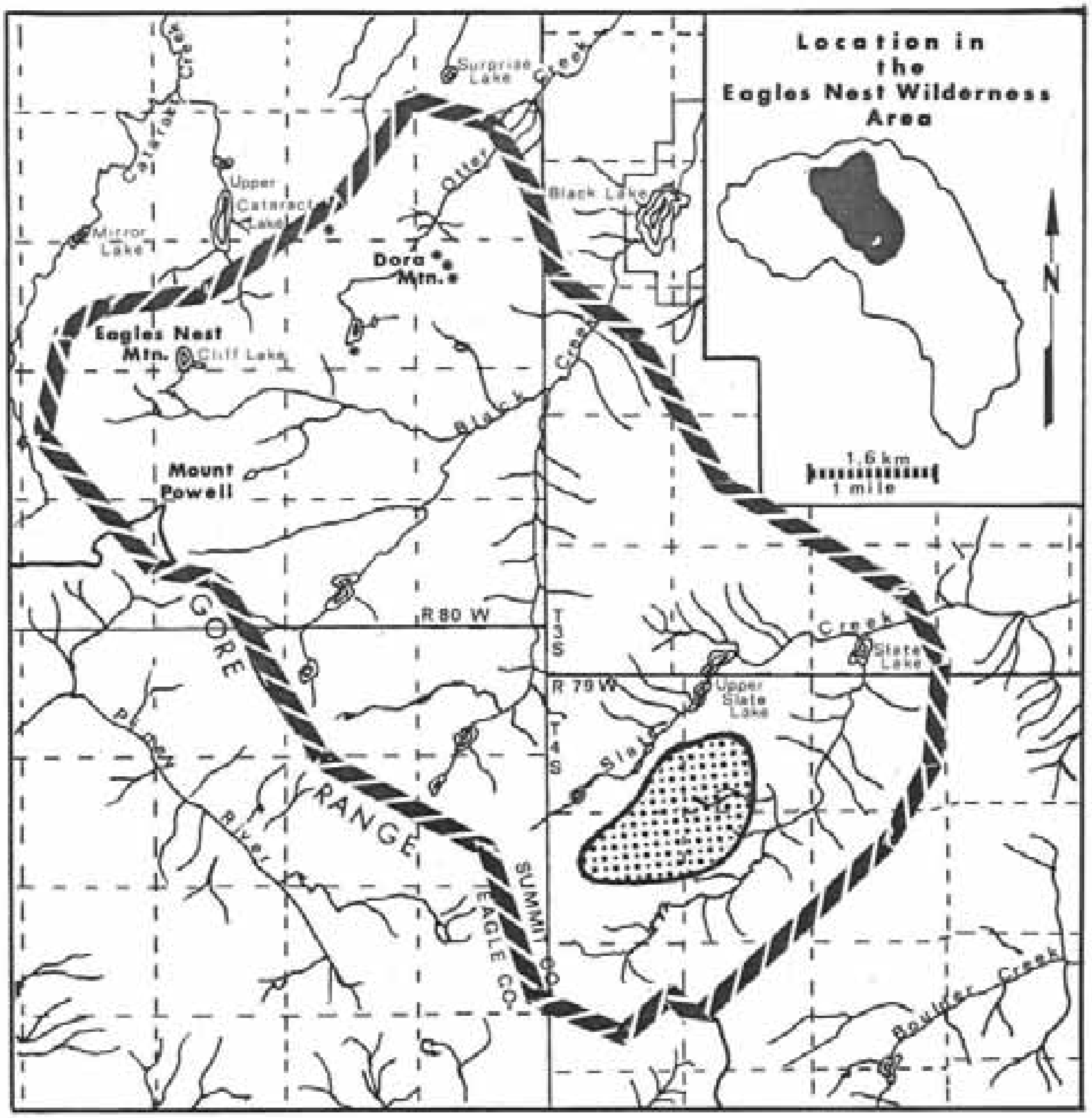

Figure 4. Summer 1977 distribution of mountain goats (broad line) and bighorn sheep (stippled area) in the Eagles Nest Wilderness Area, Colorado. Asterisks on Dora Mountain represent mineral lick localities.

use of salt blocks placed in Slate Creek. Goats have been reported to use these blocks (Dennis Havig, Range Conservationist, Arapaho National Forest; personal communication). Brandborg (1955) reported mountain goats traveling up to 24 km. (15 miles) to use licks. The 1977 goat distribution in the Eagles Nest Wilderness Area encompassed 62 $km.^2$ (24 sq. miles). Ninety-nine per cent of our mountain goat observations occurred on the Summit County side of the range. Bighorn sheep were observed within this distribution in the Slate Creek drainage (Figure 4).

Habitat Utilization

Mountain goats were observed using northern aspects in 56 per cent of the non-lick sightings. Observations at licks on Dora Mountain were excluded since these occurred on a flat summit with no particular aspect, and the influence of these licks biased the utilization of this area. North and north-east aspects accounted for 30 and 20 per cent of the observations, respectively. Eastern exposures were used in 42 per cent of the observations, while southern aspects received 26 per cent of the use. Western exposures received only 26 per cent of the use by goats. Low amounts of snowfall during the 1976-1977 winter may have accounted for an earlier use of northern aspects. Smith (1976) reported that the annual per cent utilization of southern aspects appeared to be dependent on snow depth.

Goats were observed within 0.4 km. (¼ mile) of water in 80 per cent of our observations. Twenty-six per cent were within

100 m of water. It would be difficult for goats to get further from water, due to the topography of the range.

Mountain goats used slopes ranging from 0 to 80 degrees. Thirty-seven per cent of the observations occurred on slopes of 0 to 10 degrees, reflecting the flatness of Dora Mountain. Slopes of 50-60 degrees received 15 per cent of the use, while slopes greater than 60 degrees were used in 15.5 per cent of our sightings. Mountain goats were seen using cliffs 28 per cent of the time, surface-exposed rock (fellfields) in 29 per cent, and boulderfields in 34 per cent of the observations.

Mountain goats utilized herbaceous (graminoid-forb) areas most frequently, comprising 77 per cent of our observations. Sixty-two per cent of the sightings were in high density herbaceous vegetation. Willow and spruce-fir types each occurred in only 5.4 per cent of the observations (Table 1).

During the summer of 1977, goats occurred at elevations ranging from 3,414 m. (11,200 ft) to 3,841 m. (12,600 ft), a vertical span of 428 m. (1,400 ft). Fifty-eight per cent of our goat observations occurred from 3,658 m. (12,000 ft.) to 3,719 m. (12,200 ft).

Mortality

No mortalities were observed during the study. Various bones were found in parts of the study area but were felt to be from cervids or domestic stock. Analysis of 24 predator scats has not been completed.

TABLE 1. Per cent of Observations of Mountain Goats on Particular Vegetation Types in the Gore Range, Colorado, During Summer 1977.

Vegetation Type	Density	Number of Observations	Per Cent of Observations
Graminoid-forb (herbaceous)	High	58	62.4
	Medium	8	8.6
	Low	6	6.5
	Combined	72	77.4
Krummholz (dwarfed spruce-fir)	High	2	2.2
	Medium	8	8.6
	Low	2	2.2
	Combined	12	12.9
Barren	---	7	7.5
Willow	High	2	2.2
	Medium	3	3.2
	Low	0	0
	Combined	5	5.4
Spruce-fir	High	0	0
	Medium	2	2.2
	Low	3	3.2
	Combined		5.4

We observed only two interactions between predators and goats during the study, neither of which resulted in injury or death. On June 11, a golden eagle (*Aquila chrysaetos*) made a low pass over five goats near the northeast number three lick on

Dora Mountain. The goats ran down toward the Black Creek drainage. A coyote (Canis latrans) chased a group of five yearlings from the same lick on June 22. Three of the yearlings returned to the lick within 15 minutes after the encounter. In both instances, goats ran south-southwest toward an 80 degree slope near rock cover. In Idaho, Brandborg (1955) felt coyotes and eagles were relatively unimportant predators on mountain goats while cougars (Felis concolor) and bobcats (Lynx rufus) may have been important in more remote ranges. This is due to their ability to negotiate the same terrain as goats. Both mountain lions and bobcats are known to exist in the study area. Free-roaming dogs (Canis familiaris) from Vail and other surrounding areas might contribute to goat predation in the Gore Range.

Other potential sources of mortality such as parasites, disease, snowlides, and accidents were not investigated. Brandborg (1955) speculated that snow-slides probably accounted for more accidental deaths than any other natural cause. As mentioned previously, conditions related to winter severity influence kid production and survivorship. The hazards imposed by precipitous terrain characteristic of mountain goat habitats probably also contribute to mortality.

Salt Lick Behaviour

The Colorado Division of Wildlife placed three salt blocks on Dora Mountain to hold goats in that area (Bruce McCloskey, personal communication). Only the salt that has leached into the soil remains. In addition, a local rancher was reported to have dropped salt blocks from a plane in 1976, one of which shattered on impact (Dennis Havig, personal communication). The number of goats utilizing these licks increased through mid-July with a gradual decline noticed in late July and early August. Additionally, the licks receiving the highest use changed from the northeast licks in June through mid-July to the southwest lick from mid-July on. The southwest lick appeared to be wetter than the northwest licks after mid-July. Singer (1975) found water seeping into licks was a major factor determining late summer use.

At these licks the goats had dug down into the mineral soil. One of these licks measured 178 cm. (70 1in.) by 217 cm. (85.4 in.) wide by 48 cm. (17.4 in.) deep. Two other licks measured 308 cm. (121.3 in.) by 3.8 cm. (125.2 in.) by 42 cm. (16.5 in.) deep and 408 cm. (160.6 in.) by 181 cm. (71.3 in.) by 44 cm. (17.3 in.) deep. Goats have trampled the vegetation around these licks. Trails occur along the southeast rim of Dora Mountain above Black Creek, between licks and along slopes.

The results of two soil samples from different licks show that both were low in phosphorus (0.01 % and 0.03 %) while sodium was believed to be the attracting element (0.45 ppm and 0.7 ppm) (Robert Keiss, Colorado Division of Wildlife, personal communication.) Stockstad <u>et al</u>., (1953) found sodium compounds were preferred by ruminants from mineral cafeteria and soil impregnation tests. Because of the affinity of goats to lick, these licks provided an ideal place to observe behavior.

Particular parts of the licks were used by more dominant animals. Subdominants often had to wait until the dominant animals had left the licks in order to use them. The social hierarchy at licks was found to be nannies with kids, nannies, billies, and yearlings in order of decreasing dominance. This differs with other reports where yearlings were ranked above billies (Hibbs et al., 1969) and where billies ranked highest (Singer, 1975).

Vocalizations were most frequently heard from kids separated from nannies. Bleats by adults of both sexes were heard at the licks. One nanny bleated while apparently searching for her kid which she later joined. One goat was observed flicking its tongue in and out while making a bleat-like sound. This tongue motion may have been due to excitement (Geist, 1964).

Mounting attempts were observed by goats of all age classes including kids. Rush-threats and horn-threats as described by Geist (1964) were the main types of agonistic behavior exhibited by goats at the licks.

In the licks, goats were observed eating and pawing the soil. We could hear the abrasive sounds of animals chewing the soil from over 30 m. (100 ft.) away. Although fecal pellet samples have not been analyzed, some of the pellets appeared to be composed entirely of inorganic soil. Only one observation was made of a goat drinking from open water.

There are three main dustbathing areas on Dora Mountain. These erosion sites appear to have been started as marmot (*Marmota flaviventris*) dens. Mountain goats were observed rolling and laying in these sites. These animals would lay upright in the soil, kicking dirt on their sides with their forelegs. This behavior is believed to relieve irritations under their long, dense pelage including that from ectoparasites (Brandborg, 1955; Geist, 1971). Goats were also observed scratching their heads and necks with their hindlimbs. They seemed to be quite adept at this, and not clumsy as reported by Geist (1971).

Reaction to Recreationists

We observed few encounters between recreationists and mountain goats. Where people were observed on Dora Mountain above Upper Cataract lake, no goats were sighted although hair and pellet groups were found in that area. On one occasion a couple backpacking on Dora Mountain visited the lick by the lake. One of them said he got to within 21.3 m. (70 ft.) of the goats at this lick before they flushed. That evening, none of the goats had returned to any of the licks. This couple had camped on the north ridge of Dora Mountain above the head of Otter Creek Canyon. Prior to their departure over the north side of the mountain, eight goats were spotted 150 cm. (164 yds.) east of their camp on the north ridge behind a boulder field. As the people left, the goats moved southwest toward the head of the drainage near where the two had camped.

On occasion, goats came within 4.6 m. (15 ft.) of the authors out of curiosity. Tail erection (Brandborg, 1955) was commonly observed when we approached too closely to the goats.

Interaction with Bighorn Sheep

No interactions between bighorn sheep and mountain goats were observed, although both species occurred in the Slate Creek drainage. On July 25, 1977, six mountain goats and one bighorn ram were spotted in this drainage from the helicopter. The next day, 16 bighorn sheep, including five lambs, were seen there. This area has been used as winter range by the sheep (Bear and Jones 1973). According to Bear and Jones (1973), the bighorn population in the Gore Range has declined since 1947 but has appeared to be stable since 1970. Mountain goats were considered to be too few in number (about 10) to offer much competition. Figure 4 shows the known 1977 summer distributions of mountain goats and bighorn sheep in the Gore Range. Sheep may also occur in other drainages but were not observed elsewhere during this study. Obviously further study is needed.

CONCLUSIONS AND RECOMMENDATIONS

Further research on mountain goats in the Eagles Nest Wilderness Area is needed. If the population is indeed growing exponentially, it would be necessary to determine the carrying capacity of the habitat and to predict at what population density the population will stabilize. Continued study may reveal whether or not the licks continue to hold the goats in their present distribution or whether the goats expand into surrounding suitable habitat. The effects of harvesting on population growth, distribution, and age ratios should be observed. Whether or not harvesting is compensatory or additional as observed by Kuck (1976) in Idaho remains to be seen for this herd. Winter distribution and habitat utilization should be assessed as well as the effects of snow depth and persistence on kid production and survival. In addition to continued mountain goat inventories, comprehensive information on the seasonal distribution and habitat utilization of the bighorn sheep in the Gore Range is necessary for evaluating the effects of goats on sheep habitat. This goat herd might be an acceptable population on which to develop and test computer-simulated population models useful in the management of this species.

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THE GOATS OF GOAT MOUNTAIN: EVALUATION OF A PROPOSAL

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ABSTRACT

Most studies reported in the first two symposia on goat management deal with heavily exploited or reintroduced populations. Many researchers lamented aloud that they would never know the status and composition of their respective population in pristine times, nor would they be able to determine precisely how declines had occurred. Some have suspected that hunting may precipitate population losses at rates greater than simple subtraction of the kill would indicate. It is widely agreed that there is much yet to be learned about management of mountain goats for hunting. Due to limited access, there are a number of unexploited goat populations in Northwestern British Columbia. This paper describes a potential study situation on two such populations. One population, which numbers approximately 65 animals, occupies a small, isolated mountain block with an alpine area (above 4,500 feet) of about 6.5 $mi.^2$. A forestry development road, now within 10 miles of this block, will pass within two miles by the early 1980's, thus providing potentially easy access for hunters. However, this area has been closed to hunting in anticipation of its value as a study area. The second population, approximately 120 animals, occurs on another somewhat larger (25 $m.^2$ above 4,500 feet) mountain block which is also relatively isolated from other goat ranges. This area is still open to hunting but, although a new access road is now within three miles of timberline, hunters have

not yet discovered it. The two areas are logistically practical, occurring less than 20 miles apart and within 35 miles of Smithers to the nearest population center. I believe that a comparative study of the two areas could provide excellent data on the effects of hunting on mountain goats, and the purpose of this paper is to solicit funds, students, and/or ideas to get such a study underway.

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

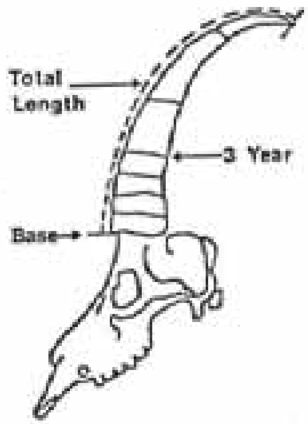
High Quality (optimal habitat)	Quality characteristics	Low Quality (marginal habitat)
larger	skull and horn size	smaller
more	lamb(or kid)-play	less
longer (and self terminating)	" " suckles	shorter
rapid	yearling maturation	delayed
larger	body size	smaller
higher	population density	lower
higher	productivity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

HORN LENGTH MEASUREMENTS

	Horn R	Horn 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		

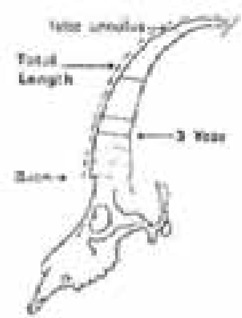
Mountain Goat:

Age (from annuli) ____________

Goat tooth extracted: Yes ☐ No ☐

Vial No. ____________

B.



ACE 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, chemozemic, 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 ($\geq$ 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,

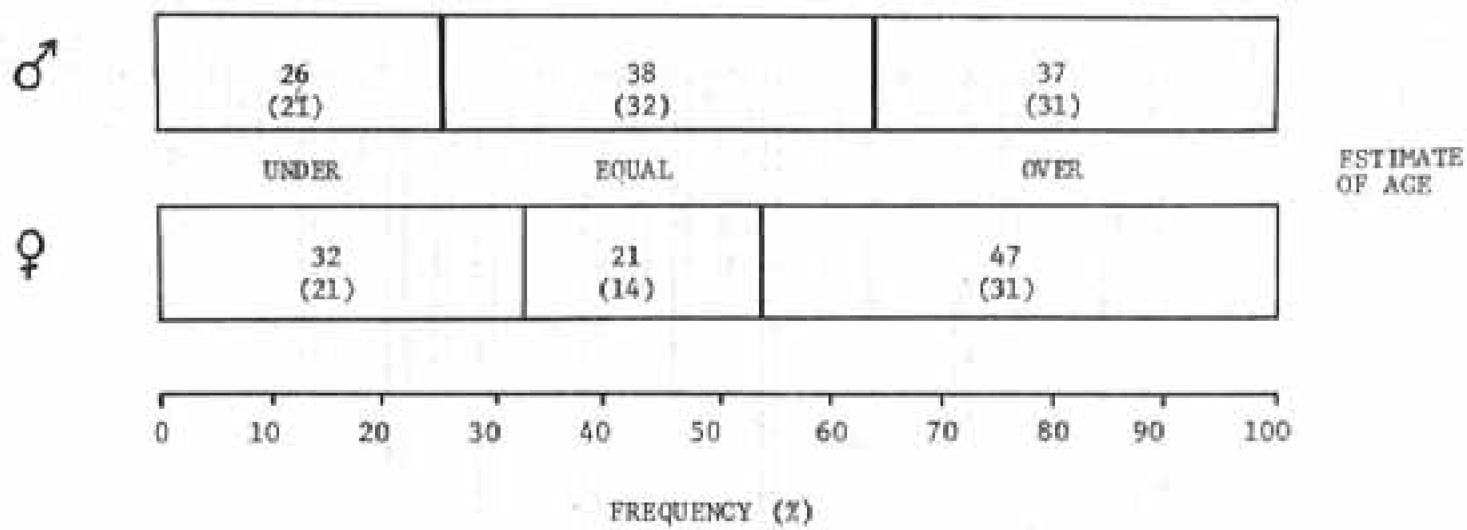


FIGURE 2. Accuracy in age estimation of male and female mountain goat horns. The data are extracted from the 1976/77 mountain goat CID forms having corresponding age analyses from both the horn and tooth cementum annuli methods. The bracketed values reflect sample size.

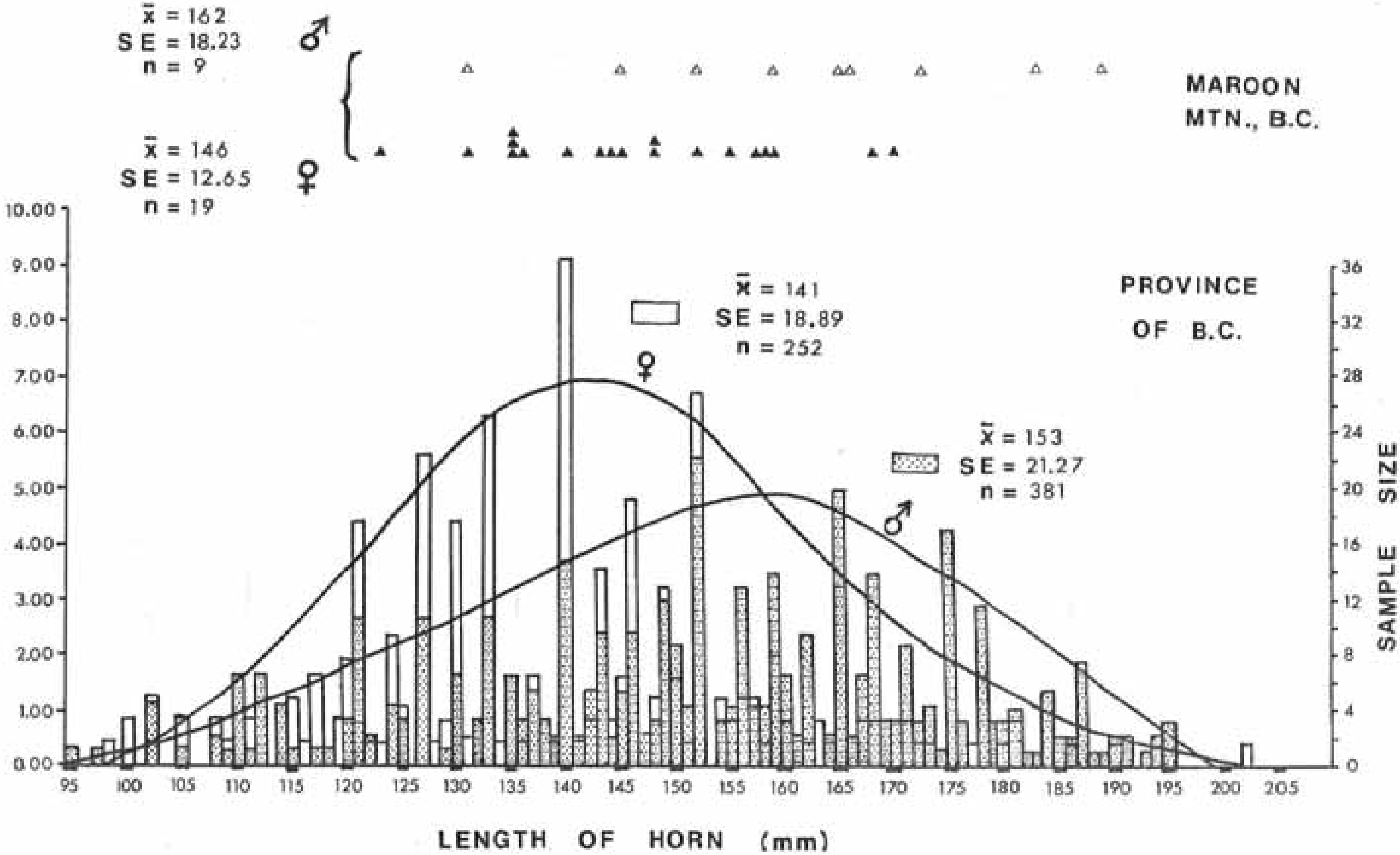
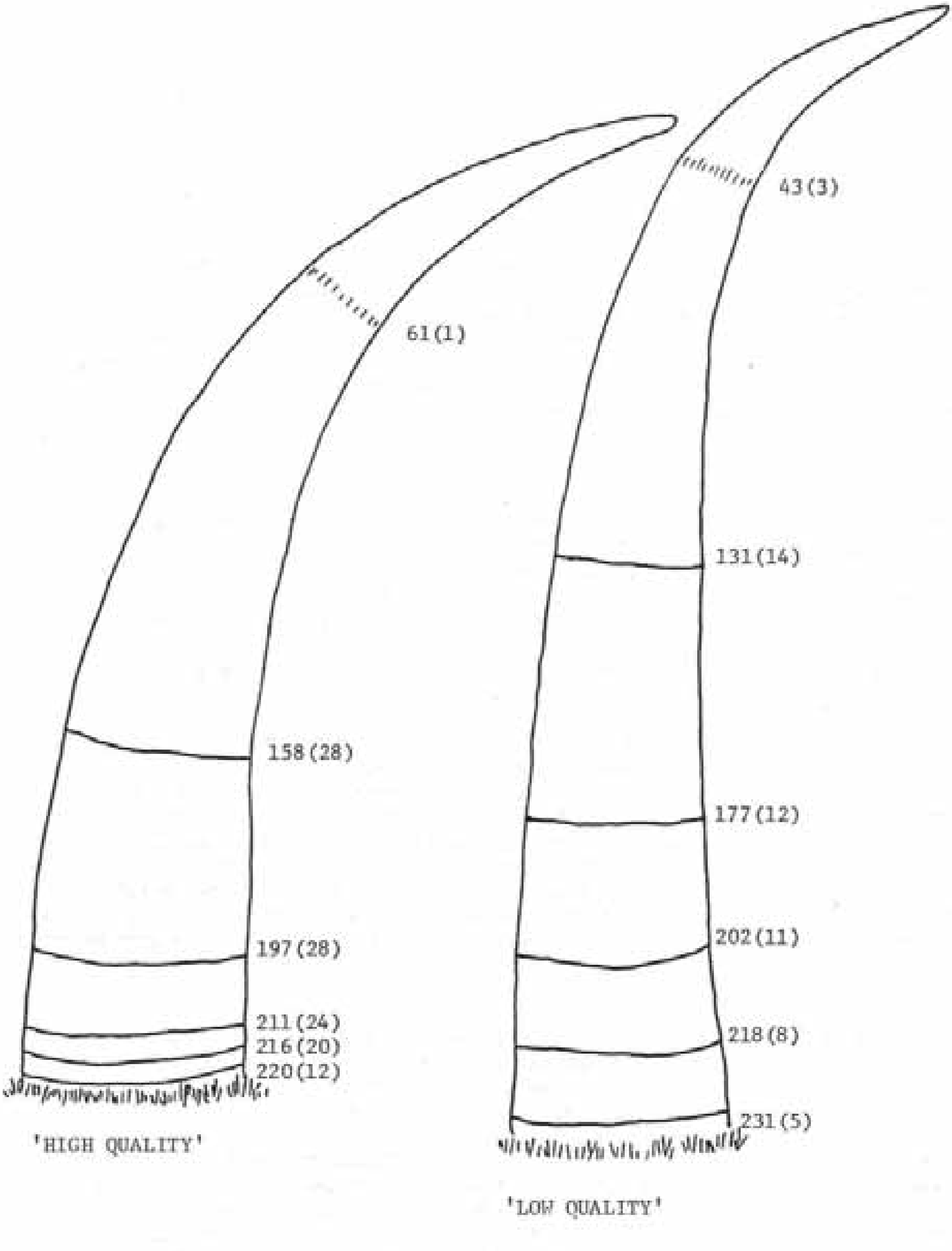


Figure 3. Comparison of both male and female linear subadult horn growth of the first two years of life (measured along the outside curve of the horn). The Provincial data are taken from the 1976/77 CID and the data from Maroon Mountain were gathered from the author's study area. Where the male frequency 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	Columbian	f	6-02	122		121 - 122	2	140			1
[AT/ESSF/CWH	Zwischengebirge	f	6-04	149		110 - 184	5	143		120 - 163	4
SMH		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	Coast Plutonic	m(p)	1-15	151		143 - 159	2	-		-	-
Prince Rupert)	Complex	f((m))	2-05	127			1	-		-	-
[AT/SMH/CWH]		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	Rocky Mountain	m(f)	7-37	176		172 - 181	3	161		140 - 187	4
Prince George)	Thrust Belt	m	7-41	146		124 - 171	11	150		140 - 165	3
(MUSKWA)		m(f)	7-51	152		102 - 195	26	136		108 - 165	19
[AT/ESSF/BWBS]				152	22.17	102 - 195	40	141	19.39	98 - 187	26
Rocky Mountain	Rocky Mountain	m(p)((f))	7-19	132			1	122		117 - 127	3
Foothills	Thrust Belt	m((f))	7-21	138		121 - 152	3	-		-	-
[AT/ESSF/BWBS]		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) $\bar{X}$ = 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 $\bar{X}$	MALE Standard Error	MALE Range	MALE n	FEMALE $\bar{X}$	FEMALE Standard Error	FEMALE Range	FEMALE N
St. Elias	St. Elias	m	6-28	143		121-160	5	133		117-152	5
[AT/ESSF]	Fold Belt	p((f))	6-29	125		115-140	3	-		-	-
				136	17.93	115 - 160	8	133	12.51	117-152	5
Coast (N. of	Coast Plutonic	f(m)	6-14	169		157 - 187	5	141		127-152	5
Prince Rupert)	Complex	m(f)	6-15[4]	162		158 - 165	2	-		127-152	-
[AT/ESSF/BWBS]	Coast Plutonic	m(p)(f)	6-21	162		152 - 175	3	136		124-140	4
	Complex	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	Omineca Crys	f((m))	6-19	149		111 - 186	7	134		121-155	5
[AT/ESSF/BWBS]	talline Belt	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	Omineca Crys-	p(m)	6-18	156		117 - 178	10	141		124-162	4
(Swannell)	talline Belt	f	7-27	160			1	-		-	-
[AT/ESSF/SBS]		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	Columbian	m(p)	6-17 (A&B)	167		156 - 179	3	164		145-190	3
(Babine)	Zwischengebirge	p	6-20	156		120 - 190	27	134		114-172	18
[AT/ESSF/SBS]		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 $\bar{x}$	MALE Standard Error	MALE Range	MALE N	FEMALE $\bar{x}$	FEMALE Standard Error	FEMALE Range	FEMALE N
Rocky (S. of	Rocky Mountain	p	4-23	146		108 - 185	5	153		152 - 154	2
Prince George	Thrust Belt	p	4-24	151		133 - 168	2	–			–
[AT/ESSF/IDF]		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	Omineca Crys-	m	3-36	186			1	–		–	–
(Monashee Mts.)	talline Belt	m	3-43	126		121 - 130	2	127			1
[AT/ESSF/IWH]		m	4-38	108			1	–		–	–
				136	34.37	108 - 130	4	127			1
		m	3-44	139		110 - 154	4	127		102 - 157	5
(Cariboo Mts)		m	3-46	–		–	–	140			1
[AT/ESSF/IWH]		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	Cascade Fold	m(p)	3-15	156		149 - 162	2	–		–	–
Plateau	Belt	p	3-16	148		114 - 175	10	135		125 - 140	4
[AT/ESSF/IDF]		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

[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.

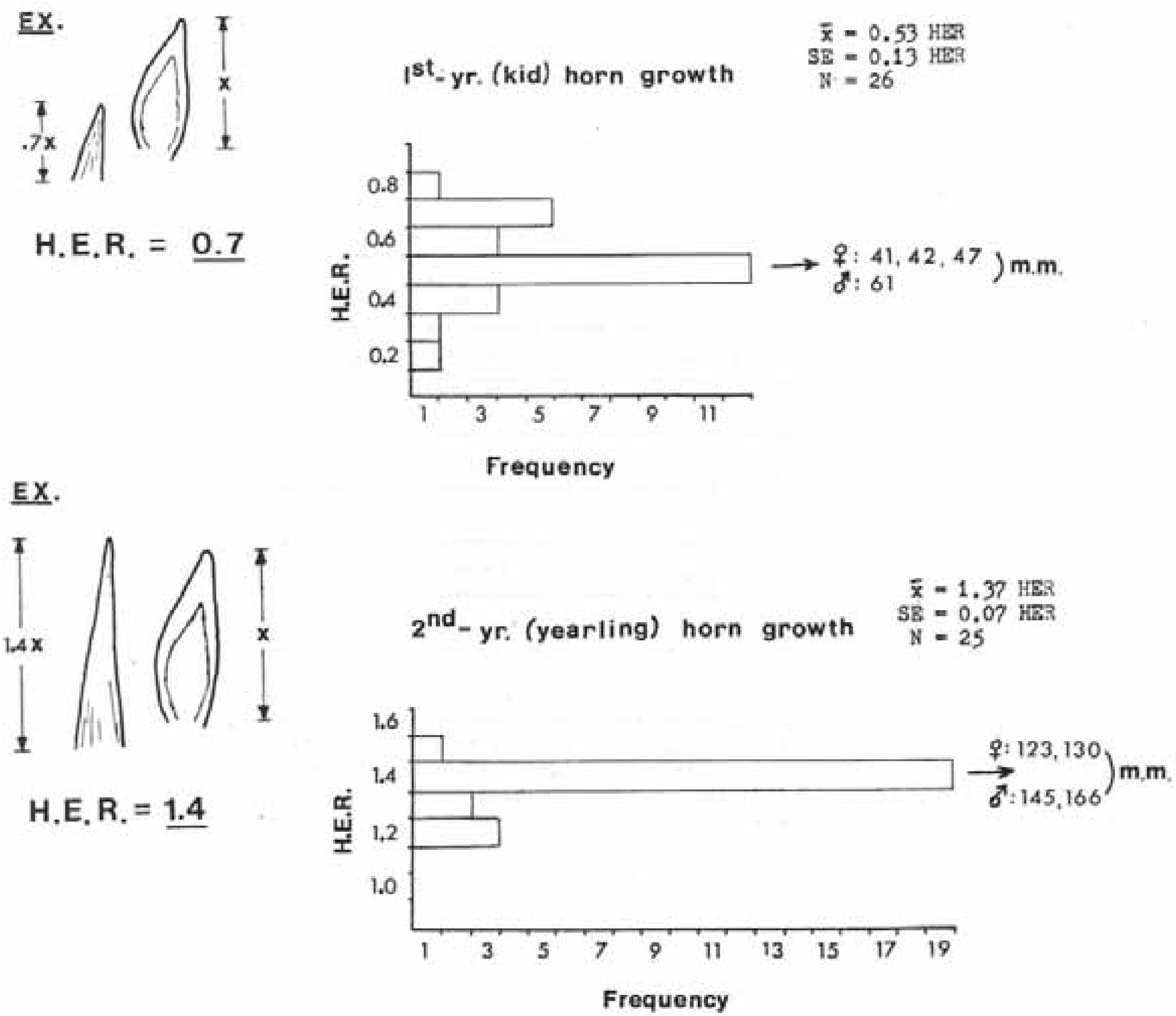


Figure 5. Occurrence of intrapopulation variation in linear horn growth. The horn variation is measured as a ratio of the vertical rise of the horn to the sagittal length of the ear and is termed Horn-to-Ear Ratio (HER). These data were collected in November on Maroon Mountain, B. C. from the author's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

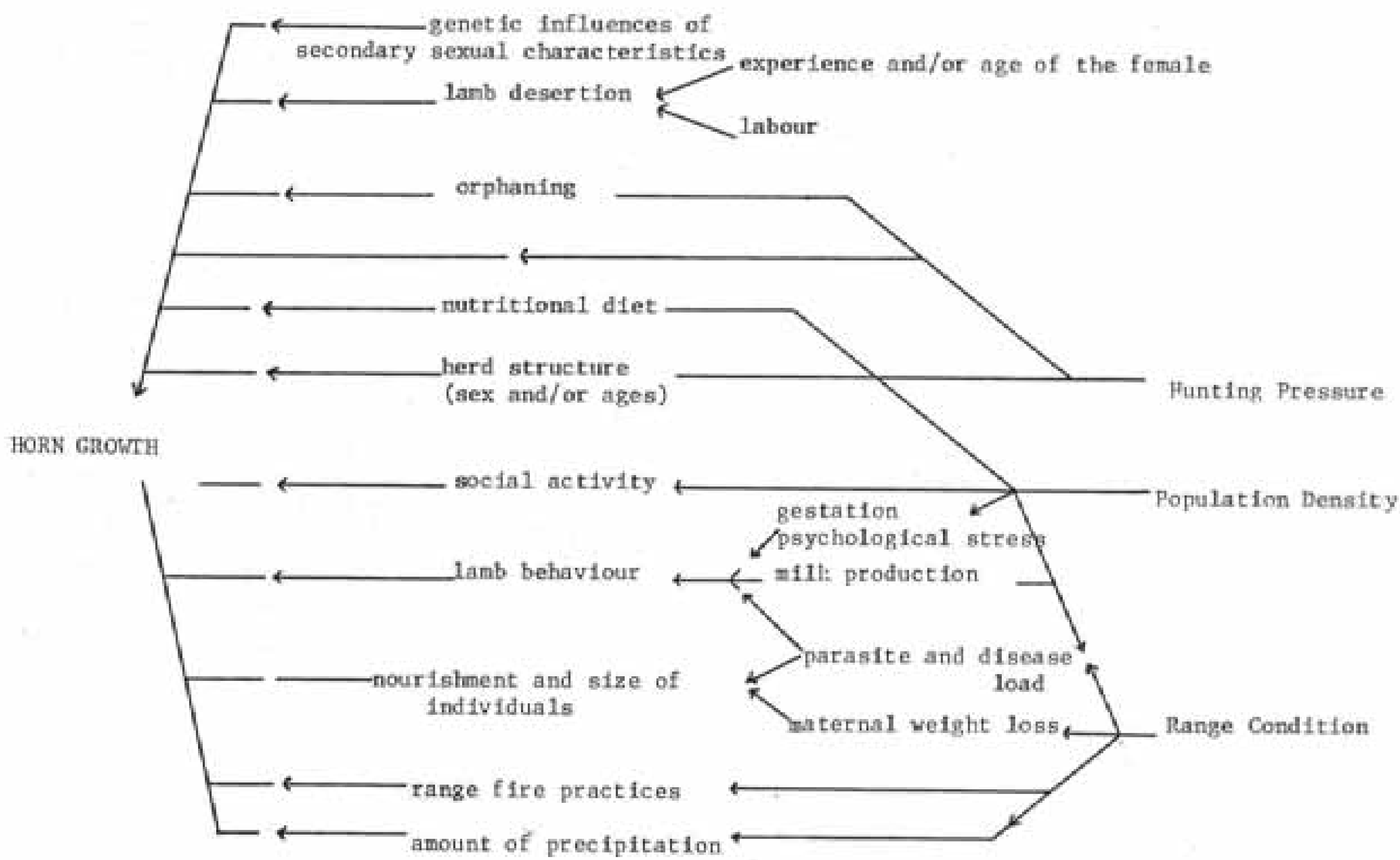


FIGURE 6. General synopsis of factors affecting the regulation of Caprini and Rupicaprini horn growth. Some determinants are documented while others are hypothetical.

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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A SYSTEMS APPROACH TO MOUNTAIN GOAT MANAGEMENT

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INTRODUCTION

The majority of species management programs in North America began with an assessment of harvest information (Table 1), progressed to refinement of population harvest analysis, and more recently incorporated inventory and survey information. Biological parameters associated with long-term cervid management programs were inappropriately assigned to mountain goat populations (Hebert and Turnbull 1977).

Age structure information (Table 1) obtained from populations and areas with undefined boundaries was collected at road checks in the East Kootenay and for the northern half of the Province at Cache Creek (Table 2).

Table 1. Aging methods for harvested goats by data source in British Columbia.

Data Source	Date Begun	Horn Annuli	Teeth (cementum layering)
			Aging Methods
Game checks			
Cache Creek	1947	1947	-
Kootenay	1958	1965	-
Compulsory Reporting	1976	1976	1976

Harvest estimates obtained from the hunter sample for large land areas (13,000 to 75,000 sq. km.) served to mask the effects of overharvest on local or individual populations (Phelps *et al*. 1976). Similarly, there

Table 2. SUMMARY OF GOAT HABITAT, HARVEST MONITORING METHODS, AND LIMITED ENTRY HUNTS, BY REGION, IN B.C.

	REGION						
	1	2	3	4	5	6	7
Estimated Area of Goat Habitat[1] (sq. kilometers)	7,525	28,600	26,550	35,855	36,425	144,390	98,625
<u>Harvest Monitoring Methods</u>							
Game Checks							
Cache Creek (1974-)			X	X	X	X	X
Kootenay (1958-)				X			
Hunter Sample (1962-)	X	X	X	X	X	X	X
Compulsory Reporting (1976-)	X	X	X	X	X	X	X
<u>Limted Entry Hunts</u>							
Date Begun	-	-	1977	1976	-	1974	-
No. of Permits							
1974						100	
1975						100	
1976				12		100	
1977			8	22		110	
1978			8	104		110	

[1]From Blower (1978)

was no definition of population boundaries, regional management boundaries often crossed ecotype boundaries and, usually, the same liberal season lengths and bag limits persisted between ecotypes (Hebert and Turnbull 1977). It has been demonstrated that social organization, sex and age structure, and habitat utilization are extremely sensitive to harvest pressure between ecotypes (Hebert and Turnbull 1977; Kuck 1977). More recently (1974), limited entry hunting restricted the number of hunters in one 3,600 square kilometer areas of the Nass range in northwestern B.C., and compulsory reporting (begun in 1976) aided in more accurately identifying the magnitude of the harvest and kill location.

In addition, there was little logical analysis supporting the divergence within bovid management. Mountain sheep management programs supported the harvest of males only and eventually changed from no horn curl restrictions (1960's) to a full curl or age restriction (1976) which crudely aligned trophy hunting restrictions, guide and limited entry hunt areas to population sensitivity. Until recently, all age and sex classes of mountain goat populations were harvested liberally and early seasons (August, September) actually enhanced the harvest of females and younger age classes, especially in areas where salt lick use was prevalent.

The ability to effectively manage mountain goats over their entire range will depend upon the identification of southern (Hebert and Turnbull 1977) and northern ecotypes, behavioral, population, and habitat characteristics which are species specific, and the relationship between the land base of inventoried and harvested populations. Thus, a major objective of mountain goat management is to obtain sufficient information to distribute an equitable and acceptable harvest throughout the entire goat range according to ecotype characteristics, while reducing or eliminating areas of both under harvest (i.e., helicopter transport hunting in portions of the coastal mainland) and those of over harvest.

RESULTS AND DISCUSSION

The development of a systems approach to mountain goat management should not logically proceed from traditional harvests to incorporation of survey data, but from survey and population data to development of harvest rates for each ecotype. Similarly, within ecotypes harvest rates should be determined for individual watersheds and be related to group composition.

Distribution and Density

On a broad level (Provincial and Regional), general mountain goat distribution and density in B.C. was mapped (Blower 1978), in conjunction with regional biologists. However, similar land units (valley bottoms must be consistently included or excluded) must be utilized to produce standarized density and range area estimates for all management regions (Table 2). Within regions, more specific information on population density and distribution should be identified on map scales of 1:250, 000; 1:125,000; or 1:50,000 for individual mountain ranges or blocks. The approximate area of mountain ranges, blocks, or elevational units (Hebert and Turnbull 1977) can be utilized to calculate population or seasonal density in order to define the broad ecotype boundaries. Stratification of the land base is necessary in order to establish the size of the management unit, ecotype characteristics, possibly population boundaries and allow selection of representative areas for both preliminary and detailed surveys.

Preliminary Inventory and Survey

Preliminary surveys using fixed-wing aircraft may be necessary if the land base is large (2,500+ square kilometers), the population distribution uneven, or the density varied. Fixed-wing transect surveys should be undertaken at 150-500 meter intervals in subalpine and alpine areas depending on the area and number of mountain ranges or blocks to be surveyed and the terrain type. Group size can be determined, as well as the relationship between per cent family groups and population productivity among ecotypes, which appears evident in southern B.C. (Hebert and Turnbull 1977) and along the Rocky Mountain chain outside B.C. (Smith 1976; Holroyd 1967; Kuck 1976).

Survey dates can be varied across the Province from late June to late September, depending on the approximate date nursery groups are formed, nursery group size and structure (ability and need to identify group size and per cent family groups) and the need to utilize molt patterns to separate adult males, young males, non-reproductive females, and productive females. Large nursery groups are formed in northern B.C. by midsummer but appear infrequently in south coastal B.C. However, surveys in the Knight Inlet area of coastal B.C. must usually be delayed past the molt, until early August, due to a large land area comprised of glaciers and a lingering snowpack. In south central B.C., surveys are conducted in early spring prior to kidding, before goats move to tree covered subalpine areas. Surveys in eastern B.C., along the Rocky Mountain chain can be undertaken in mid July in order to utilize molt patterns, obtain group size information, and determine productivity ratios. Aerial surveys from fixed wing aircraft do not usually allow determination of sex ratios and recruitment but should allow identification of kids and group size if done by late July or mid August.

Detailed Surveys

Detailed surveys are best accomplished in specific mountain ranges or blocks (i.e., Stanton or Hoodoo Creek; Hebert and Turnbull 1977), which are representative of larger land units. Transect design should incorporate 150-meter transects on north or south aspects, or both, provide information on total numbers, distribution, elevational and seasonal density, age ratios (kids, yearlings, possibly subadults, and adults), sex ratios (adult males to adult females), habitat types, and physical features (elevation, aspect, slope, terrain type, or topographic-moisture regime, etc.).

Survey design should incorporate the decision to obtain ratios of kids and yearlings/100 females (selection of a representative site and transect layout will identify female and nursery groups) or ratios of kids and yearlings/100 adults (selection of a representative site and transect layout should produce an accurate sex ratio). If only young/100 female ratios can be obtained, recruitment ratios should not be calculated without an estimate of the sex ratio. The inability to identify subadults (2.5 year olds of both sexes) will reduce the accuracy of productivity and recruitment (if a sex ratio is estimated) ratios. In actual fact, most surveys concentrate on female groups yet calculate ratios/100 adults but completely disregard sex ratios. If young/100 adult ratios are to be established, transect layout must assess range separation by sex according to elevation and aspect. The inability to identify subadults will affect the productivity and recruitment ratio less (assuming a sex ratio is obtained) because this category forms a smaller proportion of the total number surveyed.

Chadwick (1976) established subadult/adult ratios of 37.2 subadults/100 adults (21 yearling/100 adults (12.4%) and 16.2 two year olds/100 adults (9.6%).) which could be used to adjust recruitment rates, and consequently harvest rates, along the Rocky Mountain chain.

Surveys which establish age ratios with a base of 100 females do not usually have a sex ratio to relate to harvest estimates or to a compulsory check system. Thus, the recruitment ratio may be distorted due to lack of a subadult ratio and/or sex ratio, causing harvest rates to be inaccurate. If conducted properly, however, the young-to-female ratios, adjusted with a subadult ratio, could provide an accurate estimate of productivity, recruitment, productive females as a proportion of the female segment of the population and potential harvest if a sex ratio can be established.

Ground surveys should accompany detailed aerial surveys (on a representative mountain block basis) in order to complete data collection on groups, sex and age ratios, and especially more accurate identification of yearlings and subadults.

The effect of a distorted sex ratio on recruitment (yearling) ratios was demonstrated by data collected in 1977 in Knight Inlet (coastal B.C.) which indicated that approximately 2.9 yearlings/100 adults occurred (Table 3) in the south slope surveyed population, whereas the 1974-1976 data indicated that it contained 3.8 yearlings/100 adults. Considering the mild winters of 1975 and 1976, the yearling count in 1977 should have been higher. The low yearling count was possibly due to:

(a) higher overwinter mortality in 1976/1977 (this possibility is unlikely);

(b) yearlings were classed as adults from the helicopter due to

Table 3. A COMPARISON OF MOUNTAIN GOAT SEX AND AGE RATIOS IN THE

KNIGHT INLET AREA (1974-1976 & 1977)

Survey Date	Total Goats	Per Cent Adult	Per Cent Yrl.	Per Cent Kid	Kids/100 Adults	Yrl./100 Adults	Kids/100 Females	Yrl./100 Females
1974 & 1976	250	85.2	3.2	11.6	13.6	3.8	27.1	7.5
1977	111	70.3	2.7	27.0	38.4	3.8	65.2	6.5

SUMMARY OF 1977 KNIGHT INLET GOAT SURVEY

Survey[1]	Total Goats	Per Cent Adult	Per Cent Yrl.	Per Cent Kid	Kids/100 Adults	Yrl./100 Adults	Kids/100 Females	Yrl./00 Females	Males/100 Females
South Facing	100	69.0	2.0	29.0	42.0	2.9	67.4	4.7	41.9
North Facing	11	81.8	9.1	9.1	11.1	11.1	33.3	33.3	200.0
Total or mean	111	70.3	2.7	27.0	38.4	3.8	65.2	6.5	52.2

[1]South facing survey equivalent to 1974-1976 surveys; North facing survey flown in 1977 only.

the mild winter and excellent growth achieved (partial source of error); and

(c) yearlings moved with males during the redistribution in the hot summer of 1977 and so were under-represented in the sample.

There is preliminary evidence to indicate that some yearlings accompany males or nonproductive females during July and August (Hebert 1967). Thus, yearlings increased from 2.9 to 11.1/100 adults when the proportion of males in the survey increased. Consequently, there were 3.8 yearlings/100 adults in the 1977 survey when north and south aspects were included, similar to that obtained during 1974-76. In contrast, Chadwick (1977) indicates that no yearlings accompanied males only during his surveys in Glacier National Park. Similarly, seasonal redistribution of males altered the sex ratio from 100/100 females in 1976 to approximately 41.9/100 females in 1977 on the south aspect of the Stanton Creek study area (Table 3). The male component of the sex ratio was increased to 52.2/100 females when a portion of the north aspect of that mountain block (Crevice Creek) was included in the survey.

Correction for sex and subadult distortion depends upon a good knowledge of mountain goat biology and consistent apriori design of survey methodology. If harvest is based upon surveys which select for south slopes, should the count be adjusted from 3 to 4% yearlings based on experience and mild winters (without additional surveys of north slopes), or should it be adjusted at all, especially in consideration of the additional cost of accounting for yearlings and males in some years. Also, if a survey is expanded to account for distortion, does a population constitute the north and south (or east and west) aspects of a mountain range or block or the facing aspects of a river valley?

In addition, a biologist experienced in mountain goat inventory and biology should accompany, at least once, all those undertaking goat surveys in order to standardize the technique, insure comparable data for inventory-harvest comparisons, and allow comparisons between ecotypes.

Harvest

To date, there are few instances in B.C. where actual harvest rates have been applied to a specific population or land area. Partial exceptions are the recent limited-entry hunts in the Nass River and the East Kootenay (Table 2), which are based on preliminary survey information, but do not include recruitment or sex ratio data. In addition, the goat season in the Keremeos area of the Okanagan is closed due to lack of adequate population data on which to base harvest rates.

Based on the preceding information, there are several combinations and levels of population information which can be used to establish harvest regimes. However, there are three types of information:

(1) the determination of the yearling and/or subadult component of the population;

(2) the sex ratio; and

(3) the land unit from which the harvest is to be obtained, which must be considered essential to proper management.

The proportion of females in the harvest should be as low as possible until the role, sensitivity, and winter-range requirements of the family group can be established by ecotype (southern and northern B.C.).

Mountain goat management, including harvest regimes, and differences in productivity and social organization between ecotypes could proceed in two directions where the land base is extremely large. Both systems are dependent, to differing degrees, on proper inventory and identification of inventoried and harvested populations within the same land unit.

(i) Under an ideal situation, populations could be harvested on the basis of sex and age ratios, distribution, and social organization. In ecotypes of low productivity, large males could be harvested, with other segments of the population, making up the harvestable quota as population figures indicate. This assumes that compensatory mortality plays little part in the maintenance of the population. In ecotypes of high productivity, the combination of sex and age components can be more variable and flexible. This system approaches that for mountain sheep, and could consider management of family groups on the winter range (Kuck 1977, Smith 1977).

(ii) in large land units with little population or social organization information, annual harvest based on survey information (yearling recruitment) from a representative mountain block, should be directed toward adult males on a rotating watershed basis (this was recommended in the East Kootenay in 1965-1967 but was never utilized). The rotation system will depend on the total land area involved, the number of watersheds or mountain blocks available, and the level of biological information. It assumes that compensatory mortality plays little part in the maintenance of populations. The number of watersheds available for harvest (harvest pressure) at any one time (Figure 1), and the number of years they will be open, is dependent upon the productivity of the ecotype, recruitment, and the desired harvest. The rotating watershed system implies that goat populations will change from organized, stable pop-

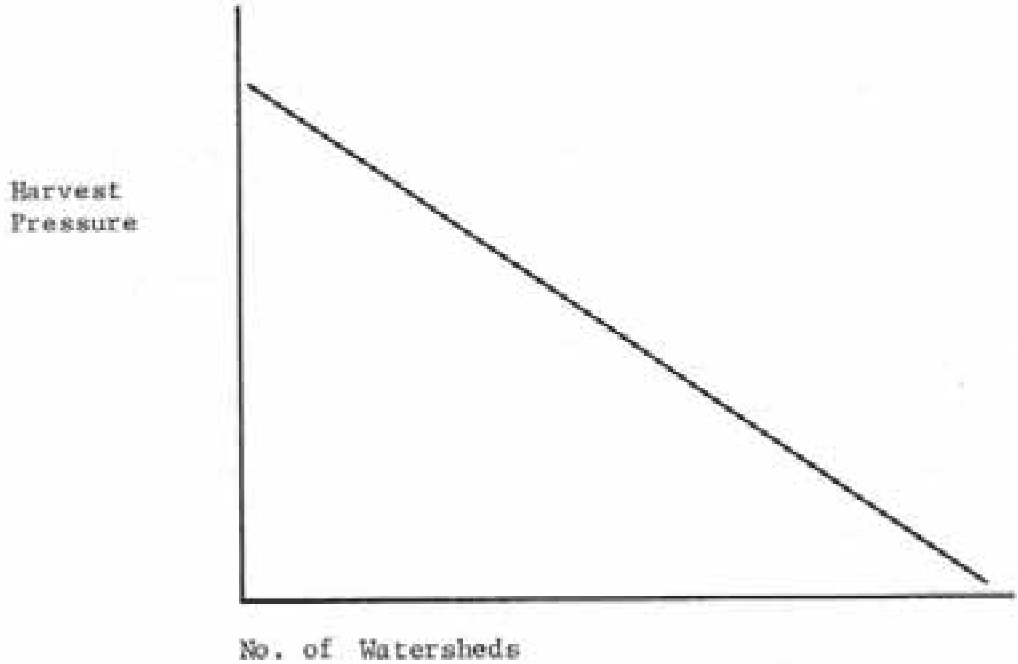

FIGURE 1. The relationship between harvest pressure and the number of watersheds available for rotational harvest.

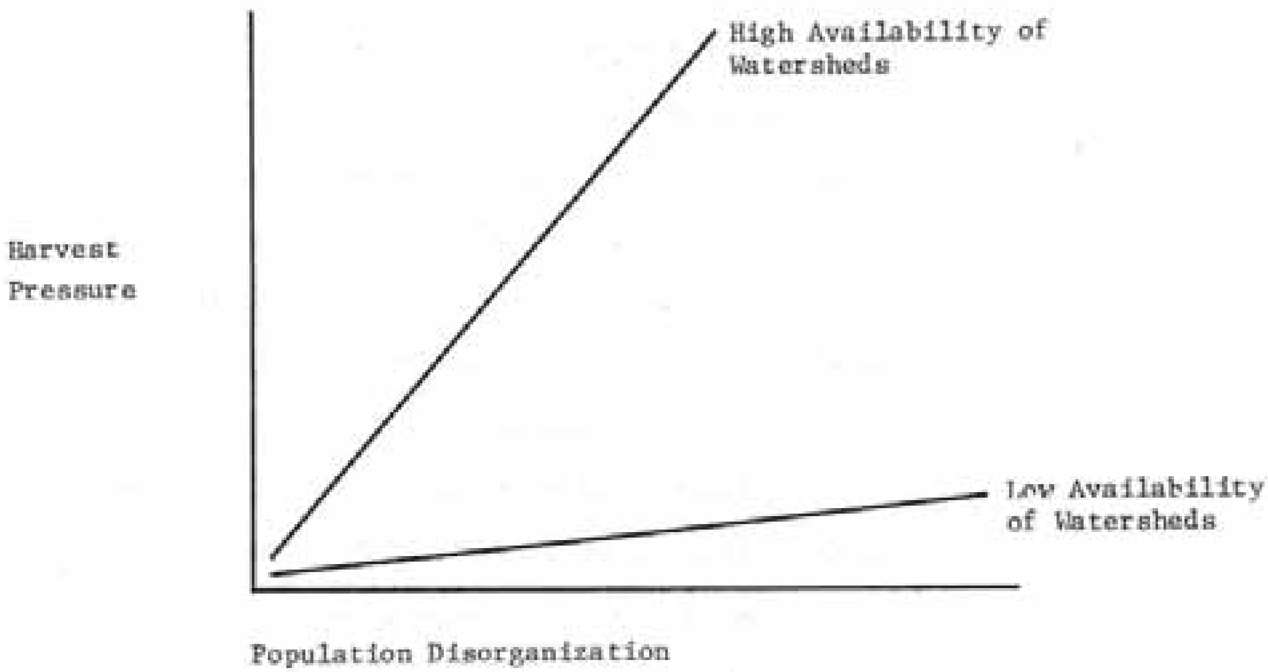

FIGURE 2. The relationship between harvest pressure and the level of population disorganization associated with the number of watersheds available for rotational harvest.

ulations to disorganized populations, (Figure 2) for various intervals of time dependent upon the availability of watersheds. Where a limited number of watersheds prevail, the level and period of disorganization may be monitored by harvest data from the compulsory check and/or the hunter sample, changes in the sex and age distribution from inventoried or harvested populations, changes in the harvest density and distribution, and changes in social organization and productivity from aerial and ground surveys.

Unless stringent controls are available, females may make up a large component of the harvest. For example, of the goats submitted through the compulsory check for aging (1977), approximately 33% of those harvested in Region 6 were female, and 58% of those harvested in Region 7 were female. It appears that game management unit (GMU) 7-39 is supplying at least 31% of the females harvested in Region 7 (Elliott, pers. comm.). The harvest distribution does not appear to center on a few populations, however, an evenly distributed harvest at this level of female harvest is also likely to be detrimental. It is possible that this population is disorganized to the extent that hunting should be curtailed for a period of time. If surveys identify a larger portion of the female component of the population, in comparison to the available male segment, the recruitment rate/100 adults will be inflated (Table 3) and, could cause an overharvest of females if sex identification by the hunter is not mandatory. Similarly, late October and November seasons may increase the vulnerability of early migrants to low-elevation winter ranges (often females and subadults). Bubenik (pers. comm.) has shown in other species that population quality changes in these circumstances, Kuck (1977) has shown that less desirable habitats remain vacant as females are harvested and the population declines, and Hebert and Turnbull (1977) have indicated that productivity and recruitment may decline in more heavily hunted populations although the number of kids/100 adults may remain unchanged.

In populations of low productivity, recruitment is generally measured by the ratio of yearlings to adults. However, recruitment actually consists of females of 2.5 and/or 3.5 years of age. Examination of Chadwick's (1977) data suggests that there is a difference in recruitment of about 2% between yearlings and two year olds. It is likely that the difference is greater than 3% in low productive coastal populations. Thus, in the most sensitive ecotypes, recruitment and subsequently harvest is overestimated, especially if mortality occurs in the 2.5 or 3.5 year class. In higher productive populations or ecotypes, such as those on the Olympic Peninsula (Stevens, pers. comm.), overwinter mortality is reduced and recruitment more closely resembles the identifiable segment (yearling) of the population because all 3.5 year old females and many 2.5 year old females breed.

Harvest systems which are not dependent on inventory systems provide an inadequate basis for temporal comparison and often populations are reduced or removed prior to recognition by managers (Figure 3). In addition, identification of access and access policy must be related to individual populations. Lack of access control often results in an overharvest of newly available underharvested populations every 2-5 years. Air access in the north provides a somewhat more even distribution of harvest for a longer period of time, but eventually it can also become

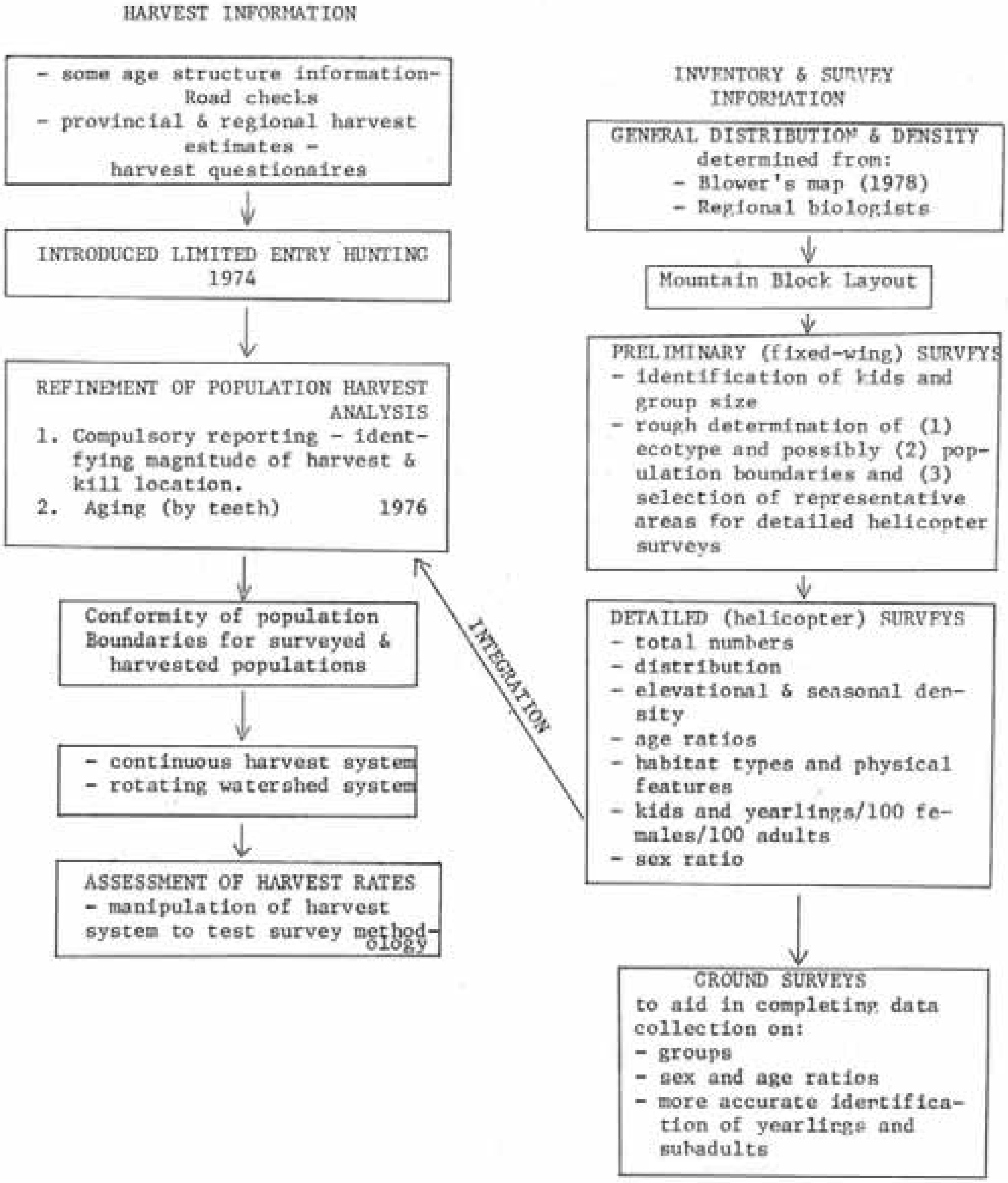

Figure 3. The relationship between harvest and survey systems.

clumped. Similarly, populations may be underharvested due to the insensitivity of the system. Management in large land units, by numbers alone, in the face of advancing access, has led to the decimation of several populations in the Province because the system could not adequately quantify population characteristics, harvest location, and magnitude of harvest.

In previous systems, hunters, weather, season length, and bag limit dictated the harvest. Present inventory - management systems must determine the harvest rate and be sensitive enough to indicate detrimental effects to the population at the time they are occuring. In addition to rotating watershed management within large land units, ground or aerial checks of representative study areas at two to five year intervals (depending on intensity of harvest) must occur in order to adjust the system. Where possible, limited entry hunting systems and compulsory checks should be used in relation to social organization, particularly for sensitive populations. Development of a conceptual framework for survey and harvest systems allows integration and the ability to test one system against the other. This requires that population or ecotype boundaries be consistent with management unit (MU) or subunit boundaries; harvest and inventory boundaries must coincide and units must be reduced in size. One of the strongest tools available to wildlife managers is the ability to manipulate harvests while testing the sensitivity of inventory methodology. However, this method has remained unused due to the inadequacy of current data systems in the B.C. Fish and Wildlife Branch and due to inadequate and inefficiently utilized inventory funds.

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MOUNTAIN GOAT MANAGEMENT - Chairman: K. M. Sumanik

J. N. Bone - Status of the Mountain Goat (Oreamnos americanus) of the Similkameen River, British Columbia.

Wayne Heimer: What is a juvenile and how do you tell?

Jack Bone: Size. Even a small adult is much bigger than an 11 month old juvenile.

Joel Berger: How do you determine the difference between males and females?

Jack Bone: Mainly by the shape of the horns; female horns curve back flatter and are usually smaller. You can also watch urination posture. Size is not often a good criterion. Usually males are by themselves; females will be in a group or with younger animals.

Bryan Foster: How many times a year do you conduct your counts?

Jack Bone: We do a very rapid count early in the spring; April - May.

Rolf Johnson: With the use of a helicopter did you experience much harassment?

Jack Bone: When they are on the precipitous areas they don't seem to react too badly. But in the spring, when they are on the lower slopes on the green-up ranges, they can move pretty fast to get back to the bluffs.

Anonymous: Do you have any idea of the per cent of goats that you see with your helicopter surveys in April and May?

Jack Bone: I think on the north side of the river, we are probably seeing about 80%, and on the south side we are seeing maybe 30%.

Bill Hall: What was the sex breakdown on your kill?

Jack Bone: It was quite high to females, about 65% to 70%.

Bill Hall: I see in your survey that you are classifying adults and juveniles and you are not doing them during the kidding time. Is this information adequate for management purposes?

Jack Bone: No, we need more population parameters: age class, sex class, better recruitment, productivity and natural mortality data.

Jim Bailey: When you had more restricted seasons and perhaps more local hunters, did you tend to get a higher ratio of males in the kill?

Jack Bone: Yes, we did.

R. Jamieson - Goat management in the Kootenays.

Jim Bailey: Regarding the delayed response of four to five years that the goat populations showed to lower density and closing of the season, do you think the delay is real, or an artifact of where you were looking for goats?

Bob Jamieson: I think we had some impact on goats in addition to the harvest. Harassment had some impact as well.. There are annual fluctuations in the population; there is a long term (50 year) forest-cycle fluctuation and there is a fluctuation in the five to twelve year period. I don't understand what it is, but I don't think it is an artifact of our technique.

Jim Bailey: You don't think it was poor weather-that the response could not occur until you had some better years?

Bob Jamieson: One winter, 1968-1969, was tough on all the game, but there is no indication that there was a series of hard winters.

Joel Berger: Have you tried to compare body size data, of hunter kills from your population to those which have been hunted elsewhere?

Bob Jamieson: I have some information from a pretty reliable fellow in the Elk Valley. He suggests that in two valleys separated by two ridges the average weight of goats in one valley is one hundred pounds more than in the other valley.

Joel Berger: If the carrying capacity of one population is increasing and the other one is decreasing, there could be a lot of competition. Do you think that might be one of the reasons?

Bob Jamieson: I have no idea with those particular herds.

W.K. Hall and J.A. Bibaud - Goats and their management in Alberta.

Tim Baumann: On your spring counts, do you fly prescribed routes, or do you just fly the area till you think you have seen all the goats?

Bill Hall: We fly each drainage, each alpine valley. We do cover more intensively areas where we know there should be goats.

Tim Baumann: You made a comment about 37% given mortality. Was that due to winter kill? What's causing your kid mortality?

Bill Hall: It's mainly due to winter severity. There are both wolves and cougars in the area, and in the summer we have grizzly bears but I don't know what their effect is. There was virtually no difference in figures between surveys flown in June and July.

Anonymous: You had two winters followed by low production and involving high mortality. Were those winters severe?

Bill Hall: No, the snow cover and the type of winter have not been that bad the last three years.

Daryll Hebert: Have you been successful with your ground and aerial surveys since 1973 in estimating more accurate or more definitive sex ratios?

Bill Hall: No, we have not. We classify adult males when possible.

Daryll Hebert: I was asking because recruitment ratios generally use kids and yearlings per 100 adults, but the fluctuation of the number of males/100 adults is anywhere from 0 to 80 or 90%.

Ray Demarchi: Do you feel that kids orphaned by hunters killing the nanny are destined to die?

Bill Hall: I think the kid and the yearling depend on the nanny a lot more than sheep do. I would say the chances of an orphaned kid surviving are probably less than if they were with a female.

Ray Demarchi: I think if you isolate your nursery groups and have another look at your data there is ample kid production. Natural mortality may run between 7 and 12% and average around 9%, but you do not need to produce a lot of kids and yearlings to maintain a population.

Victoria Stephens and C. Driver - Initial observations on a tagged mountain goat population in the Olympic Mountains.

Daryll Hebert: What per cent of the whole area are you covering in that count?

Tory Stephens: I'm not really sure how much of the area we are covering. We have seen 94% of the tagged adult females (since September) and so that is a pretty good indication that we are seeing quite a bit of the nursery group range at least. We are probably missing a lot of the males that are still in the area.

Randy Bennett: You said you had some problems with females with poor skin condition, in late winter, and you trapped the goats in summer. Did you observe any ectoparasites on the goats at this time?

Tory Stephens: No, I have not. However, I have never trapped one of the goats that looked like this so I have not been able to get a sample of it.

Jim Bailey: Did you feel that social groups, the animals tagged together, stayed together throughout the year?

Tory Stephens: They stayed in the same geographical area, but every time I went up I saw different combinations of the tagged animals.

Jim Bailey: How big a place are we talking about?

Tory Stephens: The distance between these two areas on the top of the ridge is about a mile, two miles.

D.M. Hatler - The Goats of Goat Mountain: Evaluation of a proposal.

John Elliot: Do you have any information which would give us further insight into how goats are able to move into a new range, and whether there are managment implications in that?

Dave Hatler: I do not know how well goats can colonize. The experience seems to be that we have a lot of areas that do not now have mountain goats but probably did have.

Rick Ellis: Given that there are a lot of isolated populations and a lot of phenotypic, if not genotypic, differences, do you think there really are such things as generalities about goats?

Dave Hatler: I think you have to be management specific, particularly for these isolated populations.

B.R. Foster - Horn growth and quality management for mountain goats

Joel Berger: How do high and low quality populations differ in their parameters from populations that are increasing or decreasing?

Bryan Foster: The analyses with sheep are that high quality populations, mentioning the characteristics that I did, would represent increasing populations.

Joel Berger: Is there something specific about ungulates then, which makes you use the terms high and low quality? Or could you use these terms for any population?

Bryan Foster: You could use them for any population at any level. It is only a convenient criterion for indexing populations that one cannot get out to look at in the field.

D.M. Hebert - A systems approach to mountain goat management

Dave Hatler: The difference between high and low quality populations may be how they respond to different kinds of weather years. Perhaps in some years there may be no difference?

Daryll Hebert: After looking at goat populations in Alberta, B.C., Montana, and Washington, the animals I appreciate most are the goats that inhabit the coastal mainland in B.C. where the climate is extremely harsh. We have seen, over a three year survey period (1974-1976), both our kid ratio and our yearling ratio vary very little. In 1977 our kid production doubled, strictly, as far as I'm concerned, due to the increasing mild climate.

I'm fully convinced that behaviour and use of the habitat by the family group are really dictated by the winter climate. Where it is milder, there is less influence, but where it is harsh there is almost total control by climate.

Bob Jamieson: You talked about kid/adult ratios, female/kid ratios and so on, and the effect of not being able to count males. We also need to count the two year olds, since they are messing up that ratio too.

Daryll Hebert: The two year old component can disturb recruitment as much as not being able to survey for males. If you are surveying a low productivity ecotype, true recruitment may not really be till 3.5 years, but you are still calling recruitment yearlings/100 adults.

PARATUBERCULOSIS (JOHNE'S DISEASE) IN BIGHORN SHEEP (*Ovis canadensis*) AND ROCKY MOUNTAIN GOATS (*Oreamnos americanus*) IN COLORADO

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ABSTRACT

Between 1972 and February 1978, six cases of paratuberculosis have been diagnosed in a herd of free-ranging Rocky Mountain bighorn sheep (*Ovis canadensis*) and one case in a Rocky Mountain goat (*Oreamnos americanus*) on Mount Evans, Colorado. Sightings of 20 other sheep and four other goats showing clinical signs of the disease have also been reported during this time. Diagnosis of paratuberculosis was based on gross and histopathologic examination of the animals and by isolation of *Mycobacterium paratuberculosis* from three sheep and the goat. Clinical and pathologic changes seen in bighorn sheep resembled those described in domestic sheep and goats. A discussion of the importance of finding this disease in free-ranging bighorn sheep and Rocky Mountain goat herds is discussed.

INTRODUCTION

Paratuberculosis is a specific infectious enteritis of domestic livestock including cattle, sheep, goats, camel and reindeer (Thoen 1977, Katic 1961).

It is of great economic importance to the livestock industry in much of the United States (Kopicky 1973), Canada, Eastern and Central Europe. The disease has been recognized for over eighty years, having first been described in Germany by Johne and Frothingham in 1895. Paratuberculosis is caused by *Mycobacterium paratuberculosis*, a small (0.5ux - 1.2u) acid-fast bacillus. In ruminants this bacteria causes a chronic disease with involvement of the intestinal tract, particularly the distal small intestine, ileocecal valve, cecum, associated mesenteric lymph nodes and afferent lymphatics. Most information on paratuberculosis is based on studies of the disease in domestic livestock. Descriptions of the disease in wild species are incomplete and consist mainly of isolated case reports. Paratuberculosis in bighorn sheep has only been reported once in the literature (Thoen 1977) and reports of the disease have not previously been reported in Rocky Mountain goats. Other wild species in which paratuberculosis has been reported include white-tailed deer (*Odocoileus virginianus*) (Libke 1975), roe deer (*Capreolus capreolus*) (Hillermark 1966), European red deer (*Cervus elaphus*) (Vance 1961, Katic 1961), moose (*Alces alces*) (Soltys 1967), aoudad (*Ammotragus lervia*) (Boever 1977), mouflon (*Ovis musimon*) (Boever 1977, Katic 1961), camel (*Camelus bactrianus*) (Thoen 1977, Katic 1961), bighorn sheep (*Ovis canadensis*) (Thoen 1977), reindeer (*Rangifer tarandus*) (Katic 1961), Japanese sika deer (*Pseudaxis sika*) (Katic 1961), water buffalo (*Bubalus bubalus*) (Katic 1961), yak (*Bos grunniens*) (Katic 1961), gnu (*Connochaetes alboujubatus*) (Katic 1961), and Llama (*Llama glama*) (Appleby 1954).

M. paratuberculosis is relatively resistant to environmental conditions. Viable organisms, capable of initiating infection in susceptable animals, have been recovered from contaminated pastures for one year and from barn walls for up to five years after the source of bacteria had been removed. The organism is relatively susceptable to sunlight (50-100 hours of direct sunlight will kill the organism), drying, high soil calcium, high soil pH, and continuous contact with feces and urine. The bacteria is fastidious and slow growing in culture requiring up to four months for identification. The paratuberculosis organism requires mycobactin, a product derived from Mycobacterium sp, in the culture media in order to grow.

The primary natural route of transmission of the disease is via ingestion of contaminated feces. Studies of paratuberculosis in domestic livestock indicate that animals become infected when they are very young. Experimental work with domestic lambs has shown that as few as 1,000 organisms will establish infection (Filmore 1976). Other modes of transmission, which have been documented in domestic livestock, but have not been examined in wild species, include intrauterine and transmammary infection.

Clinical signs described in domestic ruminants include a long incubation period, with most clinical cases being 2-6 years of age. Clinical signs include emaciation and often submandibular edema, which is related to low serum protein. Cattle characteristically have constant diarrhea, domestic sheep and goats may or may not have diarrhea, and in cases where it is present, diarrhea may be intermittent. Normally animals are alert and have good appetites until the terminal stage. The biggest economic problem to the livestock industry is related to decreased production (milk, wool and weight gains). A second, less dramatic, but nevertheless important loss over a long period of time, is that up to 10 percent mortality can occur annually in infected herds (Larsen 1970).

At necropsy, domestic animals show classic signs of emaciation including serious atrophy of fat depots, submandibular edema and muscle atrophy. Subserosal edema and thickening of the wall of the distal jejunum, ileum and cecum are commonly found. The afferent lymphatics from these regions are also thickened, opaque, and sometimes torturous. The associated mesenteric lymph nodes are usually grossly enlarged (2 to 5 times normal), edematous, and in the case of domestic sheep and goats, may contain areas of necrosis, caseation and mineralization.

The classic histopathologic lesions in domestic ruminants include granulomatous enteritis, lymphangitis (afferent lymphatics) and lymphadenitis (mesenteric lymph nodes and occasionally pharengeal lymphnodes and tonsil). The granulomatous infiltrate is characterized by large epitheloid macrophages with large amounts of foamy eosinophilic cytoplasm, multinucleated giant cells and variable numbers of lymphocytes. With acid-fast stains, clumps of small bacilli are found intracellularly in the phagocytic cells. Caseation and mineralization is associated with the granulomatous reaction in domestic sheep and goats, and only very seldom in cattle.

Techniques for diagnosis of the disease have only been worked out for domestic species and at the present diagnosis of subclinical cases is quite difficult. Serological testing is of some value in cattle but many false positives and negatives are found. Therefore, the test may be useful for indicating the presence of the disease in herds but is of little use for diagnosis of the disease in individual animals. Fecal culture presently is the most widely used technique for detection of paratuberculosis in domestic herds and for identification of individual infected animals. Problems associated with use of facalculture are that large numbers of bacteria are only shed relatively late in the disease and then may only be shed intermittently. The length of time required for a diagnosis and the difficulty of culturing the organism also are problems associated with fecal cultures. Promising data recently has been published applying the lymphocyte stimulation test to the diagnonis of paratuberculosis in cattle (Alhaji 1974). This test should be capable of detecting an animal sensitized to antigens of M. paratuberculosis within a short period after infection, thus detecting an infected animal long before any other test. The short period of time required for the test (two weeks) is therefore a definite advantage.

METHODS

Personnel of the Colorado Division of Wildlife submitted diseased animals to the Wild Animal Disease Center for thorough necropsy and evaluation. Some cases were presented alive and subsequently euthanized, others were shot or found dead in the field. A thorough post mortem examination was performed and representative tissue samples fixed in 10 percent formalin; mesenteric lymph nodes and sections of small intestine were frozen for later bacterial culture. Formalin fixed tissues were processed rountinely and stained with hematoxylin and eosin.

Appropriate tissues also were stained by the Kinyon acid-fast method. Bacteriology was performed by Dr. Charles Thoen, National Animal Disease Center, Ames, Iowa. The lymphocyte stimulation test was performed as described by Alhaji (1974) for bovine lymphocytes with the following modifications: (a) Heparin was used at 20 U/ml of venous blood; (b) ficoll-diatrizoate was adjusted to specific gravity of 1.077; (c) microtiter plates were used for cell culture; (d) 20 percent fetal calf serum was used in the culture media; (e) cultures were incubated for a total of five days; (f) concanavalin A (50 ug/ml) was used as a nonspecific mitogen; and (g) Otto Hiller automatic harvester was used to terminate cell cultures. A fecal smear of the mountain goat using the auramine-rhodamine stain to demonstrate the bacteria was performed.

STUDY AREA

All clinical cases of bighorn sheep were from Mount Evans and Grant, Colorado. These areas are approximately 13 miles apart. The Mount Evans herd is estimated at 150 sheep and the Grant herd at 80 animals. Exchange of animals between these two herds has been documented by observation of movements of neck-banded individuals. The mountain goat was from the Lincoln Lake area on Mount Evans.

RESULTS

Six confirmed cases of paratuberculosis from the Mount Evans/Grant herds have been documented up to February, 1978 (Table 1). Descriptions of the clinical disease, gross, and histopathology in bighorn sheep are, however, based on five cases. Case #2, a mature ewe, was subclinical; she was not showing clinical signs and all systems

TABLE 1.

Cases of Paratuberculosis

Bighorn Sheep and Rocky Mountain Goats in Colorado

Species	Date	Age	Sex	Location
Bighorn	1972	4	male	Mt. Evans
Bighorn	1-26-77	4	female	Mt. Evans (Subclinical)
Bighorn	4-18-77	6	male	Grant, Colorado
Bighorn	5-20-77	4	male	Mt. Evans
Bighorn	4-30-77	10	male	Grant, Colorado
Bighorn	1-2-78	7½	female	Grant, Colorado
Rocky Mtn. Goat	2-21-78	2½	male	Mt. Evans

appeared grossly normal on examination.

Paratuberculosis in bighorn sheep.

Gross Pathology: All the sheep examined were emaciated, had dry, rough hair coats and diarrhea. Submandibular edema was noted in three of the sheep examined. Nonspecific lesions such as serious atrophy of fat depots, submandibular edema and generalized muscle atrophy were associated with the emaciated state of the animals. Marked subserosal edema was present in the jejunum and ileum. Afferent lymphatics from these regions were opaque, thickened and torturous. Mesenteric lymph nodes were greatly enlarged (2 to 5 times normal size) and edematous. The wall of the jejunum and ileum was thickened and in some cases corrugated.

Histopathology: Microscopic features consisted of granulomatous enteritis, lymphangitis, and lymphandenitis. The primary inflammatory cells were large epitheloid macrophages and, in three cases, multinucleated giant cells. Cellular infiltration disrupting normal architecture of the intestinal wall was present in the lamina propria and submucosa of the small intestine and cecum. In severe cases, cellular infiltrate also was present in the spiral colon. Necrosis or mineralization was not found. Lymphangitis was severe in most cases with many vessels nearly occluded by thickened irregular walls and debris within the lumen. Inflammatory cells were primarily epitheloid macrophages, and in two cases, giant cells were present in the mesentery and perilymphatic areas. Mild lymphocytic perilymphatic infiltration also was present. Granulomatous infiltrate in the lymph nodes occurred primarily in the subcapsular regions of the cortex. Again, the inflammatory infiltrate was mostly epitheloid macrophages with occasional giant cells in three cases. In case #6, tonsils were examined histologically and found to have granulomatous foci present. Acid-fast stains of tissues from these animals revealed variable numbers of acid-fast bacilli present within the phagocytic inflammatory cells of intestine, lymphatics, lymph nodes and, in one case, tonsil.

Subclinical Case #2: On histopathologic examination of tissues mild lesions typical of paratuberculosis were found. Acid-fast stains demonstrated only a few bacteria within phagocytic cells of these tissues.

Paratuberculosis in Rocky Mountain Goat.

Gross Pathology: Clinical signs seen in this animal were similar to those described for bighorn sheep - emaciation, dry rough hair coat, and diarrhea. Gross examination, however, revealed somewhat different lesions. Subserosal edema was not present. Mesenteric nodes were massively enlarged and yellowish areas indicating the presence of necrosis were seen through the mesentery and on cut surface. The intestinal tract was diffusely hyperemic and a fibrino-necrotic membrane was present in the ileum. This was probably related to a secondary bacterial infection. The small intestine was greatly thickened. A 3 cm. abscess in the wall of the ileum and adhesions between ileum and peritoneal wall were present. The lymphatics were opaque but not thickened to the degree seen in bighorn sheep.

Histopathology: On histopathologic examination, massive granulomatous enteritis was present in the jejunum and ileum. Less extensive lesions were present in the duodeneum, cecum and spiral colon. Granulomatous lymphadenitis was also present. Inflammatory cells especially epitheloid macrophages and numerous large multinucleated giant cells were obvious throughout. Necrosis was present in many areas of dense cellular infiltrate. Extremely large numbers of acid-fast organisms were demonstrated within the phagocytic cells. Fecal smears stained by both acid-fast stains and the auramine-rhodamine method indicate that the goat was shedding extremely large numbers of *M. paratuberculosis* in the feces.

Preliminary lymphocyte stimulation work using blood from the Grant sheep indicated approximately 30 percent infection rate (6 or 7 animals) in this herd.

DISCUSSION

From the description of the lesions found in the five clinical cases of paratuberculosis in bighorn sheep it can been seen that the disease appears to be similar to that described in cattle. The disease in Rocky Mountain goats appears to be more like that described for domestic sheep and goats. The extensive granulomatous reaction, the large numbers of bacteria present, and the relatively young age of this animal may indicate that mountain goats are more susceptible to this disease than are bighorn sheep.

The subclinical case of paratuberculosis is of interest in that she may have been a carrier of the organism and was more likely only at an early stage of the disease. The fact that subclinical cases exist, and animals may be shedding infective organisms is an important consideration to the epizootology of the disease. The massive numbers of bacteria being shed in the feces of the mountain goat is also important. More goat cases are needed to adequately describe the disease in this species.

Several important questions should be considered in regards to the diagnosis of paratuberculosis within these two herds. First, how did the organism become established in this area? Paratuberculosis, while it is important in many areas of the United States, has not been diagnosed by the Colorado Veterinary Diagnostic Laboratory in animals in Colorado for twenty years. A possibility is that bighorn sheep and mountain goat populations contracted the disease from domestic species. A second possibility is that Rocky Mountain goats, transplanted into the Mount Evans area in early 1960, may have been infected and it has taken nearly 18 years for the disease to become established to the present degree. The extensive lesions present in the goat case gives support of this theory.

A second question is what other species may be or become infected with this strain of M. paratuberculosis? It is known that most strains readily infect domestic cattle, sheep and goats. Though this work has not yet been done, we strongly suspect that this bacteria will infect domestic ruminants as well as other wild ruminant species (mule deer, elk) where ranges overlap with infected sheep or goat herds. Cross transmission studies are needed to clarify this question and to determine the importance of this problem.

What steps should be taken to control or eradicate the disease in this area? Survey work to determine the rate of infection is necessary. More data on the epizootology and character of paratuberculosis in wild ruminants is necessary before rational steps can be taken. The lymphocyte stimulation test may be an important tool in this regard but it is still in the developmental stages. Fecal cultures presently are being run in an attempt to detect those animals shedding organisms. The lymphocyte stimulation test together with fecal culture may be a good way of diagnosing paratuberculosis and giving information as to the preval nce of the disease in these herds.

Control of the disease is a difficult problem. Treatment for paratuberculosis is not presently available. Vaccination programs in Europe have had moderate success in decreasing the number of clinical cases. However, some vaccinated animals will still contract the disease and shed organisms in the feces. Detection of infected animals and their removal from the herd also may be a possibility. This is a method employed by domestic livestock farmers in controlling paratuberculosis in their herds.

Clearly, paratuberculosis is an important problem in this particular herd and maybe of significance to other bighorn sheep and Rocky Mountain goat herds or to other domestic and wild ruminants in the area. If the disease was in fact brought into the herds by way of infected Rocky Mountain goats, this becomes an added risk when considering transplanting animals into other ranges.

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CHRONIC SINUSITIS AND OSTEONECROSIS IN DESERT BIGHORN SHEEP (*OVIS CANADENSIS NELSONI*)

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ABSTRACT

Chronic sinusitis is a major mortality factor in desert bighorn sheep and may have brought about the decimation of some populations and restricted expansion of others. The incidence of sinusitis in a captive population of desert bighorn at Zion National Park, Springdale, Utah, is 41 per cent and the disease is terminal. Sheep with sinusitis exhibit varying degrees of necrosis of the skull ranging from porous bone to areas of extensive lysis of the frontal bone, horn core, and sheath. Sheep with sinusitis undergo extensive debilitation, often to the extent of losing half their body weight. Also associated with the disease are open lesions on the forehead, which may become parasitized by fly maggots. Osteonecrosis of the orbits may result in blindness. Central nervous disorders have been related to abscessation of the brain resulting from osteolysis of the brain case. Sheep with sinusitis in its more advanced stages will become solitary, and ewes may not be capable of rearing their lambs. The skeletal results of sinusitis in the desert bighorn at the Park resemble descriptions of necrotic skulls of desert bighorns found in Arizona and Nevada. The etiological agent may be the larvae of the sheep nasal bot (*Oestrus ovis*), with the sinusitis

being initiated by necrotic larvae and subsequent invading bacteria. Corynebacteria have been the most common microbes isolated from the pus-like exudates. Trephining the frontal sinus and adjacent horn core appears to be the only effective treatment.

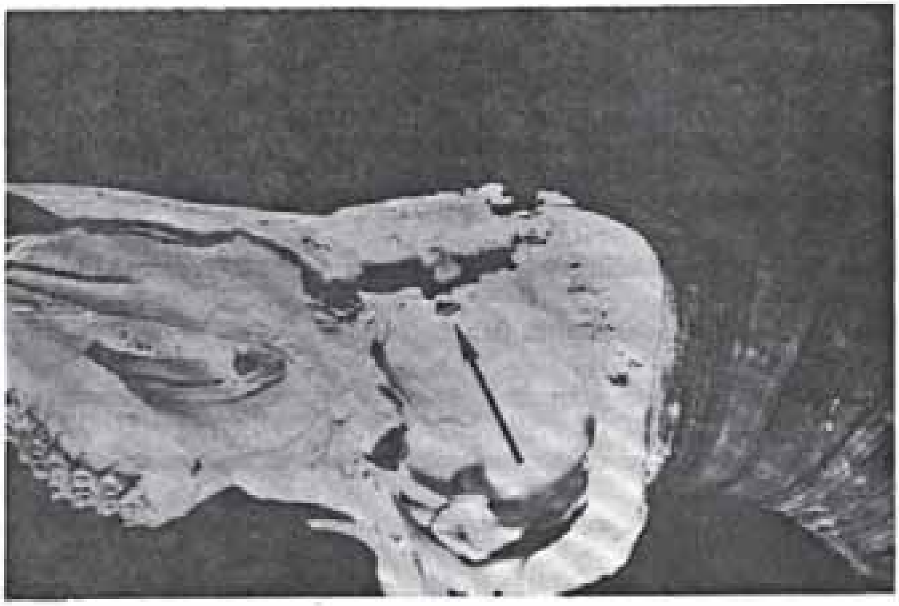
INTRODUCTION

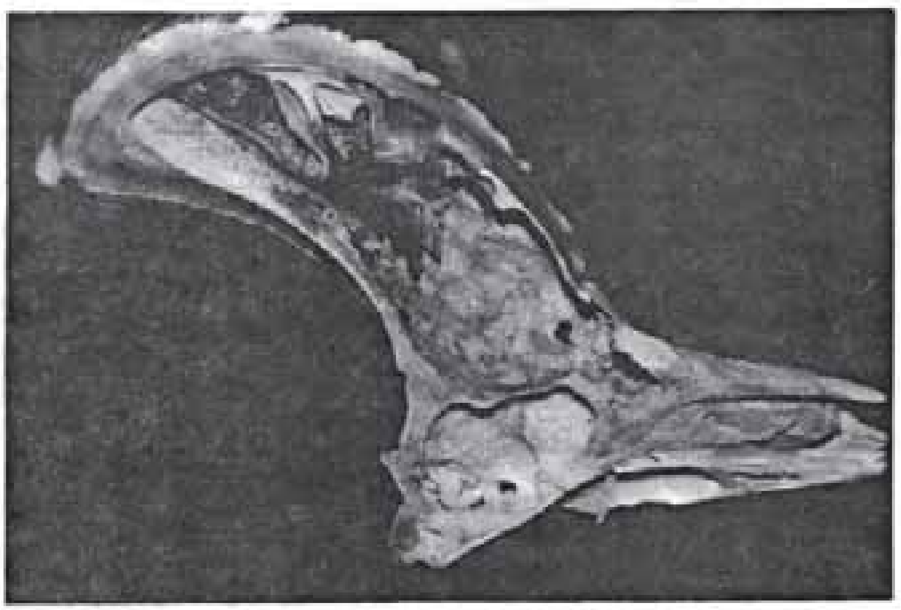
Osteonecrosis and skeletal anomalies have been reported in desert bighorn (Ovis canadensi nelsoni) skulls from Arizona and Nevada (Hansen, 1961; Arizona Game and Fish Department, 1963; Allred and Bradley, 1965). The skulls exhibited varying degrees of necrosis, ranging from spongy, porous bone to areas of extensive lysis in the frontal bone, horn sheath, and horn core. Ram skulls often displayed differential basal circumferences of horns, in association with concomitant changes of the palatal suture and occipital condyles. Skeletal anomalies in ewe skulls were more variable than those in rams. The ewes evidenced bone damage over a wider area, often involving the lacrimal bone, orbital bone, infraorbital foramen and tooth archade. Ewe skulls seldom displayed the large lesions or cavities in the frontal bone found in ram skulls. According to Allred and Bradley (1965), 23 per cent of the ewe skulls and 3 per cent of the ram skulls they examined from the Nevada Desert Game Range skull collection exhibited necrosis of the frontal bone, and 75 and 49 per cent, respectively, displayed necrosis of a lesser extent involving the tooth archade infraorbital foramen, orbital, and lacrimal bone. Although the etiological agent was not identified, the extent of skeletal damage (particularly the anomalies of the frontal bone) was considered as a causing the demise of the sheep.

RESULTS

Reports about the Arizona bighorn are scarce, mainly coming from hunters and taxidermists. In 1962, 7 per cent of the rams killed during the hunting season exhibited osteolysis of the frontal bone, horn core, and sheath (Arizona Game and Fish, 1963). The necrosis was primarily ascribed to mechanical injury followed by secondary invasion of bacteria. During 1977, a ewe was observed circling and was then diagnosed as having a central nervous system disorder. Subsequent post-mortem findings indicated that the ewe had died of two brain abscesses that entered the brain case from a necrotic left horn (Hospital Admission Record, 1977). *Corynebacterium pyogenes* was isolated from the brain abscesses.

Sinusitis that leads to osteonecrosis, as observed in the Arizona and Nevada sheep, was first observed in Utah in a captive population of desert bighorn at Zion National Park. The sheep (3 rams, 5 ewes, and 4 lambs) had originally come from River Mountains and Corn Creek in Nevada and been relocated into an 80-acre enclosure in Zion National Park, Springdale, Utah, in 1973. In 1975, a condition that was later diagnosed as chronic sinusitis was observed in a dominant ram. The ram had undergone a progressive debilitation from 1974 to the time of his death in 1975, when he weighed only 100 lbs. Post-mortem examination revealed osteolysis and abscessation of the nasal and frontal region of the skull, thinning of bone of the upper brain case, lysis of the brain case, extreme necrosis of the orbitals, and total destruction of the trabeculae within the horn cores (Figures 1 and 2). Examination of





Figures 1 and 2. Chronic sinusitis has resulted in extreme osteolysis in the frontal region of the skull, thinning of upper brain case, lysis of brain case (arrow) and total destruction of the trabeculae within the horn core.

skulls from 2 other rams and 2 ewes that also died within the enclosure indicated that sinusitis had contributed to their death. Various degrees of osteonecrosis and porosity of the bone were observed, with the most pronounced bone anomalies being seen within the horn cores. Positive verification of the disease in three of the skulls required sagital sections of the frontal sinus and horn core.

Sinusitis has recently been monitored in four living desert bighorn at Zion National Park. Prior to capture, these sheep had exhibited varying degrees of physical and behavioral changes. The characteristic progressive debilitation extended over 7-12 months, and in some cases ended in death. Some of the sheep lost nearly half their body weight before dying. Often drainage at the frontal region of the skull was observed. Developing lesions could be recognized as small matted regions of hair at the base of the horns. One sheep went blind from osteolysis of the orbit and subsequent infection of the eye. Open lesions also became sites for maggot infestations. Often the infected sheep sought seclusion to avoid harrassment by other sheep. A diseased ewe with a lamb was not able to rear her offspring because of an insufficient milk supply and a decrease in mothering ability. Once a sheep evidenced the disease, unless it was treated, the process appeared to be inexorably terminal. The incidence of sinusitis in the Zion sheep 1 year or older is 41 per cent. Organisms isolated from sheep having the sinusitis have mainly been corynebacteria, streptococci and proteus. No microbial agents other than bacteria have been isolated.

Eleven of the 13 sheep remaining in the Zion enclosure in 1978 were recently captured and examined for signs of sinusitis. Prior to capture, a 3.5 year old ewe was observed (with a spotting scope) to have an unusual tuft of hair on the forehead. Upon close examination, the tufted hair region was seen to be the result of an open and draining lesion involving the frontal sinus. The basal circumference of the horn on the infected side was larger than that of the other. The ewe was the only sheep that displayed noticeable symptoms of sinusitis.

One reason for capturing the sheep was to establish a method of early diagnosis. Besides physically examining each animal, blood samples were taken and checked for a possible marker for the disease. Comparisons, however, could only be made between the one ewe that had been identified as having sinusitis and those that appeared normal. Some of the sheep considered normal may have had an early stage of sinusitis.

Blood cell differential counts were not indicative of sinusitis (Table 1). The blood cell types and related counts of the ewe identified as having sinusitis were within the range of the sheep sampled. The total WBC counts, however, were second to the highest. The sheep with the highest count was not positive for the disease upon physical examination.

Serum components are often used as a measure to determine an animal's physical condition. Evaluation of the serum samples from the desert bighorn indicated that on the average, the blood components of ewe #2 varied from the mean (Table 2). These differences, however, could not be correlated with the differential blood cell counts. The small numbers

Table 1. White blood cell counts on desert bighorn sheep from Zion National Park, Springdale, Utah.

Sheep ID number	WBC Count	Basophils	Eosinophils	Bands	Segs.	Lymph.	Mono.
1	10,250	0	1	2	46	45	6
2*	12,250	0	0	5	53	39	3
3	9,450	0	2	10	37	38	13
4	11,900	0	0	4	60	29	7
5	10,350	0	0	5	64	25	6
6	9,750	0	4	1	73	21	1
7	13,700	0	2	2	75	18	3
8	9,400	0	1	3	79	15	2
9	9,650	0	0	4	79	12	5
10	7,850	0	0	2	63	32	3
11	10,950	0	7	1	63	23	4

* positive for sinusitis

Table 2. Serum analysis of desert bighorn sheep from Zion National Park, Springdale, Utah.

ID number	Calcium (mg/100ml)	Inorganic phosphorus (mg/100ml)	Glucose (mg/100ml)	Bun (mg/100ml)	Uric acid (mg/100ml)	Cholesterol (mg/100ml)	Total protein (gr/100ml)	Albumin (gr/100ml)	Total Bilirubin (mg/100ml)	Alkaline phosphatase (mU/100ml)	LDH (mU/100ml)	SGOT (mU/100ml)	SGPT (mU/100ml)	Creatinine (mg/100ml)
1	10.4	7.9	185	24	0.7	70	6.6	3.9	0.6	>550	760	192	41	2.1
2*	9.6	6.4	185	20	0.6	55	7.8	4.0	0.5	205	570	190	31	1.9
3	10.4	6.0	155	26	0.6	60	6.0	3.9	0.4	>550	1030	>500	54	1.6
4	10.6	10.7	286	21	1.0	60	6.4	3.8	0.5	>550	1330	390	33	2.0
5	10.1	5.6	220	12	0.5	50	6.0	3.0	0.4	>550	880	260	33	1.6
6	9.4	4.0	240	20	0.6	50	7.2	3.2	0.4	135	550	200	27	1.5
7	9.8	3.4	220	12	0.6	50	6.2	2.9	0.4	>550	760	180	22	2.0
8	10.5	5.5	260	23	0.7	60	6.8	4.0	0.7	140	720	410	27	2.0
9	10.2	3.2	240	24	0.7	75			0.7	160	700	225	33	2.1
10	9.6	3.5	245	20	0.7	80	7.2	3.9	1.5	162	745	220	23	2.0
11	9.5	4.0	250	23	0.6	60	5.8	3.7	3.7	>550	1050	355	36	1.6
	10.01 ±.1331	5.47 ±.6880	226.0 ±11.5049	21.1818 ±1.5481	0.66 ±.0388	60.91 ±3.0761	6.6 ±.2044	3.63 ±.1350	.63 ±.0973	372.90 ±61.5719	826.82 ±69.5971	284.73 ±33.1729	32.73 ±2.7139	1.75 ±.1050

*Identified as having sinusitis
BUN - Blood urea nitrogen
LDH - Lactic acid dehydrogenase
SGOT - Serum glutamine oxalacetic transaminase
SGPT - Serum glutamine phosphatase transaminase

of sheep sampled and our inability to identify sinusitis except in advanced cases have made it difficult to evaluate whether blood components can be used as a marker for early diagnostic screening. Erratic rectal temperature readings, respiration rates and heart beat patterns were attributed to excitement during handling.

It has been noted, however, that sheep with sinusitis often have slightly higher temperatures in their areas of infection. This heat differential may prove to be diagnostic. Efforts are being made, therefore, to determine if infra-red sensoring can be used to screen animals and to determine location and extent of infection

The etiological agent that causes sinusitis in desert bighorn sheep has not been established. Necrosis of the skulls of the Arizona sheep was partially ascribed to mechanical damage, particularly bone anomalies associated with the horn. Causes of the necrosis in other areas of the skull were unexplainable. A post-mortem examination of 1 of 3 Zion Desert bighorns that died from chronic sinusitis revealed necrotic bot fly larvae in the pus-like sinal exudate. Although little is known about the effects bot fly larvae may have on wild sheep, their etiology in domestic sheep has been amply described. The sheep bot fly deposits living young in the nostrils of sheep. The larvae often migrate into the frontal sinus where they reach maturity before returning to the nostrils, from whence they are sneezed out and drop to the ground. The larvae set up an irritation that results in more than average mucus coming from the nose, but this mucus only becomes thickened and discolored after secondary invasions of the mucosa by bacteria (Krull, 1969).

Cobbett and Mitchell (1941) reported that such bot fly induced inflammation of the mucosa is always associated with necrotic larvae and secondary bacterial infections. Domestic sheep parasitized by nasal bot larvae rarely die, and then only if they cannot expel the copious mucus. Death comes from suffocation or from abscesses in the deeper recesses of the frontal sinus. The heaviest larval infections have been seen only in horned sheep which have larger and more spacious sinuses.

The anatomy of the skull of the desert bighorn, which serves so successfully as a shield in their head to head duels, may be contributing to their susceptibility to chronic sinusitis, particularly if the etiological agent is the larvae of the bot fly. The brain of the bighorn is overlayed by two separate stratifications of bone that have cross connections of bone. The double roof of bone begins about 5-6 cm. anteriorally from the brain and extends to the occiput. The highly pneumated or chambered horn cores are continuous with the frontal sinus. In comparison, the frontal sinus in domestic sheep is much smaller. An infection in the posterior or lateral regions of the brain in the desert bighorn has no outlet and would be extremely difficult to drain naturally. Once established, the pervasive infection spreads throughout the horn core, frontal and maxillary sinuses, causing osteolysis of the frontal and lacrimal bones, orbitals brain case, horn core, and sheath.

CONCLUSIONS

Chronic sinusitis in bighorn sheep appears to be terminal unless otherwise treated. Treatment of any merit at the present time is limited to sheep that are captive or are available to capture. No systemic or oral antibiotics can effectively treat such an infection. The animal must be trephined. The infected sinus must then be flushed with antibacterial and antiseptic agents in both directions on a daily basis for one to three weeks depending upon the extent of the infection. Trephining involves boring one ½" hole through the frontal bone and another midway or farther up on the horn (Figure 3). The infection cannot be properly treated without both holes. To keep the opening in the frontal bone functional, it is necessary to insert a ¼" catheter for drainage. The catheter can be sutured to the forehead and alongside the nose. Sheep can be intensively treated for several weeks in isolation. However, they must be given antibiotics to prevent pneumonia.

The desert bighorns are faced with numerous mortality factors that challenge their survival. Sinusitus is one such challenge that undoubtedly has taken a heavy toll and will continue to do so.

This brief report cannot present the whole story, but it does describe the serious implications the disease has for the desert bighorn. Sinusitis in the desert bighorn at Zion National Park has taken its toll from all age groups one year or older, and at a rate of 41 per cent. Ewes may be particularly vulnerable. For the lambs, there is no known tally. Unfortunately, too little is known about the etiology of the disease to prescribe appropriate management quidelines. All concerned with the survival of the desert bighorn will have to cooperate if the remaining questions are to be answered.

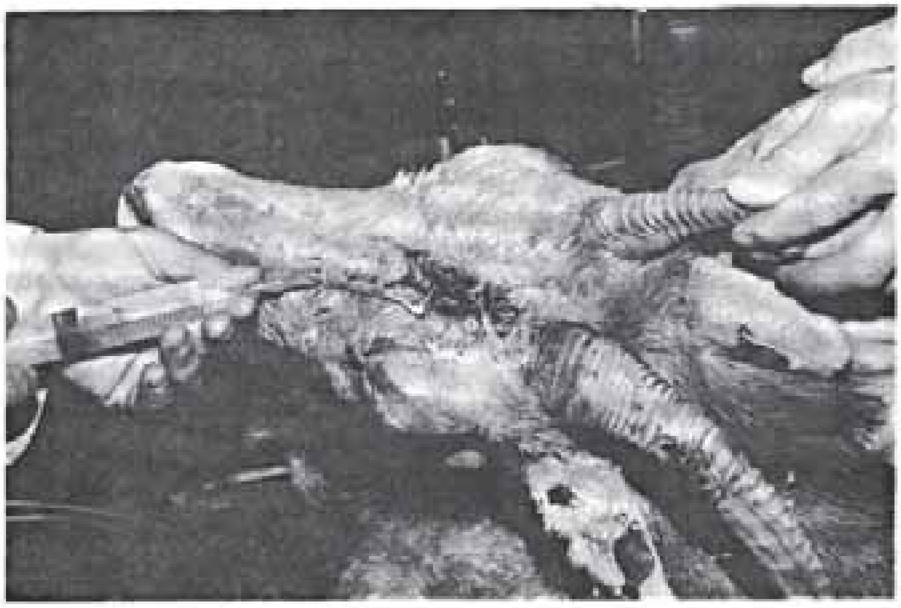


Figure 3. Trephining the frontal sinus and horn core is the only known effective treatment for chronic sinusitis.

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ACTIVITY PATTERNS OF CAPTIVE CALIFORNIA BIGHORN SHEEP (*Ovis canadensis californiana*) AT PENTICTON, B.C.

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ABSTRACT

A captive California bighorn (*Ovis canadensis californiana*) maternal group ranging within a 40 ha. enclosure at the Okanagan Game Farm near Penticton, B.C., was observed from May 1977 to December 1977. Estimates of the average daily time devoted to various activities by the herd members were made for each month of observations. Time devoted to feeding during daylight showed no seasonal trend, remaining relatively constant from May to November, but decreasing in December. Bedding time during the day proved to be highly correlated to day length ($r^2 = .85$). The times devoted to feeding and bedding by different age classes of animals were determined and compared each month. A preliminary analysis indicated no consistent differences existed between different classes of sheep. The diurnal patterns of the herd were monitored each month, and showed considerable variation from one season to the next. Winter storms caused significant changes in activity patterns, even on a day to day basis.

INTRODUCTION

In attempts to maximize the productivity of domestic grazing animals, researchers, for several decades, have studied the daily activity patterns and movements of many domestic species. Such studies have provided a wealth of information on the forage and habitat preferences and potential daily energy expenditures of free ranging livestock (Arnold 1960a, 1960b, Brody 1945, Graham 1964, Meyer et.al., 1957, Squires 1974). This information has been employed in intensive range and animal management.

Similar studies on many wild ungulates are difficult because of the poor viewing conditions afforded by the animals' natural habitat. Mountain sheep, for example, have been intensely studied in North America and yet little quantitative data is available on their daily activity patterns and potential energy expenditures. Various researchers (Mills 1937, Davis 1938, Blood 1963, Geist 1971) have described herd behaviour from relatively few days of observations, giving the time of occurrence and duration of active and non-active periods for several different herds. Van Dyke (1978) completed a more thorough study of this kind, examining the activity patterns of ewes, lambs and rams and comparing the activity budgets of the different sex and age groups within seasons. However, researchers of wild populations are usually forced to observe different animals on different days and even fluctuating numbers on the same day. This obscures individual animal behavior, resulting in average data being collected even for specific age and sex classes of animals. Animal scientists working on domestic grazers have reported that great variation in daily behaviour exists between conspecifics subjected to the same environmental conditions, not only because of age and sex differences, but because of differences in the physiological conditions, genetics, weights and forage selection of the animals as well. Therefore, to fully understand and assess the activity budgets and possible energy expenditures of herd members, identifiable individuals must remain under observation throughout the study to enable their daily behaviour to be interpreted in lieu of the factors mentioned above.

This paper presents a preliminary analysis of the daily activity patterns of a captive group of California bighorn sheep from May, 1977 to December, 1977. The same indivduals were observed for the entire study period, enabling accurate comparison of daily behaviour to be made between individual animals and age classes. Feeding and bedding durations were used for this preliminary comparative analysis. Seasonal changes in general herd activity are also presented and interpreted in terms of weather and range phenology.

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METHODS

Animals for the study were trapped in January and February, 1977 from the Vaseux Lake population, 30 km. south of Penticton. The captive herd was originally composed of 16 ewes (2 years or older), 2 female lambs, 1 male lamb and a yearling ram. Each animal was marked with a distinct collar for identification and then released into a 40 ha. enclosure, situated on steeply sloping grassland adjacent to the Okanagan Game Farm. Data collection began in May 1977 on the original group members. The 18 lambs born on site were trapped and collared in October, and monitored with the remainder of the herd from November on.

The sheep were dependent on the mature bluebunch wheatgrass (Agropyron spicatum) - big sage (Artemisia tridentata) plant community within the enclosure as a food source. Therefore, their daily activity patterns were considered to reflect those of free ranging animals on a similar range, particularly those populations not exhibiting seasonal, vertical migrations.

Observations were made through a 20-40 power binocular spotting scope from a point 200 meters outside the enclosure to eliminate disturbance to the animals. During sampling periods, between dawn and dusk, the study site was scanned every fifteen minutes and the activity of each individual was noted, together with its location using co-ordinates of a gridded map of the area. Activities were categorized as feeding, bedding, travelling without feeding, standing and other (interacting, suckling, nursing, playing, salting, watering, and body care behaviour). Five to eight observation days were completed for each month.

Using a high intensity spot lamp and the spotting scope, the activity of the herd was occasionally monitored well into darkness until all herd members appeared to be bedded. However, all night observations were not attempted because of the poor viewing conditions offered by this system.

The visibility of the animals depended on their study site location. Animals disappeared from view if they moved into the northwest corner of the enclosure because of relief and timber cover. Certain individuals repeatedly used this area and, as a result, were excluded from behavioural analyses. Therefore, data from only 12 of the original 20 herd members and 6 of the 18 lambs are presented in this report.

Adult ewes were aged by horn annuli (Geist 1966) and fell into 1 of 2 age categories: 1) 4 years or older; 2) 3 years. Yearlings made up group 3 and lambs were introduced as group 4 for November and December. Analysis of variance and single degree of freedom contrasts were used for comparing the daily foraging and bedding times of the 4 groups. The statistical significance of day to day variation in the herd's behaviour was also evaluated. The level of significance was 5%.

On some days, the entire herd was visible throughout the sampling period. Data collected on such days were used to describe the temporal distribution, frequency and approximate duration of active and non-active periods for the herd in general under various seasonal influences (lambs not included).

RESULTS

1) Foraging and bedding behaviour

Table 1 lists the average daily time devoted to feeding and bedding each month by members of the individual age groups and by the combined members of the herd as a whole. Significant group differences are indicated with small case letters.

a) Monthly trends for the herd

Average daylight hours devoted to feeding by the herd members ranged from 5.52 hours in December to 9.49 hours in September. Means for the remaining months showed only slight month to month variation, indicating a low correlation between feeding time and length of observation day ($r^2 = 0.24$). The proportion of daylight hours spent foraging varied considerably, increasing monthly from a low of 0.48 in May and June to a high of 0.81 in November. In December, only 64% of available daylight was used for feeding.

TABLE 1: AVERAGE DAYLIGHT HOURS DEVOTED TO FEEDING AND BEDDING

		MEAN LENGTH OF OBSERVATION DAYS	MEAN FEEDING TIME (HRS)					MEAN BEDDING TIME (HRS)				
			HERD	GR.1	GR.2	GR.3	GR.4	HERD	GR.1	GR.2	GR.3	GR.4
MAY		15.00	7.29 (0.48)[1]	7.46a[2]	7.00b	6.69b	-	5.57 (0.37)[1]	5.41b	5.77a	5.70a	-
	S.D.±	0.0	0.84	0.90	0.69	0.80	-	0.59	0.56	0.52	0.64	-
JUNE		16.04	7.85 (0.48)	7.81a	8.00a	7.79a	-	5.81 (0.36)	5.81a	5.74a	5.90a	-
	S.D.±	0.70	1.41	1.22	1.07	1.07	-	1.03	1.03	1.26	0.80	-
JULY -AUG		16.35	8.54 (0.52)	8.50a	8.65a	8.52a	-	5.40 (0.32)	5.48a	5.34a	5.31a	-
	S.D.±	0.59	0.99	1.05	0.96	0.97	-	0.91	0.93	0.91	0.89	-
SEPT		12.70	9.49 (0.74)	9.52a	9.07b	9.85a	-	1.54 (0.12)	1.59a	1.92a	1.05b	-
	S.D.±	0.48	1.18	1.33	1.20	0.68	-	0.80	0.78	0.66	0.73	-
OCT		10.75	7.83 (0.72)	7.90a	7.93a	7.54b	-	1.34 (0.12)	1.29b	1.64a	1.17b	-
	S.D.±	0.42	0.94	0.96	0.92	0.88	-	0.64	0.64	0.64	0.56	-
NOV		9.39	7.68 (0.81)	7.73a	7.55a	7.70a	6.92b	0.67 (0.07)	0.55a	0.87a	0.70a	0.73a
	S.D.±	0.49	0.77	0.87	0.68	0.66	1.05	0.52	0.52	0.59	0.38	0.71
DEC.		8.56	5.52 (0.64)	5.54a	5.29a	5.69a	5.23a	1.33 (0.15)	1.39a	1.38a	1.17a	0.58b
	S.D.±	0.24	1.36	1.40	1.50	1.23	0.90	1.14	1.25	1.11	1.00	0.47

[1]proportion of daylight hours

[2]a is significantly greater than b ($p<.05$)

GR. 1 = 6 ewes; 4 years or older

GR. 2 = 3 ewes; 3 years of age

GR. 3 = 3 yearlings (2 females, 1 male)

GR. 4 = 6 lambs (4 female, 2 males)

Average daylight hours devoted to bedding by herd members peaked in June (5.81 hours) and decreased monthly to a low of 0.67 hours in November. Regardless of the increased December value (1.33 hours), mean bedding time of the herd members proved to be highly correlated to daylength ($r^2 = 0.85$). As foraging occupied a greater and greater proportion of the day, the proportion of time spent bedded decreased accordingly, dropping from a high of 0.37 in May to a low of 0.07 in November. In December, bedding time increased to occupy 15% of the day.

For every month, there was significant day to day variation in the mean bedding and feeding times of the herd members ($p < 0.05$). However, for this preliminary report, no attempt has been made to interpret these daily fluctuations in detail.

b) Monthly age group comparisons

The foraging and bedding behaviour of the different age groups showed no consistent differences. In the June and July-August sampling periods, there were no significant between group differences. In May, group 1 ewes fed significantly longer and bedded significantly less than other herd members while yearlings (group 3) bedded the fewest hours. In October, yearlings fed significantly fewer hours than adult ewes and, with group 1 ewes, bedded less than group 2 ewes. With the indtroduction of the lamb group in November, the analysis showed that lambs devoted less time to foraging than other herd members. Bedding time was similar for all 4 groups. December data indicated no group differences in feeding time. However, lambs bedded less than other animals.

2) General Herd Activity Patterns

Considering that the proportion of the daylight hours spent actively foraging by the herd members increased dramatically from May to November, it is not surprising that the number and duration of active and non-active periods varied from one season to the next. Figure 1 represents the activity patterns demonstrated by the herd for May, July, September and November. Although there were some day to day fluctuations in the herd's behaviour, the patterns described in Figure 1 are considered to be representative for that month.

In May and July, the herd members followed a cyclic synchronous pattern with activity peaks occurring before dawn and at midmorning, mid-day, mid-afternoon and late evening. The most extensive activity peak was in mid afternoon when the majority of animals were active for almost 4 continuous hours. In May, the final active period did not extend far into darkness. However, in July, night monitoring with the aid of a high intensity spot lamp showed that most animals continued to feed 30 to 90 minutes after dusk.

In September and November, the herd's activity pattern was no longer clearly synchronous or cyclic. A majority of the herd was active throughout the day, with activity peaking at or shortly after dawn and continuing well after dark. Inactive periods were short and involved only a few herd members at a time. In November, it became apparent that some animals were remaining active for entire observation periods (9 hours).

Figure 2 shows the activity patterns of the herd for 2 days in December. On December 7, the first major activity peak did not occur until 10:00 hours and lasted only an hour before the majority of the

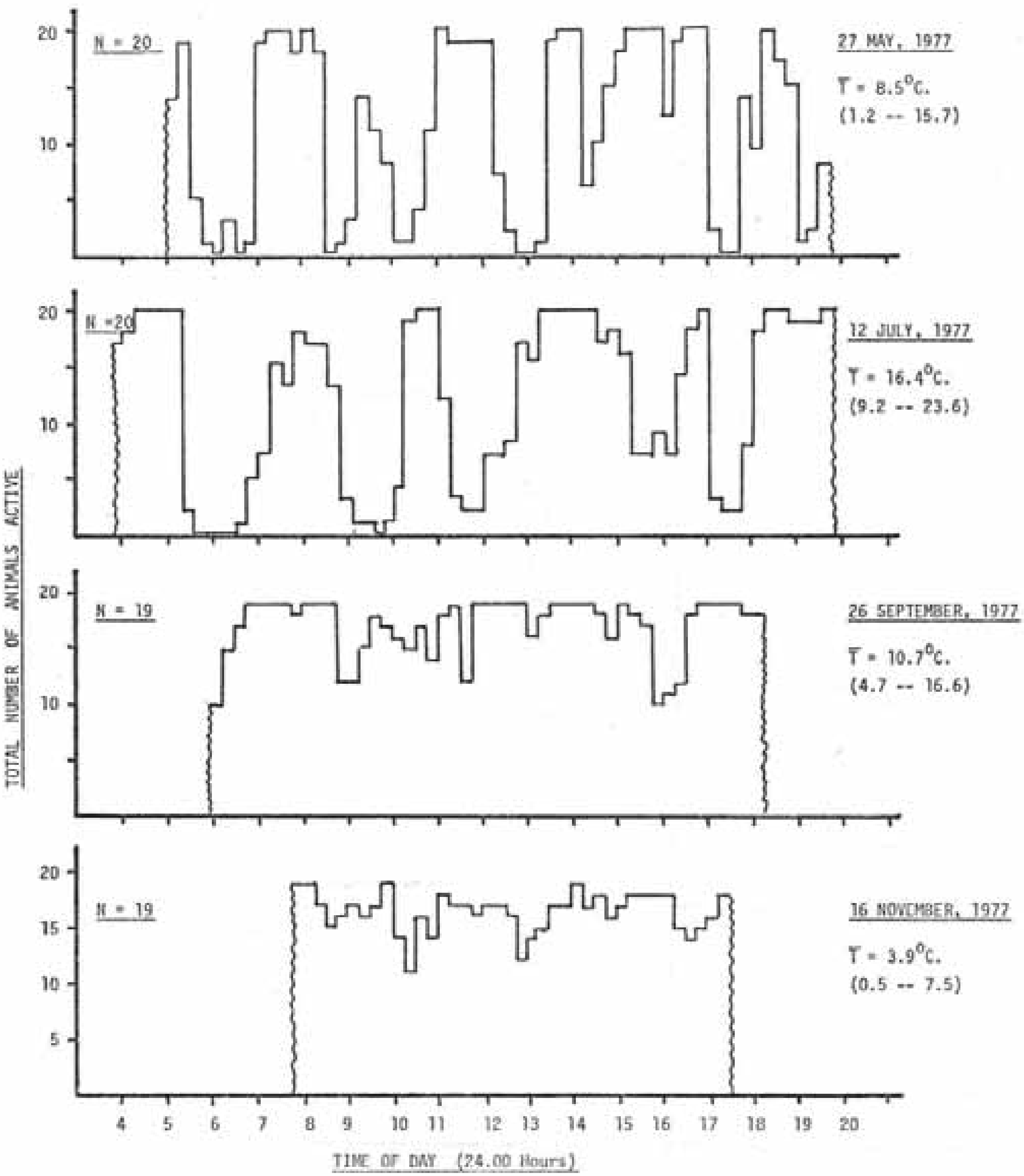

FIGURE 1. Activity of adult California bighorn sheep during daylight hours, for 4 selected days. (N = Total number of adults present; T̄ = mean daily temperature; minimum and maximum temperatures are in parenthises).

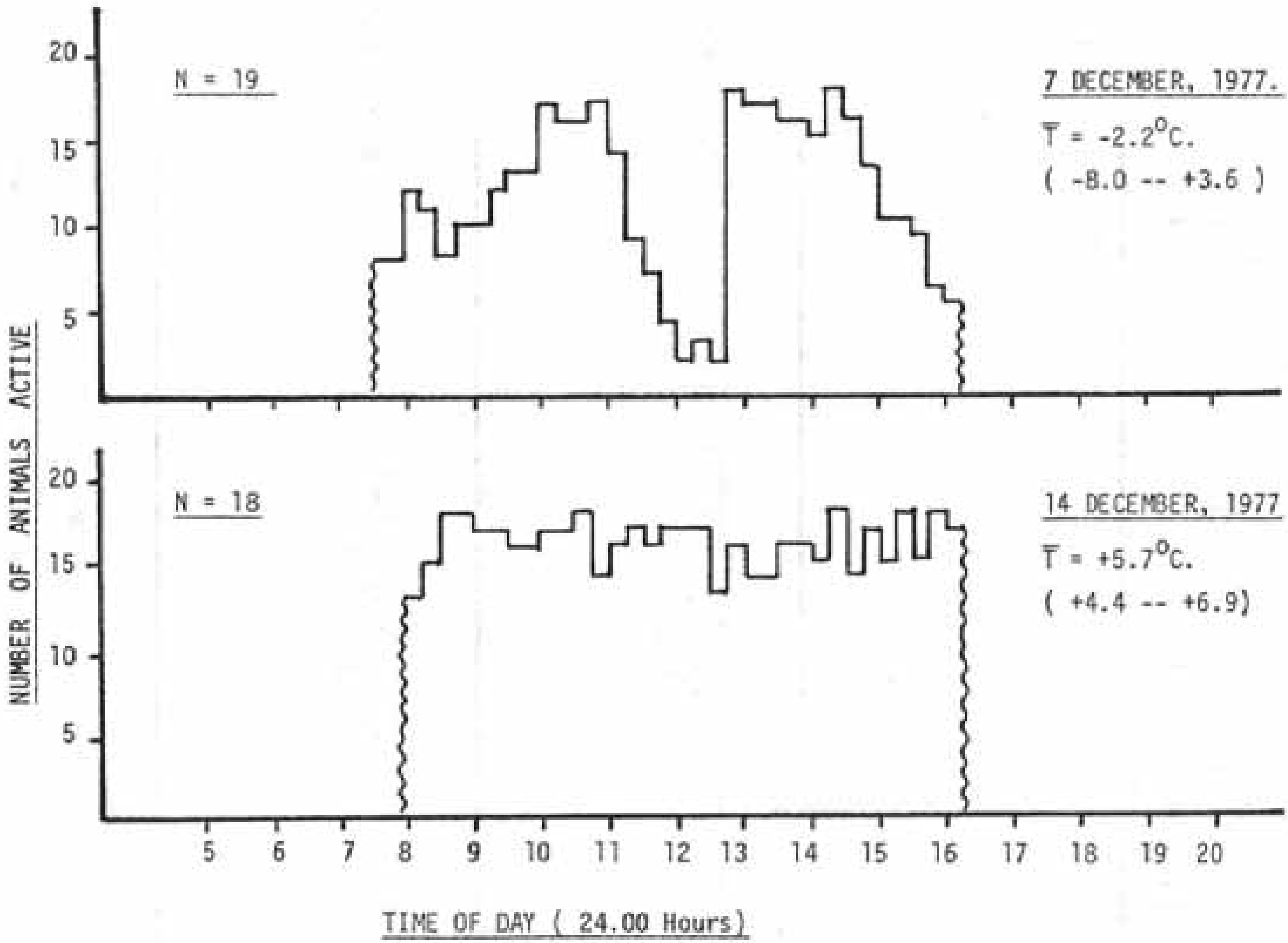

FIGURE 2. Activity of adult California sheep during a "cold" day (7 December) and during a "warm" day (14 December).

herd bedded for an extensive mid-day break. This synchronized bedding was the first observed since the summer. The entire herd was again active by 12:45 hours with the majority foraging until 14:30 hours when bedding again commenced. By dusk, 2/3 of the animals were inactive. On December 14, the herd's activity pattern converted back to it's November form, with the majority of animals being active almost continuously throughout the day.

DISCUSSION

1. Foraging and bedding behaviour

a) Analysis of herd behavior

The overall mean grazing time of the herd members for the duration of the study was 7.74 hours per day. Had observations extended over a 24 hour period, this value would have increased. With the exception of September and December values, monthly means varied only slightly around this figure, showing no seasonal trends. The increased foraging effort in September was probably an attempt by the herd to build up winter energy stores, utilizing the high quality fall regrowth of that month. The low feeding time and elevated bedding time of December appeared to be related to cold, inclement weather in the first 10 days of that month. Since movement and foraging would have been energetically costly in the deep snow and cold, windy conditions, the animals seemed to be minimizing their energy expenditures rather than attempting to maximize their energy intake.

Domestic studies have reported mixed findings on the foraging behaviour of domestic sheep. Hughes (1951) found no seasonal trends in daily grazing time other than a suppression of foraging during the winter months. However, Arnold (1960b) showed that grazing time increased and ruminating time decreased as pasture quality and quantity declined. Arnold (1962) also noted that, as pasture condition and photoperiod decreased with the progression of the seasons, a larger proportion of the sheeps' total grazing time occurred at night. As previously mentioned, monthly grazing means for this study showed no such increase. Therefore, if such a compensatory response was necessary for our captive sheep to maintain an acceptable level of nutrient consumption in the fall months, the animals must have increased their night time feeding. Some night activity was evident from changes in the bedding location of animals at dusk and dawn on consecutive observation days but could not be quantified to indicate seasonal frequency. Night movements appeared to stop during early December when stormy, cold conditions would have made activity too costly.

Other authors have reported on some night activity in bighorns. Woolf(1970) noticed feeding at intervals throughout the night but suggested that movements were "limited to the immediate vicinity of the bedground". Van Dyke (1978) also noticed night movements in Oregon. bighorns.

b) Age group comparisons

The inconsistent behavioural differences of the various age groups were difficult to interpret. All adult ewes (groups 1 and 2) had lambed in the spring and were subjected to the increased energy demands of lactation. This may partially explain why group 1 ewes grazed longer and bedded less than yearlings. The ewes of group 2, which did not behave differently than the yearlings in May, might have entered spring in slightly better condition than the ewes of group 1 because of their younger age. As a result, they were able to cope with lactation demands without increasing their foraging time. Had lambs been monitored in May when they were almost entirely dependent on milk as a nutrient source, the data would have certainly shown a small foraging time and high bedding time for this age group. Van Dyke (1978) found the foraging time of lambs to be less than adult ewes in the spring. He did not compare activity budgets of adults and yearlings.

Although no group differences appeared during the summer months, the inclusion of lamb data would again have shown foraging times of this age group to be smaller than that of other herd members. The lambs had developed some foraging habits by this time but were still suckling regularly for a portion of their diet.

From October to December, rams were present in the herd for breeding purposes. However, none of the group differences for this period can be interpreted in terms of courtship activities. Adult ewes showed no major behavioural changes as a result of harassment from rams.

Reasons for significant day to day variations in the feeding and bedding behaviour of the herd were not clear. The length of observation day remained relatively constant within a month and could not have been a major contributing factor. Weather had obvious effects on herd behaviour during December. However, during periods of consistent weather patterns, day to day variation continued to be evident, indicating that even more subtle factors were at work.

2. <u>General Herd Activity Patterns</u>

Changes in the foraging behaviour of the herd from season to season have been attributed largely to the plant phenology of the range. The cyclic nature of the herd's activity pattern for the spring and summer months likely reflects range condition for that season. Preferred ephemeral grasses and forbs were abundant and high in crude protein (Wikeem 1977, pers. comm.). Forage in this phenological state has been shown to be highly digestible (Hebert, 1973). Therefore, the animals were able to procure and digest this preferred vegetation relatively quickly. Since the rate of passage of ingesta varies directly with its intake rate and digestibility (Blaxter et.al., 1961), the turnover rate for the ingested forage was probably high. This rapid turnover rate combined with the long photoperiod of spring and summer days enabled the sheep to fill their rumens and ruminate several times during daylight in the cyclic fashion demonstrated.

Several researchers of wild mountain sheep populations have noticed fewer activity peaks for bighorns during the summer months than reported here. Mills (1937) and Davis (1938) both found 3 peaks of activity for bighorns in Yellowstone National Park, occurring at dawn, mid day and in the late afternoon. Davis and Taylor (1939) found a bimodal activity pattern in Texas bighorns with foraging peaks extending throughout the morning and late afternoon. A single rest period occurred at mid day. Van Dyke (1978) found only two consistent activity peaks for bighorns, one in early morning and one in late evening. It is difficult to interpret such between site discrepancies since foraging behaviour responds to several environmental factors. However, it is probable that differences in range condition between areas would largely explain such variable observations.

The change from a cyclic pattern of successive feeding and bedding periods to a more continuous foraging behaviour in September and November by the herd seemed to coincide with the late season maturation and fall regrowth of the range plants. Many of the forbs and grasses that were highly preferred in the spring and summer had disappeared or cured to a relatively low nutritive state. However, fall regrowth of the remaining plants, particularly bluebunch wheatgrass, provided a high quality but limited forage and was selected for by the sheep (Wikeem 1977, pers. comm.). But this regrowth, often shrouded by less palatable plant parts, was not readily accessible to the animals and required a considerable degree of foraging selectivity to procure it. It is postulated that the time required to express this selectivity reduced intake rates, enabling the animals to forage throughout most of the day without repeatedly filling their rumens. As a result, bedding periods were infrequent. Several domestic studies support this hypothesis. Meyer et.al., (1957) and Arnold (1960a) both reported that selection by sheep for new growth is very pronounced in mature vegetation. Furthermore, Arnold (1960b, 1964) showed that intake rates decrease for domestic sheep as pasture quality and quantity declines.

Reports on the fall activity patterns of wild sheep differ from the results reported here. Geist (1971) found an average of four activity peaks for Stone rams in October and at least 1 bedding period at mid-day which involved almost all visible animals. Hoefs (1974) found that a captive herd of Dall's sheep also demonstrated a major bedding period at mid-day throughout the fall months. However, he concluded that the number of activity peaks was dependent on day length. Van Dyke (1978) again noticed only single early morning and evening activity peaks.

Herd activity in December (Figure 2) demonstrated the rapid and drastic effect of weather on the diurnal pattern of the captive sheep.

On December 7, the mean daily temperature dropped to -2.2 C and a storm the previous 2 nights had deposited 20 cm. of snow, raising the snow accumulation on the site to approximately 30 cm. As a result, foraging conditions were difficult. The extensive bedding observed in the early morning was likely an energy conserving strategy of the sheep to avoid this coldest portion of the day when activity would have been energetically most costly. It is suggested that the bimodal activity pattern observed for the remainder of the day was the result of a change in feeding behaviour. The deep snow covered any remaining fall regrowth and the sheep, although cratering to some extent, seemed content to feed largely on stems and seed heads of bluebunch wheatgrass and on browse species which were above the snow. This high fibre forage, being less digestible and slowly processed would have forced the herd to bed and ruminate after short foraging periods. Hoefs (1974) offered a similar explanation for the mid-day "siesta" observed in his captive Dall's sheep herd.

Other researchers found similar winter activity patterns for mountain sheep. Geist (1971) noted that Stone rams and ewes fed very little in the morning with peak activity occurring at noon and mid afternoon. Blood (1963) presented similar results for California bighorns but showed a third activity peak at dusk.

However, Van Dyke (1978) found no avoidance of the morning hours by bighorns in Oregon.

On December 14, the mean daily temperature was 5.7 C with the minimum temperature being a mild 4.4 C. Several mild days previous to this had removed the snow cover from most of the study site. With foraging conditions again being more favourable, the sheep reverted back to a more continuous foraging behaviour. The animals were observed feeding low to the ground, presumably selecting the most recent growth of the plants. With intake rates remaining low but quality of the diet improving, it is postulated that animals were again able to forage continuously throughout the daylight hours without resting to ruminate.

CONCLUSIONS

Studies of the diurnal patterns and activity budgets of bighorn populations can provide information important for the management of these animals and their range. Sampling intensity during such studies largely dictates the nature and usefulness of the information provided.

In this study, animal activities were recorded at 15 minute intervals for the entire observation day. Five to 8 days were spent observing per month. At this sampling intensity, it appeared that seasonal changes in the range phenology were readily detected in the animals' daily behaviour. It also became apparent that certain weather patterns were very influential on the animals' behaviour. Estimating the average daily foraging time of animals within months with moderate precision was also possible at this intensity.

If detailed information on the daily energy expenditures of animals is required from such a study, sampling intensity would have to increase considerably. More sampling days per month would be required to properly interpret the day to day fluctuations in behaviour observed in this study. The sampling interval would have to be reduced to 5 minutes or less to adequately estimate the duration of short term activities, such as running, interacting, suckling, etc.

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BEHAVIORAL DEVELOPMENT IN BIGHORN SHEEP: A COMPARISON OF POPULATIONS INHABITING DESERT AND NORTHERN ENVIRONMENTS

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ABSTRACT

The development of social behavior was studied in three natural populations of bighorn sheep. All populations exhibited the same behavioral repertoires, but the utilization of specific behaviors among both infants and adults differed between populations. It is suggested that differences in the adult utilization of behavior patterns results, in part, from behaviors used during infancy. In turn, the social and physical environments affect the development of subsequent behavior patterns in sheep older than lambs. Desert sheep (in southern California) used more mounting behavior than sheep from the other two populations (British Columbia and eastern Oregon), presumably because they matured sexually almost a year earlier. Sheep in the British Columbia population used different behavior patterns more frequently, perhaps as a consequence of interactions experienced in larger bands. Additionally, playful interactions were reduced due to physical hazards in the desert environment, but they were at least nine times as frequent in the British Columbia population.

Play in large groups resulted in the utilization of more different

kinds of behavior patterns. These behavioral findings are interpreted ecologically as consequences of inhabiting environments that differ socially and physically.

INTRODUCTION

Although social behavior is an important and central aspect of the biology of a species, it is not always ranked among the highest priorities for study by wildlife biologists. Nevertheless, it seems that, in order to comprehend better "why animals do what they do" or "occur where they do," an understanding of social behavior and even developmental aspects of behavior must be attempted. Furthermore, the dynamic nature of social systems should also be considered. Understanding the behavior of a species is equally as important as understanding its movements, foraging strategies, or patterns of reproduction when trying to gain insight into its "basic biology."

Few studies of ungulate ethology have contrasted behavioral development in natural allopatric populations that span large portions of a species geographical range. Such comparative studies under natural conditions are important in assessing the role of the environment upon behavior and also in understanding the evolution of social systems.

Bighorn sheep, *Ovis canadensis*, are ideally suited for a comparative study of behavioral development because they present a number of biologically interesting problems. For instance, parturition is asynchronous in desert populations and lambs may be born at any time of the year (Hansen, 1965; Simmons, 1969), whereas in northern or mountain populations the parturition season is more synchronous (Geist, 1971). Also, group sizes are considerably smaller in the desert than they are in more northern and resource productive habitats (see Simmons, 1969; Leslie, 1977; Hoeffs, 1975).

Given these differences in environmental conditions, I was interested in exploring the following questions: (1) How does social behavior develop? (2) What environmental (social and/or physical) factors influence social ontogeny?, and (3) What is the adaptive significance for the differences?

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METHODS

Study Populations California bighorn sheep, *O. c. californiana*, were studied in the Chilcotin-Cariboo region of the central interior of British Columbia from May through November, 1976. A second population of California bighorns was studied on Hart Mountain, in the Great Basin Desert of eastern Oregon from May to August, 1977. These sheep were transplanted from the

Chilcotin to Hart Mountain in 1954, and, at the time of the transplant, numbered 18. Currently the population size in the transplanted population is about 200. Sheep in this region became extinct around the turn of the century. The last study population was located in the Santa Rosa Mountains in the Colorado Desert of California. These sheep are commonly called desert or peninsular bighorn, O.c. cremnobates. The sheep population in these arid, insular mountains is estimated at 250 (Merrit, 1974). They were studied from January through April, 1977. Further details of the habitats, climate, and study populations are found in Berger (1978).

Data Collection. Data on sheep behaviors were collected by stalking and observing sheep in the field on almost a daily basis. I observed sheep in the Chilcotin for 896 hours, those at Hart Mountain for 293 hours, and those in the desert for 454 hours. Behaviors and social interactions (see ethogram) were recorded into a cassette tape deck and later transcribed, or they were taken directly onto note cards.

Male and female sheep may be sexed visually on the basis of horn and body size differences (Geist, 1968, 1971). However, at a young age when no dimorphism occurs, lambs may be sexed by one of three methods: (1) Male lambs urinate from a standing position while females squat. This method of sexual determination was used most frequently as other methods were not always as accurate. (2) Testes may be visible in males. However, if testes are not visible, it does not necessarily preclude the possibility that a lamb is not a male. (3) Once horns develop, male horns usually grow at a faster rate than females, and they are thicker and flare more widely. Since observation of lambs was often at a considerable distance and accurate determination of sexes was not always possible, the data presented in this paper represent those situations in which I was certain of sexual identities.

Analyses. All statistical analyses of the differences between percentages (probabilities) were performed using the Brandt and Snedecor method when there were two or more samples (see Snedecor, 1956; section 9.9) and the arcsin transformation method for testing the equality of two percentages (suggested by Sokal and Rohlf, 1969: 607). This latter method generates a test statistic, t_s, which may then be compared with a normal deviate (area under the normal curve).

Ethogram. For bighorn sheep, 17 behavior patterns have been categorized and described by Geist (1971:134-143). This ethogram may be enlarged to include at least six more behaviors. Below, I list and describe the behaviors that I quantified.

SEXUAL PATTERNS

1. Mount. see Geist (1971). Mounting is the only overtly sexual pattern used by sheep.

CONTACT PATTERNS

2. Head butt. see Geist (1971).
3. Clash. see Geist (1971).
4. Touch. Two sheep that lower their heads and place them in contact with another. No pushing occurs and their heads remain in contact for at least one second.
5. Push opponent. Two or more sheep that push with their heads, their rumps, or sides, of other sheep.

THREAT PATTERNS

6. Threat jump. "This is an intention movement to clash" (Geist, 1971:143). Threat jumps are often sufficient to discourage an opponent from fighting and no further contact ensues.

7. Horn threat. "...this is an intention movement to butt and as such is a true weapon threat" (Geist, 1971: 142-143). Sheep lower their heads in a position so that they may be in a position to butt an opponent.

8. Head threat. Young sheep that have not yet developed their horns will lower and orient their heads in the same way as when horn threats are performed.

The above three patterns are indeed threats as Geist (1971) correctly pointed out, because: (i) when dominant individuals threaten subordinates, they retreat and little or no contact occurs; and (ii) when threats are insufficient to discourage the approach(es) of other sheep, contact patterns follow.

DISPLAY PATTERNS

9. Low stretch. see Geist (1971). A display of horns performed by lowering the head.

10. Twist. see Geist (1971). A display of horns performed by lowering and twisting one's head.

11. Present. see Geist(1971) A horn display performed by raising one's head and lifting the horns.

12. Front leg kick. see Geist (1971). "...is linked to the display threats of sheep, such as the low stretch, present, and twist; it is virtually a contact display threat" (Geist, 1971:139). Since front leg kicks are not a contact pattern such as butting, and probably serve to convey information about body size (as do horn displays for horn size (Geist, 1968), I have categorized front leg kicks as a display pattern.

Walther (1974) recognized that threat and dominance displays in horned ungulates may often be similar but argues that they merit distinction because basic differences also exist. For example, in bighorn sheep, threats indicate readiness for fighting by directly utilizing ones horns and placing them in a position for contact. In contrast, displays are not actively conveying a threat (although a subordinate individual may feel threatened by the presence of a dominant sheep) and displaying individuals are not oriented in a fighting position.

ROTATIONAL PATTERNS

13. Neck twist. This pattern is more exaggerated than a head shake (Geist, 1971) and it is often used in playful interactions. Neck twists are common to lambs, yearlings, and rams.

14. Gambol. Gambols entail jumping with all 4 legs off of the ground in a somewhat vertical direction. The body axis is rotated and twisted in midair. Both ewes and lambs have gamboled so high that they fell

over backwards. The oldest ram observed gamboling was about 6 years old.

15. Heel kick. Heel kicks entail jumping off of the ground and simultaneously kicking both rear legs or heels. Byers (1977) described an apparently identical motor act in ibex kids.

All of the above mentioned behavior patterns, except displays, occur during play. Rotational movements function as play signals (Berger, 1978).

RESULTS

Sex and Age Differences in Behavioral Development. Males generally used more threat, contact, sexual, and display patterns than did females (Figure 1). There were no significant differences (arc sin proportions test) in the per cent utilization of patterns used by male and female lambs. These data indicated a trend in which male lambs were more likely to engage in all patterns other than rotational movements (see discussion) than female lambs. Displays were infrequently observed in females of all ages and for males they developed only after two months of age (Figure 1).

Behavioral Development in Different Environments. The week (age) of first appearance of different motor patterns in lambs is given in Table 1. Generally, behaviors appeared at similar ages in all populations, except that two display patterns occurred about three months earlier in desert sheep than they did in Chilcotin sheep. The most probable reason displays were not observed in some populations was because I departed from those study sites before lambs developed those patterns of behavior (i.e., they were too young).

The relative frequencies of behavior patterns observed in this study are shown for lambs in Figure 2; for yearlings, ewes, and Class I rams in Figure 3. Desert lambs engaged in significantly more contact and sexual patterns than did Chilcotin lambs (see Table 2 for a summary of statistical

Table 1. Age of appearance of different motor actions in lambs. A minimum of 5 observations of a specific pattern was necessary. NO= not observed in lambs

PATTERN OF BEHAVIOR	MOTOR ACT	LOCALITY: desert	transplant	Chilcotin
CONTACT	head butt	——— one week ———		
	clash	" "		
	touch	" "		
	push opponent	" "		
THREAT	head threat	——— one week ———		
	threat jump	" "		
ROTATIONAL	neck twist	——— two weeks ———		
	gambol	——— one week ———		
	heel kick	" "		
SEXUAL	mount	——— one week ———		
DISPLAY	low stretch	3 months	NO	6 months
	front leg kick	2½ months	NO	6 months
	twist	NO	NO	7 months
	present	NO	NO	NO

Table 2. Summary of tests of equality of two percentages for relative frequencies of behavior patterns observed in lambs, yearlings, ewes, and Class I rams. DES = desert; TRANS = transplant; CHIL = Chilcotin. * = $p < .05$; ** = $p < .01$; *** = $p < .001$; numbers = t_s (test statistic - see statistical analyses). NS = no significance (see also Figs. 2,3).

Group	Comparison	CONTACT	THREAT	ROTATIONAL	SEXUAL	DISPLAY
LAMBS	DES vs CHIL	*** 4.48	** 3.13	*** 4.75	*** 5.62	-
	DES vs TRANS	NS 1.27	*** 3.68	*** 5.42	NS .86	-
	CHIL vs TRANS	*** 4.90	NS .93	*** 5.80	*** 4.76	-
YEARLINGS females	DES vs CHIL	* 2.19	*** 6.72	*** 4.90	-	-
	DES vs TRANS	NS 1.80	* 2.31	NS 1.75	-	-
	CHIL vs TRANS	* 2.08	** 2.61	*** 5.61	-	-
YEARLINGS males	DES vs CHIL	NS .48	*** 5.07	NS .36	NS 1.08	** 2.72
	DES vs TRANS	* 2.20	** 2.96	NS 1.44	* 1.90	NS .96
	CHIL vs TRANS	* 2.29	*** 3.90	NS 1.68	* 2.16	NS 1.74
EWES	DES vs CHIL	*** 6.00	* 2.49	*** 6.31	-	NS 1.68
	DES vs TRANS	NS .86	** 2.91	* 2.29	-	* 1.90
	CHIL vs TRANS	*** 6.19	* 2.02	** 3.14	-	* 1.85
CLASS I RAMS	DES vs CHIL	** 2.95	* 2.27	NS .38	*** 4.70	*** 5.76
	DES vs TRANS	*** 3.39	NS .49	NS .79	NS .77	*** 5.43
	CHIL vs TRANS	** 3.26	NS 1.08	NS .60	** 3.10	NS 1.23
CLASS I RAMS + MALE YEARLINGS	DES vs CHIL				*** 4.72	
	DES vs TRANS				** 3.12	
	CHIL vs TRANS				NS 1.73	

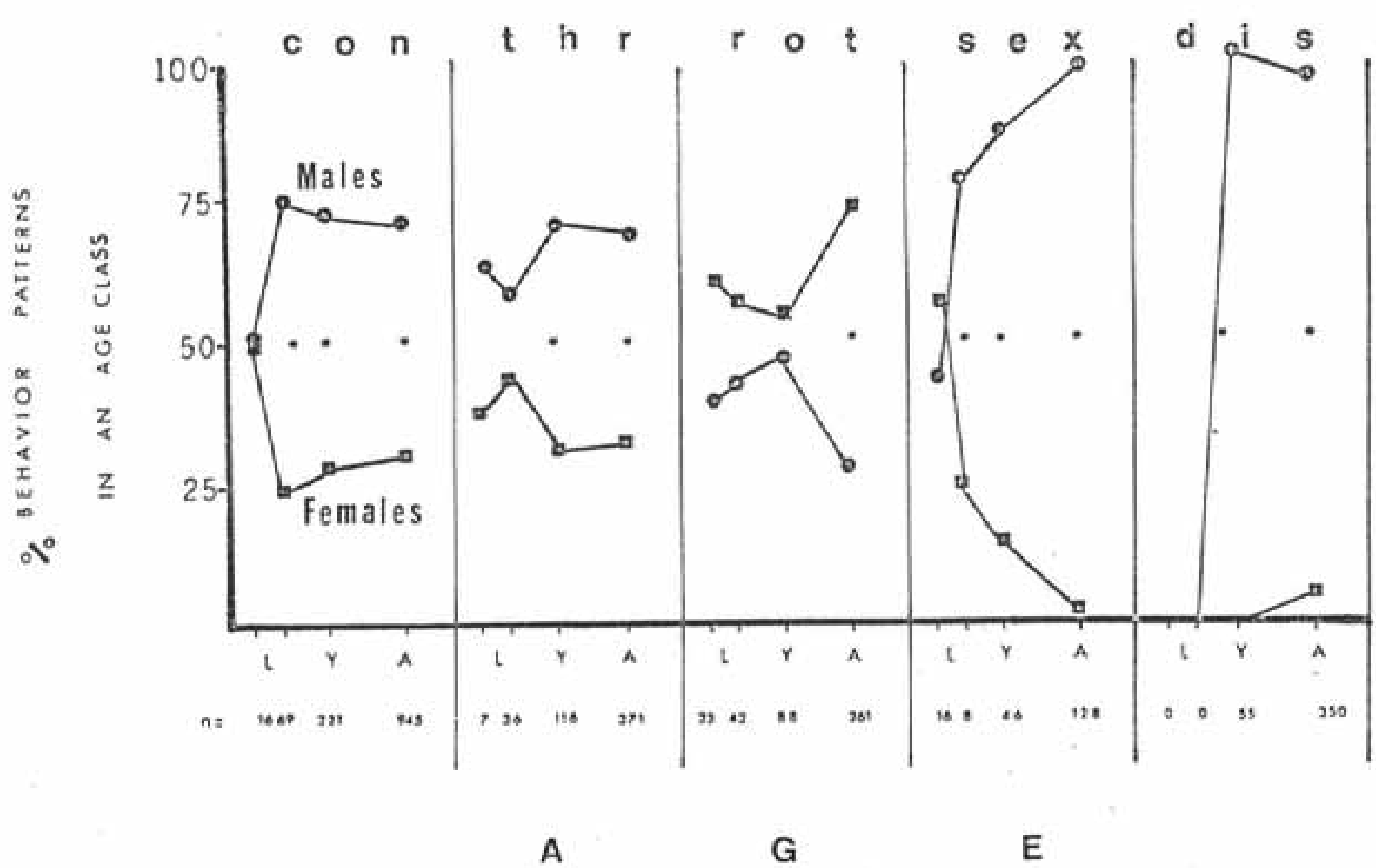


FIGURE 1. Sex and age differences in the development of behavior patterns in bighorn sheep. CON = contact patterns; THR = threat; ROT = rotational; SEX = sexual; DIS = display. L = lambs (two data points are shown for lambs; those occuring before two months of age and those after this age). Y = yearlings; A = adults (ewes and Class 1 rams). Asterisks indicate stratified significance at the p 0.05 level (arcsin transformation - see statistical analyses).

analyses for Figures 2 and 3). Conversely, lambs from the Chilcotin utilized significantly more rotational and threat patterns.

Generally, threat, contact, and sexual patterns occurred more frequently in desert yearlings, ewes, and Class I rams than they did in Chilcotin Sheep. More specifically, the major significant ($p<0.05$) differences for male sheep may be summarized as follows:

(1) desert males (=yearlings + Class I rams) mounted more often than Chilcotin equivalents.

(2) desert males (as above) engaged in more threat and contact patterns than did Chilcotin equivalents:

(3) Chilcotin males (as above) used more display patterns than did their desert equivalents.

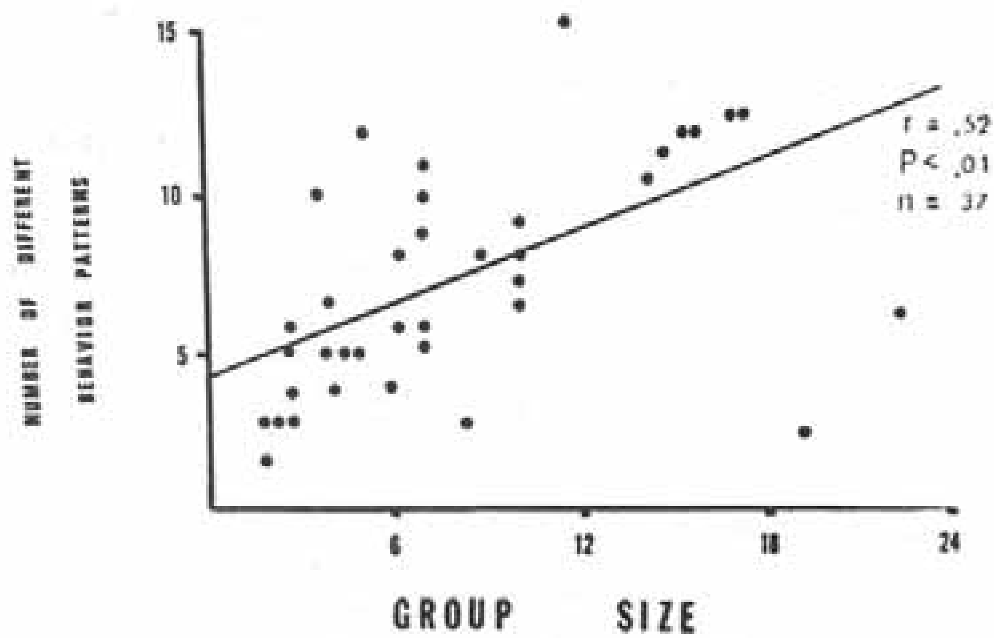
For females, the major significant differences ($p<0.05$) may be summarized as follows:

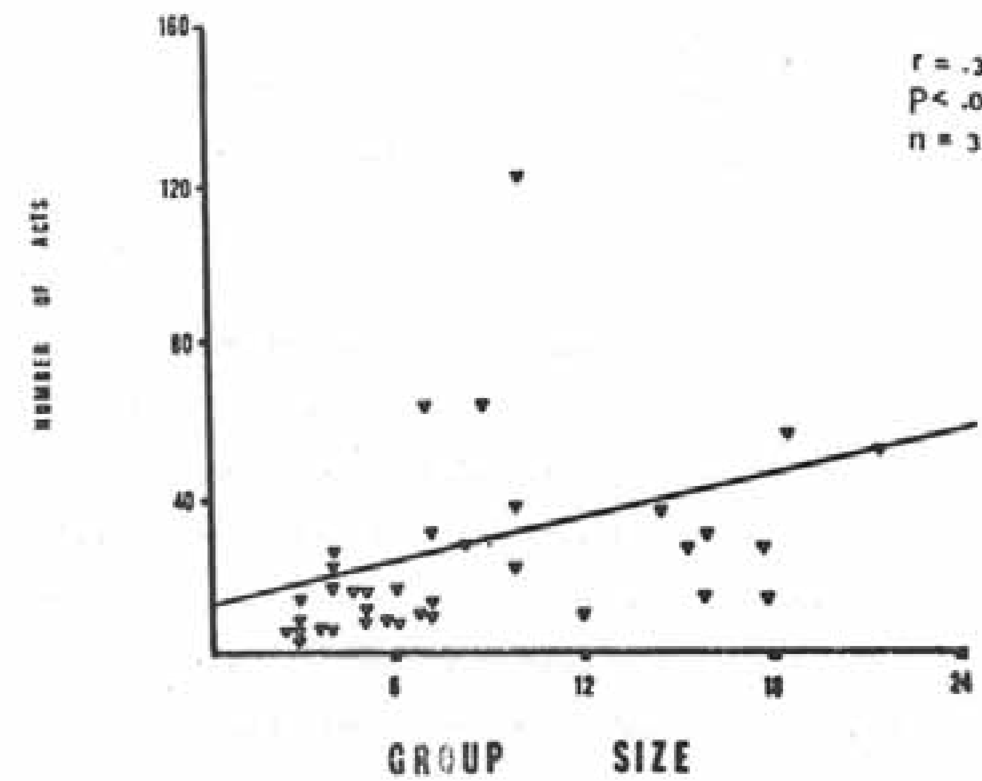
(1) Chilcotin females (=yearlings + ewes) used more rotational patterns than did desert females;

(2) desert females (as above) utilized more threat and contact patterns than did Chilcotin females. Also, in all populations, females utilized more rotational and less sexual and display patterns than males (Figures 1, 2, and 3).

Behavioral Diversity. Various sized groups engaged in play (see Berger, 1978 for a categorization of play). This activity was characterized by the utilization of motor patterns from different contexts (e.g., headbutting, mounting, chasing, jumping, etc.). In addition to those patterns listed in the ethogram, rubbing and nuzzling (see Geist, 1971) occurred during play. Sequences of play began when three or more individuals engaged in some form of exaggerated locomotor-rotational or contact activity, and it

FIGURE 2. Historgram illustrating the per cent relative frequency of behavior patterns used by three populations of bighorn lambs. For any given population, per cent relative frequency equals the total number of motor acts per behavioral pattern divided by the total number of motor acts for all behavioral patterns. D = desert population (n=572); T = transplant population (n=579); C = Chilcotin population (n=1,144).





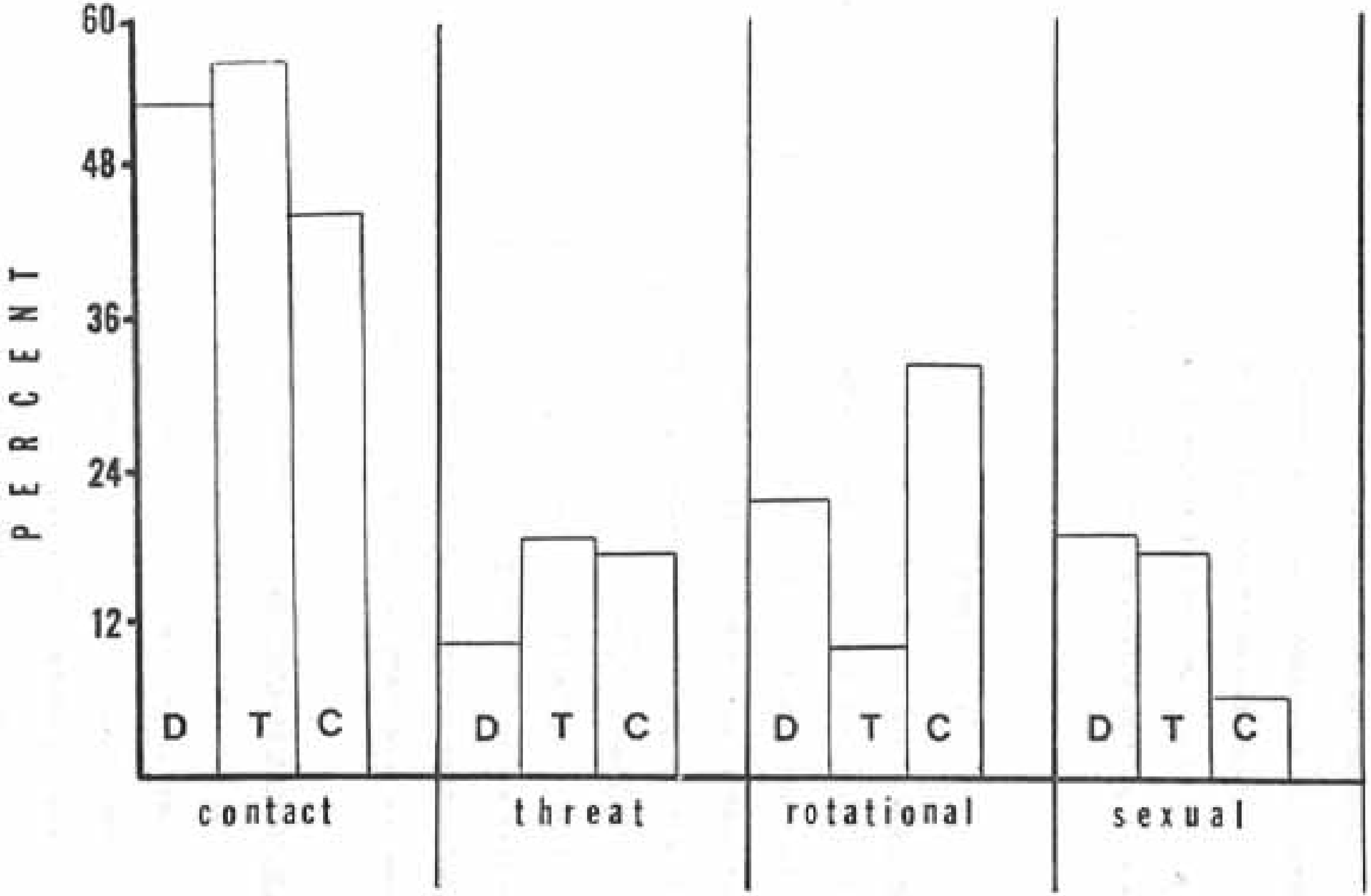


FIGURE 3. Histogram illustrating the per cent relative frequency of behavior patterns used by various sex and age classes of three populations of bighorn sheep. Within any given population, the per cent relative frequency of occurrence of a behavior and for a particular sex or age class is calculated in the same manner as it is in Figure 2. Rams equal Class 1 rams only. D = desert (n=1,120); T = transplant (n=465); C = Chilcotin (n=1,026).

terminated when less than three individuals persisted in these actions. During play, a direct relationship was found ($r=0.52$; $p<0.01$; $n=37$) between group size and the number of different behavior patterns that occurred in lambs (Figure 4). Also, a significant correlation ($r=0.33$; $p<0.05$; $n=37$) existed between the number of players and the number of acts within a sequence. That is, the more players within a group, the greater the number of acts that occurred.

DISCUSSION

Development of Motor Acts. Male and female lambs showed no significant differences in the frequency of motor pattern development probably as a result of small sample sizes (due to the difficulty in correctly identifying lamb sexes). Males tended to use more contact, threat, and sexual patterns than did females. Studies of primates (Baldwin and Baldwin, 1971; Kummer, 1971; LeResche, 1976), ungulates (Sachs, 1976; Byers, 1977), and rodents (Poole and Fish, 1976) also indicated that sexual dimorphism exists at early ages. In American sheep, Blood et al., (1970) and Bunnell and Olsen (1976) showed that males gain weight more rapidly than females. My data illustrate that behavioral dimorphism coincides with differences in growth rates.

Social Ontogeny in Different Environments. Geist (1971) stated that bighorn lambs are capable of butting, clashing, threat jumping, and mounting soon after birth. In each of my three study populations, one-week old lambs displayed these patterns. Population differences did, however, exist in the development of display patterns by males. Desert male lambs used the low stretch and front leg kick at a younger age (about 3 months) than

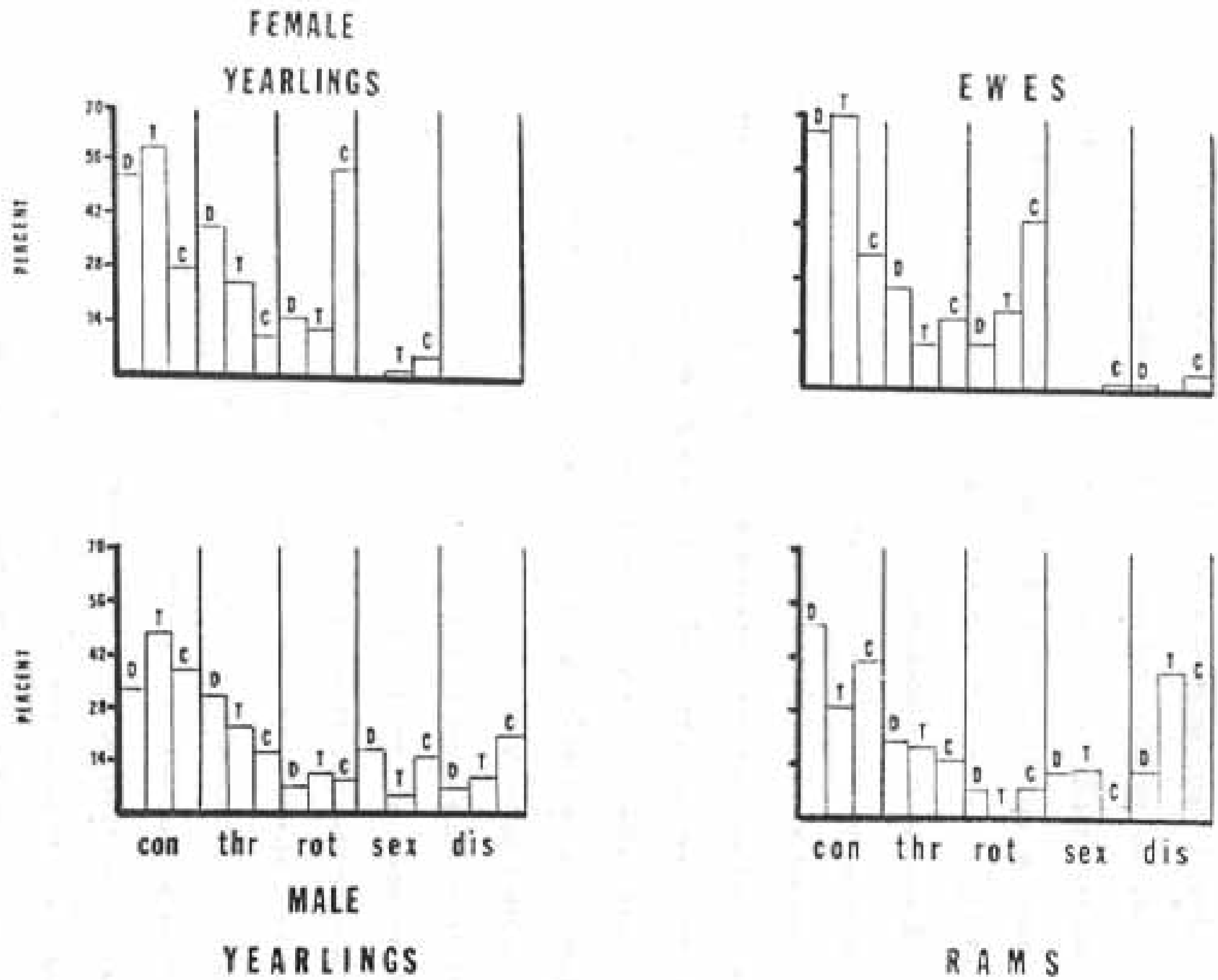


FIGURE 4. The relationship between group size and the number of different behavior patterns that occurred during lamb play sequences; and the same relationships but for motor acts within a sequence.

did Chilcotin male lambs. Other than display patterns, behavioral ontogenies followed a similar time course for populations in all environments. However, the frequency of utilization of behavior patterns was very different between environments (Figures 2 and 3). Desert lambs and desert males (= male yearlings + Class I rams) mounted more often than did their peers in the Chilcotin. Also, desert lambs and older sheep (yearlings, ewes, and Class I rams) used less rotational movements than Chilcotin sheep. Since desert sheep engaged in less social and locomotor play than did Chilcotin sheep (Berger, 1978), it is not surprising that these movements occurred less frequently in the desert population.

Two more important population differences existed. First, desert lambs used more contact patterns than Chilcotin lambs, yet the former threatened less often. Contact patterns represented more than 50% of the patterns used by desert lambs. Apparently desert lambs were behaviorally less diverse than Chilcotin lambs. In other words, desert lambs had the same behavioral repertoires as Chilcotin lambs, but individuals in the desert were less likely to perform as many different patterns. Second, desert yearlings (of both sexes), ewes, and Class I rams used more contact patterns than Chilcotin sheep of equal sex and age classes. (In contrast, Chilcotin lambs threatened more than desert lambs.) Also, desert sheep larger than lambs displayed less often than their Chilcotin equivalents.

In sum, then, lambs as well as older sheep from all three environments were characterized by the same behavioral repertoires, but desert sheep were behaviorally less diverse. They used fewer different patterns but in greater frequencies than Chilcotin sheep which used all their patterns but not as frequently. For instance, desert males used threat and contact patterns whereas Chilcotin males utilized threat and contact patterns less often but displayed more frequently (Figures 2 and 3). Hence, between environments, there was an inverse relationship between the frequency of occurrence of threats and displays.

Behavioral Development and Diversity. Several questions may now be asked regarding these population differences in social development: (1) Why was sexual behavior more prominent in desert lambs and older males? (2) What factors caused behavioral diversity to be greater in the Chilcotin? (3) Why did desert sheep play less? (4) What benefits may be accrued by more behaviorally diverse individuals?

Desert sheep grow faster and mature sexually (at about 1½ years of age) approximately one year earlier than sheep from northern environments. These regional differences appear to be genetically mediated (Berger, 1978). Since natural selection has most likely favored early puberty in desert sheep, it is not surprising that more mounting occurs at earlier ages in desert sheep than it does in northern or mountain populations. Data are not yet available on hormone levels of different aged desert sheep, but it may be possible that desert males possess higher androgen levels which may, in turn, lead to more mounting. Turner (in prep) found that desert males are born more precocial than mountain lambs and, in the former, teste descension occurs at about 2-3 weeks of age. In mountain lambs, testes descend at about 3 months.

Although Chilcotin sheep matured sexually at a later age than sheep in the Santa Rosa Mountains, they played more. Geist (1971), Shackleton(1973), and Horejsi (1976) found that more playful lambs occurred in high-quality sheep populations which were characterized by well fed, fast growing, and early maturing (defined by these authors as independence) individuals as opposed to the opposite characteristics in low-quality populations. Berger (1978) provided data that suggested sheep from the Santa Rosa Mountains were better nourished than those from the Chilcotin. Why, then, did desert sheep play less than Chilcotin sheep, thus contradicting Geist's predictions of population quality?

Berger (1978) suggested that play occurred less often in the Santa Rosa study population due to lack of suitable "playgrounds," hazards of the physical environment, and a less complex social environment (e.g., group size). Furthermore, it was suggested that greater food dispersion in the desert resulted in smaller and more widely dispersed foraging bands. Consequently, lambs spent more time alone (time not with peers or adults) and were independent at an earlier age than were transplant or Chilcotin lambs.

The social environment (group size), not surprisingly, may indeed be an important variable in the development of social patterns of behavior. Figure 4 showed that, when lambs played in larger groups, more different behavior patterns occurred than when play resulted from interactions in smaller groups. Even if the number of distinctly different behavior patterns observed was a function of more individuals available for observation, the fact remains that yearlings, ewes, and Class I rams from the Chilcotin still utilized greater behavioral repertoires than did their conspecifics from environments with smaller average group sizes (Berger, 1978). Also, more acts per sequence were incorporated into play when groups were large (Figure 4).

Since group sizes in the desert are small (Berger, 1978; Simmons, 1969) and lambs may be born at any time of the year (Hansen, 1965), those individuals born in a desert environment may not be exposed to nearly as complex a social environment as those born in mountain or northern habitats (where group sizes are larger and parturition is more synchronized). Baldwin and Baldwin (1971, 1977) found that squirrel monkeys (saimiri) in large groups played more extensively than those in small groups. A similar situation has been observed in gibbons (hylobates); little play occurred in infants presumably due to small group sizes and individual differences in body size and strength (Ellefson, 1967). Other field and laboratory studies of primates have confirmed the idea that individuals raised in enriched social environments tend to be behaviorally less retarded than those reared in socially impoverished environments (see Hinde and Spencer-Booth, 1967; Hinde, 1974; Mason, 1961a, b; 1962). The social environment, as has been amply demonstrated, plays a large role in infant behavioral development.

In desert environments, bighorn sheep lambs are not only faced with few peers but also those of differing sizes and ages. Contact play occurred infrequently between lambs of different ages and body sizes (Berger, 1978). In Death Valley, California, probably the most arid environment inhabited by sheep in North America, Welles and Welles (1961) reported small group sizes and no nursery bands. Social play may be very infrequent in such an extreme environment.

Interpretations of Demic Differences in Behavioral Ontogenies. I interpret demic differences in behavioral ontogenies in terms of ecological factors rather than genetic differences. It appears that desert sheep were behaviorally less diverse than other sheep populations due to a number of factors that included small group size, less social facilitation, and less play. These last factors most likely were a result of a precarious physical environment, while the first factor was due to the distribution of food resources. The difference in sexual behavior between my northern and southern study populations is probably a result of selection pressures for early sexual maturation in the desert environment.

In contrast to desert sheep, those in the Chilcotin used the full range of their behavioral repertoires. There are several factors that may be responsible for the increased behavioral diversity in these sheep. First, they matured sexually about a year later than those from the Santa Rosa Mountains (Berger, 1978). In many mammals, prolonged sexual maturity allows for greater learning and social experience(s) (Hinde, 1974; Wilson, 1975). Second, large groups (above a minimum size) provide more complex social environments (Anderson and Mason, 1974; Goy and Goldfoot, 1973). Third, Chilcotin sheep inhabited physical and social environments that were more conducive for play. Although, to my knowledge, it has never been demonstrated experimentally that additional play leads to the increased utilization of different motor actions, play nevertheless most probably allows individuals to refine motor skills (Rasa, 1973; Eisenberg and Lehausen, 1972; see also Bekoff, 1976; Fagen, 1976).

One might expect natural selection to favor those individuals inhabiting complex social environments (e.g., larger groups) to develop more sophisticated communication systems (i.e., visual, vocal, etc.) in order to signal more efficiently. Marler (1975, 1976) found that primates inhabiting larger and more constant groups possessed more graded signals. For Chilcotin sheep, too, it would also appear to be adaptive for individuals to communicate by utilizing as many behaviors as possible. The four display patterns, for which I provided data, are distinctly different from one another, and, although gradations do occur for each pattern, the patterns do not grade into one another (except for the low approach and twist; see Geist, 1971). Certainly, selection will favor those individuals that are more adept at communicating regardless of group size. But, in large groups, individuals who can communicate an intended message with the most precision will experience less ambiguity in reception.

In summary, the differences in behavioral ontogenies in different environments are illustrative of "open behavioral programs" (see Mayr, 1974). Adaptation and function must be scrutinized most carefully before being attributed to biological phenomena (Hinde, 1975; Tinbergen, 1965; Williams, 1966). It thus appears that, although bighorn sheep subspecies possess a species typical behavioral repertoire (Geist, 1974), environmental conditions influence greatly and modify the time course(s) that social development follows. Furthermore, this study illustrates (as has been pointed out clearly by Wilson, 1975) that behavior is indeed labile and varies in different ecological settings. Before generalizations about the nature of species specific social development are valid, different populations under contrasting ecological conditions must be studied.

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PARASITES, DISEASE, AND BEHAVIOUR - Chairman: Dr. D. Shackleton

Elizabeth S. Williams, G.G. Schoonveld, T.R. Spraker and C.P. Hibler - Paratuberculosis (Johne's disease) in bighorn sheep (Ovis canadensis) and rocky mountain goats (Oreamnos americanus) in Colorado.

Bruce Johnson: Did you say that pigs, horses, and mules could also carry the disease?

Beth Williams: At slaughter, someone surveyed pigs and horses and found, from cultures of the mesenteric lymph nodes, that Johne's or Paratuberculosis organisms were present in these animals. In most cases they will not go on to develop into a clinical case.

Jim Bailey: Do you plan any studies in other goat herds?

Beth Williams: As soon as we get a reliable test to be sure we are diagnosing Paratuberculosis we are going to do some survey work in other goat and bighorn sheep herds in the state.

T.D. Bunch, S.R. Paul and H. McCutchen - Chronic sinusitis and osteomyelitis in desert bighorn sheep

Nike Goodson: Have any tests been conducted to see if the same bacterial agent isolated in infected desert sheep is present in healthy individuals?

Stephen Paul: The sinus is not a sterile area. These are probably normal inhabitants of the sinus of any sheep.

Nike Goodson: Is the botfly a native animal in this area?

Tom Bunch: It exists all through Mexico, the U.S. and Canada. The work done in the 1940's determined that the incidence of botfly parasitism in domestic sheep was above 90%. Some work found that the incidence in lambs was over 90%.

Jim Bailey: Is this botfly problem in the studies on domestic sheep more of a problem in the south than in the north?

Tom Bunch: It is related to the drier, arid areas. It is a common agent in the desert bighorn sheep habitat. At least, there it appears to be more of a problem.

Joel Berger: It has been suggested that Desert sheep are a low quality population. Do you think the incidence of osteo-necrosis is more prevalent in desert populations than in northern populations? If so, why?

Tom Bunch: I do now know for sure. I do not think it makes any difference what condition the sheep are in; the botfly also takes healthy stock. It also seems to be higher in the females.

T.R. Eccles - Activity patterns of captive California bighorn sheep (Ovis canadensis californiana) at Penticton, B.C.

Bill Wishart: Of the animals that were standing and lying down, did you notice different age groups? Is there anything in your observations to suggest that the young animals stay out in the sun and the older, larger ones stay in the shade?

Ross Eccles: Not so much from the shade/sun point of view, but the animals that I did see standing a lot were certainly the older animals, particularly in the winter.

Anonymous: Ross, does standing minimize conductive heat loss to the ground?

Ross Eccles: I do not think so. They seem to prefer underneath Ponderosa Pines where there is tremendous litterfall for proper insulation. Perhaps moving to, and bedding down in a proper site was more stressful than standing and ruminating where they were.

Daryll Hebert: What are the convective heat losses on those particular days?

Ross Eccles: Primarily wind.

Malcolm Ramsay: Did you notice if the dominant animals initiated movement to, or away from, bedding sites more than subordinates?

Ross Eccles: It seemed to be a mixture. At first I was interpreting leading a group movement as being a dominant display, but after I saw enough interactions to rank the animals I found that almost any animal could lead a group movement.

Dave Shackleton: Do you think that associating status with various activities is, in fact, a very poor measure of dominance?

Ross Eccles: Yes. Perhaps also the terrain does not lend itself to dominance, or even necessitate a dominance hierarchy. Interactions seem to increase somewhat when the animals are forced to a point resource like the hay pile.

J. Berger - Behavioural development of bighorn sheep: a comparison of populations inhabiting desert and northern environments.

Jim Bailey: Do you know why the desert bighorn is so non-synchronous in its breeding? Second, did you observe this rather continuous breeding activity to interfere with maternal behaviour?

Joel Berger: No, I don't really know why they are non-synchronous. I think the lamb itself has no effect on ram behaviour. Rams will inspect just as frequently, ewes that have lambs as those without.

Bill Wishart: Did the transplant animals appear to be intermediate in their group size or length of time spent suckling?

Joel Berger: The group sizes and relationships of lambs to ewes were intermediate in the transplant animals, however their behaviour patterns occasionally were not intermediate. Lambs were intermediate in suckling.

WINTER HABITAT PREFERENCES OF BIGHORN SHEEP IN THE MUMMY RANGE, COLORADO[1]

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ABSTRACT

Winter distribution and habitat preferences of bighorn sheep (Ovis canadensis canadensis) were studied in the Mummy Range, Rocky Mountain National Park, Colorado by ground and aerial observations of 257 bighorn bands during 1968-1976. Intensive field study conducted during 1974-1976 indicated that mature rams remain spatially segregated from ewes and subadults during January through May. Ewe-subadult bands drifted among tundra winter ranges and low elevation ranges in the upper montane forest during winter. Bands of mature rams remained on discrete tundra ram winter ranges throughout winter. Both ram and ewe-subadult bands exhibited a preference for southfacing regions of tundra where topographic and vegetational diversity are maximum. Regional topography and weather minimize snowfall and snow accumulation in the Mummy Range making a variety of vegetational types accessable to bighorn sheep during winters of normal precipitation.

INTRODUCTION

The objective of this paper is to describe winter habitat preferences, group composition and range use patterns exhibited by a remnant herd of

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[1]The United States National Park Service financed field research conducted during this study. Data gathered during the 1974-1976 period are the subject of the Senior author's Master of Science thesis.

Rocky Mountain bighorn sheep in the Mummy Range of north central Colorado. The size of range of this herd have been greatly reduced since 1900 when the resort community of Estes Park was settled. Early sightings recorded by National Park Service personnel indicate that ewe-subadult bands occupied low elevation winter ranges which are characterized by bunch grass meadows and granitic cliffs. Loss of low elevation ranges near what is now Estes Park resulted in lungworm-induced die offs and precipitated the decline of this herd. Recent aerial surveys have indicated that a remnant herd has occupied the southern Mummy Range since the late 1960's.

STUDY AREA

The Mummy Range study area is located within the north-east quadrant of Rocky Mountain National Park roughly 72 km south of the Colorado-Wyoming border. The area lies immediately east of the Continental Divide near the northern terminus of Front Range. Average total monthly precipitation recorded at Estes Park is about 1.8 cm per month for January and February and 3.5 cm per month during March and April. Mountains in the vicinity are composed of Precambrian schist, gneiss and granite. Topographic features characteristic of valley glaciation are prominent throughout the study area. Elevations range from 2400 m at valley floors to 4100 m near mountain summits. Treeline occurs near 3400 m; roughly one-half of the study area lies above this elevation and is covered by rock outcrops, talus and tundra vegetation. Dense stands of subalpine spruce-fir forest cover approximately three-eights of the area. Stands of ponderosa pine (Pinus ponderosa), Douglas fir (Pseudotsuga menziesii), and aspen (Populus tremuloides) are interspersed with xeric bunch grass stands and mesic-hydric meadowlands in the upper montane zone below 2800 m. Vegetational associations characteristic of the area have been described by Marr (1961), Willard (1963), and Stevens (1970).

Neighboring bighorn herds occur to the north, west, and south, of the Mummy Range. These herds are separated by straight line distances of 5-25 km. Movement data necessary to evaluate the genetic status of these herds and the potential for gene flow among them is essentially non-existent at present.

METHODS

Winter distribution patterns of bighorn sheep were determined by ground and aerial observations of 257 bands recorded beween 1968 and 1976. Date, time, location, aspect, slope, vegetational cover and age-sex composition were recorded for each band observed. Bighorn sheep were classified according to Geist (1971).

Winter observations of sheep were recorded during yearly helicopter surveys conducted between 1968-1974. Intensive ground surveys were carried out during the November to May periods of 1974-1975 and 1975-1976. Supplementary observations were obtained during helicopter surveys conducted during the winters of 1975 and 1976. Population size and composition estimates were constructed on the basis of maximum non-duplicate class counts recorded during 1974-1976.

Climatological data were recorded at the Estes Park U.S. Weather Bureau station (2300 m) which is located on the south-eastern edge of the Mummy Range. Snow depth data were recorded at monthly intervals by U.S. National Park Service personnel along three U.S. Soil Conservation Service snow courses adjacent to the study area.

RESULTS AND DISCUSSION

Herd Size and Composition

A herd of 50-60 bighorn sheep occupied approximately 80 km^2 (32 square miles) of the southern Mummy Range during this study. Ram to ewe ratios were estimated at 185/100 during 1975 and 167/100 during 1976. Yearling and class I rams formed 58 percent of the ram segment of the herd during 1975 and 48 percent during 1976. Class II, III, and IV rams, in aggregate, accounted for less than 50 percent of rams wintering in the Mummy Range during 1974-1976. Estimates of lamb to ewe ratios (including yearling and adult females in the ewe class) were 54/100 during 1975 and 67/100 during 1976.

Group Composition and Range Use Patterns

Limited observations recorded during 1974 and 1975 rutting seasons indicated that mixed sex groups were widely distributed on south-facing slopes of the upper montane forest and alpine tundra between 2550 and 3950 m. Average band size was 7 sheep during the rut.

Mature rams disassociated from ewe-subadult bands during January and remained on discrete alpine tundra ram ranges during winter and spring. These ram winter ranges are located on the periphery of ewe-subadult winter ranges, in the most remote regions of the study area, and observations of ram bands have been limited. Average band size for 14 ram bands observed during 1968-1976 was 5 rams. Class I and II rams were commonly associated with class III and IV rams and accounted for 61 percent of all rams observed in such bands during 1974-1976.

Average ewe-subadult band size was 6 sheep during winter. Composition of 111 ewe-subadult bands observed during winter was 46 percent ewes and yearling females, 29 percent yearlings, class I and class II rams, and 26 percent lambs. Successive relocations of ewes identified by broken horns indicated that ewe-subadult bands drifted among tundra and upper montane forest winter ranges by traveling along ridgetops and through open stands of subalpine conifers, where snow accumulation was limited by wind.

Habitat Preferences

Both ram and ewe-subadult bands exhibited a preference for south-facing regions of tundra during winter. Ninety-seven percent of all bands located on alpine tundra were sighted on south aspects (Fig. 1). Tundra winter ranges inhabited by rams and those used by ewe-subadult bands are characterized by similar topography. Unglaciated 30-45° slopes are juxtaposed to 50-60° cliffs which have been formed by valley glaciation and subsequent weathering. *Kobresia*-dominated sedge-grass turf stands are interspersed among rock and forbs on open unglaciated slopes. *Kobresia* stands are wind-swept and remain snow-free throughout winter. Vegetation is patchy and sparsely distributed among rock outcrops on cliff sites which extend down to treeline near 3400 m. Hairgrass (*Deschampsia*) is associated with sedges, rushes, clover (*Trifolium*) and *Potentilla* in drainage depressions on cliff faces. Cushion plant associations occur on relatively steep, coarse and unstable soil sites interpersed among rock outcrops. Small stands of *Kobresia*-dominated turf occur on stable, well-developed soil sites among the cliffs.

Fifty-one percent of all bands observed on tundra winter ranges during 1974-1976 were located on 40-45° slopes and 37 percent were seen in 50-60° cliff terain (Fig. 2). Winter activity of bighorn sheep was centered about

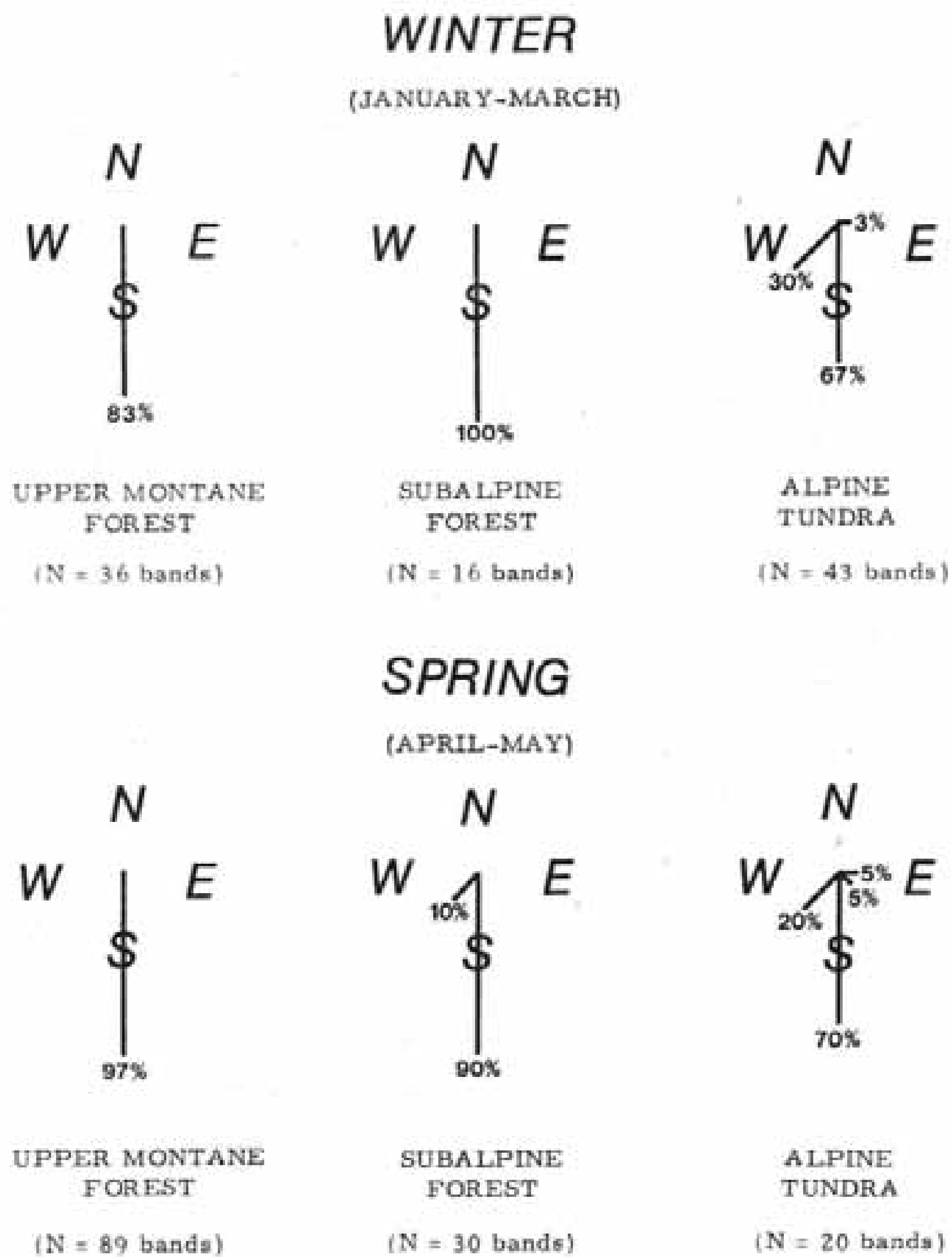

Fig. 1. Seasonal distribution of bighorn sheep observed in the Mummy Range, Colorado, 1975-1976, by aspect and vegetational regions. Percentage totals less than 100 indicate that remainder of observations occurred on level ground.

the rimrocks which separate 40-45° slopes from 50-60° cliff terrain. Sheep utilized a variety of vegetational associations on these two topographic types (Fig. 3). Preferences in cover type use related to seasonal veriations in snow depth and quality can not be demonstrated by data collected during this study. Thermal eddies and strong northwesterly winds rapidly removed light accumulations of dry powder snow from cliff sites following winter storms during December-February.

Deeper accumulations (0.3-1 m) of wet snowfall were generated by up-slope storms during the transition from winter to spring. Snowfall during March and April was generally not accompanied by the strong persistent winds of early winter. In the absence of wind, avalanche and melt removed accumulations of wet snow from tundra winter ranges at a slower rate.

Intermittent use of upper montane winter ranges by ewe-subadult bands was restricted to a 45° south-facing slope between 2550 and 2750 m; located above a mineral lick. This one remaining low elevation range represents approximately one-fifth of the total area of low elevation ranges used by this herd during the early 1900's. Open stands of aspen and ponderosa pine are interspersed with shrubs, bunch grasses, and granitic benches and boulders on this south slope. Common shrubs include choke cherry (*Prunus virginiana*), juniper (*Juniperus communis*), bitterbrush (*Purshia tridentata*), hollygrape (*Mohonia repens*), squaw current (*Ribes cereum*), and wild rose (*Rosa* sp.). Grasses of common occurrence include wheatgrasses (*Agropyron* spp.), bluegrasses (*Poa* spp.), bromes (*Bromus* spp.), and mountain muhly (*Muhlenbergia montana*).

Early winter snow accumulations on this low elevation range rarely exceeded 20 cm during the January-February periods of 1975 and 1976.

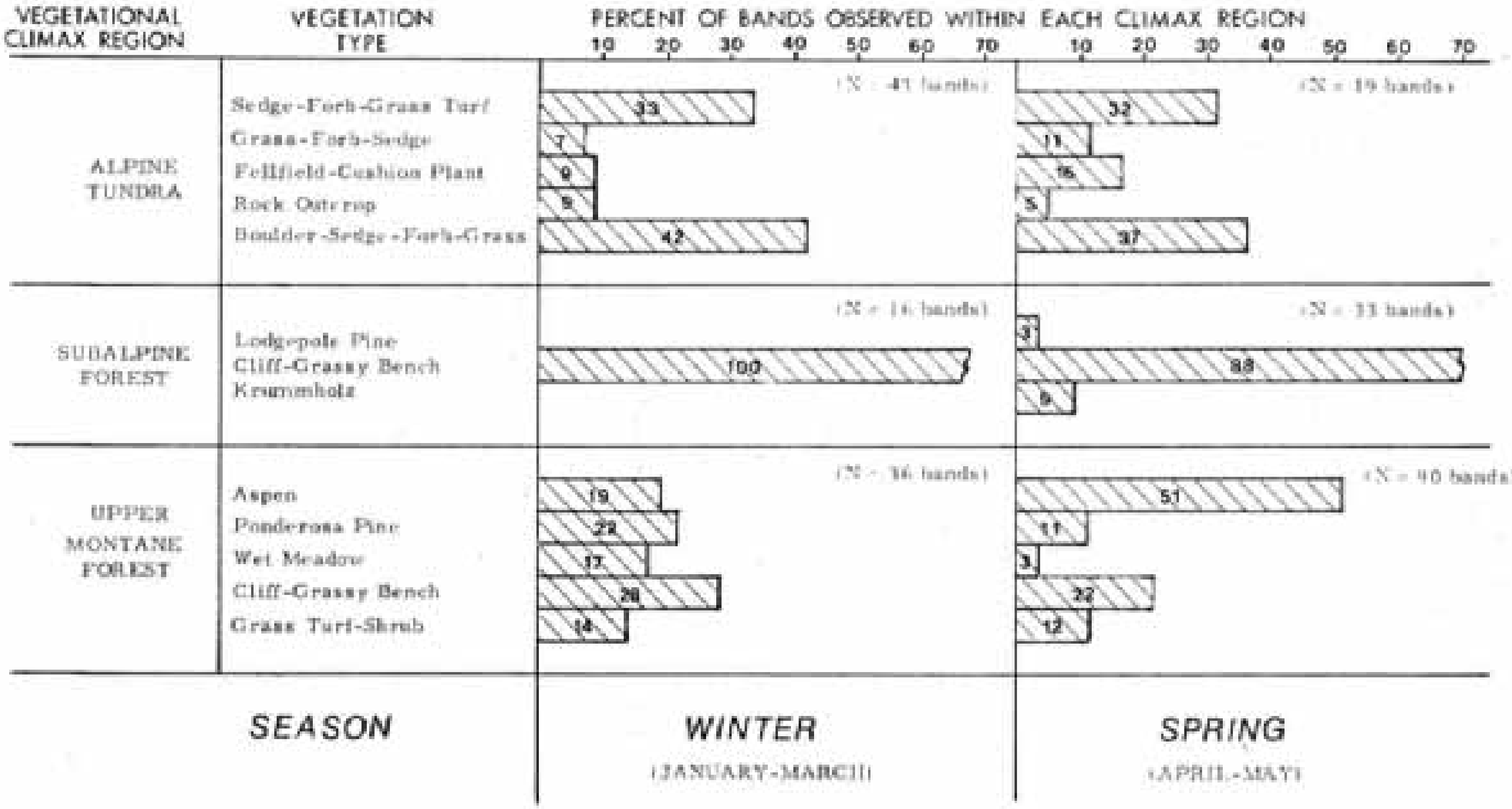

Fig. 3. Seasonal distribution of bighorn sheep observations recorded in the Mummy Range, Colorado, 1975-1976, by vegetational types.

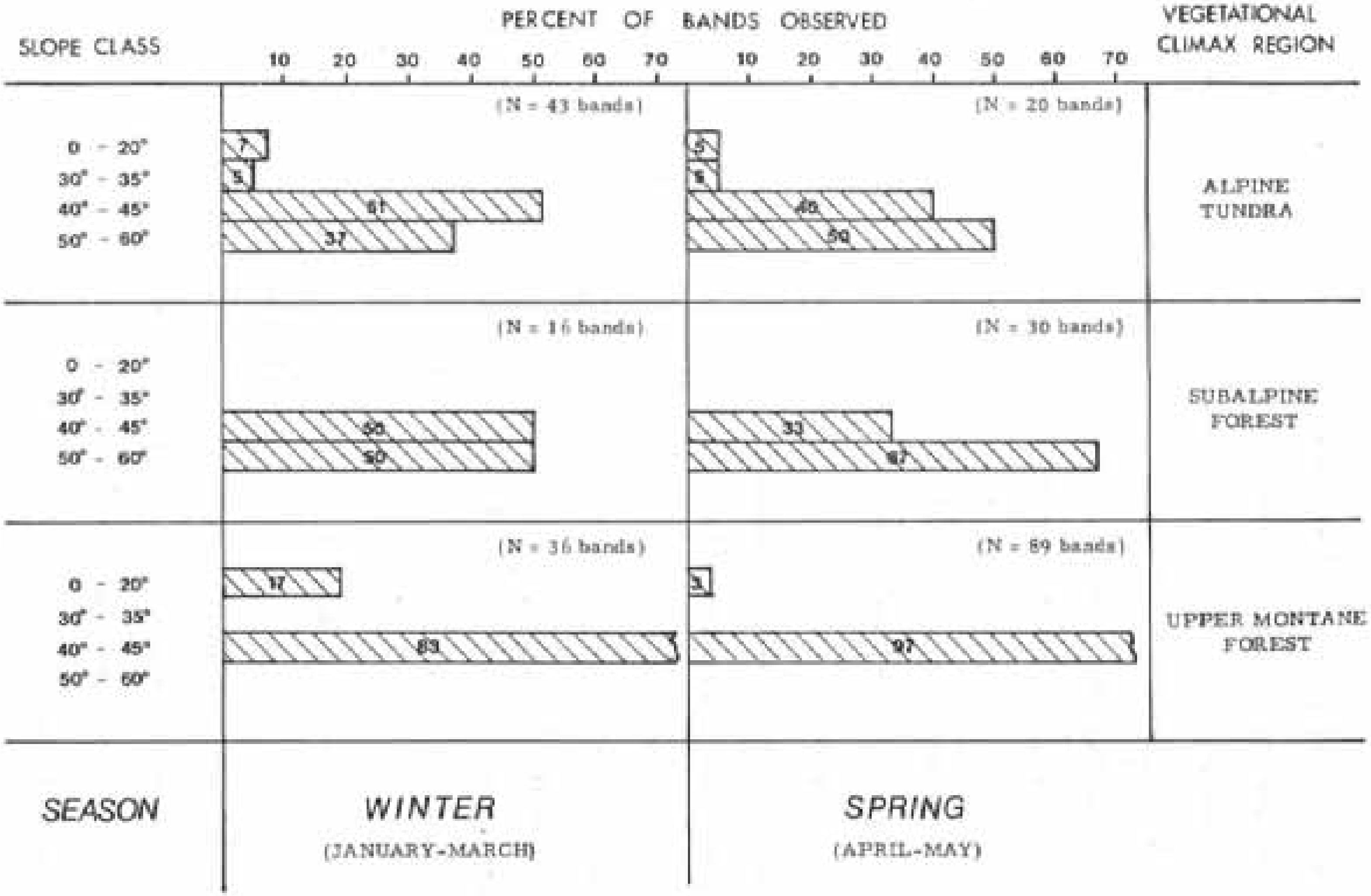

Fig. 2 . Seasonal distribution of bighorn sheep observations recorded in the Mummy Range, Colorado, 1975-1976, on four discrete classes of slope.

Wind swept snow out of bunch grass stands and into the trees, rapidly opening up the areas preferred by sheep. Late winter storms produces 30-50 cm snow accumulations which gradually melted on south-facing sheep range. Crusted and persistent snow cover was not observed on low elevation range during the 1974-1976 study period.

Total monthly precipitation recorded at Estes Park was 50 percent of normal between January and February and 74 percent of normal between March and April during winters of 1975 and 1976. Monthly snow depths for corresponding time periods along three snow courses in thw subalpine forest (between 2800-3100 m) adjacent to the study area, were 95-102 percent of normal. These data illustrate the effect of wind on snow accumulation in the subalpine forest where snowfall is supplemented by wind-deposited snow. Similarly, they emphasize the effect of wind on bighorn sheep winter ranges in this region. Clearly, winter wind is a significant "welfare factor" for these sheep and the severity of winter is dependent upon its intensity.

Recent studies of winter habitat ecology of Rocky Mountain bighorn sheep by Petocz (1973), and Geist and Petocz (1977) indicate that winter snowfall and deep frozen snow accumulations influence bighorn behavior and habitat selection in the Canadian Rockies. While similar reations to occasional heavy snowfall may occur in the Mummy Range, it appears that local interactions of regional weather with topography limit snowfall and accumulation below levels common on sheep range in the northern Rocky Mountains. Winter habitat preferences exhibited by bighorn sheep in the Mummy Range indicate that this remnant herd is able to utilize a variety of vegetational communities by concentrating on tundra winter ranges where topographic diversity is maximum that is, where open slopes are juxtaposed to cliffs.

Game managers frequently allude to cliff terain as an element of bighorn habitat necessary for escape cover; perhaps we should begin to investigate the importance of cliffs as an essential source of winter food for bighorn sheep as well.

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DIET PREFERENCE OF CALIFORNIA BIGHORN SHEEP ON NATIVE RANGELAND IN SOUTH-CENTRAL BRITISH COLUMBIA

M. D. Pitt and B. M. Wikeem

INTRODUCTION

In 1954, the total population of California bighorn sheep (*Ovis canadensis californiana*) in North America numbered only slightly more than 1,600 animals (Spalding *et al*., 1970). Three of the largest herds, containing approximately 400 animals each, occurred in British Columbia, while a similar-sized herd occurred in the southern Sierra Nevada Mountains of California.

The Junction herd, located between the confluence of the Fraser and Chilcotin Rivers in the central interior of British Columbia, has been a primary source for reintroductions of these animals into historical sheep ranges throughout western North America, particularly Washington, Oregon, North Dakota and Idaho (Spalding *et al*., 1970). In fact, approximately 42% of all California bighorn sheep in North America in 1970 originated genetically from this Chilcotin River stock.

In 1970, the total California bighorn population was estimated to be 3,200 animals (Spalding *et al*., 1970), an increase of 53% in British Columbia and 153% in the United States. Since 1970, no further data have been published, but we, in British Columbia, believe the herds have remained relatively stable. Reputed low herd productivity and competition with domestic livestock, plus alienation of winter ranges, have combined to prevent native and newly-established herds in British Columbia from increasing in size or extending their respective ranges. This situation emphasizes the need for knowledgeably-formulated management practices if bighorn sheep are to survive without the artificial aid of reintroduction.

Buechner (1960) stated that bighorn sheep are dependent more on vegetation than any other component of their environment. Many wildlife management programs have stressed, specifically, the importance of critical winter range, particularly in terms of limiting forage quality and quantity. Consequently, winter feeding of wildlife with alfalfa and grain is a technique commonly used to overcome presumed deficiencies on critical winter ranges. Winter feeding represents an artifical means for maintaining bighorn sheep population, however, and should not form the entire framework of long-term management practices.

Many researchers have investigated winter diet of California bighorn in B.C. (Sudgen, 1961; Blood, 1961; Blood, 1967; Demarchi, 1965; Morrison, 1972). However, few people have looked at diet throughout all seasons of the year, while even fewer studies have examined these diets in terms of forage preferences and selectivity. Specifically, animal diets must be carefully evaluated in terms of forage availability before conclusions about preferred or key plant species for management can be made. Furthermore, preferred plant species on the summer range can be just as important managerially as preferred plant species on the winter range; perhaps even more so since spring and summer grazing, during periods of active plant growth, may lead to long-term botanical changes. Additionally, quality of summer diet affects the ability of animals to survive winter stress, as unthrifty animals at the beginning of winter are less likely to survive until spring even if winter conditions are relatively mild.

Low herd productivity and the need for more information on California bighorn provided the impetus for a joint study among the B.C. Fish and Wildlife Branch, the University of British Columbia (Departments of Plant and Animal Science), and Simon Fraser University at the Okanagan Game Farm near Penticton in south central British Columbia. We, in the Department of Plant Science, U.B.C., have been studying the impact of grazing by bighorn on the plant community. More specifically, our overall objectives are to determine: (1) the trend in range condition produced by year-round foraging, and (2) sheep diet and forage selectivity as influenced by plant phenology throughout the grazing year. The data presented here resulted from our first summer of field work. These data, based upon diet selection of California bighorn sheep, provide a useful base for discussing the interpretation of forage preferences exhibited by any grazing or browsing animal.

STUDY AREA

During April, 1977, 20 California bighorn were released into a 42 hectare (104 acres) enclosure adjacent to the Okanagan Game Farm. The plant communities, typical of some bighorn habitat in the province, are characteristic of the lower grassland zones dominated by big sagebrush (Artemesia tridentata) and bluebunch wheatgrass (Agropyron spicatum), with browse species such as saskatoon (Amelanchier alnifolia) and snowberry (Symphoricarpus albus) in the draws at lower elevations. At higher elevations, Ponderosa pine (Pinus ponderosa) provides an overstory for rough fescue (Festuca scabrella), bluebunch wheatgrass, and mixed forbs. Aspect and drainage conditions profoundly influence vegetational patterns, with sagebrush occupying dry sites and bluebunch wheatgrass occurring primarily on more northerly aspects.

METHODS

Forage utilization and trends in range condition were assessed by sampling for herbage productivity and botanical composition both within and outside exclosures of 480 square meters (5,200 sq. feet). Bighorn sheep diet and selectivity were determined by comparing relative proportions of plant species available for use throughout the grazing year. Identification of botanical material in feces was determined with epidermal cell slides prepared for 65 of the 83 plant species found on the study site. Monthly botanical composition was determined from 40-30 meter (100 ft.) loop-transects located systematically throughout the study site.

RESULTS

Data in Table 1 indicate the importance to sheep diet of three forage classes in terms of animal preference and selectivity. Browse in the diet during the spring month of May equaled 18%, which is approximately proportional to the relative availability of these woody plant species. In contrast to browse, total forbs in spring were highly selected, contributing 40% to the diet even though only 17.7% of the botanical composition. Balsamroot (Balsamorhizza sagittata) was highly preferred, comprising 9% of the diet. This early-maturing perennial forb was actually selected at two different time periods, as sprouting plants were immediately eaten as they reappeared following initial grazing. Grasses in early spring, other than rough fescue, were typically selected against. The most abundant plant species on the study site was bluebunch wheatgrass (30.6%), which constitued only 9% of the diet. This relationship points out a pitfall of investigating only diet to determine animal forage preferences. Bluebunch wheatgrass was one of the most frequent plant species in the May diet, yet is obviously not nearly as preferred as rough fescue or balsamroot, which appeared approximately 86% more often in the diet as in the available forage, 9.0 compared to 5.2%.

Grasses as a forage group constituted the largest proportion of the animal's diet during all four months. In fact, the portion of the diet comprised of grasses increased from 42% in early spring to 77% during the summer month of August. However, in May, June, and July, grasses were apparently selected against as, in all three of these months, the relative proportion of total grasses available on the range was more than the relative proportion of grasses appearing in the diet. Only in August did these two proportions equalize, indicating that grasses, particularly bluebunch wheatgrass and cheatgrass (Bromus Tectorum), were less preferred as forage than either browse or forbs.

Rough fescue provides a major exception to this previous generalization, as in August this plant species composed 21.5% of the diet, even though occurring less than 1% of the botanical composition. However, data indicating high selectivity must be evaluated carefully. Even though a highly preferred forage species, rough fescue occurred on the study site exclusively as an understory of ponderosa pine. This pine overstory was intensively utilized by the sheep for shade during the hot August weather. Therefore, the high proportions of rough fescue in the diet may be partially attributable to its presence in shade areas as much as its apparent palatability.

Forbs displayed opposite trends to grasses, as they comprised successively smaller portions of the diet from May through August, declining from 40.0 to 14.5%. However, in all four months, forbs constituted a preferred category of forage,

TABLE 1:
BIGHORN DIET IN RELATION TO BOTANICAL COMPOSITION OF RANGE

Month	May			June			July			August		
Species	Diet	Bot Comp	RSI	Diet	Bot Comp	RSI	Diet	Bot Comp	RSI	Diet	Bot Comp	RSI
GRASS												
Agropyron spicatum	9.0	30.6	0.29	11.5	31.0	0.37	15.5	32.1	0.48	16.0	32.4	0.49
Bromus tectorum	1.0	13.7	0.07	1.0	21.2	0.05	1.0	23.1	0.04	0.0	20.7	0.0
Stipa comata	4.0	3.5	1.14	6.0	7.9	0.76	7.5	8.9	0.84	12.5	6.4	1.95
Koeleria cristata	5.0	5.9	0.85	7.5	5.9	1.27	10.0	6.6	1.52	14.0	7.1	1.97
Festuca scabrella	10.0	T		9.5	T		10.0	T		21.5	T	
Other grasses	13.0	11.5	1.13	11.5	10.6	1.08	14.5	7.1	2.04	13.0	9.0	1.44
Total Grasses	42.0	65.2	0.64	47.0	76.6	0.61	58.5	77.8	0.75	77.0	75.6	1.01
FORBS												
Balsamorhiza sagittata	9.0	5.2	1.73	19.0	3.9	4.87	1.5	2.2	0.68	0.0	2.9	0.0
Achillea millefolium	1.5	3.0	0.5	1.0	1.3	0.77	1.0	T		0.0	T	
Lupinus sericeus	3.0	1.2	2.5	1.0	T		1.5	T		1.5	T	
Other forbs	26.5	8.3	3.19	20.5	4.0	5.13	25.0	1.8	13.89	13.0	4.5	2.89
Total Forbs	40.0	17.7	2.26	41.5	9.2	4.51	29.0	4.0	7.25	14.5	7.4	1.96
BROWSE												
Artemesia tridentata	1.5	11.4	0.13	1.4	9.7	0.14	0.0	13.3	0.0	0.0	12.3	0.0
Amelanchier alnifolia	2.5	T		4.0	T		2.5	T		1.5	T	
Prunus virginiana	2.0	T		1.0	T		2.0	T		1.0	T	
Eriogonum heracleoides	3.0	1.8	1.67	0.5	1.0	0.5	0.5	1.0	0.5	0.0	1.2	0.0
Eriogonum niveum	2.5	2.2	1.14	0.0	1.6	0.0	1.0	2.4	0.42	0.0	2.3	0.0
Other browse	6.5	1.4	4.64	6.0	1.1	5.5	6.5	0.8	8.13	6.0	1.2	5.0
Total Browse	18.0	16.8	1.07	11.5	13.4	0.86	12.5	17.5	0.71	8.5	17.0	0.5

RSI = Relative Selectivity Index = $\frac{\text{\% Diet}}{\text{\% Bot. Comp.}}$ T = Trace as per cent forbs in the diet always exceeded per cent forbs available on the study site. Balsamroot in June composed 19% of the diet, while all forbs together comprised 41.5%. Beginning in July, when balsamroot withered in response to depleted soil moisture reserves, indian paintbrush (Castilleja thompsonii) (4.5%) and lemonweed (Lithospermum ruderale) (3.5%) became the most highly selected forbs. A late blooming summer species, brown-eyed susan (Gaillardia aristata), made up 2% of the diet in August, which placed this plant as the most preferred forb in late summer.

Browse as a forage class declined in the diet throughout these four months from 18.0 to 8.5%, and as a forage class was selected in approximately the same proportions as in the available forage. However, big sagebrush is an unpalatable woody species, and should not be managerially lumped with other browse species which were generally selected for, even during the dry summer months of July and August. Saskatoon, chokecherry (Prunus virginiana) and snowberry all produced selectivity indexes (% diet/% botanical composition) greater than one, suggesting that these browse plants are preferred forage species.

Once again, however, these data must be evaluated carefully. Judging the importance of a plant species, based solely upon proportions in the diet, or even selectivity indexes, may represent a hasty conclusion. Saskatoon has a relatively small selectivity index, approximately 2/1. However, this plant species may be nutritionally important in the animal's diet.

Utilization of this browse species equaled 65% from May to August. Forbs were also intensively utilized (80%), while bluebunch wheatgrass, which composed 32% of the forage and 16% of the diet from July to August, was utilized less than 1% in terms of total standing crop.

We wish to stress the importance of these utilization measures for proper management of bighorn sheep or any other wildlife species. Diet or selectivity data perhaps correlate with crude protein or other forage quality needs of the animal. However, diet and selectivity data do not impart any information regarding the potential impact of foraging animals on their own habitat in terms of range condition. Saskatoon was heavily hedged, and may not be available for spring use in subsequent years. Sumac (*Rhus glabra*)was severely browsed and may or may not resprout to satisfy spring browsing needs of these animals in coming years. Bluebunch wheatgrass composed a large proportion of the diet during all four months, yet is not being stressed by animal utilization. In other words, selectivity and utilization measurements must both be determined before sound animal and habitat management programs can be developed.

The relationship between forage quality and selectivity is complex. Relating grazing preference to a single forage parameter, such as crude protein, provides dubious conclusions. In April and May, for example, crude protein levels for all forage classes were relatively similar, and typically greater than levels required for adequate growth and maintenance. However, the sheep still exhibited marked forage selectivity. Other studies on Rocky Mountain bighorn sheep have suggested that forage moisture content correlated with food preferences (Todd, 1972). This correlation may indeed be true. Certainly, in early spring, the sheep eagerly sought succulent new forbs, and nearly eliminated some of these plant species from the grazed areas. Again, however, forage selection is not determined solely by moisture content. Rather, forage selection is in response to many complex factors that are dynamically related to both plant nutrient cycles and animal dietary needs.

Even selectivity data, based on individual plant species, may be incomplete. Bighorn sheep tend to be highly selective in their grazing of plant parts. The sheep consistently selected leaves rather than stems of bluebunch wheatgrass, June grass (Koeleria cristata), Kentucky bluegrass (Poa pratensis), rough fescue, and needle and thread (Stipa comata). Similarly, in autumn, the sheep selected fall regrowth of bluebunch wheatgrass over old growth. Bluebunch wheatgrass responds to autumn rainfall in terms of total biomass more than any other grass species on the study site, and this regrowth provided a diet of 18% crude protein. Thus, while bluebunch wheatgrass was selected against in each summer month, this plant species may still be managerially important as a forage that can provide high crude protein levels at a time of the year when protein for many other forage species is generally below maintenance.

These subtle selectivity patterns and nutritional parameters are extremely important. Bighorn sheep habitat consists of a variety of plant species, all of which contribute to diet during different and specific portions of the foraging year. Proper habitat management techniques must consider and reflect this wide habitat/diet variability.

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NORMAL METABOLIC PROFILES OF LAMB AND

ADULT CALIFORNIA BIGHORN SHEEP

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ABSTRACT

Data on 16 serum parameters, together with body weights, are presented for a captive population of 32 California bighorn ewes and lambs collected in the fall and again in winter. The purpose was to establish normal metabolic profiles for comparative nutritional and genetic studies of wild bighorn sheep populations. Estimates of repeatabilities of serum parameters are presented and their relationship to estimates of inbreeding are briefly discussed.

INTRODUCTION

Metabolic profiles have been used to assess nutritional status and health in both domestic and wild species. For example Payne et al. (1970) and Kitchenham and Rowlands (1976) have done extensive work relating health and nutritional status of dairy herds to the concentration of certain serum constituents of representative animals from these herds. Franzmann (1971a, 1971b) and Bottrell et al. (1978) have reported serum constituent levels for both bighorn and thinhorn sheep. Utilization of these profiles, in assessing herd health and nutritional status of wild species, is a recent technique and is currently undergoing intensive study, Hebert (1972; pers. comm., and this study). The practical application of these techniques in developing and monitoring supplemental feeding and stocking rate programs are obvious. No attempt is made here to evaluate the utility of various serum constituents for these purposes. Rather, the intent is to delineate the effects of age and of season on the various serum constituents in order to help establish normal levels for the age classes studied.

Data presented here are the result of a study to identify genetic markers for use in determining inbreeding in natural bighorn sheep populations. Inbreeding, in general, causes a decline in vigour, while specifically it lowers reproductive fitness. Estimates of the sensitivity and levels of inbreeding in bighorn sheep will establish the minimal size for small isolated breeding populations, and aid in determining the most suitable size and genetic composition for re-introductions.

MATERIALS AND METHODS

Data used in this study were obtained from animals in the captive herd of California bighorn sheep (Ovis canadensis californiana) of the cooperative bighorn sheep management project involving the British Columbia Fish and Wildlife Branch, the Okanagan Game Farm, the University of British Columbia, and Simon Fraser University. Animals used in this study included 8 male lambs, 10 female lambs (all born in 1977), and 14 ewes (dams of the lambs), each bled in late September, 1977, and again in December, 1977.

Serum samples were obtained from whole blood taken from the jugular vein by vacuutainers, and were later analysed by a commercial bio-medical laboratory.

The estimates of age Class (C) (male lambs, female lambs, and ewes), Season (S) (September and December) and the interaction between Class and Season (CxS) were used in the following linear model, to obtain estimates of the least-square means of body weight and each serum constituent associated with each effect.

$$Y_{ijk} = U + C_i + S_j + (CxS)_{ij} + C_{ijk}$$

Single degree of freedom contrasts were used to evaluate the effects of Class - lambs (male + female) vs. ewes and male lambs vs. female lambs. Newman-Keul multiple range test was used to evaluate differences in Class x Season interaction. The variance among individuals (V_i) and within individuals (V_w) were estimated by adding individuals within classes (I_{i1}/C_i) to the above model. The repeatability coefficients were estimated by $R = V_1/(V_i+V_w)$.

Significance levels reported in this paper are $P \leq 0.05$.

RESULTS AND DISCUSSION

The means and standard deviations for body weight and levels of each serum constituent for each Class, Season and Class by Season cell are given in Table 1. Phosphorus, blood urea nitrogen (BUN), uric acid, and potassium were all lower in the current study, while cholesterol and thyroxin were found to be higher than reported by Bottrell et al (1978). These differences are quite large, in some cases, and likely due to differences in available feed. The lambs in the study, reported by Bottrell, were fed hay with a grain supplement, while those in the current study were on native range with no supplementation. Mean values reported by Franzmann (1971a) and Franzmann and Thorne (1970) agree with the current results for phosphorous, glucose, BUN, and total protein. Calcium levels were higher and cholesterol levels lower in the present study than found by the above authors.

No significant differences were found between male and female lambs for any of the variables studied including weight. Adult ewes did not differ from lambs in serum glucose, cholesterol, total protein, bilirubin, or potassium, but were significantly heavier and differed in all other serum constituents as indicated in Tables 1 and 2.

Seasonal effects are elaborated in Tables 1 and 2, and only bilirubin, sodium, creatinine, triglyceride, and amylase showed no change due to season. Serum mineral levels (calcium, phosphorus, and potassium) declined from September to December. BUN, uric acid, cholesterol, total protein, and globulin also declined. Only serum albumin and thyroxin increased from September to December.

Significant Class x Season interactions were observed for weight, cholesterol, globulin, and creatinine (Table 1). Lambs increased in weight, while ewes lost weight from first to second sampling. It should be noted that no significant change in weight occurred within an age class; rather the weight loss of the ewes was small and not significant, but the combined gain of the lambs and loss of the ewes was a significant differential response. It was noted that many of the ewes were still lactating at the September sampling period which may account for this significant interaction. Cholesterol levels in lambs dropped while

Table 1: Means and standard deviations for body weight and serum constituent levels in California bighorn sheep for age classes and seasons

		Overall Mean	Class: Male Lambs (M)	Class: Female Lambs (F)	Class: Adult ewes (E)	Season: September (S)	Season: December (D)	Class x Season: M in S	F in S	E in S	M in D	F in D	E in D
Number of observations	(1)	64	16	20	28	32	32	8	10	14	8	10	14
Weight (kg)	Mean	36.8	26.3^{a}	24.2^{a}	52.5^{b}	36.5	37.2	25.5^{a}	22.9^{a}	53.8^{b}	27.2^{a}	25.5^{a}	51.3^{b}
	S.D.	(14.1)	(3.1)	(2.8)	(4.4)	(15.4)	(12.9)	(3.7)	(2.9)	(4.7)	(2.4)	(1.9)	(3.8)
Calcium (Ca) mg/dl	Mean	9.44	9.75^{a}	9.90^{a}	8.96^{b}	9.70^{a}	9.19^{b}	10.19	10.22	9.06	9.31	9.57	8.86
	S.D.	(0.70)	(057 1	(0.62)	(0.48)	(0.74)	(0.55)	(0.95)	(0.57)	(0.45)	(0.36)	(0.50)	(0.58)
Phosphorous (P) mg/dl	Mean	4.35	4.84^{a}	4.56^{a}	3.92^{b}	5.05	3.64	5.99	5.24	4.38	3.70	3.87	3.45
	S.D.	(1.24)	(1.45)	(1.32)	(0.91)	(1.21)	(0.81)	(0.99)	(1.36)	(0.83)	(0.74)	(0.90)	(0.78)
Glucose mg/dl	Mean	140.2	130.4	147.7	140.3	143.7	136.6	124.9	149.4	150.4	135.9	186.1	130.2
	S.D.	(39.5)	(29.4)	(44.7)	(40.7)	(41.8)	(37.4)	(35.1)	(45.8)	(42.0)	(23.6)	(45.8)	(30.3)
BUN mg/dl	Mean	27.2	26.1^{a}	25.4^{a}	29.0^{b}	29.1^{a}	25.3^{b}	27.2	26.9	31.6	25.0	24.0	26.4
	S.D.	(4.1)	(3.2)	(2.9)	(4.7)	(3.6)	(3.7)	(3.6)	(2.3)	(2.8)	(2.3)	(2.7)	(4.7)
Uric Acid mg/dl	Mean	0.247	0.244^{a,b}	0.195^{a}	0.206^{b}	0.328^{a}	0.166^{b}	0.337	0.260	0.171	0.150	0.130	0.209
	S.D.	(0.153)	(0.179)	(0.132)	(0.146)	(0.120)	(0.140)	(0.151)	(0.088)	(0.107)	(0.160)	(0.142)	(0.130)
Cholesterol mg/dl	Mean	58.5	59.1	61.9	55.7	64.6^{a}	52.3^{b}	69.4^{a}	69.7^{a}	58.3^{b}	48.8^{b}	54.1^{b}	53.1^{b}
	S.D.	(12.4)	(16.1)	(14.3)	(7.48)	(12.1)	(9.5)	(14.8)	(13.2)	(5.9)	(9.7)	(11.2)	(8.2)
Total protein gm/dl	Mean	6.52	6.54	6.36	6.61	6.84^{a}	6.19^{b}	7.07^{a}	6.80^{a,b}	6.74^{a,b}	6.00^{c}	5.92^{c}	6.49^{b}
	S.D.	(0.55)	(0.66)	(0.58)	(0.46)	(0.43)	(0.47)	(0.37)	(0.40)	(0.46)	(0.36)	(0.36)	(0.44)
Albumin gm/dl	Mean	3.21	3.27^{a}	3.33^{a}	3.09^{b}	2.81^{a}	3.61^{b}	2.91	2.89	2.69	3.62	3.77	3.48
	S.D.	(0.48)	(0.39)	(0.48)	(0.51)	(0.22)	(0.30)	(0.12)	(0.10)	(0.28)	(0.14)	(0.21)	(0.37)
Globulin gm/dl	Mean	3.31	3.27^{a,b}	3.03^{a}	3.57^{b}	4.03^{a}	2.58^{b}	4.16^{a}	3.91^{a}	4.04^{a}	2.36^{b}	2.15^{b}	3.01^{c}
	S.D.	(0.89)	(0.98)	(0.94)	(0.75)	(0.44)	(0.56)	(0.39)	(0.34)	(0.54)	(0.31)	(0.21)	(0.55)
Bilirubin mg/dl	Mean	0.44	0.41	0.48	0.43	0.48	0.41	0.41	0.48	0.51	0.40	0.48	0.36
	S.D.	(0.13)	(0.09)	(0.13)	(0.15)	(0.14)	(0.11)	(0.11)	(0.14)	(0.16)	(0.08)	(0.12)	(0.10)
Sodium (Na) meq/l	Mean	149.7	150.7^{a}	151.8^{a}	147.7^{b}	149.7	150.1	150.3	151.5	147.4	151.2	152.1	147.9
	S.D.	(3.3)	(2.6)	(2.6)	(2.8)	(3.3)	(3.2)	(2.6)	(2.7)	(3.0)	(2.8)	(2.5)	(2.7)
Potassium (K) meq/l	Mean	4.55	4.62	4.38	4.64	4.79^{a}	4.31^{b}	4.97	4.50	4.90	4.27	4.26	4.37
	S.D.	(0.81)	(0.86)	(0.83)	(0.77)	(0.99)	(0.47)	(1.10)	(1.08)	(0.88)	(0.33)	(0.49)	(0.54)
Creatinine mg/dl	Mean	2.01	1.96	1.97	2.12	2.12	1.89	1.86^{a}	1.99^{a}	2.36^{b}	1.86^{a}	1.95^{a}	1.87^{a}
	S.D.	(0.39)	(0.26)	(0.38)	(0.43)	(0.46)	(0.26)	(0.12)	(0.47)	(0.41)	(0.20)	(0.28)	(0.28)
Triglyceride mg/dl	Mean	36.8	45.7^{a}	43.3^{a}	27.1^{b}	35.4	38.19	48.6	40.4	24.4	42.7	46.2	29.9
	S.D.	(20.3)	(29.4)	(19.1)	(7.18)	(24.3)	(15.7)	(37.1)	(22.4)	(7.6)	(21.4)	(15.7)	(5.8)
Amylase (somogyi units)	Mean	45.4	44.3^{a,b}	33.7^{a}	54.1^{b}	45.1	44.8	49.12	33.7	52.4	39.5	33.7	55.7
	S.D.	(25.6)	(27.2)	(20.0)	(35.5)	(29.5)	(21.6)	(33.7)	(22.4)	(30.5)	(19.9)	(18.9)	(20.3)
Thyroxin (T_4) mg/dl	Mean	8.81	10.14^{a}	10.29^{a}	6.93^{b}	7.82^{a}	9.88^{b}	9.05	9.51	5.9	11.22	11.08	8.94
	S.D.	(3.97)	(2.52)	(2.17)	(2.98)	(3.91)	(2.82)	(2.47)	(1.93)	(2.93)	(2.19)	(2.21)	(2.71)

(1) three observations were missing - weight on a ewe in September
- amylase on a female lamb in September
- thyroxin on a ewe in December

Common subscript within an ANOVA category indicates means are not significantly different $P \leq 0.05$ (Newman-Keul multiple range test).

Table 2: Summary of analysis of variance and repeatabilities for body weight and serum constituent levels.

Dependent Variable	Units	Class (2 d.f.) Lambs-ewes	Class (2 d.f.) lambs male-ewe	Season(1 d.f.) Sept.-Dec.	Class x Season (2 d.f.)	Repeatability (R)
1. Weight	kg	-27.4*	ns	ns	*(1)	(2)
2. Calcium (Ca)	mg/dl	0.87*	ns	0.51*	ns	0 (3)
3. Phosphorus (P)	mg/dl	0.77*	ns	1.53*	ns	0 (3)
4. Glucose	mg/dl	ns	ns	ns	ns	19
5. BUN	mg/dl	-3.25*	ns	3.48*	ns	32
6. Uric Acid	mg/dl	-0.0690*	ns	0.1630*	ns	21
7. Cholesterol	mg/dl	ns	ns	13.8*	*(1)	9
8. Total protein	gm/dl	ns	ns	0.73*	*(1)	29
9. Albumin	gm/dl	0.22*	ns	-0.79*	ns	29
10. Globulin	gm/dl	-0.39*	ns	1.53*	*(1)	0 (3)
11. Bilirubin	mg/dl	ns	ns	ns	ns	0 (3)
12. Sodium (Na)	meq/l	3.6*	ns	ns	ns	0 (3)
13. Potassium (K)	meq/l	ns	ns	0.49*	ns	24
14. Creatinine	mg/dl	-0.20*	ns	ns	*(1)	0 (3)
15. Triglyceride	mg/dl	17.3*	ns	ns	ns	5
16. Amylase (somogyi units)		-15.53*	ns	ns	ns	(2)
17. Thyroxin (T_4)	mg/dl	3.29*	ns	-1.96	ns	(2)

* significant $P \leq 0.05$

(1) see Table 1 for multiple range test

(2) not estimated due to missing observation

(3) negative estimate of V_i, assumed R=O

serum cholesterol levels in the ewes remained constant. Serum globulin levels in the lambs dropped drastically from September to December, while the level in ewes dropped over that period but not to the same extent. The creatinine level for ewes was high in September and dropped to a level comparable to that of the lambs in December. The repeatabilities (correlations between repeated samples of the same individual) for serum BUN, total protein, albumin, glucose, uric acid, and potassium (Table 2) were reasonably high. This suggests these constituents may be suitable polygenic markers, because the magnitude of the among individual variance (V_I) indicates that genetic differences do exist for these traits in the population. Further evaluation is required to eliminate the real possibility that several of these parameters are controlled by simple genetic systems, in which case they may be useful as polymorphic markers.

It is also apparent, from this analysis, that approximately 10% of the variation in BUN, total protein, and albumin levels is associated with differences among individuals which has implications on sampling schemes for monitoring nutrient status of populations. No comparisons of these estimates of repeatabilities are available in the literature for this species. However, the repeatabilities are generally consistent with those found in dairy cattle populations (Peterson 1978, Kitchenham and Rowland 1976).

Differences were observed, for most variables, between lambs and adult ewes, while sex of lamb was not important. It follows that metabolic profiles, used for assessing nutritional status, would need to be adjusted for the age effects to obtain realistic estimates for a herd or population. The observed seasonal changes may be due to normal season cycles or to a decline in nutritional status. This will require additional investigation.

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COMPARISON OF CHROMOSOME AND BLOOD CONSTITUENTS
OF ROCKY MOUNTAIN AND CALIFORNIA BIGHORN
AND DALL AND STONE THINHORN SHEEP

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ABSTRACT

Karyotypes and banding patterns are described for captive Rocky Mountain and California bighorn, Dall and Stone thinhorn, and European mouflon sheep. One abnormality is noted. Data on 13 serum parameters of nine bighorn and six thinhorn sheep are presented and analyzed, and show some between- and within-species differences. Hematological values for bighorn and thinhorn sheep are also presented and briefly discussed.

INTRODUCTION

With regard to the genus Ovis, in recent years chromosome analysis has become recognized as a practical laboratory technique for research. This method has allowed reevaluation of taxonomic relationships between existing sheep into four genetic groups based on their diploid chromosome number - 52, 54, 56 and 58 (Nadler et al. 1973a, Korobitsyna et al. 1974). Further, the technique has aided in the construction of ovine evolutionary theories (Nadler et al. 1973b, Korobitsyna et al. 1974, Valdez et al. 1977), and has shown similarities to divisions based upon social behaviour and social morphology (Geist 1971).

Blood analysis is now recognized as an essential tool in the study of wildlife populations. Generally, such investigations are aimed at establishing average or basal values for a species. Once these have been ascertained, they can serve as standards against which researchers may equate existing values in order to determine the health and nutritional status of a population. Utilization of this method in the assessment of wild sheep populations is presently being investigated (Hebert, D.M. 1978 pers. comm.). Moreover, established serological and hematological profiles should provide an additional means of taxonomic classification. For example, it is reasonable to assume that sheep in a single diploid group could be further differentiated into existing genotypes (subgroups or subspecies, races or breeds) by comparing serum constituent levels. Levels of various constituents which are shown to be genetically controlled may be useful as polymorphic or polygenic markers for inbreeding studies and in determining the effective number of breeding males in a population. This latter point has obvious implications for development of harvest strategies where only males are hunted.

However, due in part to the difficulty in obtaining samples, neither chromosomal nor blood analyses methods have been extensively employed in research on wild sheep. The number of wild sheep studied by chromosomal procedures is extremely limited, with entire populations as yet unexamined. Although hematological data and serum constituent levels for bighorn and thinhorn sheep have been reported (Franzmann and Thorne 1970, Franzmann 1971a, 1971b, Peterson and Bottrell 1978) work in this field is far from complete.

Certainly a more complete interpretation of sheep evolution and taxonomy requires a larger and more representative sample to determine the range of variation. Similarly, the development of blood profiles, as a means of determining the nutritional status of wild sheep populations or their indices of inbreeding, demands much additional information . It is hoped that the chromosome data, hematological values and serological analysis described here will assist workers whose interests are in these areas.

MATERIALS AND METHODS

Four Rocky Mountain bighorn sheep (O. canadensis canadensis)from the Canadian Wildlife Service boarding pens at the University of British Columbia were sampled for preliminary chromosome analyses trials. All subsequent samplings for chromosomal, hematological and serological tests were done using lambs born and raised on the Okanagan Game Farm, Penticton, British Columbia. These animals included: 5 Rocky Mountain bighorns, 4 California bighorns (O. canadensis californiana), 3 Dall thinhorns (O. dalli dalli), 3 Stone thinhorns (O. dalli stonei) and 2 Europena mouflons (O. musimon).[1]

Sterile blood samples were taken by jugular venepuncture using heparinized vacutainer tubes (Becton-Dickson Company). Chromosome spreads (Bottrell 1977) were prepared from 72 hour whole blood cultures. Generally the numerical and karyotyping methods adopted were those described in "Cytogenetics" (Priest 1969) and in "Laboratory Procedures in Human Genetics" (Sarma and Talukder 1974). Karyotypes were established from photomicrographs taken of several good metaphase spreads. The banding technique employed was that used routinely in the University of British Columbia Medical Genetics laboratory. This method is referred

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[1]Hematological and serological tests were not done for mouflon sheep.

to as the trypsin-giemsa banding techniques (Masui, pers. comm. 1977).

Serum was obtained from clotted blood, decanted, and frozen. Serological analyses were done by the British Columbia Biomedical Laboratories, Burnaby, British Columbia. Eleven of the variables analyzed (excluding sodium and potassium) were included in a standard package. Considerations of economics, speed, and convenience governed our choice of this analysis package. Results of these analyses were then statistically analyzed to determine differences between and within the species of the sheep examined.

Hematological determinations were performed on whole blood containing ethylenediaminetetracetic acid (EDTA) by B. McCoy, Central Veterinary Hospital, Victoria, B.C. However, not all samples were analyzed for hematology values. With the resultant small sample size and missing data, a statistical evaluation could not be employed.

RESULTS AND DISCUSSION

Qualitative evaluation of cultures revealed that the medium mixture chosen - RPMI 1640 plus additions - was inadequate for Stone sheep leukocyte culture, although it did support good cell growth for the other 4 races of wild sheep.

With one exception all animals displayed typical 2N=54 diploid values and karyotypes (Figure 1). Stone sheep, which have not been previously described, exhibited the expected 2N=54 karyotype. However, one _californiana_ - Cal #6-74(F) - exhibited an abnormal 2N=54 chromosome number for 141 of 200 examined metaphase spreads. Figure 2 shows the abnormal karyotype of this sheep as determined by banding

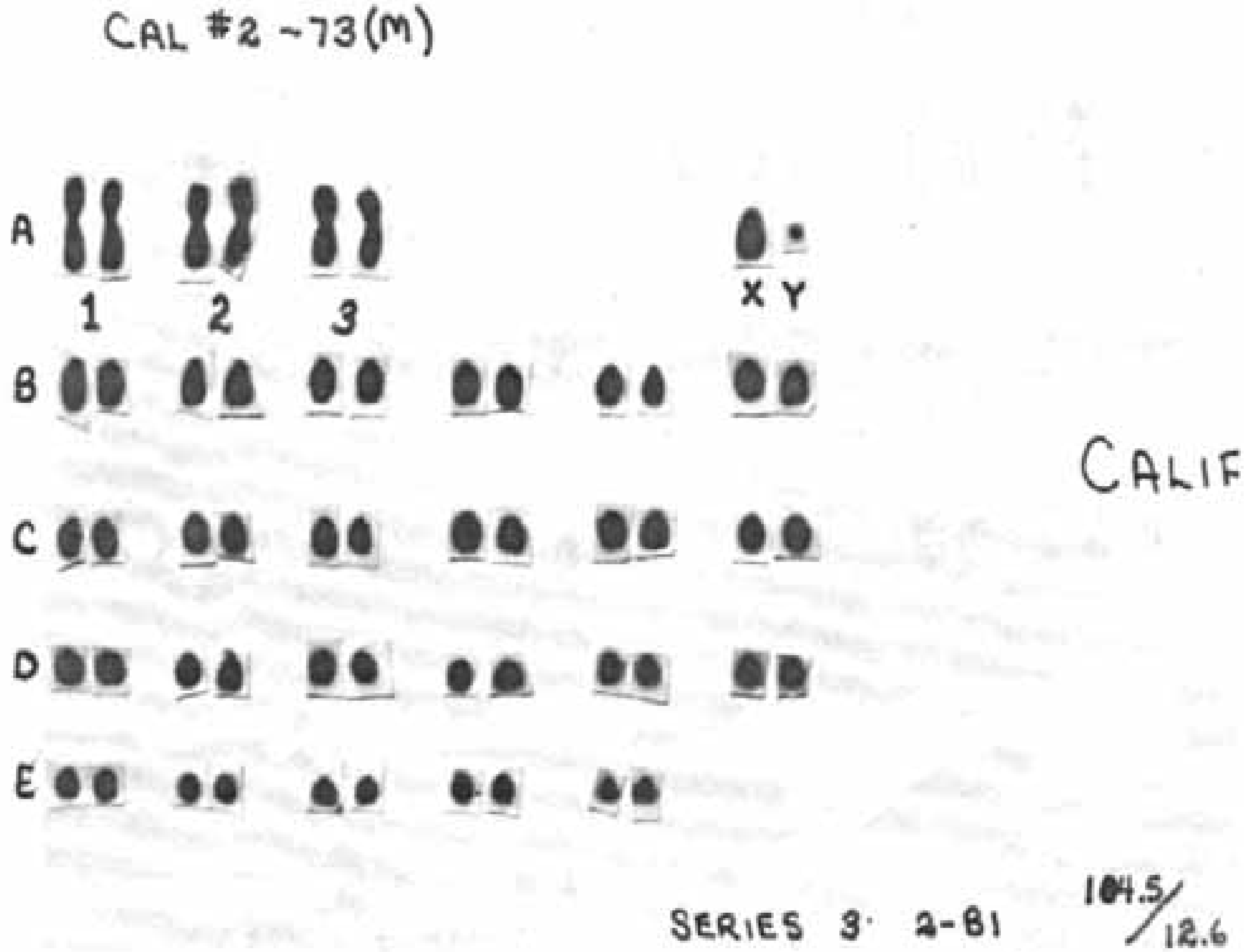

Figure 1. Karyotype of a Californian bighorn sheep (male) 2N=54

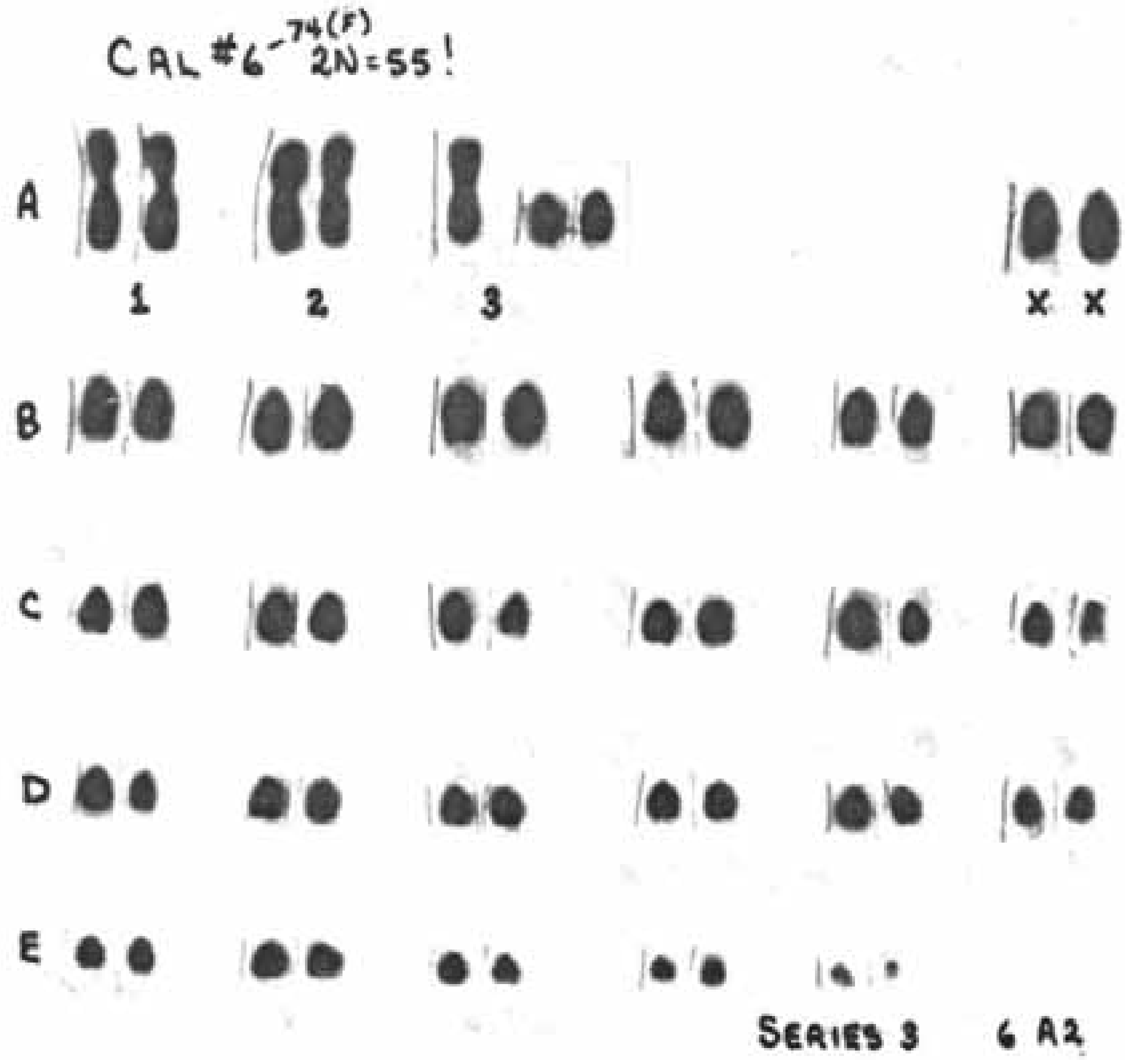

Figure 2. Abnormal karyotype of California bighorn sheep (female): Cal #6-74 (F) with 2N=55

analysis. Figure 1 is representative of the normal 2N=54 California bighorn karyotype. Unfortunately before a more careful inspection and follow up sampling of the animal could be done, the sheep died and was disposed of. Since this is the only reported instance of an abnormal diploid value being found in a North American sheep, an adequate discussion of 2N=55 bighorn sheep must undoubtedly await a more thorough investigation.[1]

The submetacentric nature of the X chromosome was evidenced in several stained preparations (Figure 2). Figure 3 is a banded karyotype thought to be representative of all the 2N=54 wild sheep studied. G - banding patterns of the three large metacentric autosomes (Group A) from each of the 5 sheep types were found to be identical. Figure 4 is a schematic illustration of these Group A metacentric autosomes. The reported Group A ideogram for the five project categories - canadensis, californiana, dalli, stonei and musimon, may be regarded as identical to that presented and discussed by Nadler (1973b) for mexicana, musimon, orientalis and, F_1 and F_2 musimon x candensis. Slight differences between Nadler's banding patterns and those of the current study were assumed to be due to interpretations and methods. Thus the Group A metacentric chromosomes of 2N=54 European, Asiatic and North American wild sheep appear to be structurally homologous. Hybridization and meiotic bivalent studies by Nadler (1973b) further substantiate these results.

Means and standard deviations for serum constituent levels of canadensis, californiana, dalli and stonei are given in Table 1. As

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[1] A. Bottrell has recently analyzed 32 California bighorn sheep. All have 2N=54 karyotypes.

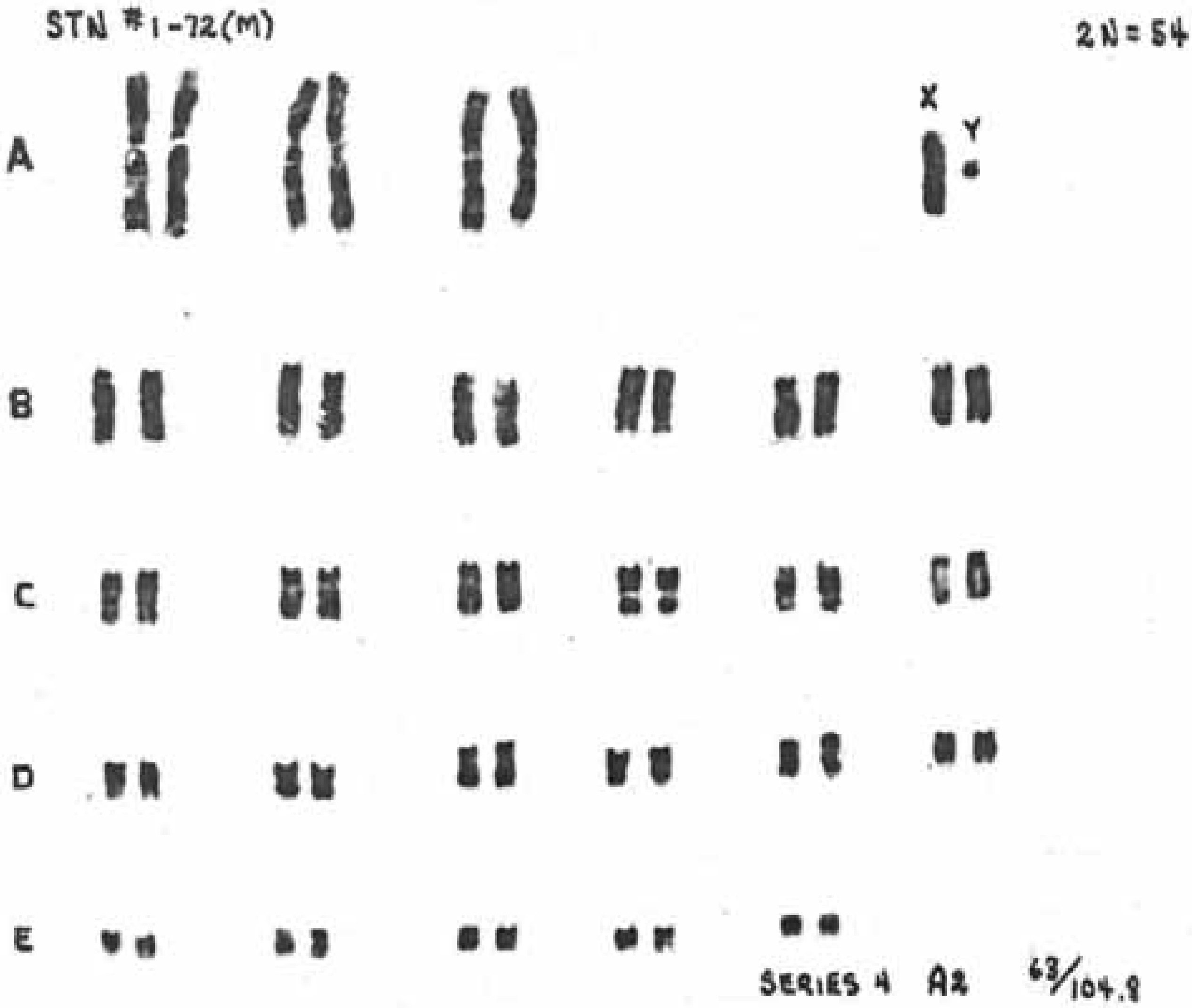

Figure 3. Giemsa-banded karyotype of a Stone thinhorn sheep (male) 2N=54. (Banding pattern presented is representative of all 2N=54 sheep studied).

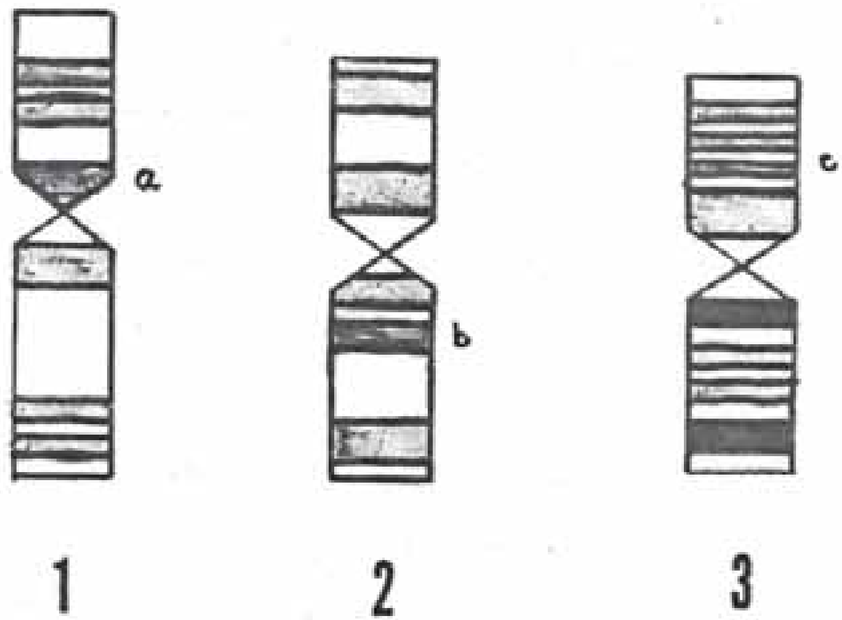

Figure 4. Schematic representation of Group A metacentric chromosomes. The letters a, b and c denote bands not appearing in Nadler's (1973b) ideogram.

mentioned above some investigations of wild sheep blood parameters have been done by Franzmann and Thorne (1970), Franzmann (1971a, 1971b) and Peterson and Bottrell (1978). Mean values for glucose, total protein, albumin, globulin, and sodium obtained here, were in agreement with the findings of these authors. The calcium, phosphorous, blood urea nitrogen (BUN), uric acid, and potassium levels found in this study were higher than those previously reported, while thyroxine and cholesterol values were lower. Many of these differences can probably be accounted for, by differences in age and diet of animals of these studies. The sheep in this study were lambs born into captivity and fed alfalfa hay with supplements; the lambs of the study reported by Peterson were range fed; while in the determinations of Franzmann lambs were often not separated from adults.

Differences in serum constituents were found between and within species of bighorn and thinhorn sheep (Table 2). Glucose albumin and alkaline phosphotase levels were unique for species. Total serum protein and albumin differed for bighorns, and cholesterol levels were higher for Dall than Stone sheep. Noting that animals sampled for this study had been born, and fed and cared for in a similar manner, which would reduce environmental influence, the differences reported here may be indicative of genetic variation between species and subspecies.

Ranges of hematological values for some bighorn and thinhorn sheep are presented in Table 3. Although hemoglobin and packed cell volume (PCV) values appear to be slightly lower than those given by Franzmann and Thorne (1970) and Franzmann (1971a, 1971b), it must be remembered that the wild sheep described in this study were lambs, while the

TABLE 1. Means and standard deviations for serum constituent levels of bighorn and thinhorn sheep

			BIGHORN SHEEP		THINHORN SHEEP	
			Rocky Mountain	California	Dall	Stone
Number of Observations			5	3	3	3
Calcium	mg %	Mean	10.10	9.78	9.53	9.33
		SD	(0.84)	(0.44)	(0.61)	(1.56)
Phosphorus	mg %	Mean	7.75	7.40	9.20	7.40
		SD	(3.66)	(1.73)	(1.59)	(3.47)
Glucose	mg %	Mean	140.5	129.2	92.67	90.00
		SD	(37.19)	(16.75)	(16.17)	(11.3)
BUN[1]	mg %	Mean	37.00	33.80	38.00	35.00
		SD	(5.29)	(3.18)	(2.00)	(7.94)
Uric Acid	mg %	Mean	0.38	0.46	0.33	0.40
		SD	(0.17)	(0.05)	(0.12)	(0.10)
Cholesterol	mg %	Mean	51.75	38.00	53.67	29.33
		SD	(8.73)	(5.14)	(28.04)	(4.93)
Total Protein	gm %	Mean	7.13	6.22	7.13	6.40
		SD	(0.15)	(0.44)	(1.22)	(0.17)
Albumin	gm %	Mean	3.80	3.48	3.27	3.10
		SD	(0.28)	(0.33)	(0.58)	(0.45)
Globulin	gm %	Mean	3.32	2.74	3.86	3.30
		SD	(0.23)	(0.16)	(0.79)	(0.52)
Alkaline Phosphatase	u/ml	Mean	275.7	356.2	215.3	173.7
		SD	(40.3)	(156.6)	(167.5)	(21.1)
Sodium	meq/1	Mean	152.5	150.6	151.7	148.3
		SD	(1.9)	(2.1)	(1.5)	(2.9)
Potassium	meq/1	Mean	5.60	5.34	6.13	5.53
		SD	(0.71)	(0.87)	(0.15)	(1.14)
Thyroxine (T_4)	mg %	Mean	4.15	4.38	5.07	2.93
		SD	(1.36)	(0.66)	(0.91)	(0.25)

1 Blood urea nitrogen.

TABLE 2. Means for serum constituent level differences between and within species of bighorn and thinhorn sheep.+

		Bighorn (9)@ vs Thinhorn (6)	Rocky Mountain (5) vs California (4)	Dall (3) vs Stone (3)
Calcium	mg %	0.51	0.32	0.20
Phosphorus	mg %	-0.73	0.35	1.80
Glucose	mg %	43.52*	11.30	2.67
BUN	mg %	-1.10	3.20	3.00
Uric Acid	mg %	0.06	-0.08	-0.07
Cholesterol	mg %	3.38	13.75	24.34*
Total Protein	gm %	-0.09	0.91*	0.73
Albumin	gm %	0.46*	0.32	0.17
Globulin	gm %	-0.55*	0.58*	0.56
Alkaline phosphatase	u/ml	121.45*	-80.5	41.60
Sodium	meq/1	1.55	1.90	3.40
Potassium	meq/1	-0.36	0.26	0.60
Thyroxin (T_4)	meq/1	0.27	-0.23	2.14

\+ Determined by analysis of variance using orthogonal contrasts from Table 1.

@ Bracketed values designate the number of observations.

* Significant $P \leq 0.05$

TABLE 3. Hematological values of bighorn and thinhorn sheep

		BIGHORN SHEEP		THINHORN SHEEP	
		Rocky Mountain	California	Dall	Stone
Number of observations		3	1	1	3
Hemoglobin	g/100 ml	14.7 - 14.9	16.4	16.0	12.7 - 17.6
Packed Cell Volume (PCV)	%	43 - 44	47	44	39 - 49
Total Leukocytes	1000/ml	11.0 - 12.9	9.4	6.0	6.6 - 10.8
Lymphocytes	1000/ml	28 - 32	29	28	12 - 38
Neutrophils	1000/ml	59.0 - 61.7	70.0	66.0	74.0
Basophils	1000/ml	0	0	0	0
Monocytes	1000/ml	1 - 6	0	4	0 - 2
Eosinophils	1000/ml	0 - 2	1	2	0

animals of their studies included both adults and lambs. Since lower hemoglobin and PCV values have been noted in very young domestic lambs (Blunt 1975), the values disclosed are probably in accord with those of prior research.

The leukocyte counts obtained in this study were in keeping with those obtained by other workers. However, the count of neutrophils is higher than that published by other authors (Woolf and Kradel 1970, Franzmann 1971a, 1971b), and the number of lymphocytes is lower. Once again it must be emphasized that this project dealt solely with lambs while the previous studies did not. Blunt (1975) has stated that in domestic sheep shortly after birth neutrophils are the dominant white blood cell type and their relative frequency decreases with age. If this is the case for wild sheep the values reported here would appear correct.

Chromosome studies in this report were complimentary to those reported in the literature. The karyotype for Stone sheep (2N=54) is reported here for the first time. One adult California ewe had an atypical karyotype of 2N=55. Species differences in seriological and hematological values between and within bighorn and thinhorn sheep are presented. It should be noted that no attempt is made here to evaluate the utility of these results in determining ovine species differences, or their nutritional status, as this will require a more extensive data base. Rather the hope at this stage is that this may stimulate other workers to collect comparable data from populations and races of sheep inhabiting many different environments.

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BLOOD CHEMISTRY AS AN INDICATOR OF NUTRITIONAL CONDITION IN BIGHORN SHEEP

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INTRODUCTION

Experimental animal physiology studies use basline values established with a control group to determine the significance of changes of a particular physiological parameter. Blood chemistry studies in wildlife biology have attempted to establish baseline values in relation to many uncontrolled variables and to utilize relative differences in values between seasons, habitat types and populations to assess animal condition and population status.

The last ten years have witnessed a dramatic increase in the use of blood chemistry to determine the taxonomic, clinical, physical, physiological and nutritional status of wild ungulates and carnivores (Cowan and Johnston 1962; Anderson et al. 1972; Cowan and Bandy 1969; Hebert 1972; Barrett and Chalmers 1977; Vaughen et al. 1973; Le Resche et al. 1974; Dieterich 1970; Kitts et al. 1956; Franzmann and Thorne 1970; Skeen 1974; Weber 1973; Pearson and Halloran 1972; Seal et al. 1975, 1978a, 1978b; Seal and Hoskinson 1978; Eubanks et al. 1976). There has been a gradual shift from assessment of carrying capacity by vegetation utilization studies and change in population characteristics to that of establishment of nutritional status of wild populations. Le Resche et al. (1974), suggests that the trend in research has been toward analyses of individual primary factors rather than of collective manifestations. In general, current research incorporates quantitative assessment of range and animal numbers with qualitative aspects of range (crude protein (CP), crude fibre, gross energy (GE)) - animal (blood urea nitrogen (BUN), serum inorganic phosphorus, hematocrit) relationships.

Domestic animal literature has documented many of these relationships, especially the clear relationship between BUN and protein intake, at levels of protein intake above maintenance (Lewis 1957; McIntyre 1970; Preston et al. 1965; Somers 1961; Mukhoty et al. 1969).

By comparison, cholesterol baseline values have been collected for wild ungulates (Le Resche et al. 1974; Seal et al. 1978b; Weber 1973), but few studies have determined its relationship with nutritional or energy status. Although Le Resche et al. (1974), states that cholesterol level reflects diet, dietary change, the state of rumen metabolism and appears to indicate a state of malnutrition, it can be altered by sex, age, season and the level of saturated fatty acids consumed. Seal et al. (1978b) suggests that cholesterol was only moderately affected by dietary composition in white-tailed deer fawns. Similarly, few studies have utilized hemoglobin or hematocrit to assess general nutritional status between populations. Karns and Seal (from Le Resche et al. 1974), indicate that hemoglobin concentration in male Minnesota moose declined between October and December, and Kirk and Davis (1970) indicate a seasonal effect on hemoglobin and hematocrit in range cattle. Seal et al. (1972), found significantly lower hemoglobin and hematocrit levels in white-tailed deer between a moderate and high diet group. Ullrey et al. (1967) used isocaloric diets varying in crude protein from 8-20 per cent and found no differences in hemoglobin or hematocrit levels between groups, while Seal et al. (1978b) found similar hematocrit levels and higher hemoglobin levels for fawns on low protein diets between groups of white-tailed deer fawns on low and high protein and energy diets.

The purpose of this paper is to explore the relationship between BUN, serum cholesterol, hematocrit and hemoglobin and a host of nutritional measurements conducted under controlled conditions, at or below maintenance.

ACKNOWLEDGEMENTS

I would especially like to thank Mr. R. Ellis for taking time from writing his thesis to prepare the computer print-outs of regression material and Mrs. M. Wyborn for aiding in initial preparation of much of the data. Dr. A Franzmann performed the serum analysis during the co-operative efforts of our studies. Ms. Holly Cleator drafted the figures and tabulated the data.

METHOD AND MATERIALS

Two groups of Rocky Mountain bighorn sheep were maintained on natural rangeland diets in order to simulate a migratory and non-migratory situation. The feeding regime and nutritional measurements have been described previously (Hebert 1972, 1973). Serum samples were collected monthly from September 1969 to May 1970 (Hebert 1972) and analyzed (Hebert 1972, Franzmann 1971) for an array of variables other than those reported (BUN, hematocrit, hemoglobin, cholesterol) in this paper. There were eight serum sampling periods but only two complete nutritional trials in the fall (1969) and two the following spring (1970). Scaled curves representing nutritional parameters were extrapolated between the last fall trial and the first spring trial in order to obtain an estimate of each nutritional parameter for each blood sampling period. Regression analysis was used to establish the relationship between serum constituents and nutritional measurements. The initial relationship consisted of all sampling dates from October to May. The second computer run eliminated the last sampling date (high quality pelleted ration), while the third computer run eliminated the first and last date for both groups. The fourth and fifth computer run eliminated the fifth and last sampling date and the first, fifth and last sampling date, respectively. This reduction in sampling dates removed anabolic effects of the high quality pelleted diet fed in May and removed the effects of a multiple vitamin supplement administered in February. In addition, it allowed by difference comparisons of levels of significance due to the effects of changes in diet quality.

STUDY AREA

The nutritional and blood chemistry assessment were conducted in bighorn sheep holding facilities in the East Kootenay region of British Columbia (Hebert 1973).

RESULTS

BUN

Blood urea nitrogen values for a simulated migratory and non-migratory group of bighorn sheep changed from an average value of 14.6 mg/100 ml during early fall to 24.2 mg/100 ml in late winter (Figure 1). During the October 1 sampling period the migratory group was ingesting good quality alpine forage (CP 11.59%) which produced a comparable BUN value of 18.5 mg/100 ml. Conversely, the non-migratory group was ingesting a submaintenance diet (CP 2-3%) which produced a low BUN value (8.8 mg/100 ml). During the period October 1 to April 14 both groups subsisted on submaintenance diets containing 2-3% CP. These diets are reflected by

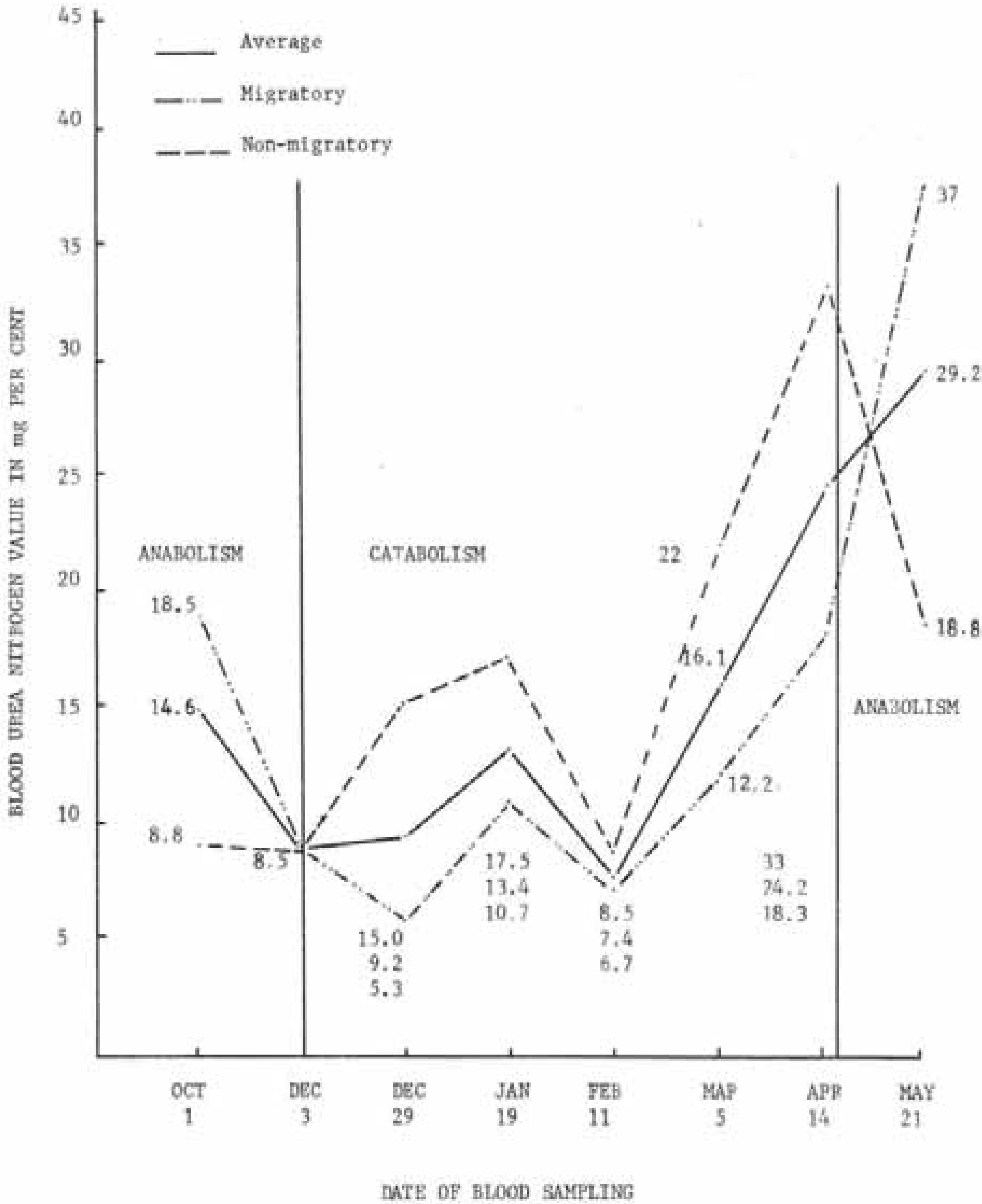

FIGURE 1.

The seasonal pattern of blood urea nitrogen, reflecting high and low quality diets.

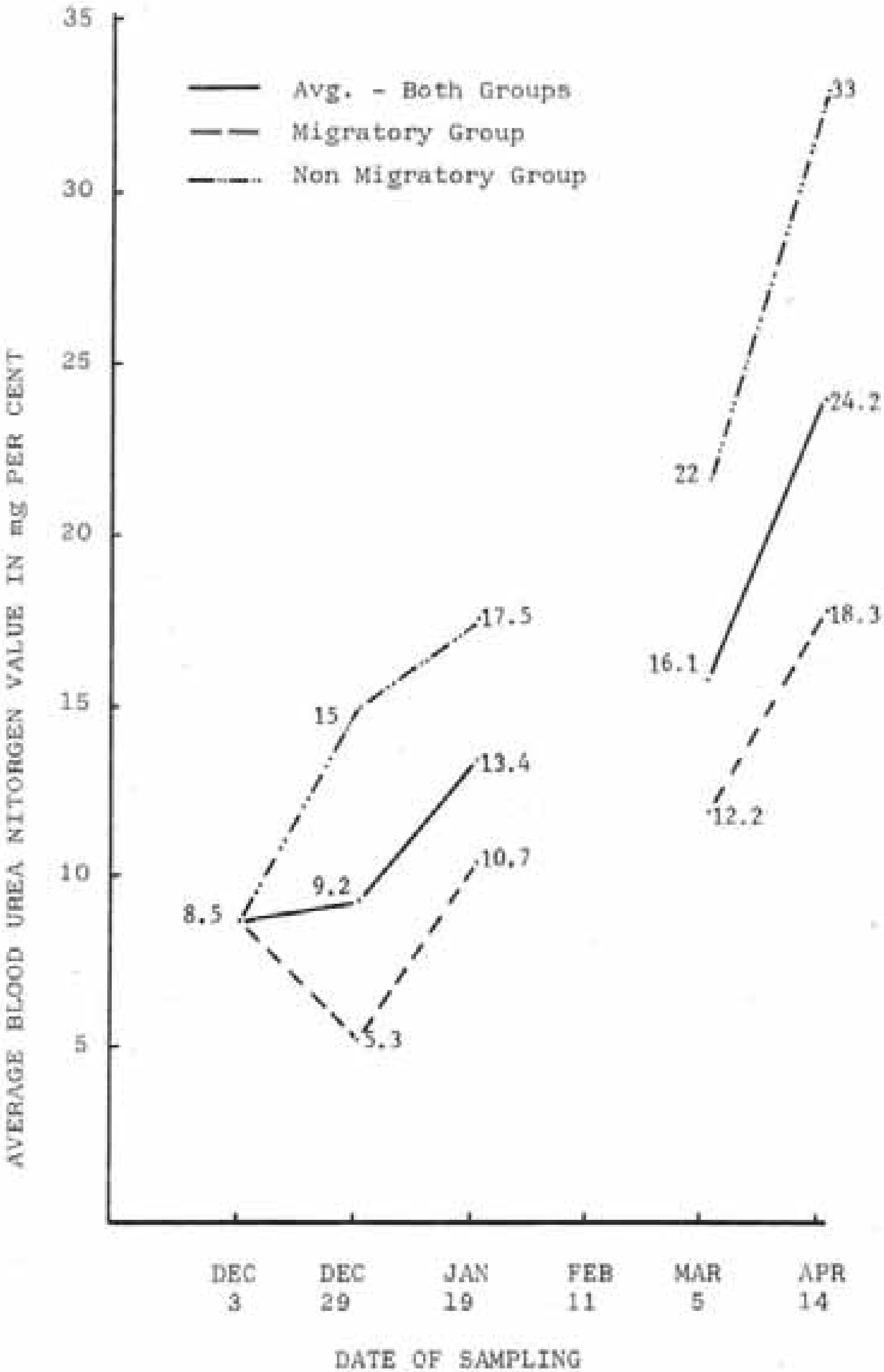

FIGURE 2 The seasonal pattern of blood urea nitrogen while on sub-maintenance diets and without the effects of multiple vitamin supplements (February 11).

an increase in the BUN value from 8.5 mg/100 ml. to 24.2 mg/100 ml as body catabolic processes provided nitrogen to the blood. Subsequently, the curves diverged during the spring period (May) as BUN became related to protein intake rather than tissue protein when both groups were placed on a high quality pelleted ration (21% CP) to simulate spring forage growth. The 5 week period between the April and May sampling dates caused the two groups to change at a different rate, from a catabolic state in the production of BUN to one related to CP intake. The migratory group, being in better body condition (Hebert 1973), adjusted to the improved diet more rapidly and increased its BUN level proportionately. The non-migratory group was in poorer body condition and the May sampling point appeared to indicate that the BUN level may not completely reflect the quality of the diet or that it was reflicting the generally poorer condition of this group when returned to a state of anabolism. During the February sampling period the animals were stressed for S-GOT value measurement and were on low quantities of a multiple viatmin which may have affected the BUN value. If this point is removed (Figure 2), the contribution of the body tissues to BUN values shows a continuous increase from December 29 - April 14 while the groups are on submaintenance diets.

HEMATOCRIT AND HEMOGLOBIN

During the sampling period, the migratory group (Figure 3) maintained a higher level of both hematocrit (average 48.3%) and hemoglobin (average 18.7%) than did the non-migratory group (38.5% + 13.9%, respectively). The data did not indicate seasonal trends for either variable but did suggest that previous nutritional differences did influence the level while the two groups were on submaintenance diets. Seal *et al.*

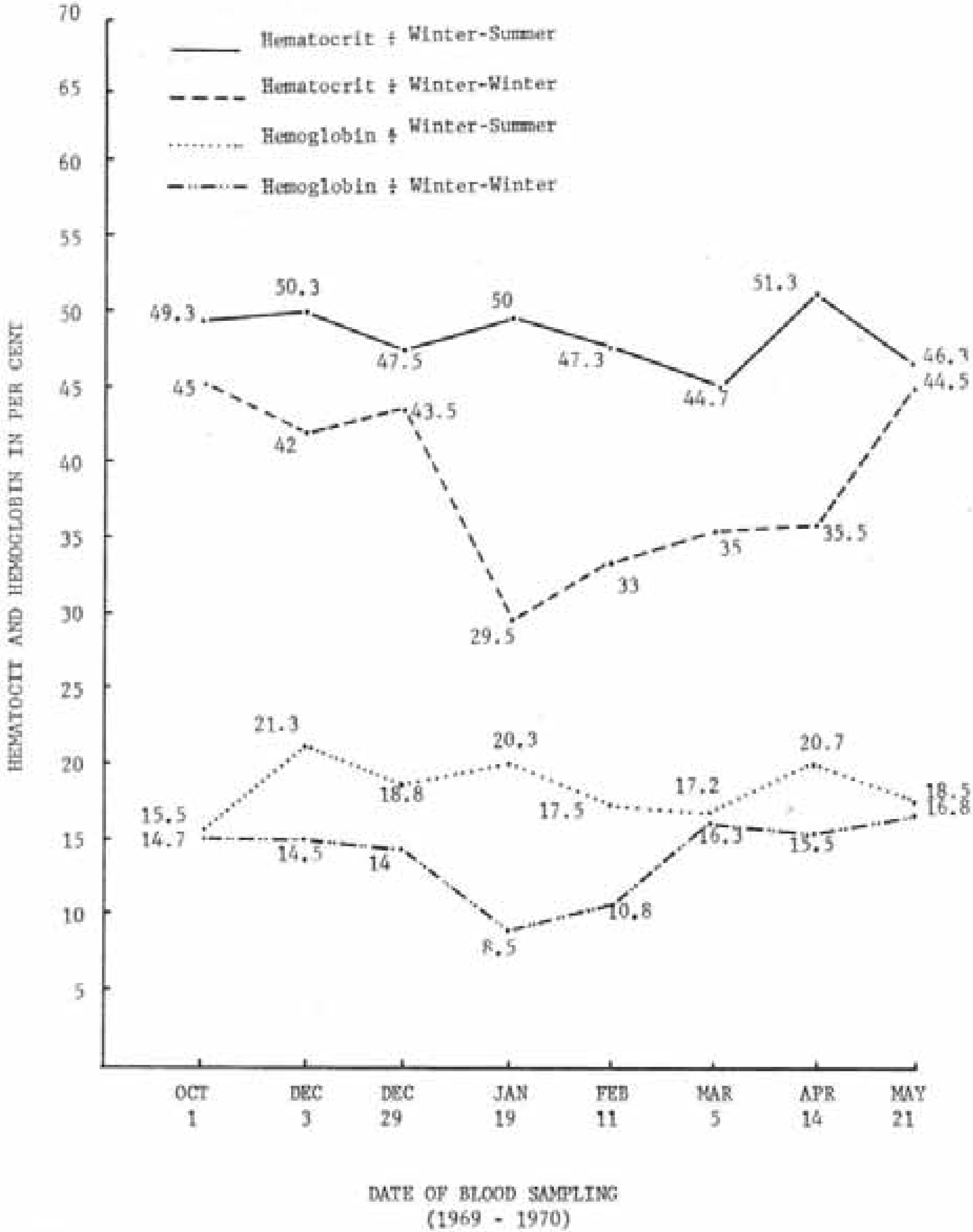

FIGURE 3

Seasonal changes in hematocrit and hemoglobin between two groups of sheep on high and low quality diets.

(1972) obtained similar results with deer. Similarly, Franzmann (1972) presented a highly significant (P = .0001) relationship between PCV and condition in his model, and the positive ranking of PCV means with condition classes in the Duncan's multiple range test suggest that PCV values are valid indicators of condition of bighorn sheep. Similarly, Meacham et al. (1964) found that both hematocrit and hemoglobin were significantly lower for protein deficient bulls. In contrast, Ullrey et al. (1967) used approximately isocaloric diets with crude protein contents of 8,13 and 20 per cent, but found no differences in hemoglobin or hematocrit levles between groups.

CHOLESTEROL

The change in cholesterol value does not appear to indicate any specific trend from fall to spring (Figure 4). However, the seasonal average for the migratory group was 86.6 mg/100 ml while that for the non-migratory group was only 72.5 mg/100 ml. The trend and the actual values indicated in this study (a peak in the fall, decline throughout the winter and an increase prior to spring green up) are very similar to that shown by Le Resche et al. (1974) for moose in Alaska. They suggest that lower values in Minnesota moose (49-56 mg/100 ml) may be attributable to differences in diet and rumen function. Serum cholesterol levels obtained in this study were higher than those obtained by Seal et al. (1978) for white-tailed deer fawns (41 - 60 mg/dl), Barrett and Chalmers (1977) for antelope (37 - 58 mg/dl) and similar to those obtained by Seal et al. (1978b) (67-90 mg/dl) in adult white-tailed deer. Franzmann (1972) obtained serum cholesterol values for bighorn sheep which varied from 71-96 mg/100 ml due to variations in excitability.

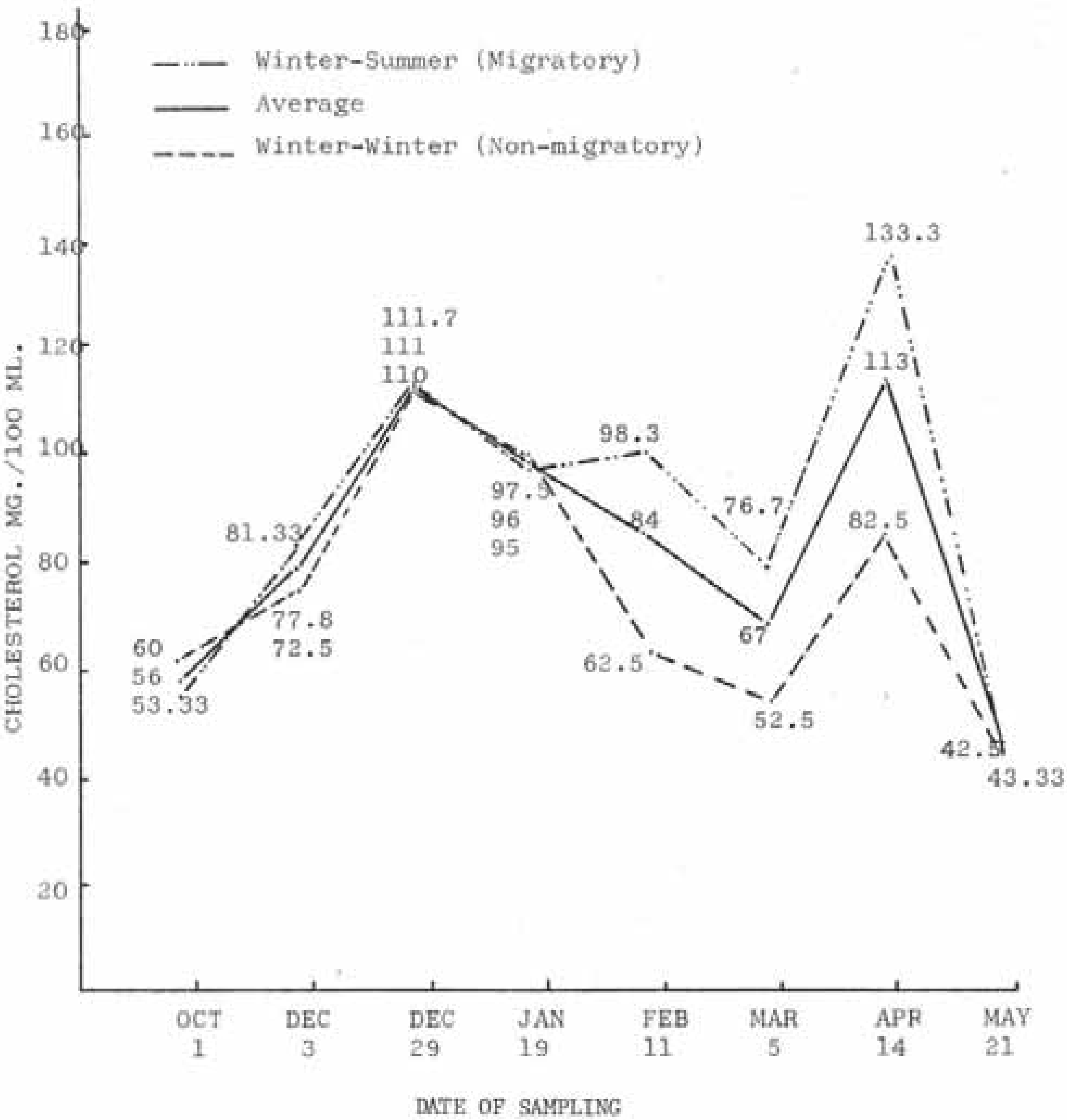

FIGURE 4. Serum cholesterol level changes in bighorn sheep on different quality diets.

BUN - NUTRITION

Seasonal blood urea nitrogen values were related to nutritional measurements shown in Table 1 & 2 for both groups of sheep. Generally, the number of significant relationships increased for both groups as anabolic points were removed and submaintenance diets reflected catabolic processes. Similarly, nitrogen retained/gm of ingested nitrogen and urinary protein/gm of ingested protein are specific indiators of metabolic nitrogen, significant for both groups at p = .05 in 4 and 5 computer runs, respectively. More general nutritional measurements were significant in only 1 or 2 computer runs. In addition, more nutritional variables (63 as compared to 41) were significant (digestible protein, body weight, nitrogen retained) for the non-migratory group due to its extensive and more consistent period of catabolism. Although the significance of the change in the number of significant nutritional variables for each computer run is difficult to interpret without additional experimentation, it does appear to be related to the effects of the change-over between anabolism and catabolism. Removal of the effects of the high quality diet (computer run 2) for the non-migratory group increases the number of significant regressions from 3 to 15. However, removal of the first and last (high quality diet) points reduces the number of of significant regression from 15 to 4 due to the effects of the anabolic point (5th point) produced by the multiple vitamin tonic. Removal of the anabolic points (5th and last) increases the significant relationship from 4 to 18. A slight further improvement is provided by removal of the first point which may be partially influenced by the change from anabolism to catabolism. The migratory group, by comparison

SIGNIFICANT BLOOD UREA NITROGEN VALUES FOR THE NON-MIGRATORY GROUP

NUTRITIONAL PARAMETERS	COMPUTER RUN 1		2		3		4		5		
	sig	r	sig	r	sig	r	sig	r	sig	r	Total
Feed intake gm/day							.05	.81			1
Feed intake/Kg BW									.008	.97	1
Feed intake/Kg BW .75									.01	.95	1
Per cent apparent digestibility of dry matter			.04	.79			.003	.95	.01	.96	3
Per cent crude protein in forage			.03	.81			.002	.97	.01	.96	3
Protein intake gm/day							.02	.89	.01	.96	2
Protein intake/Kg BW							.01	.90	.01	.96	3
Per cent digestible protein			.05	.75			.01	.91	.01	.96	3
Digestible protein gm/day			.05	.76			.009	.92	.01	.96	3
Digestible protein/Kg BW			.03	.79			.004	.95	.006	.97	3
Nitrogen balance gm/day			.04	.77			.006	.94	.009	.96	3
Nitrogen retained/gm of ingested nitrogen			.01	.85	.04	.84	.001	.97	.007	.97	4
Nitrogen retained/Kg BW			.03	.80			.004	.95	.009	.96	3
Nitrogen retained/Kg BW .75			.03	.79			.004	.95	.009	.96	3
Per cent crude protein in feces									.02	.94	1
Fecal crude protein gm/day									.02	.94	1
Fecal protein/gm of ingested protein			.01	.85	.04	.84	.001	.97	.007	.97	4
Fecal protein/Kg BW			.04	.77			.01	.91	.01	.95	3
Fecal protein/gm of food intake					.03	.86			.006	.97	2
Urinary protein gm/day									.01	.96	1
Urinary protein/gm of ingested protein	.02	.78	.04	.79	.05	.81	.008	.93	.01	.96	5
Body weight Kg	.03	.76	.05	.76			.007	.93	.03	.92	4
Body weight change Kg											0
Body weight .75	.02	.77	.04	.77			.006	.94	.009	.96	4
Digestible protein gm/day/ Digestible energy meg. cal.			.03	.79			.003	.96	.01	.96	3
Total	3		15		4		18		23		63

TABLE 1. A comparison of the number of significant relationships between nutritional measurements and BUN for the non-migratory group.

SIGNIFICANT BLOOD UREA NITROGEN VALUES FOR THE MIGRATORY GROUP
COMPUTER BUN

NUTRITIONAL PARAMETERS	1 sig	1 r	2 sig	2 r	3 sig	3 r	4 sig	4 r	5 sig	5 r	Total
Feed intake gm/day									.05	.88	1
Feed intake/Kg BW	.05	.70							.05	.87	2
Feed intake/Kg BW .75									.04	.89	1
Per cent apparent digestibility of dry matter	.006	.86									1
Per cent crude protein in forage	.003	.89							.05	.87	2
Protein intake gm/day	.004	.88							.05	.87	2
Protein intake/Kg BW	.003	.89							.05	.87	2
Per cent digestible protein	.02	.79							.05	.88	2
Digestible protein gm/day	.003	.90									1
Digestible protein/Kg BW	.002	.90									1
Nitrogen balance gm/day											0
Nitrogen retained/gm of ingested nitrogen			.04	.79	.03	.85	.03	.84	.03	.91	4
Nitrogen retained/Kg BW									.05	.88	1
Nitrogen retained/Kg BW .75									.05	.88	1
Per cent crude protein in feces	.002	.91							.05	.87	2
Fecal crude protein gm/day	.02	.78									1
Fecal protein/gm of ingested protein					.02	.87			.02	.94	2
Fecal protein/Kg BW	.01	.82									1
Fecal protein/gm of food intake	.03	.75							.05	.87	2
Urinary protein gm/day	.005	.87							.05	.87	2
Urinary protein/gm of ingested protein	.05	.71	.008	.89	.03	.86	.01	.91	.02	.93	5
Body weight Kg									.05	.87	1
Body weight change Kg	.09	.84									1
Body weight .75									.05	.87	1
Digestible protein gm/day/ Digestible energy meg. cal.	.005	.87							.05	.87	2
Total	16		2		3		2		18		41

TABLE 2. A comparison of the number of significant relationships between nutritional measurements and BUN for the migratory group.

experienced changes from anabolism to catabolism within the total sampling period (points 2-5) rather than at either end, as shown by the non-migratory group. Thus, BUN was significantly related to the nutritional variables when all anabolic points were included (computer run 1) or when they were excluded (computer run 5). Exclusion of a single or 2 of 3 anabolic points (computer run 2, 3 and 4) did not improve the level of significance. Sampling for BUN during a metabolic changeover period may produce results which do not adequately describe the condition of the animal or the population.

Preliminary data (Hebert 1973) indicates that fecal nitrogen (per cent crude protein in the feces) may be useful as an indicator of animal condition or population productivity. The potential of this nutritional parameter as an indicator of the status of the animal or population is suggested by its significant relationship with BUN in computer run 1 and 5 ($p = .002$, $r = .91$; $p = .05$, $r = .87$, respectively) for the migratory group and computer run 5 for the non-migratory group ($p = .02$, $r = .94$). These particular computer runs best describe the nutritional status of the group as evidenced by the number of significant relationships (16 to 23).

Interestingly, significant relationships were obtained with BW and $BW^{.75}$ for the non-migratory group (4 of 5 computer runs) which Le Resche _et al_. (1974) suggest are collective manifestations of nutritional intake. Both BW and $BW^{.75}$ were significant for the migratory group in computer run 5, which is the best nutritional description of this group. Similarly, BUN appears to describe both the protein and energy status of the animal through a significant relationship with the digestible protein to energy ratio. Thus, the best nutritional assessments of each group (computer run 1 and 5 for the migratory group; r = .87 and computer runs 2, 4 and 5 for the non-migratory group; r = .79, .96, .96, respectively) included this significant relationship.

Previously, Preston et al. (1965) and Somers (1961) demonstrated that protein intake was significantly related to BUN (expressed as CP gm/ $w^{.75}$, r = .99 or as gm/day, r = .97, respectively). This relationship was supported by the work of Lewis (1957) and McIntyre (1970). These studies utilized domestic animals and expressed the relationship at above maintenance levels of CP intake. Similarly, results from this study indicate a significant relationship between BUN and per cent CP in the forage, protein intake in gm/day and protein intake/Kg BW for the migratory group in computer run 1 and 5 (r = .89) and for the non-migratory group in computer run 4 and 5 (r = .90 and .96, respectively).

HEMATOCRIT, HEMOGLOBIN, CHOLESTEROL - NUTRITION

Hematocrit and hemoglobin do not show seasonal trends (Figure 3) and are not significantly related at P = .05, to the measured nutritional parameters for either group or any computer run. Cholesterol was regressed with 9 energy nutritional measurements (gross energy and digestible energy (DE)/day, /Kg BW and /Kg $BW^{.75}$; %DE, DE/gm of feed intake and DP gm/day/DE meg. cal.) in an attempt to assess energy metabolism of the wintering ungulate. There were no significant relationships at the level of P = .05.

POPULATION CONDITION

The use of blood chemistry will allow an assessment of nutritional condition and/or population productivity through seasonal comparison of relative values. However, frequency of sampling necessary to quantify seasonal periods an animal remains at each level of condition, is usually inadequate to pinpoint specific periods of change in animal growth or metabolism (Figure 5). Thus, it is more important to determine the length of time an animal or population sustains itself at submaintenance levels, if assessment of population productivity is the desired goal than it is to simply determine that they are at submaintenance levels. Consequently, the assessment of condition in Figure 5 may be expressed as PERIOD AT MAINTENANCE OR SUBMAINTENANCE X CONDITION LEVEL (BUN). Similarly, the assessment of productivity of the population may be expressed as: PERIOD OF ACTIVE GROWTH (GREENUP TO BIRTH) X LEVEL OF GROWTH OR CONDITION (BUN) (FECAL N). Population productivity may also be expressed as a response to: PERIOD AT MAINTENANCE OR SUBMAINTENANCE X CONDITION LEVEL (BUN) + PERIOD OF ACTIVE GROWTH X LEVEL OF GROWTH OR CONDITION (BUN) (FECAL N), or as a condition indice of the growth period minus the condition index of the maintenance period.

DISCUSSION

Blood urea nitrogen has been used as a valuable tool in the assessment of above maintenance protein status of the domestic ungulate for several years (Preston et al. 1965, Somers 1961). Only recently has it been examined (Franzmann 1972, de Calesta et al. 1977, Seal et al. 1978a, b) as an indicator of nutritional status of the wild ungulate. To date, BUN has not been adequately related to the below maintenance protein status of a wintering ungulate. Consequently, the BUN curve which is a function of CP intake (Preston et al. 1965, Franzmann et al. 1972) at above protein maintenance levels may have similar BUN values to the BUN curve at below protein maintenance levels. This was not addressed by Le Resche et al. (1974), Seal et al. (1978), or Franzmann (1972) and depending upon the frequency of sampling within the population may produce similar individual values from an increasing or decreas-

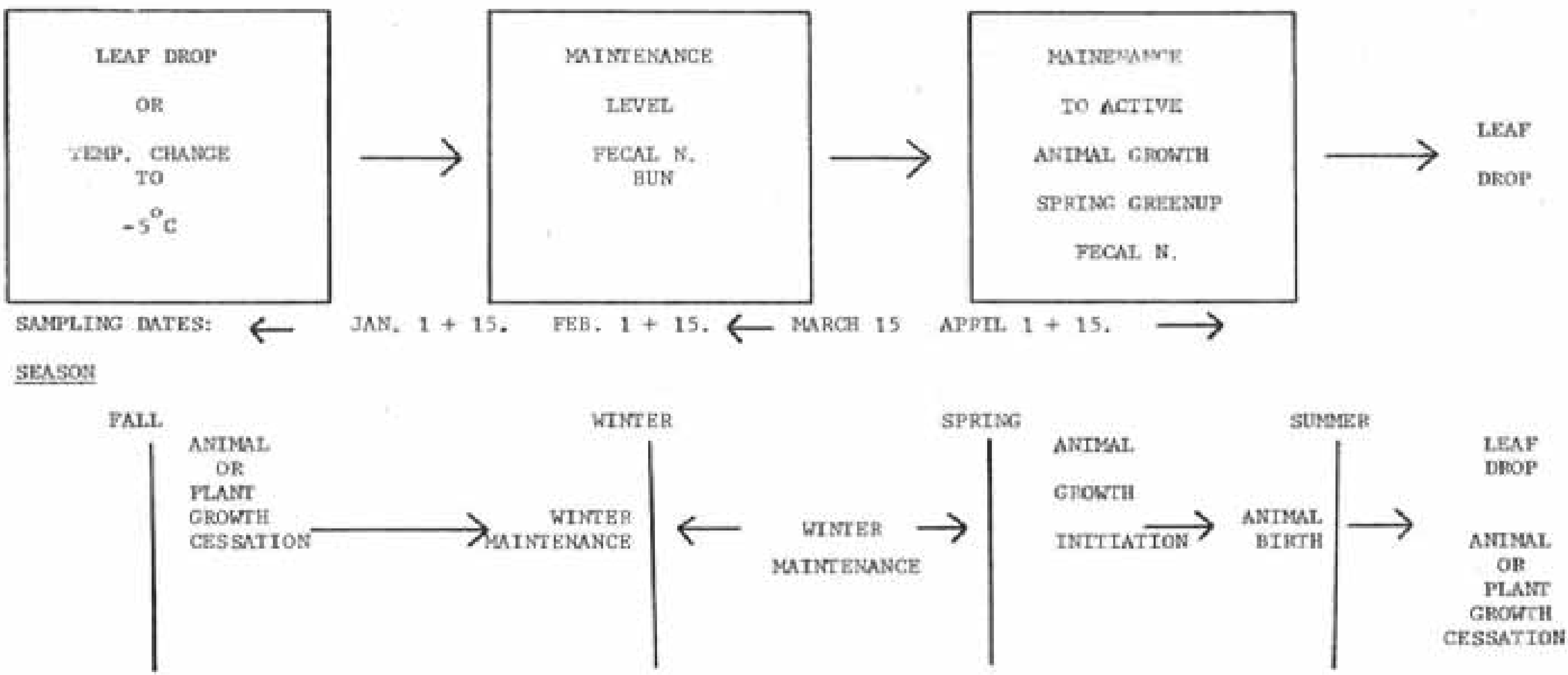

FIGURE 5. The relationship between phenology, animal condition and the seasonal time available for each process.

ing curve, since wild animals lack synchrony of declining physical condition (de Calesta 1977). It will be necessary to accurately determine the physical boundaries and parameters of the population to be sampled.

For the majority of variables, blood chemistry is still at the stage of determining base line values in the face of many uncontrolled field variables. In most studies there are too few samples to standardize for age, sex, season, habitat, climate, and declining forage quality. In some instances (BUN, inorganic phosphorus, calcium, etc.) certain values have been related to crude indices of condition but few studies of wild animals have related blood chemistry to specific nutritional measurements (de Calesta 1977). Currently, the majority of studies have concentrated on comparing relative BUN (Franzmann 1972) or inorganic phosphorus (Hebert 1972) values between seasons in their assessment of change in nutritional status. If blood chemistry is to adequately assess nutritional condition or address the variables of population productivity, recruitment or overwinter mortality, they must quantify the time period in addition to the relative seasonal assessment. Thus, the sequence and intensity of sampling become important criteria in the assessment of nutritional condition. Similarly, complementary sampling programs are important in discerning the anabolic from the catabolic BUN curve. For example, fecal nitrogen can be utilized to indicate whether an animal is above or below the protein maintenance level. In addition, fecal nitrogen is a sensitive indicator of the change between submaintenance levels of winter forage and high quality spring forage. BUN alone or with fecal nitrogen can be used to assess the relative differences between populations in the timing of dietary quality change or the relative magnitude of the change. It is apparent from this study that frequency of sampling must recognize the timing of changes in dietary quality, the period at maintenance or submaintenance and the period of previous nutrition as it influences the change between anabolism and catabolism. The non-migratory group began to change from a state of anabolism to catabolism around October 1, approximately 3 -3.5 months ahead of the migratory group. Although both groups received the same low quality diet during this period, the previous superior nutrition of the migratory group maintained their nutritional status. Similarly, hemoglobin and hematocrit can be used to indicate nutritional differences between populations or habitat types (Franzmann 1972) but may not be as useful in the assessment of relative magnitude of difference or the assessment of the time period at any particular level of condition. A detailed assessment of nutritional condition as it relates to productivity or winter mortality will undoubtedly require a combination of methods to achieve a satisfactory assessment.

The study of fat metabolism (energy) in relation to blood constituents has received little study (Le Resche et al. 1974). Coblentz (1975) feels that the chemical component used in management should be correlated to the quality of the animals diet and be involved with energy production or storage. de Calesta et al. (1977) found that free fatty acids changed during starvation, indicating that fat stores were mobilized to offset inadequate energy intake.

Coblentz (1975) and Le Resche et al. (1974) suggest that of the lipids, cholesterol may be the most important indicator of animal condition while Le Resche et al. (1974) indicates that both cholesterol and triglycerides are low in Cervids and that triglycerides will probably not be useful. In contrast, Allen (1970) indicates that triglycerides comprise 83% of the dietary lipids which enter the lacteals while cholesterol, esters and free cholesterol comprise only 7%. However, this study indicated non-significant relationships between cholesterol and specific energy intake measurements, although the seasonal curve and actual values compare favourably with Le Resche _et al_. (1974) but diverge from Coblentz (1975).

Recently, Seal _et al_. (1978b) showed a highly significant increase in non-esterified fatty acid levels (NEFA) on low energy diets and suggests that they can serve as an indicator of energy intake in deer. Similarly, Seal and Hoskinson (1978) found a 2-fold difference in serum triglycerides between 2 pronghorn antelope populations differing in nutritional status.

It appears that the energy status of wild ungulate populations should concentrate on NEFA and triglyceride levels and abandon cholesterol values.

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PREDICTION OF ENERGY EXPENDITURES
BY ROCKY MOUNTAIN BIGHORN SHEEP

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ABSTRACT

Factors influencing the metabolic rate of Rocky Mountain bighorn sheep were analysed by multiple classification analysis. Factors considered were sex, date, body weight, exposure temperature, adaptation temperature, time since last feeding, and previous gross energy intake. The overall mean energy expenditure was 2632 $kcal.d^{-1}$ (110 $kcal.kg^{-.75}.d^{-1}$). When factors were tested independently, body weight, sex and exposure temperature, in order of importance, contributed significantly to differences in energy expenditures. The total statistical model accounted for 87% of variance in the rate of energy expenditure.

INTRODUCTION

Energy metabolism represents an important adaptation of wild ruminants to their environment. The value of being able to predict energy expenditures of free-ranging animals has been highlighted in a number of studies on the consequences of behavioural patterns and, particularly, the impact of harassment. Unfortunately, energy expenditure is difficult to measure in wild species and information has accumulated slowly.

The usual procedure used to estimate energy expenditure is to estimate basal metabolism from body weight, increment it arbitrarily to obtain

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resting metabolic rate, the appropriate base, and then add the estimated energy costs of activity and thermoregulation. However, a number of factors influence resting metabolic rate. These include body weight, age, sex, season, nutritional status, ambient temperature, and adaptation to prevailing thermal environments. Several studies on wild ruminants have attempted to determine the importance of these factors. In the Cervidae, most studies have dealt with seasonal cycles of energy metabolism (Silver et al., 1971) or the effects of exposure temperature (Holter et al., 1975), age (Wesley et al., 1973) and feeding level (Weiner, 1977).

Rather than determine the importance of these factors in controlled experiments, we have attempted to develop a predictive equation based on measurement of energy expenditures of bighorn sheep under a variety of conditions throughout the winter season. This study represents an extension of an approach applied by Graham et al. (1974) in a study on domestic sheep.

ACKNOWLEDGEMENTS

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METHODS

Animals available for this study included two adult male and two adult female Rocky Mountain bighorn sheep (Ovis canadensis). One ewe was captured in Jasper National Park while the remaining subjects were reared in captivity. They were held in a large enclosure and maintained on grass hay and a pelleted alfalfa-barley ration throughout the period of study (Chappel, 1978).

Indirect calorimetry, using the respiratory pattern analyzer described by Young *et al.* (1975), was used to determine metabolic rates at controlled temperatures of 10°C to -30°C. Oxygen consumption and carbon dioxide production were converted to an energetic equivalent using the equation of Brouwer (1965). From September to May, measurements of RMR and FMR (after a 72-hour fast) were made at monthly intervals, and body weights and mean environmental temperatures for three days prior to the trail were recorded. Mean gross energy intakes of the pelleted ration were recorded in individual feeding stalls for the two weeks preceding each trial. A total of 124 measurements of metabolic rate provided the data base for this study.

Explanation of variability in energy expenditure, under a variety of experimental conditions, was sought through multivariate analysis of the interrelationship of the dependent variable (metabolic rate) and several independent variables (body weight, sex, month, exposure temperature, adaptation temperature, time since last feeding, and previous gross energy intake). Multiple Classification Analysis (MCA, Andrews *et al.* 1973) was chosen to examine the correlation of a set of predictors with the dependent variable in the context of a linear additive model.

Several statistics were employed to determine the fit of both individual predictors alone and with others of the same set. The *Eta*-squared coefficient (correlation ratio) denoted the proportions of variance explained solely by that predictor. *Beta* coefficients expressed the value of each predictor after adjusting for the effects of all other predictors. Category coefficients were obtained through solution of least squares equation (Anderson and Bancroft, 1952). The fit of the total model was determined by an R-squared value. Significance was tested using the F test.

This analysis produces a coefficient for each category of every predictor in the model. The sum of coefficients for the appropriate categories, plus the value of the grand mean, provide a prediction of metabolic rate.

RESULTS AND DISCUSSION

The grand mean metabolic rate of bighorn sheep was 2632 $kcal.d^{-1}$. Collectively, the seven independent variables accounted for 87% of variation.

When effects were examined independently, body weight, sex, ambient temperature at the time of measurement and month accounted for significant variation (Table 1). When effects were partitioned, month emerged as one of the most important variables followed by exposure temperature, body weight, adaptation temperature measured 3 days prior to the trial, sex, previous nutrition and time since last feeding.

Body Weight

As an independent effect, body weight explained the greatest proportion of variance in metabolic rate. When variance was partitioned, it lost some of its former importance. Least squares-adjusted means of metabolic rate as a function of body weight are shown in Figure 1. Over the restricted range of weights observed, the increase per unit body weight was approximately linear. Expressed on the basis of metabolic rate the overall mean metabolic rate was 110 $kcal.w^{-.75}.d^{-1}$.

TABLE 1

STATISTICAL SUMMARY OF FACTORS INFLUENCING METABOLIC RATE OF BIGHORN SHEEP

Predictor variable and categories	Eta^2	Beta	Class Coefficients
Body weight (kg.)	0.40	0.36	
50-62			-285.91
63-65			-122.60
66-70			31.74
71-75			87.88
76-88			341.93
Sex	0.31	0.20	
Female			-117.45
Male			177.45
Date	0.17	0.53	
Sept.-Oct.			-93.23
Nov.-Feb.			-250.43
Mar.-Apr.			240.10
May-June			864.13
Exposure temperature	0.28	0.45	
-35 to -20			1470.00
-20 to -10			-28.90
-10 to 0			-28.24
0 to 10			-90.14
Adaptation temperature	0.03	0.23	
-35 to -10			45.38
-10 to +10			56.59
10 to 20			-359.57
Fasting	0.09	0.17	
Fed			45.45
Fasted			-237.37
Previous nutrition ($kcal.kg^{-.75}.d^{-1}$)	0.04	0.27	
55-183			-128.78
183-220			-210.24
220-256			-53.62
256-330			202.10
330-515			223.64

R^2 complete model = 0.87 ($P < .001$)
Grand mean = 2631.87 $kcal.d^{-1}$

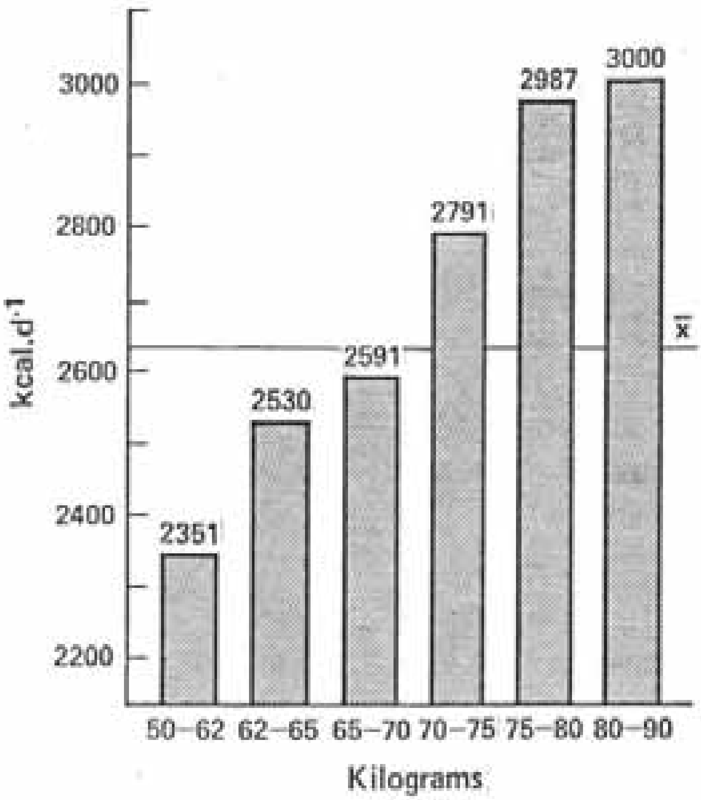

Fig. 1. Least squares means of metabolic rates in relation to body weight (kg). Grand mean metabolic rate denoted X.

Sex

Rams had metabolic rates which were 18% higher than those of ewes even when corrected for body weight differences (Figure 2). Although, in many species, the metabolic rate of males is higher than that of females, this apparently is not always the case with ruminants, perhaps because of the additional complexity of metabolic cycles. Silver et al. (1969) in a study on white-tailed deer did not find significant differences between does and bucks in summer coats. Wesley et al. (1970) found no obvious sex differences in pronghorn antelope. However, Graham (1968) reported that Merino rams had an FMR that was approximately 20% higher than wethers and ewes. Nordan et al. (1970) obtained similar results in black-tailed deer fawns.

Month

Month was an important predictor of metabolic rate when effects were fit jointly. Metabolic rates declined from fall to mid-winter, then rose to a peak in early summer (Figure 3). The amplitude of this oscillation was greater than 40%.

Because data were not collected for a complete seasonal cycle, it is difficult to compare these results with those reported for northern cervids. Silver et al. (1969, 1971) observed values in white-tailed deer which were greater than 50% higher in summer than in winter. Somewhat narrower contrasts were observed by McEwan and Whitehead (1970) in caribou. Weiner (1977) found seasonal variations in roe deer that amounted to less than 10%, while Brockway and Maloiy (1967) did not observe seasonal changes of metabolism in red deer. Differences among

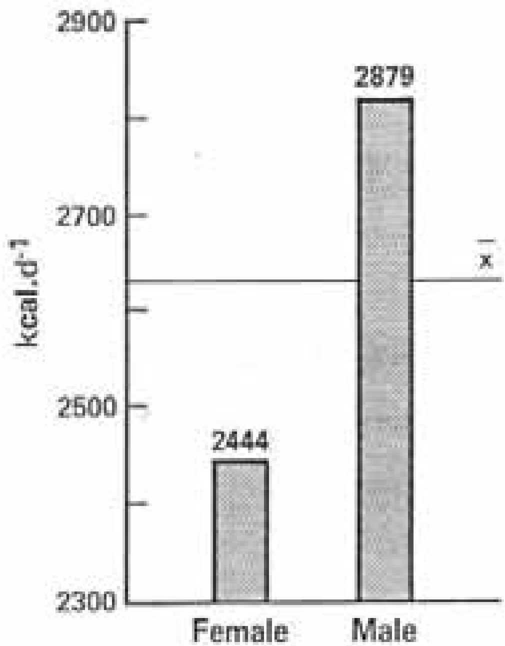

Fig. 2. Least squares means of metabolic rates of ewes and rams.

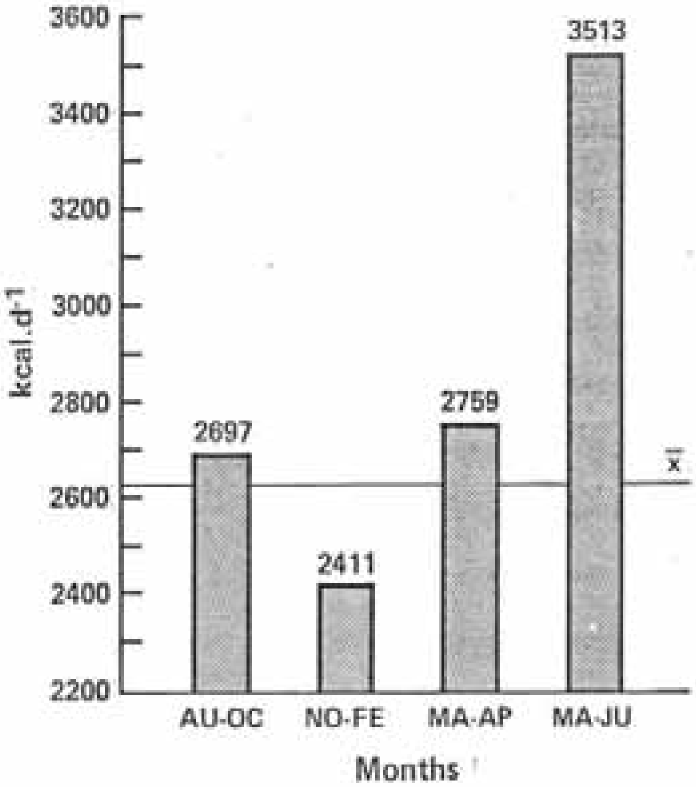

Fig. 3. Least squares means of metabolic rates in relation to dates of measurement.

these studies may be related to the environmental conditions under which animals were held. Photoperiod appears to be a dominant factor regulating seasonal metabolic cycles in wild ruminants (McEwan, 1975).

Exposure Temperature

The range of exposure temperatures used in this study included those which invoked a strong thermoregulatory response. The metabolic response to cold is shown in Figure 4. Temperatures as low as -20°C were within the thermoneutral zone but, between -20° and -30°C, metabolic rates rose sharply. Chappel (1978) has reported controlled experiments on the independent and combined effects of ambient temperature and wind on Rocky Mountain bighorn sheep.

Critical temperatures of bighorn sheep appear considerably lower than those of a number of other species of similar size. In winter coat, the lower critical temperature of roe deer, one of the smallest northern cervids, is about 0°C (Weiner 1977). Holter *et al.* (1975) estimated the comfort zone for white-tailed deer in winter to be between 5°C and 20°C. Wesley *et al.* (1973) found the critical temperature for fasting pronghorn antelope to be near 0°C and for fed animals to be between -12°C and -23°C. The superior cold tolerance of bighorn sheep, in comparison with deer, may be related to their habitat preferences. Bighorn sheep select open windswept slopes during winter, whereas white-tailed and roe deer seek forest cover where the opportunities to select favorable micro climates exist. Pronghorn antelope live in open country but do not match the northerly distribution of Rocky Mountain bighorn sheep.

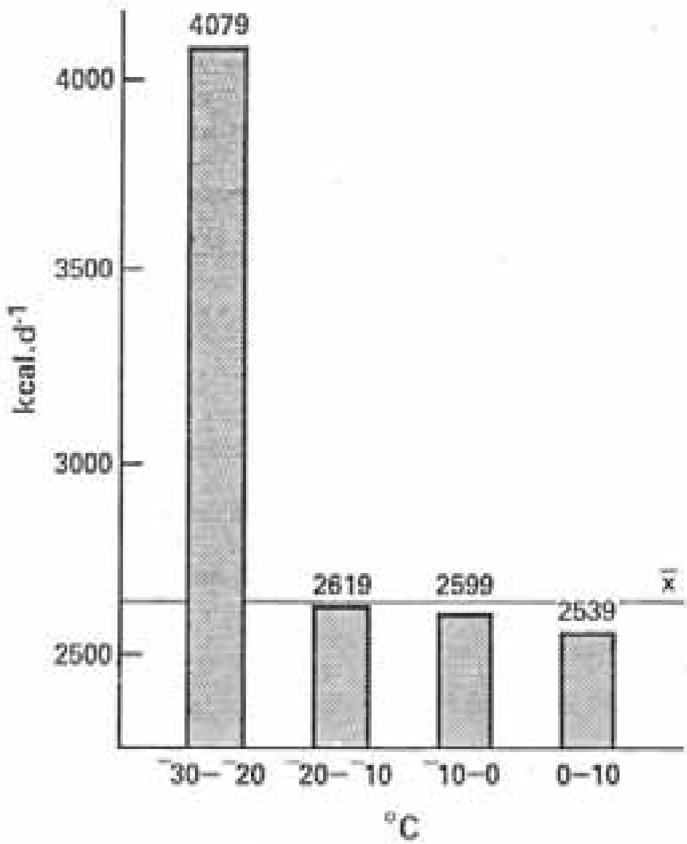

Fig. 4. Least squares means of metabolic rates in relation to exposure temperature.

Adaptation Temperature

Prolonged exposure to low ambient temperatures induced an upward adjustment of metabolic rate (Figure 5). Although mean ambient temperatures at 1 day, 3 days, 1 week, 2 weeks and 1 month prior to metabolic trials were examined, the best improvement of fit of the model was obtained with mean ambient temperatures for 3 days prior to measurement.

This factor has received little attention in studies on wild ruminants. However, gradual increases in thermoneutral metabolic rate have been found in domestic sheep (Webster _et al_. 1969) and cattle (Young, 1975) exposed to winter weather.

Fasting

In this study, bighorn sheep were fasted either 8 hours (fed group) or 72 hours (fasted group). The extent of the fast accounted for a relatively small proportion of variance, but mean differences of about 13% were observed (Figure 6).

Weiner (1977) found the resting metabolism of non-fasted roe deer exceeded values for fasting metabolism by 25-30%. McEwan (1970) estimated the difference in reindeer to be almost 20% whereas Wesley _et al_. (1973) reported the difference in antelope to be over 50%. In comparing these values, it is important to recognize that metabolic rate declines rapidly following feeding (Chappel 1978) so that differences may be due entirely to the exact time since the last meal.

Previous Nutrition

The mean intake of gross energy (kcal.kg$^{-.75}$) during the previous 2 week interval generally increased energy expenditures of bighorn sheep

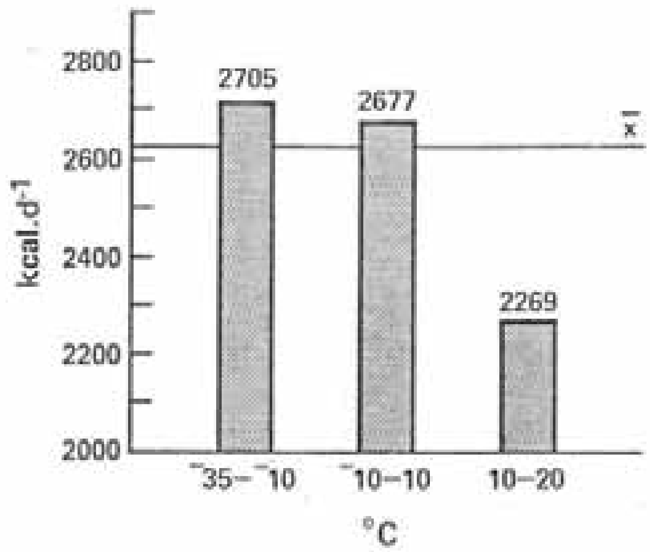

Fig. 5. Least squares means of metabolic rates in relation to mean ambient temperatures for 3 days prior to measurement.

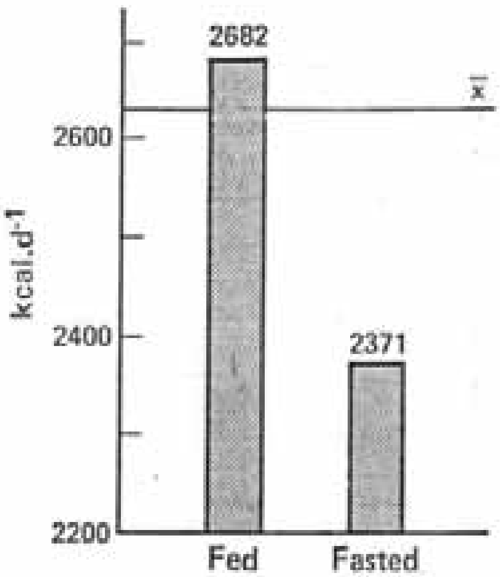

Fig. 6. Least squares means of metabolic rates of animals fasted 8 hours (fed) or 72 hours (fasted).

(Figure 7). The lowest category was made up largely of rams in rut. This may explain the deviation from a direct linear relationship.

The importance of nutritional status has been well established in work on domestic animals. Marston (1948) found differences between domestic sheep fed either at ½ or 2 times maintenance requirements which were evident up to 7 days of fasting. Graham et al. (1968) also found a direct effect of previous energy intake on metabolic rates of domestic sheep.

Application of the Statistical Model

To predict the metabolic rate of bighorn sheep within the range of conditions used in the construction of this model, the appropriate class coefficients (Table 1) are summed and added to the grand mean. The BMR of an animal weighing 66 - 70 kg. can be estimated by summing those coefficients which define the measurement (date of lowest metabolic rate, thermoneutral exposure temperature, thermoneutral adaptation temperature, fasted state and lowest level of previous nutrition). For males, the predicted value was 1714 $kcal.d^{-1}$, and for females 1480 $kcal.d^{-1}$. Using the mid-point weight, this was equivalent to 77 $kcal.kg^{-.75}.d^{-1}$ and 63 $kcal.kg^{-.75}.d^{-1}$ for males and females, respectively. This is in agreement with the accepted interspecies mean of 70 $kcal.kg^{-.75}.d^{-1}$. Approximate energy budgets of free-ranging bighorn sheep can be estimated by choosing the coefficients relevant to prevailing environmental conditions. Where certain variables cannot be measured in the field (e.g., level of forage intake), a value of zero can be substituted as a best estimate since the coefficients are simply added to the overall mean. Since the

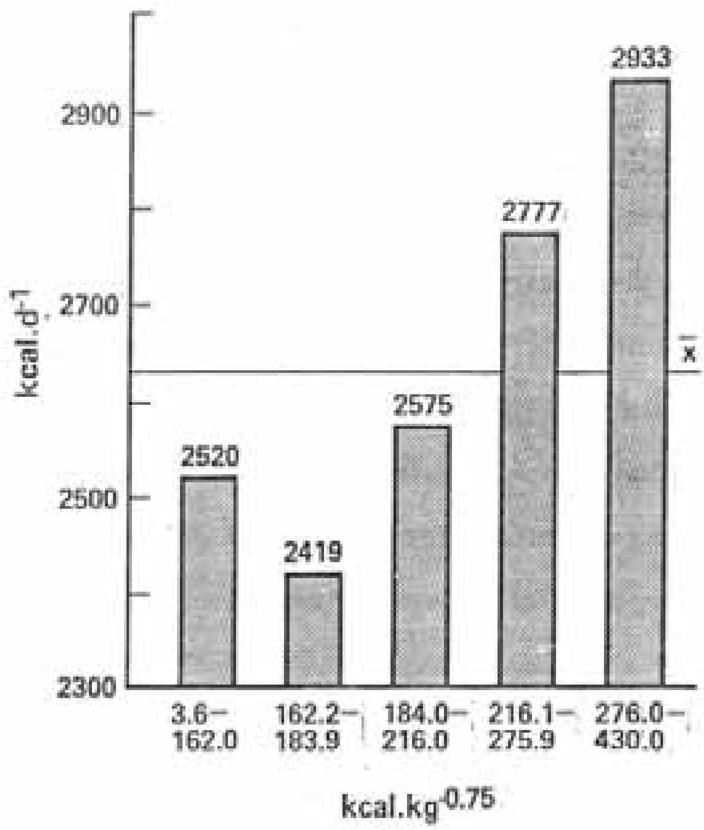

Fig. 7. Least squares means of metabolic rates in relation to mean gross energy intakes during two weeks prior to measurement.

model predicts only resting metabolic rate, costs of feeding and locomotion must be added. Chappel (1978) estimated the cost of feeding to be approximately 32% of resting metabolic rate. The energy expenditure of bedding animals was 18.9%. Since this model predicts expenditures of animals which were standing, this increment is subtracted to obtain the appropriate value for bedding animals. In our studies, the energy cost of locomotion of bighorn sheep has not been determined. However, activity increments measured in a wide variety of species, including elk which we have studied on treadmills, suggest a value of 0.5 $kcal.kg^{-1}.km^{-1}$. This could be used as an approximation until specific information on bighorn sheep becomes available.

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RANGE, PHYSIOLOGY AND NUTRITION - Chairman: Dr. D. Shackleton

T.G. Baumann and D.R. Stevens - Winter habitat preference of bighorn sheep in the Mummy Range, Colorado.

Ray Demarchi: What happened to the other 4/5ths of your mountain bighorn winter sheep range?

Tim Baumann: Loss to development around the resort community of Estes Park - mainly fencing, grazing by livestock, and human disturbance.

Ray Demarchi: Have you thought about forest succession? All the plant species you mentioned are either fire tolerant or fire dependant.

I think you've done an excellent investigation on the habitat factors, and influence and movements of the bighorn, however, you had also better start looking at the fire dependant plant communities.

Tim Baumann: Colorado State University has begun a study of fires; They have done several experimental burns adjacent to the study area.

M.D. Pitt and B.M. Wikeem - Diet preference of California bighorn sheep on native grassland in south-central British Columbia.

Don Eastman: I am interested in your comments about rough fescue. Are there other plants in those timbered areas for which the sheep did not select?

Mike Pitt: There were other plant species in the understory, primarily Blue bunch. None-the-less they selected fescue in those understory areas more than Blue Bunch. Their preference for rough fescue throughout the first three summer months was approximately 10%, and during August it increased to 20%.

Daryll Hebert: Under captive conditions I found that rough fescue stood out as being equal to alpine or sub-alpine at a time when alpine forage was definitely high in quality. It also seemed to be selected over other plant species that were in the earlier phenological stages and probably of higher nutritional quality.

Mike Pitt: I do not think that animals necessarily select for crude protein, because part of that selection is for pallatability or desirability. Big sage brush is high in crude protein but animals do not select it because of the volatile oils. Blue bunch tends to grow in large bunches with old growth in the way and is not as desirable as selecting a plant that has only fresh green material available. In the early spring on the study site they have grazed it to the ground. On the other hand June grass and Sandberg's blue grass both grow with only green material, there is no old growth in the way. It is partly an availability factor and partly a proportion of old growth to new growth.

Randy Bennett: It looked like some of your plants were being strongly selected for and this should change plant species composition within your paddock. How will this effect your results in future years?

Mike Pitt: Certainly the range this spring is much different than it was last spring; many of the browse species are not available. The real changes in their selectivity and diet patterns will occur later in the year, and I expect they will go the blue bunch.

Randy Bennett: Are you trying to regulate the number of animals in the paddock?

Mike Pitt: Yes, we base our carrying capacity primarily on the amount of grass material, biomass, available. If there are too many animals then they lose selectivity and will have to eat whatever is there.

Bill Wishart: Do the sheep leave seed heads alone?

Mike Pitt: Yes, however, just going to seed will not necessarily guarantee survival of the plants. If they are grazed to the ground they are not going to be able to produce enough new carbohydrates to last the winter in terms of root reserves. Blue bunch is a notoriously low seeder, it happens only rarely or infrequently. With this utilization, even having seed heads will not necessarily ensure survival of these plants.

R. Peterson and A. Bottrell - Normal metabolic profiles of lamb and adult California bighorn sheep

Dave Shackleton: I should point out that the melanin cycle is tied up with adrenalin, and of course that has behavioural connotations. Domestic calves with pink palates show quite marked excitability.

Steve Paul: I question the genetic significance of using those values because I think you are ignoring their clinical significance.

Ray Peterson: All age, sex, season, and interaction effects have been removed from these correlations.

We are trying to isolate what fraction of that difference is genetic and what fraction is environmental. We have labeled all the environmental factors we know at this point.

Jim Bailey: Could you explain to me what an inbreeding coefficient of 40% means. How is that calculated?

Ray Peterson: The inbreeding coefficient is, as Fisher defined it, the correlation between the combining gametes. That means 40% of the genes in that population are identical by descent. One can estimate this based on the number of breeding individuals and using probability theory.

Jim Bailey: You paint a very dismal picture about the possibility of inbreeding yet many examples of successful transplants started from rather small numbers of individuals. How do you rationalize that?

Ray Peterson: It surprised me when I heard recently there was, potentially, an inbreeding coefficient of 40% in a group. All I can say is that two things could be happening. First, the transplant was a fairly diverse group so you had a fairly large sample of genes and your inbreeding would be slower than normal. Or second, perhaps a more logical assumption, the tolerance to inbreeding in bighorn sheep is fairly high and levels can reach 40 or 50% while a certain reproductive vigour is still maintained.

Jim Bailey: Are you saying these populations will grow but, because of genetic effects alone, are doomed to fail?

Ray Peterson: Yes. Assuming that you have got enough food and so forth available, it will reach either a genetic limit, in terms of population size, which could be the inbreeding limit, or they will reach their environment limit.

Jim Bailey: If this population has grown and spread and occupied new areas, I wonder when it will come?

Ray Peterson: If you have crossing between populations, i.e., males from adjacent populations contributing, then of course this has a great deal to do with the level of inbreeding. A female does not make a great deal of difference but a male contributes genetically and produces gametes.

Wayne Heimer: Is there an intergradation as well? You suggested that they might be all black, sort of pink, or really pink.

Ray Peterson: I do not know. I saw only one pink tongue and they accused me of drinking too much beer. If we can get gene frequencies this gives us some handle on what sort of heterozygosity exists, particularly if we have a large number of these markers.

Daryll Hebert: Do you know if there is any information relating susceptibility of disease or parasites to the level on inbreeding in any species?

Ray Peterson: Inheritance of susceptibility to diseases is very hard to measure. You can note with inbreeding a decline in vigor and if you wish to extrapolate that it is also an increase in susceptibility to disease.

Ian Robertson: Are you in a position to say what sort of sampling of a wild herd is going to be necessary to establish inbreeding?

Ray Peterson: I do not think so at this point.

Anonymous: You speculated that in some of these transplants it may take several human generations for us to see a real decline in sheep populations. Can you project for a transplant of one productive male and five females, two or three of which are closely related.

Ray Peterson: If you assume the females are not related to the males then the coefficient relationship between the progeny is .25 - half sibs; there is no inbreeding at that point. Coefficient of inbreeding at the next level would be about .0625. By the third generation inbreeding will be on the order of about .25 if you close the herd at that point; 25%. Now, that is relative to when you started. Any inbreeding that you had to start with is added on top of that.

Anonymous: It might be possible to have reproductive depression within 10 or 15 years with a small plant?

Ray Peterson: I should think so. It depends on the tolerance of the species.

Anonymous: Is this mechanism for reproductive depression the exposing of homozygous recessive deleterious genes?

Ray Peterson: Yes, quite often. But when you are talking about the genetics of natural populations you are really dealing with it on a level of the tolerance of that species, and the rate of inbreeding expected under given conditions.

Bob Jamieson: Did you look at the managment implications of the research you are doing?

Ray Peterson: I think it will affect management decisions through the selection of the areas from which you selct animals for transplants. It is unlikely that a manager will see an increase in the lamb crop by importing rams or a die-off if inbreeding continues. It is important to determine the level of inbreeding they can attain and still reproduce adequately.

Bob Jamieson: That is only half of it. We have also to know what is the potential for these populations to keep that gene transfer going.

Ray Peterson: The other side of the coin is what rate of inbreeding is consistent with normal reproductive habits.

A. Bottrell, B. Gordy and R. Peterson - Comparisons of chromosome and blood constituents of Rocky Mountain and California bighorn and Dall and Stone thinhorn sheep

Wayne Heimer: I am interested in knowing what the chances are that what you saw in the bighorn might be an abnormality or an artifact, and what are the opportunities for error in a situation like this?

Al Bottrell: There are a lot of opportunities for error, and for determining it . I counted about 200 spreads and in 150 of them they showed the karyotype that I presented there. In other counts the number was less because they spread out and you lose some. That number ---150 out of 200--- is just too high a number, it can not be an artifact.

D.M. Hebert - Blood chemistry as an indicator of nutritional condition in bighorn sheep

Ross Eccles: If the body proteins catabolized during the winter, were they used as an energy source for the animals or were your feed values high enough in caloric value to satisfy them?

Daryll Hebert: I am sure they were being used for energy, and I think that is one reason why that digestible protein/digestible energy variable was relatable to blood urea-nitrogen. I was not making the type of measurements that would indicate how much was being metabolized as an energy source. The energy values that I was measuring were declining, but the gross energy component in the plants remained reasonably high, even during the winter, though that does not mean very much of it was available to the animals.

R.W. Chappel and R.J. Hudson - Prediction of energy expenditures by Rocky Mountain bighorn sheep

Jim Bailey: Could you give me a break-off point on how many miles per hour the wind speed was?

Bob Hudson: The highest wind speed tested was 10-12 m.p.h.

Ross Eccles: Were your coefficients additive? If the animal is subjected to minus 20 degrees and on a certain plan of nutrition, could you just add those?

Bob Hudson: Yes, that is the idea. This M.C.A. is a lot like multiple regression. The only difference is that, instead of using continous variables, they are broken down into discreet catagories which makes it easier for people to evaluate these things in the field. You simply sum them all up.

Rick Ellis: Could it explain things like large population die-offs?

Bob Hudson: I would say no. I would say nutritional factors affecting forage intake from ewe studies would appear to be the really critical thing.

Daryll Hebert: I found that when we had our animals down to about minus 20°F. for two and three week periods there was some attempt to respond with increased food intake, but the quality did not seem to be adequate to allow them to do it. What is the effect on an animal which cannot really respond to alow quality winter diet?

Bob Hudson: This could have serious consequences. Animals pushed into very poor body conditions because of forage quality may not be able to cope with the conditions to which we exposed these ones.

Daryll Hebert: I mentioned the same thing with blood-urea nitrogen: The time period that they spend at any one of these levels over the winter is going to be very important too, not just the fact that they reached it.

As another field technique, how useful do you think things like rectal temperature would be in measuring the time they reached a low level? The pattern that Al (Bottrell) and I found with rectal temperature corresponds with your energy finding.

Bob Hudson: I cannot really comment on that because we did not take consistent measurements throughout. In response to thermal environment, we looked at how it changed as we dropped environmental temperature, but not on a seasonal basis.

Daryll Hebert: Were there attempts to increase feed intake on the quality of diet you were giving them, after you had the animals at various levels at minus 21°(F), minus 30°(F)?

Bob Hudson: In his thesis, Randy (Chappell) had seasonal changes in food intake that showed the normal kind of cycle. I do not think he extracted how intake on any specific day might effect it. From elk studies it is quite clear that they do.

Wayne Heimer: How cold is a cold day on a Bighorn sheep range? Lower than minus 20°(F)?

Bob Hudson: Yes, quite often. Wind speeds are often higher, but associated with warmer temperatures.

Wayne Heimer: From your seasonal data it looks like November to February was the lowest. I am quite concerned about the idea that this energy expenditure during rut could be draining enough that rams may burn themselves out in a short time. Does that relate at all to that hypothesis?

Bob Hudson: We had wondered about this because we expected that rutting rams would have a very high metabolic rate but they did not.

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