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FOREWORD

The fourth biennial symposium of the Northern Wild Sheep and Goat Council was its first attempt to stage an international conference. Invitations were therefore sent to experts not only in North America but also in Europe and Asia. While few people from overseas were able to come to Whitehorse, there was wide-spread support for the idea of international meetings, similar to those conducted on a regular basis by caribou/reindeer, moose, furbearers or waterfowl experts. This support is reflected by the fact that some 20 papers were submitted to the Conference by authors from Europe and Asia who could not attend in person. In total some 60 papers were presented or were received and these were published in two documents.

This volume, entitled "Proceedings of the Fourth Biennial Conference of the Northern Wild Sheep and Goat Council" includes papers on a great variety of topics except for status reports. The status reports are contained in the second volume, a special publication by the Council, entitled "Wild Sheep - distribution, abundance, management and conservation concerns of the wild sheep of the world and closely related mountain ungulates".

Most papers in these volumes were reviewed by the sessional chairperson and one other member of the Council. However, in order to meet publication deadlines, not all papers could be subjected to this editorial process. Final versions of all papers were at the discretion of the authors. Differences of opinion between authors and reviewers did occur but were not numerous. In the realm of scientific inquiry, controversy is healthy and constructive. It stimulates professional dialogue, forces us to clarify positions and reassess hypotheses.

Awards were presented for two papers published in this volume. The Jonas Bighorn Trophy was awarded to D.K. Onderka and W.D. Wishart for their paper "A major bighorn sheep die-off from pneumonia in southern Alberta", and the award for an outstanding contribution to our knowledge about mountain goats was presented to C.A. Smith for his paper "Evaluation and management implications of long-term trends in Coastal Mountain goat populations in southeast Alaska". Citation for valuable contributions were also presented to A.V. Sandoval and T.R. Spraker, however, their papers were not submitted for inclusion into these proceedings.

Manfred Hoefs
Editor

SOME POPULATION CHARACTERISTICS OF DALL SHEEP IN SIX ALASKA NATIONAL PARKS AND PRESERVES

Francis J. Singer, National Park Service, Alaska Regional Office, 2525 Gambell Street, Room 107, Anchorage, Alaska 99503-2892

ABSTRACT

Dall Sheep (Ovis dalli dalli) were surveyed 1981-83 in six National Parks and Preserves in Alaska, which were newly designated in 1980. About 46 per cent of the sheep were observed in Preserves which are open to sport hunting and 54 percent in Parks or protected areas. Preserves contained 2-4x more legal rams per unit of land than Park lands. Sheep numbers averaged 76 percent higher than in the same portions of the new areas counted in the 1970's. Mature rams associated more with nursery groups than is commonly reported during summer and only minor segregation of ram groups was observed.

INTRODUCTION

In December 2, 1980, the Alaska National Interest Lands Conservation Act (ANILCA) was signed establishing 10 new National Parks, Monuments, and Preserves and adding lands to 3 existing National Park Service areas in Alaska. Six of the National Park Service areas had populations of Dall sheep. Sport hunting is allowed in the Preserve portions and limited subsistence hunting by local, traditional users is permitted in the Park portions of these areas.

The new Parks emphasized scenic mountainous terrain and interior areas and as a result, more Dall sheep were included than other Alaska big game species (Wright 1984). Events leading to ANILCA's passage on sport hunting of Dall sheep generated a considerable amount of debate. These events were reported in three papers presented at the Northern Wild Sheep and Goat Council Symposia (Heimer 1978; 1980; 1982). From 1981-83 the U.S. National Park Service (NPS) surveyed sheep populations in the newly designated areas. This paper presents information on the current numbers and some population features of Dall sheep in the Denali National Park and Preserve, Lake Clark National Park and Preserve, Wrangell-St. Elias National Park and Preserve, Gates of the Arctic National Park and Preserve, Noatak National Preserve, and Yukon-Charley Rivers National Preserve.

METHODS

Count units or sample blocks were arbitrarily delineated on the basis of major drainages and terrain. Efforts were made to reduce counting errors from

sheep movements by selecting unit boundaries on the basis of natural obstacles to sheep movements, such as broad flat areas, rivers, etc. Entire count units were surveyed in a day and in a consecutive fashion. Nevertheless, sheep movements undoubtedly occurred during the counting process but hopefully ingress approximated egress. Twenty-nine count units were established in Gates of the Arctic, 24 in Denali, 28 in Wrangell-St. Elias, 18 in the Noatak, and 6 in Lake Clark.

The NPS chartered helicopter (Bell Jet Ranger II) typically flew each count unit counter-clockwise thereby placing 2 observers on the left side of the helicopter against the mountain side, while the 3rd (right side) observer was responsible for observing lower slopes and across canyons. A single contour was flown usually at mid-slope except in Lake Clark and Wrangler-St. Elias, where the range of sheep habitat necessitated 2 flight contours. The following classification categories were employed: lamb, yearling, ewe, 1/4 curl ram, 1/2 curl ram, 3/4 curl ram, 7/8 curl ram, 4/4+ curl ram. Rams were assigned to the lowest category which they achieved. For example, a ram between 1/2 and 3/4 would be classified as 1/2. For the helicopter portion of the survey, this level of classification was obtained for 75 percent of the sheep seen in Denali, 95 percent in Wrangell-St. Elias, 98 percent in Lake Clark, 94 percent in Gates of the Arctic, and 82 percent in the Noatak. Some 1/4 curl ram in nursery groups were undoubtedly classed as ewes but this error source was minimized by the use of a spotting scope. Small groups were classified during 1 to 2 low passes but for larger groups of 20+, the helicopter landed 200-400 m away and 15-45x spotting scopes were used.

The Super Cub surveys were similar except that more effort was required to inspect narrow canyons, ravines and drainage heads. Also typically yearlings were not distinguished and all rams were classified as either $\leq$ 7/8 or $\geq$ 7/8 curl.

RESULTS AND DISCUSSION

Survey Effort

Approximately 505 hours of aircraft time were devoted to the counting of sheep in 1981, 1982, and 1983. These times include local travel to and from units, but not major moves or the time to supply base camps. Survey effort was 58 percent by the helicopter and 42 percent by Super Cubs. Pilot (B. Roberts) and classifier (F. Singer) were the same for 56 percent of the survey time. About 98 percent of the sheep-occupied areas in the six National Parks and Preserves were surveyed 1981-83 with both aircraft types, with 34% of the survey effort in 1981, 15% in 1982, and 51% in 1983.

The largest percentage of survey effort (36 percent) was devoted to Wrangell-St. Elias, 35 percent was devoted to Gates of the Arctic, 12 percent to Noatak, 6 percent to Denali, 4 percent to Lake Clark, and 4 percent to Yukon-Charley Rivers.

Sheep Numbers

Two large count units were not counted in Gates of the Arctic but sheep

numbers were estimated from adjacent surveyed units. Numbers in 4 other units in Gates of the Arctic were extrapolated from ADF&G counts made there in 1974. Only 2 mountains south of the Chitina River in Wrangell-St. Elias were uncounted -- only 78 sheep were counted there in 1973.

A total of 30,455 Dall sheep were counted in the 6 National Parks and Preserves. Approximately 16,523 (54 percent) of the sheep were in Park category lands and 13,932 (46 percent) in Preserve lands (Table 1). In all but Denali, the highest densities were in the Preserve sectors. Also, one count unit in Gates of the Arctic, and 7 count units in Wrangell-St. Elias are split between Park and Preserve status, suggesting additional sheep might be available for sport hunting if they moved through the mountains at hunting season. Location of sheep harvest influenced placement of Preserve boundaries (Wright 1984) and as a result, 79 percent of the sheep in Wrangell-St. Elias, the most significant State sheep harvest area, were observed in the Preserve.

We counted 76 percent more sheep in 1981-83 than were counted in 1972-78 in previously-counted portions of the Parks and Preserves (Table 2).

The considerable increases in sheep seen in those areas may be due to one or a combination of the following factors:

1) Sheep increase. An increase in sheep population numbers could have caused some but likely not all the increase we observed. Some sheep populations in Alaska have increases since 1975, e.g. Chugach State Park (Harkness, 1984), Kenai Peninsula (Spraker, 1984) and in the central Brooks Range (Singer, unpubl. data). However, other populations were stable or even declining during the same period, such as in the Talkeetna Mountains (Harkness, 1984) and in portions of the Alaska Range (Heimer, 1984).

2) Aircraft types. The helicopter, which was used for 58 percent of the work in the 1980's but not in the 1970's, may be more maneuverable, holds 3 observers, and has a more stable viewing platform than a Super Cub, which holds only 1 observer. However, the 1980's Super Cub counts were also higher than the 1970's Super Cub counts.

3) Survey efficiency. A smaller number of pilots and observers participated in the State of Alaska portions of the 1980's surveys and they had relatively more years of survey experience than in the 1970's effort.

4) Lamb crops. Hoefs and Bayer (1983) observed the Kluane Lake sheep herd to be stable 1969-80. Fluctuations of 17 percent around a mean value were largely due to differences in lamb crops. Lamb percent was higher in Alaska in the 1980's counts over the 1970's counts (Table 3), but the differences were trivial.

5) Survey intensity. Time spent per unit area where documented, increased in many of the 1980's Super Cub and helicopter surveys over the 1970's count. However, in a few areas such as all of the Noatak count units, 1980's survey times were equal or even less.

Table 1. Dall sheep numbers in 6 National Parks and Preserves in Alaska, 1981-83.

Administrative Area	Total Sheep	PARK Sub-Total	PARK Sheep/mi^2	PRESERVE Sub-Total	PRESERVE Sheep/mi^2
Wangell-St. Elias	13,095	2,717	1.7	10,378	2.8
Gates of the Arctic	12,343	10,831	1.1	1,512	2.1
Denali	2,476	2,362	2.0	114	---
Lake Clark	805	613	0.8	192	1.0
Noatak	1,556			1,556	0.4
Yukon-charley Rivers	180			180	
TOTAL	10,455	16,523		13,932	

1. Based on our estimation of sheep occupied habitat.

Table 2. Dall sheep counts in the 1970's compared to 1981-83 counts in 5 National Parks and Preserves in Alaska.

Administrative Area	Count Units Involved	Year of Last Count	Last Count	1981-83 Count	Percent Difference
Wrangell-St. Elias	2,6,7,8, 9,12,13, 14,21	1972-73	3,054	5,283	+ 73
Gates of the Arctic	5,6,7,8, 9b,16b	1974	789	1,589	+101
Denali		1978	1,104	2,362	+114
Noatak	2,3,4,5, 6,15,16	1974	834	1,074	+ 29
Lake Clark	1 - 6	1978	530	805	+ 52
TOTAL			6,311	11,113	+ 76

Table 3. Proportion of lambs in 1970's and 1980's counts in parts of the National Parks and Preserves in Alaska.

Area	1970's Counts (%)	1980's Counts (%)	Difference
Wangell-St. Elias	18	19	+1
Gates of the Arctic	18	18	0
Noatak	18	21	+3
Denali	21	23	+2
Lake Clark	28	32	+4

The difficulty of accurately surveying Dall sheep is clearly demonstrated by the survey efforts in Denali National Park. A number of authors have based their conclusions upon counts or estimates in the Park made from ground or Super Cub (Murphy and Whitten 1976; Haber 1977; Heimer 1979). Partial counts have often been reported on, however, many of the sheep cross from the northern winter range to the southern Alaska Range and back again each summer (Murie 1944; Whitten 1975). Highly inconsistent percentages of the sheep herd may be found in Park sections in any survey (Table 4), thereby mandating that the entire Park and both ranges be counted during any trend count. In addition, the helicopter count in 1981 was 114 percent higher than a Super Cub count in 1978, suggesting great inefficiency in both that and possibly all the earlier Cub counts. During the 1978-81 period, lamb ratios per 100 ewes averaged 58 percent, yearling ratios 27 percent, and lamb to yearling overwinter survival 45 percent, which does not suggest a large increase in Dall sheep (Simmons et al. 1984). The greatest annual rates of increase for Dall sheep actually documented is 11 percent (L. Nicholes, unpubl. data), 16 percent (Harkness, 1984) and 21-33 percent (Calef 1983).

Table 4. Proportions of Dall sheep found in the Outside versus the Alaska Ranges in Denali National Park during complete aerial surveys.

Year	Survey Date	Percent in Outside Range	Percent in Alaska Range
1957	Aug 14-15	54	46
1959	Jul 18	62	38
1961	Jun 29	80	20
1975	Jul 8-11	35	62
1978	Jul 22-24	47	53
1981	Jul 7-11	51	49

Wrangell-St. Elias held the most variable population with count unit densities ranging from 0.6-8.2 sheep per square mile of sheep occupied terrain, and Gates of the Arctic was the next most variable with densities ranging from

0.3-3.1 sheep per square mile. Both are large and diverse land areas. Densities of 0.3 sheep per square mile of occupied habitat or less were considered low. Densities of < 0.3 sheep per square mile were observed in 0 of 24 count units in Denali, 0 or 23 count units in the Wrangells (north of the Chitina River), but 2 of 29 count units in Gates of the Arctic, 1 or 6 count units in Lake Clark, but 9 of 18 count units in the Noatak. Four count units in the Noatak had less than 0.10 sheep per square mile.

Ram Statistics

Wrangell-St. Elias possessed the highest number of legal (7/8 + curl) rams per 100 square miles and the highest ratio of 7/8+ rams to younger rams, but it was followed closely by Denali (Table 5). Lower legal ram densities were largely due to lower sheep densities (Table 1). There were more 7/8+ rams per area on Preserve lands than Park lands and in the cases of Gates of the Arctic and Wrangell-St. Elias, the differences were very substantial, 2.6 and 4 times, respectively. In addition, in 3 of those count units (mountain units) split between Park and Preserve status, where groups were plotted on maps, 2 units had an average of 90 percent more rams in the Preserve than Parks sector. Efforts were made when the Preserve boundaries were drawn to consult hunting guides and harvest figures and to include areas with highest ram concentrations (Wright 1984).

Table 5. Legal ram percentages and relative densities in 5 National Parks and Preserves in Alaska.

Administrative Area		Total Sheep	7/8+ Rams as % of Herd	7/8+ Rams as % of all Rams	Sports-man's Index
Wrangell-St. Elias:	Preserve	7,096	10	29	29
	Park/Preserve	3,777	10	42	30
	Park	1,307	7	60	7
Gates of the Arctic:	Preserve	1,512	16	20	18
	Park	10,831	9	22	7
Denali:	Park	2,362	7	49	22
Noatak:	Preserve	1,556	9	36	4
Lake Clark:	Preserve	192	7	39	8
	Park	613	8	45	7

[1]Number of legal (7/8+ curl) rams per 100 square miles of sheep occupied habitat.

[2]Count units split between Park and Preserve status.

Ram Distributions

Past observers reported no Dall sheep rams older than 3 years in nursery groups during summer (Haber 1977; Hoefs and Cowan 1979; Hoefs and Bayer 1983). This situation was nearly approximated in lower density Parks and Preserves such as the Noatak (Table 6) but in higher density areas such as Denali (Table 6) ram association in nursery groups was 8 x higher than in the Noatak, and full curl rams were found in nursery groups as often as were younger rams.

A distinct separation of the sexes is observed in bighorn sheep (Geist 1971; Shank 1982). I observed no obvious differences in habitat selection by rams or nursery groups, and no difference in ram-ram or ram-ewe intergroup distances (t-tests for unpaired variates). I observed approximately 1 ram of all ages in nursery groups in Denali Park. A common observation by local residents and guides in both the Wrangells and Lake Clark is that many rams, in particular large-horned individuals, segregate themselves up-drainage in the steepest habitat adjacent to the glacial sources of a drainage. Average distance of ram groups was 3.0 and 5.2 miles closer than ewe groups to the glacial source of a drainage in 2 count units in the Wrangells, but not significantly closer as in 2 others of the Wrangells and not in any units in Lake Clark (t-test, $P<0.05$).

Table 6. Distribution of rams by horn size class in group types in Denali and Noatak.

Ram Curl Class	Administrative Area	No. of Rams (%) in Various Groups			Total Rams
		Ram	Nursery	Solitary	
1/4	Denali	31(72)	12(28)	0	43
	Noatak	57(86)	5(7)	5(7)	67
1/2	Denali	29(58)	19(38)	2(4)	50
	Noatak	61(94)	3(5)	1(1)	65
3/4	Denali	31(67)	14(31)	1(2)	46
	Noatak	142(96)	3(2)	3(2)	148
4/4	Denali	50(72)	17(25)	2(3)	69
	Noatak	60(98)	0	1(2)	61

Impact of ANILCA on Dall Sheep Hunting in Alaska

Heimer and Smith (1975), and Heimer (1978), estimated there were 40,000 Dall sheep in the State of Alaska. Heimer (1980) increased the estimate to

50,000. The comparable area counts presented here are 70 percent higher than corresponding 1975 and 1978 estimates, and 45 percent higher than the 1980 estimate. If this expansion factor holds true for areas outside the National Parks and Preserves, the Alaska number of Dall sheep is 73,000.

Previous calculations suggested that from 29 percent (Parker 1975) to 49% (Heimer 1980) of Alaska's Dall sheep inhabit the new National Parks and Preserves, and their creation would reduce statewide harvest of Dall sheep by 36 percent (Heimer 1980). This has not proven to be the case. Prior to Monument withdrawals, Alaska harvest of 3/4+ curl rams average 1,250 in the years 1977 and 1978. Since passage of ANILCA from 1981-83 the statewide harvest has averaged 976 or only 22 percent less. Sport hunter effort has decreased about 25 percent. In 1979, a more restrictive 7/8+ curl restriction was passed suggesting the reduction in ram harvest due to ANILCA alone was actually less than 22 percent. The State of Alaska has since refined their estimates of sheep removed from sport hunting by ANILCA based upon this survey data to 25 percent (Heimer 1982).

The new Alaska National Parks and Preserves probably contain 29-41 percent of Alaska's sheep. However, 46 percent of the sheep in the Parks and Preserves are still available for sport hunting. Modest increases in Alaska is likely as many 3/4 curl rams grew to legal (7/8+ curl) status, since some populations are apparently increasing, and as sportsmen better understand the new boundaries and regulations.

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INVESTIGATIONS INTO REPRODUCTION BY EWES OF A ROCKY MOUNTAIN BIGHORN SHEEP HERD IN WYOMING

E. Tom Thorne, Wyoming Game and Fish Department, University Station, Box 3312, Laramie, WY

Elizabeth S. Williams, Wyoming State Veterinary Laboratory, University of Wyoming, Box 950, Laramie, WY

Walter F. Williams, Department of Animal Science, University of Maryland, College Park, MD

Gary Butler, Wyoming Game and Fish Department, Dubois, WY

ABSTRACT

A 3 year study was conducted on reproduction of Rocky Mountain bighorn sheep in the BLM-Sheep Ridge herd at Whiskey Basin, Dubois, Wyoming. Thirty-four ewes were individually marked at capture. Blood progesterone levels in late winter were used to detect pregnancy. Ewe distribution in June, after the lambing period, was used as an indicator of nursing and early lamb survival. Captive bighorns were used to further evaluate the efficacy of progesterone analysis for pregnancy diagnosis. A blood progesterone level of > 2 ng/ml during the 2nd and 3rd trimesters was used as a positive test, and sensitivity was determined to be 92 percent and specificity 88 percent. Progesterone data indicated 16 percent (4/25) of the wild ewes were not pregnant in February 1981; 16 percent (3/19) were not pregnant in January 1982, 6 percent (1/16) were not pregnant in March 1982; and all (10) were pregnant May 1983. Distribution of ewes in June suggested at least 9 of 24 (38%) study ewes were without lambs in 1981, 5 of 34 (15%) were lambless 1982, and 2 of 30 (7%) were barren in 1983. Of 4 ewes tested for progesterone and/or relocated each year, two probably reproduced every year, one probably did not successfully reproduce any year, and one was apparently unsuccessful for two years and was pregnant the third year. Of 14 ewes tested twice by progesterone analysis and/or relocated in June, 8 (57%), were judged pregnant both years, 3 (21%) probably did not reproduce either year, and 3 (21%)were apparently pregnant one year but not another. Lamb:ewe ratios were generally higher than in previous years. No consistent pattern of alternate-year-reproduction was demonstrated. Possible causes of poor reproduction considered include diseases and parasites, forage production on winter range during the summer as an indication of summer nutrition, forage utilization on winter range, and ram:ewe ratios on winter range.

INTRODUCTION

Low lamb:ewe ratios indicate poor reproductive success in many sheep (*Ovis canadensis* and *O. dalli*) populations of North America (Berwick 1968, Morgan 1970, Horejsi 1972, Shackleton 1973, Stelfox 1974, Thorne et al. 1979). But causes of poor reproduction are difficult to determine.

Heimer (1978) studied a population of Dall sheep undergoing a slow, steady decline and documented alternate-year-reproduction by ewes. In the Dry Creek, Alaska herd, the mean lamb:ewe ratio was .30 among both marked and unmarked ewes from 1972 through 1974. Observations during consecutive summers revealed only 7 percent of the marked ewes were accompanied by a lamb each summer; 53 percent led lambs during alternate summers, and 40 percent were without lambs during two consecutive summers. Only seven of 15 ewes were pregnant when collected during winter. Forage conditions in the Dry Creek area were relatively poor, and Heimer (1978) described an alternate-year reproduction cycle as the cause of the population decline. Lambs were weaned at about 1 year of age, and he felt ewes grazing on inadequate forage did not breed or carry pregnancy to term while raising a lamb because of the effects of depleted energy reserves.

Among BLM-Sheep Ridge sheep of Wyoming studied in 1975 through 1978, large groups of barren ewes were observed very early in summer, and some mature ewes apparently did not go to lambing grounds each spring or stayed a very short time (Thorne et al. 1979). Presence of dry (nonlactating) ewes in those barren groups indicated reproductive failure, very early neonatal mortality, or very late conception and suggested some form of alternate-year-reproduction.

Alternate-year-reproduction is not unique to mountain sheep. It has been seen in red deer (Cervus elaphus) on Scottish hill land in a nutritionally inadequate habitat where hinds remain anestrous and fail to breed the year following a successful pregnancy and lactation. Mitchell and colleagues (1976) felt this to be related to body condition and weight as mediated by lactation and forage conditions.

Although Heimer (1978) implied prolonged suckling and lactational infertility as the mechanism causing alternate-year-reproduction among the Dall ewes at Dry Creek he (1982) recently suggested their poor reproductive performance may be due to an improper ratio of mature to immature rams and breeding of yearling ewes that are physically and physiologically unprepared. Hence, the strain of raising a lamb as a 2-year-old results in nutritional and lactational anestrous during the rut of their 2nd year and a cycle of alternate-year-reproduction (Heimer, pers. commun. 1984).

Disproportionately large numbers of young rams may result in harrassment and breeding of young ewes at a higher rate than occurs with a normal young:old ram ratio (Heimer 1982). In 1945, Pulling (1945) who studied desert bighorns (O. c. nelsoni), suggested overbreeding of estrous ewes by six or more rams caused over exertion and temporary infertility leading to reproductive failure that year. He stated "practical observers" commonly thought overbreeding due to too many rams harrassing ewes was a cause of poor reproduction. A mechanism mediated by prolactin has been demonstrated in domestic sheep (Ovis aries). Stress induces prolactin secretion in ruminants (Forbes et al. 1975, McNeilly 1980) which has antigonadal activity and suppresses behavioral estrus (Kann et al. 1976, Walton et al. 1977, Whitehead and McEwan 1980). Also among domestic sheep, the mere presence of dominant rams has an inhibitory effect upon sexual performance of subordinate rams (Lindsay et al. 1976), and an audience effect undoubtedly influences breeding behavior of bighorn rams. Geist (1971) suggested the inhibitory presence of

large rams prevents excessive harassment of ewes by young, inexperienced rams.

Among domestic sheep, the presence of rams affects onset and synchronization of estrus (Fraser 1968, Redford and Watson 1957, Watson and Redford 1960). Nichols (1978) suggested there may be a similar effect with an earlier and shorter rut occurring in the presence of older mature rams among Dall sheep. Bunnell (1980) noted two or three estrous cycles in Dall sheep. Often there is no estrus in domestic ewes associated with the 1st ovulation of the breeding season. This is apparently due to lack of exposure of the brain to progesterone, which is necessary if estrogens secreted by the ovarian follicle are to cause behavioral estrus (Van Tienhoven 1983). Among Bunnell's (1980) Dall sheep, survival was greatest in lambs conceived during the 2nd cycle. Ewes bred during the 1st cycle were younger than those conceiving later. Ewes giving birth to early lambs risk neonatal mortality due to adverse weather and inadequate milk for the lamb if green-up is delayed.

There are other plausible causes of poor reproduction. Jorgensen and Wishart (1982) demonstrated that among bighorns on Ram Mountain, Alberta a high number of mature ewes during the rut is followed by a lower percent of 2-year-old ewes giving birth to lambs. They felt the number of mature ewes, when high, may influence breeding of yearling ewes by behaviorally suppressing them or, when there are relatively few mature ewes, the attention of rams may be diverted to yearling ewes.

Bunnell (1982) and Thompson and Turner (1982) showed the breeding period of northern mountain sheep is cued to photoperiod and timed to maximize the advantages to lambs of vegetation green-up and summer growing period. Lamb survival is associated with timing of parturition and dependent upon plant phenology (Bunnell 1982). A delayed green-up, with a shorter growing season, adversely affects lamb growth and survival. On Ram Mountain neonatal mortality was influenced by maternal nutrition and by weather at the time of lambing (Jorgensen and Wishart 1982). Maternal nutrition, as evidenced by fecal nitrogen levels, was positively and significantly correlated with green-up. Nutrition late in gestation and during lactation is the major influencing lamb birth weight and rate of growth. These ultimately determine lamb fitness to survive the rigors of winter. Management, of course, cannot control timing of green-up.

Overall nutritional status influences reproductive success in many ways. In domestic ewes, previous nutrition is important in timing onset of estrous and poor nutrition may prolong gestation (Sadleir 1969). Delayed estrus or late parturition would result in bighorn lambs at the end of the growing season which had not reached a desirable body size before winter. Reproductive performance of red deer has been related to forage quality of the hind's home range (Guinness et al. 1978) and to weight of the hind at rut (Hamilton and Blaxter 1980). This is primarily a reflection of quality and quantity of summer forage. Winter feed also has been shown to be important to fetal development and growth and survival of the newborn in many species, including elk (Cervus canadensis), white-tailed deer (Odocoileus virginianus), and domestic sheep (Verme 1962, 1965; Thomson and Thomson 1949, Thorne et al. 1976), and undoubtedly is of great importance to bighorns. In Alaska, Nichols (1978) felt a Dall sheep herd he studied responded with increased lambing success to increased winter forage made available by a reduction in population.

During a previous study of the BLM Ridge-Sheep Ridge bighorns, suckling by lambs occasionally was observed in winter and by short yearlings in June (Thorne et al. 1979). Suckling causes a neurogenic stimulus that results in elevated levels of the hormone prolactin which in turn causes lactational ovarian inactivity in women, beef cattle (Bos tarus), swine (Sus scrofa), and domestic sheep. Only when lactation ceases and prolactin declines is normal ovarian cyclicity reestablished (Wagner and Oxenreider 1971, McNeilly 1980, McNeilly et al. 1982). In other animals, such as dairy cows and dairy goats (Capra hircus), normal ovarian activity and ovulation can and do occur in spite of prolonged elevated prolactin levels (McNeilly et al. 1982).

Red deer are a species in which reproductive performance is influenced by lactation. Although plane of nutrition and photoperiod are generally considered mediators of prolactin secretion (Forbes et al. 1975), Loudon et al. (1983) recently showed that frequent and prolonged suckling increases prolactin and results in lactational infertility. In hinds on a low plane of nutrition, there is an increase in suckling frequency by calves in response to low milk production. Frequent and prolonged suckling, in conjunction with increased levels of plasma prolactin, results in prolonged anestrous and delay or failure to breed at the normal time. Prolactin is controlled partially by suckling frequency, i.e. a direct relationship between suckling frequency and prolactin secretion. This response is independent of physical condition of the hinds. However, delayed or late conception has been demonstrated to occur in red deer in poor body condition and/or lactating as compared to hinds in good physical condition and dry (Mitchell and Lincoln 1973). It is possible these mechanisms caused poor reproductive performance among bighorn ewes of the BLM-Sheep Ridge herd in the past years. Observations of ewes still being suckled long after their lambs should have been weaned lends strong supporting evidence.

The BLM-Sheep Ridge Rocky Mountain bighorn herd contains 300 to 400 sheep and winters along Jakey's Fork Canyon on the Whiskey Basin Game Winter Range in Fremont County, Wyoming. This herd and its habitat, along with the Torrey Rim bighorn population which is similar in size and with which it shares the Whiskey Basin Winter Range, have been described (Butler 1977, Thorne et al. 1979). Although the BLM-Sheep Ridge herd has grown since efforts to protect and enhance its winter range began in the mid 1950's, lamb:ewe ratios have generally been low. In 1979 the population appeared in stable condition and of moderately low quality (Thorne et al. 1979). A limited number of trophy rams are shot annually and some lambs, ewes, and young rams are trapped for transplant. In recent years, an effort has been made to hold sheep numbers below carrying capacity with a resultant 65 percent utilization of winter range forage by sheep. Efficient trapping techniques were developed in the late 1970's, and size of the winter range utilized was increased by baiting sheep into previously unused areas beginning in the winter of 1981-82.

Upon leaving winter range, pregnant Rocky Mountain bighorn ewes typically move to secluded lambing areas where lambs are born. After a short time, nursery bands consisting of lambs and lactating ewes are formed, and they remain in areas characterized by readily available forage and precipitous escape cover until lambs are strong enough for migration to summer range. Simultaneously, yearlings, 2-year-olds, ewes without lambs (dry), and young rams form barren groups which later join with lactating ewes and lambs for

summer migration. Thus, for 3 to 4 weeks in early summer, female bighorn bands are split into two distinct groups (Geist 1971). This pattern was evident among BLM-Sheep Ridge ewes, and lambing grounds and nursery areas used by lactating ewes and more open, less precipitous spring-fall ranges, used by dry ewes were identified (Thorne et al. 1979).

Progesterone is a steroid hormone primarily secreted by the corpus luteum of the estrous cycle and pregnancy. Blood progesterone levels have been used to diagnose pregnancy in cattle, goats, domestic sheep, elk, white-tailed deer, and bighorn sheep (Bassett et al. 1969, Ramsay and Sadleir 1979, Vogelsang et at. 1977, Whitehead and McEwen 1980, Holdsworth 1981, Weber et al. 1982). In one study using three Rocky Mountain bighorn ewes, plasma progesterone levels associated with cyclic luteal function were 3.2 to 4.0 ng/ml and during pregnancy reached levels of 13.3 to 23.2 ng/ml until just before parturition (Whitehead and McEwen 1980). In an earlier study with big horns, Ramsay and Sadleir (1979) suggested a progesterone threshold level of 2 to 3 ng/ml during the last 2/3 of gestation was diagnostic of pregnancy.

The purpose of this 3 year study was to use blood progesterone levels as an indication of pregnancy and ewe association with nursery or barren groups as an indication of nursing and early lamb survival to determine if alternate-year-reproduction was occurring among ewes of the BLM-Sheep Ridge bighorn sheep population. Captive bighorns were used to further evaluate the efficacy of progesterone analysis for pregnancy diagnosis. A secondary objective was to explore possible causes of poor reproduction among BLM-Sheep Ridge bighorn ewes.

METHODS

An apple pulp-baited drop-net trap (Erickson 1970, Schmidt 1976, Schmidt et al. 1978, Emmerich 1982) or chemical immobilization with projectile syringe-delivered etorphine[1] and acetylpromazine[2] (Thorne 1971, Thorne 1982a) were used to capture bighorn ewes in February 1981, January and March 1982, and May 1983. With the exception of 22 ewes trapped for transplant in January 1982, all captured ewes were individually marked with a small domestic sheep-sized, numbered, plastic ear tag; a small numbered, metal ear tag; and a numbered neck band. During the 2nd and 3rd years, an attempt was made to recapture ewes that previously had been captured for this study.

Heparinized and clotted venous blood samples obtained from captured ewes were kept cool until centrifuged for plasma and serum collection 6 to 24 hours after collection. Samples were frozen (-20C) until analyzed for progesterone using a modified radioimmunoassay protocol (Knight et al. 1977) with progesterone antibody (courtesy Dr. J. L. Fleeger, Texas A&M University) characterized by Wise et al. (1975). The radioimmunoassay was validated by demonstrating parallelism to standards by internal standards and by sample dilution. Assay data were computed using a modification of a program

[1] M-99 Etorphine^{R}, Lemon Company, Box 30, Sellersville, PA 18960

[2] Acepromazine^{R}, Ayerst Laboratories, 685 Third Avenue, New York, NY 10017

developed by English (1981). Inter and intraassay coefficients of variation were 14.1 percent and 13.0 percent, respectively. Using modifications of the criteria of Ramsay and Sadleir (1979), progesterone values of $\geq$ 2 ng/ml of serum or plasma were considered to indicate pregnancy in the last 2/3 of gestation.

One 3/4 bighorn x 1/4 mouflon (O. musimon) hybrid and six bighorn sheep at the Wyoming Game and Fish Department Sybille Wildlife Research Unit were similarly tested for pregnancy. Periodic blood samples were obtained while the animals were manually restrained. During estrus, some ewes had access to bighorn rams, and the control of captivity allowed pregnancy to be confirmed by birth of a lamb. Twenty-three recently captured bighorn ewes held at the Wild Animal Disease Center, Colorado State University, Ft. Collins were also tested for serum progesterone levels in 1979 and 1980.

Sensitivity and specificity of blood progesterone values as a diagnostic test for pregnancy were determined (Rogan and Gladen 1978, Brown and Newman 1979). Sensitivity was defined as the chance a test will be positive ($\geq$ 2.0 ng/ml) when the animal is pregnant and specificity was defined as the chance a test will be negative when an animal is not pregnant.

During 8 to 12 June 1981, 17 to 20 June 1982, and 26 June to 1 July 1983, observations were made with the aid of 7x35 binoculars and 20-power spotting scopes in areas known to be used during those times by sheep of the BLM-Sheep Ridge population (Thorne et al. 1979). Attempts were made to locate and identify neck-banded ewes previously captured and pregnancy tested in order to determine if they had lambs.

Comparisons between mean progesterone values in serum and plasma and between mean progesterone values of pregnant and nonpregnant sheep in different stages of gestation were made using Student's t test. Relationships between summer forage production on winter range as an indication of summer nutrition, winter forage utilization, and rams:100 ewes on the lamb:ewe ratio the following winter were examined by determining the Pearson product moment correlation coefficient and by simple linear regression. Lamb:ewe and ram:ewe ratios and winter range forage production and utilization data were obtained from Wyoming Game and Fish Department files, Whiskey Basin Big Game Winter Range and Lander, Wyoming.

Some captured BLM-Sheep Ridge bighorns were also tested for important diseases and parasites. Sera were tested for Leptospira interrogans serovars hardjo, pomona, icterohemorrhagiae, canicola, and grippotyphosa (leptospirosis) antibodies using a microscopic agglutination test. Sera were also tested by immunodiffusion for antibodies against ovine progressive pneumonia virus. In addition, ewes were tested for Campylobacter fetus jejuni (campylobacteriosis or vibriosis) using an indirect hemagglutination serologic test and culture techniques by vaginal washings using nutrient broth inoculated into Clark's Campylobacter transport medium. Ear swabs were taken in 1982 and 1983 and examined for of Psoroptes sp. scabies mites.

RESULTS

PREGNANCY DIAGNOSIS

Gestation in bighorn sheep is about 176 days (Geist 1971, Blunt et al. 1977, Whitehead and McEwan 1980). Peripheral progesterone levels greater than 2 to 3 ng/ml during the last 2/3 of pregnancy were suggested by Ramsay and Sadleir (1979) as diagnostic of pregnancy in bighorns. Using 7 June as an arbitrary, but probable, date when over 50 percent of lambs were born (Honess and Frost 1942, Thorne et al. 1979, Bunnell 1982), the breeding peak was 14 December with 9 February the end of the first trimester of pregnancy (58 days) of BLM-Sheep Ridge ewes.

Depending upon tests anticipated to be conducted upon a blood sample, logistics, and personal preferences, blood may be collected into anticoagulant, e.g., heparin, or into a "dry" tube and allowed to clot. Plasma or serum are then collected by centrifugation. Progesterone analyses may be conducted on either form, and we had the opportunity to analyze plasma and serum from the same blood samples of 45 bighorns. There was no significant difference in circulating progesterone when plasma or serum was used for the analysis ($P > .05$). Similarly, Ramsay and Sadleir (1979) showed little difference in progesterone levels when determinations were made on plasma and serum. There were three blood samples in which plasma progesterone was $\geq$ 2 ng/ml and serum progesterone was below that level; two serum progesterone level were >2 ng/ml and the paired plasma progesterone was < 2 ng/ml. On these few occasions, the highest value was used to diagnose pregnancy.

Breeding date and day of gestation the date blood samples were collected from captive ewes were determined by calculating back from the known date of a lamb's birth. At Sybille (Table 1), nine blood samples were obtained during the last 2/3 of pregnancy; eight were correctly diagnosed using a blood level of 2.0 ng/ml progesterone as a threshold. The exception was "Sis" on 5 May 1983 with a circulating progesterone level of 0.7 ng/ml on the 139th day of gestation. Three of eight blood samples obtained during the first trimester of pregnancy had peripheral progesterone levels below 2.0 ng/ml (Table 1). As the Wild Animal Disease Center (Table 2), 17 blood samples were obtained from ewes later shown to have been in the latter 2/3 of gestation; only one was not diagnosed correctly. Blood was obtained 40 times from captive ewes shown later not to be pregnant (Figure 1); serum or plasma levels exceeded 2.0 ng/ml nine times. These blood samples were obtained during December through February when some ewes still may have been cycling. There was a definite rise in mean circulating progesterone levels in nonpregnant ewes which approached or exceeded 2 ng/ml during January and February (Figure 1).

Plasma or serum progesterone values for pregnant and nonpregnant ewes in the first trimester were not significantly different ($P > .05$); however, progesterone values for pregnant ewes in the second trimester were significantly higher ($P < .0001$) than for nonpregnant ewes during the same time period (Figure 2). Data from nonpregnant ewes were not available for the last trimester of pregnancy.

Table 1. Serum and/or plasma progesterone levels of captive, mature, female sheep at the Sybille Wildlife Research Unit, Wyoming.

Sheep	Serum and plasma ( ) progesterone in ng/ml and day of gestation if pregnant									
	23 Jan '81	9 Mar '81	22 Dec '81	22 Jan '82	26 Feb '82	2 Apr '82	8 Dec '82	1 Feb '83	10 Mar '83	5 May '83
Sara	3.4	1.5	0.4	1.9(2.9)	3.7(3.5)	0.3(1.2)	(2.8)	2.3 49 da	5.9 86 da	9.8 142 da
Sis	1.2	1.7	4.0	2.8(2.0)	1.2(0.8)	0.4(0.9)	(0.5)	3.1 46 da	7.7 83 da	0.7 139 da
Heather[1]	1.9 23 da	2.8 66 da	0.2	1.3(1.1)	4.6(0.8)	0.2(0.7)	-	-	-	-
Wildone	2.1 42 da	2.1 85 da	-	-	-	-	-	-	-	-
W-50	-	-	0.8 11 da	2.5(2.7) 42 da	2.9(3.2) 77 da	3.3(4.8) 112 da	1.4 2 da	2.0 57 da	5.9 94 da	-
Kelly	-	-	1.5	0.7 (0.9)	0.3(0.1)	(0.7)	-	-	-	-
W-48	-	-	1.9	1.7(2.0)	1.2(0.9)	0.6(0.1)	-	-	-	-

[1]Heather was a 3/4 bighorn x 1/4 mouflon hybrid; all others were bighorn.

Table 2. Serum progesterone levels of captive, female bighorn sheep at the Wild Animal Disease Center, Colorado

		Serum progesterone in ng/ml and day of gestation () if pregnant								
		1979				1980				
Sheep	Age	29 Mar	23 Aug	26 Sept	2-26 Oct	14 Feb	29 Mar	10-12 Apr	12 Aug	7-8 Sept
GTBT80	4	8.2(112)			0.6(0)					
G3TBT75	4	3.6(115)			0.7(0)					
GTBT76	3	0.9(0)				0.4(0)				
GTR38	5	4.2(89)	0.5(0)							
GTR48	5	8.4(≈126)		0.4(0)	0.9(0)					
GTBT77	Mat	4.4(109)								
GTBT32	4	1.7(111)								
GTBT35	3	6.1 (116)								
GTB746	4	4.0(P)[1]								
GT08	4				0.1(0)					
GTBT33	3				0.1(0)					
GRBT51	7						6.4(P)			
GRGT19	3						3.4(P)			0.3(0)
GRGT17	Mat						5.9(P)			
GRGT21	3						2.7(112)			0.4(0)
GRRT20	2						0.7(0)			
GRRT23	8						7.2(136)			
GRRT15	3						0.1(0)			
GRRT26	4						4.1(126)			
GRGT22	3						5.8(131)			
GRRT17	7							13.4(P)		
GRRT44	3							7.8(P)		
GRRT22	6								0.7(0)	

[1](P) = Confirmed to be pregnant at necropsy, date of gestation undetermined; (0) = not pregnant.

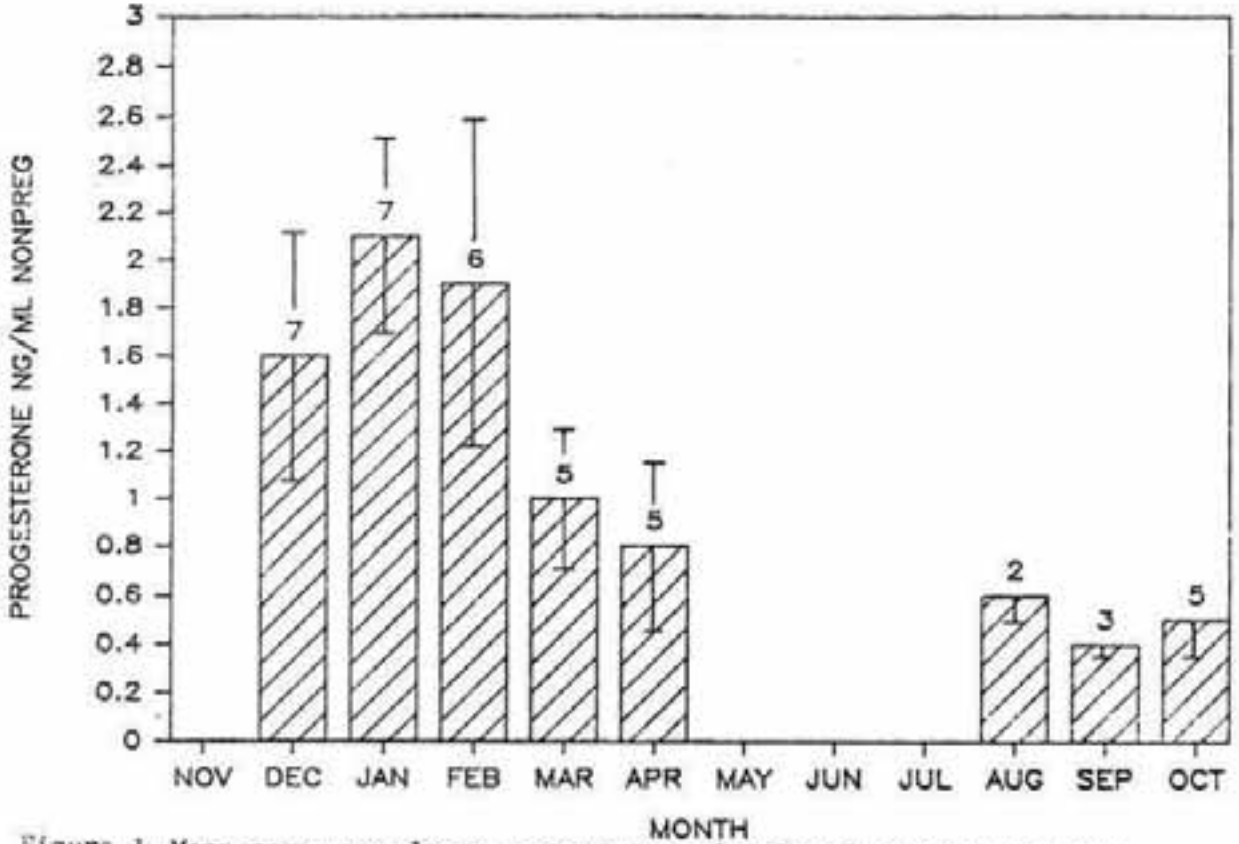

Figure 1. Mean serum or plasma progesterone levels of nonpregnant ewes throughout the year.

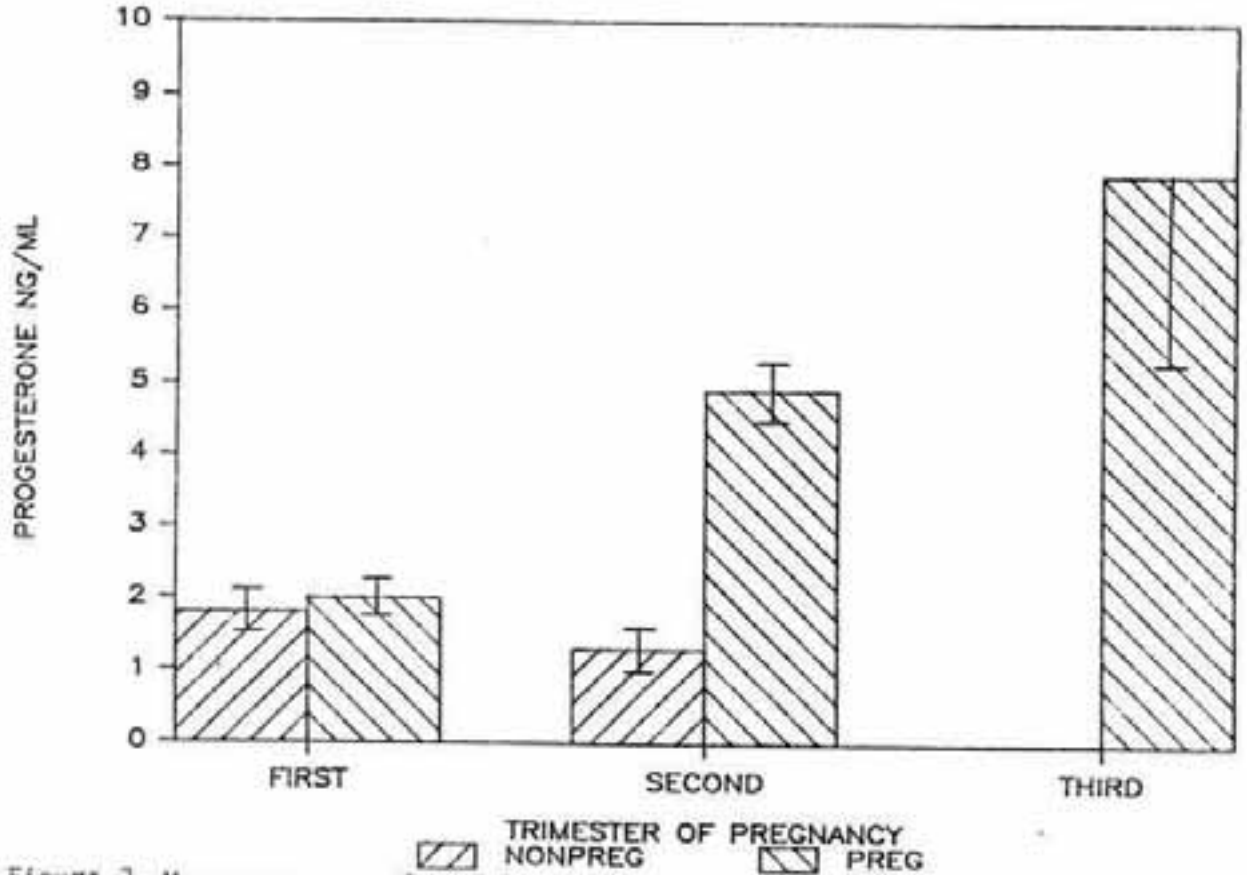

Figure 2. Mean serum or plasma levels for pregnant and nonpregnant ewes during each trimester of pregnancy.

Sensitivity of serum or plasma progesterone assay using $\geq$ 2 ng/ml during the last two thirds of pregnancy as diagnostic of pregnancy was 92 percent; specificity using the same criterion was 88 percent. Thus we would expect about 12 percent false positive results and 8 percent false negative results using this test for pregnancy in bighorns.

Progesterone levels were determined on 73 occasions from free-ranging ewes from the BLM-Sheep Ridge herd in 1981 (25), 1982 (38), and 1983 (10). In 1981, blood was collected between 3 and 21 February (Table 3) which is late in the 1st or early in the 2nd trimester of gestation, the period when Whitehead and McEwan (1980) demonstrated a temporary decline in progesterone levels. Four (16%) of 25 ewes were diagnosed as not pregnant. In two sheep, progesterone levels were 2.1 ng/ml; they may have been cycling instead of pregnant, and one of these ewes (Y-16) was seriously injured in the drop-net and euthanized. Necropsy revealed she was not pregnant.

In January 1982, 22 ewes captured for transplant were tested during the 1st trimester; 19 (86%) had progesterone $\geq$ 2.0 ng/ml and were diagnosed pregnant; three (14%) were diagnosed as not pregnant. However, these sheep were tested shortly after the usual breeding season and some may have been cycling. Sixteen additional sheep were tested during the 2nd trimester in March; only one (6%) was not pregnant (Table 3). Overall pregnancy rate in 1982 was 89 percent (34/38).

Ten ewes were tested in May of 1983 and all were judged to be pregnant (Table 3). One of these ewes died in May and was pregnant when necropsied.

Nine ewes were tested in 2 consecutive years. One was judged not pregnant either year, seven were pregnant both times, and one was pregnant in 1982 but not in 1981. Five ewes were tested in 1981 and again in 1983. Four were pregnant both years; one was pregnant in 1983 but not in 1981. One ewe was tested three times and was pregnant each year.

Attempts were made to locate and observe neck-banded ewes in June of 1981, but inclement weather made observations in precipitous lambing grounds difficult. Eight or 9 neck-banded ewes were observed 1 to 3 times each. None definitely had a lamb (Table 3), as judged from previous work which noted marked distribution differences between lactating ewes and dry ewes without lambs on spring-fall ranges (Thorne et al. 1979). Three of five ewes determined by progesterone levels as not pregnant in February 1981 were observed in June (Table 3). Only six of the 19 judged pregnant in February were reobserved in June. These ratios (3/5 and 6/19) are significantly different at the 95 percent confidence level (McDonald et al. 1981). This suggests those ewes identified with barren groups were without lambs.

In June 1982, six neck-banded ewes were observed. Five were without lambs based on their presence in barren groups; one ewe was tested by progesterone analysis in March and judged pregnant, another was diagnosed not pregnant. Of four neck-banded ewes observed in June 1983, two had lambs and both were diagnosed pregnant by progesterone analysis in May. Two were without lambs; one tested pregnant in May, the other was not captured.

Table 3. Pregnancy test results on captured sheep and judgement made in June if observed sheep had a lamb

No.	Age When Captured	1981 Progesterone Date	1981 Progesterone ng/ml	1981 Progesterone Test[1]	1981 June observation[2]	1982 Progesterone Date	1982 Progesterone ng/ml	1982 Progesterone Test[1]	1982 June observation[2]	1983 Progesterone Date	1983 Progesterone ng/ml	1983 Progesterone Test[1]	1983 June observation[2]
Y-1	4+	3 Feb	7.1	+	N.D.	5 Mar	7.5(7.5)[3]	+	N.D.	N.D.[4]			N.D.
Y-2	Old	3 Feb	3.7	+	N.D.	N.D.			N.D.	N.D.			N.D.
Y-3	3	3 Feb	7.4	+	N.D.	4 Mar	3.7(10.2)	+	N.D.	7 May	10.3	+	N.D.
Y-4	4	3 Feb	6.4	+	N.D.	N.D.			N.D.	N.D.			N.D.
Y-5	4+	3 Feb	9.4	+	N.D.	N.D.			N.D.	6 May	8.8	+	L
Y-6	4+	3 Feb	4.9	+	N.D.	N.D.			N.D.	N.D.			N.D.
Y-7	3	3 Feb	13.0	+	N.D.	N.D.			N.D.	10 May	9.9	+	N.D.
Y-8	3	3 Feb	1.0	-	N.D.	N.D.			N.D.	7 May	8.3	+	N.D.
Y-9	4+	10 Feb	16.0	+	N.D.	N.D.			N.D.	9 May	9.9	+	N.D.
Y-10	+	10 Feb	1.5	-	N.D.	N.D.			N.D.	N.D.			N.D.
Y-11	11	10 Feb	5.5	+	N.D.	N.D.			L.T	N.D.			N.D.
Y-12	3	10 Feb	4.5	+	N.D.	N.D.			L.T	N.D.			Dead-pregnant in January
Y-13	4+	10 Feb	3.6	+	N.D.	16 Mar	(9.0)	+	N.D.	N.D.			N.D.
Y-14	10+	10 Feb	2.1	-	N.D.	N.D.			N.D.	Sent to Utah 6 Jan, 1983			
Y-15	3	10 Feb	9.3	+	N.D.	N.D.			N.D.	Dead			
Y-16	Old	10 Feb	2.1	+	Dead-February not pregnant								
Y-16a	4+	10 Feb	1.2	-	N.D.	4 Mar	0.5(0.1)	-	N.D.	N.D.			N.D.
Y-17	4+	10 Feb	13.0	+	N.D.	N.D.			N.D.	N.D.			N.D.
Y-18	3	10 Feb	9.6	+	N.D.	N.D.			N.D.	N.D.			N.D.

Table 3. Continued

No.	Age When Captured	1981 Progesterone Date	1981 Progesterone ng/ml	1981 Test[1]	1981 June observation[2]	1982 Progesterone Date	1982 Progesterone ng/ml	1982 Test[1]	1982 June observation[2]	1983 Progesterone Date	1983 Progesterone ng/ml	1983 Test[1]	1983 June observation[2]
Y-19	4+	10 Feb	10.0	+	N.O.	13 Mar	7.1(5.7)[3]	+	N.O.	N.D.[4]			N.O.
Y-20	4+	10 Feb	2.7	+	W.O.	N.D.			W.O.	N.D.			N.O.
Y-90	4+	10 Feb	1.6	-	W.O.	13 Mar	5.1(9.9)	+	N.O.	N.D.			N.O.
Y-22	9	21 Feb	5.5	+	W.O.	N.D.			W.O.	9 May	3.6	+	Dead-May Pregnant
Y-23	4	21 Feb	5.5	+	W.O.	N.D.			N.O.	N.D.			N.O.
Y-24	3	21 Feb	10.0	+	N.O.	N.D.			W.O.	N.D.			N.O.
C-39	5	N.D.				13 Mar	6.4(10.2)	+	N.O.	8 May	9.9	+	L
W-28	5	N.D.				13 Mar	4.6(5.8)	+	N.O.	N.D.			N.O.
Y-88	3	N.D.				14 Mar	8.6(7.9)	+	N.O.	7 May	9.1	+	N.O.
Y-89	3	N.D.				14 Mar	11.6(8.7)	+	N.O.	N.D.			N.O.
Y-92	1	N.D.				14 Mar	3.3(6.4)	+	N.O.	N.D.			N.O.
Y-91	5	N.D.				15 Mar	7.5(9.8)	+	N.O.	7 May	10.7	+	N.O.
Y-93	6	N.D.				15 Mar	4.3(4.0)	+	N.O.	7 May	5.9	+	N.O.
Y-95	5	N.D.				15 Mar	(4.7)	+	N.O.	N.D.			N.O.
R-45	5	N.D.				15 Mar	(4.7)	+	N.O.	N.D.			N.O.
R-44	3	N.D.				16 Mar	7.4(8.2)	+	N.O.	N.D.			N.O.

[1] Judged pregnant if serum or plasma progesterone > 2.0 ng/ml.
[2] Not observed, N.O.; without a lamb, W.O.; with a lamb, L.; unable to determine, T.
[3] Serum progesterone (plasma progesterone)
[4] No data, N.D.

Table 3 summarizes proesterone data and summer observations. Data on reproduction were obtained for 14 ewes during 2 years and for four ewes during all 3 years. Of 14 ewes with data for 2 years, eight (57%) were determined pregnant or as having a lamb both years, three (21%) were determined pregnant or as having a lamb on 1 of those 2 years, and three (21%) sheep were barren both years. Of the four sheep tested and/or observed all 3 years, two were determined pregnant all 3 years, one ewe was without a lamb 2 years and pregnant 1 year, and one ewe probably did not successfully reproduce any year.

Of 41 ewes whose samples were assayed for progesterone after 9 February, 34% (14) were observed in spring. Of those tested and reobserved that spring, there was 43 percent agreement between the pregnancy determination by progesterone analysis and evidence of the ewe having a lamb or being barren in June. Where there was disagreement, the ewe was diagnosed pregnant by progesterone analysis and was dry when observed in summer suggesting neonatal mortality.

Winter range forage production in the summer, winter range forage utilization, and rams/100 ewes were not significantly correlated ($P > .05$) with lambs/100 ewes the following winter (Table 4). There was a marked increase ($P = .0531$) in lamb/ewe ratios during the period 1981-84 as compared to the period 1975-1979 (Table 4).

DISEASES AND PARASITES

Sera of 21 ewes were tested by the microscopic agglutination test against five serovars of Leptospira interrogans. Although there were some low reactions, none was higher than 1:160 and none was regarded as significant.

One ewe (Y-16) accidentally killed during trapping and subsequently necropsied had histopathologic changes suggestive of ovine progressive pneumonia. However, none of the ewes trapped in 1981, including Y-16, had detectable antibodies to ovine progressive pneumonia. Histopathologic changes of ovine progressive pneumonia and those induced by chronic Protostrongylus spp. lungworm infection may be similar.

Cultures for Campylobacter spp. were prepared from seven ewes in 1981, 21 in 1982, and 15 in 1983. A Campylobacter sp. grew from the vaginal washing of one ewe (Y-5) in 1981; however, before the organism could be identified, it was overgrown and killed by contaminating organisms. Sera of 28 ewes were tested for antibodies against goat and sheep isolates of C. fetus jejuni; five reacted at 1:160 and all others produced lower reactions. Serum from the ewe from which Campylobacter sp. was recovered was not available for serology.

Ten ewes captured in 1982 and 20 in 1983 were negative for Psoroptes sp. scabies mites when both ears were checked by swab.

Table 4. Forage production, forage utilization, ram:ewe ratios and lamb:ewe ratios from 1974 - 1984 at BLM-Sheep Ridge, Whiskey Basin, Wyoming.

Winter	Mean forage prod. previous season (Kg/ha)	Mean forage util. during winter (%)	Rams/100 ewe			Lambs/100 ewe	
			All[1]	Immature[2]	Mature[3]	Yearlings included	Yearlings excluded
1974-75	365	78	22	ND[4]	ND	19	ND
1975-76	487	83	ND	ND	ND	8	ND
1976-77	467	55	5	ND	ND	24	ND
1977-78	264	83	ND	ND	ND	ND	ND
1978-79	319	64	26	ND	ND	49	ND
1979-80	342	54	ND	ND	ND	ND	ND
1980-81	499	69	ND	ND	ND	50	ND
1981-82	460	75	43	38	13	60	71
1982-83	291	89	68	59	10	32	39
1983-84	680	ND	49	45	7	41	44

[1]Yearling ewes included
[2]Yearling through class II
[3]Class III and IV
[4]No data, N.D.

DISCUSSION

PREGNANCY DIAGNOSIS

Peripheral blood progesterone in domestic ewes remains uniformly low except during the luteal phase of the estrous cycle and during pregnancy (Bassett et al. 1969, Thorburn et al. 1969, Moore et al. 1972, Walton et al. 1977). Bighorn sheep, with the exception of a temporary decline in progesterone between 50 and 80 days of gestation, exhibit a similar pattern (Ramsay and Sadleir 1979, Whitehead and McEwan 1980). Thorburn et al. (1969) reported plasma progesterone levels during the 1st 4 days of the nonpregnant cycle in the domestic ewe were below 0.4 ng/ml, increased to 1.5 to 2.5 ng/ml during days 4 through 9, and then declined rapidly on days 14 to 15 to about 0.1 ng/ml at estrous. In domestic sheep during the nonpregnant cycle, progesterone levels peak at 2.5 to 5.6 ng/ml (Thorburn et al. 1969, Sarda et al. 1973, Yuthasastrakosol et al. 1975); and progesterone did not exceed 4 ng/ml in three bighorn ewes studied by Whitehead and McEwan (1980) and our ewes tested during the breeding season. Bunnell (1980) described two or three distinct estrous cycles in Dall sheep during the breeding season, and Rocky Mountain bighorns presumably also cycle two or three times, which would take about 48 days. For routine pregnancy diagnosis, differentiation between low progesterone levels in nonpregnant ewes and high levels in pregnant ewes is more important than precise, specific determinations of circulating hormone levels (Sugden 1978, Ramsay and Sadleir 1979) or examining fluctuations associated with the estrous cycle.

Circulating progesterone remains elevated in pregnant domestic and bighorn ewes. In domestic ewes, plasma progesterone levels during the 1st 50 days of pregnancy are 2 to 3 ng/ml and are not significantly higher than during the luteal phase of the estrous cycle. After 50 days of pregnancy, plasma progesterone increases 2 to 5 times (Bassett et al. 1969). In bighorn ewes, an elevated level may be reached by 50 days of gestation (Whitehead and McEwan 1980). Progesterone concentrations between days 60 and 80 in bighorn ewes studied by Whitehead and McEwan (1980), and in our ewes, did not fall below 2.5 ng/ml. Thus, during the 1st 2 months after the breeding season progesterone levels below 2.0 ng/ml in bighorn sheep indicate no pregnancy or very early gestation. Three of our captive ewes had 0.8 to 1.9 ng/ml progesterone between 2 and 23 days of gestation (Table 1). During the 1st trimester, 2 to 6 ng/ml should indicate pregnancy or the luteal phase of the estrous cycle. Progesterone in excess of 6 ng/ml should reflect pregnancy. False diagnoses of pregnancy may occur at levels < 6 ng/ml during the 1st 3rd of gestation. Pregnancy diagnosis early in gestation, while some ewes may still be exhibiting estrous cycle, was unreliable and impractical. As demonstrated by Ramsay and Sadleir (1979), Whitehead and McEwan (1980), and this study, a threshold of 2.0 ng/ml progesterone during the latter 2/3 of gestation is quite diagnostic.

REPRODUCTION BY BLM-SHEEP RIDGE BIGHORNS

In contrast to many of the years to this study, reproduction among BLM-Sheep Ridge bighorns in 1981, 1982, and 1983 was generally high and there was no consistent pattern of alternate-year-reproduction. Although a few

study ewes did not reproduce every year, most marked and unmarked ewes were pregnant. BLM-Sheep Ridge bighorns seemed to be responding to mangement activities; and current, relatively low reproductive losses apparently occur as prenatal, postnatal, or summer mortalities. We were unable to determine a cause, but population imbalances may be responsible for a few nonpregnant ewes and lamb mortalities.

Except for winter range manipulation and population control, little can be done to improve the nutrition of the BLM-Sheep Ridge bighorns. Although ranges used in spring and fall may be limited, summer ranges seem very adequate (Thorne et al. 1979) and these sheep capitalize upon the advantages of extensive altitudinal migrations (Hebert 1973). Our data failed to show a relationship between forage production on winter range, which we used as an indication of length of growing season, precipitation and forage quality on summer ranges, and, presumably, summer nutrition, and reproductive success.

The most significant management activities influencing BLM-Sheep Ridge bighorns and their nutrition are population control through trapping and transplanting and winter range improvement and expansion. The former has probably reduced the size of the population slightly from the late 1970's and kept the herd within the calculated limits of winter range carrying capacity since the mid 1970's. Since 1975, trapping has removed 566 sheep from the BLM-Sheep Ridge and Torry Rim populations; the majority have been from the former. The intent has been to remove sheep in relation to long term (5 year) forage utilization and hold utilization under 65 percent. This practice, after an expected lag time, likely is responsible more than any other factor for improved productivity since 1979. In addition, range expansion by baiting bighorns to a previously unused area has increased critical winter range and forage by about 20 percent (32.3 ha) since 1981. This has increased the winter range nutrient potential for the herd and likely also has contributed to relatively high lamb production in recent years.

Among BLM-Sheep Ridge bighorns, trapping and transplanting generally removes a cross section of the ewe population along with a few lambs and young rams, and it is very unlikely the number of yearling ewes has ever been high in proportion to mature ewes. Indeed, there is little evidence of ewes lambing on their 2nd birthday among these sheep. If population imbalances acting through behavior to cause reduced reproductive performance among the BLM-Sheep Ridge bighorns, it would almost have to be due to a disproportionately high ratio of young to mature rams. The sex ratio of bighorns normally is about 1:1 and the death rate of rams is low and steady between ages 2 and 8, after which mortality of rams is probably higher than that of ewes. Table 4 shows a low ram:ewe ratio and a high immature to mature ram ratio among sheep from the BLM-Sheep Ridge where rams reach 3/4 curl horn size at 4 or 5 years (Thorne et al. 1979, Table 20). Classification presented in Table 4 are somewhat biased because they were generally conducted toward the end or after rut when some older rams had left the company of ewes; however, it is apparent the young ram segment is disproportionately high in relation to mature rams. Observations during rut when as many as 4 to 6 young rams can be observed harassing ewes in the absence of large rams tends to confirm this. If this is influencing reproductive success, it would be through early birth of lambs or harassment induced temporary infertility, which would not be corrected by reduction of the overall population size or

habitat improvement. Shifting ram age structure toward older, larger rams might improve reproductive performance.

DISEASES AND PARASITES

No evidence of scabies or leptospirosis was detected among BLM-Sheep Ridge bighorns. Leptospirosis does cause abortion in some species, including domestic sheep, and mortality in juveniles; but it has not been reported in North American wild sheep (Thorne 1982b). Although not examined in this study, previous studies have failed to reveal the presence of brucellosis, an important reproductive disease of cattle and elk, among bighorn sheep of BLM-Sheep Ridge (Thorne et al. 1979).

Ovine progressive pneumonia is insidious in onset and characterized first by weight loss and, after a course of 3 to 12 months, by death (Cutlip et al. 1978). It is probably transmitted directly from sheep to sheep (Gates et al. 1978, De Boer et al. 1979). Experimentally, ovine progressive pneumonia has been shown to cause resorption or abortion of fetuses early in pregnancy (Cutlip et al. 1982). Many sheep may be persistently infected with virus and have antibodies against it without ever showing clinical signs (Cutlip et al. 1978).

Ovine progressive pneumonia has never been diagnosed in mountain sheep. The small evidence we found was too equivocal to conclude the disease was present in BLM-Sheep Ridge bighorns; however, it should not be ignored. The historic association of mountain sheep with domestic sheep and the contagious nature of ovine progressive pneumonia suggest this disease of domestic sheep could be transmitted to wild sheep. It might not run as long a course in mountain sheep as in domestic sheep because debilitated wild sheep would be unlikely to survive as long as affected domestic sheep. Occasional emaciated, debilitiated ewes are observed among BLM-Sheep Ridge bighorns with an appearance similar to domestic ewes with ovine progressive pneumonia; however, these animals are generally felt to be showing the effects of old age. Domestic range ewes with chronic diseases, including ovine progressive pneumonia, which result in debilitation and weight loss also have impaired reproductive efficiency, primarily through lowered fertility and fewer lambs born alive. Lowered fertility is presumed to be due to prolonged disease-induced stress and associated catabolism (Gates et al. 1977).

In domestic sheep, campylobacteriosis is an acute disease characterized by abortion during the last trimester of pregnancy or death of the lamb at or shortly after birth. Although infertility is not a problem, abortion rates among domestic sheep may range from 5 to 70 percent with 25 percent abortion being common (Marsh 1965, Jubb and Kennedy 1970, Dennis 1975, Smibert 1978). Campylobacter fetus is a fragile organism which is killed by exposure to oxygen and difficult to culture on artificial media. The preferred sources for isolation from domestic sheep are bile and cotyledons of the ewe and abomasal content, liver, spleen, and brain of a fetus or lamb. Culture of vaginal washings to diagnose ovine campylobacteriosis is a poor diagnostic technique which was chosen in lieu of aborted lambs and for lack of the preferred tissues for culture. Recovery of Campylobacter sp. from one ewe is not diagnostic because many animals are host to commensal nonpathogenic

Campylobacter spp. It is unfortunate the isolate recovered in 1982 could not be identified to subspecies. Negative cultures from 42 other ewes does not prove campylobacteriosis is not present because the organism is so difficult to cultivate. Five of 28 ewes tested serologically for campylobacteriosis produced low positive reactions; however, these could not be considered diagnostic because higher titers would be expected from actively infected sheep. Campylobacteriosis could be responsible for poor reproduction among mountain sheep, especially in large herds where there would be ample opportunity for transmission.

RECOMMENDATIONS

Although the BLM-Sheep Ridge bighorn population has experienced poor reproduction in the past, productivity during this study was improving and by 1983 was relatively good. We feel this was most likely due to management activities since the mid 1970's and, therefore, make the following recommendations.

1. Population control by transplanting in relation to available winter forage should be continued to maintain a healthy herd.

2. Range extension and range improvement should be continued and increased where possible.

Although this study did not confirm presence of diseases adversely affecting health or reproduction of these bighorns, equivocal evidence of two diseases was revealed and the threat of new diseases and widespread transplanting of these bighorns indicate there is no reason for complacency.

3. Surveys for presence of disease and parasites should be continued using the most reliable diagnostic techniques available.

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PREGNANCY RATE AND THE TIMING OF LAMB LOSSES IN CALIFORNIA BIGHORN SHEEP IN THE ASHNOLA, B. C.

William L. Harper, Department of Animal Science, University of British Columbia, Vancouver, B. C.

ABSTRACT

A free-ranging population of California bighorn sheep (Ovis canadensis californiana), with a history of low lamb production, was studied to determine that point in the reproductive cycle when offspring losses were occurring. A pregnancy rate of 100% was determined among adult females using Doppler ultrasound. Adult female liveweights, body condition scores, disease incidence, and serum trace element levels of captured females indicated these animals were not under nutritional stress during late gestation. Sixty percent mortality of lambs from tagged females occurred in the first three weeks postpartum. Assuming a 100% pregnancy rate, 72% mortality of lambs from untagged females occurred in the same period. Determination of prenancy rate allowed identification of the critical period in lamb survival responsible for low lamb production.

INTRODUCTION

A critical piece of information, required to fully understand the population dynamics of bighorn sheep, is the proportion of females which successfully conceive each year. This information is lacking for most populations. Counts of offspring to estimate female production are usually made after the neonatal period, a time when significant mortality can occur.

Classification counts of the Flatiron Mountain population indicate that lamb productivity has generally decreased since the 1950's and early 1960's, and has averaged only 26 lambs per 100 females since 1970 (Figure 1). Many management strategies (cattle removal, coyote removal, spring and fall burning, winter feeding, mineral supplementation, water supplementation, and antihelmintic treatment) have been, and are being, applied to this population in an effort to increase lamb production. While there was a brief increase in lamb production to 0.47 lambs:female after the first year of winter feeding, lamb counts have since declined.

The main objectives of this study were:

1) To investigate the reproductive, nutritional, and disease status of females prior to lambing, and;

2) To identify the period in the reproductive cycle where most offspring losses were occurring.

THE STUDY AREA

Flatiron Mountain is located east of Ewart Creek in the Ashnola River watershed of south-central British Columbia (Figure 2). Trapping and subsequent observation of tagged and untagged females took place primarily on the south side of the mountain (South Slope) where a continuous 400 hectare grass steppe community occurs. Elevations in the study area vary from 1000-2100 meters a.s.l. Detailed descriptions of the topography, soils, and botanical composition of the grass steppe communities of the Ashnola watershed are available elsewhere (Blood 1961; Demarchi 1965; Harper 1969; Scheffler 1972; Harcombe and Kowall 1982).

METHODS

A total of 12 bighorn females were captured during February and March, 1983, in a trap located at 1400 m elevation on the west end of South Slope (Figure 2). The population has been fed winter supplements in the form of a pelleted ration since 1978, and this was used as bait for the trapping program. Minimal amounts of bait were used to avoid confounding the nutritional status of the population. A corral-type trap was constructed 3 to 4 m high and 25 m in diameter from 1 cm mesh netting covered with burlap to form a visual barrier. A gate 3 m high and 5 m wide was released, either manually, or electrically, when bighorn were inside the corral. Once captured, the sheep were quietly driven into two plywood handling crates. The last five sheep captured were given a low dose (< 1 mg. kg^{-1}) of Rompun to achieve mild sedation.

Pregnancy status was diagnosed, based on the presence or absence of fetal and maternal tissues of pregnancy, by ultrasonic scanning using a Doppler Ultrasound Pregnancy Detector (Medata Systems Ltd., The Parade, Pagham, West Sussex, England, PO21 4WT). Specific details of this technique, and the accuracy of diagnosis for bighorn sheep (100%), are available elsewhere (Harper and Cohen, in press).

Liveweight was determined with a dial spring scale, accurate to 0.5 kg, with the animals held in a small plywood box. Body measurements to 1.0 mm, taken with a flexible steel tape, included: hind foot length, total body length, and chest girth. Body Condition Scoring (Russel et al. 1969) was used to provide a standardized subjective assessment of the fatness of live animals. A score ranging from 0 to 5, was assigned to each animal based on certain physical characteristics which vary according to the level of fat deposition around the lumbar vertebrae.

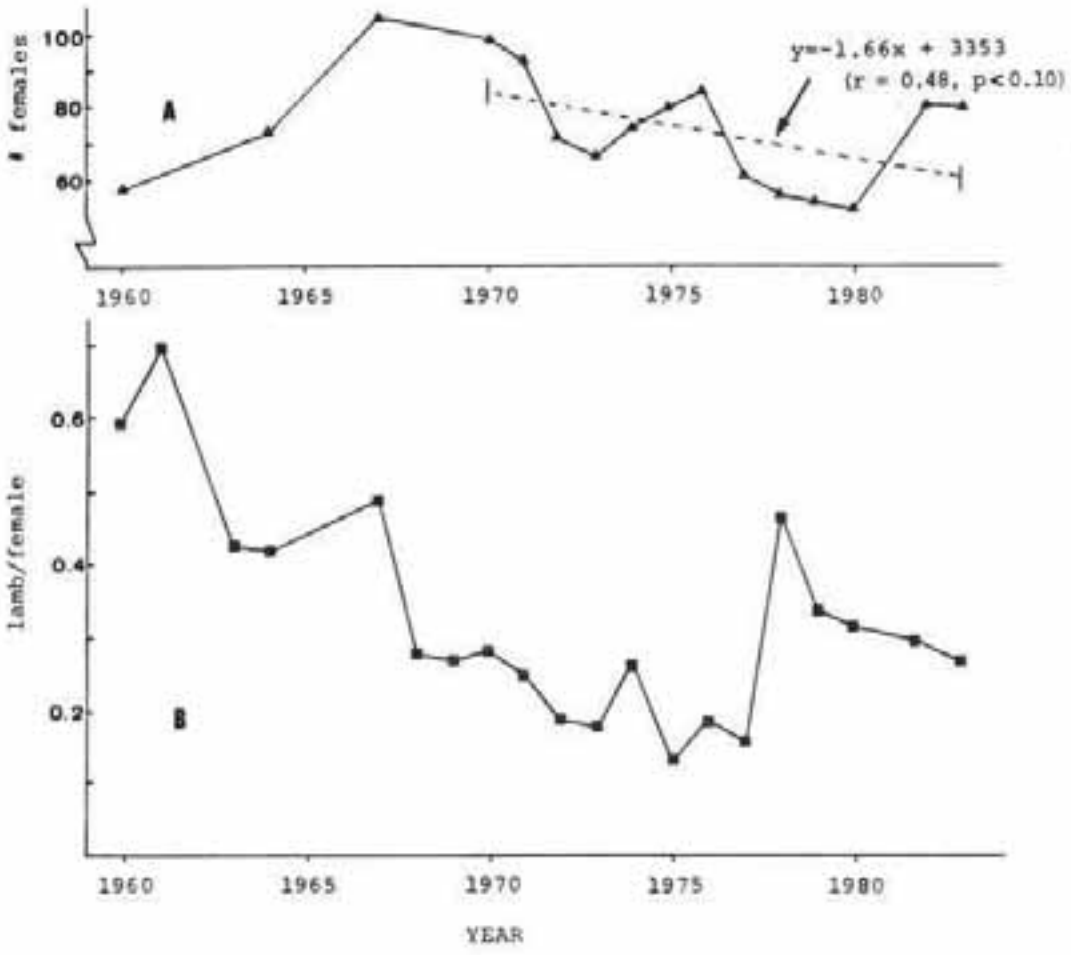


Figure 1. (A) Yearly maximum counts of females (2 years and older) on Flatiron Mountain from 1960 to 1983. (B) Ratio of lambs per adult female from 1960 to 1983 based on yearly maximum counts

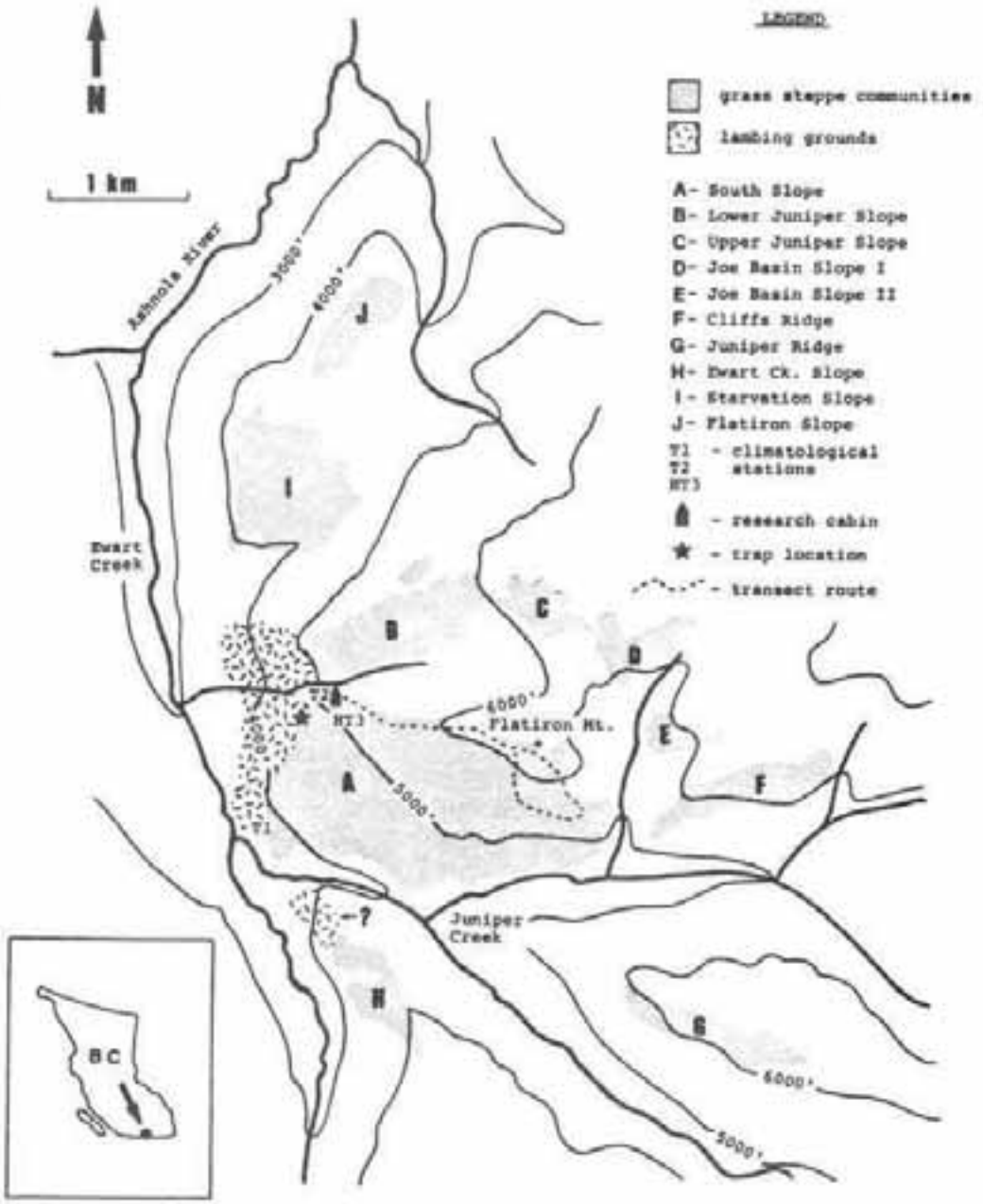


Figure 2. The study area on Flatiron Mountain in the Ashnola River watershed.

To determine trace mineral status, six blood samples were obtained by jugular venipuncture. Once the blood had coagulated, serum was separated by centrifugation, or when not possible, by letting the blood stand overnight. The serum samples were then kept on ice until they could be frozen (within 5 days), and submitted to the Veterinary Pathology Laboratory at Abbotsford, B. C. for trace element analysis and disease antibody titres. Disease incidence was also determined from nasal swabs taken from the external nares. Nasal swabs were immediately placed in sterile fixative and kept cool until submitted to the Provincial Veterinary Pathology Laboratory at Abbotsford, B. C. Culturettes (manufactured by Canlab), a sterile culture collection system containing 0.5 ml of modified Stuart's bacterial transport medium, were used to collect bacterial samples. For viral samples the Virocult collection system was used (Medical Wire and Equipment Co. Ltd.).

Before being released, the adult females were fitted with a permanent, nylon, identification collar (n=10). Five animals, including a lamb, were also given individual plastic eartags (Duflex, manufactured by Fearing).

A standardized transect, developed by B. C. Ministry of Environment personnel and employed during a previous study of the population (Ramsay 1980), was the most frequently used route for classification counts of the population (Figure 2). Only those classification counts in which all of the South Slope and Juniper Slope were thoroughly scanned are included in estimates of the total size and age-sex composition of the population.

Age-sex classes and marked individuals were identified using 7 x 50 binoculars and a spotting scope with 20X or 40X eyepieces. Bighorn were classified as lambs (less than 1 year old), male and female yearlings (1 to 2 years old), adult females and adult males (greater than 2 years old). The adult males were additionally classified into one of four age classes based on horn size (Geist 1971).

RESULTS

PHYSIOLOGICAL AND NUTRITIONAL STATUS IN LATE GESTATION

All 10 adult females captured on Flatiron Mountain between January 29 and March 24, 1983, were diagnosed as pregnant. The one capture mortality was also pregnant with a single fetus. Thus for the sample of bighorn 4.5 years and older the pregnancy rate was 100% (Table 1). Based on a gestation period for O. c. californiana of 174 days (Shackleton et al. 1984), and estimated dates of parturition of each female, fetal age at the time of diagnosis varied from 73 to 130 days (Table 1).

Mean weights and lengths of Ashnola adult females (+/- sd) were as follows: liveweight 61.6 +/- 4.1 kg (range 56.7 to 68.0 kg), total length 1608 +/- 69 mm (range 1470 to 1700 mm), and hindfoot length 393 +/- 16 mm (range 363 to 420) (Table 1). The mean chestgirth of adult females was 1011 +/- 41 mm (n=11). Body condition scores varied from 1.5 to 3.0 with a mean adult score of 2.3 (Table 1). The female lamb had the lowest body condition score at 1.5.

Table 1. Pregnancy diagnosis, weights, and measurements of bighorn females captured on Flatiron Mountain in 1983.

I.D.	AGE years	DATE OF DIAGNOSIS	FETAL AGE days	BASIS OF DIAGNOSIS[a] (Doppler ultrasound) FHR	FM	PC	UA	WEIGHT kg	BODY COND. SCORE	TOTAL LENGTH mm	HINDFOOT LENGTH mm
01	0.5	n/a						25.5	1.50	1280	-
02	4.5	07/03	128[b]	132	+	+		56.7	1.75	1650	380
03	6.5	21/02	102[c]	168	+		+	58.0	2.00	1560	364
04	6.5	06/03	122[c]		+		+	59.4	3.00	-	385
05	6.5	21/02	95-105[d]		(autopsy)			64.9	3.00	1570	405
06	7.5	07/03	119[c]	126	+	+	+	57.6	2.00	1470	410
07	7.5+	06/02	87[c]		+			67.1	2.50	1670	420
08	7.5+	29/01	86[b]		+			68.0	3.00	-	400
09	8.5+	06/02	73[b]		+	+		59.0	2.00	1630	375
10	8.5+	24/03	130[c]	108	+	+	+	64.4	1.75	1620	400
11	9.5+	07/03	105[c]		+			61.2	1.75	1600	395
12	9.5+	26/02	112[b]	162	+	+		-	2.50	1700	390

a - FHR=fetal heart rate (bpm); FM=fetal movement; PC=placental circulation; UA=uterine artery. b - Fetal age estimated from observations of newborn lambs.

c - Fetal age estimated from dates when females isolated themselves.

d - Fetal age estimated from the mean birthdate of the population.

The mean serum levels of selenium, copper, zinc, and iodine for adult bighorn and one lamb on Flatiron Mountain are presented in Table 2. The average level of 0.090 ppm selenium in the five mature females was twice the level of 0.046 ppm for the 10 month old female lamb, and the same magnitude of difference was also found in copper and zinc levels. Serum copper averaged 0.69 ppm in adult females, but was only 0.35 ppm in the lamb. Zinc averaged 0.52 ppm in the adult sera, but was only 0.25 ppm in the lamb. There was no great difference in the concentration of iodine, calcium, and magnesium between the two age classes (Table 2). Phosphorus, however, was almost twice as concentrated in the lamb serum compared to the mean level of adult females (Table 2).

On the advice of the pathologist, serum antibody tests were conducted for the presence of two highly pathogenic organisms that can cause late term abortions. Rapid Plate Tests on six serum samples for Brucella spp. were all negative. Serological tests for the presence of Leptospira spp. antibodies were also negative.

Analysis of the nasal swabs indicated the presence of four species of bacteria and one species of virus. A 30 to 50% incidence of the following three non-pathogenic bacteria was found: Flavobacter spp., non-hemolytic Corynebacterium spp., and alpha-Streptococcus. Two of six nasal swabs isolated hemolytic Staphylococcus aureus, a potentially pathogenic bacterium. All 12 nasal swabs were negative for the presence of Pasteurella spp. and hemolytic Cornyebacterium pyogenes. Viral nasal swabs were all negative for bovine viral diarrhea (BVD), infectious bovine rhinotracheitis (IBR), and adenovirus. However, six of twelve nasal swabs from these bighorn contained parainfluenza type-3 (PI-3) virus, based on successful culturing on ovine cell medium, and identification by electron microscopy (Dr. R. Lewis, pers. comm.).

PRODUCTION AND SURVIVAL OF OFFSPRING DURING THE LAMBING PERIOD OF 1983.

Periodic censuses of Flatiron Mountain from April 23 to June 11, 1983, showed that the number of females observed on the winter-spring range of Flatiron Mountain declined from 70 in late April to 50 animals by May 3 when females were leaving the herd presumably to give birth. The number of females observed remained at approximately 50 until May 10, after which it increased to 58 by May 21. The number of females observed did not return to pre-lambing period levels until May 24, and then remained at approximately 70 females until at least June 11. This exodus of animals from South Slope for a period of one month coincided with a steady increase in the observable number of lambs (Figure 3).

The pattern of lamb observations through the lambing period indicated that parturition occurred over a period of approximately 1 month between April 22 and May 22 (Figure 3). In 1983 when 13% of the females were tagged, three periods when the number of lambs decreased were identified. These were April 28 to 30, May 12 to 18, and May 26 to June 6 (Figure 3). In each case the decrease was verified due to the loss of lambs from known individuals, which coincided with the lower total number of lambs observed. The number of lambs observed on Flatiron Mountain peaked at 16 on May 22, but decreased to 15 with the loss of female #9's lamb. Maximum lamb counts remained at 15 for the entire month of June. The number of lambs then increased in early July with

Table 2. Blood chemistry of female bighorn from Flatiron Mountain.

Serum Constituent	Units	Concentration in Blood Serum: Adult females $\bar{X}$	Adult females SD	Adult females n	Lamb female n=1
Trace elements-					
Selenium	ppm	.090	.034	5	.046
Copper	ppm	.69	.08	4	.35
Zinc	ppm	.52	.19	4	.25
Iodine (total)	mcg%	5.3	1.3	4	5.0
Macro elements-					
Calcium	mg%	8.95	.41	4	9.7
Magnesium	mg%	1.95	.57	4	1.28
Phosphorus	mg%	3.25	.73	4	5.9

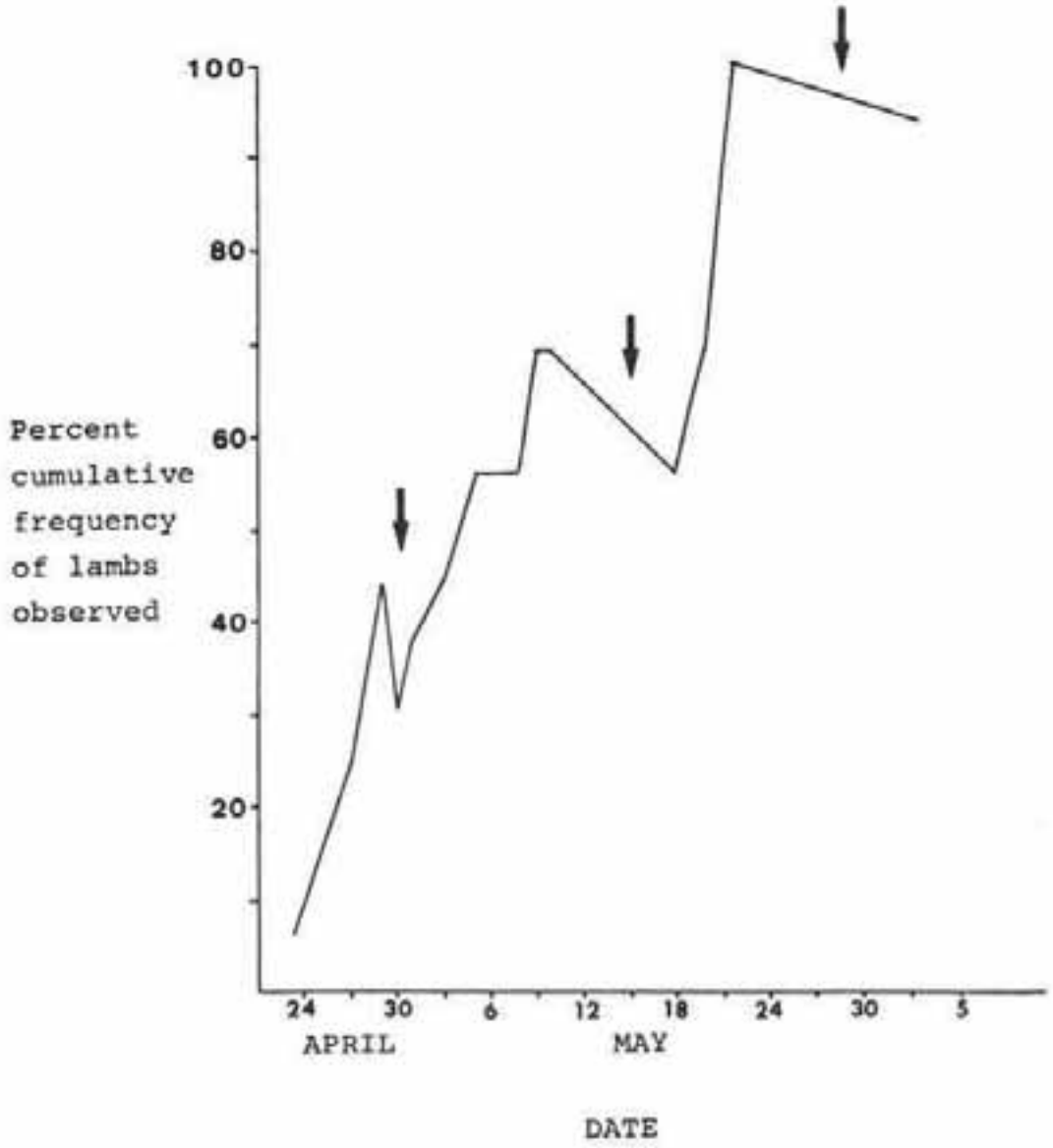


Figure 3. Cumulative frequency of newborn lambs observed on South Slope in 1983.

the return of seven females (including #6 and #11), and 5 lambs to Flatiron Mountain. The final lamb:female ratio for 1983 was thus 20/82 or 0.24.

Of the total estimated population of 82 adult females, 10 tagged females and one naturally marked female could be individually identified and observed through the lambing period. The pattern of isolation showed five of them (Category I) gave birth on the cliff escape terrain at the west end of South Slope (Figure 2), and five of them (Category II) gave birth at an undetermined location (Figure 4). Although female #10 had been diagnosed pregnant, she was consistently observed on South Slope, but never with a lamb of her own. Since it could not be determined if and when she isolated herself, she was placed in neither category.

Of the five females in Category I observed on the South Slope lambing grounds, only two (#2 and #12) had lambs which survived until early August (Figure 4). The other three females in Category I were observed with lambs, but they lost them when the lambs were between 5 and 21 days old (Figure 4). The females in Category II left South Slope for periods ranging from approximately 16 to 60 days. There was considerable variation in the date they left and in the time they spent away from the main winter-spring range. As with the females which remained on and near South Slope, only 2 of the 5 females in Category II returned with lambs. Based on the date when they isolated themselves and the date when they returned to South Slope without a lamb, the unsuccessful females in Category II lost their lambs when they were less than 20 days old. The females in Category II which lost their lambs, returned to South Slope between May 10 and May 20. Those which did not lose their lambs returned more than one month later in early July (Figure 4).

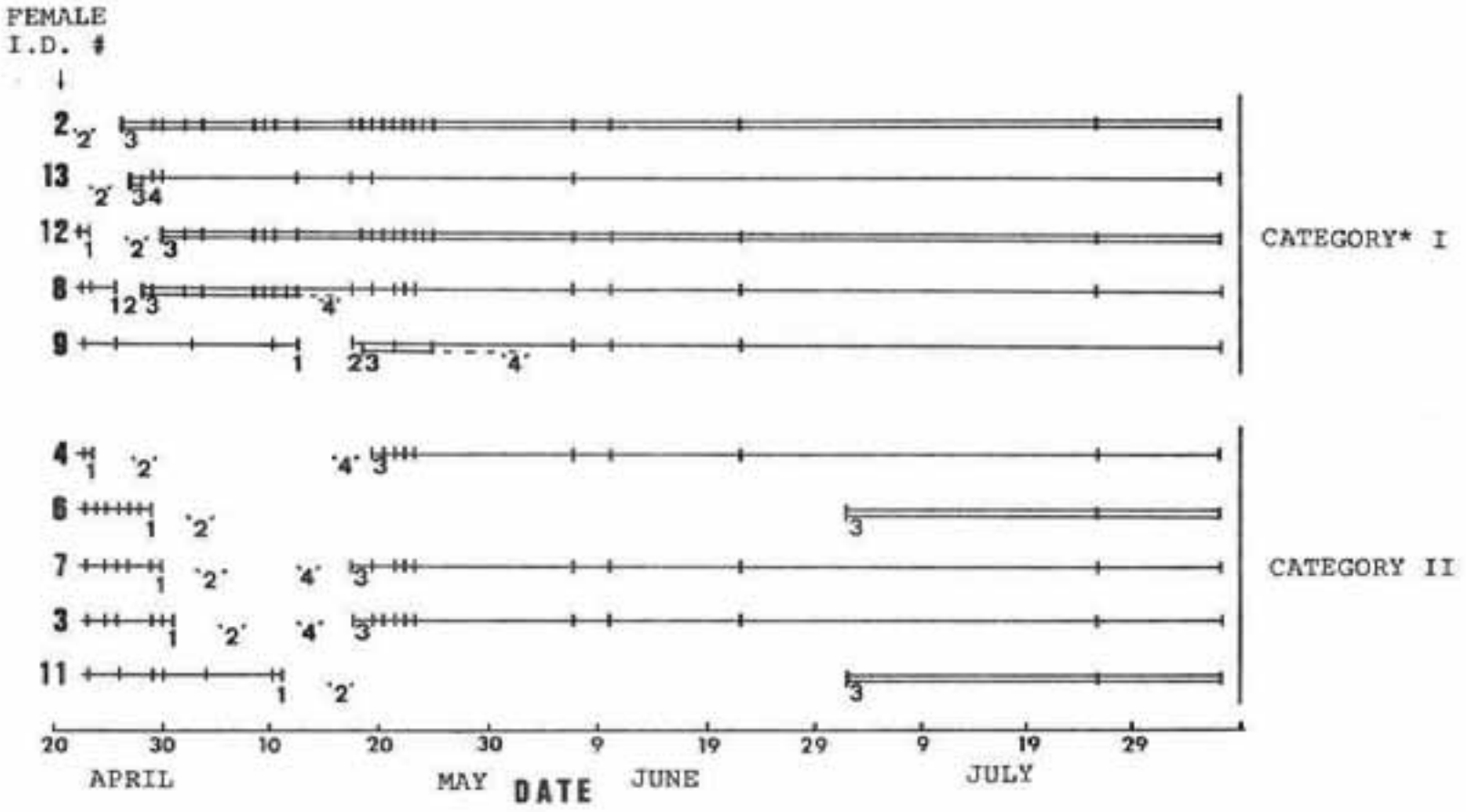
DISCUSSION

PHYSIOLOGICAL AND NUTRITIONAL STATUS IN LATE GESTATION

Assuming the sample of females is representative of the population as a whole, the 100% pregnancy rate obtained in mid to late gestation from the sample of 11 females from Flatiron Mountain indicates the cause of low lamb production is not low conception. Unless a specific disease causing late term abortion were present in the population, it is probable that most, if not all, of these pregnant females would have carried their fetuses to term.

Similarly high pregnancy rates have been determined for bighorn from the Vaseux Lake bighorn population in the South Okanagan. Autopsies of road-killed and shot females from Vaseux Lake revealed 17 fetuses from 16 females (Spalding 1966; and Ministry of Environment file notes). A sample of females captured live from Vaseux in 1977 also revealed a 100% pregnancy rate, with two cases of twinning (Eccles and Shackleton 1979). Slightly lower pregnancy rates were found in Dall's sheep from the MacKenzie Mountains in the Northwest Territories where 78% of the 94 mature females autopsied were pregnant with single fetuses (Simmons et al. 1984). Whereas it appears most wild Ovis populations have high conception rates, Heimer (1978) documented a 50% pregnancy rate, and alternate year production in a Alaskan population of Dall's sheep.

The mean liveweight of 62 kg for adult females from Flatiron Mountain is higher than would be expected if these animals were nutritionally stressed.



*Category I - those females which used the South Slope lambing grounds.
Category II - those females which left South Slope to lamb in an unknown area.

female observed without a lamb on South Slope.

female observed nursing a lamb on South Slope.

vertical bars indicate at least one observation per day.

1 - isolation
2 - parturition
3 - reappearance on South Slope.
4 - loss of offspring.
'' - numbers in quotes are estimated dates.

Figure 4. Pattern of birth and survival of lambs from identified female bighorn on Flatiron Mountain.

Liveweights of adult females in a captive research population at the Okanagan Game Farm averaged much lower at 47 kg. Despite these low body weights, lamb survival was higher in the captive population in 1982 and 1983 (64 and 82% respectively) than in the free-ranging Flatiron Mountain population (28 and 24% respectively). This suggests the nutritional level of the Flatiron Mountain population is well above any limit which would greatly affect lamb survival.

The mean body condition score of 2.3 indicates most females had adequate fat stores in mid to late winter. The lightest female measured was a lamb and it also had the lowest backfat index score. Body condition scores of bighorn from the Game Farm research population were lower than that of females from Flatiron Mountain. In domestic sheep, body condition scores were able to predict (r^2 = 0.88) the chemical fat in the fleece-free empty body (Russell et al. 1969). Using the regression relationship from domestic sheep, the mean score of 2.3 in Flatiron females suggests the chemical fat in their empty body should be around 20%. This indirect estimate is higher than the maximum 15% chemical fat measured directly in Dall's sheep females in early winter (Heimer 1980).

Although energy status of the Flatiron females appeared to be adequate during gestation, blood serum levels of copper, zinc, and selenium, may be marginally deficient based on the adequate levels which have been established for domestic sheep (Puls 1981). However, iodine, calcium, magnesium, and phosphorous are fairly normal based on domestic sheep requirements (R. Puls, pers. comm.).

Calcium levels in bighorn sheep sera range from means of 9.2 to 11.0 mg/dl (Franzmann and Thorne 1970; Peterson and Bottrell 1978; Hickey 1976). Flatiron Mountain females have calcium levels slightly lower than this range. Conversely, magnesium levels are higher than those reported by Franzmann and Thorne (1970). Inorganic phosphorus levels in Flatiron female sera are lower than those reported in Idaho and Colorado (Hickey 1976). Wyoming bighorn also had slightly higher levels of serum inorganic phosphorus than Flatiron females (Franzmann and Thorne 1970). Of significance is the low blood mineral levels found in the lamb. This is consistent with the low body condition score of this animal. However, this lamb did not die despite its apparent nutritional stress, and the survival of lambs from one month to one year of age is high (82% in 1982, and 85% in 1983).

The most interesting result of the nasal swab analysis was the isolation of PI-3 virus from 6 of the 12 bighorn females samples since Parks et al. (1972) suggested PI-3 was implicated in an acute disease situation leading to death in some captive bighorns. However, similar high incidences of PI-3 in bighorn has been documented in Colorado and Wyoming, where 62% of 29 sheep had positive antibody titres (Parks and England 1974). The high incidence of PI-3 in this population is probably not responsible for the low lamb productivity. Three of the four lambs which survived from the sample of marked females came from dams which were infected with PI-3 in mid to late gestation, and no clinical sign of disease were observed in the population.

PRODUCTION AND SURVIVAL OF OFFSPRING

Lamb Production in Previous Years

Classification counts to estimate the number of adult females and the lamb:female ratio from 1960 to present are summarized in Figure 1. The pattern of horn growth in this population did not allow accurate classification of 2 year old females, therefore, 2-year olds were included in the lamb:female ratios. Total numbers of lambs observed range from a high of 49 in 1967 (Scheffler 1973) to a low of 10 in 1975 and 1977 (Ramsay 1980). Lamb production exceeded 65% in 1960 and 1961 (Blood 1961), and remained relatively high through the 1960's ranging from 0.42 to 0.46 (Demarchi 1965; Scheffler 1973). During the period 1960 to 1967 the population was apparently increasing based on the maximum number of females observed (Figure 1). The population reached a maximum of at least 107 adult females (2 yr+) in 1967 (Scheffler 1973). Lamb production 1970 to 1983 was lower, however, and varied from 0.13 to 0.47 lambs:female (Ramsay 1980), averaging only 0.26. An apparent decline in the maximum number of adult females observed in the 1970's corresponded to low lamb:female ratios (Figure 1). From 1978 to 1980 lamb:female ratios were over 0.30 but the number of adult females continued to decline. Lamb:female ratios for 1982 and 1983 were 0.28 and 0.24 respectively, very near the average of 0.25 for the period 1970 to 1980.

Censuses conducted as part of this study indicate an increase in the number of females in the population from 1980 to 1982 (Figure 1). This apparent increase could be an artifact of survey technique and range occupation by bighorn, or could be due to increased adult survival. Lamb production during this period, however, was probably not high enough to account for the increase in female numbers.

Production and Survival of Lambs in 1983

Using an estimated 69 pregnant females (Harper 1984), the lamb production from sexually mature untagged females was 16 of 58 or 28%. This is somewhat lower than lamb production from tagged pregnant females which was 4 of 10 or 40%. Observations of marked females in Category I (see Figure 4) indicate that the losses occurred when the lambs were between 5 and 21 days old. Tagged females in Category II lost their lambs when they were less than 21 days old also. Coupled with the 100% pregnancy rate, this indicates that lamb mortality during the first three weeks of life was 60% for tagged females, and 72% for untagged females.

Once the bighorn lambs reach approximately one month of age then their survival rate increases dramatically. From maximum counts of the 1982 cohort in mid-June, the survival rate to May of 1983 was 82% (Figure 5). This is slightly higher than the survival rates determined from 1963-1964 of 71% (Demarchi 1965), and from 1960-1961 of 73% (Blood 1961).

It is apparent that the problem of low lamb production to this population occurs sometime after parturition, but before the lambs reach 3-4 weeks old. Diagnoses of pregnancy made it possible to focus in on that period in the reproductive cycle, when the majority of losses to recruitment were occurring. Factors which can affect the survival of lambs such as lactation, inclement weather, predation, and poor mothering, are currently being investigated.

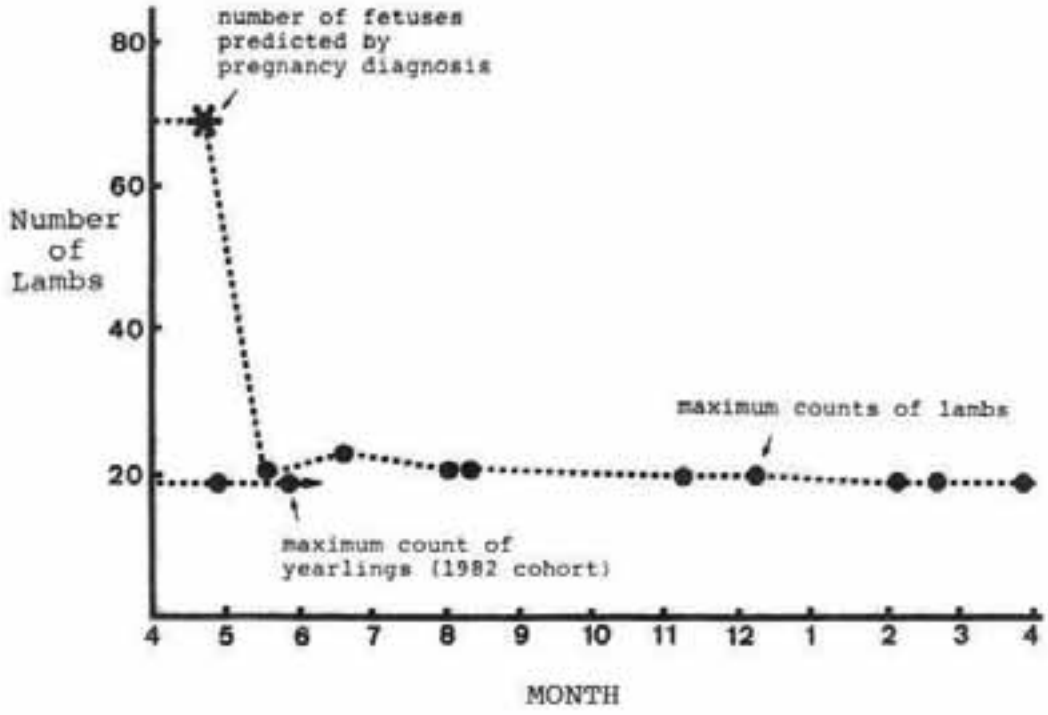


Figure 5. Survival of bighorn lambs on South Slope from June, 1982 to May 1983 based on pregnancy diagnosis in 1983, and maximum counts of lambs and yearlings.

ACKNOWLEDGEMENTS

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POPULATION DENSITY OF MOUNTAIN GOATS IN SOUTHEAST ALASKA

Joseph L. Fox, College of Forest Resources AR-10, University of Washington, Seattle, WA 98195.

ABSTRACT

Simultaneous counts by an observer on the ground and one in a fixed-wing aircraft were performed on five occasions during mountain goat (Oreamnos americanus) population surveys in southeast Alaska. The aircraft-based observer's population counts averaged 32 percent lower than those of the ground-based observer. Population counts of mountain goats were made using ground-based surveys in eight sites in southeast Alaska. Year-round goat habitat in each site was distinctly delineated by flat lowlands or bodies of water. Based on the ground counts, densities of goat populations ranged from 0.5 to 4.7 animals per square kilometer, and averaged 1.3 over the total of 219 square kilometers surveyed. These densities are substantially higher than those reported for year-round range in coastal British Columbia and suggest that coastal mountains are more densely populated with goats than previously thought.

INTRODUCTION

Density figures for mountain goat populations have rarely been reported. Problems with both the accuracy of population size determination and difficulty in defining potential goat habitat have prevented widespread calculation of this population statistic. Where density is reported, these factors demand that comparisons between studies be made with caution.

McCrory et al. (1977) reported goat densities ranging from 0.6/km^2 to to a 3.1/km^2 (overall average, 1.5/km^2) in areas of year-round goat habitat in Yoho National Park, British Columbia. Figures calculated from Hjeljord (1971) show densities of about 2.5/km^2 to 6.5/km^2 in "preferred" goat habitat (summer and winter ranges combined) on Alaska's Kenai Peninsula and Kodiak Island, respectively. In areas of "observed distribution" in northern British Columbia, Foster (1982) reported a goat density of approximately 13/km^2. Stevens (1983) reported densities from summer goat habitat in Olympic National Park, Washington as ranging from .6/km^2 to 14/km^2, with the average calculated as about 3.1/km^2. Goat densities in

year-round habitat of coastal British Columbia calculated from Hebert and Turnbull (1977) range from 0.03/km^2 to 0.59/km^2, and average 0.15/km^2. These low figures prompted Hebert and Turnbull (1977) to suggest that coastal goat populations have lower densities than those in interior regions. In another paper in this proceedings, Smith (1984) reports a goat density of 2.3/km^2 in year-round habitat in a site near the southern end of coastal southeast Alaska.

Overall, reported goat densities range from 0.03/km^2 to 14/km^2. With the variety of goat habitat designations used, including year-round range, summer range, observed distribution and preferred habitat, the large variation in densities is to be expected. Furthermore, the different methods for counting goats, from ground-based observations to aerial fixed-wing or helicopter counts, and the use of either actual counts or extrapolated estimates also interject variability into the density estimates. These problems are discussed below in conjunction with determinations of goat densities in southeast Alaska, in an attempt to make some reasonable comparisons of goat density among various regions and studies.

STUDY AREA

The study area was located in the north and central sections of southeast Alaska (Figure 1). Brief descriptions of the locations for each of the eight sites are:

1) Stroller White (58 km^2) - The area between the Mendenhall and Herbert Glaciers, 25 km northeast of Juneau.

2) William Henry (53 km^2) - William Henry Mountain and the connected NW-SE trending ridgeline immediately to its west; in the Chilkat Range, 70 km northwest of Juneau.

3) Wilkes Range (41 km^2) - Just north of the Stikine River delta, 35 km southwest of Petersburg. (The area west of the Twin lakes, i.e. including Wilkes Peak, is not included in this analysis).

The next five sites are located on the outer coast of Glacier Bay National Park, about 150 km west-northwest of Juneau.

4) Torch Bay-east (27 km^2) - From the combined valleys of South Trick Lake and Annoksek Creek to South Deception Lake and a line from there through the pass to the west arm of Torch Bay.

5) Torch Bay-west (16 km^2) - From South Deception Lake and the line to Torch Bay's west arm to Dixon Harbor and River.

6) Thistle Cove (10 km^2) - Northeast of Thistle Cove and bounded by the Dixon River.

7) Astrolabe Peninsula (7 km^2) - West of Dixon Harbor and Thistle Cove.

8) Dixon-Brady (6 km^2) - Between the upper Dixon River and the Brady Glacier, just northwest of the Thistle Cove site.

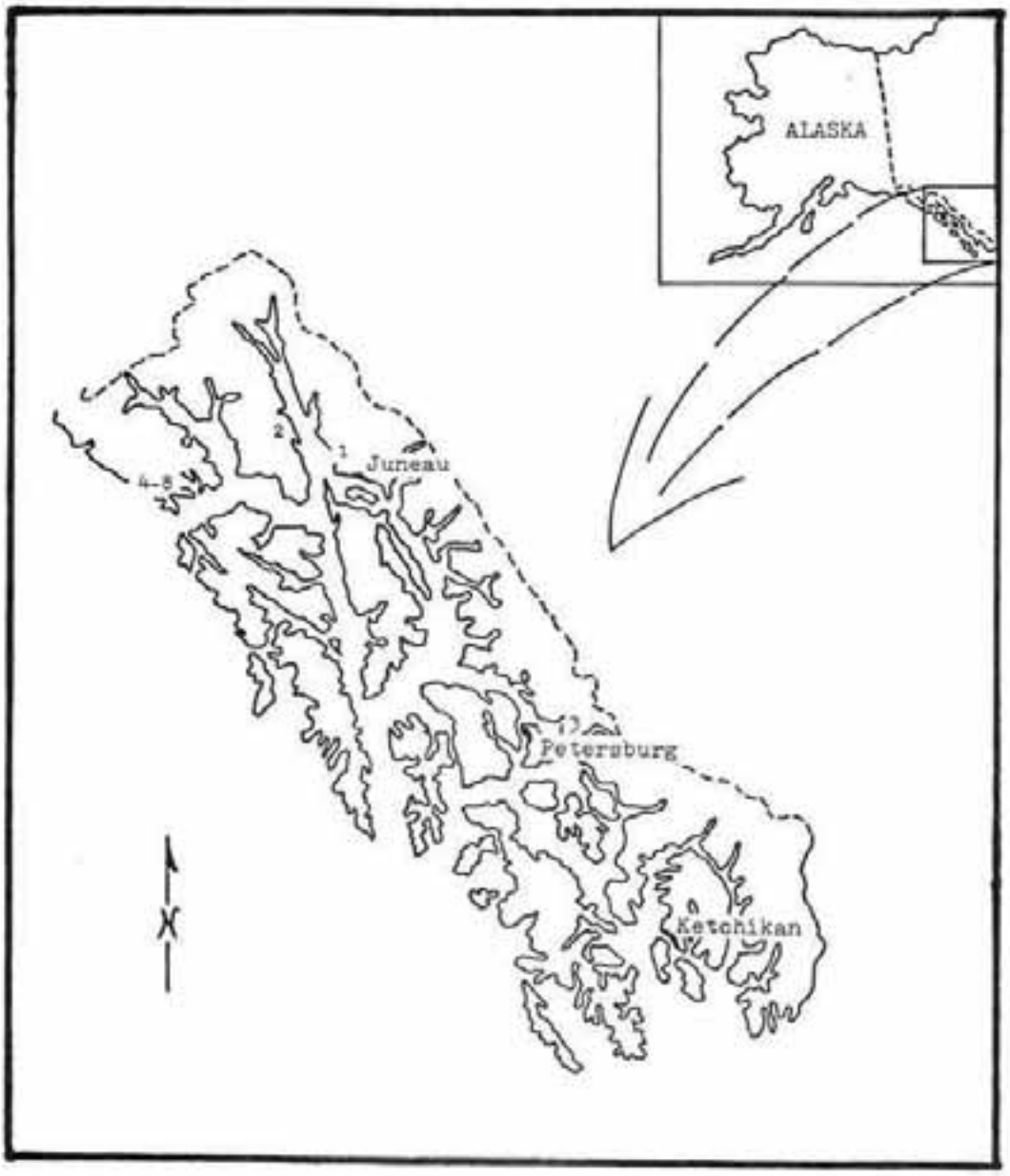

Figure 1. Study sites in southeast Alaska: 1. Stroller White, 2. William Henry, 3. Wilkes Range, 4-8. outer coast of Glacier Bay National Park.

Elevations in the study sites range from sea-level to 1750 m, with most sites being less than 1,200 m. Vegetation includes dense hemlock (Tsuga heterophylla) and spruce (Picea sitchensis) forests at low elevations, with lush subalpine and alpine meadows higher up, and sparsely vegetated rock at the highest elevations. Treeline varies from about 800 to 900 m. More detailed descriptions of plant communities typical of the study sites can be found in Alaback (1980) and Fox (1983). Mountain goats in southeast Alaska are known to utilize all elevations from sea-level to the highest points encountered within the study sites (Fox 1978, 1983).

METHODS

GOAT HABITAT

The sites used were selected primarily because they represent distinct areas of year-round mountain goat habitat. Each site was an isolated mountain block separated from other mountains by glaciers or flat lowlands. Goat habitat was defined as all terrain within the mountain block above a boundary where the mountain slopes decrease to less than 30° as they grade into relatively level lowlands or icefields and glaciers. There is no implication that the sites hold discrete goat populations, only that they represent easily delineated goat habitat.

The area of goat habitat within each site was calculated using a digital image analyzer. Overlays traced from United States Geological Survey 1:63,360 topographic maps were used to create darkened areas encompassing the identified goat habitat at each site. Once the analyzer was calibrated to the map scale it automatically measured the area of the darkened portions. These measures of goat habitat area were used in the density calculations.

GOAT COUNTS

The number of goats within each site was determined from ground-based counts, using binoculars and a 35X spotting scope. Counts were made on clear days and were conducted by travelling along ridgelines within each mountain block to observe as much habitat as possible. Goats were searched for intensively from dawn to dusk (about 18 hours) along predetermined ridgeline routes. The ridgelines used were above timberline, generally rounded and easily traversible, and afforded widespread views of the goat habitat being surveyed. Goats were monitored as best as possible throughout the day. All counts were made between June and August of 1976 and 1977.

In the Stroller White study site several replicate counts on different days were performed. Also, in the Stroller White and William Henry sites five pairs of simultaneous ground-based and aerial count were conducted. These simultaneous counts consisted of a typical aerial mountain goat population survey conducted by the Alaska Department of Fish and Game, which was performed during a ground-based count. During each aerial count, the observer spent approximately one hour searching for and counting goats from a small fixed-wing aircraft (Helio-Courier).

RESULTS AND DISCUSSION

COMPARISON OF COUNTING METHODS

Two replicate ground-based counts of mountain goats were conducted within the entire Stroller White study site during each of the summers of 1976 and 1977. The total counts were within eight percent of each other in each year (Table 1). Within a portion of this same study site, four replicate counts in 1976 and two replicate counts in 1977 were within five percent of one another (Table 2). The accuracy of ground-based counts depends on techniques used and the terrain and vegetation characteristics present, and has not been evaluated in any detail. The count totals show a high degree of consistency, and suggest confidence in their reflection of the actual goat population size. However, the number of counts was few and their consistency must be viewed with some skepticism, especially considering previous reports on the low and variable observability of goats (Ballard 1975, Foster 1982, Hebert and Langin 1982).

In the five pairs of simultaneous ground-based and aerial counts performed in the Stroller White and William Henry sites, the aerial count totals were consistently less ($p < 0.05$), by an average of 32 percent, than the ground-based counts (Table 3). Even acknowledging a probable greater variation in the results of ground-based surveys than was found here, this method was apparently more productive than aerial counts under the conditions present. The aerial counts were generally made in the afternoons of bright, sunny days and may have been adversely affected by the glare conditions present in such circumstances. Goats within or near the forest edge and those at lower elevations, even in open areas, were most often missed by the aerial observer. In one case a group of 25 goats in an area of alder and rock scree near the floor of a steep-walled valley was overlooked during the aerial count.

Although totals for the ground-based counts were substantially greater than the aerial ones, the aerial counts did include some animals not found during the ground-based search. In all cases, these animals were in limited areas which were not visible from the ground observation routes. During the full day of intensive searching from the ground, the chances of observing goats in hard-to-see locations (e.g., timberline forest patches) are certainly greater than those in an hour-long aerial search. The ground-based counts were made from easily traversible ridgelines, allowing observation of much of the potential goat habitat. Thus, the higher totals of the ground counts here are to be expected.

In contrast, Foster (1982) reported ground-based counts of mountain goats in a northern British Columbia study area to average only about 50 percent of aerial (helicopter) counts. His ground-based counts were made along forest roads, thus viewing the goats from below, and were made during all seasons and under a variety of weather conditions. These methods are not directly comparable to those used in the present study. In fact, neither set of ground-based methods could be easily applied to the other area due to various terrain or road availability restrictions. Such problems only serve to highlight the difficulties in comparing results of ground-based goat counts, or in applying methods to new regions.

Most counts of goats have been made from the air, either from a fixed-wing plane or helicopter. Small, slow flying planes and similarly maneuverable

Table 1. Ground-based counts of mountain goats in the Stroller White study site.

Date	Composition		Total
	Adults	Kids	
25 July 1977	56	22	78
15 August 1977	54	25	79
19 July 1976	51	15	66
28 July 1976	49	15	64

Table 2. Ground-based counts of mountain goats within a portion of the Stroller White study site.

Date	Composition		Total
	Adults	Kids	
25 July 1977	26	12	38
15 August 1977	28	13	41
28 June 1976	33	10	43
19 July 1976	31	10	41
28 July 1976	31	10	41
14 August 1976	31	10	41

helicopters are considered the best aircraft for finding goats (Nichols 1982). No conclusive tests have been made to determine the relative effectiveness of these types of aircraft in surveying mountain goats.

McCrory et al. (1977), Foster (1982), Stevens (1983) and Smith (1984) each used correction factors to estimate actual population sizes from their survey counts. McCrory et al. (1977) and Foster (1982) used subjective assumptions about the percent of goats missed in aerial counts, applying correction factors of between 10 and 30 percent to estimate real population size. In a limited test with marked individuals, Smith (1984) found aerial surveys (2 fixed-wing and 1 helicopter) to account for about 50 percent of the known population.

Methods for counting goats may necessarily vary from one region to another, due to specific terrain or logistic constraints. However, the reliability of the methods used should be tested. This is most easily accomplished through the use of repeated censuses with marked animals in the population. Since more investigations are being conducted using marked animals, especially radio-collared goats, these studies should be producing more such tests of census reliability.

DENSITY ESTIMATES

Goat population densities in the eight sites surveyed ranged from 0.5/km^2 to 4.7/km^2 (Table 4), with a combined average of 1.3/km^2. These figures represent a relatively wide range in population density, but reflect differences among small areas. Factors such as forage availability and amount of "escape" terrain may be important in determining the overall quality (hence, carrying capacity) of habitat within a mountain block. In addition, natural fluctuations in population size will also have an influence. At the William Henry site, for example, in 1974 Ballard (1975) counted a total of 55 goats. That was a density of 1.0/km^2, double the density reported here. The overall terrain in the William Henry mountain block is relatively gentle compared to that on the Astrolabe Peninsula, for example, and may help to explain the low goat density it supports. Using the combined average density (1.3/km^2) over the entire 219 square kilometers surveyed should smooth over these differences in comparison with other regions.

Let us assume, as Smith (1984) indicates, that aerial counts represent about half the actual population size. Considering the average 30 percent higher numbers seen in ground-based counts compared with aerial counts in the present study, an inflation of the ground counts by 10 to 20 percent may better reflect actual totals and densities. This would give an average density of about 1.5/km^2 in the present study.

Such goat density is consistent with the 1.5/km^2 reported by McCrory et al. (1977) for year-round range in interior British Columbia. Smith's (1984) reported goat density of 2.3/km^2 for year-round range in southeast Alaska is also comparable to that reported here. If the area of potential winter range substantially increases the amount of goat habitat in the Olympic Mountains of Washington, then the average year-round goat density from Steven's (1983) work could approach 2/km^2, and is similar to the above figures.

Using the roughly doubled population estimates relative to aerial counts shown by Smith (1984), we can recalculate Hebert and Turnbull's (1977) density

Table 3. Comparison of simultaneous counts of mountain goats made from the ground and from a fixed-wing aircraft.

Date	Study site	Ground Total	Aerial Total	Aerial total as a percent of ground total
15 Aug. 1977	Stroller White	79	31	39
25 July 1977	Stroller White	78	46	59
28 June 1976	Stroller White (partial area)	43	39	91
28 July 1977	William Henry	16	10	63
30 July 1976	William Henry	25	22	88

Table 4. Density of mountain goat populations at eight sites in southeast Alaska.

Site	Area (km2)	Number of goats	Density
Stroller White	57.8	83	1.4
William Henry	53.4	26	.5
Wilkes Range	41.4	38	.9
Torch Bay (east)	27.3	57	1.6
Torch Bay (west)	15.8	26	2.1
Thistle Cove	10.4	15	1.4
Astrolabe Peninsula	6.8	32	4.7
Dixon-Brady	5.7	12	2.1
TOTAL	218.6	289	1.3

estimates. Even with this increase, however, the resulting density range of 0.1/km^2 to 1.2/km^2 (average, 0.2/km^2) is still quite low. Differences in definitions of goat habitat, very low count accuracy, or actual low densities due to recent population crashes or unexplained poor quality habitat are all possible explanations for these low density figures.

In cases where density is measured within year-round goat range, one or two goats per square kilometer appears to be a fairly consistent average. The low densities reported by Hebert and Turnbull (1977) in southern British Columbia are the exception. Considering the results of this study and Smith's (1984), there is no reason to continue assuming that coastal goat populations are any less productive or of lower density than those elsewhere.

Densities based on preferred habitat or area of observed distribution are difficult to compare with those from year-round range. These designations are more restrictive than year-round range, which includes areas between often-used habitat, and therefore produce higher goat density estimates. Since goats may use habitats in other seasons or years than those when observed use was tabulated, it is possible that some areas of habitat important to goats may be overlooked, thus inflating density estimates in these more restrictive evaluations. However, the use of year-round range has its own drawbacks, especially with uncertainty concerning the proportions of good versus poor goat habitat within the boundaries delineated. Some consistent definition of important goat habitat will be essential to more detailed comparison of goat densities.

Thus, in the future, identification of habitats critical to mountain goat survival may provide the most realistic comparisons of goat density from one area to another. This will involve the development of a model for depicting goat habitat. For example, a definition of potential goat habitat which is restricted to certain types of vegetation (or amounts of forage), and specific terrain characteristics (e.g., slope steepness and distance from escape terrain) may allow more meaningful measures and comparisons of goat population densities along large latitudinal or longitudinal gradients.

ACKNOWLEDGEMENTS

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AN AGE SPECIFIC WINTER DIE-OFF IN DALL SHEEP IN ALASKA

Sarah M. Watson, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701

Wayne E. Heimer, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701

ABSTRACT

Dall sheep (Ovis dalli dalli) population estimates made in summer 1982 indicated a loss of 21% among collared ewes in the eastern Alaska Range. Reports of similar overwinter losses came from adjacent mountain ranges. Severe winter weather was presumed to be the cause of this heavy mortality. Analysis of age data for ewes missing from the marked sample population showed that 77% of the missing (presumed dead) ewes were 9 years of age or older. Mortality in age classes younger than 9 years was 5%. The high percentage population loss was probably due to unusually high survival of 12-year-old ewes during the previous winter (1980-81) which was quite mild. This cohort, then aged 13 years, died along with other old-age ewes in 1981-82. Age distribution and mortality data of collared ewes are presented. Caution should be exercised in generating mortality curves for ewes.

INTRODUCTION

It is the purpose of this paper to report on ewe mortality data which has been collected as part of a long-term study of Dall sheep ecology in the eastern Alaska Range (Heimer and Watson 1982). It is prompted by a die-off of marked ewes after winter 1981-82.

In June 1982 observations at the Sheep Creek mineral lick revealed a large proportion (21%) of the marked ewes (which constitute about 10% of the ewe population) did not return to the mineral lick. As ewes are virtually certain to appear at the lick, if they are alive (Heimer 1973), missing ewes were presumed dead. A loss of this magnitude is highly unusual in the eastern Alaska Range, and was cause for concern. When reports of similar losses were received from local residents in the northern Wrangell Mountains, the Tanana/Yukon Uplands, and Sheep Mountain, Kluane Park, Yukon, corrective management actions were taken. In the study area near Tok, Alaska, the ewe hunt was closed by emergency order. This closure may, in retrospect, appear more cosmetic or philosophical then necessary.

METHODS

Ewes were marked with visual collars at the Sheep Creek mineral lick in the eastern Alaska Range during June 1977-1979. Trapping and marking techniques used were described by Heimer et al. (1980). In subsequent years, the mineral lick was monitored for collared ewes during June, the month in which lick use is most likely to occur (Heimer 1973). In 1977, 1978, and 1979, the lick was observed incidental to trapping operations from 0400 hrs to 2000 hrs daily from the second week in June through the first week in July. In 1980 the mineral lick was observed from 12-14 June and 19-28 June. Observations were made from 0400 through 2000 hrs on those dates. In 1981, 1982, and 1983, the lick was observed continuously from 28 May through 30 June. Observations were conducted from 0300 to 2000 hrs.

Collared ewes not returning to the lick were presumed dead in the year they first failed to return (Heimer 1973). Each year's "deaths" were checked by noting if the missing individual was seen in the following year. They were then either "confirmed as dead" or re-entered as still living in the population. Some deaths were confirmed through hunter kills and the discovery of dead ewes.

The list of "confirmed" dead collared ewes for each year was divided into 2 age groups: those less than 9 years of age at death and those with ages greater than or equal to 9 years at death. Hunter killed ewes were deleted from both groups. Annual percent natural mortality in each age group was derived by dividing the number dead by the total number living at the end of mineral lick observations.

RESULTS

In June 1982, 14 of a possible 62 marked ewes failed to retun to the mineral lick. One of these ewes was seen in 1983 so the confirmed overall mortality was 13/52 (21%) of the marked population. Of the 62 total collars in the population, 13 were 9 years of age or older. Ten of these 13 ewes died. These 10 ewes were 77% of the total year's mortality of 13 ewes. This compares with an annual 5% mortality averaged over the previous 3 years for ewes 9 years old or older. Mortality during the difficult winter was 15.4 times that of earlier years for ewes of this age group.

Among ewes less than 9 years of age, mortality documented for winter 1981-82 was 3/49 or 6% (Table 1). This is identical to the average for the preceeding 3 years. Sample sizes among each cohort of marked ewes and the mortality percentages by age class are given in Table 2.

Table 1. Collared ewe mortality due to natural causes and hunter kill by age group.

Year of observation	Total collars possible		Mortality by hunters		Mortality Overall natural mortality		Mortality % Overall mortality	
	<9yrs	≥9yrs	<9yrs	≥9yrs	<9yrs	≥9yrs	<9yrs	≥9yrs
1979	24	22 2	0	0	2	2 0	8	9 0
1980	72	65 7	1	0	?*	?*	5*	4.5 8*
1981	71	64 11	1	0	9	8 1	5*	4.5* 8*
1982	62	49 13	0	0	13	3 10	21	6 77
1983	49	35 9	0	0	11**	8 3	22**	23 34

* Mortality averaged over 1979-80 and 1980-81; mineral lick observations not continuous in 1980.
** Mortality for each year is affirmed the following year. These mortalities to be reaffirmed in 1984.

Table 2. Cohort sample sizes and percent mortality by age class among collared ewes by year.

	Age in years													
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1977	0	0	6	0	0	0	0	0	0	0	0	0	0	0
1978	0	6	3	9	1	0	3	0	0	2	0	0	0	0
1979	7	13	8	9	15	7	4	4	1	3	2	0	1	0
1980	0	7	13	8	9	15	7	4	4	1	3	2	0	1
1981	0	0	7	13	8	9	15	7	4	4	1	3	2	0
1982	0	0	0	7	13	8	9	15	7	4	4	1	3	2
1983	0	0	0	0	7	13	8	9	15	7	4	4	1	3
Total	7	26	37	46	58	52	46	39	31	21	14	10	7	6
Total mortality	1	3	1	1	3	2	3	5	5	1	2	1	3	-
Percent mortality	14	8	3	2	5	4	7	13	16	5	14	10	43	-
Percent survival	86	92	97	98	95	96	93	87	84	95	86	90	57	-

DISCUSSION

The notable result of comparisons in mortality between the 2 age groups is the magnitude of percent mortality among ewes 9 years old or older during the 1981-82 winter. We realize that sample sizes are small, but we suspect the 15.4-fold increase in mortality recorded among older ewes that winter was caused by decreased ability to survive unusually severe weather.

Weather data from stations on either side of the study area (Northway 100 km east and Delta Junction about 100 km west) show winter 1981-82 was one with greater than average snowfall, and lower than average temperatures during February and March (National Oceanic and Atmospheric Administration 1982). These data indicate those months were more severe than normal.

The low average mortality for ewes in the age classes above 9 years before 1981-82 is probably indicative of unusually mild conditions during the years from 1979 to the difficult winter of 1981-82. During these years, mortality among all age classes of ewes was low, and the population increased. This increase was due to good production and recruitment (Heimer and Watson 1982), a function of mild winters as well as very limited mortality in older ewe cohorts. Hence, the difficult winter of 1981-82 resulted in a percentage loss that was most impressive among the marked ewes, but which had minimal actual impact on the population. Ewes which were lost were, for the most part, near the end of natural life expectancy.

We support the conservative management actions taken in this case, and always recommend conservatism when there are questions about correct procedures. Still, our experience shows the possible consequences of applying population mortality figures across ages classes when they are, in fact, specific to a given identifiable cohort or group of cohorts.

The age-specific mortality rates in Table 2 appear to indicate an increase in ewe mortality at about age 8. This survivorship pattern (Fig. 1) is similar to that reported for bighorn ewes by Bradley and Baker (1957), and similar to that found in Dall rams in the Alaska Range by Murie (1944). It is more difficult to rationalize a sudden increase in ewe mortality than in ram mortality since ewe behavior shows no documented changes at this age. Of course, ram behavior changes markedly with attainment of Class IV status at 8 years of age (Geist 1971). Still, the apparent increase in ewe mortality represents only a doubling of the mortality rate compared with ewes of the young age group. Further data will be required to clarify the overall picture.

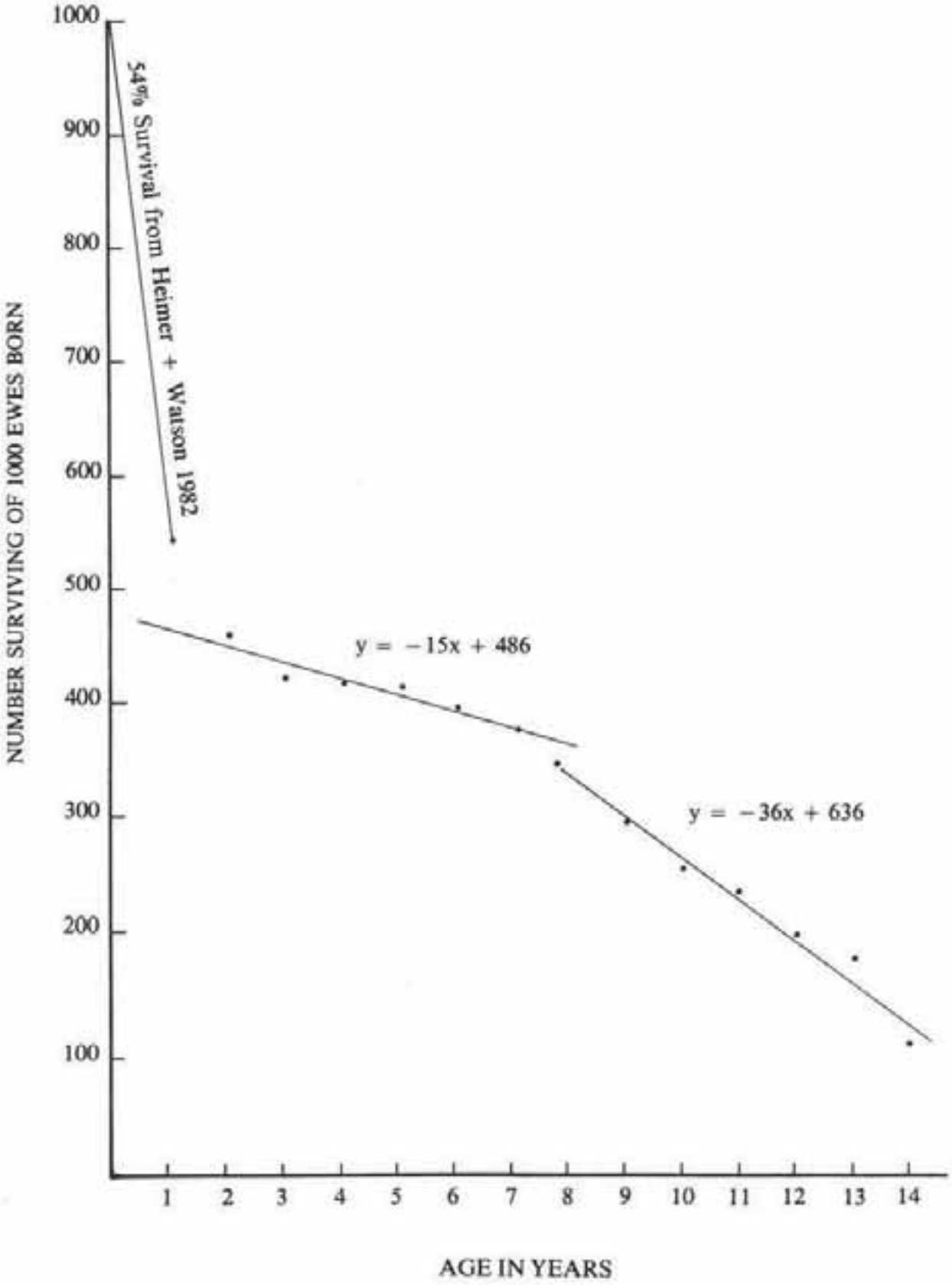

Fig. 1. Observed survival of marked Dall ewes from Sheep Creek, eastern Alaska Range expressed per 1,000 ewes born.

The high mortality between ages 1 and 2 is also worthy of note. It is clearly different than the other measured mortalities for ewes less than 7 years old, and we attribute it to the very small sample size for that cohort (n = 7).

We also note the observed mortality pattern would be greatly different if winter 1981-82 were not included in the data set. Had we omitted this difficult winter from the data set, calculations would have indicated very little effect of advancing age on ewe survival until incredibly old ages were reached. Simmons et al. (1984) reported a mortality pattern different from the one which appears to be developing here, and those cited above. The methods applied in Simmons et al. (1984) were quite different than those used in this study. We believe our work highlights the dynamic nature of Dall ewe mortality. When attempting to characterize a general phenomenon rather than reporting on a time-specific event, it is desirable to work over the longest practical time span.

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THE INFLUENCE OF WINTER SEVERITY ON DALL SHEEP PRODUCTIVITY IN SOUTHWESTERN YUKON - A PRELIMINARY ASSESSMENT

Doug Burles, Kluane National Park, Haines Junction, Yukon.

Manfred Hoefs and Norm Barichello, Yukon Wildlife Branch, Box 2703, Whitehorse, Yukon.

ABSTRACT

Over the past decade 14 Dall sheep populations in southwestern Yukon were periodically assessed through aerial surveys. Lamb production averaged 28.5% (expressed as lambs per 100 nursery sheep), but large variations were documented between years as well as between populations. For variation in productivity among populations, density was found to be a contributing factor ($r = -0.621$). Both winter temperature as well as snow were found to have an influence on lamb production the following spring. Data from three weather stations in the area showed that temperature was the more consistent variable between stations, giving a correlation coefficient with sheep productivity of $r = -0.661$. Snow (total precipitation) showed considerable regional variability in this mountainous region, and its correlation with lamb production the following spring was $r = -0.4555$. Both weather factors were combined into an index of winter severity by expressing their deviation from the long-term mean value as percentage, positive or negative. This index of winter severity was significantly correlated with lamb production the following spring ($r = -0.796$), and therefore, had a higher predictive value than either temperature or snow conditions alone, if one very deviant year (1983) was excluded. A factor in this deviation may have been the failure of females to recover from the very severe winter of 1981/82.

INTRODUCTION

Dall sheep populations are known to maintain relatively stable numbers at or near the carrying capacity of their range (Nichols, 1978; Hoefs and Cowan, 1979). Long-term studies of the Sheep Mountain population in Kluane National Park, Yukon, support this statement in that between 1969 and 1981 the largest deviation from the mean population size has been only 17%. Fluctuations were due primarily to the numbers of lambs born and surviving to yearling age. Adult mortality was relatively constant (Hoefs and Bayer, 1983). However, in

the immediate past, between 1981 and 1982, a 25% decline in this population was recorded, because of an unusual high winter mortality of adults followed by an extremely low lamb crop in spring of 1982. The primary cause of this decline was assumed to be the very severe winter (Burles and Hoefs, submitted to Canadian Field Naturalist). A further decline in this population was recorded for this winter 1982-1983, primarily because of a second poor lamb crop. This reproductive failure is more difficult to explain since snow fall and temperature in 1982-83 were better than average. Surveys of other Dall sheep populations in southwestern Yukon indicated that this poor productivity in recent years was fairly widespread. In this paper we therefore provide productivity data for Dall sheep populations in southwestern Yukon, as well as an analysis of data on winter weather conditions. It is generally assumed, that population levels in northern sheep populations are primarily influenced by weather factors (Nichols and Smith, 1971; Leopold and Darling, 1953, Murie, 1944) rather than by such limiting influences as diseases, parasites, predators or competition with livestock, which have been reported to impact bighorn sheep populations in southern Canada and the U.S.A.

METHODS

Annual aerial and ground surveys of the Dall sheep population at Sheep Mountain, Kluane National Park, have been carried out since 1969 to determine the size and composition of this population (Hoefs and Bayer 1983, Burles and Hoefs, submitted to Canadian Field Naturalist). The area is routinely patrolled by Park staff, and observations of interest, such as sheep mortalities and evidence of predators are generally recorded. During May 1983 a practicum student was stationed on Sheep Mountain to monitor lambing activities (Bourget, 1983). Concurrently a number of aerial surveys have been carried out by Kluane Parks staff and by the Yukon Wildlife Branch on other Dall sheep ranges in southwest Yukon since 1973. In this analysis 14 populations are included and only those have been considered for which at least four surveys have been conducted during this past decade.

In Kluane National Park three populations in addition to Sheep Mountain's have been monitored; these were those that occupy the Bighorn Range, Mt. Vulcan and the Auriol Range. In hunted areas in this vicinity the Yukon Wildlife Branch surveyed nine sheep ranges, which consisted of Gray Ridge, Mt. Skukum and Primrose Mountain on Rose Lake in Game Management Zones 7 and 9 south of Whitehorse; the Miners Range, Sifton Range and Champagne Range in Game Management Zone 5 north of Whitehorse, and four populations in the Ruby Range north of Kluane Lake in Game Management Subzones 5-28, 5-31, 5-34, and 5-36. In Fig. 1 the location of these sheep ranges are shown.

When conducting sheep inventories an attempt is being made to obtain a total count. Helicopters are used exclusively and the survey method used has been referred to as "drainage-pattern flight technique" (Nowlan et al. 1977, Hoefs, 1978). The survey area is divided into physiographic subdivisions with distinct boundaries. These subdivisions have a size that can be covered in a 2 to 3 hour flight. The most commonly employed aircraft is a Bell 206 helicopter, which can carry 3 passengers in addition to the pilot. The navigator, who is principal observer, is seated to the left of the pilot. The other observer is located in the left backseat, the right one being occupied by the recorder. An intercom system allows continuous contact between the survey

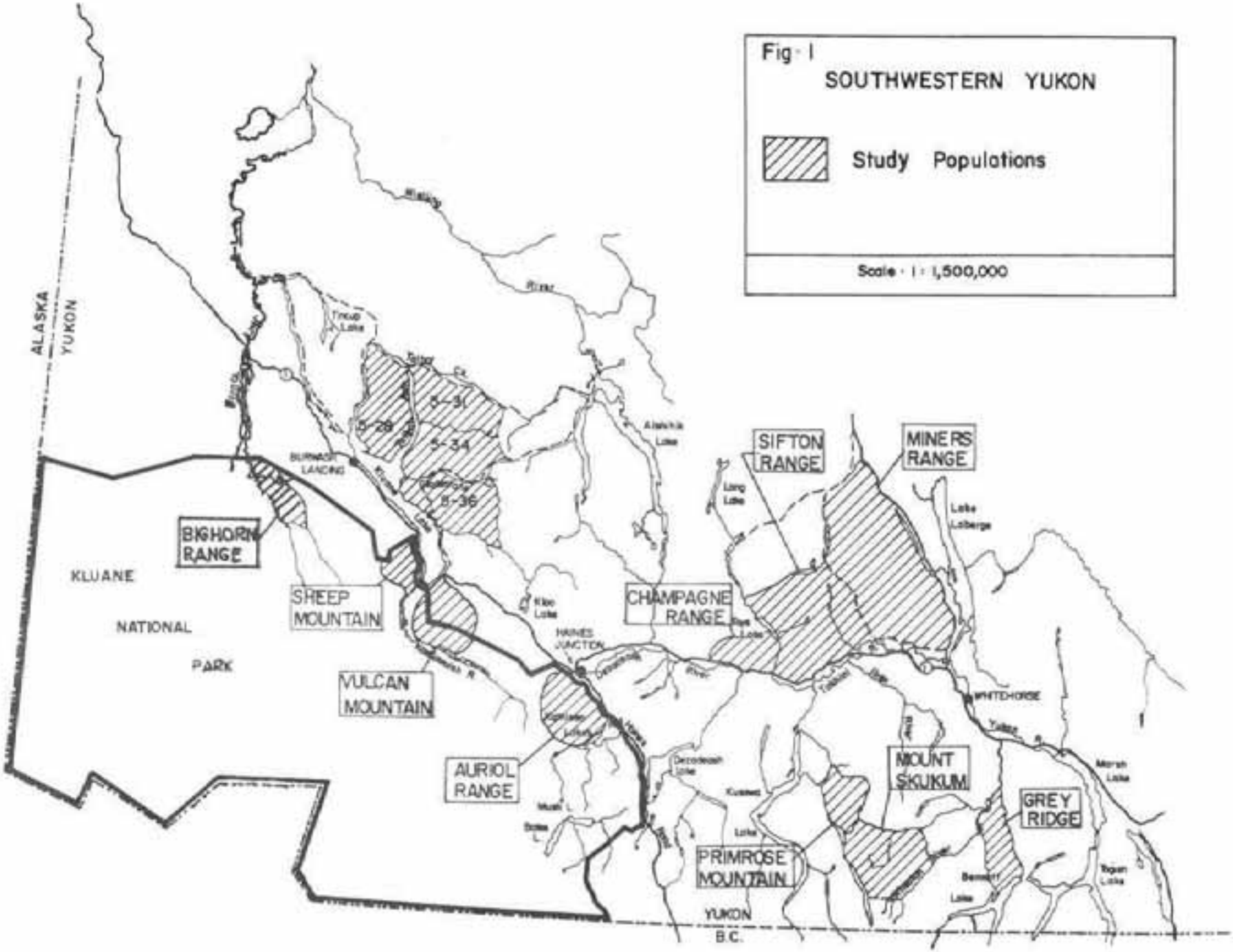


Fig. 1
SOUTHWESTERN YUKON
Study Populations
Scale - 1 : 1,500,000
ALASKA
YUKON
BIGHORN RANGE
SHEEP MOUNTAIN
VULCAN MOUNTAIN
AURIOL RANGE
CHAMPAGNE RANGE
SIFTON RANGE
MINERS RANGE
MOUNT SKUKUM
GREY RIDGE
PRIMROSE MOUNTAIN
KLUANE
NATIONAL
PARK
BURWASH LANDING
HAINES JUNCTION
WHITEHORSE
YUKON
B.C.

crew members. Each survey unit is covered by flying around it in a counter-clockwise direction at an elevation appropriate to the prevailing relief. This means that the elevation of the aircraft chosen and the distance of it from the mountains are such that the observers can keep surveillance over the slopes as well as over the ridge tops and plateaus. Wherever this is not possible with a single pass, several are made at different altitudes. The route flown and the exact locations where sheep are observed are marked on a map. All sightings are verified between the observers. If there is disagreement, another overflight is made.

The observations made are recorded on prescribed forms, which list size and composition of sheep bands, location, time of day, and other relevant information. It is known from repeated surveys made in Kluane National Park, from comparisons of ground and aerial surveys, and by using 80 marked sheep (Hoefs and Cowan 1979), that this survey technique is fairly reliable in that over 90% of the sheep can be accounted for; underestimates being influenced by terrain type and weather conditions.

While considerable variation can be expected due to terrain type, sheep density and aircraft ferry time, on the average this survey technique translates into about 100 sheep located per helicopter hour or about 120 km^2 of sheep habitat searched per helicopter hour.

In these aerial surveys, conducted in late June or July when all lambing is completed, the population composition is broken down into three components: 1) adult rams, usually three years old and older and often separated from nursery bands at that time; 2) lambs of the year and; 3) adult members of nursery bands, which include all ewes and yearlings as well as two-year old rams. In this paper "productivity" is therefore defined as the ratio of lambs to nursery sheep at that time of the year. Repeated surveys of these populations have indicated that they are relatively discrete, with the exception of that of the Bighorn Range in Kluane National Park. This population was therefore excluded from density estimations and the correlations done which use density as a variable.

Data on temperature and precipitation were obtained from three weather stations in the area: Whitehorse, Haines Junction and Burwash, the locations of which are shown on Figure 1. Mean winter temperatures, considering the period October to April inclusive, were computed for each year of the past decade, as well as total winter precipitation (snowfall) for the same months. The data for each given year were then compared to the long-term mean value, and the deviation was expressed as percentage (negative or positive). These two deviations, one for temperature and one for snow, were then combined by addition, and the sum referred to as the "index of winter severity". It is known that other weather factors, i.e. wind, also have an influence on sheep (Hoefs, 1975). However, wind is very variable in mountainous terrain, and the weather stations are far removed from the sheep ranges. The wind data measured there have relevance only to a few sheep ranges close by and wind could therefore not be incorporated into this index of winter weather severity. Commonly applied statistical tests were used in the analyses.

RESULTS

In Table 1 the statistics on 14 Dall sheep populations monitored are listed. In Table 2 the annual productivity data are given for each of these 14 populations over the past decade. This table allows an assessment of variations among populations as well as among years. The population sizes varied from 564 on the Bighorn Range in Kluane National park to 67 on the Champagne Range northwest of Whitehorse. The greatest densities have been recorded for Primrose Mountain with 2.52 sheep per km^2, and for Sheep Mountain with 2.13 sheep per km^2 and the lowest densities for the Miners Range and the Sifton Range with 0.56 and 0.71 sheep per km^2, respectively. The mean productivity for all populations and all years has been 28.5 lambs per 100 nursery sheep. Among populations, the Sheep Mountain herd had the lowest productivity with only 17.8% (n=11), while the Sifton Range populations had the highest with 36.7% (n=9).

Great variation in productivity was also documented between years (Table 2). Very low lamb crops were reported for 1976, 1982 and 1983 with 16.3%, 20.3% and 17.9% respectively, and very good productivity for 1973, 1977 and 1980 with 42.0%, 36.9% and 38.1% respectively. For variation in productivity among years there was a tendency for years with low productivity having a greater variation (S) than years with high productivity ($r = -0.570$). There was also a tendency among populations that those with a lower productivity had a greater variation (S) in productivity among years ($r = -0.553$) than those with higher productivity.

Weather data and computed indices are listed in Tables 3, 4 and 5. The mean winter temperature (October to April) for all three stations was -11.0°C (Table 3). Whitehorse had the mildest weather (-9.1°) and Burwash the coldest (-12.8°C). Considerable variation was recorded among years. Mild conditions prevailed in 1976-77 with only -5.5°C, more extreme conditions were observed in 1973-74 and 1981-82 with -14.7° and -13.6°, respectively. Table 3 also shows the index of winter temperature severity. In relation to the long term mean winter temperature, this index for the three years mentioned works out to be for 1976-77: +50.0%, 1973-74: -33.6% and 1981-82: -23.6%.

Total winter precipitation (snowfall), from October through April 30 is listed in Table 4. Overall, the mean value for all years and all three stations was 123.7 mm. Burwash is the driest area with only 73.3 mm, while Haines Junction obtains the highest snowfall with 194.0 mm. Variation among years is lower than for temperature. Overall, the winters of 1972-73 and 1977-78 were relatively dry with 94.0 and 86.6 mm precipitation, respectively. On the other hand, the greatest overall snowfalls were recorded 1974-75 and 1981-82 with 160.3 and 166.6 mm. However, in contrast to temperature, the trends in snowfall between stations were not synchronized. For instance for the Whitehorse region the winter 1980-81 had the highest snowfall with 137.9 mm, while that particular winter had below average snowfall in the Burwash district (61.5 mm). On the other hand, most snow fell in Burwash in 1979/80 with 103.5 mm, while during that winter little snow fell around Whitehorse (84.4 mm). Because of this variation observed in regional snowfall the use of mean values to extrapolate weather conditions over larger areas, is much less predictive than the use of mean temperature data. Table 4 also lists the indices of winter precipitation, calculated from the deviation of the long term means. The year 1981-82 had an index of 34.6% (above the long term mean), while the year 1977-78 had one of -30.2% (less than the long term mean).

Table 1: STATISTICS ON 14 DALL SHEEP POPULATIONS IN S.W. YUKON

No.	Population	Years of Survey	Sheep Number $\bar{X}$	Range Size km^2	Density Sheep/km^2	Productivity* $\bar{X}$ - s
1.	Bighorn Range	5	564	?	?	31.4 12.4
2.	Mt. Vulcan	6	407	352	1.17	29.0 10.3
3.	Mt. Skukum	3	368	417	0.88	29.0 12.2
4.	Auriol Range	6	353	354	1.00	32.3 13.8
5.	GMZ 5-31	5	353	340	1.04	22.8 8.2
6.	GMZ 5-28	4	331	308	1.07	27.7 8.2
7.	Primrose Mtn.	6	262	104	2.52	26.4 14.8
8.	GMZ 5-36	8	252	336	0.75	26.2 11.5
9.	Sheep Mtn.	11	241	113	2.13	17.8 10.4
10.	GMZ 5-34	5	230	341	0.67	27.2 10.2
11.	Miners Range	9	149	258	0.56	31.8 10.0
12.	Sifton Range	9	142	201	0.71	36.7 11.0
13.	Grey Ridge	7	87	110	0.77	34.0 15.2
14.	Champagne Range	8	67	40	1.67	27.0 12.3

* Lamb/100 nursery sheep in July

Table 2. Trend in productivity of 14 Dall sheep populations in southwestern Yukon, expressed as lambs per 100 nursery sheep.

Population	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	$\bar{X}$	S
Bighorn Range					33.0	30.5			53.8	21.7	18.2	31.4	12.4
Mt. Vulcan					41.1	22.0	32.5	42.4		16.2	19.9	29.0	10.3
Mt. Skukum GMZ 7-30	44.1									14.3	28.5	29.0	12.2
Auriol Range					48.0	26.6	46.5	35.2	30.9		6.7	32.3	13.8
Ruby Range GMZ 5-31		32.1					29.8	25.7		15.0	11.5	22.8	8.2
Ruby Range GMZ 5-28		28.8						37.6		29.6	14.9	27.7	8.2
Primrose Mt. GMZ 7-23	56.0						12.7	33.3	23.1	17.6	15.6	26.4	14.8
Ruby Range GMZ 5-36		42.7		11.8	36.3	35.1	24.0	31.7		8.3	19.7	26.2	11.5
Sheep Mt.	24.2	12.1	7.1	13.3	17.9	39.8	30.9	22.8	16.6	4.1	7.3	17.8	10.4
Ruby Range GMZ 5-34		20.9					35.9	41.0		25.5	12.6	27.2	10.2
Miners Range GMZ 5-50			76.7	18.1	30.3	29.3	38.2	54.2	25.5	38.7	24.8	31.8	10.0
Sifton Range GMZ 5-49			29.7	24.5	45.7	46.7	50.7	50.7	33.8	22.7	25.8	36.7	11.0
Grey Ridge GMZ 9-03	43.5		34.7			59.5	18.5	42.0	29.3	10.7		34.0	15.2
Champagne Range GMZ 5-47				13.6	43.0	11.1	30.0	40.0	12.3	39.4	26.8	27.3	12.3
$\bar{X}$	42.0	27.3	24.6	16.3	36.9	33.4	31.9	38.1	28.2	20.3	17.9		
S	11.4	10.3	10.5	4.6	9.2	13.4	10.6	8.8	11.8	9.2	6.9		

Table 3: MEAN WINTER TEMPERATURE (October to April inclusive) °C

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
Whitehorse	-8.5	-13.2	-8.5	-11.0	-3.7	-9.9	-10.5	-7.0	-7.2	-11.5	-8.9	-9.1
Haines Jct.	-12.6	-14.6	-10.6	-13.4	-5.5	-13.7	-10.0	-8.2	-8.6	-13.8	-10.1	-11.0
Burwash	-14.6	-16.4	-12.7	-14.2	-7.3	-13.9	-13.6	-9.9	-9.8	-15.6	-13.3	-12.8
$\bar{X}$	-11.9	-14.7	-10.6	-12.9	-5.5	-12.5	-11.4	-8.4	-8.5	-13.6	-10.8	-11.0
A$\Delta\bar{X}$ (%)	-8.2%	-33.6%	3.6%	-17.3%	50.0%	-13.6%	-3.6%	23.6%	22.7%	-23.6%	1.8%	

Table 4: TOTAL WINTER PRECIPITATION (October to April) in mm

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
Whitehorse	79.5	98.2	119.6	129.8	92.6	64.9	122.7	84.4	137.9	121.6	89.2	103.7
Haines Jct.	114.4	104.9	287.8	188.1	180.4	169.7	207.5	208.6	225.0	290.0	158.1	194.0
Burwash	88.1	93.0	73.4	98.5	56.6	25.2	61.9	103.6	61.5	88.2	56.3	73.3
$\bar{X}$	94.0	98.7	160.3	138.8	109.9	86.6	130.7	132.2	141.5	166.6	101.2	123.7
B$\Delta\bar{X}$ (%)	-24.0%	-20.2%	29.5%	12.2%	-11.1%	-30.2%	5.6%	6.9%	14.5%	34.6%	-18.3%	

Table 5: INDEX OF WINTER SEVERITY (October to April) in %

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83
A ($\Delta\bar{X}$(T) %)	-8.2	-33.6	3.6	-17.3	50.0	-13.6	-3.6	23.6	22.7	-23.6	1.8
B ($\Delta\bar{X}$(P) % .(-1))	24.0	20.2	-29.5	-12.2	11.1	30.2	-5.6	-6.9	-14.5	-34.6	18.3
Index A + B	15.8	-13.4	-25.9	-29.5	61.1	16.6	-9.2	16.7	8.2	-58.2	20.1

In Table 5 the two indices, one for winter temperature and one for winter precipitation, have been combined to derive at the index of winter severity. Based on these two parameters only, it is obvious from Table 5 that the winter of 1981-82 was the most severe winter with an index of -58.2% followed by 1975-76 with -29.5%. The mildest winter was 1976-77 with an index of +61.1%.

In Tables 6, 7 and 8 the 14 Dall sheep populations have been allocated to one of these three weather station districts, based on distance from weather stations or known similarity in weather patterns. The same weather parameters as previously described for the entire survey area were computed for each of these three sub-units. The aim was to assess whether the trends observed and their correlation with productivity could be improved on.

In general the trends observed were similar in the three districts, but some differences could be documented. The three populations in the Haines Junction area, those on the Auriol Range, Mt. Vulcan and Sheep Mountain, all of which are in Kluane National Park and have a fairly high density, had a significantly lower productivity (21%) than either the Whitehorse (31.7%) or the Burwash district populations (29.3%). While temperature data show a similar trend, we have already made reference to considerable regional variation in precipitation.

The winters 1975-76 and 1981-82 were severe in all three areas, while in addition the winters 1973-74 in the Burwash area, 1974-75 in the Haines Junction area and 1978-79 in the Whitehorse district had a high index of winter severity primarily because of regionally heavy snowfall.

DISCUSSION

Many factors can influence the productivity of sheep populations, among them weather parameters, predator pressure, range conditions and population quality, diseases, parasites and various types of disturbances. For most Yukon Dall sheep populations these factors are not known, with the exception of the Sheep Mountain population, where some of these parameters have been monitored (Hoefs and Bayer, 1983; Burles and Hoefs submitted to Canadian Field Naturalist, Burles, 1984 unpublished report). For the Southwest Yukon weather parameters are the only factors whose impact can be assessed, and resulting correlations with these must be interpreted cautiously, considering the distances of the few local weather stations from sheep ranges, and the known variations of weather factors such as wind and precipitation in mountainous terrain. For "among-years" variations we have used winter temperature and winter precipitation in this analysis; we have not used wind, since the information base for individual sheep ranges was insufficient. For assessments of variation in productivity among sheep populations, density, population size, hunting pressure and accessibility of range were used. The latter parameter may be an indicator of disturbance.

Of all these parameters, which may influence differences in productivity among populations, only density appears to be relevant (Fig. 2). There is a trend of populations with a higher density having a lower productivity ($r = -0.621$). This trend was also observed during sheep surveys in the Ogilvie Mountains in the northern Yukon (Larsen, 1978). There was no correlation

Table 6. WINTER WEATHER AND PRODUCTIVITY OF DALL SHEEP POPULATIONS IN THE WHITEHORSE DISTRICT*

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
A. Productivity(%)	47.9%	-	30.4%	18.7%	39.7%	36.7%	30.0%	44.0%	24.8%	20.8%	24.3%	31.7%
B. Mean Temp (^{o}C)	-8.5	-13.2	-8.5	-11.0	-3.7	-9.9	-10.5	-7.0	-7.2	-11.5	-8.9	-9.1
C. Total Prec. (mm)	79.5	98.2	119.6	129.8	92.6	64.9	122.7	84.4	137.9	121.6	89.2	103.7
D. Index of winter severity	29.8	-39.8	-8.7	-46.0	70.0	28.6	-33.7	41.7	-12.0	-43.7	-12.8	

*The Whitehorse district includes populations No. 3, 7, 11, 12, 13, 14
Correlation coefficient: A-B (r = -0.543) A-C (r = -0.728) A-D (r = 0.876)

Table 7: WINTER WEATHER AND PRODUCTIVITY OF DALL SHEEP POPULATIONS IN THE HAINES JUNCTION DISTRICT*

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
A. Productivity(%)	24.2	12.1	7.1	13.3	35.6	20.6	36.6	33.5	23.8	10.2	13.6	21.0
B. Mean Temp (^{o}C)	-12.6	-14.6	-10.6	-13.4	-5.5	-13.7	-10.0	-8.2	-8.6	-13.8	-10.1	-11.0
C. Total Prec. (mm)	114.4	104.9	287.8	188.1	180.4	169.7	207.5	208.6	225.0	290.0	158.0	194.0
D. Index of winter severity	26.4	-27.1	-44.8	-18.8	56.8	-12.0	2.4	18.0	5.8	-75.0	-10.3	

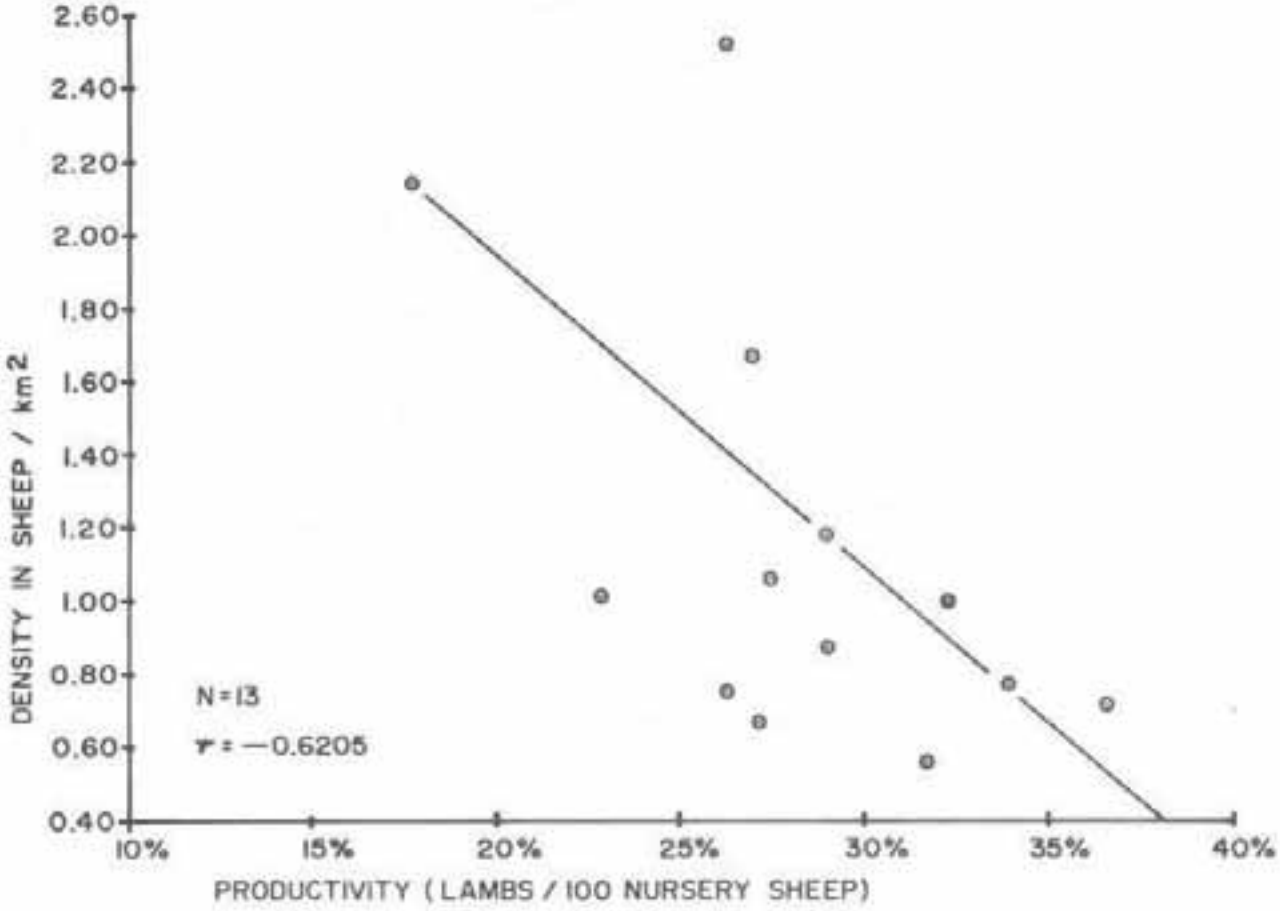
*The Haines Junction district includes populations No. 2, 4, 9
Correlation coefficient: A-B (r = -0.661) A-C (r = 0.188) A-D (r = 0.814)

Table 8: WINTER WEATHER AND PRODUCTIVITY OF DALL SHEEP POPULATIONS IN THE BURWASH DISTRICT*

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
A. Productivity(%)	-	31.1	-	11.8	34.7	32.8	29.9	34.0	53.8	20.0	15.4	29.3
B. Mean Temp (^{o}C)	-14.6	-16.4	-12.7	-14.2	-7.3	-13.9	-13.6	-9.9	-9.8	-15.6	-13.3	-12.8
C. Total Prec. (mm)	88.1	93.0	73.4	98.5	56.6	25.2	61.9	103.6	61.5	88.2	56.3	73.3
D. Index of winter severity	-34.4	-55.0	6.4	-45.3	65.8	57.0	9.3	-18.6	39.5	-42.2	19.3	

*The Burwash District includes populations 1, 5, 6, 8 and 10.
Correlation coefficient: A-B (r = -0.484) A-C (r = -0.231) A-D (r = 0.494)

FIG. 2. RELATIONSHIP BETWEEN DENSITY AND PRODUCTIVITY IN DALL SHEEP POPULATIONS



between population size and productivity ($r = -0.072$), but there were indications that in larger populations there was less fluctuation in productivity among years ($r = -0.467$). The correlation between density and productivity may point in certain populations to capacity-filled winter ranges and the influence on lamb production of shortage of winter forage for ewes. This has been shown for the Sheep Mountain population in years of peak population size (Hoefs, 1984). While the mean productivity over the past decade showed some relation to density, the correlation of the very low production observed during the spring of 1982 and 1983 with density, $r = -0.396$ and $r = -0.426$ are very weak. Therefore, less than 20% of the variation observed in these two years can be attributed to density-related phenomena.

Both winter temperature (Fig. 3) and total winter precipitation (Fig. 4) have an influence on productivity the following spring. The correlation coefficient between temperature and productivity, $r = -0.661$, is higher than that for snowfall, $r = -0.455$, which is understandable in light of the variable nature of the latter, as already discussed.

Both these factors are known to impact ungulates in general, as a survey of the relevant literature will reveal. Cold temperature imposes a considerable energy drain on the animals, which is particularly important to pregnant ewes. Deep snow covers winter forage of grazing animals. Time and energy must be spent in digging craters and freeing of forage, less time can be spent with actually grazing. Cold temperature and deep snow are independent events whose impacts on sheep will be additive.

We have therefore combined these two variables into the index of winter severity already described. The correlation coefficient between this index of winter severity and productivity the following spring is $r = 0.796$ if the 1983 data are not included (Fig. 5). Fig. 6 shows the trend in productivity and winter severity over the past decade. In general this index predicts reasonably well; good lamb crops were documented in 1973, 1977 and 1980 following winter with a positive index of winter severity. Poor productivity was documented for 1976 and 1982 following extreme winter conditions with very low negative indices of winter severity. The impact of the winter 1981/82 on the sheep population of Sheep Mountain and all its ramifications have been described in detail by Burles and Hoefs, 1984 (submitted to Canadian Field Naturalist) and need not be repeated here. Similar problems were faced by other populations during that winter as well as in 1975/76.

On the other hand, we have no explanations for the poor productivity observed during the spring of 1983. With a mean value of only 17.9% it was one of the lowest productivities recorded for this entire decade, in spite of the fact that both winter temperatures and snowfall were better than average, and the computed index of severity was +20.1%. Burles (1984) has speculated on possible reasons for this poor lamb production. Some of his assumptions, i.e. separation of rams and ewes during the rut because of early snow in October, high predator pressure and consequently disturbance during winter and low productivity of winter forage because of a dry growing season, may have relevance to the Sheep Mountain population but are unlikely to influence sheep productivity over the entire southwestern Yukon. On the other hand, some of his other assumptions may have relevance. The winter 1981/82 was severe over the entire area and had considerable influence on the sheep. It is likely that

FIG.3. RELATIONSHIP OF PRODUCTIVITY TO MEAN WINTER TEMPERATURE

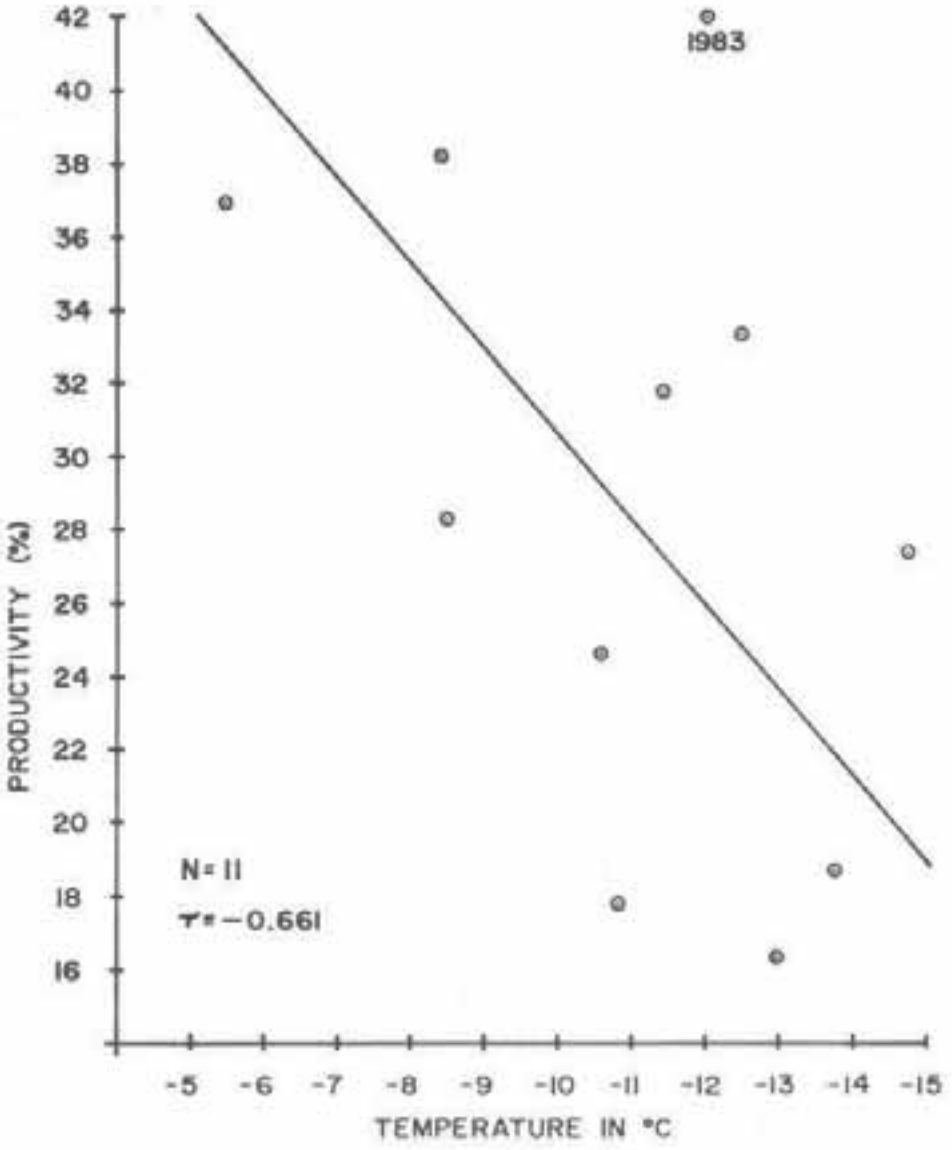


FIG. 4. RELATIONSHIP OF PRODUCTIVITY TO TOTAL WINTER PRECIPITATION

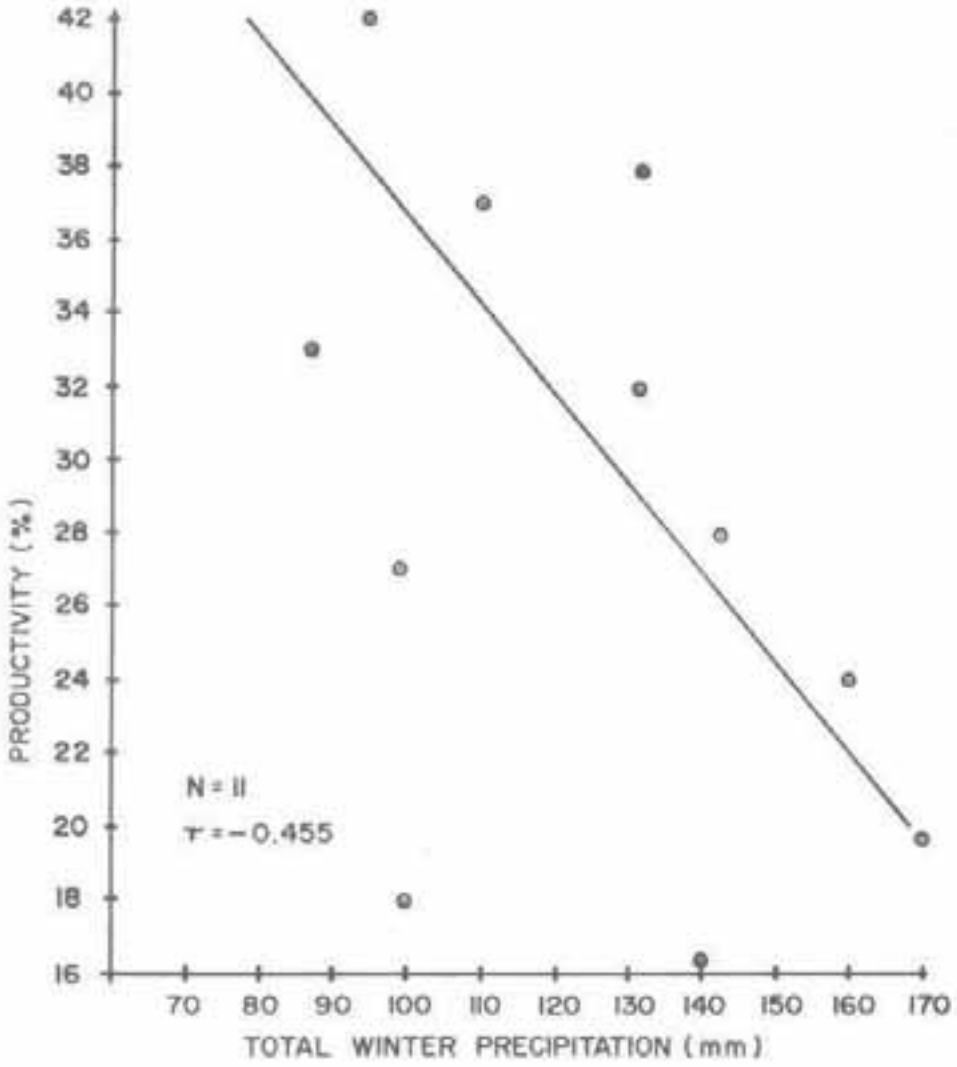


FIG.5. RELATIONSHIP OF WINTER SEVERITY AND DALL SHEEP PRODUCTIVITY THE FOLLOWING SPRING

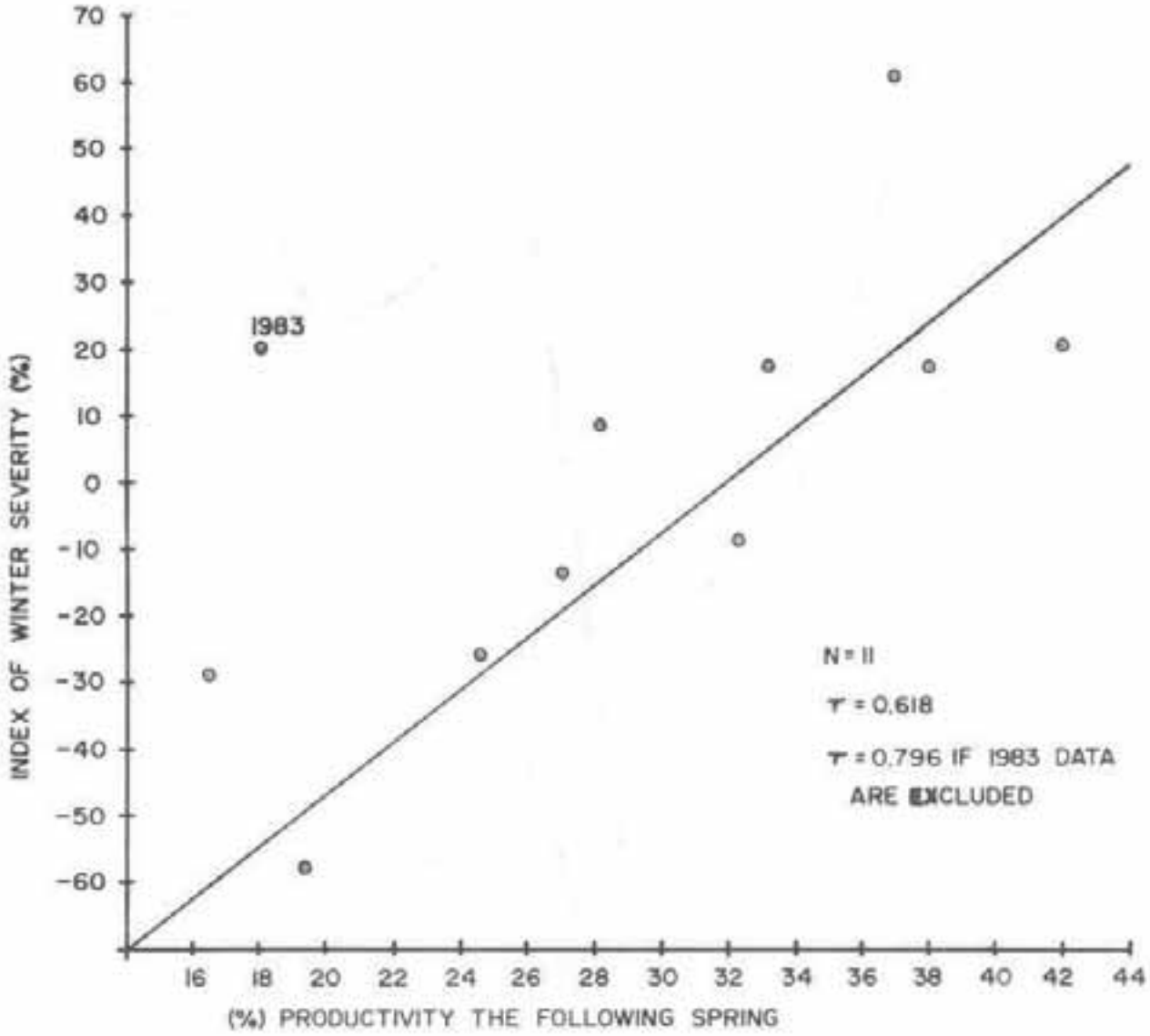
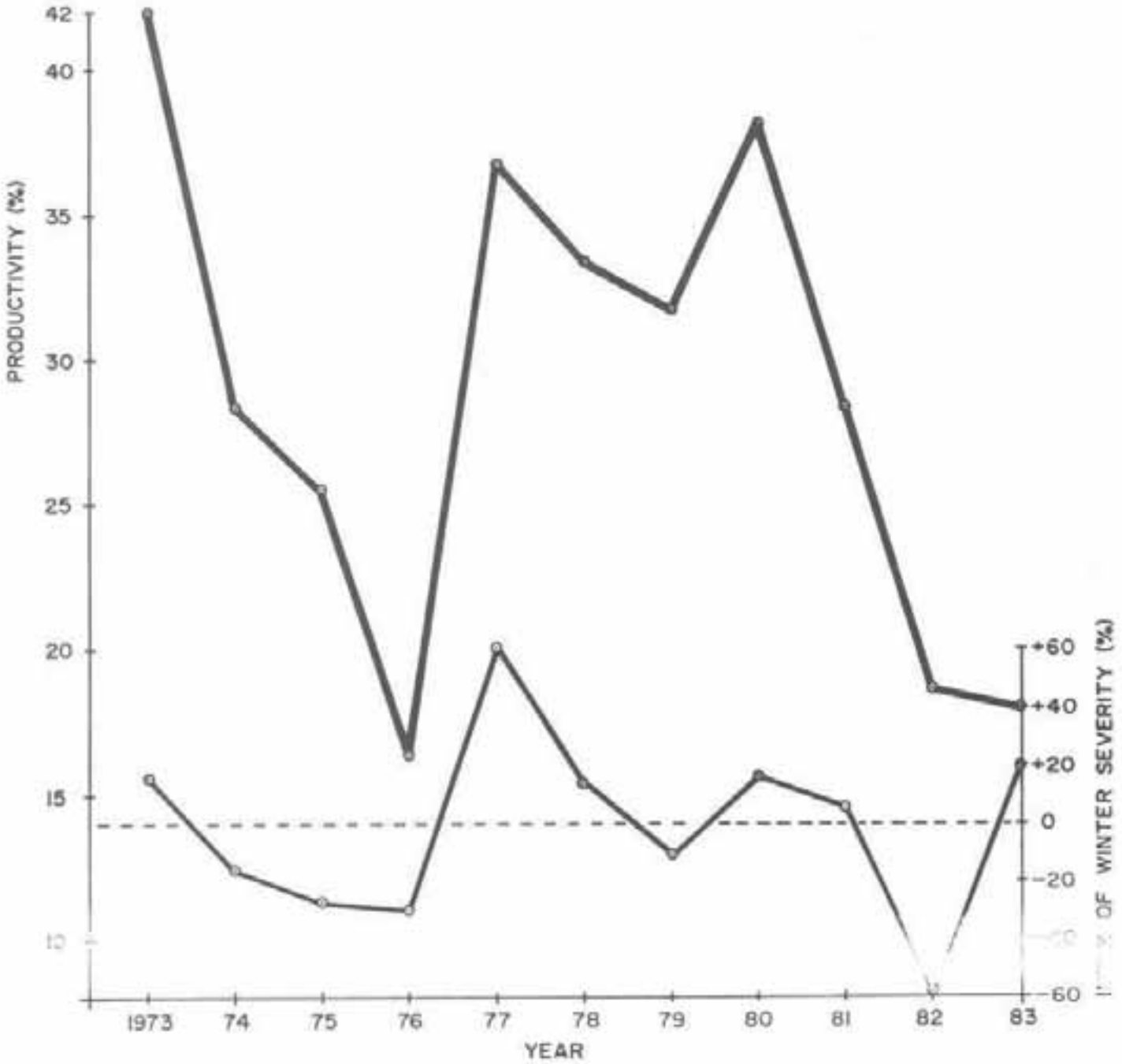


FIG.6. 10 YEAR TREND IN PRODUCTIVITY AND WINTER SEVERITY



many ewes did not recover sufficiently by the next rutting season to come into estrus. Both Nichols (1978) and Heimer (1978) have described for Alaska sheep, that ewes in poor physical shape, particularly those leading a lamb, may give birth only every second year. Another possibility is the mummification of fetuses in females in poor physical shape, that will prevent their becoming pregnant the following year. This has so far not been documented for sheep, but has been described for pronghorn antelope, deer and moose (Barrett, 1982). These data for 1983 do not follow the general trend observed over the past decade, and if included into our analyses lower the predictability of the index of winter severity from about 64% to 38%.

Attempts to improve this predictive potential of this index by assigning populations to one of the three weather station regions have met with limited success (Tables 6, 7, 8). In general temperature is a more reliable indicator than precipitation and correlations of productivity with temperature are better. In all cases is the index of winter severity a better method in predicting lamb production the following spring, than either of the weather parameters alone. The correlation of this index with productivity including the 1983 data, was as follows for the three regions:

Whitehorse: $r = 0.876$ (Table 6);
Haines Junction: $r = 0.814$ (Table 7); and
Burwash: $r = 0.494$ (Table 8).

The discrepancy observed in the 1983 data, is primarily due to observations made in the Burwash district.

We hope to improve on this index of winter severity by including wind, which has negative as well as positive aspects to it. A strong wind may expose foraging areas and therefore counteract the effects of deep snow. However, a strong wind may also combine with a reasonable temperature to give a wind chill index, not tolerable to sheep (Hoefs, 1975). Here the impact of wind is negative and additive. We also know that favorable temperatures early in the growing season and precipitation during the growing season will influence forage production of winter ranges which in turn will influence the productivity of dense populations (Hoefs, 1984).

Considering that these two important variables could so far not be included for lack of information, the index of winter severity derived predicts perhaps as well as we can hope for.

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THE INFLUENCE OF CLIMATE, HABITAT AND NATURAL SELECTION ON THE NUMBERS OF FERAL SHEEP (*Ovis aries* L.) ON CAMPBELL ISLAND (SUBANTARCTIC)

M.R. Rudge, Ecology Division, Department of Scientific and Industrial Research, Private Bag, Lower Hutt, New Zealand

ABSTRACT

Domestic sheep were introduced to Campbell Island in 1895, and pastoral farming was pursued until 1931. The sheep were then abandoned. From 1916 to 1961 the population had declined at $r = -0.05$ but between 1961 and 1969 it grew at $r = 0.14$.

During the farming years the vegetation was burned and overgrazed. It slowly recovered under lighter grazing as the populatin dropped, and in response to a general climatic warming in the southern hemisphere. When they were not longer shorn, the sheep grew double fleeces which may have reduced their ability to copulate. Intensive natural selection has now led to sheep with clean limbs and bellies, and in females the ability to shed fleece each year and breed at one year old. It is postulated that, by the early 1960s, the combined effects of more food and shelter, warmer lambing months, early female fertility and longer reproductive life, resulted in a growth in numbers which has continued to 1983.

INTRODUCTION

This paper is about a population of feral sheep, that is, sheep that have run wild from the domestic state. Unlike the true wild sheep and goats which are of prime interest to this Conference, they are not a valuable game animal nor generally regarded as a rare species to be conserved. Indeed, as aliens on a subantarctic island that has high values for native flora and fauna, they are pests.

Wildlife managers would have exterminated this population long since had there not been two great uncertainties. The first of these was that the population seemed to be declining to natural extinction; and the second was that the sheep may even have been improving the conditions for nesting sea birds (Wilson and Orwin 1964). The resolution of these questions has been a fascinating exercise for New Zealand biologists and wildlife managers for over 20 years.

The circumstances and setting for this study are quite different from those facing North American wildlife managers. Nevertheless, the history of this population does have some useful lessons in emphasising the subtle interplay of environment, habitat, and natural selection in the lives of wild animals and in the business of trying to manage them.

Campbell Island lies some 500 km south of the southern tip of the New Zealand mainland at 52°S 169°E (Figure 1). It is uninhabited except for a meteorological station. It represents the remnant eastern rim of an eroded

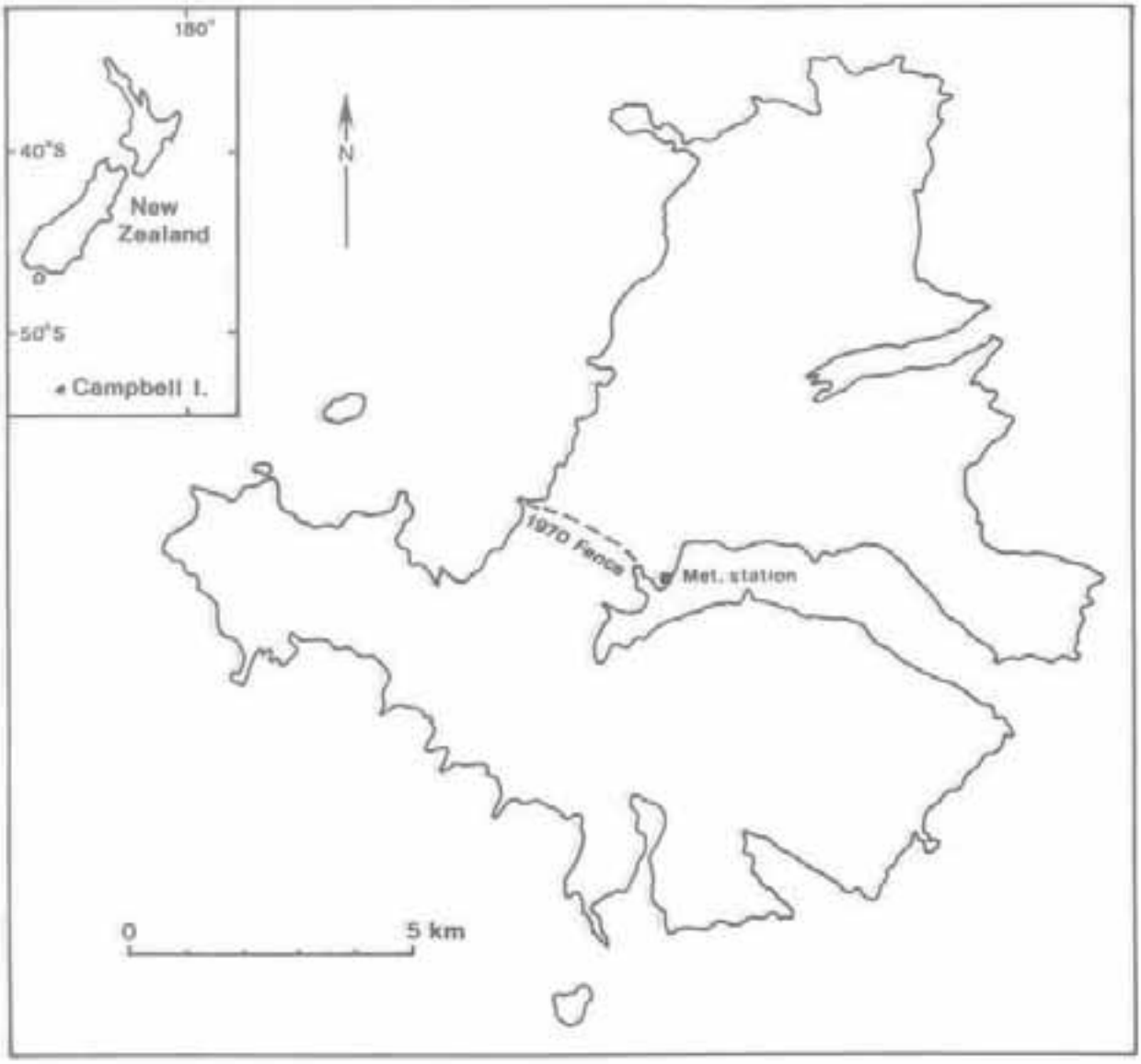

Figure 1. Location of Campbell Island and of place names mentioned in the text.

volcanic cone and has an area of about 109 km^2. The terrain is generally hilly with five peaks over 457 m and it is blanketed with peat. The woody vegetation is a low forest of scrub dominated by Dracophyllum scoparium, D. longifolium and Myrsine divaricata. The original non-woody part of the vegetation was, broadly speaking, a tussock grassland of Chionochloa antarctica with giant endemic herbs. The whole vegetation was burnt and grazed during the farming era, and introduced pasture grasses were sown (Meurk 1975, 1976, 1982). Campbell Island is most noted for being the world's main breeding ground of the Southern Royal Albatross (Diomedeae. epomophora).

Domestic sheep were taken to the island in 1895, and pastoral farming was pursued with varying success until 1931 when it became uneconomic. Over 4000 sheep and about 20 cattle were then left to their own devices. In 1961 there were about 1000 sheep which amounted to a decline of about 5 percent per year since 1916 (Wilson and Orwin 1964). It was suggested that the population might gradually die out naturally.

By 1969 the sheep population had not continued to decline as predicted (Figure 2) but had increased by a factor of about three, an average of 14 percent per year (Taylor et al. 1970). Such a dramatic growth in numbers raised questions about the future of the nesting Royal Albatrosses. The island was thereupon divided into two with a fence, and all sheep on the northern half were killed in 1970 to establish a long-term experiment on albatrosses, sheep and vegetation. Sheep on the southern side were counted until 1984 when all but about 500 were killed.

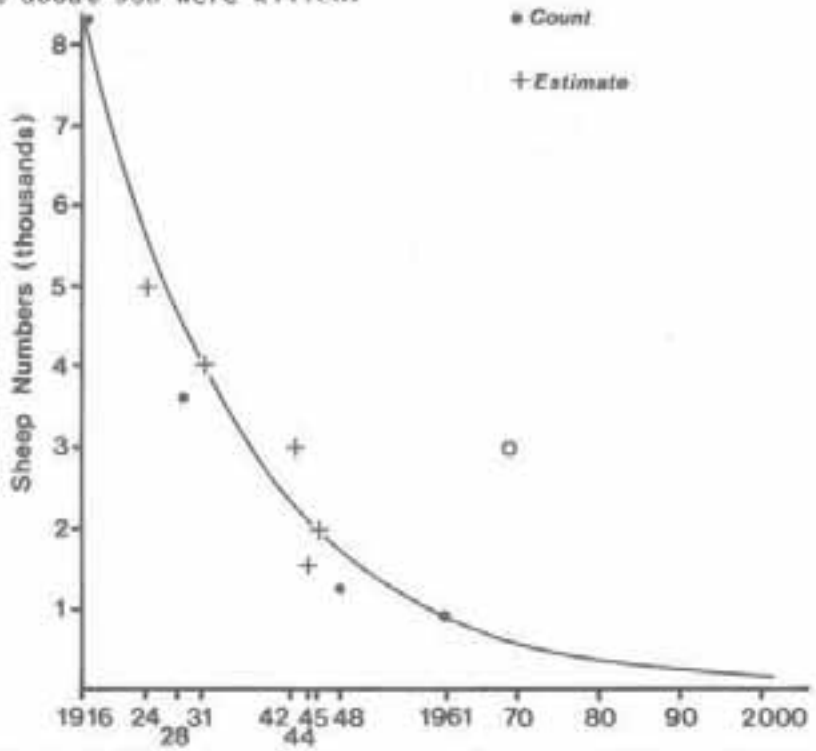

Figure 2. The exponential decline in sheep numbers between 1916 and 1961 extrapolated to 2000 AD. The number actually counted in 1969 (3000) is shown as O (modified from Wilson and Orwin 1964).

The age distribution of over 1000 sheep shot in 1970, and changes in the population have now been analysed in some detail (Rudge, in prep.) This present paper summarises some of the changes that have been observed in the environment and carrying capacity of the island, and in the genetic constitution of the sheep.

CHANGES IN THE SHEEP AND THEIR ENVIRONMENT

Conditions on Campbell Island were relatively simple compared with many mainland situations. The population was not influenced by immigration or emigration, there were no mammalian predators, and hunting amounted to providing the occasional roast for the station staff. Although the historical record is blurred, it clearly shows a steady decline in numbers, a dramatic increase, and movement of sheep into untenanted areas. Any explanation for these changing fortunes has to account for both phases of the population performance, and the enhanced carrying capacity of the island that sustained the increasing numbers of sheep.

THE METEOROLOGICAL CONDITIONS

The climate and weather on Campbell Island have two general effects. Firstly, the long-term climatic trends would influence plant productivity, the ratio of woody to herbaceous vegetation, and vegetation zonation. For the sheep these effects determine the amount of food and of shelter. Secondly, there is the severity and frequency of short-term events at crucial times, most particularly at lambing.

The period 1900-1935 (effectively, the farming years) was the coldest in the recorded history of New Zealand. The last shepherds to leave in 1931 saw icebergs floating by and ice stacked up on the shores (Spence 1968). Since 1946 the southern hemisphere has been in a warming phase (Salinger and Gunn 1975, Salinger 1980). Between 1935 and 1975 the mean annual temperature rose by 1°C, and the mid 1950s were particularly warm over the whole New Zealand region. The duration and frequency of strong winds has also fallen so that there is less evaporative cooling, and more actual heat for plant growth. A general integrator of these combined effects is the summation of Growing Degree Days (GDD), = (no. of degrees by which the daily mean temperature is above a base line) X (the number of days). In the period 1942-1955, 8 of the 14 years had GDD values below the long term mean (LTM) for the island, and the other 6 were only slightly above; but from 1956 to 1962 only two years were below the LTM and the rest were above it by about 10 percent (Figure 3). There was another warm period between 1968 and 1971.

The other relevent climatic events are sudden, high-intensity deteriorations in the weather. These are difficult to discern in a general meteorological record and even harder to relate to animal performance and behaviour hour by hour and day by day. The most crucial time is when lambs are born, and if this coincides with prolonged wetting or wind chill then survival is jeopardized. Lambs were born throughout the year, but the resident Meteorologists noted that most appeared between August and December.

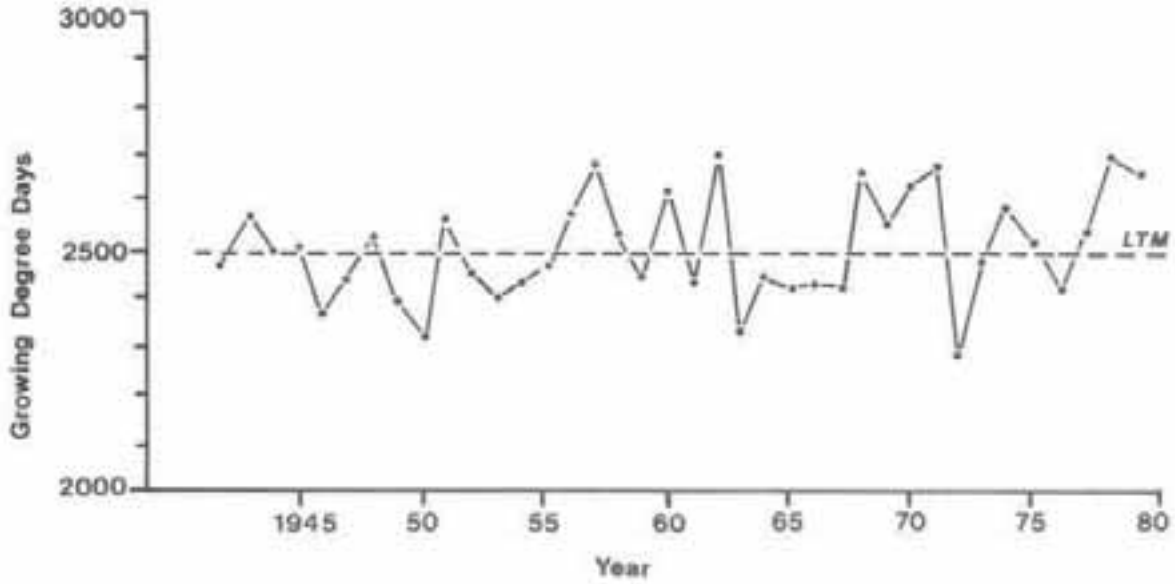

Figure 3. Growing Degree Days on Campbell Island from 1942-1979.

An examination of the island's Meteorological Station record shows that up to 1955 the mean monthly temperatures in four successive lambing months rarely rose above the LTM (Figure 4). From 1955-1962 the pattern was essentially the converse. In the 1965-71 period, August was particularly mild but this did not carry consistently through into the succeeding 3 months. Over the same years the number of raindays (greater than 0.2 mm) remained in the range 70-100 percent.

Hailstorms, which combine a sudden drop in temperature, increased wind velocity, and wetness, showed no consistent trend towards better conditions for lambing. Some individual years such as 1956 and 1965 had relatively few hailstorms, but the period 1959-1964, when the population was apparently beginning its dramatic growth, had some of the highest hailstorm frequencies in the 40 year record. Haildays correlated closely with frequency of winds above Beaufort 8 (gale).

These meteorological records reflect what every summer field worker experiences on the island: brief fine periods broken by sudden, violent squalls of rain and hail.

In summary then, the general climatic conditions were improving slowly and consistently during the years of declining numbers, but lambing was probably still beset by fierce unpredictable storms in most months and years.

THE VEGETATION

During the late 19th century and throughout the farming era when the vegetation was burned, snow tussocks (Chionochloa antarctica), were the chief victims (Meurk 1975, 1976, 1982). At first they re-sprouted vigorously but, after being repeatedly burned and then grazed, they died to be replaced by a pasture consisting mostly of northern hemisphere grasses.

Since 1930, partly in response to steady climatic warming, scrub has spread to higher altitudes and become thicker (Bell and Taylor 1970, Meurk 1976). This spread was assisted by the more open nature of the grazed swards because the scrub seedlings are shade intolerant and are slow to invade tussock grassland (Zotov 1965). The scrub species are unpalatable to sheep but do provide shelter for them.

When farming ended in 1931 there were between 4000 and 5500 sheep (Wilson and Orwin 1964, Spence 1968). They declined to about 1000 by 1960 and this alone, even without an improvement in climate, must have allowed all components of the vegetation to recover in quantity. Some indication of this process was demonstrated on the northern side of the fence in the decade after all sheep were killed there in 1970 (Dilks and Wilson 1979,

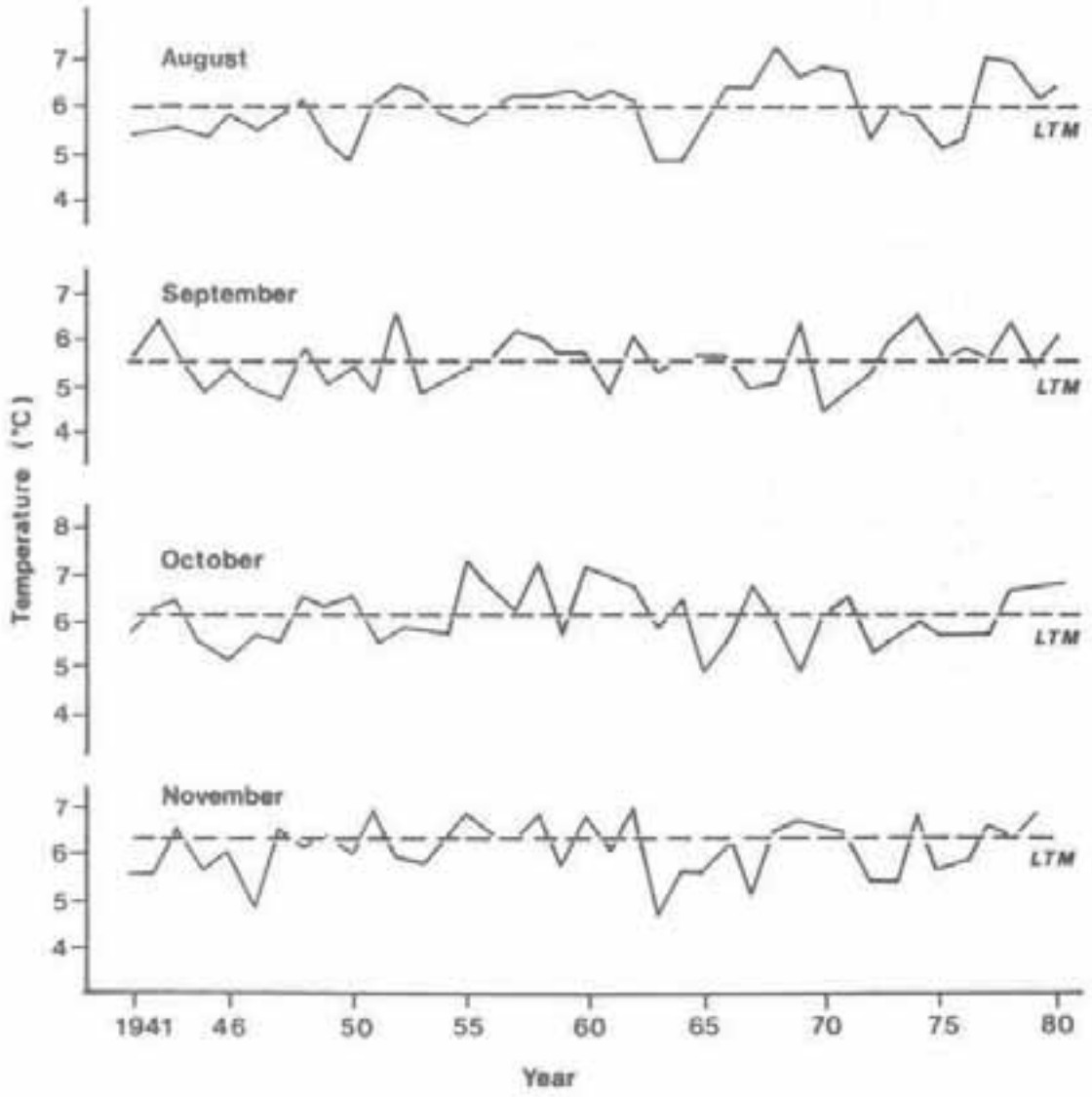

Figure 4. Mean monthly temperature in main lambing months on Campbell Island relative to the long term mean for 1941-1980.

Meurk 1982). Chionochloa tussocks and introduced grasses grew thickly up to 0.5 m tall, and the giant endemic herbs became common. Changes of this sort must have occurred in the lightly populated parts of the island between 1931 and 1960. Indeed, Wilson and Orwin (1964) reported that areas with few sheep in 1961 were covered in rank vegetation. By 1969 many of these same places were carrying hundreds of sheep on closely cropped swards (Taylor et al. 1970).

In particular years there were flushes of plant growth. Meurk (1976) describes the profuse growth and flowering of Chionochloa in 1975 after the unusually warm summer of 1974. Something similar must have happened in the exceptionally warm years of the 1950s.

THE SHEEP

Several lines of evidence suggest that the Campbell Island sheep are genetically rather different today from those that were abandoned. During the farming period some natural selection would have already been operating because management was so poor. By 1931 there were already at least 1000 'wild' sheep which had habitually escape the musters (Spence 1968). The flock was not treated for internal parasites, nor culled for quality. Skuas (Stercorarius skua lonnbergi) "used to get down on quite a few lambs" (Spence 1968). In 1975 even penned adults had to be protected from skuas (Regnault 1976). Hydatid cysts were common in livers, but as soon as sheep dogs left the island the disease would have died out.

Un-mustered animals developed double fleeces that trailed on the ground (Spence 1968), and such multiple fleeces would have been universal once shearing was discontinued. But by the mid 1970s, most of the females were progressively shedding their whole fleece, and most rams were shedding at least their belly fleece (Regnault 1976). In other sheep populations that have been feral for 40-70 years both sexes completely shed their fleeces and this is correlated with an increase in pigmentation (Rudge 1983, Orwin and Whitaker 1984). Adalsteinsson (1984) has shown that pigmented sheep have an enhanced fertility. However, the Campbell Island population remained predominantly white (98.7 percent) during the expansion phase. Even so, productivity virtually doubled from about 34 lambs per 100 ewes in farming days (Wilson and Orwin 1964) to 62 in 1970.

Even though pigmentation did not change, other features of fleece growth may be closely correlated with early fertility and a longer reproductive life in females (Regnault 1976). Thick fleece on the belly of males and round the perineum of females, matted with peat and faeces, could impede copulation. Any females inseminated as yearlings would have the combined stresses of pregnancy and winter to induce fineness and breaks in the fibre. Females thus freed of their fleece could breed in succeeding years, but those which did not breed as yearlings would possibly never do so. In males the selection would be for clean bellies. Observations consistent with Regnault's hypothesis are that: double fleeced females were almost invariably lambless, the untidiest females usually had the biggest, healthiest lambs, legs were long and clean, and most rams had clean bellies (Regnault 1976); and that Campbell Island sheep go into oestrus at 8 months old which is earlier than other breeds under the same management regime (Bigham and Cockrem 1982).

CONCLUSIONS

It seems clear that no single factor precipitated the changed performance of the sheep on Campbell Island, but there remains the problem of why population growth did not seem to begin until about 1960. The mid 1950s were, afer all, exceptionally benign in general climatic character, and possibly also in the particular months of lambing. The vegetation had been lying fallow for some 25 years and must have been well along in its recovery from the burning era. Genetic changes would have been accumulating in the sheep and being manifested during the period of decline rather than waiting to erupt at some particular date.

The behaviour of the animals may well have played a part in delaying their resurgence. The shepherds remarked that when sheep were released from shearing pens they always went back to their own part of the island. Limited observations on family groups (Regnault 1976), and personal observations showed that females and lambs lived in very circumscribed ranges. The genetic balance may well have been changing within localised groups but until population pressure built up in the familiar ranges, animals did not move out and exploit the resurgent growth elsewhere. The descriptions by Wilson and Orwin (1964), of rank vegetation in areas that were to become densely populated within 10 years, support this view. Even then, the colonizers had to pass another threshold of breaking down rank vegetation to promote fresh young growth by their own grazing. Once the colonization phase began the way was open for the sheep to exploit the rich food resources and their new genetic constitution.

ACKNOWLEDGEMENTS

During the long gestation of this paper I have benefited from the results of later field surveys and many discussions with colleagues particularly D.J. Campbell, R.H. Taylor and P.R. Wilson of this Division, and J.D. Hessell and S. Goulter of the N.Z. Meteorological Service. Jocelyn Berney was the patient typist, and Tony Pritchard helped with editing and artwork.

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INTRODUCED MOUNTAIN GOATS IN THE SNAKE RIVER RANGE, IDAHO: CHARACTERISTICS OF VIGOROUS POPULATION GROWTH

James A. Hayden, Montana Cooperative Wildlife Research Unit, School of Forest Resources, University of Montana, Missoula, Montana 83412.[1]

ABSTRACT

Between 1969 and 1971, 12 mountain goats were translocated from northern Idaho to the Snake River Range of southeastern Idaho. Status and ecology of the resulting population was examined between March 1982 and December 1983. The 1983 estimated population of 142 animals has sustained a mean exponential rate of growth (r) of 0.20 since the last introduction; r was estimated at 0.26 for the period 1 July 1982 to 1 July 1983. Productivity was high during 1982 with 71% of adult females (> 3-year-olds) producing young, and 25% of the sibling groups being twins. During 1983, 86% of adult females were observed with young, 33% with twins. Observed annual survival was also high between 1982 and 1983; kid survival was 88%, yearling survival was 95%, and average subadult/adult survivial was 93%. Yearling and 2-year-old sex ratios were not significantly different from unity, but observed adult goat ratios were heavily biased toward females. Mean and maximum group sizes were smallest during late spring, when solitary goats were most prevalent. The propensity for groups to cluster was highest and most variable during winter. High-quality habitat appears to be fully occupied before use of less-optimal habitat commences. Goats are now beginning to colonize the Teton Range, where their presence may threaten a resident bighorn sheep population. An aggressive management and research philosophy is proposed.

INTRODUCTION

The Snake River Range is located near the southern boundary of the historical distribution for mountain goats (Oreamnos americanus) (Rideout 1977). The Snake River Range and adjacent Teton Range are isolated by over 160 km of plains and desert from the nearest native population of goats--those of the Lemhi Range of central Idaho. Skinner (1926) explicitly described the Teton Range as an area for which there was no conclusive evidence for the existence of mountain goats.

1 Present address: Idaho Fish and Game Dept., 5205 S. 5th Avenue., Pocatello, Id. 83201.

The Idaho Fish and Game Department initiated a transplant program in the Snake River Range with hopes to initiate a mountain goat population in lieu of the bighorn sheep population previously extirpated from the area (F. DeShon, pers. comm.). During early July of 1969, 1970, and 1971, a total of 12 mountain goats were relocated from northern Idaho into the Snake River Range at 2 sites (Figure 1, Table 1). Although neither area was fully censused for goats prior to this study, partial surveys and incidental observations indicated that the transplants were successful and the population had grown suostantially (K. Neilson, pers. comm.).

Table 1. Composition of mountain goat transplants into the Snake River Range and Big Hole Mountains, Idaho.

Date	#Gts.	Composition	Source Population	Destination
July 1969	5	2 females, 1 male (age unknown)	Snow Peak, ID	Palisades Creek (Snake River Range)
		1 male, 1 female (age unknown)	Black Mtn., ID	
July 1970	3	3 yearling males	Black Mtn., ID	Black Canyon (Big Hole Mtns.)
July 1971	4	Adult female, Adult female with male kid, yearling male	Black Mtn., ID	Black Canyon (Big Hole Mtns.)

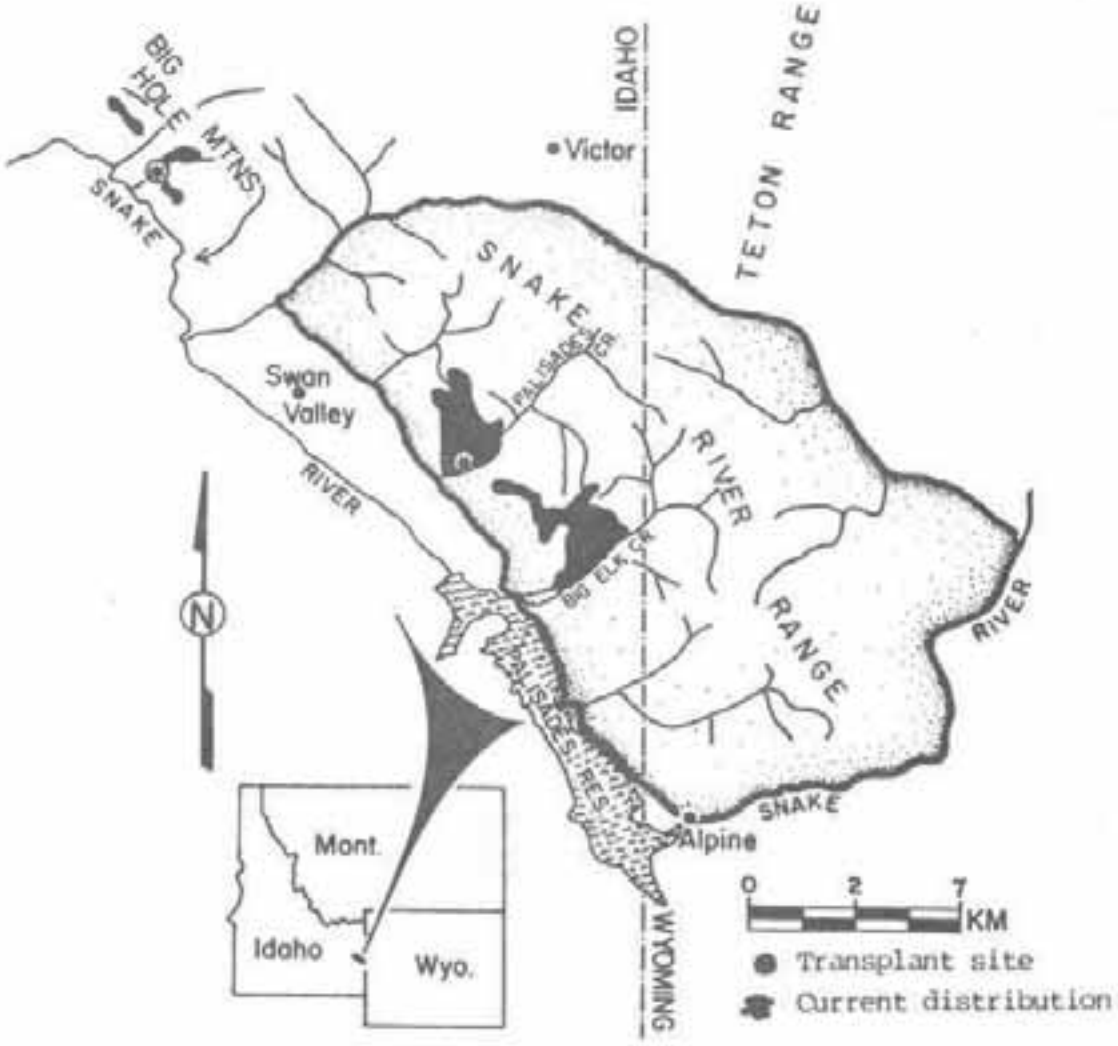
This study, conducted between March 1982 and September 1983, was initiated to determine the status and ecology of the mountain goats resulting from these introductions. The purpose of this paper is to present the population characteristics observed during the study, a period of rapid population growth not influenced by hunting. In addition, I hope to bring to attention a probable conflict between the goats originating in the Snake River Range and the bighorn sheep (Ovis canadensis) native to the Teton Range.

Support for the study was provided by the Idaho Department of Fish and Game, the U.S. Forest Service, the National Rifle Association, and the Mazamas. The Montana Cooperative Wildlife Research Unit assisted me greatly during data analysis and writing of this paper.

STUDY AREA

Running from northwest to southeast, the Snake River Range spans the Idaho/Wyoming border. Adjacent to the northeast lies the Teton Range, a larger, more rugged range, with elevations to 4197 m. The Snake River Range is small, only about 1200 square km, but elevations range from approximately 1735 to 3060 m. The northwestern 1/3 of the range is known as the Big Hole

Figure 1. Map of the Snake River Range study area, including transplant sites and areas of current distribution (1982-1983).



Mountains, and has a maximum elevation of only 2748 m. The South Fork of the Snake River and Palisades Reservoir form the southern boundary of the Snake River Range (Figure 1).

Peaks of the range are connected by a central axial divide. Cirque basins, common especially throughout the central portion of the range, frequently retain snow through late July (L. Merrill, pers. comm.). Cliff strata are made up almost entirely of a hard, gray limestone.

No true alpine or krummholz areas exist in the Snake River Range. High elevation areas are characterized by large, dry meadows scattered with Engelmann spruce (Picea engelmannii), subalpine fir (Abies lasiocarpa), limber pine (Pinus flexilis), and an occasional Douglas fir (Pseudotsuga menziesii). At the southeastern end of the range, meadows are much larger, and herbaceous vegetation is more lush than elsewhere.

At low elevations, closed stands of Douglas-fir, mixed with bigtooth maple (Acer grandidentata), Rocky Mountain maple (A. glabrum), serviceberry (Amalanchier alnifolia), limber pine, and ninebark (Physocarpus malvaceus), dominate cool exposures between cliff bands. Warm exposures are dominated by old-growth curl-leaf mahogany (Cercocarpus ledifolius) and Utah juniper (Juniperus osteosperma).

Early seral stages characteristic of debris chutes were typified by bigtooth and Rocky mountain maples, along with scattered shiny-leaf ceanothus (Ceanothus velutinus), chokecherry (Prunus virginiana), and/or red osier dogwood (Cornus stolonifera).

METHODS

FIELD TECHNIQUES

Identification of Sex and Age

Goats were examined through a 15-60x telescope. The identification of genitalia was infrequent. Sexes were classified on the basis of horn curvature and basal width (Brandborg 1955, Lentfer 1955). Additional features provided clues for classification: the association with a kid, general social behavior and timing of the molt (Chadwick 1973), and coat color during the rut (Brandborg 1955). I found it difficult to distinguish the sex of yearlings before midsummer.

When possible, goats were classified as kid, yearling, 2-year-old, or adult. Ages were estimated largely on the basis of rostrum length (Smith 1976), as well as on beard and horn length (Brandborg 1955). Body size, social behavior (Chadwick 1973), pantaloon development (Smith 1976), timing of the molt, and coat color during the rut (Brandborg 1955) provided additional clues for estimating age.

Census Techniques

The entire Snake River Range was censused a minimum of once every 3 weeks between 27 March and 15 September 1982, and between 18 June and 15 August 1983.

Full censuses were also flown periodically during winter 1982. When a group of goats was sighted, I marked their location and age/sex composition on a 7.5 minute topographic map. The time, weather, general behavior of the group, age/sex composition of the group, and incidental observations were recorded in a notebook. During aerial censuses a cassette recorder was used in lieu of the notebook. Standard routes were followed during each census, although minor deviations were necessary to assist in classification.

Ground Censuses. Classification of goats to age-class 2 was possible only during ground censuses. Goats were located and identified by scanning with 8 x 30 binoculars and a 15-60x telescope. All drainages in the area were censused during composition counts, with additional attention given to the Palisades and Big Elk Creek drainages, the 2 major centers of mountain goat activity.

Aerial Censuses. During 1982, 3 aerial censuses were conducted to help assess seasonal distribution and numbers of goats. A Hiller-Soloy helicopter was used to census winter ranges on 10 April and 8 December, when goats were concentrated on winter or winter/transitional ranges. A Bianca Scout plane was used to survey summer ranges on 21 and 22 July. Two aerial censuses were completed during 1983. A Cessna 180 was used to survey summer range on 25 June, 20 July, and 21 July. A helicopter census on 9 December was aborted due to severe weather.

During the helicopter surveys drainages were systematically investigated for goats and goat tracks. Each drainage was divided into several segments by subdrainage. Each segment, typically from 1 to 1.5 km in length, was flown from top to bottom at contour intervals of approximately 60 m. During the April 1982 census, my second week in the field, I was only able to classify goats as kids or non-kids. During the December census, I was also able to distinguish yearlings and the sex of adults from the air.

Because the summer range was so large, and because there was little snow for tracking, the plane censuses were more extensive than intensive. All drainages, including low-elevation cliffs and winter ranges, were flown from top to bottom. Long, high-altitude ridgetops were flown first, in segments of approximately 2 km. Due to the relief of the area and the reconnaissance nature of the fixed-wing flights, drainages associated with each segment of ridge were flown at 120 m contour intervals. Narrow drainages were flown by side-slipping and slowly gliding back and forth straight down the drainage. The minimum speed of the plane (85 km/hr) proved too swift for me to reliably classify goats other than to kids or non-kids.

ANALYTICAL TECHNIQUES

Calculation of Demographics

The discrete nature of the Snake River Range population allowed application of the cohort completion method (Smith 1976) to surveys throughout the year. By this method, identifiable age/sex categories were repeatedly counted, and the highest count was assumed to be closest to the true size of that category. The summation of all age/sex categories (including unknowns) thereby represents the minimum calculated population size. These counts were assumed to reflect the population immediately following the kidding season. Back-calculation of age/sex categories to previous years provided additional

information. All demographics reported are taken from the populations resulting from the cohort completion method. A basic assumption behind this method is that goats are properly classified, and the classification to each category is equally reliable. Although this method does not assume equal observability between age/sex categories, it does assume that differences in observability are not extremely disparate.

Statistical Analysis

The DECSYSTEM 20 time-sharing computer at the University of Montana was used in data analysis. Basic descriptive statistics and file manipulation were made easier through use of the 1022 Database Management System program (Jackson 1982). The SPSS Program (Nie et al. 1975, Hull and Nie 1981) was used for more advanced descriptive statistics and non-parametric analysis of density indices. For the analysis of ratios, the G-test (Sokal and Rohlf 1981) was used in lieu of the Chi-square test because of better reliability and ease of calculation. Simple FORTRAN programs were written by the author to calculate harmonic statistics (See Neft 1966), and to perform G-tests. These programs are available upon request.

Calculation of Population Parameters

The instantaneous, exponential rate of growth (r) for the population was estimated according to the following formula:

$$r = \frac{\ln(N_t/N_0)}{t}$$

where, r = estimate of the exponential rate of increase;
N_t = population size at time t;
N_0 = population size at time zero; and,
t = time period length

Population birth and death rates were calculated for each segment of the population from the composite population for 1 July of each year (following the kidding season).

Analysis of Grouping

Grouping was analyzed according to Adams and Bailey (1980) for each drainage and for the entire population. Similar to the method employed by Chadwick (1977), a goat was considered to belong to a specific group if within 50 m and currently or recently engaged in similar activities. Areal concentration of groups was analyzed by examining the distance between groups. Sample size necessitated the lumping of drainages. Straight arithmetic comparisons of the distance between groups are sensitive to the dispersal of even a few individuals, and not to concentration or clustering, and therefore do not make a good measure of concentration. By transforming the distance between groups (or individuals) in a harmonic or inverse manner (DIST ===> 1/DIST) this problem is circumvented (See Neft 1966). Harmonic transformations have been used with individual animals to help describe home ranges (Dixon and

Chapman 1980, Samuel et al. 1983), and have appropriate applications in the analysis of populations.

The average (harmonically-transformed) distance from 1 location (group) to all others, represented as H_d, was calculated according to the following formula:

$$H_d = \frac{n}{\sum_{i=1}^{n} \sum_{j=2}^{n} \frac{1}{Mj}}$$

Where, H_d = the harmonic mean distance from the "anchor" location to all other locations;
n = the total number of locations, and;
M_j = the distance from the "anchor" location (i) to the "object" location (j)

The average H_d among the population of locations is known as H_p, which provides a measure of concentration directly comparable to that of other areas, or to the same area, but at different times (See Neft 1966).

The broken topography of mountain goat habitat severely hinders H_p comparisons, and in fact, detracts from the application of mean harmonic measures (as with any present measure of seasonal or home range). However, a more indirect application of harmonic mean measures yields information on the relative dominance of the clustering effect within an area, and how this changes with time (Neft 1966).

The location of the point on the map with the smallest distance to all other locations is known as H_c, and its value is represented by H_r (which equals the H_d for that point). The ratio of H_p to H_r indexes the dominance of the clustering exhibited by the population of locations--but is not a measure of concentration (as is H_p by itself).

The location of H_c and the associated value of H_r can be estimated by overlaying an artificial grid on the map of locations, and evaluating the H_d associated with each grid intersection. This is the general method used by Dixon and Chapman (1980) and Samuel, Pierce, Garton, Nelson, and Dixon (1983) to map harmonic home ranges. Except when sample sizes are small, or locations very widely scattered relative to the desired degree of precision, the coordinates of the location with the smallest H_d can be used as a reasonable estimate of the location of H_c, and that H_d can similarly be used to approximate H_r.

Neft (1966) considered a H_p/H_r ratio of over 2.0 to represent a strong clustering effect, and a ratio below that to indicate poor or no clustering. The theoretical range for this ratio is from 0 to infinity, but in practice, it normally ranges from 0 to 6, and is rarely over 15.

RESULTS

Two major concentrations of goats were found in the Snake River Range. The primary center of activity was in the Palisades Creek drainage, and a secondary center was in the Big Elk Creek drainage (Figure 1). Near the site of the first release, the Palisades Creek herd comprised about 2/3 of the total population during the study. Most of the remaining goats were found near Mount Baird, the highest peak of the range. A maximum of only 5 goats were seen near the site of the 1970 and 1971 release site, at Black Canyon, in the northwestern portion of the range.

The minimum observed population size was 103 goats in 1982, and 142 goats in 1983. The calculated population was 109 goats in 1982, and 142 goats in 1983. Using the calculated populations, the r-value was estimated at 0.26 for the change from 1982 to 1983. Censusing was intensive during this study, and I feel reasonably confident that the population-segment estimates (Table 2) are within 10% of their true size.

Because transplant demographics were obviously very skewed from that of a reasonable population structure, and because the goats were transplanted in more than 1 year, I took the growth of the adult female (> 3 years old) segment of the population at the time of the last release to be a more true indicator of overall population growth. In 1971, a maximum of only 4 adult females was possible. The r-value for this segment of the population to 1983 was 0.20.

Productivity was high during both 1982 and 1983 (Table 3). No significant differences in productivity were found between 1982 and 1983, or between drainages in either year (G-test, $P>0.10$). By 28 May 1982, I had not observed any neonates, but a severe snowstorm on that date severely hindered visibility. On 30 May, I found 5 kids (including 2 sets of twins) among 6 non-kids in the same area. By 21 June, the kid crop was apparently complete. The population was not examined during the 1983 kidding season.

During early summer 1982, 21 of 29 adult females (72%) were observed with kids, and 5 of 21 sibling groups (24%) were twins. During the same period in 1983, 30 of 35 adult females (86%) were observed with kids, and 10 of 30 sibling groups (33%) were twins.

In terms of precipitation from November through March, the 1981-82 winter was the most severe since 1957 (when those records were first kept at Palisades dam). The 1982-83 winter ranked 6th among the preceding 26 years. Despite these severe winters, the calculated survival rate for the population including unclassified goats was 94% between 1982 and 1983. Survival was estimated at 92% for the classified population for this period, with no significant differences between kid, yearling, and average subadult/adult rates (G-test, $P>0.95$). Observed kid survival was 88%, yearling survival was 95%, and the average subadult/adult survival was 93%.

The age structure of the population was extremely broad-based, with less than 2/5 of the classified population in the adult category during either year. There was no significant difference in age structure between 1982 and 1983 (G-test, $0.30>P>0.20$) (Figure 2).

Table 2. Composition of mountain goats in the Snake River Range, Idaho using the cohort completion method (Smith 1976).

		Classification[1]														
Year	Location	AF	AM	AU	2F	2M	2U	2+F	2+M	2+U	YF	YM	YU	K	U	TOTAL
1982	Palisades	15	4	0	4	5	0	0	1	0	5	6	2	12	4	58
	Big Elk	13	4	0	1	2	0	1	3	1	2	1	5	13	0	46
	Other	1	1	0	1	1	0	0	0	0	0	0	0	1	0	5
	Total	29	9	0	6	8	0	1	4	1	7	7	8	26	4	109
1983	Palisades	23	7	0	7	9	1	0	0	0	4	4	11	24	2	92
	Big Elk	12	11	0	1	1	2	0	1	0	1	2	1	16	1	49
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	35	18	0	8	10	3	0	1	0	5	6	13	40	3	142

[1] A:adult; 2:age class 2; 2+: 2 years or older; Y:yearling; K:kid; U:unknown; M:male; F:female.

Table 3. Natality in mountain goats of the Snake River Range, Idaho; 1982-1983.

	1982			1983		
No. Kids Produced	No. Adult Females[1] Palisades	Big Elk	Total[2]	No. Adult Females[1] Palisades	Big Elk	Total[2]
0	6	2	8	4	1	5
1	6	9	15	14	6	20
2	3	2	5	5	5	10
	15	13	28	23	12	35
Productivity	0.87	1.00	0.90	1.04	1.33	1.14
Proportion of AF's without a kid	0.04	0.15	0.28	0.17	0.08	0.14
Proportion of twins per AF	0.20	0.15	0.18	0.22	0.42	0.29
Proportion of twins per productive AF	0.33	0.18	0.25	0.26	0.45	0.33

[1]Adult females are 3 years of age or older.
[2]Includes observations from other portions of the range

Figure 2. Comparison of sex ratios in the Snake River Range mountain goat population when subadult cohorts are included with older goats.

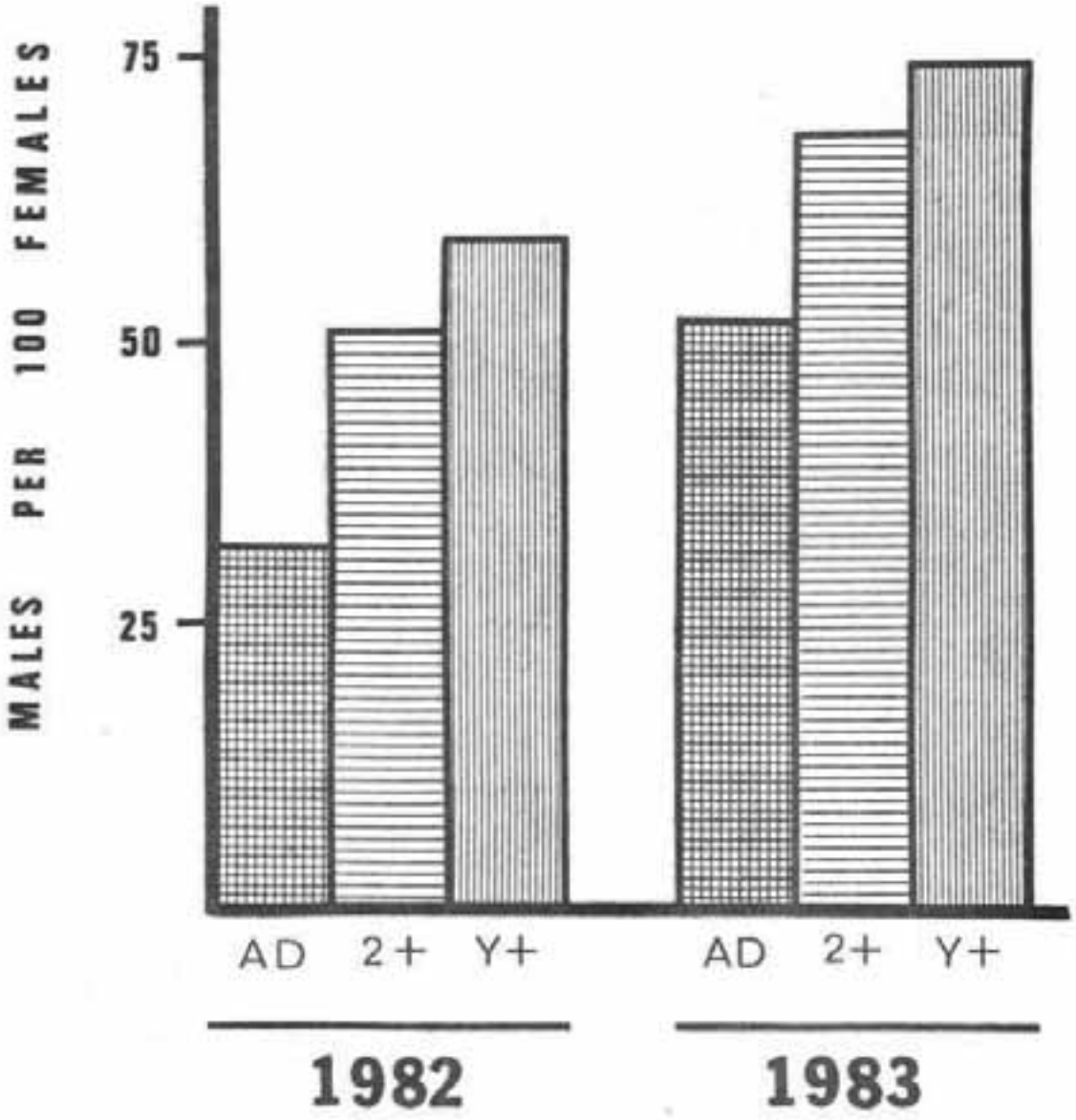


Figure 3. Age structure of mountain goats from complete surveys in the Snake River Range, Idaho, 1982-1983.

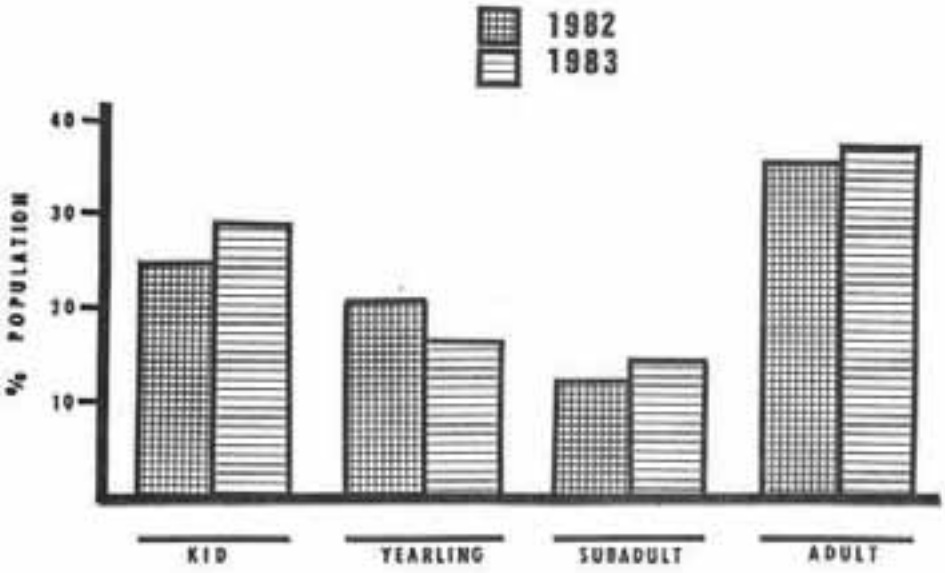
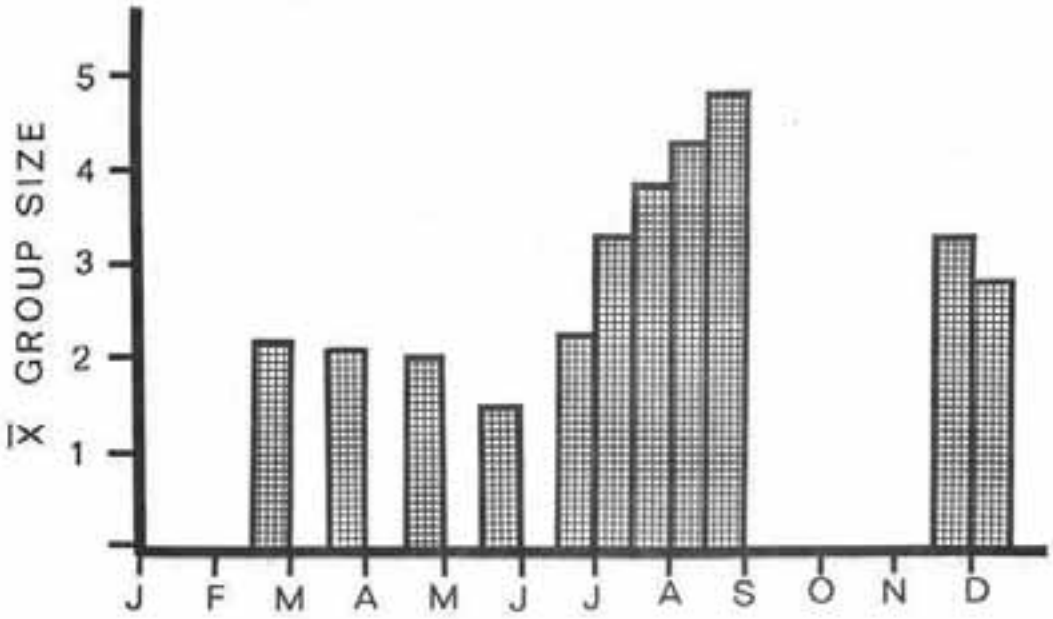


Figure 4. Bimonthly group mean group sizes of mountain goats observed during full surveys of the Snake River Range, Idaho. Data are from 1982 and 1983 (combined).



The sex ratio was even among yearlings (G-test, 0.90>P>0.80) and 2-year-olds (G-test, 0.6>P>0.5). Adult sex ratios, however, were heavily biased toward females (G-test, P<0.001). Inclusion of yearling and 2-year old cohorts in sex ratios for the population (Figure 3) therefore masked the relative proportion of sexually mature males to sexually mature females (G-test, 0.10>P>0.05).

Mean group size was smallest during mid-May and highest during mid-July (Figure 4, Table 4). The proportion of goats that were solitary animals was lowest during mid-summer. The standard error of groups was smallest during late-winter/early spring.

Seasonal H_p/H_r ratios calculated for the Snake River Range (Table 5) indicate a strong clustering effect (according to Nef's 1966 criterion), especially during winter. Analysis of the variation of these ratios between summer and winter indicated a difference that was not quite significant statistically (Kruskal-Wallis test, P=0.15), but the sample size for each season was small (N_1 = 4, N_2 = 5), thereby limiting the power of the test. It appears that winter concentration ratios may be more variable than summer ratios, perhaps a reflection of the variability of winter conditions versus the relative stability of summer conditions. Sample size was too small to permit comparisions between years.

DISCUSSION

With regard to the characteristics discussed by Pianka (1970), mountain goats may be viewed as a very 'k'-selected species. Where mountain goats are found in small, semi-isolated populations, management should be precise and based on accurate information. Unfortunately, the general lack of knowledge about population structure, age-specific rates of productivity and survivorship, and the influence of social behaviour confound such a management scheme. Consequently, management has been, at best, based on an extrapolation of much more general data.

Perhaps the most important factor contributing to this management approach is the difficulty in counting and classifying mountain goats. Accurate sex ratios are difficult to determine because males and females look very similar and males are frequently more dispersed than females. Many researchers classify goats only as kids or non-kids, although some identify the yearling cohort. Several researchers have classified 2-year-olds also (Chadwick 1973, 1977, Smith 1976, Dane 1977, Nichols 1980, Risenhoover and Bailey 1982, Smith 1982), despite problems inherent with variation in horn growth (Foster 1982) and other aging criteria.

In many areas, goats can only be classified as kids and non-kids for practical or economical reasons. Where more detailed breakdowns of age-structure are possible however, the analysis of population dynamics is made easier.

Bias From Differences in Population Structure

The structures of recently-introduced populations (those that have not yet achieved a near-stable age distribution and growth rate) are difficult to

Table 4. Grouping characteristics of mountain goats in the Snake River Range, Idaho. Data are from full surveys of drainages only.

Date	# of Goats	Range in Group Size	Mean Group Size	Standard Deviation	Standard Error	% Groups as Singles	% Goats as Singles
15[1] February	70	1-6	2.19	1.42	0.65	41	19
15 March	135	1-8	2.08	1.63	0.78	52	25
15 April	120	1-9	2.03	1.67	0.82	56	28
15 May	78	1-6	1.50	1.18	0.79	79	53
1 June	76	1-9	2.23	2.00	0.90	53	24
15 June	326	1-15	3.36	2.99	0.89	30	9
1 July	146	1-22	3.84	4.16	1.08	37	10
15 July	295	1-24	4.54	4.45	0.98	34	7
1 August	122	1-14	4.36	3.98	0.91	29	7
15 August	135	1-17	4.82	4.10	0.85	18	4
15 November	130	1-14	3.33	3.19	0.96	44	13
1 December	206	1-9	2.82	2.25	0.80	42	15

[1] The first half of a given month is represented by a 1 and the second half by a 15.

Table 5. Harmonic mean measures of distribution of groups of mountain goats in the Snake River Range, Idaho (see Neft 1966).

Season	Date[1]	H_p	SE	H_r	H_p/H_r[2]	No. Groups
Winter	11/15	71.59	0.37	38.02	1.9	12
	12/00	203.54	0.89	61.86	3.3	62
	2/15	122.54	0.81	27.66	4.4	25
	3/15	205.05	0.98	35.38	5.8	47
	4/15	111.07	0.43	49.18	2.3	47
	Average	142.76	****	42.42	3.4	
Summer	7/00	169.27	0.46	67.52	2.5	21
	7/15	230.50	0.74	94.78	2.4	12
	8/00	98.12	0.59	39.42	2.5	21
	9/00	102.87	0.59	47.94	2.1	10
	Average	150.19	****	62.42	2.4	

[1]For the day, 00 indicates the first half of the month, and 15 indicates the second half.

[2]Indexes the dominance of the clustering within the distribution.

compare except grossly because of the many complications involved. Population structures of recently-introduced populations vary from one locale to the next because of differences in the size and demographics of the transplants, timing between transplants, number of transplants, and variability of genetic potential.

These factors, in conjunction with the amount of time elapsed between the transplant(s) and the study of the population, make a clear analysis unrealistic. The progressive, rippling instabilities of the structure of introduced populations are further complicated by factors that often make the comparisons between established populations difficult. Such factors include:

1. study procedures/data reliability;
2. seasonal strategies of habitat use (e.g. winter survival on high vs. low elevation ranges);
3. inherent habitat constraints (e.g. browse vs. graminoid/forb winter ranges);
4. variable sources of natural mortality;
5. the influence of local climate;
6. variable hunting regimes and other direct influences of man; and,
7. indirect influences of man (e.g. mining near kidding areas.

Each age-class of a population contributes to population parameters in a particular manner. The best comparison of parameters between populations is by using age-specific rates. However, the construction of such tables for mountain goats is rarely feasible except for kid, yearling, and in more intensive studies, the 2-year-old age-classes. Comparisons of lumped rates between populations are possible only if population structures are similar, but much information is still lost.

Age-specific fecundity schedules have not been developed for mountain goats. As found, for example, with mule deer (Robinette and Gashwiler 1950, Robinette et al. 1955), fecundity during the first year of sexual maturity can probably be expected to be lower than that of the next few age-classes, and a gradual drop in fecundity can be expected in the oldest age-classes. Under these conditions, the productivity exhibited by a population with a young age-structure would be different than that of a population of the same size, but with an old age-structure, even if they were on identical ranges. This influence should be kept in mind when interpreting productivity rates and other parameters from this and other recently-introduced populations.

Habitat Colonization

The strong affinity for cliffed areas by mountain goats is well-documented. Kuck (1977), during his study of a rapidly-declining goat population in the Pahsimeroi Range of Idaho, found that the value of a cliff or cliff complex appeared to be more related to physiographic characteristics than to vegetative characteristics.

The Palisades Creek and Big Elk Creek drainages have the steepest low-elevation base slopes in the range. In the Palisades Creek drainage, the tier-like

arrangement of cliffs and the abundance of curl-leaf mahogany, a high-quality browse, makes this area an especially lucrative winter range for mountain goats. The Big Elk drainage, with very good regeneration of mahogany and many large cliffs, appears to have good potential. Beyond these 2 areas, however, cliff areas of the Snake River Range are decidedly smaller and more isolated.

Another large drainage of the range, Indian Creek, contains a fair number of low-elevation cliffs with ample forage, but the base slope itself is noticeably much more shallow. Here, at the southeastern end of the range, snowfall seems to be heavier than elsewhere, as prevailing winds from the southwest pick up moisture from Palisades Reservoir before dumping it as snow in the mountains. Thus, in addition to less effective snow-shedding properties, heavier snowfalls make this a less desirable winter range.

In general, there are many areas in the Snake River Range that are comparable vegetatively to occupied areas, but no areas are nearly similar physiographically. Mountain goats in the Snake River Range appear to be colonizing and filling the high-quality habitat of the Palisades Creek and Big Elk Creek drainages well before colonizing less-optimal habitat in other portions of the range. The high densities of goats in these 2 primary areas indicate that there may be a large difference in quality between that of the currently-occupied habitat and that of the next best (and as yet unoccupied) habitat.

Population Dynamics

The mean r-value for the first 12 years of the Snake River goat population is comparable to the 20-year rate calculated by Guenzel (1980) for transplants into the Selkirk Mountains of Idaho, and the Black Hills of South Dakota. Only the transplants into the Crazy Mountains, Montana, and the Gore Range, Colorado exhibited faster growth.

The high growth rate found in this population is probably related to good forage quality and quantity. The abundance of curl-leaf mahogany, and additional composite of juniper, Douglas-fir, maples, ceanothus, etc. form an excellent browse-based winter range. Goats in the Snake River Range have not been present in large numbers for an extended period of time, and the winter vegetative communities have not approached the zootic disclimax typical of most browse-based ranges.

Heavily-impacted winter ranges with poorly-sprouting browse species (such as curl-leaf mahogany) do not have the inherent ability to quickly recover. Subsequently, a substantial lag may follow a herd reduction before the vegetation can recover enough to increase productivity and survival. Similarly, high-elevation ranges, because of their short growing seasons and more harsh environment, usually cannot recover quickly either. J. Swenson (pers. commun.) notes that in situations where the vegetation can quickly recover, a more compensatory response to goat hunting may be expected. In any case, the 2 year lag between birth and sexual maturity makes any compensatory response a slow one.

Productivity

Productivity observed during this study was high relative to other populations (Table 6). This appeared primarily to be the result of a high rate of twinning despite a substantial number of females observed without kids.

Even age-specific productivity rates rarely reflect parturition accurately. Use of a productivity rate implies that we have knowledge of the actual number of young being produced, when in fact, we derive this as an estimate some time after birth of the young. Thus, early juvenile mortality is incorporated with both non-conception and non-parturition of successfully bred females in the statistic, and productivity statistics should be interpreted with this in mind.

Caughley (1977) notes that the age of fecundity is often lower in rapidly-growing populations than those with no (positive) growth. Stevens and Driver (1978) observed "several" 2-year-old nannies accompanied by kids in the introduced population of the Olympic Peninsula, Washington. They also reported that no adult female observed during their study was seen without a kid at her side. In the Snake River Range population, the age of sexual maturity was approximately 2.5 years for the first breeding. Several times during late-summer 1982, I observed what appeared to be an age-class 2 female with a kid. Confirmation of the nanny's age was not possible, however, and she may have merely been a "low-quality" 3-year-old.

Maturation of young goats continues through winter, but at a slower rate than during the remainder of the year. Most age-class 2 goats were distinguishable from other age-classes through mid-winter, and a few individuals were distinguishable through early spring. Although age-class 3 goats were not readily discernible during June, behavioral cues and impressions of slightly smaller body sizes, rostrum lengths, and horn size often hinted that certain animals were likely 3 years of age.

I was not able to reliably age age-class 3 goats in either year of the study. However, of those nannies that I felt were likely to be 3-year-olds, none had twins. I suspect that the twinning rate (and by inference, parturition rate) among 3-year-old females is much lower than that of older females.

During the collection of behavior data during late June 1983, a nanny with what appeared to be a set of triplets was observed for extended periods of time over a 4-day period. Suspected triplets were not observed during any census, however, and so are not included in the productivity summary. Lentfer (1955) reported the only other cases of suspected triplets, in the rapidly-growing, introduced population of the Crazy Mountains, Montana. Of 311 kids observed during the 2 years of his study, Lentfer classified 3 sibling groups as triplets and felt he had evidence for 3 additional sets.

Caution is necessary in the interpretation of multiple birth statistics. On 19 August 1982, I witnessed 2 kids to leave a nanny in one group and join a different group. Disturbed by my presence, a group of 9 goats slowly crossed the hillside away from me. One kid became separated from the rest of the group and began bleating loudly, whereupon the second kid broke from the group and ran back to the first kid. The remainder of the group continued across the

Table 6. Comparison of productivity estimates between selected studies. All estimates expressed as the number of kids per 100 females 3 years of age or older.

Location	Source	Year	Kids per 100 mature females	Population Size
Montana	Chadwick 1973	1971	44	25
		1972	73	29
		1973	89	31
Montana	Smith 1976	1974	40	132
		1975	39	110
Montana	Chadwick 1977	1974	56	314
		1975	55	300
		1976	57	232
British Columbia	Dane 1977	1968	13	36
		1969	27	18
		1970	35	36
		1971	50	32
		1972	50	37
British Columbia	McFetridge 1977	1974[1]	75	32
		1974[1]	27	23
		1975[2]	69	39-42
		1975[2]	80	31-33
Alaska	Nichols 1980	1977[3]	108	45
		1977[4]	70	58
		1978[3]	79	41
		1978[4]	54	59
		1979[3]	77	42
		1979[4]	87	37
Colorado	Riesenhoover and Bailey 1982	1981	100	118
Idaho	This study	1982	98	109
		1983	114	142

[1] Mt. Hamell.
[2] Goat Cliffs.
[3] Ptarmigan Lake.
[4] King's Bay.

hill and out of sight. Neither the nanny or any other goats showed c oncern over the absence of the 2 kids. Meanwhile, both kids took up bleating loudly and were answered by a kid in a group of 3, also including a nanny and a 2-year-old male.

The 2 kids then joined the new group, and after a 10-15 minute period of acquaintance and play, bedded next to the nanny. I observed this new group for the next 40 minutes, and the kids appeared to be well-accepted into the group.

Foster and Rahs (1982) concluded that the separation of a nanny and her kid was not an uncommon phenomenon, and that orphaned kids will often join a foster group. They supported Rideout's conclusion (1974, as cited by Foster and Rahs) that nanny/kid separations do not always lead to the kid's death, and note that metabolic dependency on nursing is probably complete before mid-August under normal circumstances.

Among bighorn sheep, Hass (1984) documented nursing of lambs on females other than their mother in a low winter-stressed population on the National Bison Range, Montana. This type of behavior would increase the chances for survival of orphaned young during summer. It is not reported if this allo-mothering extended to protection and care of the "stranger's" lambs, which would increase orphan survival well beyond the nursing stage. Cooperative nursing and other forms of allo-mothering have not been described among mountain goats. It appears most likely that orphan survival and health is largely a function of the orphan's own resources and its ability to join a foster group.

Survivorship

Productivity for introduced mountain goats is higher than that of native or established populations as indexed by the proportion of kids to females 2 years of age or older (Bailey and Johnson 1977). The high survivorship observed in the Snake River Range supports the hypothesis that survivorship, the second important determinant of population growth, can be expected to follow the same pattern.

The opportunity for a goat to die by an accident is probably less here than on most winter ranges. The cliffs themselves are relatively small, and avalanches are not abundant--possibly because of shallow base slopes.

Golden (Aquila chrysaetos) and bald (Haliaetus leucocephalus) eagles are frequently observed in the Snake River Range. Both species nest within or adjacent to these mountains. Coyotes (Canis latrans) are abundant and bobcats (Lynx rufus) are also present. Mountain lions (Felis concolor) are common in the range, and tracks were observed almost on a daily basis on the Palisades Creek winter range during late winter and early spring. The low mortality rate for the goats reflects the low influence of predation on the population, at least outside the neonatal period.

Poaching has been identified as a major source of adult mortality in other areas, and has apparently affected this population also. On 27 March 1982, during the first survey of the study, I found the headless carcass of a large adult billy. Apparently left within the previous 3 weeks, the carcass had been caped and left on a hiking trail below a winter range cliff. The caped

carcass of another adult billy was found in the southeastern part of the range during a Wyoming elk hunt during September 1983 (G. Roby, pers. commun.). Casual reports from local residents indicate that one resident may have taken up to 4 illegal goats from this population, and there are rumors of illegal guided hunts. How much poaching has affected the growth of the Snake River Range population remains unknown. My presence in the range probably lessened the degree of poaching during the study.

Juvenile Mortality

The lower productivity observed in 1982 likely incorporates early juvenile mortality. In terms of total winter precipitation, the winter preceding the 1982 kid crop was the most severe in the previous 25 years. This may have weakened at least the smaller (and presumably younger) nannies, and affected the fetus.

On 28 May 1982, a heavy, wet snow fell, and the weather remained very cold and wet through 7 June. This is the first, and perhaps crucial, part of the kidding season in the Snake River Range. The combination of a harsh winter and a cold, wet kidding season probably contributed to early juvenile mortality, and might have been incorrectly interpreted as poor production.

Additionally, I may have directly contributed to the mortality of a set of twins. During an exploratory survey on 30 May 1982, I rounded a rocky outcrop and came face-to-face with a nanny and 2 very young kids. Hoping the nanny would lead the kids away, I froze. Instead, she stamped her feet several times and left the vicinity, but the kids could not keep up. Immediately leaving and circumventing any area I thought visible to the unseen nanny, I retraced my path back to a hidden vantage point about 750 m from the kids. The abandonment took place at about 1500. Although the kids bleated frequently, the nanny did not return by 2030, at which time I couldn't see any more. I did not find evidence of the kids upon my return to the area on 1 June. These kids were extremely small and were probably less than 2 days old. Unless the nanny returned soon after I left, it is doubtful the kids survived that night because of the inclement weather.

Grouping

One manner in which the analysis of a population may be augmented is by examining the density of the population. A major drawback in the calculation of densities is that it is often difficult to empirically define the boundary of the area under consideration in a biologically meaningful manner. There is also a difficulty in predicting what habitat is suitable (or tolerable) to mountain goats, i.e. which areas within the general boundary may be included. Broad demarcations tend to include large amounts of area not suited to mountain goats. The steepness of the base slope and other topographical considerations contribute to the amount of "preferred" area estimated. Comparisions of densities are generally useful only within a specific locale from year to year, and the interpretation of changes in these densities is limited.

In lieu of examining density, examining grouping patterns infers much about the same relationships. As noted by Adams and Bailey (1980), average group size is a function of many factors, including season, population size

relative to available resources, physiography, vegetation structure. Other factors include population structure, reproductive success, survivorship, winter severity, and continuity of the habitat. Needless to say, it is extremely difficult to attribute differences in patterns of grouping to any one or certain combination of specific factors.

The seasonal group size and annual pattern of grouping of goats in the Snake River Range population was typical of populations that winter at low elevations. The mean group size during summer was slightly larger than those compiled by Adams (1981) for subalpine-wintering goats, and the mean group size during winter fell in the middle of the range of means he compiled. Goats in the Snake River Range appear to fragment into slightly smaller groups during winter, and coalesce into slightly larger groups during summer. Adams and Bailey (1980) theorized that larger group sizes could be expected in recently-introduced populations because of a lack of severe competition. The range of group sizes, percent groups as singles, and percent of goats that were singles also compare most closely with those reported for Colorado goats wintering on subalpine ranges (Adams and Bailey 1980, Adams 1981).

Dispersal

In this study, as found with most other mountain goat populations, immature goats of both sexes and adult billies were less centralized on seasonal ranges than adult females. It was not uncommon to find yearling and 2-year old females associated with adult males during late spring and early summer. This type of association would facilitate the permanent colonization of new locales.

Mountain goats have been observed annually during summer in the Teton Range since 1975, and have recently been observed wintering there (M. Whitfield, pers. commun.). Recently, the composition and timing of the sightings indicate that their presence in the Tetons is becoming less ephemeral in nature. The establishment of a permanent goat population in the Tetons may already have begun. A nanny and kid were observed in Webb Canyon, in the northernmost end of the Tetons during late June 1983 (M. Whitfield, pers. commun.). The Tetons are still well-covered by snow through this period, and it is unlikely that these animals travelled the 57 km length of the range (and a portion of the Snake River Range) in less than 2 weeks--especially in light of the age of the kid. It is not known if this female wintered in Webb Canyon or nearby. Historically, this area has been used by bighorn sheep as a lambing area, but not as a winter range (Whitfield 1983).

During late winter in the Tetons, the high-elevation patches of bighorn winter range become ice-capped forcing sheep onto the cliffs (Whitfield 1983). Thus, although bighorns and mountain goats normally tend to segregate on a physiographic basis, the presence of goats in the Tetons would probably lead to sheep competing with goats for forage and space, and possibly to 2-way competition, because of this critical, late-winter habitat is more typical of that to which the mountain goat has adapted.

CONCLUSIONS AND RECOMMENDATIONS

The Snake River Range population is currently growing extremely rapidly and may be approaching the carrying capacity of the occupied habitat. This rapid growth has been made possible by an abundance of browse on winter ranges, which has received minimal use until the recent past. The distribution of the population infers that the primary habitat of the range has been occupied, and further range expansion will be to areas of much lower quality. It is likely, therefore, that density regulation will begin to play a major role in population dynamics in the near future. As goats disperse into less-optimal habitat, expansion into the Teton Range can be expected--with probable detrimental effects to the bighorn sheep population of that range.

It appears that agressive management of the goat population at this time could mitigate a severe overshooting of the carrying capacity of the Snake River Range. The first hunt on this population was conducted during November 1983 and included 6 permits: 3 in the Palisades Creek drainage and 3 in the Big Elk Creek drainage. For fall 1984, the hunt was expanded to 5 permits in each area. To effectively slow population growth to a rate that would allow the early stabilization of population size, 10 to 13% of the population (currently 15 to 20 goats) should be harvested over the next 2 to 5 years to allow the vegetation to achieve the zootic disclimax that will ultimately determine population characteristics. Harvest need not be concentrated on billies during this period, and, in fact, should include mature females. Intensive aerial and ground trend and composition surveys are necessary each year to evaluate the status of the population during this critical period to allow the evolution of a more conservative management scheme as density regulation commences. This close monitoring is key to a successful management plan.

When future trend and composition analyses infer that density regulation is beginning to play a major role in population dynamics, the harvest should be reduced substantially. The current Idaho standard of a 4 or 5% harvest for mountain goats would be more appropriate at this time. If the harvest were concentrated more on the male segment of the population, a slightly higher harvest would be possible.

Careful monitoring and further study of this population is also recommended for more universal reasons. This population presents a rare opportunity to examine a relatively isolated population at various levels of density regulation. An ecological study by Hayden (unpubl. data) prior to the hunting of this population, and an ongoing behavioral study by Whitfield and Hayden (unpubl. data) provide baseline material for more indepth, longterm studies exploring the concepts of habitat colonization and selection, the role of social behavior, population dynamics, the effectiveness of aggressive management with introduced populations, and other ecological concepts.

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BIGHORN SHEEP OF THE TETON RANGE, WYOMING: ECOLOGY OF A REMNANT POPULATION

Michael B. Whitfield, Palisades Ranger District, Targhee National Forest, Idaho Falls, Idaho 83401.

Barry L. Keller, Department of Biology, Idaho State University, Pocatello, Idaho 83209.

ABSTRACT

Man's activities in the Teton Range since settlement in the late 1800's have drastically altered bighorn sheep (Ovis canadensis canadensis) numbers, distribution, and habitat conditions in the Range. Major historical impacts were domestic livestock grazing and associated diseases, excessive hunting, restriction of winter ranges, curtailment of natural wildfire, and loss of genetic communication with other bighorn populations. Today's Teton Range bighorn population is restricted to two small portions of its former range. On summer ranges, Teton Range sheep select habitat with greater terrain roughness, gentler slopes, and closer proximity to escape terrain than found randomly, or than reported from other studies of bighorns. Teton Range sheep are more generalized foragers than reported from other populations, with shrubs used to a high degree in summer. Bighorns avoid areas of concentrated recreational use. In winter, sheep are isolated on patches of high, windswept tundra. Teton bighorn display many charcteristics associated with low quality, relict populations, and inbreeding is probable. Continued domestic sheep grazing and hunting, increased recreational activity, and potential competition with introduced mountain goats (Oreamnos americanus) may threaten the long-term existence of bighorn sheep in the Teton Range.

INTRODUCTION

Man and wild sheep have coexisted throughout the Rocky Mountains for over 9,000 years (Miller 1972). At the appearance of Euro-Americans in Wyoming and Idaho, bighorn sheep were among the most successful ungulate found (Honess and Frost 1942, Smith 1954). However, settlement in the late 1800's brought about the general decline of wild sheep populations throughout the west (Buechner 1960).

Geist (1971) observed how natural bighorn populations use their habitats through occupation of as many as six seasonal home ranges. However, bighorn use of the habitats available to them varies greatly among localities (Blood 1963, Woolf et al. 1970, Johnson 1980). Remnant populations, such as that of the Tetons, lose portions of their former ranges, with resultant losses in long-term viability (Woodard et al. 1974). Low-quality bighorn populations, which exhibit slow-growing rams (Geist 1971), low survivorship of lambs to yearling age (Buechner 1960), and relatively small group sizes (Leslie 1977), may learn inefficient traditions of habitat use (Geist 1971).

At the initiation of our study in 1976, little was known about the bighorn sheep of the Teton Range. Our objectives were to document a historical perspective of bighorns in the Tetons, to delineate seasonal distributions, and to measure how seasonal distributions are related to selected biotic and abiotic factors.

This study resulted from cooperation among three agencies. The authors acknowledge S. Johnson, Targhee National Forest, G. Roby, Wyoming Game and Fish Department, and W. Barmore, Grand Teton National Park for advice and assistance throughout the study. S. Gregory collected and identified most of the plants. J. Anderson, T. Ore, and J. Baily reviewed the manuscript. The University of Wyoming-National Park Service Research Centre funded winter flights.

STUDY AREA

The Teton Range is in the northwest corner of Wyoming adjacent to the Idaho/Wyoming State boundary. The range is approximately 25 km east-west by 60 km north-south. Elevations vary from 1230-4198 m. The range trends north-south with lands of Targhee National Forest (TNF) on the west slope and Grand Teton National Park (GTNP) on the east slope.

A westerly dipping fault block, the Tetons feature jagged crystalline peaks of Precambrian gneiss and schist at their center. Eroded limestone of Mississipian age is 1,000 feet thick in the north, west, and south of the range. Soils are typically thin, dark loams which rest over weakly-developed, stony subsoils (Nelson 1971). The Teton Mountains are typically warm in summer (27°C maximum) and cold in winter (-45°C minimum), with snow depths commonly in excess of 4 m at elevation 2440 m.

Daubenmire (1978) described a subalpine fir (Abies lasiocarpa)/Engelmann spruce (Picea engelmannii) province above 2450 m on the south and west slopes. A shrub belt, dominated by currants (Ribes spp.), marks the transition between subalpine fir/Engelmann spruce and alpine tundra associations (Daubenmire 1978). Above 3050 m, the alpine tundra zone is vegetated by a diversity of graminoids, forbs, and dwarf willows (Salix spp.) (Spence and Shaw 1981). Potential bighorn competitors include elk (Cervus elaphus), mule deer (Odocoileus hemionus), and introduced mountain goats. Potential predators include coyote (Canis latrans), mountain lion (Felis concolor), grizzly bear (Ursus arctos), and golden eagle (Aquila chrysaetos).

METHODS

PAST POPULATIONS

Journals, letters, and narratives of trappers, topographers, and hunters hinted at presettlement sheep distribution. Information on postsettlement bighorn distribution came from personal interviews with longtime residents of the valleys that surround the Teton Range. This information is supplemented from records filed at Grand Teton National Park, Moose, Wyoming and Targhee National Forest, Ashton and Driggs, Idaho.

PRESENT SEASONAL DISTRIBUTIONS

Seasonal distributions were assessed by ground reconnaissance of the entire range and periodic helicopter and fixed-wing flights along preselected routes. Ground travel routes were planned to allow maximal survey with a 25-40 power spotting scope. Sex and age classification followed Geist (1971).

HABITAT CHARACTERISTICS

In the southern portion of the Range a study area which met generalized habitat criteria (Honesss and Frost 1942, Geist 1971) was divided into 200 x 200 m grids on 7.5-minute topographic maps. We randomly selected 81 intersection points from these grids for habitat analysis samples. At each sample point, we measured elevation with an altimeter, percent slope (general area) with a clinometer, and general aspect as a compass bearing. We estimated the straight line distance to areas subjectively defined as escape terrain. Topographic roughness was expressed as the square root of the summed deviations of four defined slopes from the general slope (T. Ore pers. comm.). The four defined slopes were 50 m to the right and left of the sample point perpendicular to the general slope, and 50 m up slope and 50 m down slope. Possible values ranged from 0 to 180. As an example, a value of 60 could result if the general slope of a canyon wall and the specific right, left, and up slope values were 30°, and a vertical cliff (90°) was located 50 m down slope from that sample point. Soil samples were analyzed for percent of key elements.

Ground cover was sampled on a 50 m transect along the contour in a standardized direction from the sample point. Cover transects were actually completed at 42 of the 81 randomly selected points during summer (1 July - 15 September), although transects were completed at all 81 points in spring (15 June - 1 July). During summer cover transects were completed at 12 additional sites where bighorns were observed in winter. Canopy cover was estimated for all plant species in 20 2 x 5 dm frames placed at regular intervals along the transect, and midpoints were recorded for percent-class intervals (Daubenmire 1959). We recorded cover by litter, bare ground, and rock in the same percent classes. Two 1/10 m^2 biomass plots were clipped from each spring and summer sample transect. Tree cover was measured in 5 x 20 m rectangles which originated at a sample point. Fecal pellets were collected for microhistological analysis to determine food habits (Sparks and Malechek 1968) at Colorado State University. Bighorn fecal pellet groups were counted within a 2 x 50 m belt along each transect line. Observations or evidence of human activity, domestic animals, and wildlife were recorded.

We recorded habitat features at 57 specific sites where bighorns were observed feeding or bedding during the summers of 1976-1983. At these sites, we measured physical features as described above, recorded major plant species, and estimated percent cover by major growth form.

Summer recreational use of the West Slope of the Tetons was characterized through concurrent recreation studies from 1976-1979. Visitor use from late June to mid-September was estimated through randomized trailhead and backcountry route samples. At trailheads we used 12 h samples correlated with infrared traffic counters. In the backcountry, we walked defined routes through destination areas on randomly selected evenings to estimate camper use.

RESULTS AND DISCUSSION

PAST POPULATIONS

Precise estimates of presettlement and early postsettlement bighorn populations in the Tetons are not available. Several journals and 87 old-timer reports point to the early and immediate effect of settlement on Teton Range sheep. Settlement of Teton Valley, Idaho, and Jackson Hole, Wyoming, began in the 1880's, and by 1900 at least 1,000 people lived in Teton Valley (Green 1974). Human activity in the West Slope of the Tetons was more widespread than at any time before or since the settlement era. Small sawmills sprang up in most of the canyon bottoms. Prospectors scoured the mountains and developed mines in Berry Creek, Moran Canyon, Bitch Creek, Death Canyon, Darby Canyon, and Fox Creek, all within or near bighorn habitat. Immense numbers of domestic sheep grazed the entire West Slope and portions of present day GTNP. Trappers and big game hunters were active throughout the Range in all seasons.

Bighorn sheep populations in areas which adjoin the Tetons-the Gros Ventre, Snake River, and Big Hole Mountains-declined or became extinct early in the postsettlement era. These populations had probably exchanged genetic material with Teton Range sheep. Bighorns were effectively eliminated from most low elevation habitat by 1900. Teton Range sheep made sporadic winter use of the Gros Ventre Buttes, lower Rendezvous Mountain, Bitch Creek, and Fox Creek into the 1930's, but were eliminated from these ranges by continued human developments. In the northern West Slope, bighorns were restricted to rugged, inaccessible terrain on the crest of the Range. At the extreme southern end of the Tetons, a notable concentration of bighorns was eliminated by 1960. Clearly, the bighorn sheep habitat available in the Tetons prior to settlement may have supported several times the number of sheep found in the much smaller area occupied today.

The decline of Teton Range bighorns resulted from several factors which may have acted in concert. Chief among these factors were competition from domestic sheep, diseases, excessive hunting, restriction of winter ranges, and curtailment of wildfire.

During the late 1800's and early 1900's, large numbers of domestic sheep grazed throughout the Teton Range. U.S. Forest Service records (Fig. 1) indicate that from 1910 to 1915, over 25,000 permitted sheep grazed the southern half of the Range for nearly 70,000 Animal Unit Months (AUMS) each

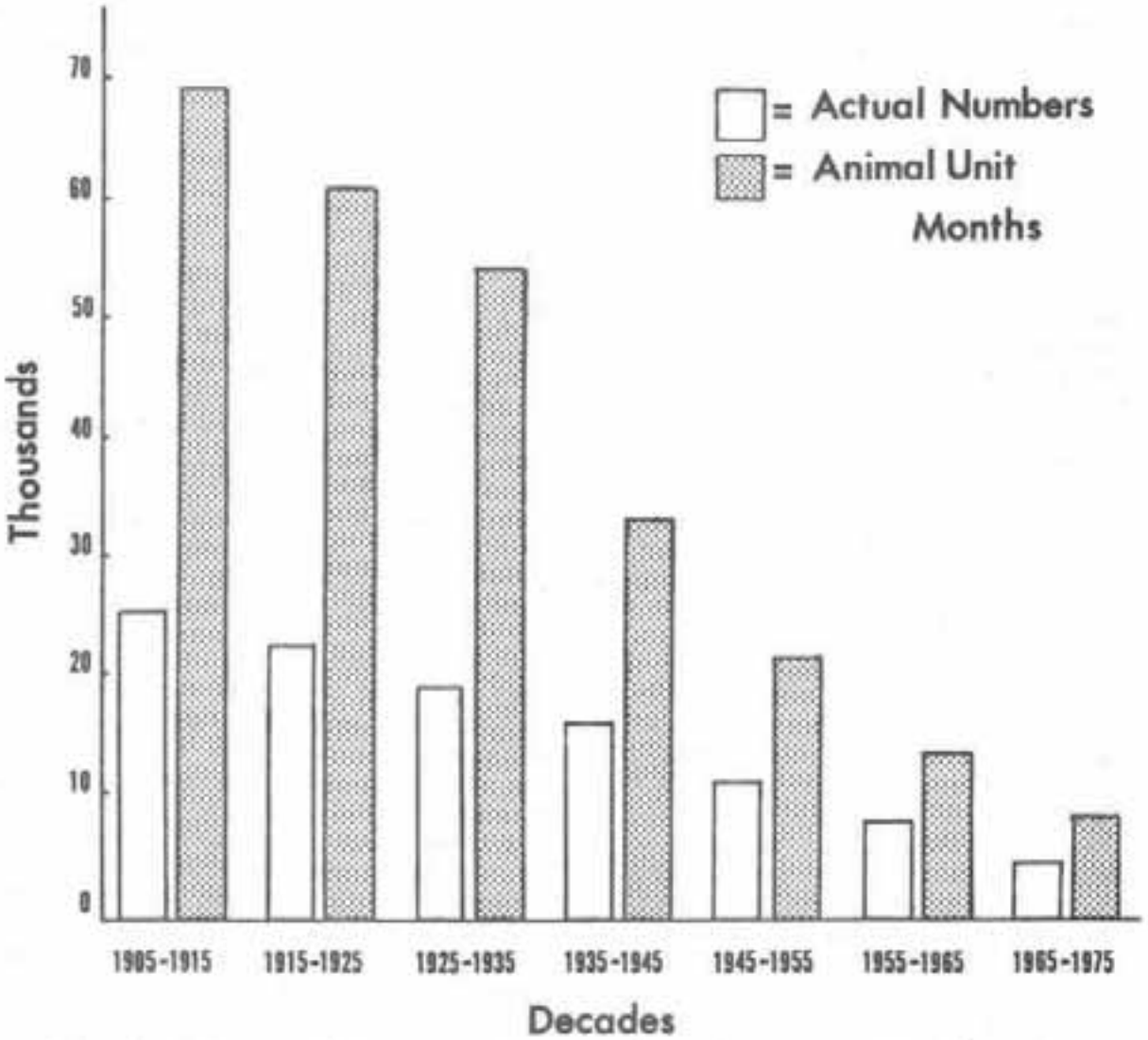

Fig. 1. History of domestic sheep use (actual, not permitted) on the West Slope of the Teton Mountain Range, Bitch Creek to Coal Creek. Use estimates may be inaccurate due to many gaps in the records and changes in allotment boundaries. As nearly as possible, estimates are intended to reflect the average actual use during the decade. In areas where history is lacking, use is assumed to be the same as that indicated for the earliest year in the time period. Years of non-use are considered in averages. For this discussion, one Animal Unit Month (AUM) is equal to one animal month, or one ewe with lamb for one month.

year. Annual use of this same area in recent years is below 5,000 sheep for 9,000 AUMs. During the first two decades of domestic livestock use of the Tetons, 1890-1910, when no records were kept, use probably exceeded the high levels recorded in 1910-1915. In this era of no-control, which preceeded establishment of Targhee National Forest in 1908, herders pushed huge bands of sheep in a season-long race for the choicest grazing areas (E. Winger, pers. comm.). From their homes in Teton Valley, shepherd's families were often able to trace the mountain locations of domestic sheep herds by observation of campfires at night and dust columns during the day (S. A. Stevens, pers. comm.). Forest Service records and herder observation (L. Henrie, pers. comm.), indicate that these domestic herds often grazed in habitats used by bighorns.

In reaction to forage depletion and soil erosion, permitted livestock numbers were gradually decreased (Fig. 1). Despite livestock closures, previously overgrazed slopes in several drainages were subject to severe flooding in the early 1950's (Baird in. litt.). Decades of overgrazing in the Tetons have left numerous scars within former bighorn habitat: extensive areas with thin soil cover, vegetative communities dominated by ruderal species, and erosion channels and pavements. Social intolerance to the large domestic herds, with associated dogs and herders, may have stressed bighorn sheep psychologically. Today's bighorn population is distinctly limited to rough, high elevation terrain along the crest of the Range and peaks in GTNP. The southern Tetons, which were notably overgrazed into the 1950's, are no longer inhabited by bighorn sheep.

A die-off of thousands of bighorn sheep from scabies occurred throughout the western United States between 1870 and 1890 (Buechner 1960). No conclusive proof has been presented to determine if bighorns died from contact with the scab mite of domestic sheep or a similar mite endemic to wild sheep. Scabies in mountain sheep in the 1880's was reported from every section of Wyoming (Honess and Frost 1942).

Post (1971) indicated that a major factor in the decline of bighorn populations has been lung diseases. He suggested that pneumonia may have been involved in the extensive die-offs attributed to scabies. The pneumonia complex, which consists of several bacterial species, usually associated with lung nematodes of the genus Protostrongylus, was implicated as the prime morality factor in bighorn die-offs since 1900. Unnaturally high lungworm infections, which may have led to death of bighorns, occurred when sheep wintered and summered in the same area (Spraker 1974) or were pushed onto winter range early by human disturbance (Wishart et al. 1980). Such unnatural use of winter ranges may make sheep more subject to infection when snail activity at concentration sites is high (Wishart et al. 1980). Teton Range bighorns have long been forced to summer and winter in the same high elevation habitat. Such year-around use of the same range may be a particularly significant factor in late-winter lamb mortality in Colorado (Spraker 1974).

Sheep herders occasionally observed wild bighorn rams mixed with their domestic herds (L. Henrie and W. Christensen, pers. comm.). Thus, the avenue for disease spread, from domestic sheep to wild sheep, existed. Although no record of major bighorn die-offs in the Tetons was found, W. Stone (pers. comm.) observed the remains of many bighorns south of Rendezvous Mountain in the early 1940's. He did not determine the cause of death.

Excessive, unregulated hunting of bighorn sheep for meat and horns was a major factor in the decline of bighorn sheep in many of their former ranges (Buechner 1960, John 1975, Tsukamoto 1975, Hickey 1978). Buechner (1960) credited persistent hunting of populations already decimated by disease with continued decreases in sheep numbers. Early hunting of sheep in the Tetons and adjacent ranges removed relatively few sheep from the presettlement populations. A thorough review of the journals of explorers, trappers, and hunters revealed few encounters with wild sheep presettlement (Whitfield 1983). The more important effect of the arrival of the Euro-American era may have been the elimination of bighorn migration routes which crossed major human travel-ways. Opportunistic hunting along these travel-ways may have curtailed genetic communication with other bighorn populations. Poaching may have been a more direct threat in the 1930 to 1970 era, after Teton Range bighorns were reduced to a small, remnant population (A. Murie in. litt.).

Teton Range bighorns once migrated seasonally to lowland winter ranges (Whitfield 1983). Human encroachment upon winter ranges, and developments which blocked migration routes, gradually eliminated bighorn use of almost all the lower elevation habitats. At low and midslope elevations, the exclusion of wildfire in the Tetons over the past 80 years has allowed conifer invasion of seral forb and grass communities which were maintained in presettlement days by frequent wildfires (Whitfield 1983).

PRESENT SEASONAL DISTRIBUTIONS

Some 1279 observations of bighorn sheep were recorded in the Teton Range from 1969 to 1981. Twenty-eight study flights and 228 days of field effort were used to learn seasonal movements. We found most sheep in two population centers; one in the northern end of the range, and a second on the south-central portion of the range. Geist (1971) noted separate seasonal ranges for ram and ewe groups. Bighorn groups in the Tetons were significantly segregated by sex in spring and summer ($p \leq 0.05$, X^2test). Sheep were generally found at or near treeline in all seasons but spring, when many bighorn descend to lower elevations. Values for the mean observed elevation throughout the entire year were 2992 m (+ 395 m, 95% C.L.) for ewe groups, and 3025 m (+ 343 m, 95% C.L.) for ram groups. These means were not significantly different ($p > 0.05$, Group Comparison t).

Whereas study efforts in spring were limited, some range-use patterns were evident. By early April, hard snow allowed bighorns to scatter widely throughout the Teton Range. Although some sheep, predominantly rams, remained on high elevation winter ranges, many spring observations were at elevations below 2600 m, where green-up begins. Several unusual observations of bighorns in forested areas at low elevations 6-12 km from recognized habitat in the northern Tetons suggest more widespread use of low elevations than we detected. Bighorns were also found in lower elevation granitic areas at the center of the range where few sheep were seen in other seasons. Lambing ranges were in steep, rugged limestone cliffs on the lower south exposures of three major drainages.

Spring-like conditions lingered into July, with extensive snow cover above 2700 m. Bighorns at higher elevations focused upon southerly exposures, where plant growth progressed rapidly. In early summer sheep were often seen on green benches and around lake basins frequented by backpackers. These sheep shifted

to more remote areas as recreation use peaked in late July and August. Although ewe groups remained in rugged terrain near the major crest trail, ram groups predominated in areas little used by recreationists.

In late July and August, sheep shifted to east and north exposures. Throughout the Range in August and September most sheep were observed near Krummholz at about 3050 m elevation. Heavy frosts occurred in early September. We observed equal use of north and south exposures in early September, but in later fall, sheep strongly favored eastern and southern exposures. Large, sexually-mixed groups became prominent by late September, a reversal from the pronounced spatial segregation of ewe and ram groups in summer. This mixing of sex and age classes preceded the rut by two months. Lasting snow fell in the Tetons by late September.

We recorded no observations of Teton Range bighorns on historic low-elevation winter ranges. All observations from mid-November to mid-March were on isolated patches of windswept alpine tundra or snow-free Krummholz ridges above 2800 m elevation. Sheep generally restricted themselves to small snow-free areas with southern aspects. These areas were often over 300 m from escape terrain. Sheep dispersed more widely over high ridges or into adjacent cliffs during the heavy, wet snowfalls of late winter. Winter observations were at an average elevation of 3034 m. Mixed groups were frequently seen.

POPULATION CHARACTERISTICS

The population dynamics of Teton Range bighorns were inferred primarily from five key flights or series of flights between 1969 and 1981 when 42 to 75 sheep were observed per flight (Table 1). We also attempted to assess all summer observations with probable duplictions eliminated, although this information is less reliable. Observations from the May-June lambing period and the November-December rut were not included because of probable bias in the observabilities of sex- and age-cohorts.

Caughley (1974) cautioned against the casual interpretation of age ratio data to determine population dynamics in the absence of information on population rate of increase. Buechner (1960) added the further complication of separating yearlings and two-year-old females from reproductive ewes (three years plus), particularly when observed from aircraft. Two-year-old females were difficult to differentiate from older ewes. Corrected ratios (Table 1) assume that 23% of classified ewes were actually non-breeding two-year-old females, and that all lambs, yearlings, and two-year-old males were accurately classified (Buechner 1960). Use of the reported observation data to develop sex- and age-ratios further assumes no bias in observability of individual cohorts.

Actual lamb:ewe ratios lay somewhere between observed and calculated values. If it is accurate to assume that there were equal numbers of two-year-old females and two-year-old males in the population, our ram classifications suggest that two-year-old females made up only 7-11 percent of classified ewes. Total summer observation ratios, as adjusted to avoid duplication, yielded a range of lamb:ewe ratios from 0.29-0.85. These ratios suggest sometimes poor, but generally high lamb production. Some years of poor lamb production would be expected from sheep that live in the harsh winter and spring environment of the Tetons. The fall, 1980 flight (24-25, Sept.) showed

Table 1 Sex/age ratios from unduplicated bighorn sheep observations in the Teton Mountain Range, Wyoming, 1969-1981.

Date	Observed[a] Lamb to Ewe Ratio	Calculated[b] Lamb to Ewe Ratio	Observed[a] Yearling to Ewe Ratio	Calculated[b] Yearling to Ewe Ratio	Observed[a] Ram to Ewe Ratio	Calculated[c] Ram to Ewe Ratio
July, 1969	0.85	1.10	0.00	0.01	0.85	0.85
Jan.-March, 1976	0.57	0.74	0.00	0.01	0.74	0.74
Summer, 1976	0.67	0.87	0.25	0.32	1.42	1.42
Summer, 1977	0.29	0.38	0.00	0.01	1.13	1.13
Summer, 1978	0.53	0.69	0.13	0.17	0.47	0.47
Jan., 1979	0.40	0.52	0.12	0.16	0.56	0.56
Summer, 1979	0.50	0.65	0.05	0.06	0.70	0.70
Sept., 1980	0.69	0.90	0.00	0.01	1.08	1.08
March, 1981	0.44	0.57	0.00	0.01	0.48	0.48

[a] Observed ratios derived from observations shown in Whitfield (1983).

[b] Calculated lamb-to-ewe ratios and yearling-to-ewe ratios assume that breeding ewe numbers equal classified ewes minus 23 percent for two-year-old ewes (Buechner 1960).

[c] Ram-to-ewe ratios assume that equal numbers of nonbreeding animals were classified with each sexual cohort.

little to no decline in lamb:ewe ratios from the average summer observations from other years. The late winter flights pointed to a loss of 13-25 percent of summer lamb crops.

Lamb:ewe ratios may provide little insight into actual rates of population increase, but merely indicate a rate or productivity (Buechner 1960). In the Teton Range, extremely high lamb mortality apparently occurred in late winter and early spring. Few yearlings were observed, and high lamb:ewe ratios indicated that few yearlings were misclassified in ewe groups. Ram age class ratios also suggested poor lamb to yearling survival. Yearling:ewe ratios averaged about 0.10 in our observations.

Ram:ewe ratios approached or exceeded 1 in most Teton Range surveys. An even ram:ewe ratio is expected in a non-hunted population, or in a population where all age classes are hunted equally. Between the January, 1976 and January, 1979 flights, five 3/4 curl rams were removed from the population by legal hunting (G. Roby pers. comm.). Two more 3/4 curl rams were taken before the March, 1981 flight. A decline in winter ram:ewe ratios of 26% between January, 1976 and March, 1981 suggested minor ram mortality apart from hunting. We found relatively few bighorn remains despite considerable time in bighorn habitats. This low mortality rate among bighorns over yearling age fits well with models of stable or slowly declining populations (Geist 1971). K. Becker (pers. comm.) found many bighorn remains in the habitat of a high quality population.

Brody (1945, as cited by Geist 1971) first discovered the inverse relationship between growth rate and life expectancy as an indicator of population quality. A low-quality bighorn population associated with a stable or declining population size, should have rams with relatively small bodies, slow horn growth, late sexual maturity, little social activity, and long lives (Geist 1971). Lambs in a low quality population should have relatively low survivability to yearling age (Buechner 1960). Low quality populations result from relatively poor forage availability (Geist 1971). Groups sizes in areas of poor forage quality should be relatively small (Morgan 1970, Leslie 1977).

Teton Range bighorns exhibited many of the characteristics of a low quality population. Harvested Teton Range rams had relatively tighter horn curls, smaller horns, and more stress rings in all age classes than did rams from other Wyoming populations (G. Roby pers. comm.). Several 11-year-old rams were barely 3/4 curls when harvested. The population turnover rate appeared to be low. We saw little of the lamb play behavior described from other populations (Geist 1971), and lamb mortality late in the first winter of life was high. Average group sizes (4.6 overall) were smaller than observed for most Rocky Mountain bighorn populations (Skiba 1981).

HABITAT RELATIONSHIPS

In 1978-1979, we recorded bighorn use at 42 randomly selected points during summer as a use index based upon evidence of use and actual observations. Extensive use by sheep occurred at only seven of the summer sites, not enough to characterize bighorn preferences. We returned to the Tetons in August, 1983, to record habitat features at 57 sites where we had recorded bighorn observations during the summers of 1976-1983.

The areas from which we randomly selected sample points were defined, in general terms, by literature descriptions of bighorn habitat. However, comparisons of habitat features at these randomly selected sites with features at sites where bighorns were observed revealed that the sheep were selective (Table 2). Bighorns chose rougher terrain, gentler slopes, and greater proximity to escape terrain than found randomly ($p \leq 0.05$). There were not significant differences in shrub and herbaceous plant cover (Table 2). Several random samples fell within forested areas. Although Teton Range bighorns frequented scattered Krummholz at the edges of forested areas, we never saw bighorns or their sign within dense tree cover.

Bighorn sheep were rarely seen beyond 75 m from escape terrain. Feeding sites averaged 61 m from escape terrain, whereas bedding sites averaged only 7 m from escape terrain, a significant difference ($p \leq 0.05$, Group Comparison t). On several occasions, we saw bighorns feed in open areas about 60 m from escape terrain, but then move to cliff edges or rough ridge crests to bed. Exceptions to this general observation occurred on several high elevation plateaus, where sheep often bedded in the same areas where they fed. These areas were rarely visited by humans. Bighorns did some feeding at most bed sites, and at some sites, the predominant use was difficult to determine.

Topographic roughness values averaged 24 for feeding sites, and 42.24 for bedding sites, again a significant difference ($p \leq 0.05$, Group Comparison t). Mean percent slope values were similar for feeding and bedding sites, 31 and 27 respectively. Sheep often fed in relatively flat meadows and bedded on relatively flat ridge tops at cliff edges, but these sites were usually near to escape terrain on slopes of greater steepness than found at the specific observation sites. Feeding areas were significantly better vegetated than were bedding areas ($p \leq 0.05$), particularly for forbs, with a mean percent canopy cover of 29 on feeding sites and 12 on bedding sites. Lush meadows near escape terrain were heavily used.

Food habit analysis by the microhistological technique was completed on 19 fecal samples. We collected fresh pellet groups from 13 summer areas, 5 from known, classified sheep, between 30 June and 30 August. Six pellet groups were collected from winter ranges. The analysis reported summer diets of 23 percent graminoids, 13 percent forbs, and 64 percent shrubs and trees. Winter diets consisted of 29 percent graminoids, 32 percent forbs, and 38 percent shrubs and trees. Johnson (1980) noted that forbs were underestimated by approximately 20 percent in microhistological analysis when compared with direct feeding observations of tame bighorns. Johnson (pers. comm.) was concerned that important forbs eaten early in development, before cell walls were well lignified, would be easily missed by the fecal analysis technique. The Teton Range results certainly raised this concern, particularly when compared with direct feeding observations of five of the bighorns from which summer pellet samples came. Teton Range sheep were often seen feeding voraciously in forb communities. These communities were notably diverse, with 163 forb species identified in vegetation samples.

The Tetons support an extensive shrub belt at about 3050 m elevation, particularly in association with broken cliffs, and dense stands of dwarf *Salix* at higher elevations. Johnson (pers. comm.) reported a depauperate shrub belt in subalpine areas he sampled in New Mexico, where sheep strongly favored forbs. Teton Range sheep appeared to eat a wide variety of plant species in

Table 2. Comparison of habitat features at randomly selected sites with sites where bighorn were observed during summer in the Teton Mountain Range, Wyoming, 1976-1983.

Habitat Feature	Random Summer Samples $\bar{X}^a$	Observation Site Samples $\bar{X}^b$	Test Result[c]
Graminoids (% Canopy Cover)	8.9	8.6	t = 0.09; n.s.
Forbs (% Canopy Cover)	25.3	18.5	t = 1.51; n.s.
Shrubs (% Canopy Cover)	5.6	7.6	t = 1.02; n.s.
Percent Slope	51.9	31.4	t = 4.72; ($p \leq 0.05$)
Topographic Roughness Index	16.7	32.1	t = -4.23; ($p \leq 0.05$)
Distance to Escape Terrain (m)	76	36	t = 2.84; ($p \leq 0.05$)

[a] This sample set includes only randomly selected summer samples. Winter range samples are excluded because their selection was based upon bighorn use. Therefore, n = 42.

[b] This sample set includes measurements from n = 57 specific sites where bighorn were observed during summer.

[c] Mean values of habitat features from randomly selected sample points and bighorn observation sites were evaluated with the two-tailed t test for group comparisons (Zar 1974).

H_o: $\bar{X}$ from random summer samples = $\bar{X}$ from observation site samples for each habitat feature.

$t_{0.05(2),97} = 1.985$ n.s. = not significant ($p > 0.05$)

summer, including many shrubs, in contrast to the usual characterization of bighorns as selective grazers. These differences may be due to the relatively rich forb and brush flora of the Tetons, and to preferential use of habitats wherein shrubs are dominant, but appear to be amplified by inherent errors in the fecal analysis technique.

Shannon et al. (1975), through simple and partial correlation analysis of 11 environmental variables, found that vegetation accounted for a large proportion of the variance associated with bighorn distribution in British Columbia. However, in a review of literature on a wide range of animal communities, Schoener (1974) noted that resources are most frequently partitioned through spatial separation on the habitat dimension. Food specialization is less commonly the major mode of dividing resources, particularly for large herbivores. In association with elk, deer, and other ungulates, bighorns were spatially separated from other species through a preference for the more rocky, inaccessible terrain (Hudson et al. 1976, Barmore 1981).

Bighorns from low-quality populations (Stewart 1975, Kopec 1981, Whitfield 1983) appeared to be more closely tied to escape terrain than were sheep from high-quality populations (Frisina 1974, Stewart 1975, Tilton 1977). Low-quality populations result from relatively poor forage availability (Geist 1971) or lack of genetic diversity (Skiba and Schmidt 1982). Learned traditions of restricted habitat use may contribute to poor nutrition (Geist 1971).

We suggest that loss of traditional migration routes and low elevation winter ranges due to human encroachment, habitat degradation due to overgrazing and wildfire suppression, and avoidance of opportunistic poachers and large domestic sheep bands, have taught Teton Range bighorns to remain strictly tied to remote, vegetatively poor terrain. This tradition of habitat use is inefficient in the present era, when most of the historical conflicts no longer exist. Direct evidences for inefficient habitat use are an unusually strong tie to topographically rough escape terrain, and a high level of browse consumption in summer.

REACTIONS TO HUMANS

Man is not inherently an unpleasant stimulus to bighorn sheep. Bighorn from totally unhunted populations may habituate to people to the point of ignoring human presence, or even seeking it (Geist 1975). However, if hunted to even a light degree, rams soon learn to avoid humans (Horejsi 1976). Thorne et al. (1978) noted that rams of the Whiskey Mountain, Wyoming bighorn populations actively avoided people, except during the rut and spring green-up, and were rarely seen in summer. Rams abandoned optimal summer and winter ranges to avoid human contacts (Thorne et al. 1978), although ewe groups reacted much less negatively to humans.

Passive human disturbance may prevent bighorn sheep from exploiting their entire habitat potential, may cause increased energy expenditures, and may lead to increased predation (Horejsi 1976). Activity patterns and distribution on occupied ranges may be altered, and parts of ranges abandoned by bighorns when human use of an area is high (Horejsi 1976).

In the Tetons, areas of high and low recreation use were interspersed. Bighorn sheep significantly avoided high-use areas ($p < 0.05$, Group Comparison t). The sheep were seen within several high-use areas in early summer, but most of these animals moved to more remote areas as recreation use increased in mid-summer.

Since 1976, when hunting was first permitted in the Tetons, the number of ram observations steadily declined, particularly class III and IV rams. These large rams made up 24 percent of the classified observations in summer, 1976. They were easily observed, and we often approached them to within 50 m. By 1978 and 1979, large rams made up only 6 percent of the classified summer observations. Flight distance, the distance from an approaching observer which causes flight in animals (Altmann 1958), increased dramatically. Our appearance in isolated canyons caused displacements of large rams at flight distances up to 2 km.

MANAGEMENT IMPLICATIONS

Survey flights and field observations appear to show a decline in the Teton Range bighorn population from 1976 to 1981. Although this survey information is inconclusive, yearling:reproductive ewe ratios are cause for concern. Simmons et al. (1984) suggest that yearling recruitment rates below 14.8% indicate a declining population. Our observed yearling ratios indicate a need for careful monitoring of yearling recruitment, and of those factors which contribute to it.

Since 1977, exotic mountain goats from an introduced population in the Snake River Range to the south of the Tetons have been sporadically reported throughout the Range (Whitfield 1983). Although mountain goats are not yet established in the Teton Range, there is strong potential for growth of a Teton Range population (J. Hayden pers. comm.). We fear that mountain goats and bighorn sheep may compete for the limited habitat available in the Tetons, to the ultimate disadvantage of the native sheep. Particularly severe competition could develop on the high elevation winter ranges. Mountain goat/bighorn sheep interactions in the Tetons deserve careful monitoring.

Teton Range bighorns are members of a low quality, relict population. However, the genetics which allow them to persist in the most difficult of habitat conditions make this population particularly valuable. We conclude that their continued survival in the Range depends upon decisive management efforts to conserve and expand their occupied habitat, and enhance their genetic base. We recommend specific controls of recreational activity, including hunting, cessation of domestic grazing in several important areas, prescribed burning to reduce conifer and brush cover, and possibly reintroduction of genetically vigorous sheep into abandoned, historical habitats (Whitfield 1983).

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SUMMER DISTRIBUTION AND ABUNDANCE OF MOUNTAIN GOATS IN MT. RAINIER NATIONAL PARK, WASHINGTON

Joanne Michalovic, National Park Service, P.O. Box 25287, Denver, Co. 80225.

ABSTRACT

During the summer of 1983, a study to determine the summer distribution and abundance of mountain goats in Mt. Rainier National Park, Washington, was undertaken. This was the first comprehensive attempt at quantifying goat numbers and locations parkwide. A systematic methodology was formulated which could be used by the park in future years to monitor population trends, and which would make subsequent data comparable to the present study.

Field methods used to gather data included three fixed-wing aerial surveys and nine systematic ground surveys, by all or some of the same four project participants. Support material was provided from random sightings reported on goat observation cards by backcountry rangers, and from historical data obtained from the park archives.

Since no animals were marked or collared during the study, it was necessary to obtain the best reliable data by minimizing counting error and duplicate sightings. Subpopulation units of mountain goats were determined by delineating and mapping areas of distribution and use obtained from the aerial and ground surveys, and comparing various characteristics of each unit to known information on goats reported in the literature, in relation to their environment and to each other. Based on the analysis, there were six subpopulation units of mountain goats in Mt. Rainier, National Park during the summer months, occupying about 314 square kilometers from roughly 1280 meters to 2280 meters in elevation. Each unit was inclusive of one or more nursery groups which appears to occupy central, apparently optimal home range, and was assumed to have limited association with similar groups in other units; associated male bands occupied what was assumed to be peripheral habitat in the unit, and may have had some limited contact with other units through wandering and dispersal.

The estimated population of mountain goats in the park was 374 to 500 individuals. An air to ground survey accuracy ratio of 69 percent to 92 percent was formulated from the ground and aerial surveys, and applied to the maximum aerial count in each subpopulation unit to obtain the indexed population range. Since it was assumed only a limited amount of intermingling occurred between units, duplication was equally assumed to have occurred only to a minimum extent.

Parkview mountain goat densities were 1.8 to 2.4 goats per square kilometer. Kid to older goat ratios ranged from 16:100 to 20:100.

No conclusive statements were made concerning population condition and trend. One year's worth of data that relies on unmarked animals is not sufficient evidence to substantiate conclusions regarding herd status,

fitness, or productivity. Data from other published studies were presented for illustrative purposes only, and may not be comparable to results in Mt. Rainier until further investigations refine more precisely the environmental and physiological parameters operating to influence populations within the park.

The study will continue during the summer of 1984 to obtain a second year's worth of data. In addition, fecal pellet analysis, including tests for parasites, nitrogen, and DAPA, are planned for the different subpopulation units. Coupled with abundance and density determinations, the investigations may provide additional, although generalized, insight into the relative quality of goat condition in the park, and will assist the National Park Service to priorize and determine the need for further research.

INTRODUCTION

Prior to the present study, there were limited attempts to quantify mountain goat (Oreamnos americanus) numbers and locations in Mt. Rainier National Park, Washington. Most of the early information about the native populations consisted of generalized statements, based on informal and periodic field sightings by park rangers on patrol. Other information on spring and fall migrations, winter range areas, rutting areas, kidding areas, winter survival rates and herd health and productivity was extremely limited, if not non-existent.

In 1964 and 1965, Johnson conducted what was then the most complete reconnaissance of mountain goats in Mt. Rainer National Park. He selected two areas for concentrated observations: one area in the eastern half of the park and one in the western half. Methods and procedures for censusing these two areas were of sufficient detail for repeatability, however, no quantitative method to systematically determine if observed goats were part of larger groups was established. For example, if one were to go into one of these areas today and not see any goats, it may not mean that the population has declined. It may just be that the animals were occupying a different part of their range. Johnson noted that "whole herds have disappeared from some areas under study and have remained absent for months at a time". This illustrated the disadvantages of censusing one particular location, rather than attempting to establish the geographical extent of an entire assemblage of goats.

There has been no one systematic methodology formulated for censusing mountain goat populations that is applicable to all circumstances. When studying goat populations, investigators frequently employ the use of radio collars, ear tags, or some form of marking. This is especially useful in monitoring movement, home range, or dispersal, with the assurance that one is tracking the same individuals over extended periods of time. Marking animals can also be used in a mark recapture program to obtain population estimates by finding a ratio of marked to unmarked goats during surveys, and applying various mathematical models for calculation.

Other researchers forego the use of collars or ear tags in surveying populations. Surveys which do not involve the use of marked animals are spoken of in vague generalities in the literature, and techniques employed are

not definite. Any attempt to duplicate these surveys or to try and retrieve a systematic methodology for use as a guide elsewhere would be a hard task.

McCrory and Blood (1977) conducted mountain goat surveys in Yoho National Park in Canada. They said their field methods made use of systematic surveys with care being taken not to allow overlap of counts. In 1961, the Washington State Department of Game conducted a statewide mountain goat survey primarily making use of ground counts. Johnson (1983) speaks of observers hiking through goat habitat, making counts, and estimating population numbers. Wright (1977) in his reconnaissance surveys into the Mt. Baler-Snoqualmie National Forest in Washington stated he made three to six backpack trips into summer goat range.

The objectives of the present study were to obtain previously non-existent baseline data on mountain goat distribution and abundance within the park by establishing systematic and repeatable methodology that could be employed by minimally trained park personnel. In this way, future population trends could be periodically monitored.

The use of radio collars or marked animals were not employed during the present study. Primary reasons centered around a lack of lead time for proper planning, lack of available funding, and lack of personnel that could devote substantial amounts of time to the project to justify the purchase and use of equipment.

National Park Service resource managers rarely have the luxury of implementing a pure research proposal when there are no apparent resource problems. Investigations which do get extensive funding are usually justified upon the extent to which results can directly aid management in decision making, or in helping to solve a crisis situation. However, a catch 22 exists in that we frequently cannot detect subtle deteriorations in the resource without first having the baseline data and continual monitoring, but we cannot have the data collection and monitoring until the crisis arises. I felt that what was most important, was to obtain as much reliable information as possible to expand the park's knowledge of its mountain goat population, given the constraints of time, funding, personnel, and lack of equipment.

Recognizing the limitations of a census without marked animals, I attempted to design a systematic methodology that would produce minimal duplication of counts. While not producing data that could be statistically tested to prove or disprove assumptions, it gives the park preliminary information upon which further investigations can be built and justified. All assumptions and limitations were clearly stated; if and when more detailed future research takes place, results can be further refined.

I wish to extend my deepest appreciation and respect to Bob Dunnagan, Assistant Superintendent of Natural Resource Planning at Mt. Rainier, who gave me the support, encouragement, and freedom to pursue the accomplishments of this and other studies. Cathy and Bill Franks and Tom Carrells spent immeasurable amounts of time in the office, in the field and in the air preparing for and carrying out the study. Their devotion, insight, and encouragement provided the impetus for much of the work accomplished. The

rangers and staff of Mt. Rainier, whose enthusiasm for resource management was made obvious during the summer, provided invaluable support material by dutifully and consistently filling out goat observation cards. I want to thank the numerous friends and associates who took the time to review my work and provide guidance and constructive criticism in refinement of my analysis, particularly Dale Reed, Torey Stevens, Murray Johnson, Ray Scharpf, Dick Taber, and Ed Schreiner. And finally, thanks to Bill Briggle, who brought me to Mt. Rainier in the first place.

THE STUDY AREA

Mt. Rainer National Park is located in south-central Washington on the western slopes of the Cascade Range. The park itself occupies roughly 98,600 hectares. Elevation ranges from 4,367 meters at the top of Mt. Rainer to a low of 488 meters in the Ohanapecosh Valley. The mountain supports approximately 48 active glaciers covering an area of about 9,800 hectares. The general topography could be described as extremely rugged with precipitous peaks and ridges centrally radiating from the mountain, dropping away to deep, U-shaped, and heavily forested valleys (Bradley 1982).

Annual precipitation is exceptionally heavy, ranging from 1.5 meters at the lowest elevation to over 2.5 meters at higher elevations. Approximately 90 percent of the total precipitation falls between November and April. At the higher elevations in the park, most of the winter precipitation accumulates as snow. The snowpack commonly reaches depths in excess of seven meters (Bradley 1982).

Air temperatures average -1 to -4°C in January. Summers are comparatively cool, with July averages of 10 to 15°C (Bradley 1982). The indicated low and high temperatures were from weather stations at 837 meters elevations and 1682 meters elevation, respectively.

Large expanses of subalpine and alpine meadows surround the mountain. The area comprises physiographic habitat requirements of mountain goats described by Chadwick (1977, 1983), Kuck (1977), Smith (1977), Bailey and Johnson (1977) and others, including steep cliffs, open meadows, permanent snowfields and ridgetops. The subalpine and alpine areas give way to permanent ice and snow at its upper reaches, and to dense old-growth coniferous forests at the lower elevations.

The subalpine meadow zone, including open subalpine woods, occurs from approximately 1,520 and 2,130 meters elevation, and comprises roughly 10,000 hectares. Vegetation in this zone has been extensively described by Henderson (1974). She identified 5 distinct vegetative types: heath-shrub, lush herbaceous, wet sedge, low herbaceous, and dry grass. Conspicuous shrubs within this zone include Phyllodoce empetriformis, Cassiope mertensiana, Vaccinium deliciosum, and Phlox diffusa. Common herbaceous plants are Valeriana sitchensis, Lupinus latifolius, Veratrum viride, Polygonum bistortoides, Aster ledophyllus, A. alpigenus, Ligusticum grayi, Castilleja parviflora, Anemoneoccidentalis, Potentilla flabellifolia, Arnica latifolia, and Antennaria lanata. The most common grass is Festuca viridula, and the most

common sedges are Carex spectabilis and C. nigricans (Bradley 1982). Tsuga mertensiana is interspersed with meadow vegetation in parkland areas.

Alpine flora grows from approximately 2,130 to 3,350 meters elevation and comprises an area roughly 6,200 hectares. Edwards (1980) described 2 main alpine community types on Mt. Rainier: heather meadows and fellfields. Of 117 species found in this zone, only 26 grow above 2,440 meters; 29 species are on the Washington state rare and endangered plant list. Many endemics may be locally abundant, but found nowhere else on earth. Subalpine species may also grow in the alpine. Species with the widest distribution around the mountain within the alpine include Draba aureola, Polemonium elegans, Tauchia stricklandii, Juniperus communis, Smelowskia ovalis, Saxifraga tolemeii, Phyllodoce glanduliflora, Carex phaeocephala, Spraguea umbellata, Lupinus lepidus, Phlox diffusa, Penstemon davidsonii, and Aster alpigenus.

From June through September 1983, approximately 6,224 visitors camped in subalpine meadow area of the park. About 4,317 additional mountain climbers, during the same period, camped in the alpine areas and higher.

METHODS

COLLECTION OF DATA

Historical Data

The park files, records, and archives contained much historical information on mountain goats which was retrieved and complied for limited use in the present study. The information was not used in determing present numbers and distribution, but only as corroborating evidence to support or reject assumptions. Historical park data was acquired from three primary sources:

1) Park wildlife observations cards documented goat sightings by park personnel and visitors from 1905 to the present. The cards are used to register all animal sightings as a part of the park's natural history records.

2) A search was made of the park archives to retrieve all historical information on mountain goat populations. Wildlife census reports (1926 - 1951), annual wildlife reports (1926 - 1976), annual superintendent's reports (1904 to 1966) showed population estimates that were based upon informal and insufficient field censusing procedures, and must not be regarded as dependable data (John Ritter, Superintendent, Mt. Rainier National Park 1966). During the war years, no information on wildlife was included in any reports.

3) From 1972 to the present, park personnel made summer aerial flights to census elk populations. Goat numbers and locations were recorded, along with other wildlife observations.

Aerial Surveys

Three aerial surveys were conducted to assess goat numbers and locations parkwide: two in mid-June and one in mid-September, 1983. Each flight had 4 observers, including the pilot. Scheduling was on a standby basis. Flights were made when the weather was clear, when the pilot had no other obligations, and when observers were not in the field or had no additional park responsibilities. Time allocated for each trip, based on available funding, was three hours. Census techniques were systematic, not random. All counts covering potential goat habitat consisted of systematically circumnavigating Mt. Rainier by flying up one side and down the other side of ridges which centrally radiate from the mountain. The elevation range covered was about 1,370 meters to 3,100 meters. Side trips to independent mountain ranges included the Tatoosh Range, Mt. Wow, Shriner Peak, and the Mother Mountains. Surveys here followed treeline at aproximately 1,676 meters elevation. Due to the limited flying time, the Crystal Mountains along the eastern boundary of the park were not surveyed.

During each flight, goat numbers and locations were recorded on a portable hand-held cassette player. No attempt was made to classify sex or age from the air. Following each flight, the information was transcribed to a U.S. Geological Survey 15 minute topographic map of Mt. Rainier.

Systematic Ground Surveys

Nine ground surveys were made into Mt. Rainier's backcountry by all or some of the same four observers, from June through August, 1983. Trip locations were based on areas of known goat habitation taken from Murray (1964 and 1965), from previous park wildlife observation cards, and from goat sightings retrieved from past elk census flights. Other factors influencing location selection were accessibility, ease of cross country travel, visibility in terms of amount of land area not obscured by trees or topographic features, and time availability of observers based on other park responsibilities.

Observations were made with a 20x and 48x power spotting scope, a 9x35 binoculars, 7 to 12x35 power binoculars, and 7x26 power binoculars. Because mountain goats are only sightly sexually dimorphic, classification is difficult at best, even to the trained observer, therefore animals were classified as either kids or older goats. Yearlings were only classified sporadically and therefore were not included in any data analysis. Nursery groups were distinguished from male bands based on the presence of kids, and certain behavioral and morphological characteristics of group members, including urination posture, stage of molt, and group size and composition. Horns were usually not used to differentiate between the sexes because the subtle differences were not always discernible at great distances. Identification was based on Nichols' (1980) summary of useful criteria for distinguishing age and sex of mountain goats during the summer.

No animals were marked or collared during the study. This had the potential to increase counting error due to movement within and between areas, causing duplicate sightings. In an effort to obtain the best reliable data within the constraints of limited time and funding, the following strategy was

employed for ground counts. During any one particular trip, the observers would individually, or in pairs, spread themselves over considerable distance throughout the area being surveyed, while keeping in radio communication. The number of goats that could positively be ascertained to have been in an area during the observation time, without duplication, was recorded and mapped in the field on U.S. Geological Survey 7-1/2 minute topographic maps. This information was transferred to 15 minute topographic maps upon return from each trip. Observation times were centered around periods of maximum synchronous goat activity (Peck and Freeman 1972, Rideout 1975, Fox 1977, Smith 1974, Chadwick 1973). This primarily occurred during early morning and late evening hours, but it was not uncommon for observers to actively search out goats all day long.

Random Sightings

Random goat sightings were made and reported from April through September in 1983 by park staff, primarily backcountry personnel. Goat observation forms, used by Nichols (1980) were duplicated and made available to park employees at seven ranger stations throughout the park. A summary of characteristics used to distinguish sex and age classes of goats was also furnished. During seasonal employee orientation, I spent a short period of time explaining identification techniques and the use of the goat observation form. Random sightings were also reported on the park's wildlife observation cards by employees and visitors. Forms and cards were returned to me. The sightings were plotted on a 15 minute topographic map of the park.

ANALYSIS OF DATA

Distribution

Analysis of data included the synthesis and interpretation of information obtained from the field work during the summer of 1983. Distribution of goats was established by compiling aerial, ground survey, and random sightings onto a composite map of Mt. Rainier, and by noting the date, time and method of each sighting on the map. Subpopulation units in Mt. Rainier were determined by delineating areas of concentration and comparing certain characteristics of each unit to known behavioral tendencies of mountain goats in relation to their environment. Parameters taken into account included size of home range of other goat populations reported in the literature; strong home range affinities of goats, especially females and nursery groups; higher tendency of males to disperse, wander, and occupy peripheral habitat between subpopulations; seasonality; elevation; topographic features potentially limiting movement (Stevens 1983, Johnson 1983, Kuck 1977, Rideout 1974 and 1977, Smith and Raedeke 1982, Risenhoover and Bailey 1982, Adams, Masteller, and Bailey 1982), and my personal knowledge and judgment of certain potential habitat areas. The subpopulation units in Mt. Rainier were defined as assemblages of goats which may include one or more nursery groups that appeared to occupy central, aparently optimal home range, and was assumed to have limited association with similar groups in other units; associated male bands occupied what was assumed to be peripheral habitat in the unit, and may have had some limited contact with other units through wandering and dispersal. The size of

each subpopulation unit was determined by planimetric estimation on a U.S. Geological Survey 15 minute map of Mt. Ranier National Park.

Abundance

Once the subpopulation units were defined, abundance was calculated and indexed. Air to ground survey accuracy ratios were established using data obtained from the aerial and ground surveys in Mt. Rainier during 1983.

Abundance in each of the subpopulation units in Mt. Rainier was calculated by an indexed population estimate:

1) The maximum ground survey count in three subpopulation units was obtained. (Data was used from only the three units where systematic ground surveys were done.)

2) The maximum aerial survey count in the 3 units was compared to the ground count to obtain an air/ground survey accuracy ratio.

3) An accuracy range was produced from the lowest and highest air/ground ratios to be applied to all the subpopulation units.

4) The maximum aerial flight count for each of the subpopulation units was then indexed using both the low and high air/ground ratio, producing a population range for each unit.

5) The overall population of the park was then a composite of all the subpopulation units, plus male groups not associated with any unit, or in transit (Stevens 1983).

Since it was assumed only a limited amount of intermingling occurred between subpopulation units, duplication was equally assumed to have occurred only to a minimum extent. However, because air and ground surveys did not occur simultaneously over a particular unit and animals were not marked, confidence limits in the expressed population range estimate were probably large.

Density Determination

Densities were determined for each subpopulation unit using the estimated population ranges and the planimetric computation for the area occupied by each unit. To calculate true density, however, one needs the actual area of suitable habitat occupied by goats, which can only be calculated using marked animals.

Kid:Older Goat Ratio Determination

Kid:older goat ratios were determined from observations during ground surveys by project observers, and were expressed at kids/100 older goats (yearlings and older), as did Kuck in his study of the impact of hunting on Idaho's Pahsimeroi goat herd (1977), Smith and Raedeke in Alaska (1982), and McCrory and Blood in British Columbia (1977). Data was also taken from other researcher's findings which reported population structure as kids:100 females,

yearlings:100 females, and males:100 females, and recalculated to represent kids:100 older goats, making it relatively comparable to the present study.

RESULTS AND DISCUSSION

Aerial Surveys

Three flights were conducted during the summer. The first two flights had the same four observers including the pilot; the last flight had two different observers participating. The pilot had previous experience flying Mt. Rainier on elk surveys during the 1982 field season. Results of each flight are summarized in Table 1.

Table 1. 1983 aerial surveys.

Date:	7/18/83	7/21/83	9/12/83
Plane	Cessna Turbo 182	Cessna Turbo 182	Cessna 182
Direction around mountain:	Counterclockwise	Clockwise	Counterclock-wise
Temperature (°F):	Low 60's	Low 60's	Low 70's
Cloud Cover:	40%	0%	0%
Turbulence:	None	None	None
Number of Goats observed:	301	277	204

A detailed account of the specific locations of goat sightings during each flight is available from Mt. Rainier National Park.

Many factors influenced the scheduling of aerial flights, however, the overriding control was always the weather. Rain, fog, or low clouds frequently cancelled previously arranged trips. At other times when weather was clear, high winds (greater than 30 to 35 mph) at upper elevations discouraged the type of small aircraft use necessary for routinely surveying the mountainside. An additional limitation to scheduling was other obligations and commitments of the participants, including the pilot. Attempts were made to fly the survey when there was a high cloud cover, minimal turbulence aloft, and in the early morning hours following sunrise, or early evening hours before dusk.

Aerial census techniques were systematic, not random. Caughley (1976) stated that estimation of numbers is most precise when sampling is random, however, in so doing problems are encountered which may often result in a loss of accuracy overwhelming the gain derived from immaculate survey design. Although systematic sampling is less theoretically sound, Caughley noted three major problem areas that do not hamper systematic sampling:

1) Random location of sampling units places a strain on the navigator, especially in mountainous terrain. Unit boundaries are difficult to determine and many mistakes can be made.

2) Planes are noisy, causing animals to move, and if sampling units are contiguous with one another, a double counting of animals may result.

3) Random location results in the lowest coverage of sampled area per hour of flying.

Ballard (1977) and Nichols (1980) have indicated that variability in counts was most closely associated to observability. Nichols found that more goats could be counted in high overcast conditions, with calm air, in early to mid summer. Hall (1977) also stressed the importance of having at least a 20 percent cloud cover, which would cause a soft, even light without glare. Conversely, sunny days produced a strong light contrast between sunny and shaded slopes which was difficult for the eyes to adjust to, produced a strong glare from snowfields, and may find goats less active (Fox 1977). Early morning and early evening hours were probably the best time to census populations, because goats would likely be feeding and hence more observable (Chadwick 1973, Peck 1972, Nichols 1980).

None of three aerial flights were conducted under completely ideal conditions, however, the first flight approximated the parameters outlined above most closely, due to the presence of clouds, late time of day, cool temperatures and season; this flight yielded the highest count of goats. The results are probably still low, due to the relative inexperience of two of the participants in aerial censusing.

The second flight, conducted in the early morning, yielded a similar, but slightly lower count. Even though temperatures were relatively cool and the observers were becoming more proficient, there were no clouds, and glare increasingly became a problem.

The third flight in September produced the lowest count, probably due to a combination of factors. Temperatures were high, cloud cover was absent, and there was much glare on the landscape. It is quite possible goats were seeking relief from the sun in concealed or timbered areas; few were seen on snowfields at the highest elevations. In addition, most of the snow had melted in alpine and subalpine meadows, revealing numerous rocks, which resembled dusty or dirt smeared goats. Hebert and Langin (1982) found aerial surveys in September unsuccessful in locating significant numbers of goats in coastal British Columbia. They indicated goats may be in the timber at this time. Nichols (1980) also found that from the end of July to the first

snowfall, many goats may not be visible during the main part of the day because they are seeking relief from the heat.

Another consideration in the low goat count in September may have been that two observers had been replaced with novice participants. Systematic transects using the same observers in British Columbia produced more accurate estimates (Hebert and Langin 1982). Houston (1982) implied a positive aspect of aerial flights included consistency of observers and pilots used. If it is an observer's first flight in a small plane over remote and awe inspiring wilderness, it is my opinion that the potential is there for the attention to drift from surveying for goats, to looking at the scenery.

The use of a non-turbo Cessna plane on the last flight probably had no effect on the number of goats seen. The difference between a turbo and non-turbo is that the engine performance of a turbo at high altitude is more efficient, not necessarily affecting maneuverability or air speed (personal communication, Renton Aviation, Renton, Washington).

All goats were probably not seen from aerial surveys. Caughley (1976) related a story of when he checked the accuracy of an aerial survey by sitting behind the regular observer and looking out the same side of the plane. The differences in observation were marked. He noted that every time survey accuracy had been tested, animals had been missed. The inexperience of the observers in aerial censusing, plus diverse terrain characteristics associated with mountain goats in Mt. Rainier probably emphasized this during 1983 aerial flights.

Other factors contributed to the knowledge and assumption that goats were missed during aerial surveys. Since billies were found in small groups during the summer in terrain that was more rugged, and in range that was peripheral to or separate from females, they were less likely to be observed, and therefore were probably under represented (Bailey and Johnson 1977, Risenhoover and Bailey 1982, Adams, Masteller and Bailey 1982).

There were instances when it was verified that the observers overlooked goat groups during aerial flights. However to be consistent with methodology, only the maximum number of goats seen by project observers was included in the population estimate.

In keeping with the methodology, some individuals could not be counted even though they were known to inhabit certain areas. For example, even though it was known that 5 individuals frequented the Stevens Peak area of the Tatoosh, as reported by U.S. Forest Service personnel, only the observation of one individual during an aerial survey was counted.

Finally, due to a lack of available flying time, the Crystal Mountains and the Chinook Pass area were not surveyed by air, nor were any ground trips made there. Since goats have been reported in this area, these groups, primarily males, were not represented.

Ground Surveys

Nine field trips were made into Mt. Rainier's backcountry to ground

survey for mountain goats by all or a combination of the same four observers for use in establishing air to ground survey acccuracy ratios. Results of each trip are summarized in Table 2.

Houston (1982), when discussing elk ground surveys, said that if observers were not in close contact, counting errors could result from animals moving within and between counting units. This was minimized during the present study with the use of radios by observers to keep in contact and verify synchronous sightings, by additional evidence from goat observation cards, and by meticulous and careful data analysis.

Wadkins (1962) in a Washington State Department of Game Job Progress Report estimated 50 percent of the population could be observed from ground surveys. Recent Department of Game studies to determine survey accuracy were undertaken using a capture/recapture program in Olympic National Forest in western Washington, and on Mt. Chopaka and Nason Ridge in eastern Washington. The intent was to intensively study areas to develop information that could be applied elsewhere. Results corroborate Wadkin's estimate.

Ground survey accuracy in Olympic National Park was calculated with marked goats over a six year period by using a ratio of number of goats seen during a census, to the estimated total. June through September ground survey accuracies from 1976 to 1981 averaged 68 percent (personal communication, Victoria Stevens, January 1984). The ground counts in Mt. Rainier were not adjusted to reflect ground survey accuracy prior to establishing an air to ground accuracy ratio. This information could not be obtained from my field work done in this study. I also felt it was not appropriate to interpolate from Olympic National Park data, even though terrain, vegetative cover and macroclimatic weather patterns associated with goat habitat were similar to Mt. Rainier. The goats in Olympic are in different stages of habitat colonization and dispersal, which may affect sightings.

In some instances, discrepancies arose as to whether sightings being made by the different groups of project observers were of the same or different groups of goats. To resolve questions such as this, it sometimes proved fruitful to go through the 1983 goat and wildlife observation cards for data to help substantiate a decision. In instances when collaborative evidence was not available, the decision was always to go with the conservative estimate to minimize duplication.

Detailed trip reports were prepared by participants and copies are available from Mt. Rainier National Park. The reports included information on weather, trail conditions, additional wildlife observations, and incident reports of movement, grouping, and behavior of goat populations being observed. In an effort to maximize repeatability of ground counts for future studies, vantage points used during each field trip, along with the locations of goat sightings were also included.

Random Sightings

From April until November, there were 95 goat observation cards and 56 wildlife observation cards with goat sightings made by park personnel and

Table 2. 1983 montain goat ground surveys.

Trip Location	Dates	Group of Observers	Observers Per Group	Maximum # of nonkids seen at one time	Maximum # of kids seen at one time	Total
Emerald Ridge	6/28-29	1	3	10	4	14
Shriner Peak	7/8-10	1	2	2	0	2
Windy Gap	7/12-14	1	3	6	0	6
N. Puyallup Glacier	7/16-17	1	2	21	5	26
Crescent Lake/ Mineral Mountain	7/22-25	2	2	51	9	62
Colonades	7/29-31	1	2	33	8	41
Spray Park	8/3-4	1	2	8	0	8
Cowlitz Chimneys/ Cowlitz Park/ Cowlitz Rocks	8/11-16	2	2		33/184*	223
Owyhigh Lakes	8/25-28	1	1	13	3	16

* A total of 33 kids out of 184 goats were observed at one time in the Cowlitz Chimneys, Cowlitz Park and Cowlitz Rocks area. The total number of goats in the next column (223) includes an additional 39 observed on Goat Island Mountain at the same time, however, distance was too great to distinguish kids at that location.

from occasional park visitors. The goat and wildlife observation forms provided supportive material. Due to the haphazard nature of the sightings, differing experience levels of observers, and inconsistent and non-systematic survey techniques, they were used only to collaborate conclusions drawn from the aerial and systematic ground surveys.

SUMMER DISTRIBUTION

Determining subpopulation units in Mt. Rainier assumed that the animals do not wander indeterminately around the mountain, without any sense of social structure limitations and resource utilization strategy, and that there were pliant limits to where they would go and to what they would do. Subpopulation units needed to be outlined in order to minimize the potential for duplicate counts during population estimation.

There were six subpopulation units of mountain goats in Mt. Rainier during the summer months, which were termed the West, Northwest, Northeast, East, South, and Mt. Wow (refer to Figure 1). They were inclusive of one or more nursery groups with females, kids and subadults, and male bands which had an association within the designated range. Movements between subpopulations were negligible for the purposes of the study, exclusive of wandering males. It was recognized that the units were not independent, isolated entities, but that migration, wandering and dispersal occurred. A boundary line is an abstraction, constantly expanding and contracting as goats respond to different physiological and environmental stimuli. The boundaries reflected and included those areas where the majority of goats were most likely to be associated with, given the parameters addressed in the following discussion. In addition to the six subpopulations, three independent male groups, which were either associated with populations outside the park, or in transit between subpopulation units within the park were noted and addressed. These were the Tatoosh, Shriner Peak, and Mother Mountain groups. A general discussion of the variables used in determining subpopulation units follows.

Goat locations were mapped from 1983 aerial surveys, systematic ground surveys, and random sightings, and preliminary boundaries around areas of habitual concentration, delineating the flexible limits of each subpopulation unit, were drawn. It soon became apparent that females and nursery groups were consistently oriented towards what appeared to be central, more desirable habitat in terms of apparent forage quality and quantity, escape terrain, and thermoregulatory features of the landscape, as others have described in the literature. Males and male groups occupied what appeared as peripheral, more marginal range. This type of grouping or configuration is documented extensively in the literature. Geist (1971) and Chadwick (1973) noted that females and subadults occupied optimum habitat within available range, assuring the resource base was available to the productive segment of the population, while males were found in more marginal range in rugged, higher elevation areas, specially in the summer. Risenhoover and Bailey (1982) also found that male groups were in more rugged terrain in the summer, peripheral to female groups, and may even be in forested areas.

In addition, many investigators have discussed in length the fidelity of goats, particularly females and nursery groups to home range, and the higher

Figure 1

MOUNTAIN GOAT SUMMER DISTRIBUTION

Mount Rainier National Park: Subpopulation Units, Independent Male Groups.

SUBPOPULATION UNITS:	AREA SQUARE MILES	AREA SQUARE KILOMETERS
WEST	16	42
NORTHWEST	17	44
NORTHEAST	24	61
EAST	37	96
SOUTH	14	37
MOUNT WOW	2	4
INDEPENDENT MALE GROUPS:		
MOTHER MTN.	4	10
SARVER PEAK	3	8
TATOOSH	4	10
TOTALS	121	314

FIGURE 1

MOUNTAIN GOAT SUMMER DISTRIBUTION

MOUNT RAINIER NATIONAL PARK

tendency of males to wander between areas. Stevens (1983), Kuck (1977), Rideout (1974, 1977), and Chadwick (1977) have reported that females had a strong fidelity for home range, and that summer range use from year to year was relatively constant. Chadwick goes further to say that consistent use of the same locations enforces knowledge of key feeding areas, protected bedding sites, escape terrain, and efficient daily travel routes, which may confer important survival advantages, primarily to females, since they are more likely to inherit the range.

I assumed therefore, that extensive movement of nursery groups between subpopulation units, at the expense of the aforementioned advantages to remaining traditional in range use, and therefore associations with other units, would be uncommon. I also recognized, as did Chadwick, that there could be extensive movement within subpopulation units.

By the time billies are about two to three years of age, they are becoming increasingly solitary, or associated with exclusively male groups. Because of this tendency, I assumed males were more likely to be represented on the periphery of a subpopulation unit. Chadwick (1977) found adult males solitary 50 percent of the time, and two year olds 36 percent of the time. Dane (1977) reported that adult males are only infrequently a part of the main female/subadult/kid herd. This separation was emphasized during the summer months (Johnson 1983), as I also found. Several reasons have been put forth to justify this behavior. Competition would be minimized and the potential for injury to kids from billies reduced (Risenhoover and Bailey 1982). Chadwick (1971) postulated that unsatisfactory social interactions and stress generated by conflicting sexual and agnostic drives caused adult males to move independent of female groups, and that there was greater social stability of male groups when not in association with female groups.

Once males leave, they may range widely and travel long distances between herds, Chadwick (1977), Dane (1977), Adams, Masteller and Bailey (1982), Rideout (1977), Smith and Raedeke (1982), and Stevens (1983), all refer to the tendency of males to move between areas, even outside of the rut. Dispersal may be an avoidance to inbreeding or a response to some limited resource base, as Stevens suggested, or to lessen social conflict as Chadwick emphasized. This further justified the initial perimeters of each subpopulation unit, which showed males on the edges where they could disperse freely, and which were apparent marginal areas in terms of optimum habitat requirements. This seemed to make the subpopulation unit boundaries a more accurate representation of potential range based on the known goat behavioral characteristics reported in the literature.

In addition to home range characteristics of female and male groups, elevation was used to further refine the limits of each subpopulation unit. Throughout its present range in North America, mountain goats occupy different elevations in the summer, due to latitudinal variations in vegetation structure and the location of the treeline (Johnson 1983). Treeline in Mt. Rainier ranges from 1,620 meters in the west and south parts of the park to 1,240 meters in the east (Henderson 1974).

Out of the 148 wildlife and goat observation forms dated from April until November, 95 had elevation reported on them. The range of goat sightings was

from 1,280 meters to 2,290 meters. Ninety one percent of the reports were between 1,650 meters to 2,160 meters. The most commonly reported elevation (19 percent) was 1,830 meters.

During the nine field trips made by project observers, all goat sightings and wanderings recorded were between 1,490 meters and 2,290 meters, occurring from the end of June to the end of August. The most common elevation was 1,950 meters.

All aerial survey sightings were also within the elevation range of 1,280 meters to 2,290 meters with one exception. Two adults, included in the southern peripheral edge of the northwest subpopulation unit, were observed at 2,530 meters on Curtis Ridge.

The elevation range of 1,280 meters to 2,290 meters was used as a guide in refining unit boundaries because it was inclusive of the ground, aerial and random sightings; it was not, however, used as an absolute. The author's personal knowledge of certain areas precluded their incorporation into subpopulation unit boundaries, because of dense forest without outcroppings, close proximity of visitor use or roaded areas, or areas with no past sightings even though they may have been within the appropriate elevational limits.

In general, boundary estimates using elevation were oriented towards the conservative side so as not to overrepresent marginal or peripheral habitat on the edges of the subpopulation units. Otherwise densities, when determined, would be grossly underrated, since goats, especially nursery groups, may use range intensively, not extensively, and the smaller male bands are the ones more typically found on the far reaching edges (Chadwick 1977).

Topographic features, to a lesser extent, were also used to ascertain subpopulation units. Stevens (1983) noted that topography was a limiting factor in home range. For example, while glacier travel is certainly not uncommon for mountain goats, if major glacial systems appeared to fall out at the margin of a subpopulation unit, and only males were observed in the vicinity, I assumed that major movements of nursery groups did not typically occur across these areas. In addition, even though goats have been known to swim across rivers, it has not been frequently documented in the literature, and therefore under the same conditions described for glaciers, major river systems were used to delineate boundaries where appropriate.

Each subpopulation unit had instances where the variables discussed could not resolve whether to separate or combine two units. On these occasions, I relied on personal knowledge and judgment, along with collaborating evidence from park records and historical files to justify decisions.

After examining the variables and refining the extent of each subpopulation unit's limits, area was calculated. Mt. Rainier National Park has approximately 314 square kilometers or about 31,300 hectares of potential goat habitat. This included central, optimum range occupied by females and nursery groups, and peripheral areas occupied by male bands. Vertical relief was not accounted for. A complete and thorough discussion illustrating specific rationale used in delineating each of the subpopulation units, giving

detailed boundary justification using the variables previously discussed, is available from Mt. Rainier National Park.

Table 3 summarizes particular aspects of each subpopulation unit's range and size. Henderson (1974) and Edwards (1980) respectively studied the vegetation in the subalpine and alpine areas in the park. Combined, the area supporting subalpine and alpine vegetation was 12,350 hectares. This is usually the type of habitat most typically associated with mountain goats. Clearly, the present study showed an estimate of potential goat habitat considerably higher, indicating that the animals used more of the landscape than just subalpine and alpine meadows, and may rely on glaciers, rocky areas and timber for ecological and physiological requirements.

Table 3. Size of mountain goat subpopulation units and independent male group range in Mt. Rainier National Park.*

Subpopulation unit or male group	Maximum linear distance of range (kilometers)	Area (sq. kilometers)	Area (hectares)
West	12.0	42	4,170
Northwest	12.0	45	4,490
Northeast	12.7	61	6,130
East	12.4	95	9,480
South	13.3	37	3,700
Mt. Wow	6.4	6	630
Shriner Peak	not applicable	10	1,130
Tatoosh	not applicable	8	810
Mother Mtn.	not applicable	10	950
	TOTAL	314	31,290

* Independent male group range is presented in order to calculate total area of summer distribution.

Different investigators have reported varying results when determining magnitude of home range. Johnson (1983) generalized that mountain goat summer range in Washington state averaged 11.4 to 15.4 square kilometers. However, the estimates for Washington were for the most part, determined from harvested and managed populations in areas that did not have the expanse of available and protected habitat found in Mt. Rainier National Park, and therefore may not be comparable. Goats on Klahhane Ridge in Olympic National Park had a summer range of 13 square kilometers, and at Royal Basin and Lake Constance in the same area the range was 16 square kilometers (Stevens 1983).

Rideout in Montana (1974, 1977) found mountain goat summer range varied with age and sex. Yearlings commonly averaged 41.2 square kilometers. The yearlings' maximum summer range coincided with most of the approximations for Mt. Rainier's subpopulation units (Table 3), which reflected all individual movements and were therefore also a maximum. This large range of yearlings is common in other ungulates as well, and Rideout stated it may be due to the

animal's sudden subordinate role when its nanny gives birth, and its rejection and subsequent forced movement from one female kid group to another. Relative to each other, the subpopulation unit characteristics within the park appeared fairly constant, with the exception of Mt. Wow. Mt. Wow appeared to have characteristics consistent with Steven's account of summer range in the Olympic Mountains, Johnson's statewide average, and Rideout's estimate for adult males and females in the Sapphire Mountains of Montana.

Some researchers have reported home range as the greatest linear distance between two observations of known individuals. Adams, Masteller and Bailey (1982) reported the average on Sheep Mountain and Gladstone Ridge in the Sawatch Range of Colorado was 6.4 kilometers, while the maximum was 15.9 kilometers. In the Bunker Creek drainage in Montana, Chadwick estimated 11.2 kilometers was the maximum length of summer range use. The maximum figures coincided well with the estimates for Mt. Rainier, which were also assumed as maximum distances. Mt. Wow again best corresponded to average findings (Adams, Masteller and Bailey 1982).

Mt. Wow may typically represent the habitat that is available to many other goat populations, in terms of its isolation from other expanses of habitat, small size, adjacent clearcutting in the national forest, and exposure to hunting pressures because of this proximity. As stated before, the habitat along the slopes of Mt. Rainier may be atypical because of the wide reaches of protected alpine and subalpine terrain.

It may not be appropriate to compare figures from one geographical area, and from one study to another. The subpopulation units in Mt. Rainier contained one to several nursery groups that may have periodically associated, disbanded, and reformed with one another. They also contained the individual male bands located throughout the area. The subpopulation unit estimates in Mt. Rainier therefore took into account all female range and all associated male peripheral wandering areas. They may appear high when compared to other studies, which may have just included the home range of one particular herd within a larger population, roughly corresponding to a nursery group within a subpopulation unit in Mt. Rainier. Also, results from other studies were from collared or marked animals, indicating more precise data.

In addition, different aspects of a population affect its behavior and movement. The Olympic mountain goats are recently introduced and are, generally speaking, in a state of dispersal and colonization, where Mt. Rainier's goats are native, and presumably have established traditional range. Density, competition, and availability of limiting resources also affected dispersal of goats and subsequent range size in Olympic (Stevens 1983). Since the status of these parameters has not been scientifically and quantitatively established for goats in Mt. Rainier, it is inappropriate to compare results with other populations where health, vigor, and population dynamics have been verified.

Abundance

The estimated population range of mountain goats in Mt. Rainier National Park was 374 to 500 individuals. This estimate was based on clear systematic

methodology making it possible to repeat in the future and thus detect trends in population size.

Table 4 illustrates the computation used in indexing the systematic ground surveys. Three subpopulation units, west, northwest, and east, had sufficient systematic ground survey time to establish a reliable count. The ground counts were then used to establish an air/ground survey accuracy range for use in population estimation. A resultant accuracy range of 69% to 92% was applied to the maximum aerial count in each subpopulation, as shown in Table 5. Many factors influenced survey accuracy, including but not limited to weather, topography, snow cover, vegetative cover, season, type of aircraft, and experience and consistency of observers. Estimates are probably low due to goats missed during ground and aerial surveys.

In 1894, John Muir "reckoned" there were over 200 goats on the slopes of Mt. Rainier (Johnson 1964). This largely reflected the manner in which goat numbers were recorded in the park over the years; the most striking feature of population estimates in historical and recent park files and archives is that they were always in neat, rounded figures, periodically shown to increase and decrease linearly. Most of the early information on goats consisted of generalized statements about population increases during the period which predator control philosophy was popular. Narrative descriptions were vague and qualitative. Estimates were usually dependent upon the interest and subjective interpretation of one or two rangers, whose prime duty was to patrol, not census mountain goats. Reports were laced with statements such as "past studies and present sightings were used as a guide;" and "no formal census was made." It cannot be ascertained how counts were performed, how numbers were estimated, how the goats were distributed parkwide, and if the numbers were truly accurate representations. The data cannot be taken as absolute, and can only be used as a reference to make generalized assumptions, not definite conclusions.

Partial data is presented for the reader's information to illustrate relative numbers and trends:

Year	Estimate
1926	250
1930	250-275
1935	310-400
1940	400-500
1945	350-400
1950	300
1965	350
1970	350
1975	400

Murray Johnson (1964) estimated the numbers of animals at 339-385. While based on actual counts, the figures did not account for all areas, and did not account for duplicate counts on wandering animals. Numbers were based on sightings at single locations in time. The potential errors of not accounting for total subpopulation structure, dynamics and movement are described elsewhere. Since methodologies were different, sources of data acquisition

Table 4. Determination of air/ground survey accuracy ratios for use in estimating population range.

Subpopulation unit or independent male group	Systematic ground survey results (G)*	Maximum aerial count (A)	Computation of air/ground survey accuracy ratio (A/G=X/100)	Air/ground survey accuracy ratio
West	41	31	31/41 = X/100	76%
Northwest	62	57	57/62 = X/100	92%
Northeast	No systematic ground survey done			
East	223	153	153/223 = X/100	69%
South	No systematic ground survey done			
Mt. Wow	No systematic ground survey done			
Tatoosh	No systematic ground survey done			
Mother Mtns.	No systematic ground survey done			
Shriner Peak	2	0	0/2 = X/100	0%**

*Maximum number of goats seen in an area during observation time without duplication.

**This percent is not used in the range of aerial survey accuracy when determining population estimates. Only one flight was made over this area.

Table 5. Determination of estimated mountain goat population using an aerial survey accuracy range of 69% to 92%.

Subpopulation Unit of independent male group	Maximum aerial count (A)	Calculation of low estimate (L) A/L = 92/100	Calculation of high estimate (H) A/H = 69/100	Estimated population range (L to H)
West	31	31/L = 92/100	31/H = 69/100	34-45
Northwest	57	57/L = 92/100	57/H = 69/100	62-83
Northeast	41	41/L = 92/100	41/H = 69/100	45-59
East	153	153/L = 92/100	153/H = 69/100	166-222
South	28	28/L = 92/100	28/H = 69/100	30-41
Mt. Wow	29	29/L = 92/100	28/H = 69/100	32-42
Tatoosh	1	1/L = 92/100	1/H = 69/100	1-2
Mother Mountains	4	4/L = 92/100	4/H = 69/100	4-6
Shriner Peak	0	0/L = 92/100	0/H = 69/100	0
			Total	374-500

different, and number of observers actively involved over the entire park different, it cannot be finally concluded that the population in Mt. Rainier has increased from 339 to 385 individuals in 1964, to a range of 374 to 500 individuals in 1983.

In general, it appears as if the mountain goat population within the park may be stable, or has slightly increased since the early part of the century. Most mountain goats are sensitive to disturbances, such as close proximity of roads and road building activities, increased access to habitat, loss of habitat, logging, mining, and visitor use. While populations in portions of the Olympic and Rocky Mountains can be approached to within a few feet at mineral licks, goats within Mt. Rainier exhibited a high intolerance of human interactions (generally less than several hundred yards). Wright (1977) studied the low productivity of the Barometer Mountain goat herd in the Mt. Baker-Snoqualmie National Forest in Washington. He observed the correlation of logging operations with the sudden movement of goats out of the area. Chadwick (1973) suggested goats abandoned areas where road building and logging operations occurred in the Swan Ranger of Montana. Wildlife biologists in Alberta, Canada partially attributed the mountain goat decline there to improved access into goat habitat provided by logging industries (Chadwick, 1973).

As is apparent to anyone who has visited Mt. Rainier, logging has occurred in some areas to within six inches of the park boundary; the park has been likened to an ecological island. Manipulation of habitat in the Gifford-Pinchot and Mt. Baker-Snoqualmie National Forests may have forced goat populations from adjacent Forest Service land, to immigrate into the protected and relatively undisturbed environment of Mt. Rainier. It is not known whether any subpopulations or groups of goats in the park are experiencing pressures of crowding, competition, and stress. This could only be determined from intensive, long term studies of population dynamics and population health and vigor, and forage quality and quantity.

However, the goats in Mt. Rainier may just be exhibiting a natural population increase due to long range climatic trends, decrease in predators or decrease in competition. The relatively high numbers may also just represent the results of the first comprehensive count.

DENSITIES

Mountain goat densities were calculated using the estimated population range. The densities for the individual subpopulation units are in Table 6. They ranged from 1.8 to 2.4 goats per square kilometer parkwide. The estimates did not include the three independent male groups, for it was not determined if they permanently used the range or were in transit between subpopulation units.

Since it has been theorized that goats use range intensively, not extensively (Chadwick 1977), the densities may be oriented towards the low end of the scale. This is especially true since subpopulation units included all the peripheral males wandering where female groups were rarely seen to venture during the summer months, if at all. To determine the actual home range size

of the involved nursery groups, and to calculate a representation of actual density, use of telemetry or marked animals must be employed, along with extended and continuous observations.

Table 6. Mountain goat density

	Goats/kilometer^2
West	.8 - 1.1
Northwest	1.4 - 1.8
Northeast	.7 - 1.0
East	1.8 - 2.3
South	.8 - 1.1
Mt. Wow	5.3 - 7.0
Parkwide Average	1.8 - 2.4

The same reasons that the author put forth for the difficulty of comparing home range size between Mt. Rainier and studies in other geographical areas are applicable here. Since the parameters of population health, vigor and fecundity have not been established for any of Mt. Rainier's goats, densities cannot be construed as being "high" or "low". Further investigations are required to determine if densities can be correlated with resource availability, competition, and individual and population health.

Selected results from other studies, presented in goats per kilometer squared on summer/fall range are presented only for illustrative purposes in Table 7.

Table 7. Comparison of mountain goat densities on summer/fall range; results of selected studies.

Area	Goats/kilometer^2	Source
Olympic Mountains, Washington		Stevens 1983
Klahhane Ridge	14.0	
Royal Basin	2.0	
Constance	4.0	
Mt. Anderson	1.7	
Baileys	3.2	
Glacier Meadows	0.06	
Yoho National Park, B.C.	1.5	McCrory & Blood 1977
Sapphire Mountains, Montana	0.6 - 1.1	Rideout 1977
Black Hills, South Dakota	1.5 - 4.6	Richardson 1971
Kodiak Island, Alaska	7.7	Hjeljord 1973
Kenai Peninsula, Alaska	2.6	Hjeljord 1973
Swan Mountains, Montana	1.2	Chadwick 1973
Glacier National Park	1.2	Chadwick 1973
Mt. Baker-Snoqualmie National Forest, Washington	0.6	Wright 1977

The Klahhane Ridge density of 14 goats per square kilometer is the highest known density in North America. Stevens (1983) extensively examined and compared characteristics of this subpopulation to others within the Olympic National Park. She consistently found that in this high density population there was slower growth and maturation, lower reproductive rates, lower nutritional levels as shown by nitrogen and hematocrit, declining average horn growth rates, and higher dispersal rates. A study such as this in Mt. Rainier, which would compare different groups between subpopulation units, would indicate the relative status of herd fitness. With a potential of increasing threats to the national park from external sources, the condition of internal resources, including goat populations, needs to be established and periodically monitored prior to any degradation.

Kid Ratios

Kid ratios were determined exclusively from systematic ground surveys and are expressed as kids per 100 older animals. Sufficient information was gathered to determine ratios from three subpopulation units as expressed in Table 8. Ratios ranged from 16 kids per 100 older goats in the Northwest unit to 20 kids in the West unit.

Table 8. Kid ratios in Mt. Rainier National Park, 1983.

Subpopulation Unit	Kids/100 older goats	Month
West	20	July
Northwest	15	July
East	18	August

Productivity is not an absolute indicator of population health and vigor although it has been used as a comparative index in a number of studies. The method of productivity in this study (kids:100 older goats) was the best that could be done under the circumstances although it was recognized that it was not the most refined indicator. However, it can be replicated in the future by minimally trained field assistants.

Johnson (1983), in his report on the mountain goats of Washington, presented the productivity of various populations around the state as kids per 100 adult females. The author recalculated his data to express population structure as kids per 100 older goats, for comparability with Mt. Rainier (Table 9). In studies undertaken in Washington state in 1939 and 1940, and again from 1976 through 1981, kid ratios ranged from 25 to 58 kids per 100 older goats.

At first glance, it appears as if kid ratios in Mt. Rainier may be substantially lower than other areas of Washington. However, this cannot be conclusively stated. A single year's worth of data does not show trends in the overall productivity of the population. Stevens (1983) found highly variable reproductive rates from year to year in Olympic National Park, corresponding to weather patterns, which in turn affected forage quality and availability.

She found a positive correlation of reproductive rates with the total winter precipitation (November to March) 1.5 years before birth; and a similarly high correlation between reproductive rates and April snow depths 13 months before birth. The model she presented assumed ovulation rates in the fall were dependent on the amount of nutrients stored by adult females during the previous summer, which would be dependent upon ther winter precipitation, affecting quality and/or availability of forage.

Table 9. Population structure of mountain goats in Washington (taken and recalculated from Johnson 1983).

Area	Period	Kids/100 Older Goats
Pasaytan Wilderness	1939-1940 S,F,W*	39
Chopaka Mountain	1939-1940 S,F,W	35
Mt. Chopaka	1977-1980 Sp	27
Lake Chelan	1939-1940 S,F,W	30
Olympic National Park	1976 F	58
Barometer Mtn./Mt. Baker	1976 S,F,W	25
Nason Ridge	1978-1981 Sp	33
Olympic National Forest	1979-1980 Sp	33

* Sp = spring; S = summer; F = fall; W = winter.

In April of 1982, precipitation reported at Paradise Ranger Station in Mt. Rainier was 28.5 centimeters; the previous 30 year average was 19.3 centimeters. The increased precipitation and resultant snowfall conceivably could have affected forage availability at higher elevations into the summer, thereby affecting the nutrients stored by the adult females pre-ovulation, and ultimately manifesting as low kid ratios during 1983. However, there was not sufficient data to perform statistically valid correlation analysis on reproduction in Mt. Rainier, and what influenced it.

Another variable influencing kid ratios is the time of year when counts are made. Late spring/early summer counts, when kids are first born, reflect higher numbers than late summer or fall. Surveys in Mt. Rainier to determine kid ratios were done from July through mid-August, which allowed time for neonate mortality to take its toll on the young. This is typically attributed to climbing accidents and rockfalls, and to a lesser extent, predation (Chadwick 1973).

A third factor in kid production involves the nature of the population. Tabor and Stevens (1980) found colonizing populations, such as the introduced

herds on the Olympic Peninsula, had higher reproduction than interior Washington populations. According to this postulation, ecological carrying capacity in Mt. Rainier may be realized, thus influencing forage availability and reproductive success.

Disturbance and adjacent land use may also reflect low kid ratios. This has been demonstrated in native, non-expanding populations. Chadwick (1973) associated initial logging activities and related hunting and poaching pressure, with low ratios in five areas in Montana; these ranged from 8 to 22 kids per 100 older goats (recalculated by the author from data expressed as kids per 100 adult females). It is not known what effects, if any, logging, road building, increased access, hunting, and poaching peripheral to Mt. Rainier are having on internal mountain goat populations.

Finally, as Johnson (1983) stated, "... annual kid production can only be assessed accurately if the proportion of young to breeding age females can be determined." This can prove to be a formidable and error laden task; one which was not undertaken in the scope of this project.

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ECOLOGICAL RELATIONSHIPS BETWEEN DESERT BIGHORN SHEEP AND DOMESTIC CATTLE IN SOUTHEASTERN UTAH

Michael M. King, Department of Fisheries and Wildlife UMC 52, Utah State University, Logan, UT 84322

Gar W. Workman, Department of Fisheries and Wildlife UMC 52, Utah State University, Logan, UT 84322

ABSTRACT

Ecological relationships between desert bighorn sheep (Ovis canadensis nelsoni) and domestic cattle were investigated in the White Canyon area of southeastern Utah. Cattle and bighorn sheep utilized different topographic types and had significant differences in diet composition during the winter grazing season. Bighorn failed to move into and use areas vacated by cattle when cattle were moved to summer ranges. At present there are insufficient data to conclusively ascribe failure of bighorn to use areas used by cattle to social intolerance or to differential habitat preferences. Critical management issues with respect to bighorn-cattle interactions in Utah are discussed.

INTRODUCTION

Desert bighorn sheep (Ovis canadensis nelsoni) are native to the harsh canyon country of southeastern Utah. Much of this land is administered by the United States Bureau of Land Management (BLM). In order to adequately plan for the desert bighorn in their livestock grazing environmental statement, the BLM contracted Utah State University to conduct a long-term ecological investigation of desert bighorn sheep on land they administer in southeastern Utah. A major objective of the study was to determine desert bighorn-domestic cattle relationships in the White Canyon cattle allotment in San Juan County, Utah. Ecological relationships between cattle and bighorn were evaluated with respect to overlap in use of topographic types and diet overlap during 1981-1983.

We gratefully acknowledge the Bureau of Land Management and Utah State University for the financial support for the study. The Utah Division of Wildlife Resources provided the vehicle and lodging used throughout the course of the study as well as monthly fixed-wing aircraft flights.

STUDY AREA

The study was conducted in the White Canyon cattle allotment in San Juan County, Utah (Fig. 1). The 1000 km^2 allotment is bordered to the north by Dark Canyon, to the west by Lake Powell, to the south by the Wingate Mesa, and to the east by Natural Bridges National Monument. Large precipitous mesas rise from rough-broken valley floors, creating a rugged environment for both cattle and bighorn. Elevations range from 1458 m to 2478 m throughout the area.

Five distinct topographic types occur in the area (Fig. 2): (1) Chinle talus slopes, characterized by shadscale (Atriplex confertifolia) - galleta grass (Hilaria jamesii) - ephedra (Ephedra spp.) vegetation on slopes that average 60% or greater, (2) Mossback - Shinarump mesa tops, characterized by blackbrush (Coleogyne ramosissima) - galleta grass vegetation interspersed with often dense stands of pinyon pine (Pinus edulis) - juniper (Juniperus osteosperma) on slopes averaging 0-10%, (3) Moenkopi talus slopes, characterized by black brush - galleta grass and pinyon pine- juniper vegetation types on slopes averaging 30-40%, (4) Organ Rock talus slopes, characterized by pinyon pine- juniper stands with blackbrush - galleta grass understory on slopes averaging 20-40%, and (5) Cedar Mesa Valley floors, characterized by blackbrush - galleta grass vegetation interspersed with pinyon pine- juniper on slopes averaging 0-10%.

The history of livestock grazing in the White Canyon area begins as early as 1887 when a few cattle were grazed there (Wilson in Trefethen 1975). During this early period accurate grazing records were not kept; however, in the 1940's and 1950's as many as 7000 cattle and 7180 domestic sheep were grazed in the area that now comprises Canyonlands National Park and south to the San Juan River (BLM grazing records, San Juan Resource Area Office, Monticello, Utah). In 1959 this big allotment was subdivided into 3 smaller allotments, including the White Canyon Allotment essentially as it is today. Current grazing priviledges for the White Canyon Allotment are for approximately 450 cattle managed in a year-round pasture rotation system (R. McClure pers. commun.). Cattle generally remain in the White Canyon portion of the area from early November to late April or early May when they are moved to summer ranges. The permittee runs a cow-calf operation on the allotment.

Desert bighorn sheep also have a long grazing history in the area as evidenced by the common occurrence of bighorn representations in aboriginal petroglyphs and pictographs dating back 4000-8000 years (Turner 1971). Accurate estimates of desert bighorn for the area are not available because of the difficulty in getting aerial survey data in such a rugged area. Bates (pers. commun.) estimates that approximately 20-25% of the bighorn in an area are observed during annual helicopter surveys based on double-count estimates (Magnussen et al. 1978) conducted by Utah Division of Wildlife Resources (UDWR). During the 1983 aerial survey, UDWR personnel classified approximately 40 sheep in the White Canyon area. A liberal estimate for desert bighorn in the area would therefore be 150-200 animals.

Figure 1. White Canyon area of southeastern Utah.

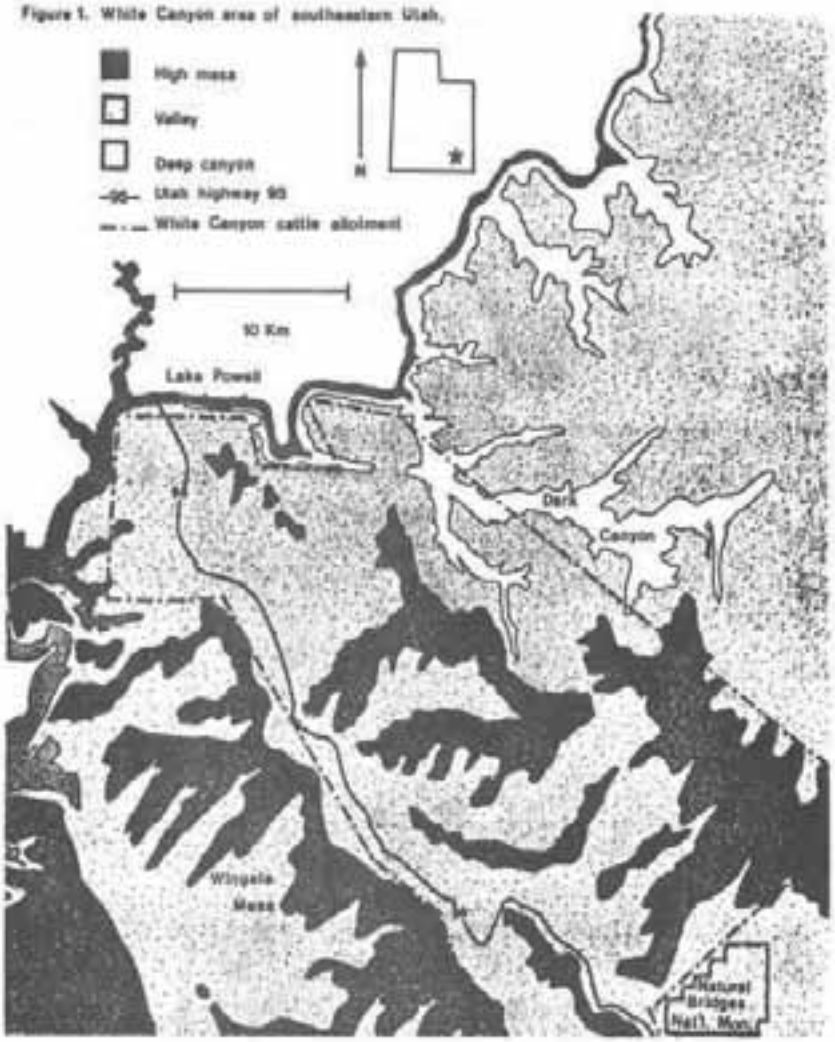
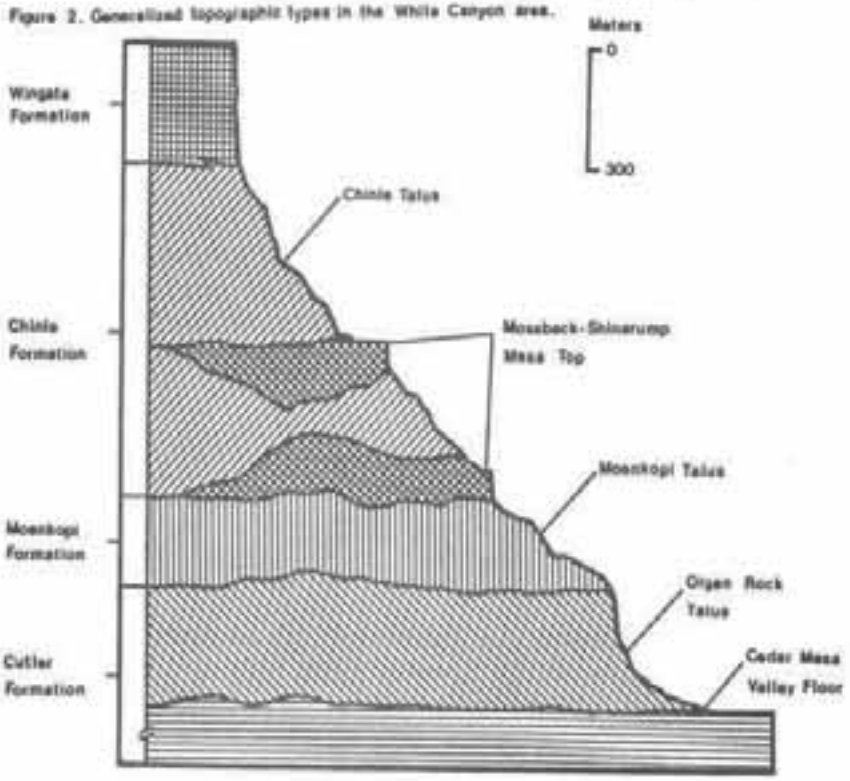


Figure 2. Generalized topographic types in the White Canyon area.



METHODS

Fieldwork was conducted from 1981-1983. Bighorn and cattle were observed during each of 2 grazing seasons (November-April, 1981-1982 and 1982-1983) to determine habitat and forage use patterns when cattle and bighorn were sympatric. Bighorn were also observed during 2 non-grazing seasons (May-October, 1982 and 1983), when cattle were not present on the range to determine if patterns of bighorn habitat use were different after cattle were removed from the area.

HABITAT USE

Bighorn and cattle were located while hiking or driving through the study area. Observations were made during all daylight hours and throughout the grazing season. Each time bighorn or cattle were located, the number of animals in each of the 5 topographic types was recorded. Data were analyzed by constructing a 2 x 5 contingency table comparing use of the 5 topographic types by bighorn and cattle (Steel and Torrie 1980). The same analysis was used to compare selection of topographic types by bighorn during the grazing season vs. the non-grazing season.

FORAGE USE

Food habits of bighorn and cattle were investigated by observing feeding animals with 10 x 50 binoculars and a 15-60 power spotting scope (generally from distances less than 100 m) and recording frequencies of plant use. Observations were made during all daylight hours and throughout the grazing season. Use of a culm of grass, leaf or stem of forbs, or leader or leaf of trees or shrubs constituted one feeding instance (Lauer and Peek 1976). Feeding instances were recorded for each bighorn or cow in a feeding group at 2 minute scan sampling intervals during feeding bouts (Altmann 1974). Diet items were recorded by plant species when possible or by forage class (grass, forbs, browse) when species couldn't be identified. Feeding records were expressed as frequencies and, therefore, do not represent actual quantities of forage ingested.

Diet similarities were determined by constructing a 2 x 3 contingency table comparing use of each of 3 forage classes by bighorn and cattle (Steel and Torrie 1980). A Percent Similarity Index (PSI) was also calculated to determine equity of bighorn and cattle diets with respect to proportions that shared diet items contributed to total diets for each animal species (Whittaker 1975).

RESULTS

HABITAT USE

During the 2 grazing seasons, a total of 288 bighorn and 618 cattle sightings was recorded in the White Canyon area (Table 1). Contingency analysis indicated a highly significant difference in selection of topographic types between bighorn and cattle ($X^2 = 689.2$, df = 4, $P < 0.01$). Cattle were only observed on Cedar Mesa valley floors (81%) and Organ Rock talus

slopes (19%), whereas bighorn were observed in all topographic types, but primarily on Moenkopi (39%) and Chinle (31%) talus slopes (Fig. 3). Bighorn were selecting higher, steeper talus slopes and cattle were using lower, gentler slopes and valley floors.

Table 1. Comparison of numbers of cattle and bighorn in various topographic types during the grazing season (November-April 1981-82, 1982-83) in the White canyon Area in southeastern Utah. Numbers in parentheses are expected values based on the assumption of no difference.

	Topographic type					
	Mossback-Shinarump mesa top	Chinle talus	Moenkopi talus	Organ Rock talus	Cedar Mesa valley floor	Total
Desert bighorn	33 (10.5)	89 (28.3)	112 (35.6)	29 (46.1)	25 (167.5)	288
Cattle	0 (22.5)	0 (60.7)	0 (76.4)	116 (98.9)	502 (359.5)	618
Total	33	89	112	145	527	906

Chi-square = 689.2**, df = 4, $P < 0.01$

A total of 677 bighorn were observed and classified with respect to topographic type during 2 non-grazing seasons (Table 2). Contingency analysis indicated no significant difference in use of topographic types by bighorn during grazing vs. non-grazing seasons ($X^2 = 5.6$, df = 4, $P > 0.10$) suggesting that bighorn did not use habitat differently when cattle were not on the range (Fig. 4).

Figure 3. Topographic types selected by bighorn and cattle in White Canyon during the grazing season.

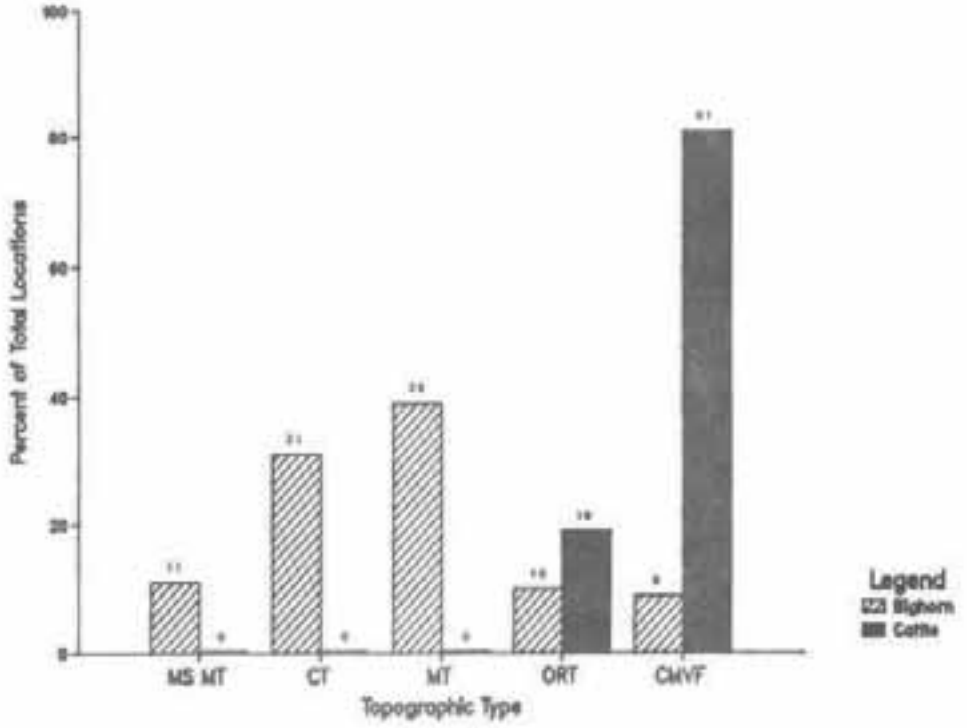


Figure 4. Topographic types selected by bighorn in White Canyon during the grazing and non-grazing seasons.

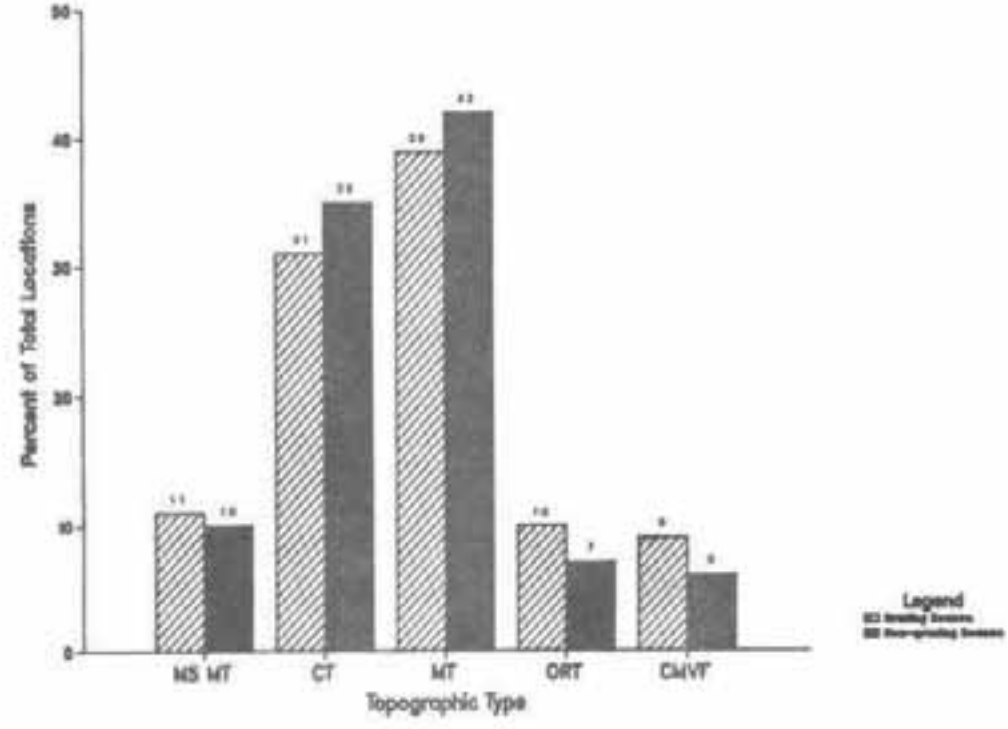


Table 2. Comparison of number of bighorn in various topographic types during the grazing season (November-April 1981-82, 1982-83) and the non-grazing season (May-October 1982, 1983) in the White Canyon area. Numbers in parentheses are expected values based on the assumption of no difference.

Season	Topographic type					
	Mossback-Shinarump mesa top	Chinle talus	Moenkopi talus	Organ Rock talus	Cedar Mesa valley floor	Total
Grazing season	33 (29.8)	89 (97.3)	112 (117.6)	29 (23.6)	25 (19.7)	288
Non-grazing season	67 (70.2)	237 (228.7)	282 (276.2)	50 (55.4)	41 (46.3)	677
Total	100	326	394	79	66	965

Chi-square = 5.6 ns, df = 4, $P > 0.10$

FORAGE USE

During 2 winter grazing seasons 91 cattle were observed during feeding behavior and 2331 feeding instances were recorded. Grass (56%) was most often selected by cattle, but browse (43%) was also an important component of cattle diets (Table 3). Important plant species selected by cattle were: (1) cheatgrass (Bromus tectorum), 31%, (2) galleta grass, 21%, (3) blackbrush, 14%, and (4) shadscale, 14% (Table 4).

One hundred thirty-four bighorn were observed during feeding behavior and 2306 feeding instances were recorded. Browse (91%) was highly selected over grass (8%) and forbs (1%) by bighorn (Table 3). Important plant species selected were: (1) blackbrush, 73%, (2) cliffrose (Cowania mexicana), 16%, (3) cheatgrass, 3%, and (4) galleta grass, 2% (Table 4).

Contingency analysis indicated a highly significant difference in diets between cattle and bighorn with respect to forage class ($X^2 = 1214.2$, df = 2, $P < 0.01$). Cattle were primarily grazers and secondarily browsers, while bighorn were almost exclusively browsers (Fig. 5).

Although forage classes were used differently by bighorn and cattle, there was considerable overlap in plant taxa selected. During the grazing

season, cattle and bighorn both used 10 identified taxa, 8 of which were common to both animals. However the relatively low PSI value of 21 (Table 4) is indicative of minimal diet overlap on a proportional basis (as PSI approaches 100, diets approach equity).

Table 3. Comparison of cattle and bighorn diets by forage classes during the grazing season (November-April 1981-82, 1982-83) in the White Canyon area. Numbers in parentheses are expected values based on the assumption of no difference.

	Forage class			
	Grass	Browse	Forbs	Total
Cattle	1306 (751.5)	1016 (1566.9)	9 (12.6)	2331
Desert bighorn	189 (743.5)	2101 (1550.1)	16 (12.4)	2306
Total	1495	3117	25	4637

Chi-square = 1214.2**, df = 2, P < 0.01

Figure 5. Percentage of forage classes in diets of cattle and bighorn during the grazing season (Nov.-Apr. 1981-82, 1982-83).

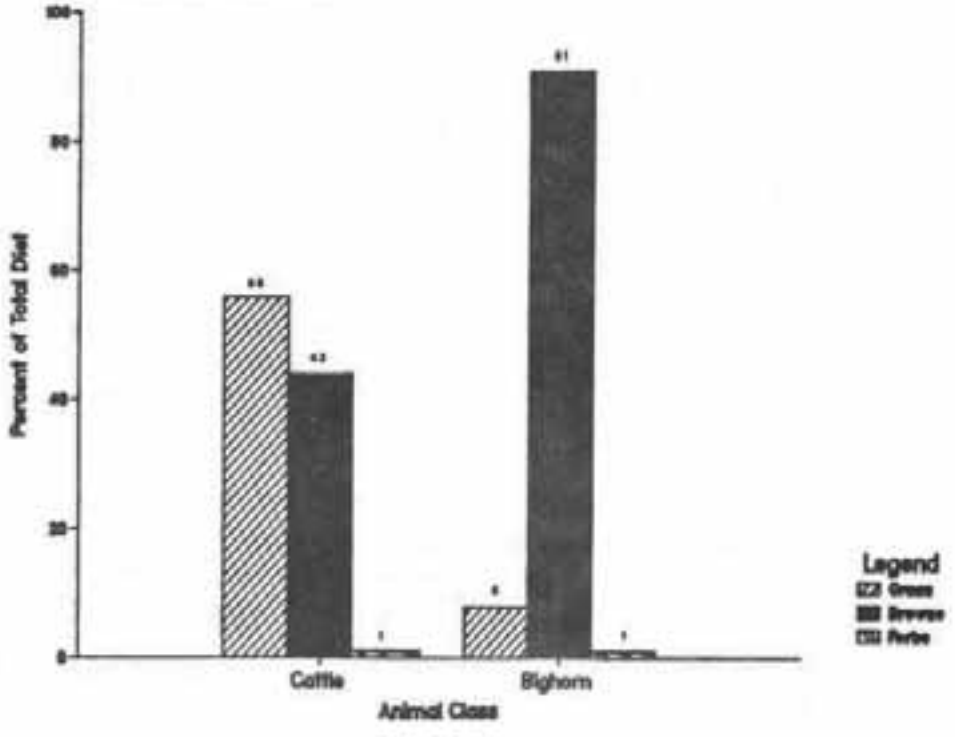


Table 4. Plant species selected by cattle and desert bighorn in the White Canyon area during the grazing season (November-April 1981-82, 1982-83).

	Bighorn (n=134)		Cattle (n=91)		
	Feeding instances (n)	Percent total	Feeding instances (n)	Percent total	PSI value
Coleogyne ramosissima	1690	73	346	14	14
Cowania mexicana	376	16	0	0	0
Bromus tectorum	81	3	734	31	3
Hilaria jamesii	47	2	492	21	2
Oryzopsis hymenoides	40	2	66	3	2
Rhus trilobata	18	1	0	0	0
Elymus salinus	15	1	0	0	0
Ephedra sp.	7	tr	74	3	0
Stanleya pinnata	7	tr	0	0	0
Guteirrezia sorothrae	4	tr	120	5	0
Juniperus osteosperma	3	tr	2	tr	0
Chrysothamnus sp.	3	tr	4	tr	0
Atriplex confertifolia	0	0	320	14	0
Atriplex canescens	0	0	150	6	0
Unidentified forbs	9	tr	9	tr	--
Unidentified grass	6	tr	14	tr	--
Unidentified browse	0	0	0	0	--
Total	2306	100	2331	100	21

tr = < 1%

DISCUSSION

The current relationship between desert bighorn and cattle appears to be one of ecological separation with respect to use of topographic types and forage selection. Bighorn select higher, steeper, more rugged talus slopes, while cattle select lower, gentler slopes and valleys not far from roads and developed water sources. This differential use of available topographic types occurred during the winter grazing season when cattle and bighorn were sympatric as well as during the non-grazing season after cattle were moved to summer ranges. Bighorn and cattle diets have several common taxa during the winter grazing season, however, cattle diets are dominated by grass whereas bighorn were almost exclusively browsers.

This evidence may lead land managers to infer there is little or no conflict between desert bighorn and domestic cattle in the White Canyon area. However, there are several fundamental issues that must be resolved before a

more liberal grazing management plan can be prescribed.

First, there is the question of whether observed ecological differences between bighorn and cattle result from differing preferences or from a social intolerance-avoidance factor. Evidence from previous studies on this issue is largely divided between those suggesting differences are based on habitat preferences (McCann 1956, Barmore 1962, Ferrier and Bradley 1970) and those suggesting bighorn avoid areas used by cattle (McCullough and Schneegas 1966, Follows 1969, Albrechtsen and Reese 1970, Dean 1975, Horejsi in Trefethen 1975).

In Utah there is evidence that bighorn avoid areas that have been grazed for long periods. Bates (1982) described habitat expansion by desert bighorn into areas once grazed by cattle after cattle were removed from Canyonlands National Park. Irvine (1969) and Wilson (in Trefheten 1975) describe a case of vacation of normal home range areas by desert bighorn when cattle were experimentally introduced into an area. It is also noteworthy that when bighorn were located on valley floors and lower slopes during the current study in White Canyon, their stay was short-lived or transitory, generally during escape or travel from one mesa to another.

The most powerful test for this problem would be to remove one species or the other from the area so that a response by the remaining species could be monitored (Connel 1977). In this manner, critical proof of competitive effects of the removed species on population growth or habitat expansion by the remaining species could be established (Wagner 1978). It would be enlightening to remove cattle from White Canyon or similar areas for a period of several years so that population effects could be monitored.

Second, although food habits were quite different in 1981-1983, they could change with different environmental conditions. It is not surprising that bighorn and cattle diets are different considering they use different topographic types. Much of the disparity in diets was likely a function of differences in plant compositions among the topographic types in the White Canyon area (Wilson 1968). Since bighorn were only rarely observed in areas used by cattle, food habits of bighorn in those areas could not be adequately sampled to determine degree of diet overlap. However, considering the high percentage of shared diet taxa (80%) it is not unlikely that diets might converge if cattle and bighorn were forced to use the same topographic types (Wagner 1978). McCullough (1982) studied Rocky Mountain bighorn sheep (O. c. canadensis) and cattle in a Colorado area where summer grazing by cattle was on bighorn winter range. Based on habitat type and diet overlap, he concluded that if cattle were removed, an additional 117 bighorn could have been supported in this area.

A situation like this in which cattle may be more directly competing with bighorn for food or space may occur in the White Canyon area if livestock operators are allowed to use mesa tops and upper talus slopes by driving cattle up existing roads, or to manipulate vegetation on mesa tops to make them more favorable to cattle grazing. This situation occurred during the winter of 1983 when a state school section was chained on top of a mesa within 1-2 miles of an area actively used by desert bighorn. Another state school section in the same area is scheduled to be chained in the spring of 1984. This chaining may act to further reduce already limited bighorn habitat. If

cattle are moved into close proximity of bighorn, diets may converge or bighorn may leave the area.

Third, there may be problems of disease transmission between bighorn and cattle. Positive titers for blue tongue, a viral disease that can be fatal to lambs or adults, have been found in bighorn and cattle in the White Canyon area (King and Workman 1983a, 1983b). Blue tongue is one of several diseases suspected to be responsible for high rates of lamb mortality by predisposing lambs to secondary pneumonia infections (DeForge et al. 1982). Cattle and bighorn may be serving as reservoirs from which the blue tongue virus is transmitted between populations. Further studies should be encouraged to determine if cross transmission occurs between cattle and bighorn and the potential effects of the disease.

The cautionary examples presented in the foregoing discussion do not by any means prove, nor do they disprove, there are competitive relationships between cattle and desert bighorn sheep in southeastern Utah. However, the current study and those previous have raised several issues that need to be resolved through appropriately designed research programs before any liberalized grazing plans should be implemented.

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A COMPARISON OF THE BIOLOGY AND IMPACT OF FERAL GOATS (Capra hircus L.) ON SUBTROPICAL AND SUBANTARCTIC ISLANDS.

M.R. Rudge, Ecology Division, Department of Scientific and Industrial Research, Private Bag, Lower Hutt, New Zealand.

ABSTRACT

Three populations on islands in the New Zealand region illustrate why feral goats are pests in many parts of the world in a variety of habitats. On subtropical Macauley Island goats reduced a burnt forest to grassland, and reached a density of 10/ha. About 22 percent of females bred twice each year. On nearby Raoul Island, goat density was 1/ha. The forest canopy was intact but regeneration was suppressed. Field and autopsy observations in 1972 indicated that if goat density were reduced, vegetation would recover and productivity would rise. By 1981-83, productivity had indeed risen from between 83 and 94 kids/100 females/year to 170 kids/100 females/year; and 23 percent of females bred twice each year compared with 1.5 percent in 1972. On subantarctic Auckland Island population density was 0.05/ha. Observations in 1973 suggested that the population was at the extreme of its environmental tolerance, numerically static, restricted in range and having little effect on the vegetation. By 1983, measured plots and photopoints showed that woody vegetation could slowly increase despite goats; but that lowland tussock grass and some localized palatable trees could be eliminated. There are sound biological reasons why goats are everywhere hard to exterminate. It seems that there are very few places where they can be tolerated without changing the vegetation. Control operations must be planned so as to minimize compensatory responses in goat productivity through increased food resources.

INTRODUCTION

Goats are one of the most widespread of domesticated animals (Rudge 1984a). They are found on all continents and many islands, amongst large and small human communities, and throughout all levels of the economic spectrum. They are small enough to be easily managed either individually or in groups, and eat a wide range of food of varying nutritional content, to produce milk, meat, and hides. Over a wide range of climatic conditions, they remain healthy and prolific. For centuries these characteristics have made goats valuable, not only as conventional stock animals, but also to supply fresh meat on sailing ships, and subsequently as the initial livestock of colonists in distant lands.

Because goats were such good travellers, foragers and general purpose livestock, they were commonly liberated in remote places, such as islands, to provide meat for shipwrecked castaways. Many such small transplants have since prospered to become large free-living populations.

The resilience and adaptability that were high among the merits of goats have now made pests of them in many places and particularly on islands. The classical example is the deforestation of the island of St. Helena (Darwin 1845), but their impact has also been tremendous in the Galapagos archipelago (Lewin 1978, Perry 1969), Hawaii (Yocom 1967, Scowcroft and Giffin 1983), New Zealand (Howard 1965), and in the desertified areas of the Mediterranean and Africa (Furon 1958).

New Zealand has never had native browsing mammals in its fauna. Many species of the introduced mammals are now pests (Wodzicki 1950, Gibb and Flux 1973) and the goat is prominent among them. For about 40 years vigorous control campaigns have been conducted with varying degrees of success. This has been done pre-eminently to protect native vegetation for its own sake, the native animals depending on that vegetation, and catchments susceptible to erosion. A variety of control methods has been used (Parkes 1984a), but despite all this effort, the distribution of goats on the mainland islands of New Zealand is still much the same as in the 1930's, although densities are now generally much lower (Figure 1).

On the smaller offshore and outlying islands the situation is a little different. Thirteen island populations have been exterminated, and only seven now remain. Islands are particularly valuable in the conservation strategy for New Zealand. Many have a high level of local endemism and others are used to liberate endangered species if there are no significant pests present.

A new consideration in conservation philosophy has arisen recently in a plea for nations to consider the contribution they can make to the genetic conservation of livestock (U.N. Food and Agriculture Organization 1975, Bowman 1981). Some of New Zealand's feral livestock species, such as sheep, provide opportunities to contribute to this cause (Rudge 1982, 1983), but the reputation of goats would seem to rule them out immediately. Now that so many populations have been exterminated, there may be some among the rest that are candidates for preservation. This paper compares three populations to illustrate some of the more obvious and more subtle effects of goats that must enter into such evaluations. Two cases come from the subtropical Kermadec Islands, and one from the subantarctic Auckland Islands.

THE KERMADEC ISLAND POPULATIONS

There are two main islands in the scattered Kermadec group, Macauley and Raoul (Figure 1). Both are volcanic and Raoul is still active. Macauley is the smaller of the two and is about 320 ha in extent, 2 km by 1.6 km, and rising to 213 m a.s.l. When it was discovered in 1788 it was described as covered in forest dominated by Kermadec ngaio (Myoporum obscurum), with deep rich litter layers and abundant bird droppings (Bowes 1787-79). At some unknown dates after that the vegetation was burnt and some goats were liberated. In 1827 it was described from a distance as being covered in rank grass and without a single tree (D'Urville 1832). In 1836 the whaling captain

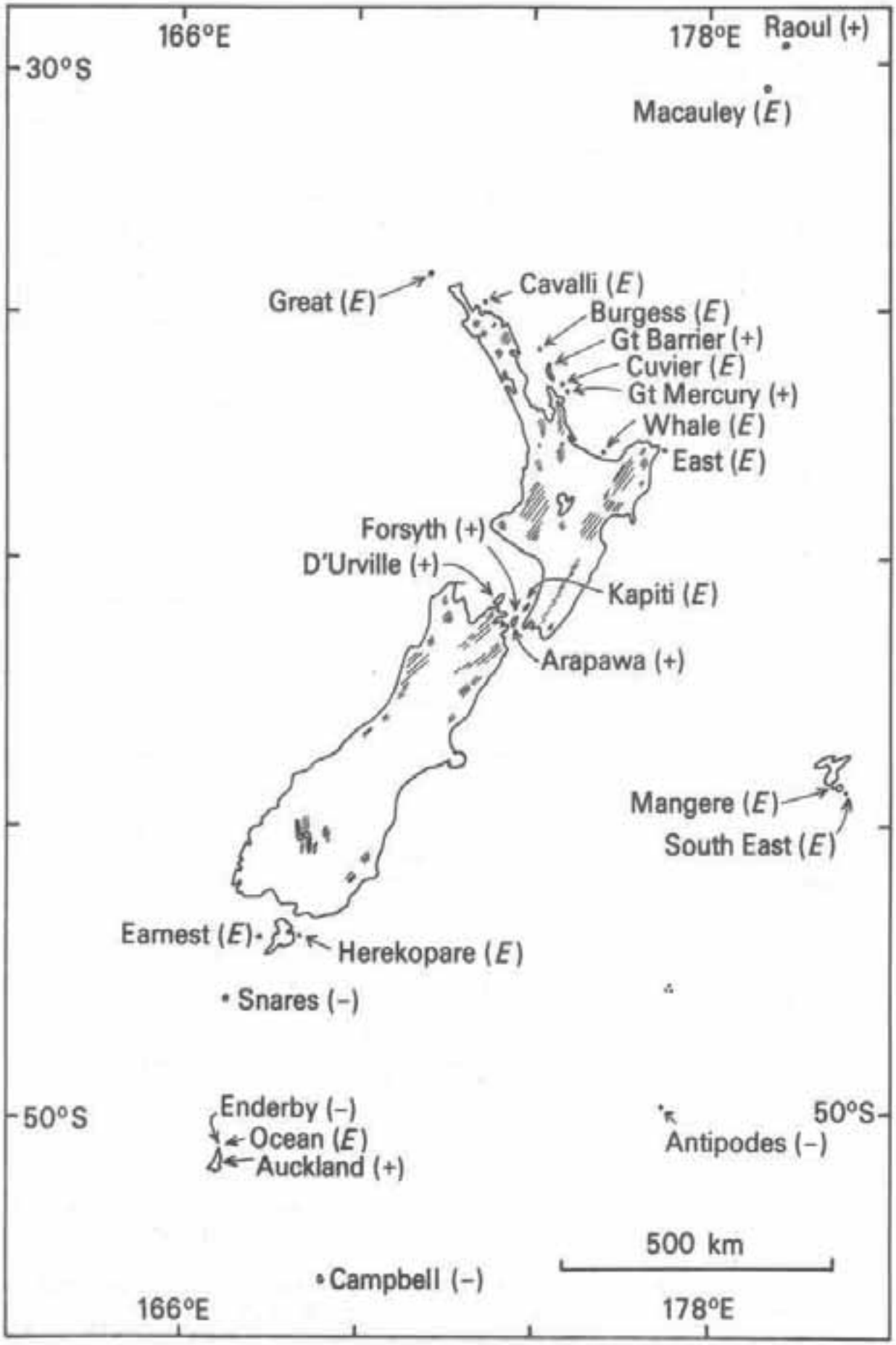

Figure 1. Distribution of feral goats in New Zealand in 1984. Mainland populations hatched; island populations present (+), died out naturally (-) or exterminated (E).

W.B. Rhodes landed and recorded a few stunted trees, herbage, and many goats (Rhodes in Straubel 1954). By 1966 the island was still entirely covered in herbaceous vegetation and the few remaining ngaio trees were confined to inaccessible cliffs (Sykes 1969). The density of goats was 10/ha, which as a visual comparison is about the stocking level of sheep on many New Zealand hill country farms. Despite this density, 22 percent of females were breeding twice each year, as indicated by simultaneous pregnancy and lactation. Of the kids, 33 percent died before birth but overall recruitment was 170 kids/100 females/year (Williams and Rudge 1969). This island represents the 'conventional' case of feral goats living at high density in a deforested habitat that had been altered initially by man. In this instance almost all of the 3200 animals were eliminated in a single operation in 1966 and the remaining 18 in 1970 (Sykes 1977).

Raoul Island was discovered by Europeans in 1793. It was uninhabited, and there is no sign that it ever had a permanent Polynesian population. It covers just under 3000 ha and rises to 518 m on the crater rim. Although volcanic activity has devastated the island from time to time, the predominant vegetation has probably been forest for the last 2000 years (Sykes 1969). Two main types of forest are recognized, both dominated mostly by Kermadec pohutukawa (Metrosideros kermadecensis). Evidence of transient Polynesian occupation has been found and here were several attempts at European settlement in the 19th century (see Sykes 1977). These intrusions left a legacy of adventive plants, several of which have become pests (Devine 1977, Sykes 1969). Goats and pigs were introduced some time before 1836 (Rhodes in Straubel 1954). In contrast to Macauley Island, they made their impact on an essentially pristine forest vegetation. The pigs were never very numerous and died out about 1964 (Sykes 1977). Externally the island still presents a lush forested appearance which belies the influence of the goats within it. Sykes (1969) summarizes the comments of botanists since Oliver (1910) on the destructive impact of the goats and the need to control them. Many formerly prominent plants had, by 1966, become restricted to cliffs and the vicinity of the Meterological Station (Sykes 1977). Few or no young plants of the main canopy tree, pohutukawa, were seen anywhere in 1966, and undergrowth was generally sparse or severely cropped (Sykes 1969).

Since 1933 there had been many sporadic attempts at goat control (sometimes encouraged by bounty payments to the meteorological staff) but serious work did not begin until 1972 (Parkes 1984a). By then the population was estimated at about 3000 (Sykes 1969), a density of 1/ha. The population has been reduced slowly since then until it is now on the verge of extinction (Parkes 1984a). Some characteristics of the population and its performance were examined in 1972 autopsy samples (Rudge and Clark 1978). This showed that in the parts of the island (such as near the Station), where density had been reduced by sporadic hunting, the animals grew faster as kids, and were larger and heavier age for age than elsewhere on the island. These differences in condition reflected the greater food supply from the recuperating vegetation. In contrast to Macauley, only 1.5 percent of females on Raoul bred more than once each year, and overall productivity for the island was between 83 and 94 kids/100 females/year. Goats on the New Zealand mainland showed greater productivity than this with 26 percent of females breeding twice each year, and 25 percent of pregnancies producing twins (Rudge 1969). In light of this it was predicted that as the population was reduced on Raoul there would be a rapid increase in understorey vegetation (food) and greater productivity among

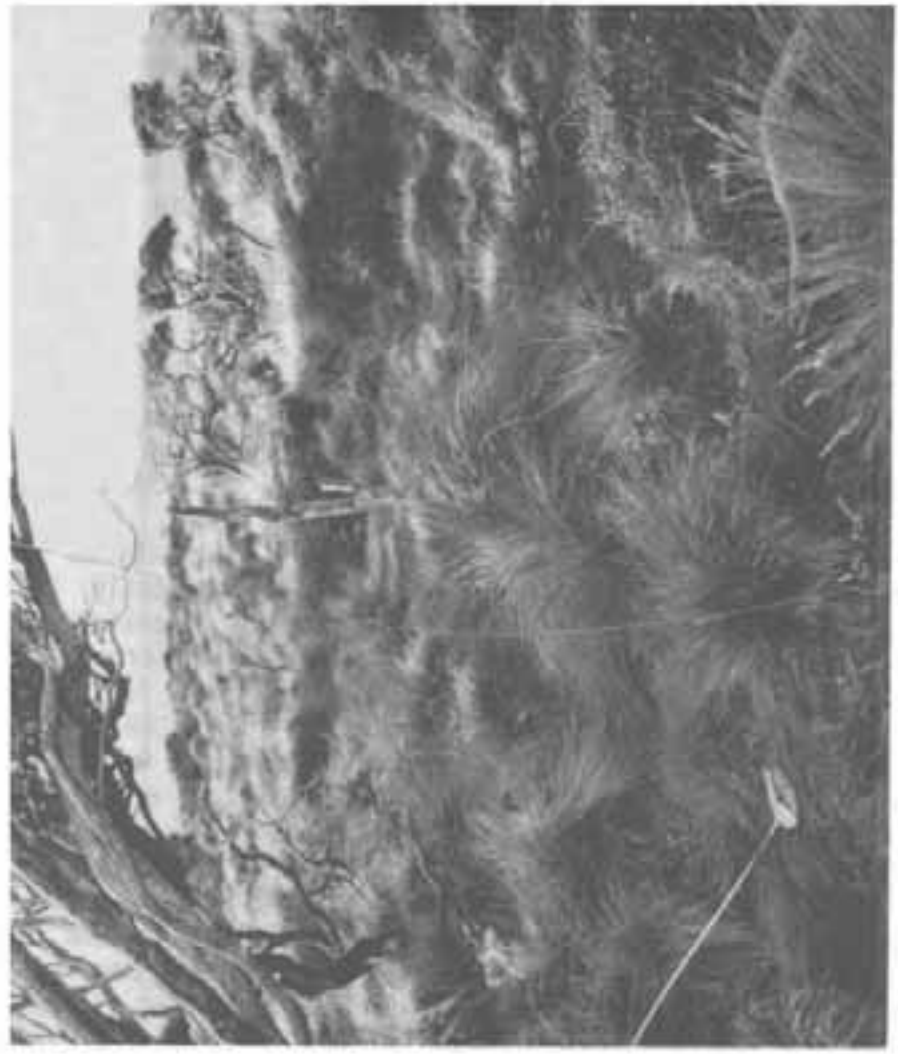

Figure 2. Loss of Hebe elliptica forest on Auckland Island and invasion by Poa litorosa tussock. Left 1973, right 1983.

seedlings of woody species which then overwhelmed it. This tussock had been uprooted by pigs in many places and was prominent in their faeces.

Although some of the palatable woody plants were browsed by goats they were commonly growing strongly within protective envelopes of unpalatables. Most of the food of the goats came from the swards of introduced grasses, and they ate only small amounts of the native tussock grasses. With one exception the subantarctic woody associations seemed to be holding their own against browsing. This exception was where goats had browsed the salt-tolerant, but palatable, Hebe elliptica on a windward cliff top and allowed the wind in to erode the rata canopy beyond it.

This then seemed to be a population of goats living at their extreme of environmental tolerance, limited in range, static, and not threatening any plant communities. Ten years later, in 1983, the goat population and the marked vegetation plots and photopoints were re-examined (Campbell and Rudge 1984). The number of goats counted over part of the goat range was similar to what was in the same area in 1973 (52 and 58 respectively). Their range had not increased but some were seen feeding at higher altitudes than before. Some of the vegetation transects were identical plant for plant with the transect diagrams and photographs of ten years earlier. In other sites, woody vegetation had advanced over the swards, tussocks, and moorland. By contrast, a site where browsing had broken the forest edge of Hebe elliptica in 1973 was almost totally transformed to Poa litorosa grassland by 1983 (Figure 2).

The greatest change was seen and measured in the lowland Chionochloa tussock grassland. On three transects within the area common to goats and pigs, the sparse cover had been reduced by 96, 74 and 34 percent and was almost completely eliminated; and at two sites in the range occupied only by pigs it had been reduced by 8 and 11 percent. Goats ate only small quantities of this tussock in 1973 and the bulk of their feeding time was spent on the swards of introduced fine grasses. Nonetheless the cumulative effect of ten more years of light cropping, together with rooting and tearing by pigs, was enough to kill most of the remaining adults and suppress seedlings. The visual effect was striking in paired photographs taken ten years apart (Figure 3). Clearly, goats and pigs together are capable of eliminating this tussock from the lowland.

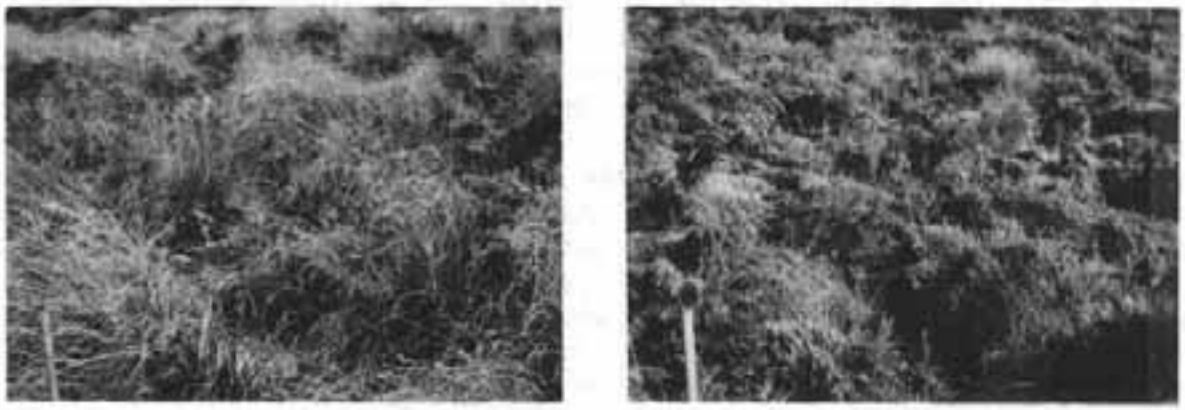

Figure 3. Reduction of Chionochloa antarctica tussock in an area inhabited by goats and pigs. Left 1973, Right 1983.

the goats. These responses and the physical difficulty of hunting through thickets would work against further control.

Autopsy information gathered during the following years of goat control confirmed the 1972 predictions (Parks 1984a). By 1981-83 productivity of the females had more than doubled to 170.3 kids/100 females/year. Whereas only 1.5 percent of the females bred twice each year in 1972, 23 percent were doing so in 1981. This meant that the population had a doubling time of about 20 months. Control was also physically hampered by the resurgent vegetation (Parkes 1984b).

THE AUCKLAND ISLAND POPULATION

The Auckland Island group lies some 400 km south of the mainland of New Zealand and is classed among the world's subantarctic islands (Figure 1). The main island covers 45,975 ha and rises to 665 m. They were discovered in 1806 and pigs were liberated on them the next year (McLaren 1948). Pigs prospered on the large subantarctic endemic herbs and drastically reduced their abundance both in the flora and vegetation (Challies 1975). Whalers, sealers, shipwrecked sailors, explorers and would-be settlers all burnt the vegetation in various parts of the islands. Thus when goats were set free at different times in the late 19th century as food for shipwreck castaways, it was usually into habitats that had been modified already (Rudge and Campbell 1977). Of the ten known liberations, eight simply died out and one population was exterminated in 1941-42. Only one has survived, since at least the turn of the century, on the relatively sunny (but still windy) northwestern end of the main island. The precise reasons for this differential success are not known, but, as it was only at the northern sites that animals endured for any time, the islands must be marginal in climate and food resources for goats.

In 1973, when the first survey was made of the goat population and its influence on the vegetation, the population consisted of some 100 animals scattered over roughly 2000 ha of range (density 0.05/ha). Distribution seemed to be limited by a deeply channelled stream, dense belts of scrub, and wet windy conditions at the higher altitudes that animals would have to pass through to reach other parts of the island. The goats spent virtually all of their time in feeding activity. Productivity could not be assessed, but few young animals were seen.

In 1973 the distribution of vegetation and of human activity (burning, cutting) showed that the vegetation had been altered by man in much of the goat range (Rudge and Campbell 1977). Woody vegetation had regenerated despite the goats after the era of burning. On the relatively sheltered shores it had returned to a rather simple forest in which southern rata (Metrosideros umbellata) was dominant over five other woody species. The forest had sparse ground and shrub layers whether or not goats lived there, giving it the misleading appearance of having been eaten out. With increasing exposure and altitude, essentially the same combination of plants, but with varying relative dominance, formed scrub associations with moorland or tussock in between. On coastal sites the tussock grass Poa litorosa formed continuous cover. In the upland above 300 m another tussock grass, Chionochloa antarctica, replaced scrub. At lower altitudes this tussock alternated with the scrub. It seemed to have been an abundant colonizing plant in the recent past, giving shelter to

DISCUSSION

The population performance and influence of goats on the Kermadec Island matches the general perception of these animals on islands. They were introduced into forested habitats which, in one instance, had already been greatly modified by man. On Macauley Island they were able to reduce that habitat to a floristically and structurally simpler grassland which evidently still suited them. The population density was high yet they remained prolific but with high pre-natal and juvenile mortality. On Raoul Island the continuity of the forest cover belied the great changes that had been inflicted internally on its structure and floristic composition. Although the forest was not scarred with canopy gaps, erosion (other than around the craters) or large areas of goat-induced swards such as on Macauley, there were clear signs of progressive deterioration. The benefits for the vegetation that could be expected from reduced numbers were indicated in the vicinity of the Meteorological Station. But conversely, the goats living in that area gave warning that with a reduced density and improved food supply, productivity could rise. A similar response was found during control on Santa Catalina Island, California (Coblentz 1982).

When control was undertaken on Macauley Island it was easy to exterminate the population because there was so little cover. The grassland responded immediately, but the remnant animals were easy to see and shoot 4 years later. On Raoul, probably less than half of the population was removed from the forest in the first effort in 1972. Thus, both the animals and the vegetation had time to respond in ways which made further control work progressively harder. The forest understorey became more dense and grew rapidly to head height, hindering hunting by man and dogs. This resurgent food source was manifested in the remaining goat population by improved body size, growth rates and condition; and, most importantly in greater productivity. But by 1982 the population could be counted in tens rather than thousands, and extermination was in sight. At that stage numbers were capable of doubling every 20 months if control work lapsed (Parkes 1984a).

On both Macauley and Raoul Islands, there was abundant evidence that the populations were making severe demands upon the vegetation, and were an obvious management problem. On the Auckland Islands it was not even clear whether or not there was a problem, because the population did not seem to conform to this traditional model of high numbers producing an impoverished habitat. Eight known liberations had failed naturally. The only remaining population was at a low density, seemingly unproductive and possibly even declining. With one exception, there seemed in 1973 no serious impact on vegetation. Despite the goats, woody vegetation had steadily recovered from man's disturbance for about 100 years. Although this population was in a valuable Nature Reserve it seemed to be at least tolerable, and was perhaps one of the few candidates for genetic conservation as it was surviving at the extreme of environmental tolerance.

These conclusions for Auckland Island had to be revised when the marked plots were re-examined one decade later. Although woody communities generally had continued to advance on appropriate sites, the Hebe/rata coastal fringe had disintegrated and receded, to be replaced by unpalatable Poa litorosa tussock grassland. This dramatic change was betrayed clearly by logs, and standing dead and dying trees. Photographs taken in 1874 suggest that this coastal forest community had been even more extensive then.

In the lowland herbaceous communities, changes were not as immediately obvious. Indeed, if the 1973 photographs had not been used in the field in 1983 it would have been difficult to register the virtual elimination of Chionochloa based on the evidence of memory. Unlike woody plants, dead tussocks leave no durable evidence. However, large dead tussock bases were found in places under the advancing margin of scrub, indicating something of the natural succession. This process may even have been assisted by goats eating the tussocks, because woody plants have difficulty establishing in their shade (Zotov 1965). The evidence from 19th century photographs and on the ground strongly suggests that Chionochloa was indeed abundant in that period after burning. Goats and pigs have slowly reduced it, and the decade just monitored has seen the virtual removal of its last remnants.

Because lowland Chionochloa often gets replaced by woody vegetation, its loss need not in itself be serious, but there is the implication that goats may then exploit it at higher altitudes and so migrate round the stream heads to other parts of the island. On the other hand they may remain within the area of their preferred food, the introduced grass swards, and gradually decline as the woody vegetation continues its steady advance. There seems little chance that in their present impoverished habitat they would achieve the explosive productivity seen in the Kermadecs, but even that cannot be guaranteed. The resurgence of the sheep population on Campbell Island (some 100 km further south) in the 1960's, seemed equally unlikely (Wilson and Orwin 1964, Rudge 1984b). If, by some means the goats reached the sheltered forests of the eastern cost, where the understorey is richer, productivity could well rise. At present it seems that within their present range the goats are competing with a simple but highly adapted vegetation and that there is a fine balance to which neither can gain the ascendancy. Although this is an interesting scientific conundrum it must defer to the more important requirements of the Nature Reserve.

The question remains as to whether it is necessary to control these goats or just keep watch on them. The possibility that they will extend their range remains small but is now identifiable. The issue is complicated by the presence of pigs, as they too browse and root up Chionochloa. Even before the goats were liberated, pigs had removed an entire vegetation type of large subantarctic endemic herbs and tussocks (Challies 1975). The goats colonized an impoverished habitat and have survived in it during the slow recovery of the woody elements. Their measured impact in recent times is to accelerate the elimination of Chionochloa aided by pigs. Removing goats alone (which would be simple compared with Raoul Island) would be of limited benefit so long as pigs remained. Hebe elliptica forest would recover but the large endemic herds would not. If pigs alone were removed a whole new palatable herbaceous flora would reappear and the goats might then become more productive and extend their range.

From these comparisons it is possible to make some specific comments and also to provide numerical insights into what has happened in many places where goat control has been so protracted (e.g. the Galapagos Islands, Lewin 1978). Clearly goats are adaptable and resilient animals capable of dramatically modifying the habitat and yet still prospering in it. Each of these three examples posed a different problem, and the solutions described all contribute to the general question of goat control, or of preservation in a genetic conservation programme.

In the Kermadec Islands the problem was obviously one of massive infestations of thriving populations. On Macauley, the degraded open habitat allowed the population to be almost annihilated in a single operation. Regrowth of the grass and herb vegetation was not a problem in completing the task because it remained below waist height. On Raoul Island, a limited investment in 1972 brought limited progress towards extermination, but a massive penalty in terms of dense forest regrowth, and heightened productivity in the goats. The exercise was immediately doomed to be of long duration, and not until 1984 was the end in sight. Clearly in habitats where plant growth is rapid, drip-feed annual budgets are not appropriate to the biological realities. Large costs at the start of a campaign, and a stated consequence of appropriate techniques, are more likely to be successful and more satisfying for the operators.

In the Auckland Islands it is still not clear that there is a goat problem beyond the doctrinaire one of having them in a Nature Reserve. Their impact has been, and still is, rather subtle, and clearly there is a long drawn-out battle being fought between them and the well-adapted subantarctic vegetation. This, and the intertwined contributions of human impact and pigs, have emerged only through long-term measurements and must all be taken account of in managing the island. But from what we now know of goat productivity when food supplies improve, we can broadly predict what would happen if these animals extended their range to richer areas. At present such an extension remains only a possibility, but because of it the case for preserving this population in a genetic conservation programme is greatly diminished.

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ANNUAL ECOLOGICAL CYCLES OF ROCKY MOUNTAIN BIGHORN SHEEP POPULATIONS WITH HIGH ELEVATION WINTER RANGES IN THE EAST KOOTENAYS

Goetz Schuerholz, TAESCO Consultants Ltd., P. O. Box 69, Duncan, B. C. V9L 3X1.

ABSTRACT

Classified carry-over counts of the Elk River Valley Bighorns resulted in a 10 year average of 55 lambs to 100 ewes. Sheep winter range is confined to windswept high-elevation slopes and ridges with significant selection for south and southeastern aspects. Overall habitat use was highest in Alpine Tundra and Subalpine Meadows and lowest in the Alluvial Complex and Riparian Meadows. Elevations above 2400 m received highest overall range use. Slopes between 26 and 40 degrees were significantly more used in winter than in other seasons. Mineral licks seemed to be critical habitat requisites from early spring to summer. Overall diet was significantly dominated by graminoids. Winter range fidelity was confirmed for the Ewin and Sheep Mountain populations. All populations are migratory and use established travel corridors for long distance movements.

INTRODUCTION

Periodic die-offs are associated with most Rocky Mountain Bighorn sheep populations (Stelfox 1971, Demarchi 1967, Bandy 1966). Factors believed to contribute to major die-offs are high population densities, inter- and intraspecific competition, range competition with livestock, winter range deterioration, absence of fires and predators, heavy infestations of parasites, and diseases (Stelfox 1971). Assessing the 1962 to 1967 major population crash of the East Kootenay sheep populations, Demarchi and Demarchi (1967) concluded that sheep wintering on ranges above 2400 meters were not affected. This has been attributed to the generally high productivity of alpine grasslands (Stelfox 1976), the high nutrient content of the dormant forage (Hebert 1972), the absence of interspecific competition, and forage availability of the usually snowfree upper slopes of southern exposures (Schuerholz 1982).

Currently, 8 high-elevation winter ranges supporting a total of 400 to 500 animals are known from the Southern Rocky Mountains of British Columbia; they are located east and west of the Upper Elk River Valley (Warkentin, pers. comm.).

This paper deals with the population ecology of sheep wintering on Ewin Ridge, Sheep Mountain and Todhunter/Imperial, east of the Elk River Valley (i.e. approximately 76% of all Elk Valley populations). Particular attention is given to winter ranges, habitat utilization, diet composition, and population movements.

METHODS

The study area covers approximately 200 km^2 of mountainous terrain with 400 ha of alpine and subalpine high quality sheep winter range.

Bighorn were classified from helicopter and from the ground on all winter ranges each year since 1981 (Schuerholz 1982). The data were supported by Government records dating back to 1971.

A 1:20,000 vegetation map was produced which served as a basis for the habitat assessment of the four sheep winter ranges. Seventeen cover types (Table 1) synonymously used with "habitat types" were differentiated, based on dominant vegetation, vegetation structure and degree of disturbance. The plant community types which form a vegetation cover type were investigated through 170 vegetation plots located by computer-assisted tabular analysis as described by Ceska and Roemer (1978).

Habitat use by season, elevation, and aspect was identified through 2444 browse pellet plots on 153 line transects proportionately representing the 17 cover types.

Table 1. Habitat types in East Elk River Valley Study Area.

Alpine Tundra
Subalpine Meadow
Alpine Larch
Engelmann Spruce Subalpine Fir
Englemann Spruce Lodgepole Pine
Lodgepole Pine
Douglas Fir
Riparian Meadow
Engelmann Spruce Riverbottom
Alluvial Complex
Slide Area
Burned
Logged
Disturbed
Talus
Non-vegetated
Rock

Daily and seasonal movements of sheep were monitored through weekly survey flights, and ground triangulations using 15 radiocollared animals instrumented between 1981 and 1983. Relocations were recorded on UTM grid co-ordinates and analysed through the computer "Home Range" model described by Harestad (1981).

Composite fecal samples collected in February, June, August and October, served to investigate seasonal diet composition and plant species preference as described by Davitt (1980).

RESULTS AND DISCUSSION

POPULATION STRUCTURE AND POPULATION CONDITION

Ewin Ridge supports approximately 47% of the Elk Valley Sheep population while Sheep Mountain supports 20%, and Todhunter and Imperial support combined 9%.

The helicopter census records from 1971 to present show large fluctuations in numbers of sheep on the 4 winter ranges (Table 2). These fluctuations are believed to reflect environmental conditions of each survey rather than changes in population sizes (Schuerholz 1983).

Comparing the 13 years record, the data suggest that the respective populations are stable. The mean lamb:ewe ratio of 55:100 for the record period indicates good recruitment and high lamb survival.

Fecal samples collected from the winter range in 1981 showed very low parasite loads which may suggest that the respective populations experience a low stress level (Schuerholz 1982).

RANGE USE

Of the 17 cover types, Engelmann Spruce-Subalpine Fir, Engelmann Spruce-Lodgepole Pine, and Subalpine Meadow are most abundant in the study area. The pellet group counts show the highest pellet group densities for Alpine and Subalpine Meadows (Table 3) on the winter range.

Sheep seem to select east-southeastern aspects throughout the year and avoid valley bottoms in the study area (Figure 1). Ridge tops seem to be preferred habitat independent of season. High elevation ridges (0 -5^{0}) are preferred bedding sites by sheep and are used for long-distance travel, which may explain the pellet group concentration. Slopes from 26 to 40 degrees were used more in winter than in any other season (Figure 2). Comparing elevations, habitats above 2400 m revealed highest pellet group densities (Figure 3).

The distinct seasonal use of elevational ranges seems to be controlled by snow. Sheep in the study area winter in high elevations utilizing the windblown southfacing upper slopes and ridge tops from December to May. As was evidenced through this study, even in years with low snowfall, Ewin Bighorns are unable to leave the high elevation winter ranges before May (Schuerholz 1982) due to high snowpack in elevations below 2400 m. In spring, sheep follow the receding snowline downslope and start to disperse to their respective summer ranges as soon as snowpacks in the valleys to be crossed permit. From spring to fall, sheep may be found in all elevational ranges.

Preliminary analysis of 3 years records of radiocollared sheep revealed that sheep from all 4 winter ranges are migratory. Range fidelity was substantiated for winter ranges, spring mineral-lick home ranges, and to a

Table 2. Results from the helicopter surveys of the four sheep winter populations.

DATE	LOCATION	# LAMBS : FEMALES	# OF RAMS	TOTAL NO. OF SHEEP	PRINCIPLE OBSERVER
Feb.20, 1971	Ewin	54 : 100	10	106	Warkentin
	Todhunter	78 : 100	3	28	"
	Imperial	-	-	-	"
	Sheep Mt.	not surveyed)			
Feb. 7, 1973	Ewin	29 : 100	22	147	Warkentin
	Todhunter	-	-	-	"
	Imperial	-	-	-	"
	(Sheep Mt.	not surveyed)			
Mar. 7, 1975	Ewin	52 : 100	16	103	Warkentin
	Todhunter	-	-	-	"
	Imperial	66 : 100	4	14	"
	(Sheep Mt.	not surveyed)			
Mar. 6, 1976	Ewin	37 : 100	15	88	Warkentin
	Todhunter	87 : 100	6	21	"
	Imperial	63 : 100	10	90*	"
	(Sheep Mt.	not surveyed)			
Mar.12, 1979	Ewin	48 : 100	22	95	Warkentin
	Todhunter	-	-	-	"
	Imperial	50 : 100	7	28	"
	(Sheep Mt.	not surveyed)			
Mar. 6, 1981	Ewin	50 : 100	27	179	Schuerholz
	Todhunter	57 : 100	12	23	"
	Imperial	25 : 100	1	11	"
	(Sheep Mt.	not surveyed)			
Feb. 4, 1982	Ewin	52 : 100	7	97	Schuerholz
	Todhunter	57 : 100	2	13	"
	Imperial	40 : 100	3	10	"
	(Sheep Mt.	not surveyed)			
Feb. 4, 1983	Ewin	51 : 100	24	147	Schuerholz
	Todhunter	43 : 100	3	26	"
	Imperial	50 : 100	-	1	"
	Sheep Mt.	46 : 100	31	50	"
Mar.10, 1984	Ewin	78 : 100	21	123	Crows Nest
	Todhunter	-	-	-	Resources
	Imperial	75 : 100	1	15	"
	Sheep Mt.	85 : 100	15	54	"

* questionable

Table 3. Sheep pellet group densities by cover type

HABITAT TYPE	NO. OF PLOTS	NO. OF PELLET GROUPS	*DENSITY
Engelmann Spruce-Subalpine Fir	193	26	.13
Engelmann Spruce-Lodgepole Pine	241	19	.08
Lodgepole Pine	132	1	.01
Alpine Larch	93	9	.09
Alluvial Complex	22	0	0
Riparian Meadow	37	0	0
Subalpine Meadow	897	560	.62
Disturbed	1	0	0
Slide Area	95	21	.22
Talus	62	23	.33
Logged	79	3	.04
Douglas Fir	34	1	.03
Engelmann Spruce Riverbottom	27	0	0
Alpine Tundra	74	100	1.35
Rock	13	4	.31
Burned	240	23	.10

* Density is expressed in pellet groups per plot.

Fig.1. Seasonal range use of Elk Valley Bighorn by aspect. Considered are exclusive winter and summer ranges and range areas used within both seasons.

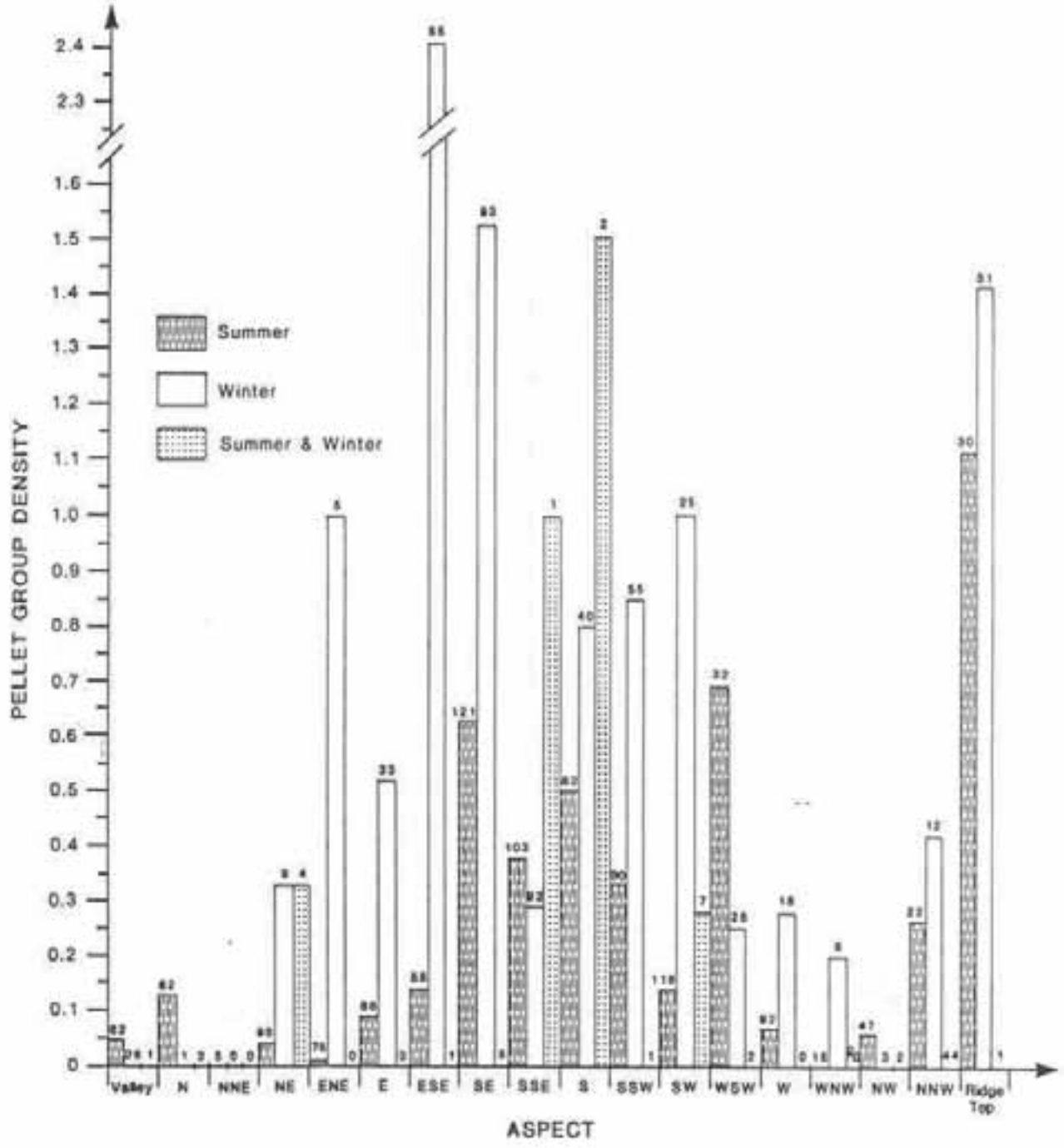


Fig.2. Seasonal distribution of Elk Valley Bighorns by slope. Considered are exclusive winter and summer ranges and range areas used within both seasons.

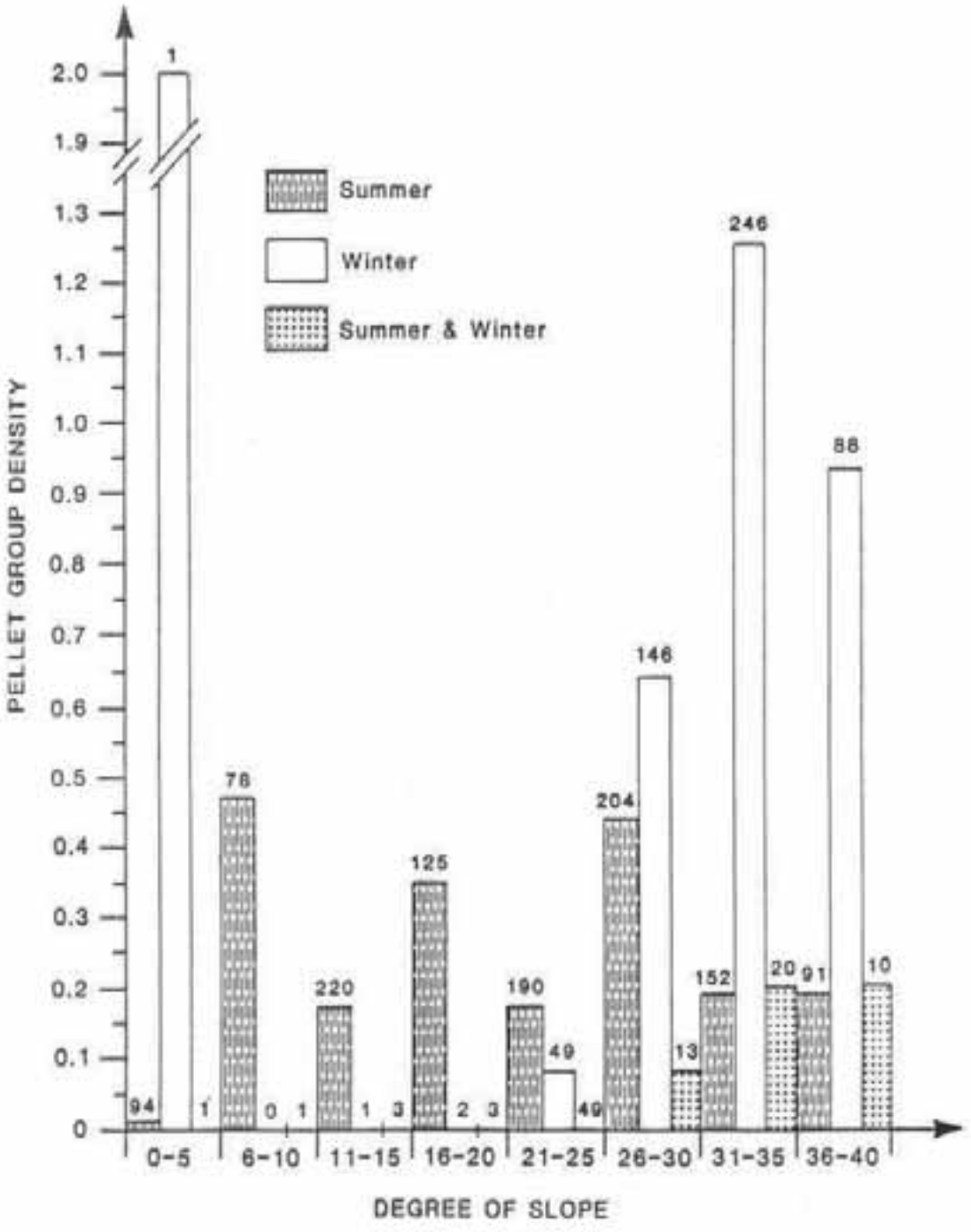
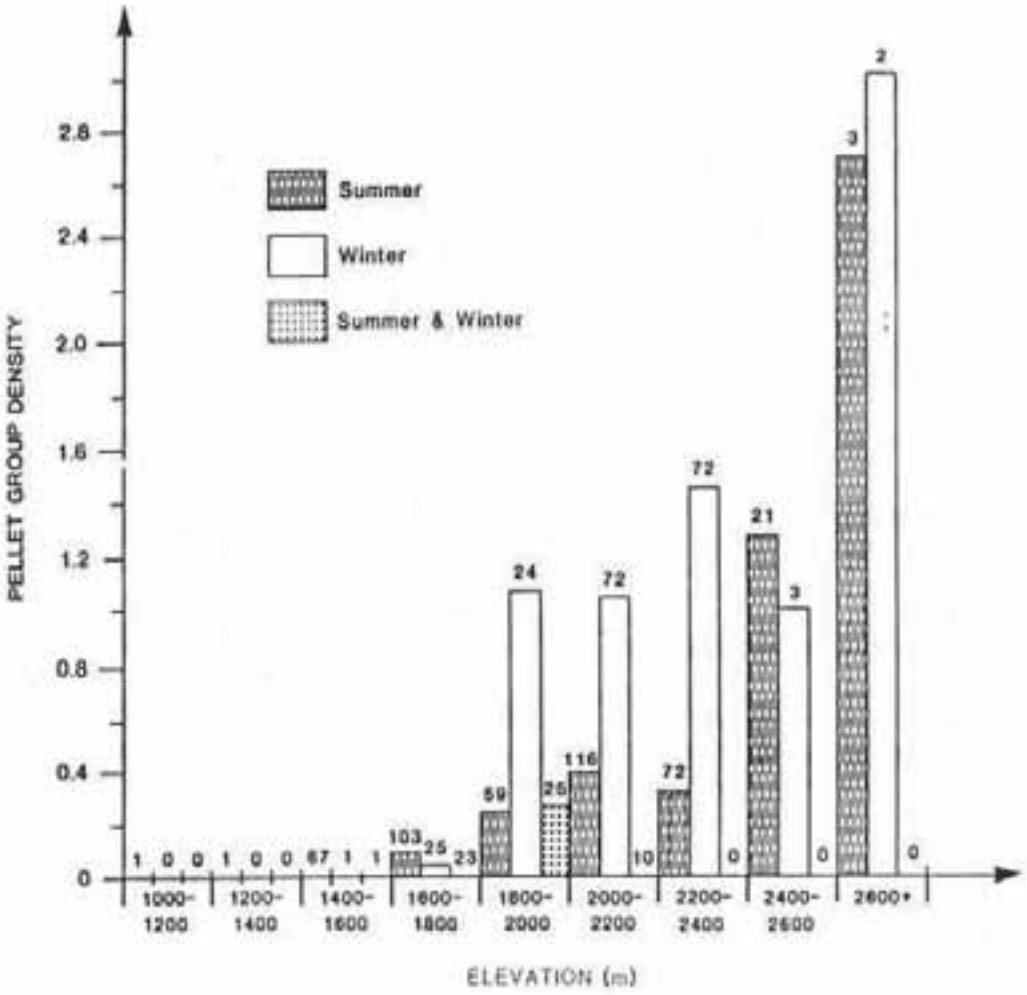


Fig.3. Seasonal distribution of Elk Valley Bighorn by elevation. Considered are exclusive winter and summer ranges and range areas used within both seasons.



lesser degree for summer ranges. Long-distance travel between seasonal and home ranges seemed to occur via well established routes which mostly followed mountain ridges. Some home ranges of sheep from Ewin and Sheep Mountain overlapped; however, little interaction between the two populations was observed except for rams during the rutting season. Rutting generally occurred close to the respective winter ranges with a peak in November. Rams and ewes were found on the same winter range.

From the radio telemetry data, it was deduced that sheep in the study area lamb in the Engelmann Spruce-Subalpine Fir forests, below and adjacent to the winter ranges. This applies in particular to the Ewin population. The ewes of the Sheep Mountain group seemed to lamb in rugged cliffs adjacent to the winter range. The Ewin population did not seem to form nursing bands as described by other researchers (Geist 1971, Stelfox 1978), except when found in open terrain.

FORAGE COMPOSITION

The fecal analysis for the four sheep populations revealed a diet pattern which seemed to reflect mostly the phenological plant development from spring to mid-summer. Sheep forced by deep snow to stay on high-elevation winter ranges until early summer (i.e. Ewin Ridge and Sheep Mountain populations), consumed proportionately more graminoids (59%) than sheep from lower montaine forests (28%). The diet of the latter at this time was dominated by forbs (57%) and shrubs (14%). In comparison, sheep from Subalpine-Alpine ranges used fewer shrubs (3%), but also utilized forbs (36%). Conifers constituted a low percentage of the diet for both range elevations, although more conifers were used on the higher ranges.

Forbs were second most important in the diet of Elk Valley Bighorns; they received a moderately higher use on the lower ranges. The comparison of diets on the two elevational ranges for the spring-early summer season by plant species indicates a distinct use of Festuca scabrella within graminoids (Table 4). On the higher elevation ranges Penstemon spp. receives highest use amongst forb species in contrast to Epilobium augustifolium on lower ranges. Again, this reflects mostly the availability of the plant species on the respective ranges in that season. It is interesting to note that sheep used both Sambucus spp. and Salix spp. in early spring and summer.

The summer-fall diet of sheep is dominated by graminoids on both elevational ranges (Table 5). Second most important are forbs which receive a moderately higher use on the lower elevation range. Shrubs and conifers are found in the diet on both ranges, but in negligible quantities. On a plant species level, it is interesting to note that fescues constitute 41% of the diet on the higher elevation range and 16% on the lower elevation range (Table 4). Further, there is a distinct shift in use of Penstemon spp. from spring to fall by elevation. In early summer, 21% is found in high-elevation samples versus 7% in late summer. The same species constitutes 9% of the sheep early-summer diet in lower elevation range and 14% in late summer on the same range.

The winter diet is dominated by graminoids. On Todhunter and Imperial ranges, more forbs are utilized than on the 500 m higher located Ewin Ridge and Sheep Mountain ranges (Table 6). A diet comparison by plant species shows

Table 4. Spring-early summer diet of Bighorn sheep by elevational range

	Subalpine-Alpine		Lower Montane Forests	
	Species	% Diet	Species	% Diet
GRAMINOIDS	Festuca scabrella	32.9%	Festuca scabrella	8.6%
	Poa spp.	8.3	Poa spp.	5.6
	Elymus spp.	4.3	Elymus spp.	3.2
	Phleum alpinum	5.7	Carex spp.	4.0
	Carex spp.	1.5	Phleum alpinum	5.1
	Other graminoids	6.4	Other graminoids	1.6
		59.1%		28.1%
FORBS	Penstemon spp.	20.8%	Epilobium angustifolium	15.9%
	Antennaria lanata	6.2	Anaphalis margaritacea	3.9
	Other forbs	8.7	Penstemon spp.	9.0
		35.7%	Antennaria lanata	2.1
			Dryas octapetala	2.3
			Unknown forb	2.0
			Other forbs	21.5
				56.7%
SHRUBS	Shrubs	2.5%	Sambucus spp.	6.0%
		2.5%	Salix spp.	4.5
			Other shrubs	3.9
				14.4%
CONIFERS	Conifers	2.7%	Conifers	0.8%
		2.7%		0.8%

Table 5. Summer-fall diet of Bighorn by elevational range

	Subalpine-Alpine		Lower Montane Forests	
	Species	% Diet	Species	% Diet
GRAMINOIDS	Poa spp.	11.1%	Festuca scabrella	16.4%
	Elymus spp.	4.8	Poa spp.	11.3
	Carex spp.	10.8	Festuca spp.	11.3
	Festuca spp.	41.1	Elymus spp.	8.1
	Other graminoids	5.7	Carex spp.	2.8
		73.5%	Agropyron spicatum	8.3
			Other graminoids	7.5
				65.7%
FORBS	Antennaria lanata	6.2%	Penstemon spp.	14.4%
	Penstemon spp.	7.0	Lupinus spp.	6.2
	Other forbs	8.4	Other forbs	6.5
		21.6%		27.1%
SHRUBS	Shrubs	3.5%	Shrubs	3.6%
		3.5%		3.6%
CONIFERS	Conifers	1.4%	Abies spp.	3.0%
		1.4%	Other conifers	0.6
				3.6%

Table 6. Winter diet of Bighorns by elevational range

	Ewin Ridge		Sheep Mountain		Todhunter-Imperial	
	Species	% Diet	Species	% Diet	Species	% Diet
GRAMINOIDS	Festuca scabrella	60.6%	Festuca scabrella	56.5%	Festuca scabrella	53.3%
	Poa spp.	11.7	Poa spp.	21.9	Poa spp.	14.7
	Carex spp.	5.1	Carex spp.	10.8	Carex spp.	2.0
	Agropyron spicatum	6.5	Other graminoids	6.7	Other graminoids	8.6
	Other graminoids	5.4		95.9%		78.6%
		89.3%				
FORBS	Antennaria lanata	2.3%	Forbs	4.1%	Antennaria lanata	8.7%
	Other forbs	6.3		4.1%	Penstemon spp.	2.0
		8.6%			Other forbs	9.1
						19.8%
SHRUBS	Shrubs	0.1%			Shrubs	1.6%
		0.1%				1.6%
MOSS	Moss	2.0%				
		2.0%				

highest use of Festuca scabrella for all winter ranges, reflecting the relative abundance of this species (Schuerholz, 1982).

Stelfox (1976) reports that for sheep wintering in high elevations in Banff, Jasper and Waterton Parks, fescues and wheatgrass are very important diet components, confirming the findings for the Elk Valley Study area.

A literature review of sheep diets suggests that sheep are opportunistic feeders and exhibit a varied diet, even over short distances, depending on the availability of forage species (Sudgen 1961, Schuerholz 1982). Of the approximately 100 plant species identified on the winter ranges in the study area, almost 50% have been used as food plants by Bighorns in other parts of British Columbia and the Western United States (Table 7).

Based on the fecal analysis relative values were assigned to plant species found in the fecal materials. The results show highest values for graminoids and forbs (Table 8). Shrubs and conifers have very low overall diet values. Fescues and bluegrasses have the highest overall values within graminoids. Penstemon spp. is the only forb with a moderately high overall value. Shrubs, conifers and bryophytes show low values for all seasons and ranges.

CONCLUSIONS

The relatively high quality of the winter range in the study area is attributed to the mostly fire-induced, herb-rich tall-grass meadows which predominate on south-facing slopes of all high altitude winter ranges in the Elk River Valley (Ogilvie 1978), the lack of competition with other ungulates and/or livestock, and most importantly, the favorable microclimatic conditions which keep the upper slopes free of snow through strong westerly winds (Schuerholz 1982).

The dietary fecal analysis suggests that the best year-long range is that which offers a wide variety of forbs, shrubs and grasses. The winter ranges in the study area offer a mixture of all three forage classes, and a large number of plant species known to be utilized by Bighorns in other areas. Given the high productivity of the Ewin Ridge alpine meadows (Schuerholz 1983) and the fact that alpine forage has been found to be more nutritious than that of conventional low elevation winter ranges (Hebert 1972), it may be concluded that the Elk Valley winter ranges can sustain healthy sheep populations as long as population densities can be controlled at current levels. Preliminary carrying capacity estimates for the sheep winter ranges indicate that the Ewin Ridge range is currently stocked below the level of carrying capacity (Schuerholz 1983). The survey data for the same population suggest that it has been stable for the past 10 years.

Assuming that winter range is the single most important factor controlling the sheep population, it can be concluded that the Elk Valley sheep herds from Ewin Ridge, Todhunter, Imperial and Sheep Mountain are not prone to a major die-off as long as densities are maintained at the current levels and no contagious diseases enter the population.

Table 7. Plant species found on the Elk Valley sheep winter ranges and used as food by Rocky Mountain and California Bighorn sheep[1] in other areas of British Columbia and the Western United States (from Schuerholz 1982)

Plant Species	Average Usage Rating*2	Range of Use*3	No. of times reported as food plants*4
GRASSES, SEDGES & RUSHES:			
Agropyron spicatum	high	-	11
Agropyron spp.	low	low-medium	8
Bromus spp.	low	-	2
Carex spp.	low	low-high	15
Elymus spp.	low	-	1
Festuca spp.	medium	low-high	17
Kobresia myosuroides	low	-	2
Koeleria cristata	low	low-medium	13
Luzula spicata	low	-	1
Poa spp.	low	low-high	17
FORBS:			
Achillea millefolium	low	-	9
(Allium cernuum)	low	-	2
(Anaphalis margaritacea)	low	-	1
Anemone spp.	low	-	2
(Antennaria microphylla)	low	-	1
Antennaria spp.	low	-	2
Antennaria umbrinella	low	-	1
Arenaria spp.	low	-	1
Artemesia spp.	medium	low-high	11
Aster spp.	low	-	2
Astragalus spp.	low	-	7
Bistorta vivipara	low	-	2
Cerastium spp.	low	-	1
Draba spp.	low	-	2
Epilobium angustifolium	low	-	1
Erigeron compositus	low	-	1
Erigeron spp.	low	-	6
Eriogonum spp.	low	-	6
Galium spp.	low	-	2
Hedysarum spp.	low	-	3
Heuchera cylindrica	low	-	2
Lithospernum ruderale	low	-	1
Lupinus spp.	low	-	11
Oxytropis spp.	low	-	5
Penstamon spp.	low	-	2
(Phacelia hastata)	low	-	2
Phacelia sericea	low	-	2
Polemonium spp.	low	-	1

(cont....)

Table 7 (cont.)

Plant Species	Average Usage Rating*2	Range of Use*3	No. of times reported as food plants*4
Potentilla spp.	low	-	1
Ranunculus spp.	low	-	1
Sedum spp.	low	-	1
Senecio spp.	low	-	4
Taraxacum spp.	low	-	3
TREES AND SHRUBS:			
Amelanchier alnifolia	low	low-medium	6
Arctostaphylos uva-ursi	low	-	10
Juniperus spp.	low	-	4
Picea engelmannii	low	-	2
Pinus contorta	low	-	5
Potentilla fruticosa	medium	low-high	3
Rosa spp.	low	-	9
Salix nivalis	medium	-	1
MOSSES AND LICHENS:			
mosses	low	-	2
lichens	low	-	2

*1 The four species in brackets were utilized only by California bighorn sheep.

*2 Plant species were ranked low, medium or high with regard to the level of use reported by each author. The overall average value is listed here.

*3 If a wide range of use was reported.

*4 Out of a total of 20 references: (Constan 1972), (Cowan and Guiget 1965), (Banfield 1974), (Berwick 1968), (Blood 1970), (Flook 1964), (Hebert 1973), (Honess and Frost 1942), (Keiss and Schoonveld 1974), (Morrison 1972), (Moser 1962), (Oldemeyer, et al. 1971), (Riggs 1977), (Schallenberger 1966), (Singleton 1976), (Smith 1954), (Stelfox 1976), (Sugden 1961), (Todd 1972), (Todd 1975).

Table 8. Relative values of plant species for Bighorn sheep

Species Name	Relative Forage Values*1										
	Winter				Spring-Early Summer			Summer-Fall			Overall
	E*2	S*3	T*4	$\bar{x}$*7	Sa*5	L*6	$\bar{x}$	Sa	L	$\bar{x}$	$\bar{x}$
GRAMINOIDS											
Festuca scabrella	+	+	+	+	+	0	+		+	0	+
Festuca spp.								+	+	+	0
Elymus spp.					-	-	-	-	0	0	-
Phleum alpinum					0	0	0				-
Carex spp.	0	+	-	0	-	-	-	+	-	0	0
Poa spp.	+	+	+	+	0	0	0	+	+	+	+
Agropyron spicatum	0			-					0	-	-
Other graminoids	0	0	0	0	0	-	-	0	0	0	0
FORBS											
Antennaria lanata	-		0	-	0	-	-	0		-	-
Penstemon spp.			-	-	+	+	+	0	+	+	0
Lupinus spp.									0	-	-
Epilobium angustifolium						+	0				-
Anaphalis margaritacea						-	-				-
Dryas octapetala						-	-				-
Unknown forb						-	-				-
Other forbs	0	-	0	0	0	+	+	0	0	0	0
SHRUBS											
Sambucus spp.						0	-				-
Salix spp.						-	-				-
Other shrubs	-		-	-	-	-	-	-	-	-	-
CONIFERS											
Abies spp.									-	-	-
Other conifers					-	-	-	-	-	-	-
MOSS	-			-							-

*1 Symbols used for relative forage values are:
+ highly valuable (over 10% of diet)
0 valuable (5-10% of diet)
- low value (less than 5% of diet)

*2 Ewin Ridge

*3 Sheep Mountain

*4 Todhunter - Imperial

*5 Subalpine - Alpine

*6 Lower Fording

*7 Statistical Mean

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MINERAL LICK USE BY DALL SHEEP IN THE WATANA CREEK HILLS, ALASKA

Nancy G. Tankersley, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99502.

ABSTRACT

A small isolated Dall sheep population in the Watana Creek Hills, Alaska, uses a mineral lick area in lower Jay Creek. This study was done in 1983 to document this lick use because the proposed Susitna River Hydroelectric Project would flood the lower reaches of Jay Creek. A minimum of 31% (at least 46 rams, ewes and young) of the estimated 1983 sheep population travelled 8 km (5 mi) or more from typical alpine range to the licks in the lower 6.5 km (4 mi) of Jay Creek. Sheep travelled through flatlands of shrubland and forest to this area even though another smaller lick with similar chemical anomalies was used within their alpine range. Lower Jay Creek contains a large rock bluff used for resting, feeding and licking, and several exposures of fine-grained soil in the creek valley which was eaten by the sheep. Soil samples from well-used lick cavities contained large ($\geq$ 1740 ppm) and significantly higher ($P<0.05$) amounts of sodium, the suspected lick attractant, than did soil collected away from lick sites.

INTRODUCTION

Studies of big game species near the proposed Susitna River hydroelectric development were begun in 1980 by the Alaska Department of Fish and Game (ADF&G). During preliminary surveys from 1980-1982, Dall sheep (Ovis dalli) were observed using mineral licks in a forested area of lower Jay Creek in the Watana Creek Hills, several km from typical alpine habitat (Tobey 1981, Ballard et al. 1982, Tankersley 1983). The lick area is adjacent to the proposed Watana impoundment which would flood lower Jay Creek up to 670.6 m (2200 ft). The hills contain a small (usually less than 200 individuals), relatively isolated, sheep population. Detailed studies on the use and importance of this area to sheep were begun in 1983.

Mineral licks are heavily used by Dall sheep in Alaska and Canada (Dixon 1939, Palmer 1941, Gross 1963, Pitzman 1970, Heimer 1973, Gill 1978). Some sheep have been documented to travel about 19 km (12 mi) to visit a lick before moving to summer range (Heimer 1973). Use of mineral licks occurs mostly in

spring and early summer (mid-May through mid-July in interior Alaska) (Fraser and Tankersley, in prep). Because of the apparent importance of mineral licks to Dall sheep in Alaska, Heimer (1973) recommended that licks be designated critical habitat areas.

Although various elements have been suggested as the one sought by ungulates at mineral licks, sodium is the most likely candidate (Stockstad et al. 1953, Hebert and Cowan 1971, Weeks and Kirkpatrick 1976, Weeks 1978, Fraser and Reardon 1980, Tankersley and Gasaway 1983).

The goal of this study was to document the use and importance of the Jay Creek lick to the Watana Creek Hills sheep population. This included observing and quantifying use of the lick area, classifying the sexes and ages of lick users, determining the seasonal timing of use, and chemically analyzing lick samples. Results were compared to sheep use of the East Fork slide lick, also in the Watana Creek Hills about 12 km (7.4 mi) north.

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STUDY AREA

WATANA CREEK HILLS

The Watana Creek Hills in the northeastern Talkeetna Mountains (Fig. 1) are approximately 52 km^2 (20 mi^2) in size and are roughly bisected by Watana Creek and an unnamed drainage. Elevations range from 914-1797 m (3000-5896 ft). The vegetation is predominantly black spruce (Picea mariana) with birch (Betula glandulosa) and willow (Salix spp) shrubs in the lower elevations, and alpine tundra in the higher elevations. Steep rocky cliffs are common in the central hills. Wolves (Canis lupus), brown bears (Ursus arctos), and in lower elevations, black bears (Ursus americanus) inhabit the area.

The Jay Creek mineral lick area occurs in the lower 6.5 km (4 mi) of the creek where elevations range from 579-914 m (1900-3000 ft). The vegetation is predominantly spruce woodland with scattered stands of deciduous trees, and birch/willow shrubland. About 3.2 km (2 mi) from the mouth on the west side is a large bluff with rock outcrops (Fig. 2). The Bluff extends along the creek for about 0.3 km (0.2 mi) rising to 777 m (2550 ft). The Bluff rock is mostly quartz biotite schist with feldspar inclusions in fracture zones and veins. Some soil occurs between the rock crevices and coats some rock surfaces and was

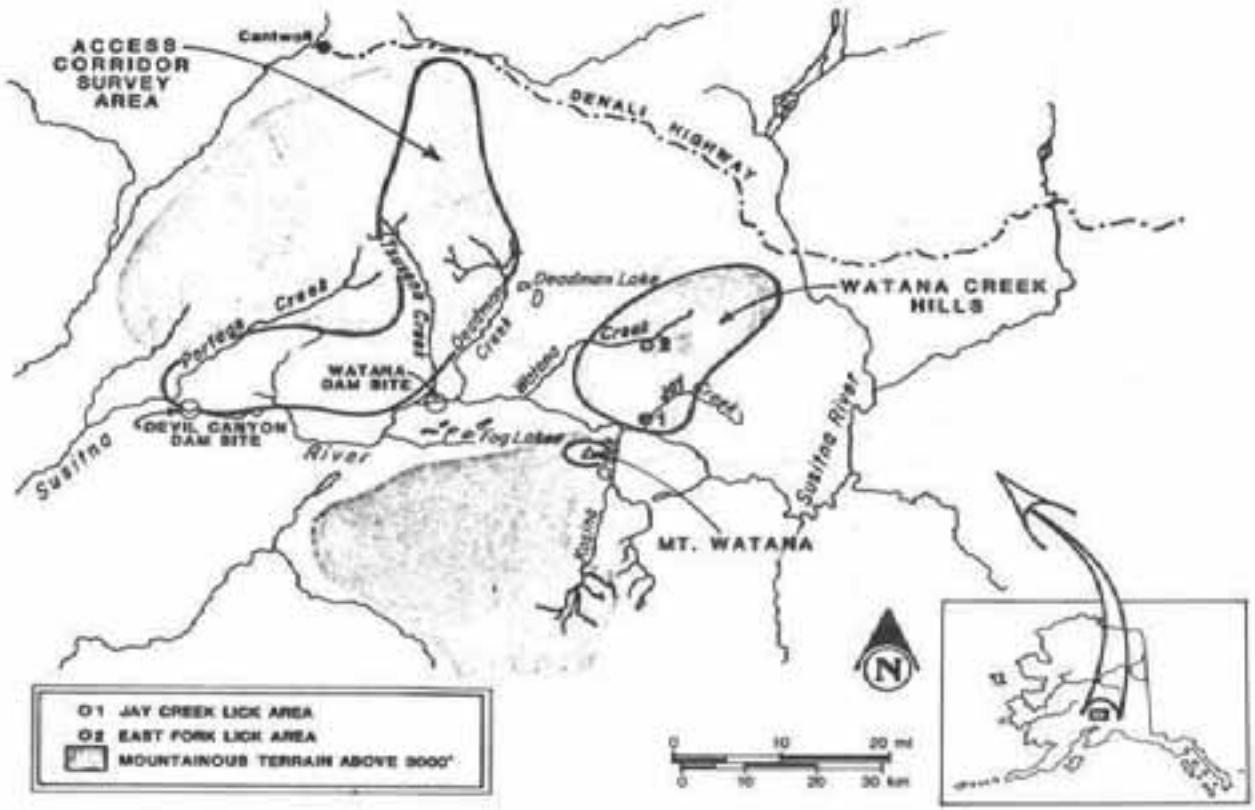

Fig. 1. Susitna River Hydroelectric study area.

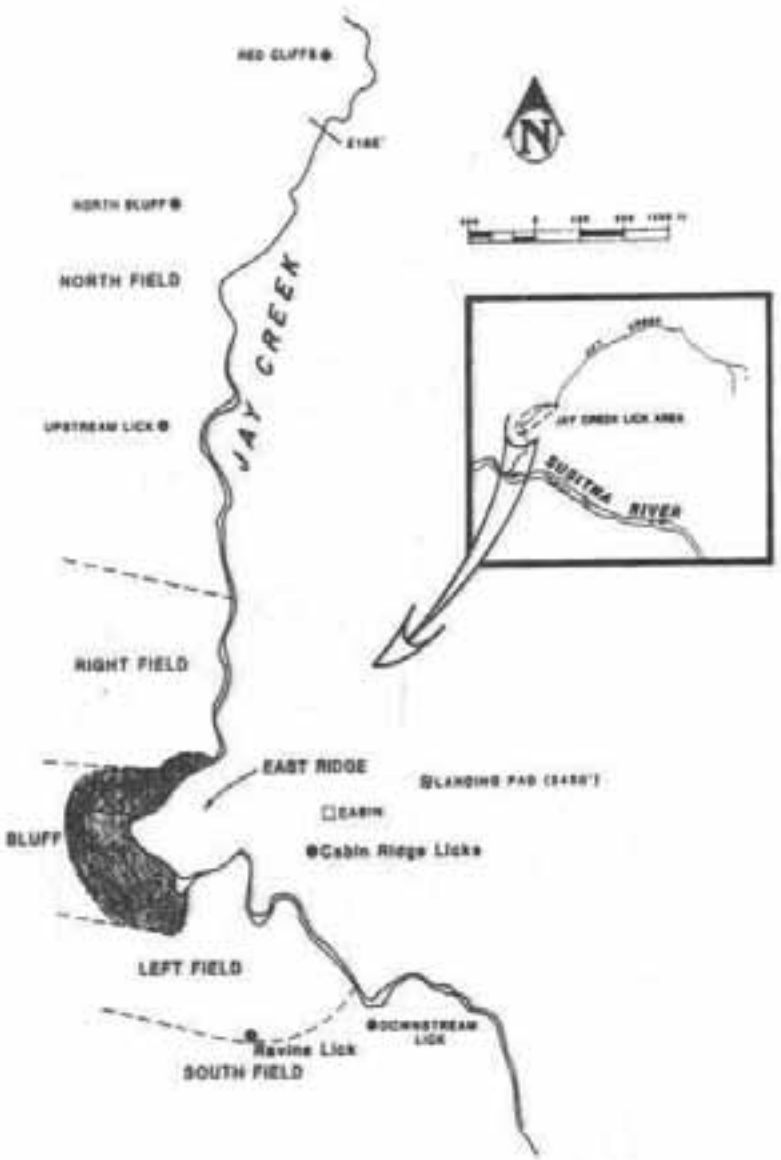

Fig. 2. Lower Jay Creek mineral lick area.

presumably the lick substrate used by sheep. At several places along the lower creek valley, soil banks are exposed. Some of these are very fine-grained deposits of glacio-lacustrine origin which were popular licking sites. Sheep had eaten so much soil at some of these exposures that they left small caves or cavities (on East Ridge, Cabin Ridge and South Field Ravine, Fig. 2). Archeological sites containing animal bones more than 4,000 years old have been discovered associated with several licks.

Another mineral lick is about 12 km (7.4 mi) north of the Jay Creek licks (Fig. 1) adjacent to the East Fork of Watana Creek. Sheep eat wet gray clay exposed in a small area on an unvegetated slide approximately 1067 m (3500 ft) in elevation. The clay probably originated in a shear/fracture zone in the bedrock. The slide is approximately 76 m (250 ft) at its base, rising 76 m (250 ft) high in a triangular shape and exposes metavolcanic rocks, predominantly metabasalts. The surrounding vegetation is predominantly alpine tundra with willows and alders (Alnus spp.) lining the creek slides. Steep, rocky cliffs are common in the area. Sheep live in the surrounding area year-round.

METHODS

SHEEP OBSERVATIONS

On 5 and 7 April 1983 21 sheep were color-marked on winter range in the Watana Creek Hills to facilitate identification of individuals at the Jay Creek and East Fork licks, and also to determine the distance travelled to the Jay Creek licks. Sheep were marked with paint-filled dart syringes fired from a Cap-Chur rifle or paint pellets fired from a Nel-Spot "007" pistol. A Bell 206 IIIB helicopter was used in the marking operation.

A detailed ground-based study of sheep in the Jay Creek lick area was begun 11 May and ended 11 July 1983. After 14 May, the area was observed from 0400-2100 hours daily, with a few exceptions due to rest periods, fog, helicopter logistics or lack of personnel. Observations were made from or near a small plywood cabin (Fig. 2) with the aid of 10 x 40 binoculars and a 20-45x spotting scope. Intermittent ground and aerial observations of the area were also made from 11 July - 10 August.

When sheep were seen in the area, the number of sheep in each location or lick site (Fig. 2) was recorded every ten minutes From these instantaneous scan samples (Altmann 1974), the location of each sheep recorded was assumed to last for 10 minutes. This provided an estimate of sheep-hours spent in certain locations. The sex, age, ram horn size, and time of all sheep entering or leaving the study area, as well as those present at 0400 hours, were recorded daily. Sheep in the lick area were categorized as: adult ewe, lamb, yearling, two-year old; $\geq$ 1/4-curl ram, $\geq$ 1/2-curl, $\geq$ 3/4-curl ram, or $\geq$ 7/8-curl ram. Ages and curl size were assessed by referring to drawings in Nichols (1972) and the Alaska Hunting Regulations No. 23 (1982-83). Young rams were distinguished from ewes by their genitals. Observations of color-marked sheep and other easily identifiable individuals were noted daily. Elevations of lick sites and other areas used by sheep were estimated with a Micro M-1 surveying altimeter.

Sheep using the East Fork slide lick were observed daily from 28 May-16 June, and from 22-24 June usually from 0400-2100 hours. The number of different sheep that used the lick, as well as their sex, age and curl size (rams') were recorded daily.

LICK SAMPLING AND ANALYSES

Forty-four soil and rock samples from lick areas and comparative sites were collected in the Watana Creek Hills during June and July for element analyses. Some well-used licks (East Ridge, South Field ravine, Cabin Ridge) had obvious cavities where sheep had eaten into the soil (Fig. 3), which made locating sampling sites easy. However, sites on the Bluff, and lesser used upstream and downstream sites did not have this feature, so exposed soil in the general vicinity of observed licking was taken. Jay Creek control samples were taken from exposed soil on unused sites, sometimes with a different color and texture, along the creek and other areas in the hills. Lick samples from the East Fork slide lick were taken from the two small sites where the clay was eaten. Control samples were taken from exposed soil on the slide which was not eaten by the sheep. Samples were collected with plastic utensils and placed in plastic bags to avoid contamination.

Samples were analyzed by the inductively-coupled argon plasma (ICAP) scan method for calcium, cobalt, chromium, copper, iron, potassium, magnesium, manganese, selenium, sodium, nickel, silicon, tin, vanadium, and zinc, plus 22 samples were analyzed by turbidimetric method for sulfate. All 44 samples were analyzed for water soluble cations, and 25 of these were also analyzed with a 4:1 reagent grade nitric: hydrocholoric acid leach for "total" elemental content. To normalize the results a $\log_{10}$ transformation of ppm levels was used before testing for differences in means (t-Test). To calculate means for elements from samples containing levels below detection limits, the sample level was assigned the maximum possible level (e.g., 0.09 ppm for aqua-regia digestion results, 0.04 ppm for water soluble results, 0.9 ppm for sulfate).

AERIAL SURVEYS

A late winter sheep distribution survey of the Watana Creek Hills was done with a Piper PA-18 Super Cub on 9 March 1983, and another survey to document summer distribution and to obtain a more complete population count was flown on 20 June 1983. All sheep observed on these surveys were classified by ram horn size, or as "ewes" (mostly ewes, yearlings and 2-year olds) or lambs, and their locations plotted on a 1:250,000 scale U.S.G.S. topographic maps.

RESULTS

AERIAL SURVEYS

Ninety-seven sheep (eleven rams and 86 ewes, sub-yearlings and two-year-olds) were recorded during the aerial survey on 9 March 1983. Most of the sheep were observed on wind-blown or south-facing slopes on the western end of the hills 11 km (7 mi) or more northwest of the Jay Creek lick area.

Fig. 3. Lick cavity in glacio-lacustrine soil. Hole at left is 15 cm in diameter.

On the 20 June survey a total of 149 sheep (34 rams, 96 ewes, yearlings and two-year-olds, and 19 lambs) were observed. Again, the majority of the sheep were found on the western end of the hills, however, one large group was observed east of the Jay Creek lick area in low rolling hills. The major concentration of lambs was north of Watana Creek, across from the East Fork lick.

JAY CREEK LICK AREA

Groups of sheep entered the lick area for the first time from the mountains to the north or northwest, a distance of at least 8 km (5 mi). Two color-marked sheep travelled at least that distance. Often, the Bluff was visited first, and then sheep would travel around the Bluff, South Field, East Ridge or upstream areas (Fig. 2) from a few days up to 2 weeks. Only one group of sheep (6 ewes and 1 lamb) were ever seen venturing south of the downstream lick (Fig. 2) for 2 hours on 17 June. Sheep spent 14% of the time below 671 m (2200 ft), the maximum impoundment level,1 and 46% of the time below 701 m (2300 ft). Most of the well-used lick sites are located between 671-701 m.

Most sheep were observed returning to the north or northwest. However, sheep frequently used the area east of Jay Creek after 30 May. Twenty-nine sheep were seen in the low rolling hills about 4 km (2.5 mi) east of the Bluff during the aerial survey 20 June. Observations of sheep near bluffs along the Susitna River during May and June 1982-84 indicate that additional lick sites may occur up to 20 km (12.4 mi) east of the Jay Creek area. The area east of Jay Creek is characterized by gentle topography and nearly complete snow cover from October to April and is not used as winter range.

From 11 May-11 July up to 31 different sheep were seen daily in the Jay Creek mineral lick area (Fig. 4). By adding the highest number of different sheep seen in each sex-age class at any time, a minimum of 46 different sheep using the Jay Creek licks was calculated. Some recognizable individuals (two color-marked and others) stayed 2-15 days. Some sheep made at least two trips to the lick area from the hills to the north.

Rams used the area exclusively from 11-28 May and most ram use occurred before 14 June (Fig. 4). Large groups of ewes and yearlings appeared on 29 May. The numbers of ewes and yearlings in the study area dropped on 1 June, then slowly increased with another peak during 16-18 June. Lambs first appeared in the study area during this second peak. Lick use declined by late June although a few sheep were still coming to the lick area as late as 10 August.

EAST FORK SLIDE LICK

Because this lick is within the typical alpine summer range of these sheep, they did not have to travel a long distance to use this lick. Consequently, sheep would visit the East Fork slide lick for hours rather than days at a time. No color-marked sheep were noticed in the East Fork area, but other recognizable sheep made repeated lick visits in a day. Up to 37 different sheep were observed at the lick per day from 28 May-16 June and 22-24 June (Fig. 5). By adding the highest number of sheep seen in each sex-age class per day, at least 47 different sheep used the lick during this period. No sheep were identified to use both Jay Creek and East Fork slide licks, although this may have occurred.

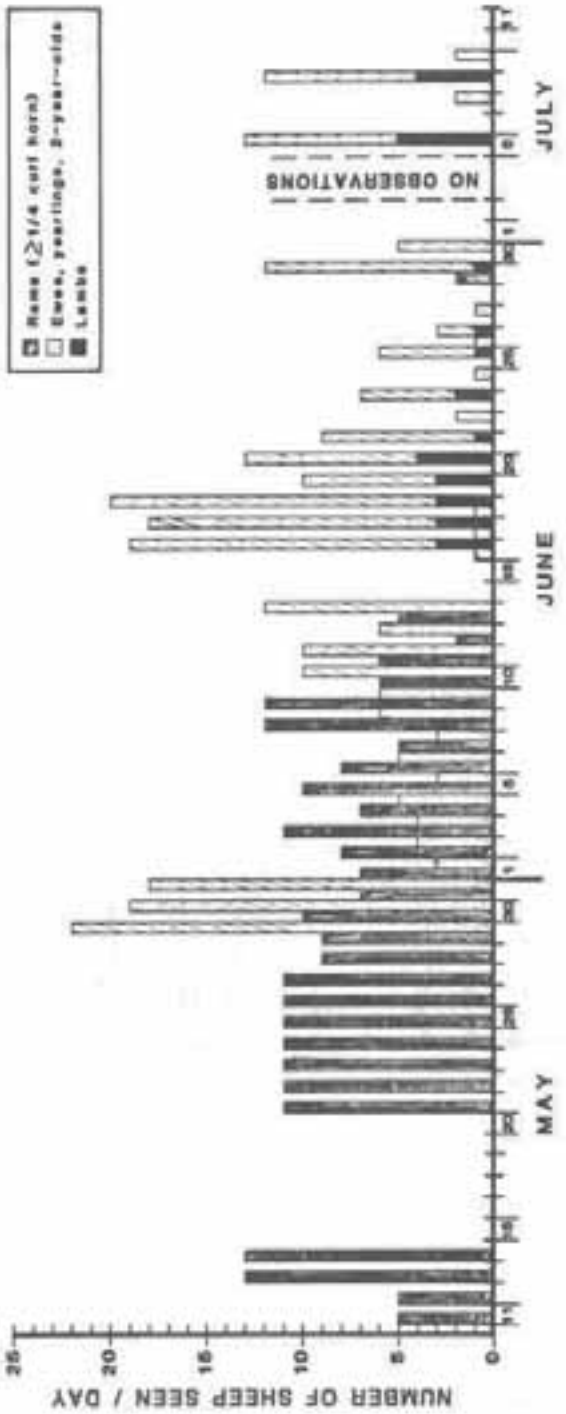

Fig. 4. Sheep seen at Jay Creek lick per day.

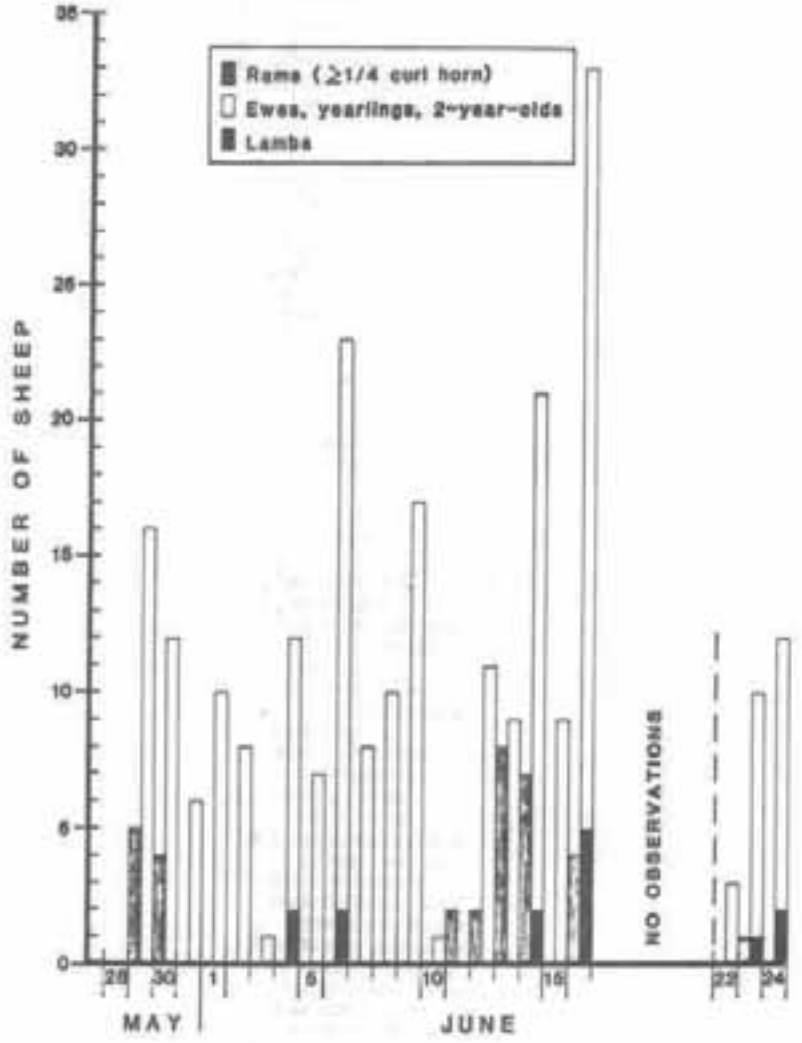

Fig. 5. Sheep seen at East Fork slide lick per day.

Possibly because observations began later, ram use of the East Fork slide licks was much lower than at Jay Creek (Table 1), and was nonexistent during 31 May-10 June (Fig. 5). The majority of rams observed on the 20 June aerial survey were east of Jay Creek and none were in the vicinity of the East Fork slide lick. Use by ewes and yearlings was higher at the East Fork slide lick (Table 1). Although the mountains north of Watana Creek were a major nursery area, only two groups (of 5 and 11 ewes, yearlings and lambs) were seen crossing Watana Creek from the north to visit the East Fork lick.

Table 1. Average number of different sheep seen per day per hour of observation for East Fork and Jay Creek licks from 28 May to 16 June and 22-24 June.

	Rams	"Ewe" Group	TOTAL
East Fork	0.09	0.67	0.76
Jay Creek	0.35	0.43	0.78

LICK ANALYSES

Samples from well-used Jay Creek lick cavities (East Ridge, Cabin Ridge and South Field Ravine) were significantly higher ($P < 0.05$) in "total" sodium and chromium, and somewhat higher ($0.10 < P < 0.05$) in "total" copper, iron and magnesium, compared to control samples (Table 2). The lick samples also contained higher ($P < 0.05$) amounts of water soluble sodium, magnesium, calcium, sulfate and phosphorus (Table 3).

Samples from well-used lick cavities were also higher ($P < 0.05$) in water soluble sodium, magnesium and phosphorus than Bluff samples (Table 3). Water soluble calcium was also somewhat higher ($P = 0.56$) in the lick cavity samples compared to Bluff samples. Not enough Bluff samples were analyzed for "total" elemental content to compare with lick cavity results. Soil from the lick cavities was very fine-grained whereas the Bluff soil collected was much coarser and no lick cavities were found on the Bluff to accurately pinpoint licking sites. These chemical and physical differences shed doubt on the accuracy of selecting the Bluff lick sample locations.

Lesser used lick sites were significantly higher ($P < 0.05$) in "total" calcium and manganese (but not sodium or magnesium) than control sites and copper was somewhat higher ($0.05 < P < 0.10$) (Table 2). Water soluble sodium, magnesium, calcium and sulfate were higher in the lesser used lick sites compared to control samples ($P < 0.05$, Table 3).

Water soluble sodium, magnesium and phosphorus were also significantly higher ($P < 0.05$) in the East Fork slide lick samples compared to control samples, along with several other elements (Table 4). However, unlike the Jay Creek licks, water soluble silicon and iron were the two most abundant elements

Table 2. Mineral element results (ppm) from aqua-regia digestion of soil samples taken from Jay Creek lick and control sites.[a/]

Sample #	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Si	Sn	V	Zn
						Lick Cavities								
3	10,200	20	40	100	44,000	1,300	18,700	625	2,800	30	200	5.0	110	105
4	7,500	17	30	100	35,000	410	14,600	475	1,740	25	420	0.6	84	90
7	9,470	20	40	99	38,700	640	17,370	790	3,410	30	200	<0.10	100	94
8	15,100	16	30	82	30,500	725	14,650	520	3,960	28	264	<0.10	86	79
19	11,100	16	33	77	30,100	1,110	14,560	456	1,785	27	280	<0.10	82	78
20	10,600	16	36	70	33,170	1,200	13,120	500	1,750	29	225	<0.10	88	85
$\bar{x}$	10,662	17.5	35[b/]	88[c/]	27,919[c/]	898	15,500[c/]	561	2,574[b/]	28	265	0.99	91.7	88.5
						Low Use Sites								
17	11,100	16	37	70	35,560	1,380	12,400	560	1,090	30	120	<0.10	92	88
18	11,230	15	31	60	32,300	1,230	11,200	520	1,000	26	175	<0.10	85	76
21	18,220	16	24	46	30,900	420	12,200	545	675	24	228	<0.10	81	58
22	19,500	13	23	45	26,940	425	11,870	464	945	21	217	<0.10	81	54
23	22,740	23	44	138	49,860	865	25,500	905	500	38	98	<0.10	108	130
24	29,700	28	52	145	18,840	645	26,630	1,050	385	42	139	<0.10	124	126
27	13,560	12	15	77	23,990	535	9,670	375	1,140	14	277	<0.10	62	45
28	11,800	12	16	65	24,200	550	9,135	420	940	12	390	<0.10	74	50
$\bar{x}$	17,231[b/]	16.8	30.3	80.8[c/]	30,312	756	14,826	605[b/]	834	26	206	0.09	88	78
						Bluff								
13	6,320	22	23	170	45,150	620	13,830	690	155	25	175	<0.10	105	74
14	10,450	15	25	84	37,200	320	9,740	429	840	22	249	<0.10	87	63

(continued on next page)

Table 2 (cont'd).

Sample #	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Si	Sn	V	Zn
	Control Sites													
16	6,200	17	24	100	33,970	230	13,460	448	180	28	215	<0.10	84	80
29	11,560	16	37	50	30,600	780	10,800	560	1,225	25	270	<0.10	95	68
31	6,190	8.9	22	28	18,980	550	5,100	280	765	16	895	<0.10	55	110
32	14,100	7.8	20	40	16,000	990	6,670	228	1,260	17	182	<0.10	42	58
44	6,685	14	27	44	28,100	1,050	10,560	515	685	22	125	<0.10	72	83
$\bar{x}$	8,947	12.7	26	52	25,530	720	9,318	406	823	21.6	337	0.09	70	80

a/ Se was not detected in any of these samples (<0.10 ppm)

b/ Means calculated from log (10) transformations were significantly higher ($P<0.05$) than means from control samples.

c/ Means calculated from log (10) transformations were somewhat higher ($0.10<P<0.05$) than means from control samples.

Table 3. Water soluble mineral elements and sulfate (ppm) from samples taken from Jay Creek lick and control sites.

Sample #	Ca	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Se	Si	SO_4	V	Zn
						Lick Cavities									
1	16	<0.05	<0.05	8.8	4.7	7.9	0.12	30	<0.05	0.10	<0.05	11		<0.05	<0.05
2	14	<0.05	<0.05	2.0	3.7	6.2	<0.05	30	<0.05	<0.05	<0.05	6.9		<0.05	<0.05
3	52	<0.05	0.18	3.4	2.8	34	0.06	465	<0.05	0.34	<0.05	9.3	665	<0.05	<0.05
4	530	<0.05	0.14	0.29	5.6	250	<0.05	360	<0.05	0.80	<0.05	5.0	2450	<0.05	<0.05
6	560	<0.05	0.08	0.13	5.9	101	0.07	330	<0.05	0.43	<0.05	9.0		<0.05	<0.05
7	250	<0.05	0.08	0.33	2.6	121	<0.05	760	<0.05	0.27	0.27	6.6	2600	<0.05	<0.05
8	590	<0.05	0.18	0.16	6.5	300	0.18	750	<0.05	1.0	0.22	7.1		<0.05	<0.05
19	290	<0.05	<0.05	0.13	5.2	360	<0.05	130	<0.05	0.63	<0.05	4.6	2300	<0.05	<0.05
20	360	<0.05	<0.05	0.09	5.4	190	<0.05	180	<0.05	0.50	<0.05	5.7	2050	<0.05	<0.05
$\bar{x}$	296[a/]	0.04	0.09	1.7	4.7	152[a/]	0.07	337[a/]	0.04	0.46[a/]	0.09	7.2	2013[a/]	0.04	0.04
						Low Use Sites									
17	40	<0.05	<0.05	0.52	4.5	8.5	<0.05	16	<0.05	<0.05	<0.05	6.1		<0.05	<0.05
18	22	<0.05	<0.05	0.90	4.5	7.2	<0.05	11	<0.05	<0.05	<0.05	7.2		<0.05	<0.05
21	25	<0.05	<0.05	0.46	2.9	3.7	<0.05	2.4	<0.05	<0.05	<0.05	4.8	<1.0	<0.05	<0.05
22	27	<0.05	<0.05	1.0	3.0	3.9	<0.05	2.4	<0.05	<0.05	<0.05	5.3	16	<0.05	<0.05
23	465	<0.05	<0.05	0.29	7.9	125	<0.05	13	<0.05	0.25	<0.05	2.9	1000	<0.05	<0.05
24	185	<0.05	<0.05	0.24	5.0	33	<0.05	4.0	<0.05	<0.05	<0.05	2.5	800	<0.05	<0.05
25	23	<0.05	0.13	3.1	3.0	9.8	<0.05	6.3	<0.05	0.12	<0.05	9.5		<0.05	<0.05
26	26	<0.05	0.14	4.3	2.6	4.2	0.05	4.9	<0.05	<0.05	<0.05	12		<0.05	<0.05
27	480	<0.05	<0.05	0.15	11	295	<0.05	245	<0.05	0.64	<0.05	1.9	1950	<0.05	<0.05
28	48	<0.05	0.05	3.7	6.3	2.7	0.11	6.7	<0.05	0.17	<0.05	5.2		<0.05	<0.05
$\bar{x}$	134[a/]	0.04	0.06	1.5	5.1	49.3[a/]	0.05	31.2[a/]	0.04	0.14	0.04	5.7	753[a/]	0.04	0.04

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Table 3 (cont'd).

Sample #	Ca	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Se	Si	SO_4	V	Zn
							Bluff Soil								
9	75	<0.05	<0.05	0.38	6.6	26	<0.05	4.8	<0.05	0.08	<0.05	2.6		<0.05	<0.05
10	48	<0.05	0.07	1.0	1.8	4.5	<0.05	6.0	<0.05	0.09	<0.05	6.4		<0.05	<0.05
13	39	<0.05	0.72	35	3.2	14	1.2	3.1	0.06	0.07	<0.05	47	<1.0	<0.05	0.14
14	44	<0.05	<0.05	1.4	1.1	2.8	<0.05	9.9	<0.05	<0.05	<0.05	9.6	<1.0	<0.05	<0.05
$\bar{x}$	52	0.04	0.22	9.4	3.1	11.8	0.33	5.9	0.05	0.07	0.04	16.4		0.04	0.07
							Bluff Rock (Crushed)								
11	24	<0.05	0.07	2.7	1.9	2.5	0.08	9.6	<0.05	0.15	<0.05	5.1		<0.05	<0.05
12	30	<0.05	0.06	0.37	1.3	1.9	<0.05	3.8	<0.05	0.10	<0.05	1.3		<0.05	<0.05
							Control								
15	30	<0.05	0.08	5.5	2.6	2.8	0.10	0.85	<0.05	<0.05	<0.05	8.0		<0.05	<0.05
16	3.0	<0.05	0.09	9.1	1.6	1.1	0.44	0.50	<0.05	<0.05	<0.05	8.4	<1.0	<0.05	<0.05
29	26	<0.05	0.10	17	4.0	7.4	0.28	1.9	<0.05	0.08	<0.05	21	20	0.05	0.09
30	32	<0.05	0.12	24	6.8	10	0.43	1.4	<0.05	0.33	<0.05	31		0.08	0.14
31	15	<0.05	<0.05	3.6	3.2	1.7	0.17	2.7	<0.05	0.14	<0.05	3.8	<1.0	<0.05	<0.05
32	17	<0.05	0.06	11	6.1	4.4	0.08	0.8	<0.05	<0.05	<0.05	12	<1.0	<0.05	<0.05
40	1.9	<0.05	0.05	1.0	1.6	0.27	0.15	2.4	<0.05	0.06	<0.05	2.7		<0.05	<0.05
41	2.2	<0.05	0.05	1.0	1.3	0.29	0.06	3.4	<0.05	0.10	<0.05	2.9		<0.05	<0.05
42	11	<0.05	<0.50	0.14	8.0	2.2	0.05	3.4	<0.05	<0.05	<0.05	1.8		<0.05	<0.05
43	2.3	<0.05	<0.05	0.39	1.9	0.65	<0.05	5.1	<0.05	0.12	<0.05	2.1		<0.05	<0.05
44	150	0.19	0.88	135	14	60	5.5	4.4	0.27	0.32	<0.05	139	140	0.43	1.1
$\bar{x}$	26.4	0.05	0.18	18.9	4.6	8.3	0.67	2.4	0.06	0.12	0.04	21	32	0.08	0.15

a/ Means calculated from log (10) transformations were significantly higher ($P<0.05$) than means from control samples.

Table 4. Water soluble mineral elements and sulfate (ppm) from soil samples taken from the East Fork lick and control sites.[a/]

Sample #	Ca	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Si	SO_4	V	Zn
	East Fork Lick													
33	87	4.1	1.8	645	29	510	3.3	245	0.86	0.96	315		4.0	0.46
34	90	<0.05	1.4	270	40	300	2.6	255	0.60	0.61	200	230	1.2	0.25
35	21	1.2	0.4	245	33	150	1.7	115	<0.05	0.35	820		1.9	<0.05
36	38	2.0	0.56	465	33	300	2.9	150	<0.05	0.79	1750	200	3.8	<0.05
$\bar{x}$	59	1.8	1.04[b/]	406[b/]	34[b/]	315[b/]	2.6[b/]	191[b/]	0.39	0.68[b/]	771[b/]		2.7[b/]	0.20
	East Fork Control													
37	5.8	<0.05	<0.05	6.9	1.5	1.8	0.40	1.6	<0.05	<0.05	5.8		<0.05	<0.05
38	18	<0.05	<0.05	0.22	1.8	1.1	<0.05	1.2	<0.05	<0.05	1.1	<1.0	<0.05	<0.05
39	14	<0.05	<0.05	0.14	3.7	13	<0.05	0.30	<0.05	<0.05	1.7	4.0	<0.05	<0.05
$\bar{x}$	12.6	0.04	0.04	2.4	2.3	5.3	0.16	1.03	0.04	0.04	2.9		0.04	0.04

[a/] Se and Sn were not detected in any of these samples (<0.05 ppm).

[b/] Means calculated from log (10) transformations were significantly higher ($P<0.05$) than means from control samples.

in the East Fork samples. The laboratory staff reported that they were unable to completely filter out or centrifuge the extremely fine particles from the water leach. Consequently, some of the elements reported may be high because of this phenomenon. Not enough samples were analyzed for "total" elemental content to compare the East Fork slide lick and control sites statistically (Table 5).

DISCUSSION

The Jay Creek lick area adjacent to the proposed Watana impoundment is used by a large proportion of the sheep population in early summer. At least 31% of the observed 1983 population used the Jay Creek lick area, and up to 31 individuals (21% of the population) were seen in the lick area at one time. Rams used the licks by mid-May, followed by pregnant or barren ewes and yearlings, with ewe-lamb groups arriving after June 15. This pattern is similar to those reported for mountain goats (Hebert and Cowan 1971), Dall sheep (Heimer 1973), and moose (Tankersley and Gasaway 1983). Sheep travel some distance to use this lick as both winter and summer surveys located most of the population 11 or more km (7 mi) from the Jay Creek lick area. Two color-marked sheep travelled 8 km (5 mi) to the Jay Creek lick area between April and late May. Although Heimer (1973) reported that sheep have travelled greater distances to a lick, this travel was within typical alpine habitat which included cliffs for escape (W. Heimer, Alaska Dept. Fish and Game, pers. comm.). In contrast, the Jay Creek lick area and much of the main travel corridor is atypical sheep habitat, being relatively flat with low shrubland and trees and little escape habitat from predators.

It appears that the essential macro-elements of sodium, magnesium and calcium are the predominant components. Sulfate was also a major water soluble component. Of these elements and compounds, sodium is most likely the main attractant. High levels of sodium are often reported from natural licks (Fraser and Tankersley, in prep.) and sodium is the only element that has been shown to be selected for by ungulates at lick sites (Stockstad et al. 1953, Fraser and Reardon 1980). Essential microelements such as copper may also be important lick elements. Indications of a copper deficiency in Alaskan moose have been reported (Flynn et al. 1977), but more studies are needed to demonstrate a link between trace element deficiency and lick attraction. Water soluble cations would certainly be available for sheep digestive intake. However, the acid in the rumen is not as strong as that used for "total" elemental content and not all of the elements released by aqua-regia digestion would be metabolically available to sheep.

While the East Fork slide lick had higher "total" sodium levels (as well as magnesium and calcium) than did the Jay Creek licks, sheep still endured the danger of travel to the Jay Creek lick and visited it at a rate similar to the East Fork slide lick. This may be because water soluble elements at Jay Creek are more important, or because of the limited size of the East Fork licking area, or due to habit, earlier spring phenology, or some other benefit of the Jay Creek area. Also, the similar visitation rates may not necessarily reflect the same amount of licking done in each area. This is because sheep visit the East Fork slide lick for hours rather than days at a time (like at Jay Creek). In any case, the significant use of the Jay Creek area in addition to the East Fork slide lick is well documented, but not well understood.

Table 5. Mineral element results (ppm) from aqua-regia digestion of soil samples taken from the East Fork lick and control sites. a/

Sample #	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Si	V	Zn
East Fork Lick														
34	30,200	27	90	92	40,770	510	39,100	1,050	8,150	105	135	110	97	47
36	49,000	42	115	114	64,700	590	69,500	1,440	13,400	10	140	645	155	65
East Fork Control														
38	31,370	29	34	346	48,540	180	21,340	930	345	42	545	160	149	82
39	21,530	39	<0.10	400	58,900	385	17,400	1,960	70	42	345	610	<0.10	125

a/ Se and Sn were not detected in any of these samples (<0.10ppm).

The proposed impoundment may affect sheep use of the Jay Creek licks. Sheep spent a large proportion of time (46%) below 701 m (2300 ft) where most of the lick sites were located. The area below 671 m (2200 ft) would be directly affected by the impoundment; erosion below 701 m may eliminate some lick sites, but may also expose new ones. Flooding and mudslides and ice shelving in the impoundment and drawdown zone (629-671 m) may inhibit sheep from crossing Jay Creek to readily use licks, escape cliffs and feeding areas on both sides. Also, disturbance from timber removal within the impoundment area and possible increased recreational use of the area may hinder sheep use. Archeological finds in the immediate vicinity should encourage caution about disturbing these licks which may have been used by sheep for a very long time.

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STATUS AND FOOD HABITS OF JAPANESE SEROW

Seiki Takatsuki, Biological Institute, Faculty of Science, Tohoku University, Sendai, 980, Japan.

Kazuo Suzuki, Biological Institute, Faculty of Science, Tohoku University, Sendai, 980, Japan.

ABSTRACT

Japanese serow (Capricornis crispus)once used to be an "animal of mystery", but recent studies have been revealing its ecology and other biological aspects. The distribution of this ungulate shows a good correspondence with that of the deciduous broad-leaved forest zone in the northern half of Japan except Kokkaido Island. This species is principally a forest dweller. It is territorial and forms small groups (three individuals at most). The population has been increasing since 1959 when the supervision of poaching was tightened, and recently the damage on plantations has become a social problem. Accordingly, culling was begun in central Japan in 1976. Rumen contents of 124 Japanese serows collected in the winter of 1979-1980 were analyzed by the point frame method. The analysis revealed that browse is the most important constituents (57.0%), and among them, Chamaecyparis obtusa, a planted conifer, contributed as much as 27.0% of the diet. Sasa spp., dwarf bamboos, were also important and accounted for 27.2%. Besides these, the following items were important in several samples: conifers such as Abies spp., Tsuga spp., Cryptomeria japonica, Pinus spp., Thujopsis dolabrata, evergreen broad leaves such as Ilex crenata and I. pedunculosa, sedges and ferns. Based on this analysis together with other studies, we considered Japanese serow to be a "browser".

INTRODUCTION

Food habit studies are a prerequisite for understanding the ecology of wildlife and for its management. Prior to the analysis of the rumen contents of Japanese serow (Capricornis crispus), we focused on the following two questions:

Firstly, we intended to examine whether the Japanese serow was a browser or a grazer. Recent studies on feeding ecology of ungulates (e.g. Bell 1971;

Jarman, 1974; Estes, 1974; Hanley, 1982) have found a general trend in their body size, habitat use, behavior and social organization. According to them, small ungulates living in dense forests, being territorial, forming small groups, are in terms of food habits browsers or concentrate selectors. On the other hand, larger ungulates living in open habitats, being non-territorial, forming larger groups are grazers or bulk and roughage eaters. This tendency was also confirmed by anatomical studies on digestive organs (Hofmann, 1968; 1973; Kay et al., 1980). Based on these syntheses, we can expect the Japanese serow to be a browser, because the information on this species support that it is a forest dweller, is territorial and principally solitary (Akasaka and Maruyama, 1977; Sakurai, 1981). The information on the food habits were, however, only qualitative (Akasaka and Maruyama, 1977; Suzuki et al., 1978), and some quantitative reports dealt with only small samples (Yamaguchi et al., 1974: Chiba and Yamaguchi, 1975; Miyao, 1976).

Secondly, we intended to examine the occurrence or contribution of dwarf bamboos in the dietary composition. These plants are unique in that they grow abundantly on the forest floors and that they are evergreen. Therefore, we can expect them to be important forages for the serow. However, the information to support this assumption is quite insufficient.

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GENERAL STATUS OF JAPANESE SEROW IN JAPAN

In the 1960's, no scientific information was available on the ecology of Japanese serow, and it used to be called "the animal of mystery". Scientific studies were begun in the 1970's and have been progressively revealing its ecology.

The distribution of the Japanese serow shows a good correspondence with that of deciduous broad-leaved forests in the cool temperate zone of northern Japan, except Kokkaido which is not inhabited by this ungulate (Fig. 1). This species can live even in the deep snow area, which is different from another ruminant - Sika deer (Cervus nippon). In Kyushu and Shikoku, the distribution is restricted to higher mountains. Japanese serows live solitarily, in pairs or in pair-offspring units. They are territorial and their home ranges seldom overlap (Akasaka and Maruyama, 1977; Sakurai, 1981).

The population of Japanese serow once decreased and in 1934 this species was designated as an endangered animal and has been legally protected. The supervision of illegal hunting was strictly tightened from 1959, and since then the population has been gradually recovering. On the other hand, for the last two decades many roads were constructed even into high mountains and natural forests were clear-cut for plantation on a large scale. As a result, the damage on planted trees, e.g., Chamaecyparis obtusa and Cryptomeria japonica, by Japanese serow became a social problem in the later 1970's. Following this situation, a population control was begun in central Japan in 1976. This control will be conducted in more localities in the future.

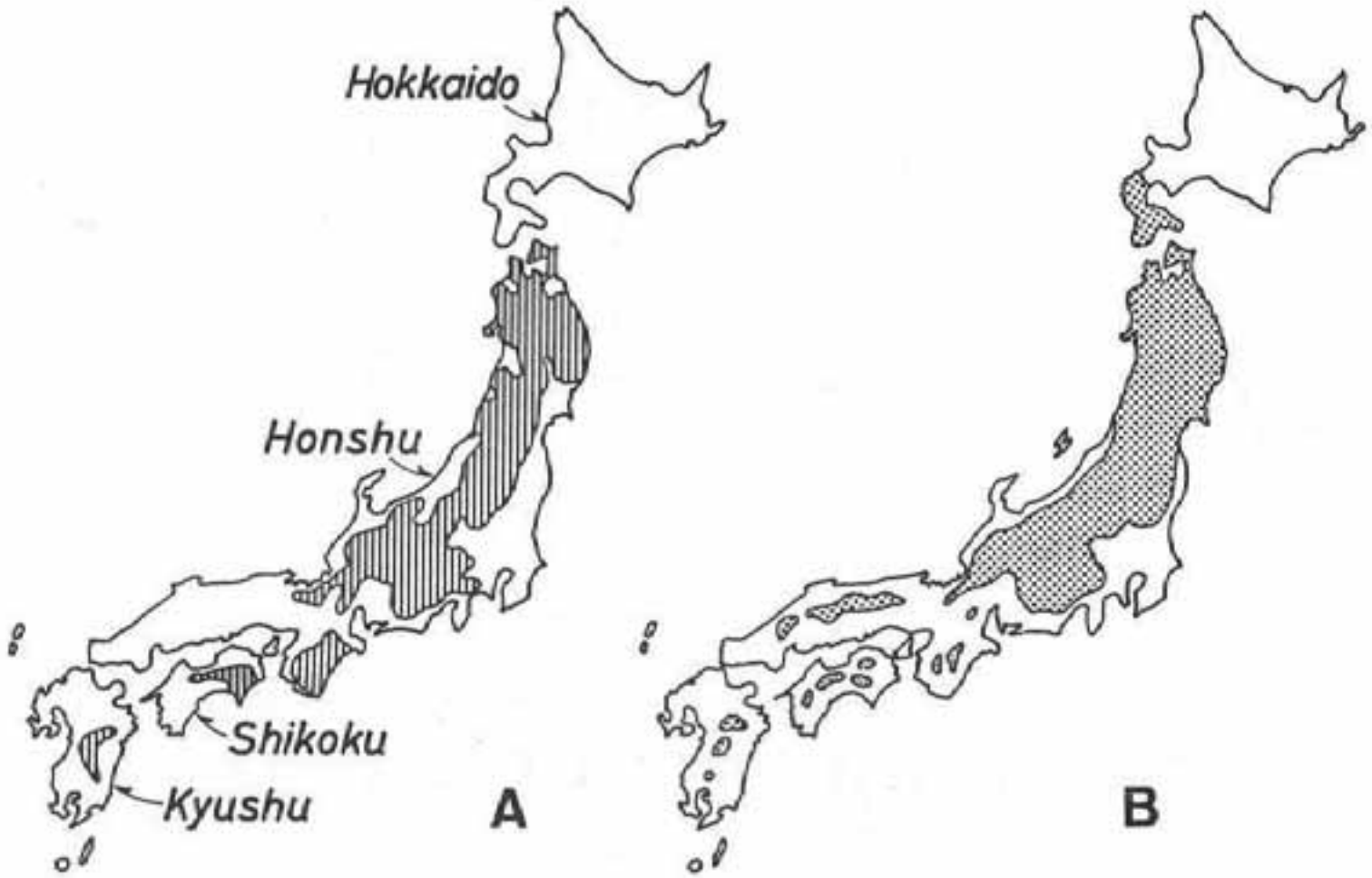

Fig. 1. Distributions of Japanese serow (A) and deciduous broad-leaved forest (B). After Furubayashi et al. (1979) and Yoshioka (1973).

METHODS

A hundred and twenty-four samples of rumen contents of Japanese serow were collected from animals shot for population control from Gifu and Nagano Prefectures, central Japan (Fig. 2) from December, 1979 to early April, 1980.

Rumen contents of about 500 ml were sampled and stored in ethyl alcohol (over 60%). These rumen contents were washed through a 2.0 mm mesh screen, and residues were analyzed by the point frame method (Leader-Williams et al., 1981; Chamrad and Box, 1964). Plant fragments were spread uniformly over a laboratory dish with grid of 5 mm interval, and the points covered by the fragments were scored for each category. Up to 400 points were counted for each sample. Plant fragments were identified to genus and species if possible, otherwise, they were assigned to forage categories listed below.

I. Browses
   - Conifers
   - Broad-leaves
   - Unidentified browses

II. Graminoids
   - Dwarf bamboos
   - Grasses, sedges and others

III. Others
   - Forbs, ferns and unidentified materials

RESULTS

GENERAL TREND

Table 1 shows the results of rumen contents analysis. In terms of forage classes (browses, graminoids and others), "browses" were the most important constituents to make up as much as 57.0%. Among them, coniferous leaves accounted for 31.4%. "Graminoids" occupied about one third of the total and "others" occupied only a small portion.

Table 1. Composition of rumen contents (N = 124).

Item	Mean	±	S. E. (%)
Browses	57.0	±	25.6
Conifers	32.8	±	17.4
Chamaecyparis obtusa	27.0	±	18.1
Broad-leaves	20.8	±	18.4
Undentified browses	3.5	±	5.3
Graminoids	35.5	±	25.7
Dwarf bamboos	27.2	±	24.5
Grasses, sedges & othes	8.3	±	14.6
Others	7.5	±	13.7

Fig. 2. Location map of sampling sites.

MAJOR FORAGE PLANTS

Chamaecyparis obtusa was the most important constituent as a single species to account for as much as 27.0% (Table 1). This species is one of the native conifers of this area, but its supply as a forage for the Japanese serow has been increasing because of the enlargements of the plantation areas in this species' habitat. It was ascertained by the present analysis that Chamaecyparis obtusa was eaten by the serow and that the proportion in the diet was substantial.

Other coniferous trees were important in several samples. Twenty-four samples contained conifers other than Chamaecyparis obtusa for more than 10%; Abies spp. in 7 samples, Thujopsis dolabrata in 6 samples, Cryptomeria japonica in 5 samples, Tsuga spp. in 2 samples, Pinus spp. in 2 samples and unidentified conifers in 1 sample. Table 2 shows the mean values and frequencies of these species. It is noteworthy that though the mean values were small, if occurring the proportion (x/F in Table 2) were usually larger. It suggests that these trees do not occur constantly in the serow's habitat, but if they are found by the serow, they are eaten in considerable amounts.

Table 2. Mean value and frequency of coniferous species found in rumen contents (N = 124).

	Mean value X	Frequency F	Σ X/F
Chamaecyparis obtusa	27.0	124	27.0
Abies spp. & Tsuga spp.	2.8	35	9.8
Pinus spp.	0.8	21	4.4
Thujopsis dolabrata	1.1	16	8.1
Cryptomeria japonica	1.3	14	11.5

Dwarf bamboos made up 27.2% of the dietary composition. This forage category contains several Sasa spp. including Sasa kurilensis and S. palamata and possibly Sasamorpha borealis. These results support our second assumption that dwarf bamboos will be important in the diet of the serow.

TRIANGULAR ORDINATION

Each sample is plotted in the triangular diagram according to its composition (Fig. 3). Most plots concentrate on and around the line connecting browses (B) and graminoids (G). According to the distributional patterns, the plots are categorized into the following types.

i) Browse Type

Many points are concentrated in the corner B (browses). Of the 47 samples, 32 samples were occupied by Chamaecyparis obtusa for more than 25%. Other important species were Abies spp., Cryptomeria japonica and other evergreen broad-leaved trees.

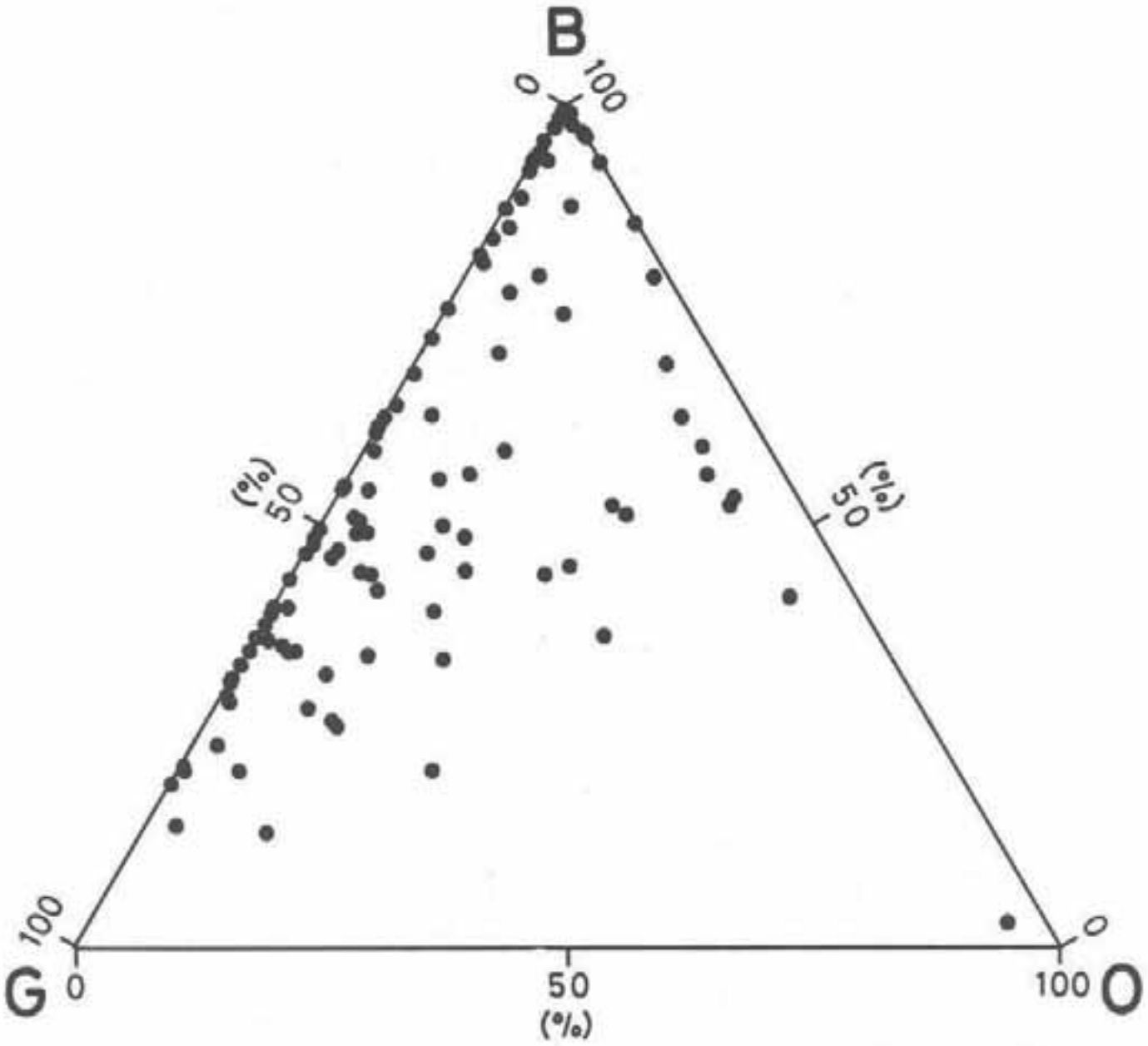

Fig. 3. Triangular ordination of rumen contents. B: Browses, G: Graminoids, O: Others

ii) Browse-Graminoid Type

Another concentration is recognized around the central part of the line BG, which means in these samples browses and graminoids were codominant. Forty (32.3%) samples belong to this type. Among them, the combination of dwarf bamboos and Chamaecyparis obtusa was most frequently found. Other important constituents were Tsuga spp., Cryptomeria japonica, Pinus parvi-flora and Abies spp.

iii) Graminoid Type

Graminoids were predominant in 29 samples (23.4%), and most of them were dominated by dwarf bamboos.

iv) Other Types

Only eight samples were not categorized into these types. The main compositions were as follows.

No. 14: Chamaecyparis obtusa: 30.5%, ferns: 25.8%, Thujopsis dolabrata : 10.5%.
No. 20: evergreen broad-leaves: 40.8%, ferns: 36.3%.
No. 31: ferns: 31.3%, deciduous broad-leaves: 20.5%, dwarf bamboos: 16.0%.
No. 69: ferns: 68.0%, Chamaecyparis obtusa: 23.5%.
No. 81: ferns: 35.3%, Chamaecyparis obtusa: 28.0%.
No.105: ferns: 93.0%.
No.114: ferns: 42.0%, deciduous broad-leaves: 19.8%, Thujopsis dolabrata: 19.3%.
No.328-2: Chamaecyparis obtusa: 44.1%, Shortia sp. (Diapensiaceae, evergreen forb: 31.3%.

DISCUSSION

The distribution of the Japanese serow mostly corresponds to that of deciduous broad-leaved forests (Fig. 1). In these areas, the seasonal changes in climate and plant phenology are sharp and clear. Most plants are dormant in winter, and therefore this is the critical season for the wildlife living there. This is the reason why the rumen contents of Japanese serow in central Japan contained many evergreen plants including Chamaecyparis obtusa and other coniferous trees, dwarf bamboos, Ilex spp., sedges and ferns.

The results of this analysis indicate that browse was the most important constituent in the winter diet of Japanese serow in central Japan. Among the browse, Chamaecyparis obtusa and other native conifers were important, which suggests that the serow potentially has the food habits to utilize them. Before our analysis, Yamaguchi and Takahashi (1979) synthesized the information on the food habits of Japanese serow. They listed 15 kinds of conifers and 19 kinds of evergreen broad-leaved browse species, and pointed out that they were important forage plants especially in winter. The present results together with other fragmental information support our first assumption that the Japanese serow is a browser. They also support the indication by Schaller (1977, p.287) that Capricornis spp. are selective in food habits among the

subfamily Caprinae, and also support the generality of the socio-ecological theory proposed by Bell (1977), Jarman (1974) and Estes (1974).

Our second assumption was the importance of dwarf bamboos in the diet of Japanese serow. The results of this analysis showed that they contributed as much as 27.2%, which verified our expectation. Dwarf bamboos grow densely on forest floors in the cool temperate zone of northern Japan. This type of forest, for example Fagus crenata forest, is one of the most characteristic vegetation types of Japan. It is true that the contribution of dwarf bamboos was large in the diet, but since their availability as forage is also substantial, we cannot conclude that they are preferred by Japanese serow. Much is left to study on the interrelations between dwarf bamboos and Japanese serow.

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FOOD HABITS OF DALL SHEEP ON REVEGETATED COAL STRIPMINE SPOILS IN ALASKA

Charles L. Elliott, Agricultural Experiment Station, 301 O'Neill, University of Alaska, Fairbanks, AK. 99701.

Jay D. McKendrick, Agricultural Experiment Station, University of Alaska, Palmer, AK. 99645.

ABSTRACT

The food habits of Dall's sheep (Ovis dalli dalli) grazing on revegetated coal stripmine spoils in Alaska were examined from 1980-82. Red fescue (Festuca rubra) and bluejoint (Calamagrostis canadensis), seeded native grasses, comprised 49 percent and 10 percent of the summer diet, and 40 percent and 15 percent of the winter diet, respectively. The presence of escape terrain, benches, and windblown areas in winter may encourage Dall sheep use of these reclaimed areas.

INTRODUCTION

The value of stripmined lands as wildlife habitat in the contiguous United States has been studied for many years (Yeager 1942, Riley 1954 Samuel 1979). Characteristics of surface mined lands that are considered attributes of good wildlife habitat may be: topographic diversity, diversity of vegetation, interspersion of microhabitats and open water areas (Suchecki and Evans 1978). If wildlife management options involving reclamation are to be promoted, their value and feasibility must be established. It must be demonstrated that creation of good wildlife habitat is an attainable product of reclamation, can be economically feasible, and is a viable land use alternative. These attributes have been demonstrated for surface mined lands in the coal areas of eastern and western portions of the United States but such information for Alaska is scarce. The purpose of this study was to provide baseline data concerning wildlife responses to, and use of, revegetated stripmine lands in Alaska. The specific objective was to document the food habits of Dall's sheep utilizing revegetated stripmine spoils on the Usibelli Coal Mine, Inc., in Interior Alaska.

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DIET REVIEW

To understand how the food items ingested by Dall's sheep on reclaimed coal mine spoils compare with items consumed on native ranges, a review of Dall's food habits in Alaska was necessary. Viereck (1963) observed Dall's sheep in the Tonzona River and Mt. Hayes area of Alaska. The forage species taken were quantified as 'occasionally, commonly, or abundantly utilized'. Most of the 47 food plants listed were summer forages and included: Epilobium latifolium, Artemisia arctica, Anemone parviflora, Poa alpina, Achillea borealis, Trisetum spicatum, Salix reticulata, Festuca altaica, and Kobresia myosuroides.

Whitten (1975) studied the habitat relationships of Dall's sheep in Denali National Park and Preserve. He observed feeding sheep and recorded plant species consumed. During summer, Salix glauca, S. arctica, S. planifolia, Boykinia richardsonii, Arnica alpina, Artemisia alaskana, Dodecatheon frigidum, Saxifraga davurica, and Oxyria digyna were eaten. Winter foods were determined by examining feeding craters. Within the craters, bunchgrass (mostly alpine fescue (Festuca altaica)) seemed to be the item most often grazed. Winters (1980) reported grasses and sedges comprised the bulk of items identified in the rumens of two sheep collected in winter near Sheep Creek in the Tanana River drainage.

The most detailed account of Dall's sheep diets within Alaska is that of Nichols and Heimer (1972). They used the microhistological technique to determine the seasonal food habits of three sheep herds located along the Kenai River drainage. Sedges, alpine fescue and other grasses made up most of the summer diets on all areas. The use of sedge decreased markedly by midwinter, while the use of alpine fescue increased. Consumption of other grasses, including red fescue (Festuca rubra), alpine sweetgrass (Hierochole alpina), and Poa spp., was fairly constant throughout the year. Shrubs, mainly willows, made up a small portion of the diet throughout the year, with somewhat decreased use in spring. Mosses and lichens were evident in the winter diets.

Heimer (1983) determined the botanical composition of spring and winter rumen contents for two sheep populations in the Alaska Range. The Dry Creek Herd (located 40 km east of the Usibelli Mine) consumed mainly graminoids. Grasses and sedges comprised 69 percent and 74 percent of rumen contents in spring and winter, respectively. The diet of the Robertson River population (located 300 km east of Dry Creek) was similar to the Dry Creek herd in its consumption of grasses and sedges in winter (56%), but the Robertson River herd supplemented their spring diet of graminoids (50%) by ingesting the basal portions of oxytropes (24%).

STUDY AREA

The study area was the Usibelli Coal Mine, Inc., located near Healy, Alaska, within the northern foothills of the Alaska Range (Figure 1). Elevations in the region range from 396-914 m. The region is dissected by a number of streams, the largest being Healy Creek (Figure 2).

Much of the vegetation existing on the study area is within five broadly defined vegetation associations that correspond to the Level II classification of Viereck and Dyrness (1980) (Figure 3). The conifer forest cover type is a combination of open and closed spruce forest. The open spruce forest is located on upland terraces and consists of sparsely distributed low-growing spruce and low-to-prostrate shrubs. Principal trees and shrubs include black and white spruce (Picea mariana and P. glauca), quaking aspen (Populus tremuloides), mountain cranberry (Vaccinium vitis-idaea), willow (Salix spp.), birch (Betula spp.), blueberry (Vaccinium spp.) and alpine bearberry (Arctostaphylus alpina). The closed spruce forest is characterized by dense stands of mature spruce occurring along drainages, ridges, terraces, and south-facing slopes.

The tall-shrub cover type consists of an alder (Alnus crispa) - willow (Salix alaxensis) association. This habitat occurs most frequently at the bases of north-facing terraces and along creek drainages and floodplains. The tall-shrub cover type was also prevalent on the sites disturbed by mine-related activities (e.g. road building, active mining) that were never reclaimed but allowed to revegetate via natural succession.

The disturbed, revegetated cover type represents the sites on the mine that have been seeded with graminoids and forbs (Table 1). A reclamation

Table 1. Seed mixture applied to revegetated area used as range by Dall's sheep on the Usibelli Coal Mine, Healy, Alaska. Area seeded in 1972.

Plant Species Seeded (Common Name)
Alopecurus pratensis (Meadow Foxtail)
Agropyron cristatum (Crested Wheatgrass)
Bromus inermis (Manchar Bromegrass)[a]
Calamagrostis canadensis (Bluejoint)[a]
Festuca elaitor (Meadow Fescue)
Festuca ovina var. duriuscula (Hard Fescue)
Festuca rubra (Boreal Red Fescue)[a]
Lolium perenne (Tetraploid Perennial Ryegrass)
Lolium temulentum (Common Annual Ryegrass)
Medicago sativa (Alfalfa)
Phalaris arundinacea (Reed Canarygrass)
Phleum pratense (Climax Timothy)[a]
Poa pratensis (Kentucky Bluegrass)[a]
Trifolium hybridum (Alsike Clover)
Trifolium repens (White Dutch Clover)

a: indicates species still present in 1980.

Fig. 1. Location of Healy study region, southcentral Alaska.

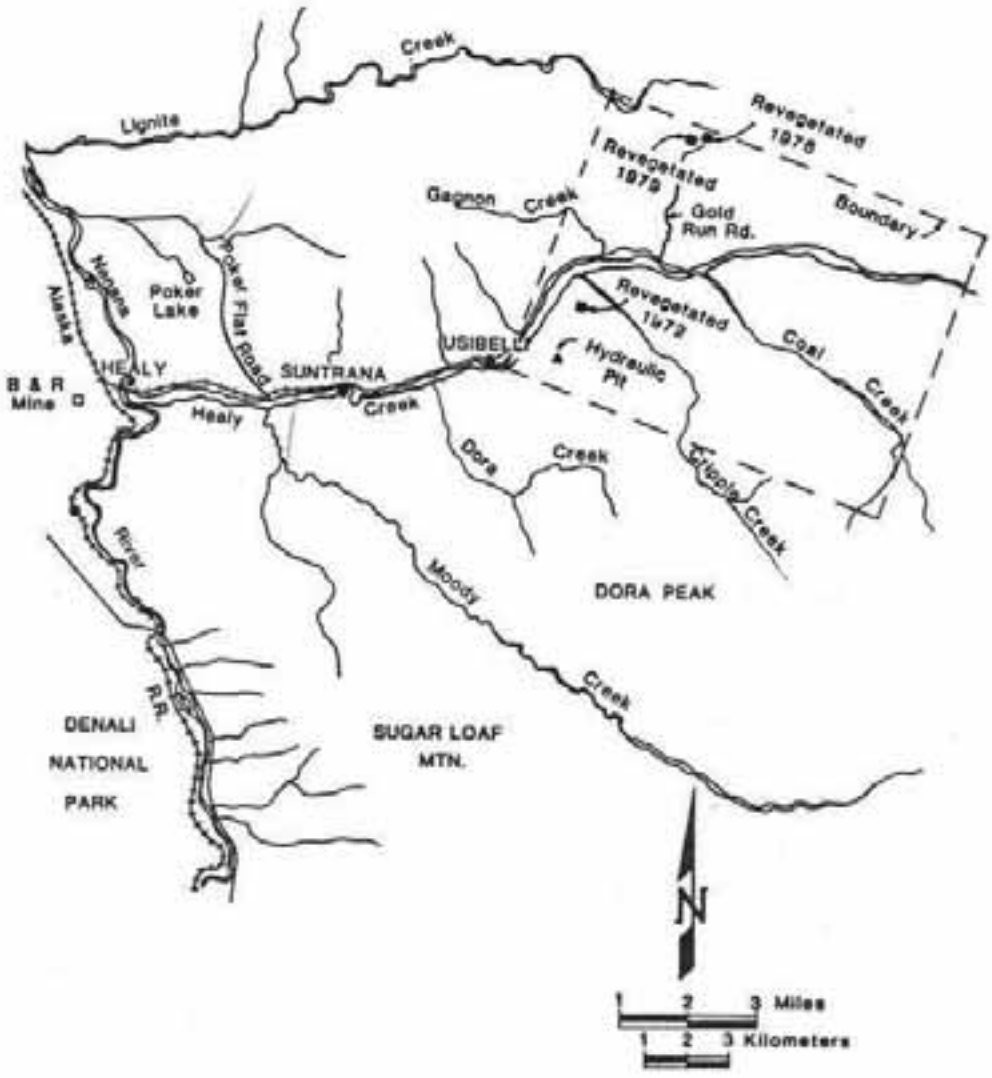
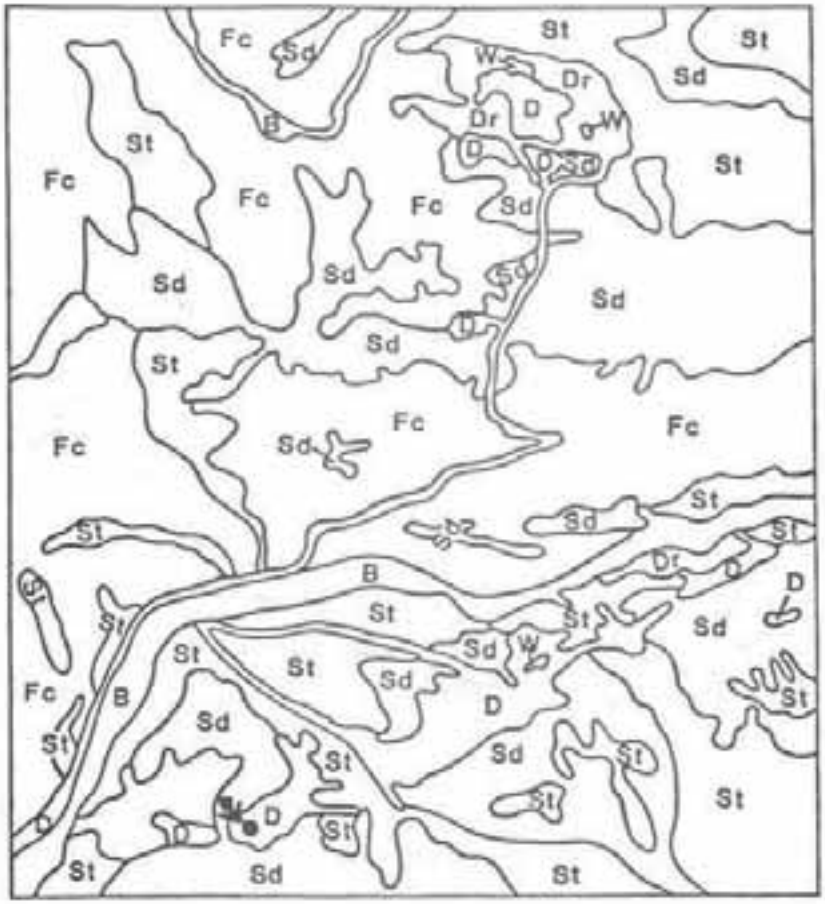


Fig. 2. Location of Usibelli Coal Mine, Inc.



LAND COVER TYPES

Fc	Conifer Forest
St	Tall Shrub
Sd	Shrub Tundra
D	Disturbed – unreclaimed
Dr	Disturbed – revegetated
B	Barren Flood Plain
W	Water

N

0 1 MILES

0 1 KILOMETERS

Fig. 3. Cover type classification of principal study area. Region outlined by dashed line on Fig. 2 represents the area depicted in this figure. Arrow indicates the Hydraulic Pit area.

program was instituted in 1972 on the Usibelli Mine. At present there are approximately 1000 ha of reclaimed land. The disturbed, unreclaimed cover type represents areas which have been disturbed by mining but are not yet reclaimed. The areas support little to no vegetation.

The shrub tundra cover type was typified by the glandular birch (Betula glandulosa) and ericaceous shrub-sedge association.

The region on the Usibelli Mine used to the greatest extent by Dall's sheep is an area known as the 'Hydraulic Pit'. Revegetated in 1972, the Hydraulic Pit area resembles a 'stair step' configuration; a large, flat expanse of revegetated grasses that terminates in a 30-50 m highwall. At the base of the highwall is another flat area of seeded grasses.

METHODS

Botanical composition of the diet of Dall's sheep was determined by the microhistological examination of fecal material (Hansen and Flinders 1969). Holechek et al. (1982) reviewed the advantages and disadvantages of using fecal analysis for diet determination.

Two alterations were made in the procedure of Hansen and Flinders (1969). Diet slides were prepared using Naphrax high resolution diatom mounting medium instead of Hertwig's and Hoyer's solution. Five slides per fecal sample, and 20 locations per slide were examined to estimate the major species in the diet (Holechek and Vavra 1981).

Fecal pellets for diet analysis of Dall's sheep were collected in two ways. In winter, bands of sheep on the mine area were located twice a month. The locations of fresh fecal pellets were noted and the pellets collected after the animals moved to another area. This process was repeated until 20 fresh fecal samples per month were collected. During summer, sheep use of the Usibelli Mine was low, the number of animals sighted per observation on the area during this time ranged from 1-9. Trying to find and follow sheep for pellet collection in summer proved impractical. To acquire feces for diet analysis, 30, 4 m^2 circular plots were located in areas frequented by sheep during the summer of 1980. These plots were marked with painted wooden stakes and cleared of pellets on 11 May, 1981, and cleared again on 29 August, 1981. The 13 pellet groups collected were used to represent the summer diet.

The percent composition of each plant species identified in the diet was determined following the method outlined by Holechek and Gross (1982). The frequency of each plant species identified was divided by the total number of observations for all species. This number multiplied by 100 estimates the percent, by weight, composition of the diet.

RESULTS AND DISCUSSION

FOOD HABITS

Dall's sheep used the Hydraulic Pit area of the Usibelli Mine primarily as winter range. Winter and summer diets of sheep on the mine were primarily

composed of grasses (Table 2). Seeded red fescue and bluejoint (Calamagrostis canadensis) were the most important items in the diet, comprising 49 and 10 percent of summer diets, and 40 and 15 percent of winter diets respectively. This consumption of grasses parallels reported winter use of graminoids by sheep on the Kenai Peninsula (Nichols and Heimer 1972) and in interior Alaska (Murie 1944, Whitten 1975).

Table 2. Food habits (estimated percent dry weight of the diet) of Dall's sheep utilizing the revegetated Hydraulic Pit area, Usibelli Coal Mine, Healy, Alaska. Number of fecal pellet groups examined are given in parentheses.

Food Item	Summer Diet May-August, 1981-82 (N=13)	Winter Diet Sept.-April, 1981 (N=160)
Festuca rubra	49	40
Calamagrostis canadensis	10	15
Melilotus spp.	T	5
Vaccinium spp.	T	1
Chenopodium album		1
Rubus chamaemorus	2	1
Salix spp.	3	3
Medicago falcata	T	3
Brassica campestris	2	T
Descurainia sophioides		T
Pedicularis capitata	2	
Lepidium densiflorum		T
Arctagrostis latifolia	T	T
Parnassia palustris		T
Valeriana capitata	T	
Artemisia tilesii		T
Betula glandulosa		T
Moss/Lichen	18	8
Unknown Forbs	11	23
Unknown Graminoids	2	2

T: indicates trace amount, less than 1%.

Sheep foraged on the reseeded Hydraulic Pit area for varying lengths of time. Bands were identified by noting individuals with distinctive characteristics such as the length of broken horns or body scars. Groups of sheep were observed foraging on the seeded area for 2-5 days and then sighted 3-15 kms away feeding in windblown areas. Well-used trails leading from the Hydraulic Pit to cratered sites near Healy Creek and along the ridge between Cripple and Dora Creeks were additional evidence of foraging outside reclaimed

areas. The large portions of both summer and winter diets composed of unknown forbs (Table 2) was felt to result from feeding outside the study area.

Dall's sheep are not noted for their use of lichens and mosses. The high occurrence of mosses and lichens (Table 2) in the sheep diets at Usibelli was considered to have resulted from the accidental ingestion of these materials while feeding and a bias in the technique. Mosses are easily overestimated by the microhistological technique because they fragment more than other plants; even tiny moss particles are easy to identify. Dearden et al. (1975) reported high numbers of moss fragments can cause the underestimation of other forages. Dearden et al. (1975) found that mosses were completely indigestible, and thus of insignificant nutritional importance in digestion trials with reindeer (Rangifer tarandus), cattle (Bos spp.) and bison (Bison bison).

HABITAT USE

The attractiveness of the reclaimed areas as sheep winter range was documented during this study. Dall's sheep normally migrate to high elevation ranges in summer (Murie 1944, Hoefs and Cowan 1979). Dall's sheep at Usibelli exhibited similar habits. They left the mine in spring and summer, and returned in the autumn and winter to graze on the reclaimed areas near the Hydraulic Pit and on adjacent native range.

In their study of Dall's sheep in the Yukon Territory, Canada, Hoefs and Cowan (1979) observed that the intensity with which wintering areas were used depended on the proximity of the areas to escape terrain. Almost all low elevation winter ranges they examined had escape terrain nearby. Exceptions were mineral licks or large open areas where approaching predators could be easily detected. They also noted the importance of preferred bedding sites, areas along canyons or on elevated spots which allowed surveillance of the surrounding area. The Hydraulic Pit area conforms to Hoefs' and Cowan's description of a desirable winter range. The flat revegetated areas are adjacent to steep walled terrain that is readily used by the sheep to escape predators (personal observation). Additionally, the presence of narrow bench-like areas provides ideal bedding sites which the sheep predictably use. These bedding sites, with their view of the surrounding area, further exemplify similarities between the Hydraulic Pit and native winter range.

The proximity of the wintering area to human activity, which may deter predator (e.g. wolf) activity, vertical topography for bedding sites and escape routes, and the tendency for the area to be kept snowfree by wind, have all served to enhance the attractiveness of the mine site to the local sheep population.

Of the graminoids used for revegetation in Alaska, red fescue and bluejoint were the species most consumed by Dall's sheep. However, the presence of desirable habitat characteristics and the availability of nearby native range for supplemental feeding may be greater factors governing Dall's sheep use of reclaimed mine spoils on the Usibelli Mine than are the plant species seeded for reclamation.

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"COOPERATIVE" NURSING BY BIGHORN EWES ON THE NATIONAL BISON RANGE

Christine C. Hass, Department of Zoology, University of Montana, Missoula, Montana 59812.

ABSTRACT

Observations of individually marked bighorn ewes and lambs (Ovis canadensis) on the National Bison Range in Montana revealed that, in 1982 and 1983, lambs were obtaining 32-85 percentage of suckles from ewes that were not their mothers. Two ewes in each 1982 and 1983 lost their own lambs and continued to nurse all lambs in the nursery band. One ewe in 1982, and 3 ewes in 1983 nursed their own as well as all other lambs. Lamb survivorship was only 10 and 27 percent in 1982 and 1983. Possible effects of kinship, inbreeding, and parasites, and factors influencing lamb survivorship are discussed.

Alloparenting, that is the care of a conspecific young other than one's own, has been reported in some 120 mammalian and 150 avian species (Reidman 1982). Alloparental care ranges from "babysitting" or guarding behavior, in which a female may stay with a group of youngsters while the mothers forage away from the group, to actual adoption of another's young.

Usually considered altruistic, alloparental care may have some selective benefits to the donor in the form of beneficial parental experience, increased inclusive fitness, reciprocal altruism, or exploitation of fostered young (see Reidman 1982). Cooperative care could be favored if the inclusive fitness of the individuals involved was enhanced, and might be expected in groups with relatively high degrees of relatedness between group members (Hamilton 1964).

Alloparenting, especially allomothering, appears to be rare in ungulates, and chiefly consists of "babysitting" behavior (Reidman 1982). "Cooperative nursing" in which a mother knowingly provides milk to an alien young, is distinct from "thief suckles", in which a young mammal obtains milk from an alien mother apparently without her knowledge. Thief suckling is common in reindeer (Rangifer tarandus; Espark 1971) and occasional in giraffes (Giraffa camelopardalis; Dagg 1970, MacClintock 1973). Cooperative nursing has been reported in chital (Axis axis; Schaller 1967), collared peccaries (Tayassu tajacu; Byers and Bekoff 1981), African lions (Panthera leo; Schaller 1972) and both African elephants (Loxodonta africana) and Asiatic elephants (Elaphus maximus; Eisenburg 1972).

Many ungulate females bring their precocial young into so-called "nursery bands" (Espmark 1971, Geist 1971, Estes 1974, Lent 1974, Schaller 1977, Cluttonbrock et al 1981). In many cases, these appear to be groups of unrelated females, characterized by mother and infant attachment and lack of cooperative care (Gubernick 1981b, and references therein). Several authors

have commented on the exclusiveness of the mother-young attachment in wild sheep (Ovis spp.). Urial ewes (Ovis orientalis) reject alien young (Schaller 1977), as do most bighorn ewes (Geist 1971, Shackleton 1973, Horejsi (1976). VOvis Both Shackleton (1973) and Horejsi (1976), working with bighorn sheep in Canada, have commented on the reduction in fitness a ewe would suffer by nursing alien young.

This report documents repeated instances of bighorn ewes nursing alien young, behavior which may or may not fall in the category of "cooperative care" (Hamilton 1964).

METHODS

Study Population

In 1983, fifty-two bighorns, 21 rams and 31 ewes, lived on the National Bison Range. These animals were descendants of 12 sheep that were introduced onto the refuge in 1922. The National Bison Range (NBR), in northwestern Montana, is a National Wildlife Refuge of 7504 ha. (19,000 ac.). The refuge is surrounded by a 2.4 m game fence that prevents immigration or emigration of the wild ungulates. All ungulates maintained within the refuge (elk (Cervus elaphus), bison (Bison bison), pronghorns (Antilocapra americana), mountain goats (Oreamnos americanus), white-tail deer (Odocoileus virginianus), mule deer (O. hemionus), and bighorns) are carefully managed to prevent overgrazing.

The bighorns on the refuge are habituated to people and may be approached to within less that 10m. The herd has been closely observed, year-round, since June 1979. The herd was watched from June 1979 until May 1982 by J. Hogg, and by myself from June 1982 through April 1984.

Identification of Individuals

All of the sheep are individually recognizable by horn characters, physical abnormalities such as torn ears, or ear tags. To facilitate rapid identification, some sheep were splattered with sheep paint, or Nyanzol A dye. Both the paint and the dye were squirted on the animals' coat or horn tips at close range from a hypodermic syringe. This resulted in a variable pattern of splotches that were visible over 1 km away.

Observations during the fall rut yielded approximate conception dates for most ewes. Thorough searches were conducted to find lambs as soon as possible after parturition. Lambs less than 24 hours old were usually catchable. Upon capture, lambs were weighed and ear tagged, and sex was recorded. A ewe in isolation with a lamb less that 5 days old was assumed to be its mother. If the lamb was observed for the first time in the company of more that 1 ewe, it was assigned to the ewe that it reclined next to most often, because lambs recline preferentially with their mothers (Hass, unpub. data). All lambs in 1983 were later sprayed with paint or dye for quick identification. Censuses conducted in early May, and throughout the lambing period, revealed which ewes

were pregnant and how many failed to conceive during rut or lost fetuses during early gestation.

Data Collection

Data presented here were collected during the summers of 1982 and 1983. In both years, the lambing periods on the NBR began in mid-May and almost all ewes had lambed by June 20. All-instances behavioral samples (Altmann 1974) of suckling bouts were obtained during almost daily observations of the nursery bands. In 1982, the sampling period began 22 July and terminated 7 September. The sampling period in 1983 extended from 25 June through 15 September. The lambs were under continuous observation for 4-8 hours during each observation period. A suckling bout began when the lamb was judged to have grasped the teat, and terminated when the lamb moved its head, voluntarily or otherwise, away from the udder.

For each suckling bout observed, the following were recorded: identity of ewe; identity of lamb; time of suckle (nearest minute); duration of bout (nearest second); whether ewe or lamb initiated bout; whether ewe or lamb terminated bout; and orientation of lamb during bout (left side, right side, or underneath). In 1983, all the above were recorded, plus it was noted whether or not the ewe sniffed the lamb's nose before or rump during the suckle.

Suckle attempts were suckles less than 3 seconds in duration, or obvious and unsuccessful attempts by the lamb to grasp a nipple. Suckle attempts were always terminated by the ewe. Suckle success was the ratio of the number of suckles to the number of suckles and suckle attempts combined.

Ewe suckle rates were obtained by dividing total suckle duration by the number of minutes of continuous observation in an observation period. Suckle rates are a hyperbolic function of lamb age. Suckle rates were inverted (to obtain a linear function) and regressed against lamb age. The equations for the lines obtained by regressing inverted suckles rates against lamb age were then integrated for the period covering 40-100 days of a lamb's age. This integration yielded the area under the curve described by suckle rate vs. age, and resulted in an approximation of the total time a lamb spent suckling between 40 and 100 days of age. This unit was termed "Total Suckle Time" (Hogg 1983). Total Suckle Time was felt to be a valuable measure of post-natal reproductive effort when compared between ewes, between lambs, and between years.

Individual ewes were referred to by two-letter abbreviations of their names, and lambs were referred to by their mother's initials followed by "1" (for lamb).

Ages of ewes were estimated in 1980, ewes older than 5 years cannot be reliably aged in the field (Geist 1966) and were lumped as "older" (5+) ewes (Hogg 1983). Ewes that nursed only their own lambs were referred to as "Own Only" (OO) ewes, those that nursed their own as well as others as "Own Plus" (O+) ewes, and those that had lost their own lambs but continued to nurse other lambs as "Helpers" (H). The use of the term "Helpers" does not imply

function or intent, but is meant to be a description of the behavior observed, as has been established in the literature (Skutch 1961, Brown 1975, Wilson 1975).

RESULTS

In 1982, 24 ewes produced 21 lambs. Of these, only two were still alive when I began censuses in late June. The fates of the missing lambs were uncertain, although predation appeared to be the cause of their disappearances (Hoss 1983, see DISCUSSION). When sampling began in mid-July, it was apparent that 4 ewes were nursing two male lambs. Of the 4, only 1 (DB) nursed only her lamb. OH nursed her own lamb as well as the other lamb. AL and TT, the other ewes, had lost their lambs, but continued to nurse both OHI and DBI until at least September when observations terminated (Fig. 1a). Both lambs received a substantial proportion of suckles from ewes that were not their own mothers (Fig. 1b). In 1982, 53 percent of observed suckles were on alien ewes.

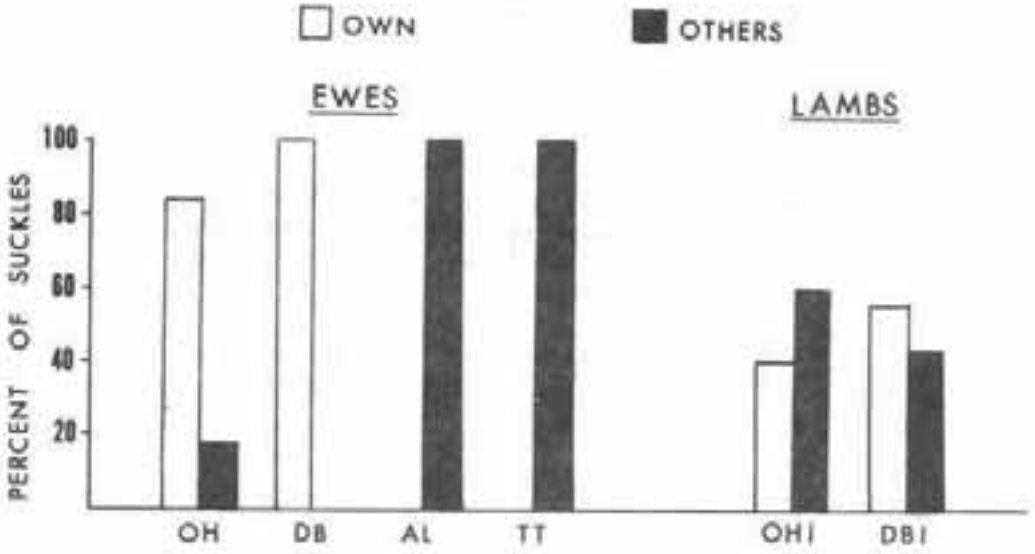

Fig. 1. Percent of suckles observed between own and other lambs and ewes in 1982.

The lambs were not nursed equally by the ewes. OH nursed her own lamb almost 5 times more than DBI, AL nursed OHI almost 3 times more than DBI, and TT nursed both lambs almost equally (G-test, G=1.37, P>0.,50; Table 1).Mean suckle durations on O+ ewes were greater than OO or H ewes, but there were no significant differences in mean suckle durations, whether comparing the OO ewe with the O+ ewe (t=1.77, P>0.05), the OO ewe with the H ewes combined (t=0.31, P>0.90), or the O+ ewe with the H ewes (t=1.71, P>0.05). There was also no significant difference in the mean suckle duration for O+ ewe on her

own lamb vs. the alien lamb (t=1.09, p>0.20).

No significant difference was noted in lamb orientation (side suckled on), for either lamb (OH1: G=2.31, P>0.05; DB1: G=0, P>0.90) or both combined (G=1.25, P>0.10). This is not surprising because lambs can suck from either teat from either side.

Table 1. Number of observed suckles and mean observed suckle duration (seconds) by each lamb on different ewes in 1982.

Class:		00	0+	H	H
Ewe:		DB	OH	AL	TT
Lambs:					
OH1	No.	0	29	27	17
	Mean dur.	0	21	20	18
DB1	No.	35	6	27	10
	Mean dur.	19	23	19	18

Ewes, for the most part, controlled the suckle bouts (Table 2), initiating and terminating most of them. There were no significant differences among 00, 0+ and H ewes as to the proportion of times that ewes, vs. lambs, initiated suckle bouts (G=0.19, P>0.90) or terminated them (G.052, P>0.50).

Table 2. Percent of suckle bouts that were initated and terminated by each ewe for each lamb in 1982. For example, of the 29 suckle bouts recorded between OH1 and OH, OH intiated 86 percent, or 25, of them.

Lambs:		INIT.				TERM.			
		OH1		DB1		OH1		DB1	
Class	Ewe	%	n	%	n	%	n	%	n
00	DB	0	0	100	30	0	0	94	35
0+	OH	86	29	100	6	100	29	100	6
H	AL	89	27	100	10	94	17	91	11
H	TT	75	17	100	10	100	27	100	10

Forty-nine suckle attempts were recorded in 1982. Lambs attempted to suckle more often from ewes that would allow them to suckle at some time, but the correlation was not significant (r=0.54, P>0.05), probably due to small sample size. DB1 was successful 77 percent of the time on DB (00) and 75 per

cent of the time on OH. OH1 was successful in 81 percent of the suckle attempts on his mother. Both were successful 70 percent of the time on the Helpers. There were no significant differences in suckle success among the 3 ewe groups (G=0.90, P>0.05) or between their own and alien lambs on the O+ ewe (G=0.03, P>0.05).

Total Suckle Time (TST) for ewes ranged from 1.71 to 4.14 hours. DB and TT nursed an estimated 2.69 and 1.91 hours respectively, while AL and OH accounted for the extremes of 1.71 and 4.14 hours, respectively. The per lamb TST averaged 5.23 hours. A large difference was apparent in lamb TST's with OH1 achieving 7.27 hours and DB1, 3.94 hours.

In 1983, 26 of 27 ewes were judged pregnant. Three lambs were found dead (2 died in birth or shortly thereafter (O'Gara, pers. comm.) and one was apparently crushed by the ewe), 12 lambs disappeared within 3 days after they were born (5 of these were handled the day before they disappeared), 2 lambs disappeared when 18-21 days of age and 1 lamb disappeared when approximately 51 days old. As in 1982, predation probably accounted for many of the disappearing lambs. In addition, 2 ewes were seen in unusual distress prior to parturition and were never observed with lambs. Only 6 lambs (23 percent) survived until the end of the summer.

When observations began in late June, 9 ewes were nursing 7 lambs (the lamb that disappeared at 51 days old (BN1) was last seen July 16; some of the data from that lamb are included in subsequent analysis). Of the 9, BR, BN, UM, and LE nursed only their own lambs. OH, DE and TT nursed their own and all other lambs, and AL and FS had lost thier own lambs but continued to nurse all remaining lambs. Suckles of alien lambs accounted for 48-100 percent of total observed suckles (Fig.2 A). BR and LE were each observed letting alien lambs suckle twice (approximately 3 percent of the total observed suckles).

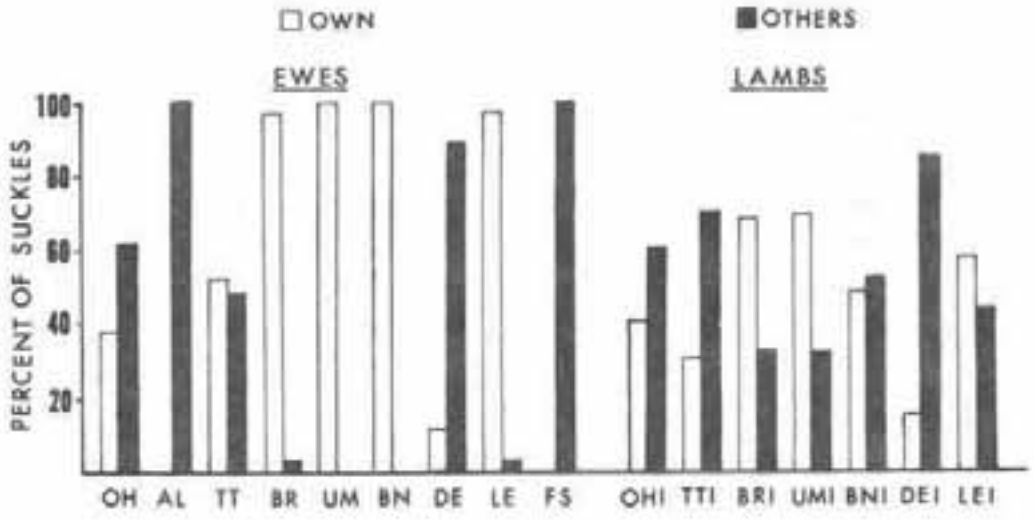

Fig. 2 Percent of suckles observed between own and other lambs and ewes in 1983.

observed suckles). This was judged insignificant and these ewes were considered to suckle only their own lambs. Lambs obtained 32 - 85 percent of suckles from ewes that were not their mothers (Fig. 2b), and 4 of the 7 lambs were observed suckling more often from other ewes. When observations began on June 25, the 3 male and 4 female lambs ranged from 15 to 35 days of age. Again, the lambs were not nursed equally (Table 3). In 1983, a total of 50 percent of all observed suckles were on ewes that were not the lamb's mothers.

For the ewes that nursed other lambs, only FS showed no significant difference among the number of suckles by various lambs ($G=9.94$, $P>0.05$). Of the ewes that still had their own lambs, all except TT discriminated significantly among the lambs that were not their own. Of the 7 ewes that still had their lambs, only 1 (DE) did not nurse her own lamb preferentially (Fig. 2a).

Table 3. Number of observed suckles and mean suckle durations (in seconds) of each lamb on each ewe in 1983.

Class:		OO	OO	OO	OO	O+	O+	O+	H	H
Ewe:		LE	BR	UM	BN	OH	TT	DE	AL	FS
Lambs:										
LE1	No.	64	2	0	0	13	7	4	8	15
	Mean Dur.	17	23	0	0	24	20	15	18	16
BR1	No.	0	71	0	0	7	4	7	9	7
	Mean Dur.	0	21	0	0	16	17	19	14	16
UM1	No.	0	0	82	0	4	6	10	7	10
	Mean Dur.	0	0	15	0	14	21	20	12	13
BN1	No.	0	0	0	16	2	1	9	1	4
	Mean Dur.	0	0	0	18	29	11	24	23	13
OH1	No.	0	0	0	0	26	2	24	6	7
	Mean Dur.	0	0	0	0	29	13	22	17	17
TT1	No.	0	0	0	0	12	24	24	7	14
	Mean Dur.	0	0	0	0	18	20	24	13	16
DE1	No.	2	0	0	0	5	2	10	38	10
	Mean Dur.	16	0	0	0	23	21	22	19	17

The suckle duration for 00 ewes was significantly less than 0+ ewes nursing their own (t=7.06, P<0.001) or other lambs (t=4.47, P<0.001). 0+ ewes nursed their own lambs for a longer duration than they nursed alien lambs (t=4.27, P<0.001). There was no significant difference in suckle duration between 00 and H ewes (t=1.09, P>0.20). These results differed from those of 1982 when no difference among groups was found, perhaps due to a much greater sample size in 1983.

As in 1982, there were no significant differences in the orientation for any lambs (OH1: G=0.07, P>0.50; DE1: G=0.14, P>0.50; TT1: G=2.00, P>0.10; BR1: G=2.46, P>0.10; UM1: G=1.61, P>0.10; BN1: G=0.61, P>0.10; LE1: G=0.63, P>0.10) or all lambs combined (G=0.27, P>0.50).

Ewes initiated and terminated most suckle bouts in 1983. There were significant differences among the 3 groups for the proportion of times that ewes vs. lambs initiated suckle bouts (G=11.48, P<0.05), with 00 ewes initiating significantly more bouts that did ewes that nursed other lambs (G=10.32, P<0.05; Table 4). No significant differences were found among the 3 groups as to whether the ewes or lambs terminated bouts (G=0.09, P>0.90).

Table 4. Percent of suckle bouts that were initiated and terminated by each ewe class on own and alien lambs in 1983. See sample in Table 2.

Lamb Class:	INIT.				TERM.			
	Own		Alien		Own		Alien	
Ewe Class	%	n	%	n	%	n	%	n
00	80	202	100	3	88	216	100	3
0+	60	50	66	110	100	53	90	126
H	--	--	71	119	--	--	99	132

In 1983, 467 suckle attempts were recorded. There was a significant correlation between the number of times lambs attempted to suckle from any ewe, and the number of suckles they obtained from that ewe (r=0.77, P<0.01, Fig. 3). Lambs rarely attempted to suckle from ewes that would not permit them to nurse, e.g. alien lambs seldom attempted on 00 ewes, and lambs usually attempted most often on their mothers. Lambs of 00 ewes had a success rate of 72 percent on their mothers, while lambs of 0+ ewes only had a 46 percent success rate on theirs. Aliens were successful 53 percent of the time on 0+ ewes, and 49 percent of the time on Helpers. There were significant differences among the 3 groups in suckle success (G=11.53, P<0.05), with lambs having a higher success rate on their mothers if their mothers were 00 ewes rather than 0+ ewes (G=6.44, P<0.05). There was no significant difference in success rate on 0+ ewes whether the lamb was the ewe's own or an alien (G=0.58, P>0.05).

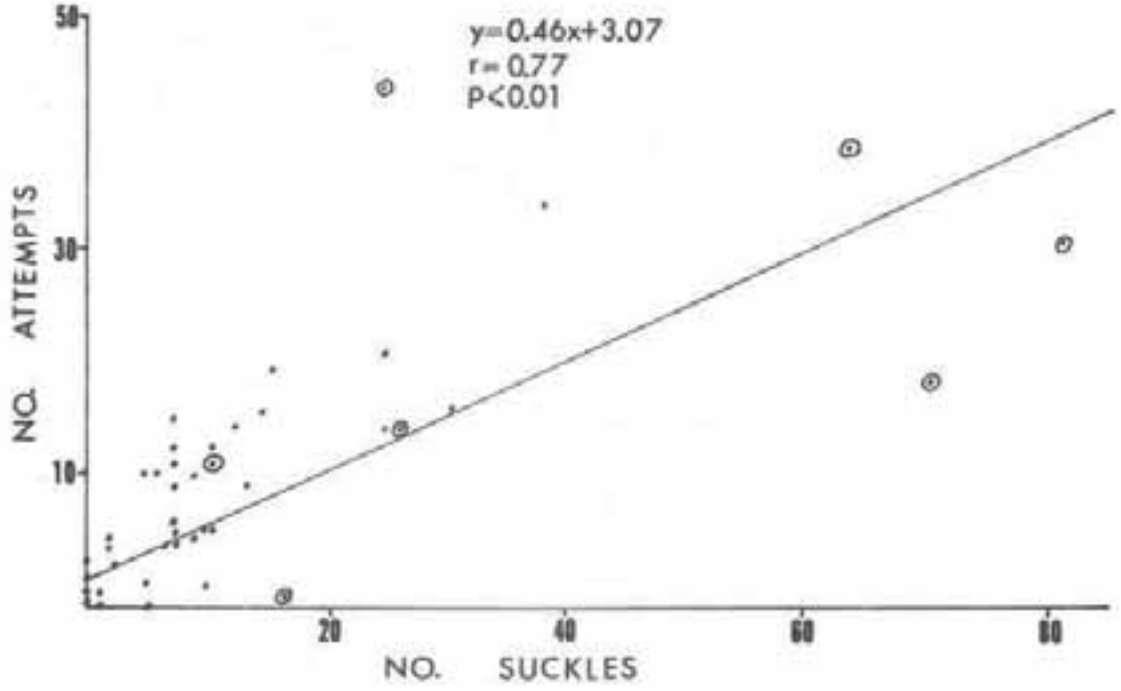

Fig. 3. Relationship between number of suckle attempts and number of suckles for all ewe-lamb pairs in 1983. Circles around points indicate a mother-offspring pair.

Ewe Total Suckle Time in 1983 ranged from 1.52 to 3.52 hours, with an average of 2.36 hours. Helpers had a mean of 2.47, OO ewes averaged 2.05 hours, and O+ ewes averaged 2.59 hours (Table 5). There was no significant difference between ewes that nursed only their own lambs and those that nursed others (Wilcoxon 2-sample C=12, P>0.10). The per lamb TST averaged 3.14 hours.

Table 5. Total Suckle Times, in hours, for ewes and their lambs in 1983. See METHODS for calculation of TST.

Class	Ewes		Lambs	
OO	LE	1.52	LE1	3.07
OO	BR	2.60	BR1	3.65
OO	UM	2.05	UM1	3.36
O+	OH	2.11	OH1	1.82
O+	TT	2.13	TT1	3.25
O+	DE	3.52	DE1	2.39
H	AL	2.82		
H	FS	2.11		

The lamb TST's ranged from 1.82 to 3.65 hours, with an average of 2.91. This is significantly lower than the 1982 average of 5.69 (Wilcoxon 2-sample C=12, P=0.05).

OO ewes sniffed their lambs significantly more often than did O+ and H ewes (G=52.7, P<0.001), and ewes that still had their lambs (OO and O+) sniffed lambs significantly more often than did Helpers (G=36.8, P<0.001; Table 6).

Table 6. Percent of times that different ewe classes were observed sniffing lamb's nose before or rump during a suckle bout.

Ewe Class:	OO		O+		H	
	%	n	%	n	%	n
	95	201	85	162	64	125

In 1983, 26 instances were observed in which 2 lambs suckled from a ewe simultaneously ("double-suckles"). Thirteen of these cases were on ewes that still had their own lambs (O+), in 8 of those cases, the ewe's own lamb was not one of the 2 suckling. There was a significant difference between the average total duration (both lambs combined) for O+ ewes (35.1 seconds) and for H ewes (22.1 seconds; Wilcoxon 2-sample C=53.5, P<0.05). There was no significant difference in suckle duration for O+ ewes whether nursing 2 lambs at once or their own, (t=1.43, P>0.10) but cumulative suckle duration was significantly greater for 2 lambs, than for a single alien lamb (t=5.18, P<0.05). The cumulative suckle duration for 2 lambs on Helpers was also significantly longer than for a single lamb (t=2.85, P<0.05).

DISCUSSION

Allomothering is usually considered altruistic, due to the high cost of lactation and the resulting decrease in reproductive potential (Reidman 1982). Lactation produces a considerable drain on a female's resources. For most mammals, including sheep, a female that "wastes" her resources on offspring other than her own may jeopardize her own offspring's survival as well as her future reproductive potential (Shackleton 1973, Horejsi 1976, Reidman 1982).

During the summers of 1982 and 1983, all of the lambs on the NBR received a substantial number of suckles from ewes that were not their mothers. Seventy-five percent of the ewes in 1982, and 56 percent of the ewes in 1983 nursed lambs that were not their own. Lambs obtained up to 85 percent of observed suckles from ewes that were not their own mothers. Numerous researchers reported that bighorn ewes would rebuff alien lambs (Geist 1971, Shackleton 1973, Horejsi 1976, Berger 1979), but apparently in none of these

studies were all the lambs and ewes individually known.

Two types of allomothers were present in the NBR herd; ewes that still had their lambs, and those that lost their lambs. Different hypotheses may explain allomothering behavior in each group, so I will discuss the 2 groups separately.

I. Ewes that still had their lambs (0+ ewes).

There are several hypotheses which might explain allomothering in this group:

A. Ewes are failing to consistently identify their own lambs.

The importance of olfaction in lamb recognition by its mother has been reported (Morgan et al. 1975, Grau 1976, Poindron 1976, Poindron and Le Neindre 1980, Gubernick 1981a,b, Rosenblatt and Siegel 1981). Olfactory discrimination by ewes might fail in several ways:

1. Interference during the critical period, preventing formation of an exclusive bond (Poindron and LeNeindre 1980, Rosenblatt and Siegel 1981). This is unlikely because ewes isolate themselves prior to parturition and remain isolated with their lamb for at least 5 days after the lamb is born (pers. obs.). However, the lambs of most of the NBR ewes were handled between 1980-84. Handling was not associated with allomothering behavior, but repeated human disturbance may produce a cumulative effect resulting in poor mother-young bond formation (J. Hogg, Pers. comm.).

2. Anosmia. Domestic sheep (Ovis aries) and goats (Capra hircus) that were experimentally rendered anosmic were unable to discriminate between their own and alien young (Baldwin and Shillito 1974, Klopfer and Famble 1966, Poindron 1976). In one experiment in which ewes were made anosmic prior to parturition, both the ewe's own lamb and alien lambs were less successful in suckle attempts (25 percent compared to 64 percent, by the ewe's own lamb, on intact ewes). Anosmic ewes sniffed lambs during only 50 percent of suckle bouts, compared to 78 percent of the time by intact ewes (Poindron 1976).

In the NBR bighorns, lambs were successful 77 and 72 percent of the time on their mothers, if their mothers were 00 ewes, and 81 and 46 percent of the time if their mothers were 0+ ewes (values for 1982 and 1983 respectively). Aliens were successful 0 and 16 percent on 00 ewes, and 75 and 53 percent on 0+ ewes. The higher values for 1982 are probably due to a lower lamb-to-ewe ratio (2 lambs and 4 ewes in 1982 compared to 7 lambs and 9 ewes in 1983). In 1983 lambs were successful more often on 00 ewes and less successful on 0+ ewes and Helpers. This was not the case in 1982, so on the basis of suckle success, I hesitate to make any conclusions. However, 0+ ewes did not discriminate between their own and alien lambs and 0+ sniffed lambs significantly less often when suckling than 00 ewes. The lack of discriminatory ability in the 0+ group of ewes may be due to anosmia.

Bighorn sheep on the NBR are infested with sheep nasal bots (Oestrus ovis; O'Gara pers. comm.), which have been present in the herd since at least 1936 (Capelle 1966). Sneezing, coughing and nasal discharge are evident

throughout the summer months. Nasal bots in domestic sheep may produce minute hemorrages, mucosal defects at the site of attachment, and constant irritation and thickening of the nasal mucous membranes (Jubb and Kennedy 1970, Capelle 1971). Female bot flies deposit larvae on the nostrils of sheep during the summer months. The first-instar larvae (about 10 millimeters in length) remain in the nasal passages for 1-9 months. Second-instar larvae (3.0 - 14.5 millimeters, Fallis 1940, cited in Capelle 1966) migrate into the frontal sinus and develop rapidly. Third-instar larvae (24 - 30 millimeters in length) migrate out the nostrils and are sneezed out by the sheep and pupate in the ground (Capelle 1966). Nasal bot larvae might render bighorn sheep partially or completely anosmic through cumulative scarring, due to either the constant irritation of the first-instar larvae or subsequent minor infections. The presence of large numbers of second- and third-instar larvae might also inhibit a ewes olfactory ability enough to disrupt the imprinting process soon after parturition. Second- and third-stage larvae have been reported in the Wildhorse Island and Sun River herds in late May (Capelle 1966). The effects of nasal bots on the olfaction of bighorn sheep is not known; they apparently do not affect olfaction in domestic sheep (T. Bunch, pers. comm.). Nasal bot-induced secondary infections leading to severe osteolysis and death is common in desert bighorns (Paul and Bunch 1978, Bunch 1980) but has only been reported once in a Rocky Mountain bighorn (Turner 1982).

Nasal bot-induced anosmia might explain why some ewes are not discriminating their own from alien lambs in this herd. Ecological factors might result in differential levels of infestion, which might explain why there were no O+ ewes observed in 1980-81 (J. Hogg, Pers. comm.).

3. Inbreeding effects. The bighorn sheep currently inhabiting the NBR are all decendants of a group of 12 animals that were introduced over 60 years ago. Refuge records do not indicate any additional transplants. The population has fluctuated from 10-100 animals, but has remained between 40-70 animals for the last 20 years (National Bison Range Refuge Narrative Reports 1922-1984). The coefficient of inbreeding in this herd is undoubtedly high (see Soule 1980). The exact effects of inbreeding in bighorn sheep are unknown. The herd falls under Geists' (1971) definition of a high quality population with regard to age at first reproduction, size, and yearling development. It remains possible that the lambs are so closely related that they cannot be distinguished from one another. This hypothesis fails to explain why some ewes still discriminated against alien lambs.

B. Kin selection.

Hamilton (1964) put forth the idea of "inclusive fitness", that is, the sum of an individuals reproductive success, plus that of its relatives, represents the individuals "inclusive fitness". According to Hamilton's genetical theory of social behavior (1964), a social act that increases the inclusive fitness of the performer will be promoted by natural selection.

Bighorn ewes usually live in groups consisting of adult females, yearlings and lambs. In many populations, rams shift to separate bachelor herds when 2-4 years of age, but ewes remain with their maternal band (Geist 1971). Ewes may actually associate in extended matriarchies of closely related individuals, rather than in allied groups of unrelated females as previously

suggested (Geist 1971, Gubernick 1981b). African and Asiatic elephant females are reported to exist in extended matriarchies; infants are allowed to nurse from any lactating female in the group, although the mother provides most of the care for her own infant, (Eisenberg 1972). African lions also exist in matriarchal groups where lactating females allow any cubs to suckle (Schaller 1972). Among ungulates, those that live in small, discrete units reportedly cooperate in defense against predators, while those in large, unallied groups generally do not (van Lawick-Goodall and van Lawick-Goodall 1970, Kruuk 1972). Cooperative defense has been reported in bighorns (Shank 1977). On the NBR all of the ewes associate in an extended matriarchy. Whether this is substantially different from a more natural situation that allows immigration and dispersal of individuals is not known.

Coyote predation may have accounted for most, if not all, of the disappearing lambs. Coyotes were frequently sighted in the lambing areas in 1982-83, and many coyote scats contained bighorn lamb hair. The NBR lacks the rugged, cliffy areas in which mountain sheep ewes in other populations retreat to lamb (Spencer 1943, Geist 1971, Pitzman 1971, pers. obs.). Lamb survivorship was significantly less in 1982 and 1983 (10 and 23 percent) than in 1980 and 1981 (50 and 53 percent, Hogg 1983; $G=6.35$, $P<0.05$) when no 0+ ewes were observed (J. Hogg, pers. comm.). Low survivorship of the lambs may prompt some ewes to "cooperatively" care for the surviving young, with the theoretical result that lambs have a better chance of surviving than if cared for by only 1 ewe. This "group selection" of related individuals is then a form of kin selection (West Eberhard 1975, Wilson 1975).

0+ ewes tended to be older than 00 ewes (Table 7). An increase in age results in a decrease in reproductive potential. A 10-year-old ewe will produce potentially fewer lambs in her remaining reproductive lifetime than

Table 7. Classes and ages of lactating ewes in 1982 and 1983. (+)=ewes that were estimated to be at least 5 years old in 1980.

Year	Ewe	Class	Age
1982	DB	00	6
	OH	0+	7+
	AL	H	7+
	TT	H	6
1983	LE	00	8+
	BR	00	3
	UM	00	2
	BN	00	2
	OH	0+	8+
	DE	0+	7
	TT	0+	7
	AL	H	8+
	FS	H	8+

will a 5-year-old ewe. A ewe may increase her inclusive fitness (Hamilton 1964) more by investing in not only her own lamb, but also the other lambs (her relatives), provided she can do this without detriment to her own offspring.

Ewes that nursed alien lambs may be hurting their own lambs. In 1983, but not in 1982, lambs of O+ ewes had lower TST's than lambs of OO ewes, but this difference was not significant (Wilcoxon 2-sample C=5, P>0.10). However, all lambs "cooperatively" nursed in 1982 and 1983 were still alive and in good shape as of April 1984. The cost of lactation was evident in the poor coat and general body condition of lactating ewes compared to non-lactating ewes, but all ewes that nursed alien lambs in 1982 produced healthy lambs in 1983, and all ewes that nursed aliens in 1983 appeared pregnant in April 1984.

Cooperative nursing in chital may be related to high levels of predation (Schaller 1967) and cooperative nursing in collared peccaries is one of several cooperative behaviors exhibited in their familial groups (Byers and Bekoff 1981).

C. Rare or isolated event.

It remains possible that the allomothering witnessed in the last two summers on the NBR is simply an error that occurs too infrequently for natural selection to act upon (Dawkins 1976). So many authors have commented on the exclusiveness of the mother-young bond in ungulates (Geist 1971, Shackleton 1973, Horejsi 1976, Schaller 1977, Shillito Walser 1977, Gubernick 1981a, b, Reidman 1982) that it would be easy to view this allomothering as an isolated event. What appear to be patterns may actually be coincidences.

II. Ewes that had lost their lambs (Helpers).

Predation was probably the proximate cause for the occurence of all Helpers in this herd, particularly if they had lost their lambs when at least several days old and the ewes were not physiologically "primed" for the peak lactation period (Moen 1973, Hanwell and Peaker 1977). Also, the pain of an overfull udder might motivate ewes to nurse alien lambs to alleviate the discomfort. Domestic ewes that lost their own lambs sometimes adopted aliens (Arnold and Morgan 1975). Both AL and FS lost their lambs when at least 10 days old in 1983, similar data are not available for 1982. Two helpers were also present in the NBR herd in 1980 and 1 in 1981 (J. Hogg, pers. comm.). The continuation of nursing behavior throughout the lactation period could be a cooperative effort on the part of the Helpers to aid in the survival of the remaining lambs (their relatives; see Kin Selection above). Ewes control the suckle bouts by initiating and terminating them, presumably Helpers could wean lambs any time they chose to. Flexibility in the length of the weaning period has been described by Berger (1979). The fact that Helpers nursed all lambs in the nursery band, instead of adopting a particular lamb, may support either the Kin Selection or the Anosmia hypothesis.

Ewes on the NBR have nursed more than 1 lamb, apparently without jeopardizing their reproductive fitness. The end result, whether intentional or not, appears to be cooperative care, with the lambs receiving more milk. Most of

this is due to the additional milk provided by the Helpers. This study does not permit discrimination among the hypotheses presented here.

Further detailed research on the NBR herd, and other herds is necessary to determine the extent of allomothering behavior in bighorn sheep.

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GROWTH RATES OF ROCKY MOUNTAIN BIGHORN SHEEP ON RAM MOUNTAIN, ALBERTA

Jon T. Jorgenson and W. D. Wishart, Alberta Fish and Wildlife Division, 6909 - 116 Street, Edmonton, Alberta T6H 4P2.

ABSTRACT

Rams grew rapidly until 4 years old after which annual weight increments decreased considerably. Ewes reached most of their maximum weight by age 2. Lambs and yearlings of both sex classes had slow growth until early June and then increased linearly until early September after which rate of gain decreased. Summer weight gain for older animals was relatively more rapid through most of the summer and also declined by September. Summer weight gain of lambs to 2-year-olds was more rapid in rams than ewes. Growth rates of ewes declined after 2 years with a small constant increment up to 5 years of age. There were no differences between years in individual growth rates despite considerable interyear differences in primary production as measured by summer precipitation. Growth rates were more rapid in ewes that were not lactating compared to ewes with lambs. Lambs appeared to gain slightly in weight over winter while older animals progressively lost more weight over winter. Energy costs associated with gestation were reflected in greater winter weight losses of pregnant ewes after parturition. Interannual differences in overwinter weight loss were evident and highly correlated with late winter snowfall and mean temperature from January to May.

INTRODUCTION

Body weights of bighorn sheep (Ovis canadensis) and other ungulates have been used as a measure of population quality when comparing herds (Geist 1971, Shackleton 1973, Nievergelt 1966). Expanding populations of sheep have been characterized by large horn and body size, rapid growth, short life expectancy and high fecundity, while smaller horn and body sizes, slower growth rates, longer life expectancies and lower fecundity characterize declining or stable herds. Bunnell (1978) documented interannual differences in horn growth and found them to correlate with differences in precipitation and with yearly differences in recruitment in a Yukon Dall sheep (Ovis dalli) population. For bighorn sheep, however, there has been very little data published on annual growth rate patterns in free ranging sheep and on growth rates of individuals during the summer from which comparisons could be made with other herds.

The inability to capture and recapture free-ranging Rocky Mountain bighorn sheep on a regular basis has apparently limited the availability of individual weight gain data in the literature. Blood et al. (1970) reported weights of winter captured bighorn rams and ewes of different ages in Alberta as well as weight gains of lambs over one year. Age and sex specific winter weight loss data have also been recorded for Dall sheep (Bunnell and Olsen 1976). Hoefs (1974) reported changes in weight of a single captive Dall ram over a 17 month period.

The purpose of this paper is to examine weights and rates of weight gain for comparison with other herds. Patterns of summer weight gain and individual growth rates for males and females of different ages are presented. Interannual differences in growth rates are documented, as well as, the effects of energy expenditures such as winter survival and reproduction on body size and growth rates.

STUDY AREA

Ram Mountain (52º 25'N, 115º 45'W) occupies the southern half of the Brazeau Range in west central Alberta. The mountain is geographically isolated in surrounding conifer covered foothills on three sides while the north Saskatchewan River provides a significant barrier on the north side. The area ranges in elevation from 1082 m - 2173 m above sea level with treeline at approximately 1830 m. The terrain is varied with bare rock summits, talus slopes, wooded slopes, low relief alpine tundra and rugged escarpments and cliffs. The alpine and subapline vegetation of Ram Mountain are described in detail by Johnson (1975) and are characteristic of the eastern slopes of Rocky Mountains in Alberta north of the Bow River.

METHODS

Sheep were captured and tagged in a corral-like structure baited with salt (Wishart et al. 1980). The bighorns were individually marked with various combinations of colored, lettered and numbered collars and ear tags. Weights, horn measurements and standard body measurements were recorded for each capture. Only the weight data will be reported in this paper. Trapping extended from approximately 25 May to the first week of October between 1978 and 1983. Capture frequency per individual ranged from one to seven times. Weights of individuals were taken every two weeks whenever possible.

Summer weight gain patterns were determined by calculating the mean of all weights for a particular sex-range class every two weeks. Individual growth rates were calculated by including all weights obtained for a specific animal between 1 June and 1 September (25 May = X_1 for regression). A Mann-Whitney U test (Siegal 1956) was employed to test for differences between years, sexes, and age classes.

To calculate overwinter weight changes, it was necessary to know the growth rates of an individual for two consecutive years. This requirement effectively eliminated many animals from the sample. The difference between the 1st September (x_1 coordinate = 100) estimated weight in year (i) and the estimated weight on 1st June (X_2 coordinate = 8) in year (i + 1) gave an estimate for overwinter weight loss. Weight loss estimates would be minimum values for all animals since weight continued to increase at a slow rate past 1 September and by 1 June the following spring, some weight gain would already have occurred. Thus, maximum pre-winter and minimum post-winter weights for individuals were not know.

To compare interannual differences, it was necessary to eliminate the effects that age might have upon weight loss. An index similar to the

"quality index' used by Bunnell (1978) to assess interannual differences in horn increment was utilized here for weights. Essentially the index measures the difference between the average weight loss for individuals of similar age in a particular year and the average weight loss for all individuals (of that same age) in all years. Thus one could determine the amount of deviation above or below the average age specific weight loss for all years by dividing the index by the standard deviation of weight loss within a year.

Meteorological data were obtained from the Nordegg Ranger Station that was located 19 km northwest of the study area at 1326 m in elevation. High winds were common and snow could fall during any month of the year on Ram Mountain.

RESULTS

June weights were plotted for ewes and rams from approximately 3 weeks of age to 7 years of age (Fig. 1). A very rapid linear increase was noted in rams up to 4 years after which weight gain decreased considerably. Ewes, however, had generally reached most of their adult weight by 2 years.

The contribution to weight gain from horn and skull growth in rams was most significant in rams 4 years and older. Average skull and horn weights of central and northern ram specimens from the Wildlife Branch museum for yearlings, 2-year-olds, 4-year-olds, and 7 years and over were 0.7 kg (N=2), 1.6 kg (3), 4.5 kg (6) and 8.0 kg (4) respectively. The difference in horn and skull weight between 1 and 4-year-old rams was 3.8 kg while the difference in body weight was about 50 kg. Therefore, less than 10 percent of the weight gain between 1 and 4-year-old rams could be attributed to increasing skull mass. However, between ages 4 and 7+ years a difference in skull weight of 3.5 kg was accompanied by only a 10 kg increase in body weight. In older rams therefore, as much as 35 percent of the increasing body weight could be attributed to horn and skull growth.

Rams weighed more than ewes in all age classes, except lambs where the difference was not significant (P 0.10) and amounted to only 1.1 kg. The difference in weight of yearling ewes and rams was significant (P 0.05), but the average difference was only 4.6 kg.

SUMMER WEIGHT GAIN

Rate of weight gain during the field season (25 May - 11 October) was determined for rams up to 2 years and ewes up to 4 years. Capture frequency for older individuals was too low to make similar comparison.

Weight gain for lambs and yearlings of both sexes appeared to follow a logistic growth curve (Fig. 2 and 3). Weight gain was relatively slow up to the first week in June and then maintained a highly linear (r^2 = 0.98 rate of increase until the beginning of September after which weight gain appeared to slow. A more dramatic decrease in weight gain after September would probably have been recorded had it been possible to weigh more sheep at that time.

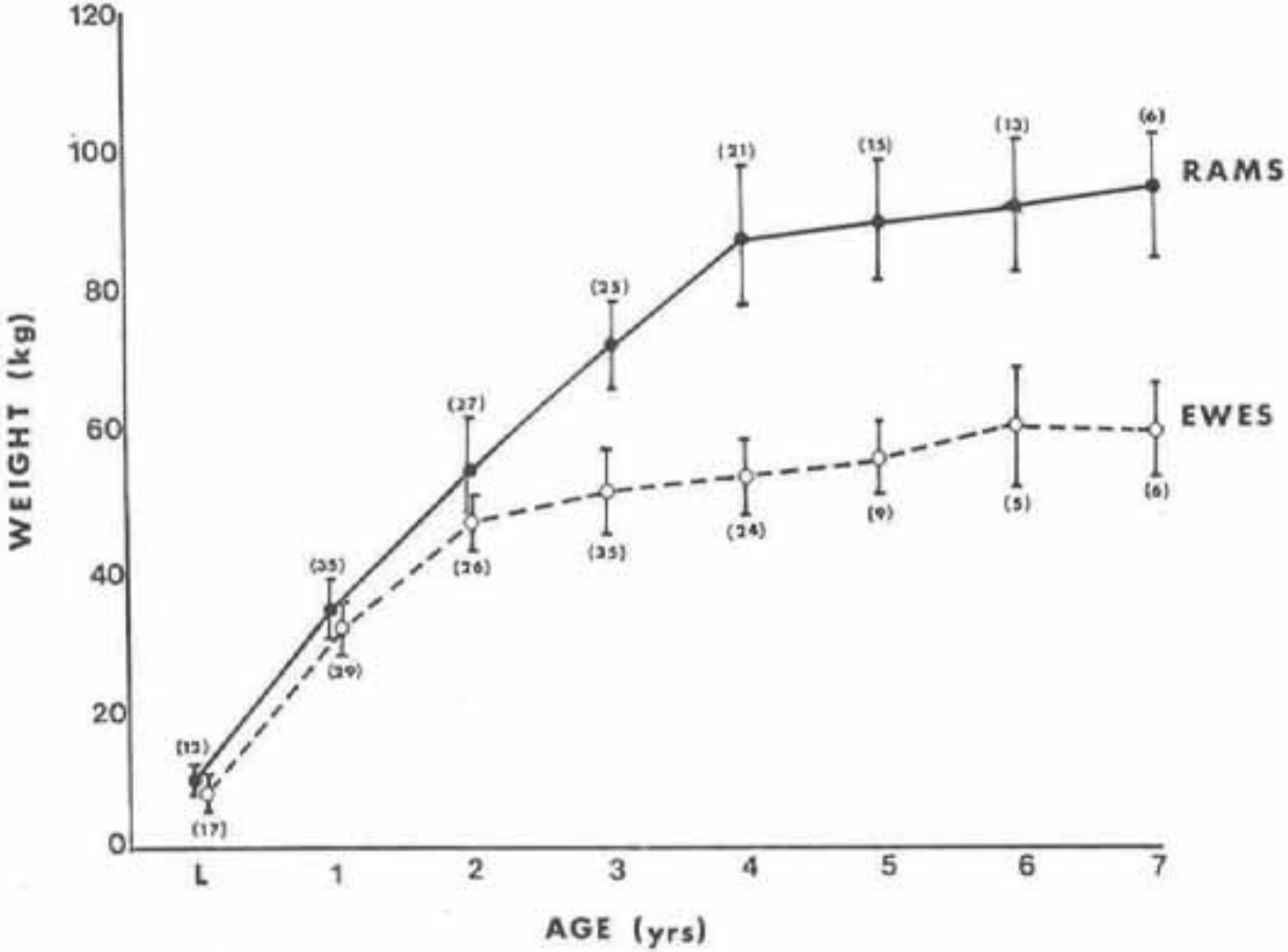

Figure 1. Spring weights of ewes and rams (lamb-7 years) from Ram Mountain, 1978-1983. (Dots, vertical lines and parentheses represent means, standard deviation and sample size respectively).

Compared with lambs and yearlings, summer weight gain by ewes and rams older than 1 year followed a logarithmic curve with weight gain being more rapid during the first 6 weeks of summer and then declining thereafter (Fig.3). The proportion of variability in weight with time for these age classes was 94 percent or greater assuming a logarithmic function and 87 percent assuming a linear function.

The slope of each age-sex specific summer growth pattern may be taken to represent an average rate of weight gain. Actual average rates of weight gain (as measured by the linear slope of each regression) were 0.29 kg/day and 0.25 kg/day for male and female lambs respectively (Table 1). Yearling and 2-year-old males progressively put on weight considerably faster than their female counterparts. Ewes more than 2 years old maintained a relatively stable rate of weight gain at least up to 5 years. Though sufficient data was not available for comparable analysis, 3 year-old rams appeared to maintain a very high rate of growth compared to the same aged ewes (Fig.1). After 4 years, summer growth rates for rams appeared to slow considerably.

INDIVIDUAL GROWTH RATES

The number of animals for which individual growth rates could be determined were limited depending on age class and capture frequency within age classes. Therefore, reliable statistical comparisons often could not be made. With growth having been shown to be linear only up to late summer (Fig.2), individual rates of weight gain were calculated between 8 June - 1 September. Though average growth of 2, 3 and 4-year-old ewes was closer to a logarithmic growth function, it was assumed to be linear for purposes of calculating individual weight gain for these age classes.

Within age classes, growth rates between years were significantly different (P 0.05) in only a few instances (Tables 2,3). Generally, there were no consistent interannual differences particularly when all age classes were combined. Small sample sizes made statistical comparisons less valid in many cases. Within age classes and within years,there was little individual variation in growth rates for lambs and yearlings. For older age classes, individual variation became greater.

GROWTH RATES AND REPRODUCTIVE SUCCESS

To examine the impact of reproduction on growth rates, weight gains in non-parous ewes and ewes that lost lambs shortly after parturition were compared with weight gains of parous ewes. Parous 2-year-old ewes which bred as yearlings gained weight throughout the summer at a significantly slower (P 0.05) rate than their unproductive counterparts (Table 4). Parous ewes over 2 years also experienced a slower growth rates than the few (N=2) barren ewes for which individual growth rates could be calculated.

Ewes that lost their lambs shortly after birth would probably be spared the added energy expense of lactation and would be expected to gain weight faster than ewes with lambs. Indeed, ewes that lost lambs gained weight at an average 0.22 kg/day (N=10) compared with 0.16 kg/day (N=111) for ewes with

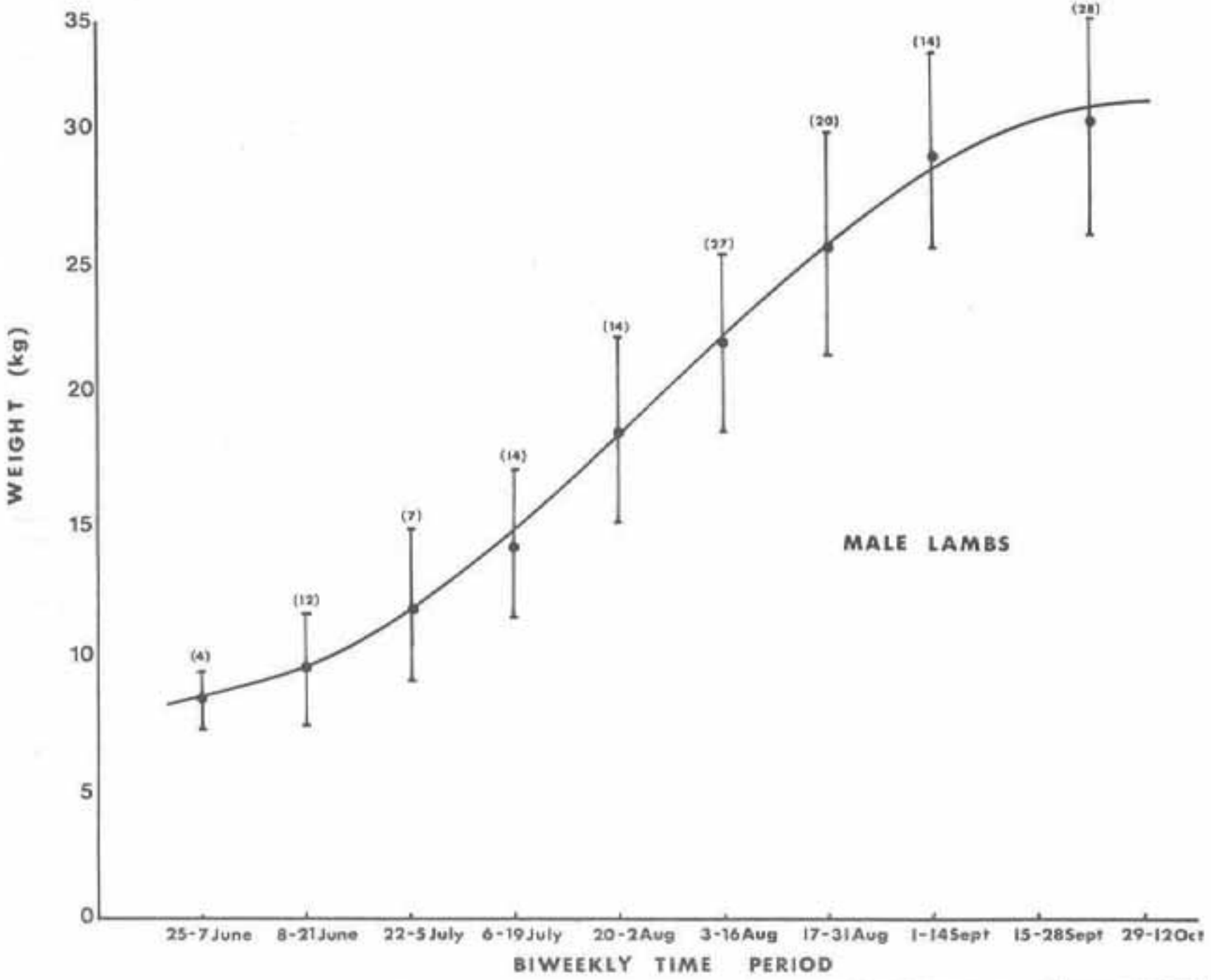

Figure 2. Summer weight gain of male lambs (1978-1983). (Dots, vertical lines, parentheses represent biweekly means, standard deviation and sample size respectively).

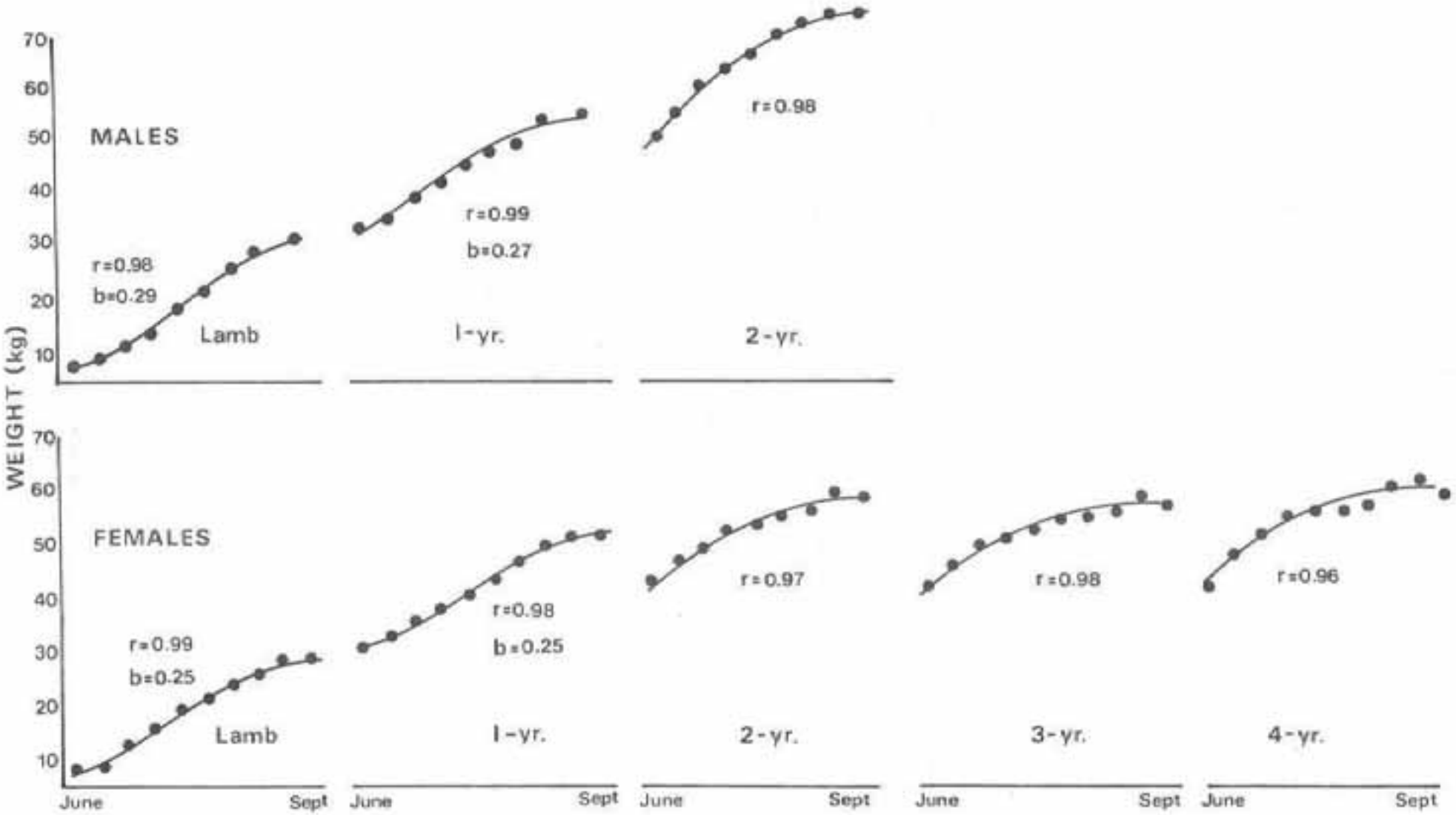

Figure 3. Summer weight gain of rams (lambs-2 years) and ewes (lambs-4 years) from Ram Mountain, 1978-83. (Dots represent biweekly mean weights).

Table 1. Average rates of weight gain for ewes and rams aged 1 to 5 years (1978-1983).

Age	Average rate of weight gain (kg/day)	
	Rams	Ewes
Lambs	0.29	0.25
Yearlings	0.27	0.25
2-Years	0.31	0.19
3-Years	N/A	0.17
4-Years	N/A	0.18
5-Years	N/A	0.19

Table 2. Mean individual growth rates (kg/day) of bighorn rams from Ram Mountain (1978-1983).

Age		YEAR					
		1978	1979	1980	1981	1982	1983
Lambs	$\bar{x}$	0.24	0.24	0.25	N/A	0.24	0.24
	SD	0.02	0.02	0.25		0.05	0.01
	N	7	5	6		5	3
Yrlgs	$\bar{x}$	0.20	0.23	0.23	0.18	0.20	0.18
	SD	0.03	0.03	0.03	0.05	0.05	0.04
	N	5	8	7	12	9	5
2-Yrs	$\bar{x}$	0.23	0.31[a]	0.20[a]	0.23	0.27	0.22
	SD	0.04	0.07	0.04	0.03	0.03	0.05
	N	2	5	3	4	10	9

[a]Significantly ($P<0.05$) different.

N/A = Not available.

Table 3. Mean individual growth rates (kg/day) of bighorn ewes from Ram Mountain (1978 - 1983).

Age		Year					
		1978	1979	1980	1981	1982	1983
Lambs	$\bar{x}$	0.20	0.23	N/A	0.19	0.22	0.21
	SD	0.01	0.05			0.03	0.01
	N	3	6		1	6	2
Yrlgs	$\bar{x}$	0.19	0.22	0.19	0.17	0.19	0.19
	SD	0.05	0.03	0.02	0.03	0.03	0.03
	N	5	11	6	2	6	9
2-Yrs	$\bar{x}$	0.18	0.19	0.16	0.12	0.15	0.13
	SD	0.04	0.04	0.03	0.05	0.06	0.05
	N	8	6	10	4	7	6
3-Yrs	$\bar{x}$	0.22[a]	0.18	0.17	0.16	0.16	0.12[a]
	SD	0.05	0.05	0.10	0.08	0.04	0.05
	N	5	10	5	8	6	5
4-Yrs	$\bar{x}$	0.12	0.17	0.14	0.20	0.20[a]	0.12[a]
	SD	0.01	0.04	0.04	0.03	0.06	0.07
	N	2	3	5	2	10	6

[a]Significantly ($P<0.05$) different within age group.

N/A = Not available.

lambs (Table 4). Weight gain in ewes that lost lambs was comparable to weight gain of barren ewes.

Table 4. Growth rate comparisons between parous, non-parous, and ewes losing lambs (1978-1983).

	2-year-olds			3-year-olds		
	Parous	Non-parous	Lost Lamb	Parous	Non-parous	Lost Lamb
Growth Rate	0.15	0.16	0.23	0.16	0.24	0.22
N	15	22	4	96	2	10
Standard Deviation	0.04	0.04	0.01	0.06	0.01	0.04

OVERWINTER WEIGHT LOSS

Overwinter weight loss is a significant factor affecting subsequent weights of bighorn sheep. Not only does the weight loss leave a base weight on which to add the current seasons growth, but it also reflects the condition of an animal coming out of the winter and this in turn determines the weight of the animal going into the next winter. Average overwinter weight changes from 6 October to 1 June indicate that lambs (males and females) increase slightly in weight, while older animals progressively lose more weight with age over winter (Fig. 3). Data on rams more than 2 years old and ewes older than 5 years was insufficient to make comparisons. After parturition, 3 and 4-year-old ewes had lost an average of 14 kg or approximately 23 percent of their pre-winter body weight. Some ewes lost as much as 20 kg.

The total weight of fetus, fetal membranes and amniotic fluids which is expelled at birth is unknown for bighorn sheep. However, in domestic ewes about 37 percent of the weight of the reproductive tract (term) consists of fluids and associated structures (Rattray et al. 1974). The average bighorn lamb weighs about 4.0 kg at birth (Geist 1971) and if the percentage of the conceptus consisting of non fetal material is similar to domestic ewes, then the total weight lost at parturition would be approximately 6 kg. This would account for about one half of the average overwinter weight loss of 3 and 4-year-old ewes.

Minimum overwinter weight losses for individuals were calculated from 1 September to 1 June. Though weight changes in male and female lambs were similar, female yearlings lost more weight than yearling males. This

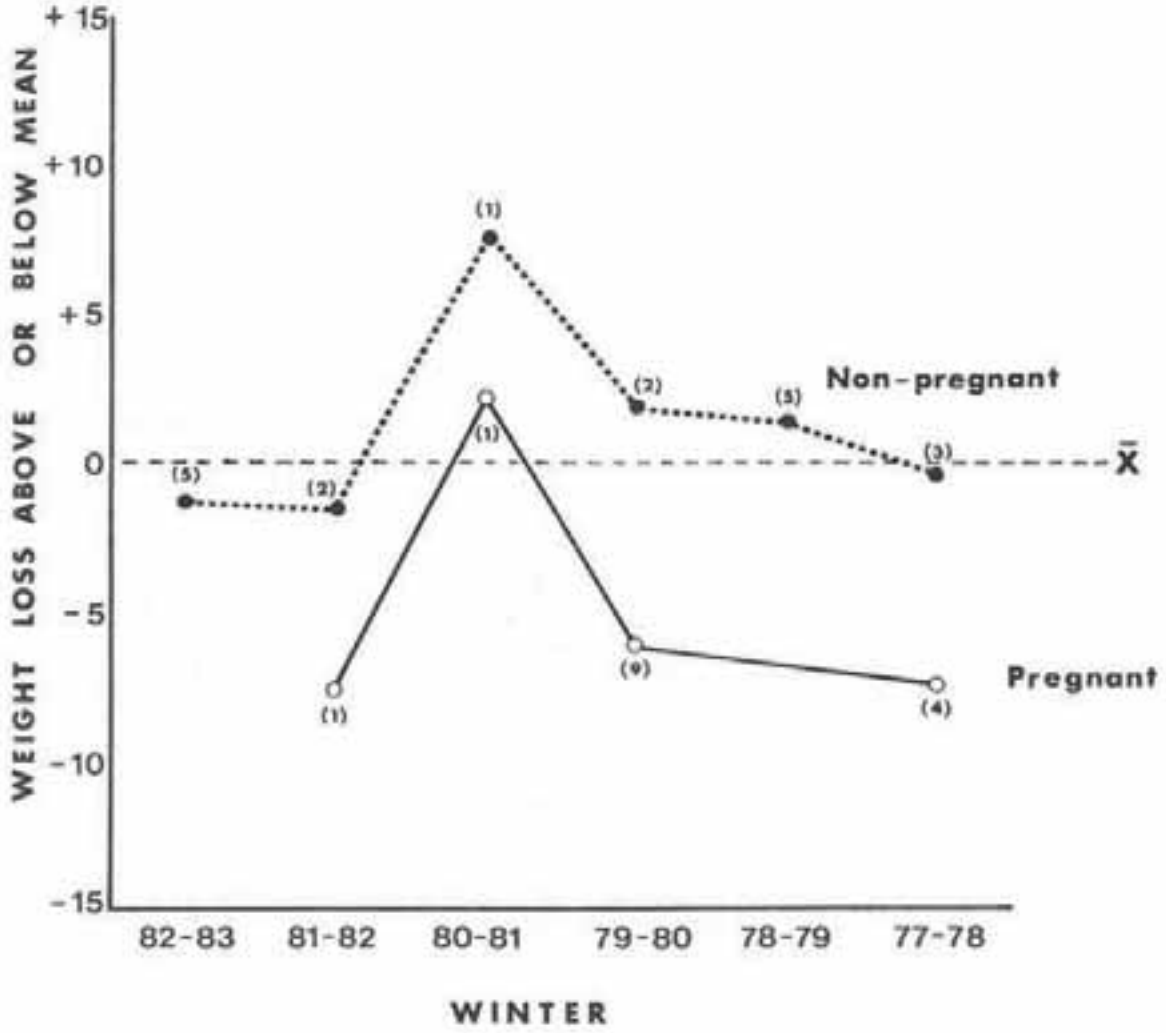

Figure 4. Winter weight loss of pregnant and non-pregnant yearling ewes.

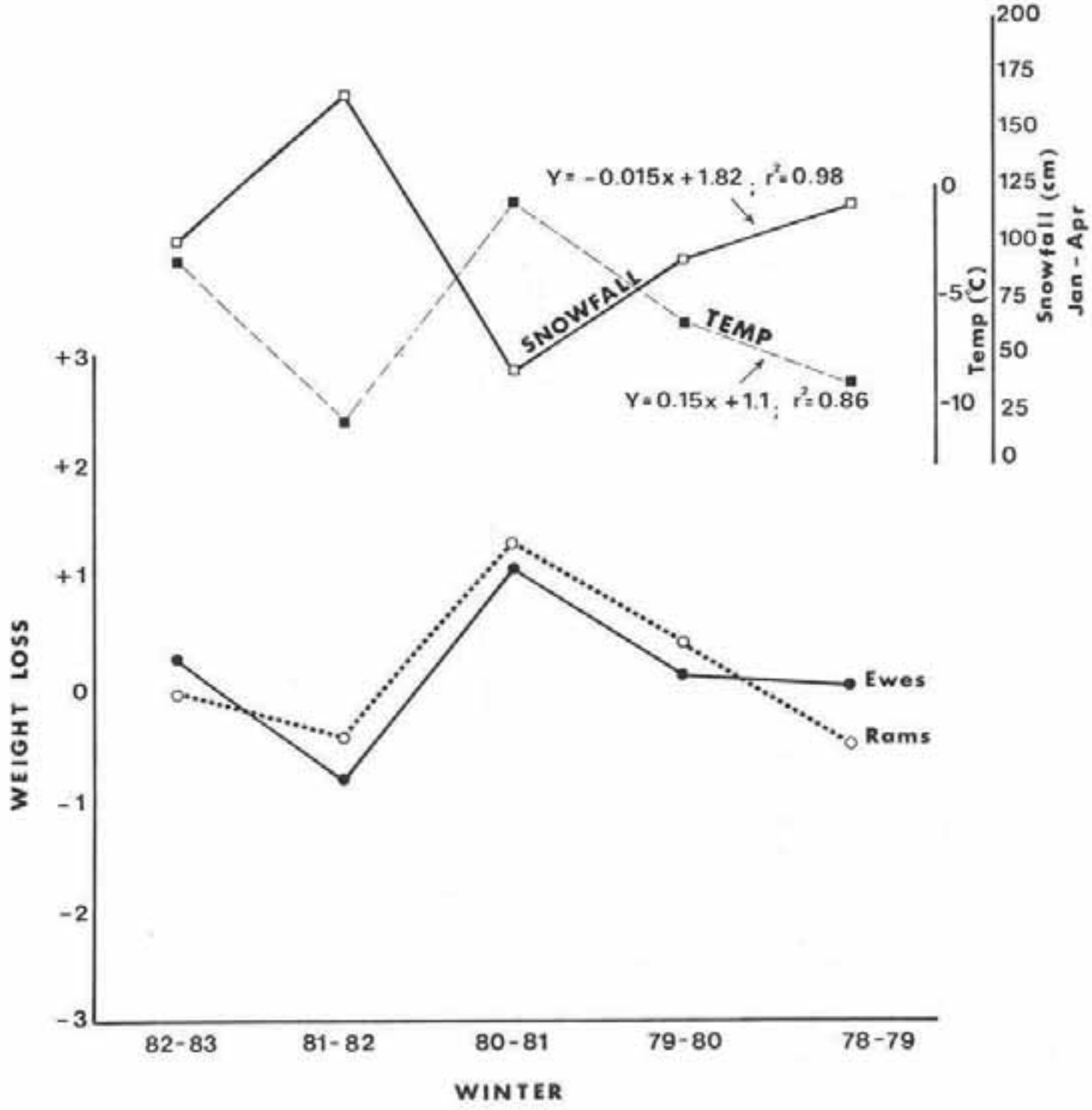

Figure 5. Overwinter weight loss and winter severity for bighorns from Ram Mountain (1978-1983).

difference was accountable by the inclusion of pregnant yearling ewes which lost more weight than non-pregnant yearlings (Fig. 4). There were too few barren ewes in the older age classes to make a similar comparison.

Interannual differences in overwinter weight change were examined in rams from lambs to 2-year-olds and in ewes from lambs to 4 years using the weight-loss index. Since pregnancy rates in yearling ewes were variable and weight loss of pregnant yearling ewes was shown to be greater than non-pregnant yearlings (Fig. 4), pregnant yearlings were not included. Ewes older than 2 years for which weight losses could be calculated were all pregnant and thus equally affected. During the winter of 1981/82 a greater than average weight loss was observed in both ewes and rams while only rams lost more weight than average in the 1978/79 winter (Fig. 5). During the 1980/81 winter, ram and ewe weight losses were 1.1 to 1.3 standard deviations below average.

Overwinter weight loss appears to be influenced greatly by the severity of the winter with late winter conditions contribution the most. Regressing both mean monthly temperature (°C) and total snowfall (cm) between January and April with the weight loss index, yields a highly significant relationship for both rams and ewes (Fig. 5). Snowfall was positively correlated with weight loss while mean monthly temperature was negatively correlated.

DISCUSSION

Compared with bighorns from southern Alberta (Blood et al. 1970), Ram Mountain sheep appeared to stop growing at an earlier age. Rams from Waterton Park continued increasing in weight up to 7 years while those from Ram Mountain gained only slightly past 4 years. Southern rams and in particular ewes, were considerably heavier than Ram Mountain sheep. Weight differences were probably even greater, since those reported by Blood et al. (1970) was taken in late winter after winter loss was at a maximum, whereas, sheep on Ram Mountain were weighed in June following a brief period of weight recovery. Sheep from southern Alberta have been shown to exhibit greater horn and skull growth than their northern counterparts (Wishart and Brochu 1982).

Summer growth was observed to be more rapid in older animals ($\geq$ 2 years) than in lambs and yearlings. This change in growth rate appears to be compensatory to an increasing weight loss over winter for older sheep. Older individuals seem to have the capacity to recover from greater weight loss with rapid early summer growth. Such ability to make up weight losses has been noted in orphaned bighorn sheep (Jorgenson et al. in prep.), white-tailed deer fawns (McEwan et al. 1957) and in domestic livestock (Pomeroy 1955). Rapid recovery from winter weight losses would be most advantageous for lactating ewes who need to care for newborn lambs. The added energy expenditure of lactation would tend to slow this recovery which was reflected by faster growth rates of ewes that did not produce a lamb and those that lost their lambs soon after parturition. Clutton-Brock et al. (1982) demonstrated lower body weights, lower kidney fat and lower rump fat in lactating red deer compared with barren females.

The energy costs of reproduction were further documented by greater weight loss suffered over winter by pregnant ewes. The difference noted in

ewes that bred as yearlings may have been greater than that seen in older females because yearling ewes on Ram Mountain normally do not breed and they are smaller than older ewes. Older, non-pregnant ewes would also be expected to lose less weight than pregnant ewes though the difference may not be as great.

Extreme weight losses could affect the survival of both ewe and fetus which would be compounded during severe winters. However, survival and lamb production remained high on Ram Mountain (unpublished data) even after the relatively hard winter of 1981/82 when overwinter weight losses were the greatest. Apparently, weight losses would have to be greater than what was recorded in 1981/82 for survival to be affected. Possibly a poor quality herd may be affected sooner than one of higher quality like Ram Mountain.

The weight that a bighorn attains each year would be dependent on the previous winter weight loss, summer rate of weight gain and on the length of the growing season. Winter weight loss has been shown to be dependent primarily on the severity of the winter. Stelfox (1974), similarly found large overwinter weight losses in ewes of Alberta's National Parks. Weight losses ranged from 7 to 22 percent of pre-winter body weight in ewes. Average growth rates for individuals of each age and sex did not vary from year to year regardless of interannual differences in spring and summer precipitation which Bunnell (1978) and Nievergelt (1966) found to correlate with interannual differences in horn growth. It appears that for weights, rate of gain is fairly constant and that any interannual differences observed in body weights would depend on the length of the growing season which would be dependent on the timing of spring green up.

In terms of productivity, survival and life expectancy the Ram Mountain sheep herd is one of high quality (Jorgenson and Wishart 1983). However, compared to bighorns in southern Alberta, the Ram Mountain herd is of poor quality relative to body size and horn growth. Wishart (1969) attributed the larger horn and body sizes of southern sheep to an optimum combination of climate, soil and vegetation. Since growth rates appear to be constant from year to year on Ram Mountain, it is probable that differences in body size observed in other herds may be the result of longer growing seasons and a larger overwinter weight base on which to add the next seasons growth. A long growing season followed by low winter weight losses appear to be factors influenced by more advantageous bioenergetic conditions. Rates of growth may also be faster in southern Alberta sheep herds, but until they can be trapped frequently at regular intervals their growth rates remain unknown.

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HORN GROWTH IN DALL'S SHEEP: A PRELIMINARY REPORT

M.B. Bayer, Faculty of Management, The University of Calgary, Calgary, AB, Canada

N.M. Simmons, Faculty of Environmental Design, The University of Calgary, Calgary, AB, Canada

ABSTRACT

Dall's Sheep (Ovis dalli dalli) horn growth was analysed from a sample of 69 rams killed in the Mackenzie Mountains, Northwest Territories by sport hunters. Mean age at full curl was 8.3 years and mean curl diameter was 28.8 cm. Rams with greatest early horn growth experienced lesser annual growth after 3 1/2 years than those with slower early growth. However, the rapid early-growth rams developed longer horns with larger basal diameter than the slow starters. Differences in horn growth characteristics between rams from Mackenzie Mountains and rams from four Alaskan mountain ranges are described.

INTRODUCTION

An arc of cold, dry winters bringing relatively shallow, granular snow cover marks the fringe of Dall's sheep (Ovis dalli dalli) habitat in Alaska and northern Canada. Published records of average winter temperatures and precipitation indicate a similarity in climate in the Brooks Range, Alaska, Richardson Mountains, Yukon and Northwest Territories (NWT), and northern Mackenzie Mountains, (NWT). The temperatures in these regions are cold and snowfall is sparse and relatively dry. The more southerly and westerly Alaska Range and Ogilvie Mountains are warmer, and experience heavier, moister snowfall. In the extreme is the Kenai Peninsula with the warmest temperatures and far greater snowfall and rain.

Researchers have correlated environmental conditions with horn growth (Bunnel 1978; Nievergelt 1966; Heimer and Smith 1975; Geist 1966a, 1971; Shackleton 1973, 1976). Geist (1966a) hypothesized that individual rams which show relatively rapid early growth of horn show relatively slower subsequent growth. Bunnell (1978), using data from Yukon sheep, examined this hypothesis and proposed that rates of horn growth are associated with nutrition. We continue this examination by focussing on incremental horn growth in Dall's sheep from Alaska and the NWT.

Research into the characteristics of the Dall's sheep population in the Mackenzie Mountains began in 1966 (Simmons 1968, 1969), shortly after the area was opened to non-resident sport hunters. The seasonal movements and demography of the sheep have since been described by Simmons (1982) and Simmons etal (1984). During the 1966-73 study period, the population was largely unaffected by humans, and researchers determined that the population level of females and juveniles was stationary. The harsh climate resulted in the highest mortality occurring during the winter in the first year of life.

Feeding and movements were relatively unrestricted by snow (Simmons et al 1984).

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STUDY AREA

The sheep in our sample were collected by sport hunters in the central Mackenzie Mountains. This area is characterized by relatively unstable limestone, dolomite, and shale slopes covered with sparse vegetation. Annual precipitation is 25-30 cm. Rainfall comes mainly in July and August. Most of the range is covered with shallow, lightly-crusted snow (< 50 cm) during winter. There are an average of 70-75 frost-free days a year. During winter, grasses and sedges (Carex, Festuca, Hierochloe, Kobresia, Poa, and Trisetum, among others) are most favoured by sheep and were readily available (W.H. Hoffmann, unpubl. rep., Can. Wildl. Serv., 1973). Winter ranges were most commonly on areas of gentle alpine tundra isolated by spruce (Picea sp.) covered plateaus and lowlands. Winter sheep density was about 1.0 per square kilometer (Simmons 1982), much lower than that reported by Hoefs and Cowan (1979) for the Yukon Territory.

METHODS

Horn measurements reported here were collected from 69 NWT rams (48 full curl) at Alberta taxidermists' shops and in private collections in southern Alberta. The age of each ram was estimated by counting the annual growth segments (Geist 1966b). The length of the longest horn and the lengths of growth segments were measured along the frontal surface of the horn. The first 2 1/2 years of growth was taken as one segment because of indistinct boundaries for the lamb and first-year segments. Horn length for full curl, the point at which horn curl describes a 360^{0} arc when viewed in profile, was measured, and age at full curl was estimated by measuring back from the horn tip. No estimate of horn-tip wear, which can be substantial (Hoefs and Nette 1982), was made. Horn-curl diameter was calculated from horn length at 360^{0}. Basal circumference and tip-to-tip spread were also measured. Measurements were taken using a 1/4 inch flexible steel measuring tape and recorded to the nearest 1/8 inch (3 mm).

A sub-sample of horns was selected which showed no brooming, were full curl or more, and were at least 9 years old. The longest horns from 18 heads met these criteria, and were ranked, longest to shortest, according to the length of the 0-2.5 year increment and split into two sub-samples of nine each. Differences in age and horn growth characteristics between the two sub-samples were examined using one-tailed t-tests.

Mean age and mean horn length at full curl for rams from Alaska Range East, Brooks Range, Chugach Range, and the Kenai Mountains were taken from Heimer and Smith (1975, Tables 1, 7 and 13). Horn-curl diameters were calculated from horn length at full curl. Mean length of growth segments for rams from these four Alaskan ranges were taken from Erickson (1970).

Differences in mean age, mean curl diameter, and mean length of growth increments for the Alaskan and Mackenzie Mountains rams were examined using chi-square analysis.

RESULTS

Mean annual horn growth increments for 69 Dall's rams are shown in Table 1. The growth increment formed during the year of death has not been included. Few rams in the sample were more than 10 years old.

The mean age at full curl was 8.3 years (Table 2), earlier than rams from Alaska Range East (8.7 yrs.) and Brooks Range (9.6 yrs.), but later than rams from the Kenai Mountains (8.0 yrs.) and the Chugach Range (8.1 yrs.) (Table 4). The mean curl diameter (28.8 cm) is similar to the calculated mean curl diameter for Chugach Range rams (28.5 cm), but is smaller than those calculated for the Kenai Mountains (29.0 cm), Brooks Range (29.8 cm) and Alaska Range East (29.2 cm) (Table 4). However, no significant differences among mean ages at full curl and among mean curl diameters were found.

The measurements for the 2 sub-samples of full curl rams of at least 9 years of age (Table 3) show some important differences. Horns with rapid early horn growth show significantly larger mean measurements for length of longest horn ($P<0.025$), 0-2.5 year increment ($P<0.0005$), tip-to-tip spread $P<0.025$), and horn base circumference ($P<0.05$). The mean total length of the 3.5-8.5 year increments for horns with rapid early horn growth was significantly shorter ($P<0.01$) than for horns with slow early horn growth. These results support the hypothesis that rapid early horn growth will be followed by slower growth (Bunnell 1978, Geist 1966a). Moreover, the mean length of each increment from 3.5 to 8.5 years for horns with slow early growth is as large or larger than the respective increments for horns with rapid early growth (Figure 1).

Variation among the mean lengths of 0-2.5 year growth segments for Mackenzie Mountains rams and rams from 4 Alaskan mountain ranges (Table 4) is significant ($P<0.005$). However, the variations among the mean lengths of the 3.5-9.5 year increment and among the mean lengths at 9.5 years are not significant. Plotting the mean lengths of 0-2.5 year growth segments shows an upward trend in mean length beginning with rams from the cold, dry Brooks Range and ending with the warm, wet Kenai Mountains (Figure 2). The mean lengths at 9.5 years show a similar trend for all mountain ranges except for the Kenai Mountains. Age at maximum mean horn length appears to decline as climatic conditions become warmer and wetter (Table 4).

DISCUSSION

Analysis of our small sample of rams from the Mackenzie Mountains indicates characteristics of ram horn growth that warrant further investigation with a larger sample. The future use of horn volume as a size measurement will reduce the variables operating on our linear measurements. Furthermore, horn volume is the best measure of trophy quality and may be a better indicator of social ranking than horn curl.

Table 1. Mean length of horn growth increments for a sample of 69 Dall's Rams from Mackenzie Mountains, N.W.T.

Horn Growth Increment (yrs.)	Number in Sample	Increment Length	
		Mean (cm)	Standard Deviation (cm)
0 - 2.5	69	39.00	7.11
2.5 - 3.5	69	14.36	2.42
3.5 - 4.5	67	12.10	1.83
4.5 - 5.5	65	9.40	1.80
5.5 - 6.5	56	7.08	1.44
6.5 - 7.5	50	5.19	1.27
7.5 - 8.5	37	3.94	0.78
8.5 - 9.5	25	2.93	0.77
9.5 - 10.5	14	2.43	0.75
10.5 - 11.5	3	2.01	0.48
11.5 - 12.5	2	1.91	0.90
12.5 - 13.5	2	1.59	0.90
13.5 - 14.5	1	1.59	-

Table 2. Summary of horn measurements for a sample of 69 Dall's rams from Mackenzie Mountains, NWT.

Measurement	Sample Size	Mean	Standard Deviation
Length of longest horn (cm)	69	90.1	8.80
Length of horn at full curl (cm)	48	90.4	5.71
Estimated age at full curl (yrs.)	48	8.3	1.36
Diameter of horn curl (cm)[a]	48	28.8	1.82
Circumference of horn base (cm)	69	31.7	1.83
Tip-to-tip spread (cm)	67	58.3	8.22

[a] Calculated from horn length at 360°.

Table 3. Horn measurements for Mackenzie Mountains Dall's rams with slow and rapid horn growth during first 2.5 years of life.

Measurement	Slow Early Growth			Rapid Early Growth		
	Sample Size	Mean	Standard Deviation	Sample Size	Mean	Standard Deviation
Estimated age (yrs.)	9	10.3[a]	0.87	9	10.6[a]	1.58
Estimated age at full curl (yrs.)	9	8.8[b]	1.09	9	8.2[b]	1.86
Length of longest horn (cm)	9	93.7[c]	7.08	9	99.7[c]	4.17
Horn length at full curl (cm)	9	89.5[d]	4.96	9	93.5[d]	4.88
Horn curl diameter (cm)	9	28.5	1.58	9	29.7	1.55
0 - 2.5 year increment (cm)	9	34.6[e]	6.11	9	45.0[e]	4.11
3.5 - 8.5 year increment (cm)	9	55.0[f]	4.28	9	50.0[f]	3.71
Tip-to-tip spread (cm)	8	60.6[g]	7.28	9	67.6[g]	5.17
Circumference of horn base (cm)	9	31.3[h]	1.84	9	32.8[h]	1.80

[a] $t = 0.50$, P 0.10

[b] $t = 0.83$, P 0.10

[c] $t = 2.19$, P 0.025

[d] $t = 1.72$, P 0.05

[e] $t = 4.24$, P 0.0005

[f] $t = 2.65$, P 0.01

[g] $t = 2.31$, P 0.025

[h] $t = 1.75$, P 0.05

Table 4. Mean horn measurements for Dall's rams from Mackenzie Mountains, N.W.T. and four mountain regions in Alaska.

Measurement	Geographical Region				
	Mackenzie Mountains	Brooks Range	Alaska Range(E)	Chugach Range	Kenai Mountains
0-2.5 yr increment (mm)[a]	346	336	390	398	438
(n)	(69)	(32-42)[b]	(72-82)	(67-73)	(47)
3.5-9.5 yr increment (mm)[a]	550	535	532	553	507
(n)	(69-25)	(42-17)	(84-24)	(73-18)	(46-5)
Mean length at 9.5 years (mm)[a]	896	871	922	951	945
(n)	(25)	(17)	(24)	(18)	(5)
Maximum mean horn length (mm)[a]	1099[c]	918	958	951	945
(n)	(1)	(5)	(11)	(18)	(5)
Age at maximum mean length (yrs.)[a]	14.5[c]	11.5	11.5	9.5	9.5
Horn length at full curl (mm)[d]	904	937	918	895	910
(n)	(48)	(68)	(118)	(48)	(23)
Diameter of horn curl (cm)	28.8	29.8	29.2	28.5	29.0
Estimated age at full curl (yrs.)[d]	8.3	9.6	8.7	8.1	8.0
(n)	(48)	(68)	(118)	(48)	(23)

[a] Erickson (1970).

[b] Range of n used in calculations.

[c] Mean horn length and mean age for the 3 oldest rams in the sample are 917 mm and 14.2 years, respectively.

[d] Heimer and Smith (1975).

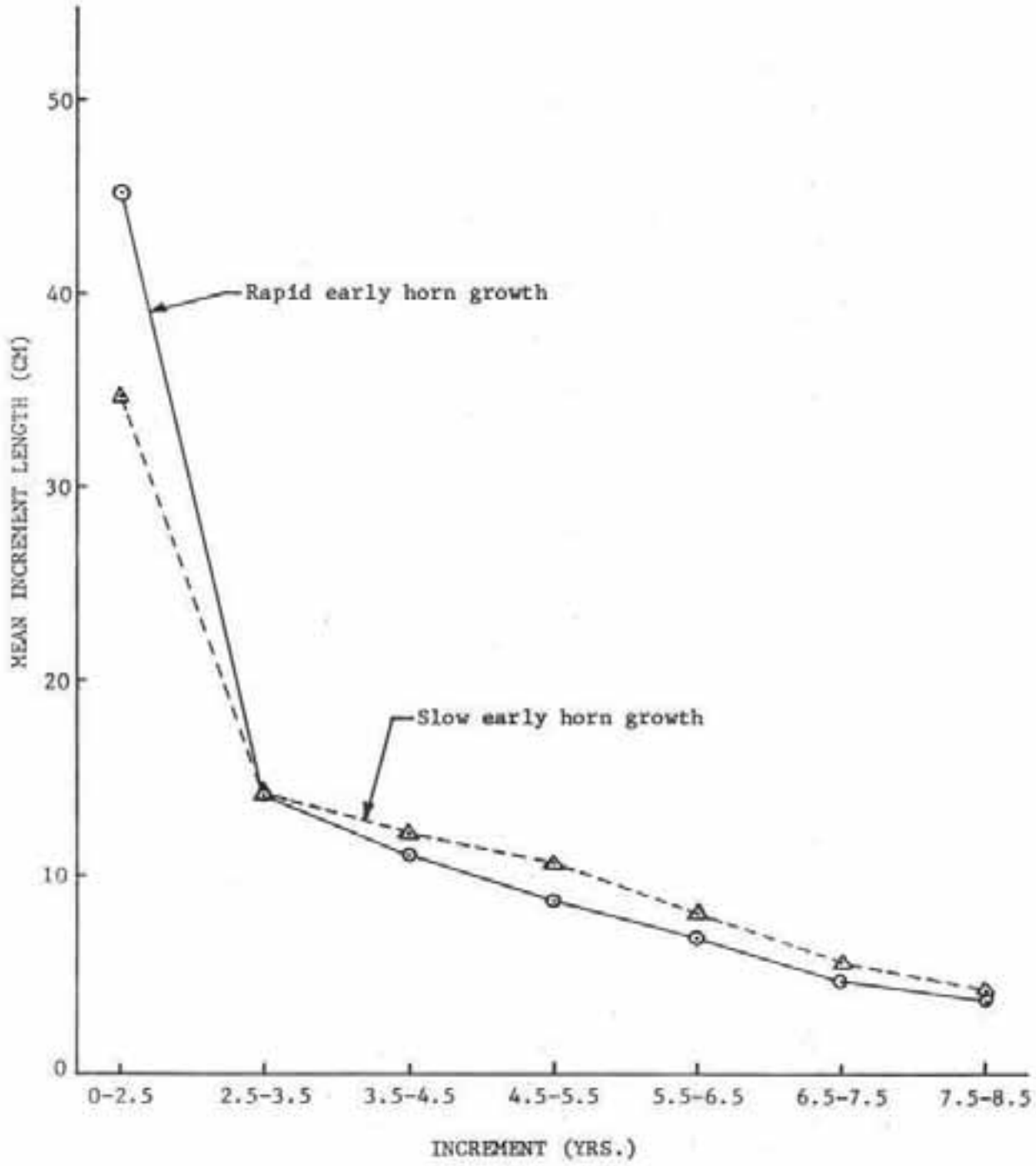

Figure 1. Mean increment lengths for rapid and slow early horn growth in Dall's rams from Mackenzie Mountains, NWT.

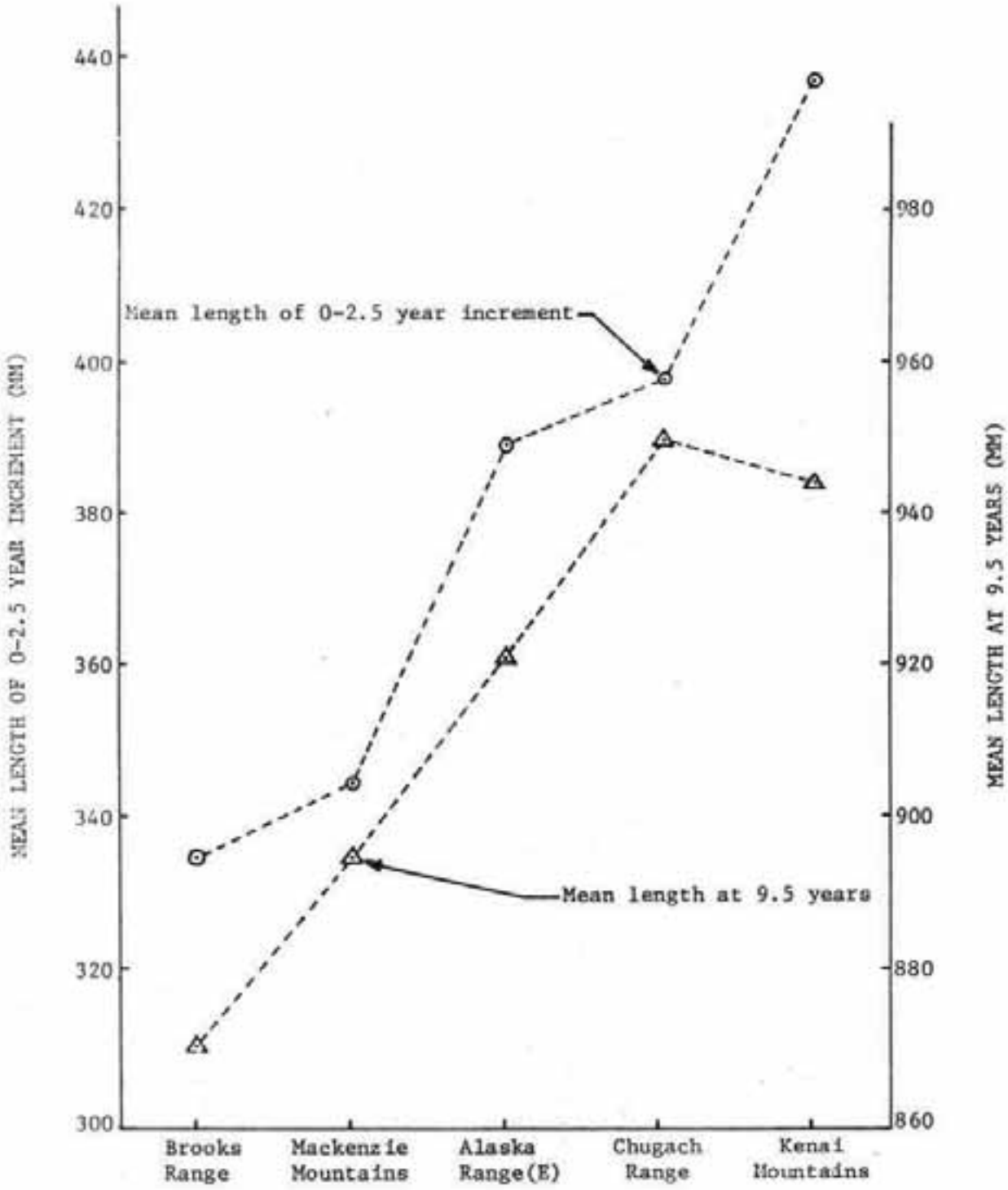

Figure 2. Mean lengths of horn growth increments for Dall's rams from the Mackenzie Mountains and five Alaskan mountain ranges.

Rams from the cold, dry northern ranges exhibit slower early growth than rams from the warmer, wetter ranges to the south. The extreme is the Kenai Peninsula with its high rainfall and lush vegetation. This cline supports the relationship between horn growth and nutrition proposed by Bunnell (1978). Rapid early horn growth also appears to be associated with shorter longevity, and warrants further investigation.

Compensatory horn growth in rams exhibiting slow early growth was also observed in the Brooks Range (W. Heimer, pers. commun., 1984). Mackenzie Mountains rams having rapid early horn growth also exhibit significantly greater basal circumference and tip-to-tip spread. It would be interesting to determine whether Alaskan sheep, particularly Kenai rams, also exhibit this relationship.

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VOLUME AND DENSITY OF HORNS OF DALL RAMS

Robert König, University of Giessen, Arbeitskreis für Wildbiologie und Jagdwissenschaft, Giessen 6300, Germany.

Manfred Hoefs, Yukon Wildlife Branch, Whitehorse, Yukon, Y1A 2C6, Canada.

ABSTRACT

Volume determinations were carried out on 42 horns of Dall rams by means of the water displacement method. The density of the horn sheath ($\bar{x}$ = 1.227 gr/cm^3) was found to be constant and therefore can be used for volume determination if the weight of a horn sheath is known. Both horn sheath and horn core grow throughout life, but at different rates. The core's proportion of the total horn volume is higher in early ages (42% to 38%) and declines with increasing age, making up only 15% to 12% in very old rams (12 to 13 years). Total horn volume increases from about 30 cm^3 in a one year old ram to over 3000 cm^3 in 12-year old rams; over the same period the sheath volume grows from 25 cm^3 to 2600 cm^3. While the small sample sizes did not allow a reliable assessment of growth increments in volume per age class, it became obvious that volume growth is better correlated with age than horn growth in length. In contrast to growth in length, where the 2nd and 3rd annual increments are the longest, most volume is produced in the 4th to 6th year age classes.

INTRODUCTION

The horns of wild sheep are among the most coveted trophies. It is therefore not surprising that a number of trophy evaluation schemes have come into being (Boone and Crockett, Pope and Young, Safari International, Rowland Ward, and Conseil International de la Chasse et de la Conservation du Gibier), by means of which the horns of sheep can be assessed and compared. While details in methodology vary between them, all of these schemes use horn lengths and horn circumference measurements as the most important criteria. These assessment methods were therefore adopted when biologists first began to describe sheep horns for age determination (Cowan 1940, Geist 1966, Hemming 1969) or as parameters of population quality (Taylor 1962, Geist 1971,

Shackleton 1973, Bunnell, 1978). Only very recently has it become apparent that the real size of a sheep horn, its mass or volume, is not properly reflected in either length or circumference measurements, nor in the conventional combinations of these two, as in the Boone and Crockett scoring formula. As an example, tightly curling horns have different volumes than large curls with the same total lengths, a given circumference measurement will describe different cross-sectional areas, depending on whether their shapes are triangular, rectangular, oval or circular. A different method is therefore called for to estimate the volume of horns. Heimer and Smith (1975) made the first attempts in this direction. They used the formula for determining the volume of a cone as an approximation, and then applied a correction factor determined from volume assessments by the water displacement method. Zingg (1980) used surface areas as an indicator for the mass of ibex horns. König and Hoefs (1982) used the water displacement method to establish the volume of whole sheep horns as well as annual increments. Here the assumption was made that the use of external features such as incremental lengths and circumference at the annuli are reliable indicators for volume determinations. The true annual increment is a fairly complicated cone-like structure, as is shown in Fig. 1. It cannot be measured externally; only with longitudinal sections of the horn can its shape be assessed. However, an estimation of incremental annual volume sizes is possible if the total volumes of horns of an adequate sample size of all age classes were known. The volume increment per given age class would then be the difference in mean volume values of neighbouring age classes. Since variations in horn growth parameters are large, a fairly substantial, homogeneous sample size is necessary, preferably from the same population. Volume assessment is complicated by the fact, that a horn consists of a bony core, which is an extension of the frontal bone, and a keratinous sheath, which grows on this core. While it was known that both core and sheath grow throughout life of a ram, it was not known whether they grow at the same rate. Differential growth will complicate volume determinations of annual growth increments.

In this analysis we addressed the following hypotheses:

1. Is the ratio of sheath to core volume a function of age, or does it remain constant throughout life?

2. Does growth in horn volume follow the same pattern as growth in horn length or are the peak growth periods reached in different ages?

3. Is horn density a constant to be used for volume determinations, if the weight of a horn sheath is known?

METHODS AND MATERIAL

The skulls of 42 Dall rams were available for assessment. From each skull the longest or least damaged horn was used. The horn sheaths were removed from their bony cores and volume determinations were carried out by the water displacement method. First the horn sheath was submerged and assessed, afterward the hollow of the horn was filled with fine gravel and sealed off with wax. The wax layer followed the contours of the horn base as well as possible to approach the outline of the basal circumference of the horn core. The horn was submerged again and total volume was determined. The volume of

FIG.I. HORN SAGITTAL SECTION OF 7-YEAR-OLD RAM (AFTER TAYLOR, 1962)

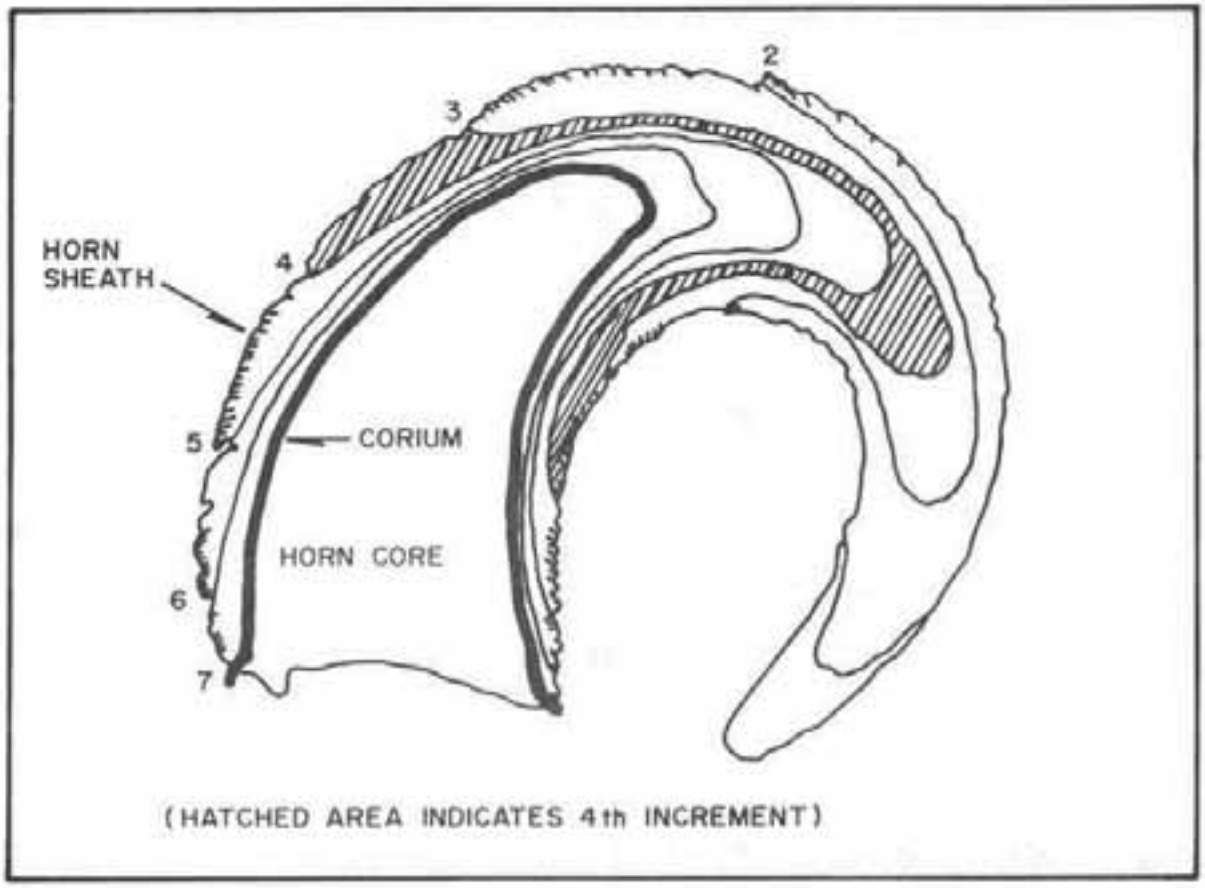


FIG.2. RELATIONSHIP OF TOTAL HORN VOLUME TO AGE (INDIVIDUAL VALUES)

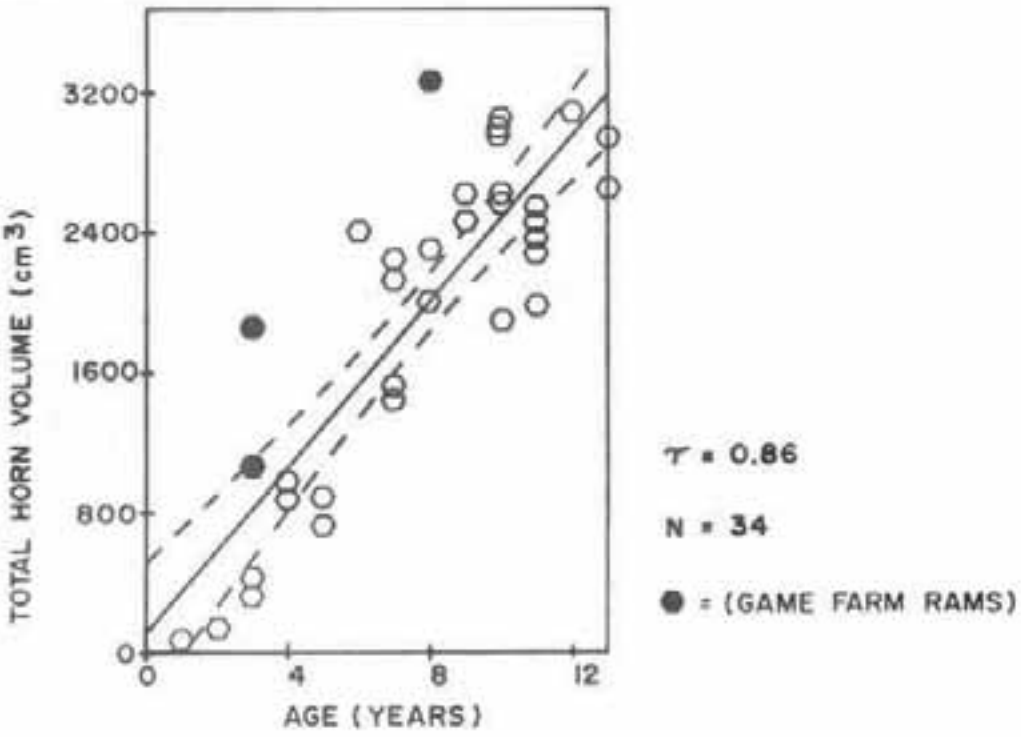
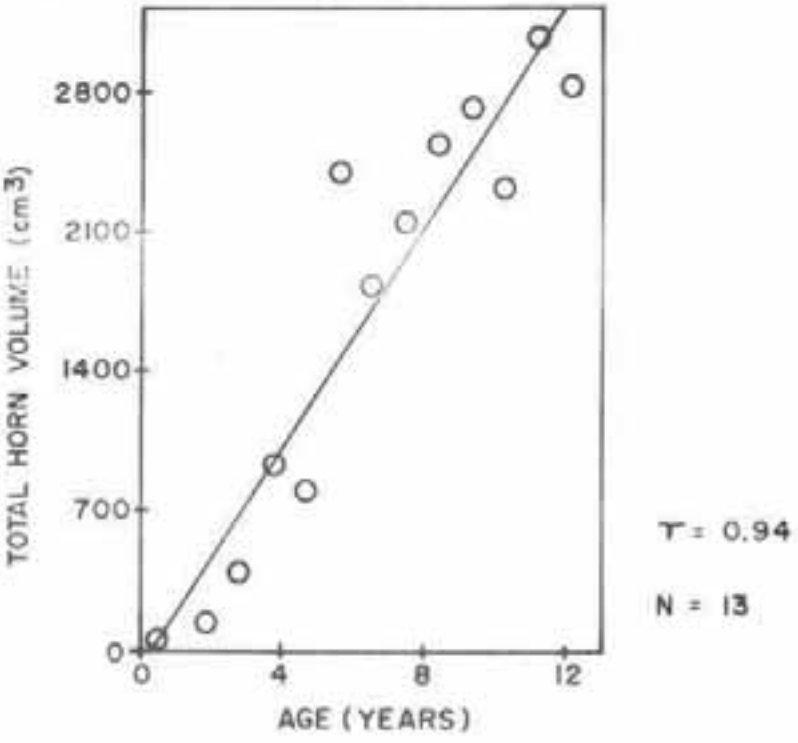


FIG.3. RELATIONSHIP OF TOTAL HORN VOLUME TO AGE (MEAN VALUES FOR AGE COHORTS)



the core was then assessed by subtracting sheath volume from total volume. In a live horn there is a third component, the membrane or tissue, which covers the core and produces both bone for core growth as well as keratin for sheath growth. The volume of this material was neglected in these assessments, since it had dried up and disintegrated in old specimens. However, the amount of this tissue is so small, that it is insignificant in volume determinations of sheath and core. Age determinations were carried out using the horn annuli technique (Hemming 1969, Geist 1966).

Most of the horns assessed came from the Sheep Mountain population of Dall sheep in Kluane National Park, which has been subject of study for a number of years (Hoefs and Bayer, 1983). The 42 horns covered all ages, but for certain cohorts the sample size was very small. The horns were also weighed and their density determined. Not all tests could be done with the full sample size since 3 horns came from rams raised in the Yukon Game Farm, which had significantly larger horns than their wild relatives, and for 4 horns reliable age determination was not possible. Therefore, tests using age as a variable were from a sample size of 35.

RESULTS

Table 1 lists individual measurements for sheath and core volumes, total volumes, ratios between these and computed densities for 42 individual horns, and in Table 2 these data are summarized per age class.

A) THE DENSITY OF HORN SHEATH KERATIN.

The density of horn sheaths averaged 1.227 gr/cm^3 with a standard deviation of 0.030 gr/cm^3 (Table 1). The lowest density recorded was for a ram less than one year old with 1.10 gr/cm^3, the highest density recorded was 1.28 gr/cm^3 for a one-year old ram. However, these extreme values must be viewed with caution, since the error in volume determination of very small horns is greater relative to those of larger horns. The density values for horns > 1 year varied between 1.16 and 1.26 and were fairly constant. Correlations between horn sheath density and age, total horn volume, horn sheath volume and core volume were not significant. The weight of the sheath is therefore a useful measure of the keratinous material produced in all age classes. Also no consideration to density variation needs to be given in the determination of ratios between horn sheath and core development, since densities remain similar in different growth relationships. The constant density of 1.227 + 0.030 allows a reasonably accurate volume assessment of the horn sheath by weight.

B) THE GROWTH OF THE HORN

The total volume of the horns continued to grow with age, but not in a perfectly linear manner. In Fig. 2 the total horn volume of all horns is plotted as a function of age, with the exception of the horn of the lamb. The linear regression coefficient is 0.86. It is obvious from the figure that there is considerable variation in horn volume among the individual horns in each age cohort. In Fig. 3 the mean values for each age group are shown, the variation from the linear regression function is high ($r = 0.94$). This variation does not allow a reliable assessment of the type of function that

Table 1. Individual horn volume values, ratios and specific weights.

Age	Total Volume T	Sheath Volume S	Core Volume C	S:C	S:T	Density
<1	5	3	2	1.50	0.60	1.10
1	64	39	25	1.56	0.61	1.28
2	135	80	155	1.45	0.59	1.25
3	317	185	132	1.40	0.58	1.19
	415	255	160	1.59	0.61	1.20
	425	260	165	1.58	0.62	1.21
4	875	505	370	1.36	0.58	1.23
	975	670	305	2.20	0.69	1.24
5	720	535	185	2.89	0.74	1.25
	885	622	263	2.37	0.70	1.26
6	2400	1710	690	2.48	0.71	1.23
7	1440	1110	330	3.36	0.77	1.23
	1525	1165	360	3.24	0.76	1.24
	2125	1705	425	4.01	0.80	1.23
	2240	1830	410	4.46	0.82	1.22
8	2005	1555	450	3.46	0.78	1.22
	2300	1680	620	2.71	0.73	1.25
9	2465	1960	505	3.88	0.80	1.23
	2615	1950	665	2.93	0.75	1.26
10	1895	1455	440	3.31	0.77	1.25
	2555	2055	500	4.11	0.80	1.22
	2620	2270	350	6.49	0.87	1.23
	2950	2445	505	4.84	0.83	1.21
	2975	2350	625	3.76	0.79	1.23
	3000	2450	550	4.45	0.82	1.18
	3040	2450	590	4.15	0.81	1.22
11	1895	1455	440	3.31	0.77	1.25
	2275	1895	380	4.99	0.83	1.23
	2365	2015	350	5.76	0.85	1.24
	2450	2000	450	4.44	0.82	1.25
	2540	1990	550	3.62	0.78	1.23
12	3075	2620	455	5.76	0.85	1.24
13	2640	2240	400	5.60	0.85	1.21
	2025	2560	365	7.01	0.88	1.23
	2930	2300	630	3.65	0.78	1.24
Age unknown						
	2115	1745	370	4.72	0.83	1.23
	2225	1780	445	4.00	0.80	1.21
	2440	1950	490	3.98	0.80	1.23
	3580	2860	720	3.97	0.80	1.26
Game[3]	1055	660	395	1.67	0.63	1.23
Farm[3]	1850	1375	475	2.89	0.74	1.16
8	3260	2830	430	6.58	0.87	1.24

Table 2. Mean values for age cohorts of horn volumes and ratios (volume in cm^3).

Age	N	Total Volume T	Sheath Volume S	Core Volume C	C/S	S/T
1	1	34.5	21.0	13.5	0.66	0.61
2	1	135.0	80.0	55.0	0.69	0.59
3	3	385.7	233.3	152.3	0.65	0.60
4	2	925.0	587.5	337.5	0.60	0.65
5	2	802.5	578.5	224.0	0.39	0.72
6	1	2400.0	1710.0	690.0	0.40	0.71
7	4	1832.6	1452.5	390.0	0.27	0.79
8	3	2521.7	2021.7	500.0	0.27	0.79
9	2	2540.0	1965.0	585.0	0.30	0.78
10	7	2719.3	2225.0	494.3	0.23	0.82
11	5	2322.0	1899.0	423.0	0.22	0.82
12	1	3075.0	2620.0	455.0	0.17	0.65
13	3	2831.7	2366.7	465.0	0.20	0.84

would best describe growth in horn volume. This function may in fact be an S-shape relationship rather than a linear one, an assumption supported by incremental volume calculations (Hoefs and Barichello, 1984). It appears that there is slow volume growth to the 2nd year, then accelerated horn volume development between the 3rd and 9th year, and again a slowing down and flattening of the growth curve from the 9th year to the end of life (13 to 15 years). However, for the limited data used in this analysis, the linear function is a useful approximation. The relatively steep and constant acceleration in volume growth over a longer time period, is in contrast to the non-linear growth in horn length. Horn growth in length reaches a maximum during the 2nd or sometimes 3rd year, and decreases rapidly as the ram ages. The real horn growth expressed as volume increases is more constant over the years and reaches its maximum between the 4th and 6th year. These findings support earlier published information (Konig and Hoefs 1982),from which a relevant diagram is reproduced here (Fig. 4).

C) THE CONTRIBUTIONS OF HORN SHEATH AND HORN CORE TO THE GROWTH OF THE HORN AS A WHOLE.

Horn sheath and horn core grew at different rates. The core's proportion of the total horn volume was higher in the early ages and declined with increasing age; correspondingly, the sheath contributed little initially but significantly to the total volume as the ram aged. This means that with increasing age, keratin production accelerates relative to bone formation. For a 1 to 2 year old ram, the horn sheath made up about 60% of the total volume, compared to about 85% in 12 to 13 year old rams. The ratio of core volume to horn volume changed accordingly, from 0.655 in one-year-old rams to about 0.170 in 12-year- olds (Figs. 5 and 6). Variations among individuals in this horn growth parameter were considerable in all age groups (Fig. 6), making an estimation of the functional relationship difficult. Based on the present sample size, a linear function is a useful approximation ($r = -0.85$). The core volume also increased with age, but the correlation was weak ($r = 0.69$) (Fig. 7), and conditional to the growth of the total horn volume ($r = 0.84$) (Fig. 8). From these relationships it becomes obvious, that the contribution the core makes to total horn volume decreases with increasing horn size, regardless of rapid growth in the early years, or prolonged growth over a number of years. The ratio of core to sheath is not only an age-specific characteristic, but it is also dependent on total volume accumulation. This becomes apparent through the method of partialization of total volume (Fig. 9) (Sokahl and Rohlf, 1969). Here the correlation coefficient of the ratio core to sheath with age is $r = -0.40$. On the other hand, if there is a partialization of age, the correlation of this ratio to total volume works out to be $r = -0.51$ (Fig. 10). Therefore, both, age and growth rate influence the ratio of core to sheath. The older and the bigger a horn the smaller the contribution the core makes to total volume.

The fairly high remaining variation indicates, that great individual differences can be expected. At this time, it is not established whether these differences are genetic in origin or determined by environmental factors. The ratio of sheath to core volume and total horn volume may be a species-specific chracteristic. However, no detailed information is available for other Ovis types, so comparisons are not possible.

FIG. 4. ANNUAL HORN GROWTH OF TWO DALL RAMS EXPRESSED AS GROWTH IN VOLUME AND IN LENGTH

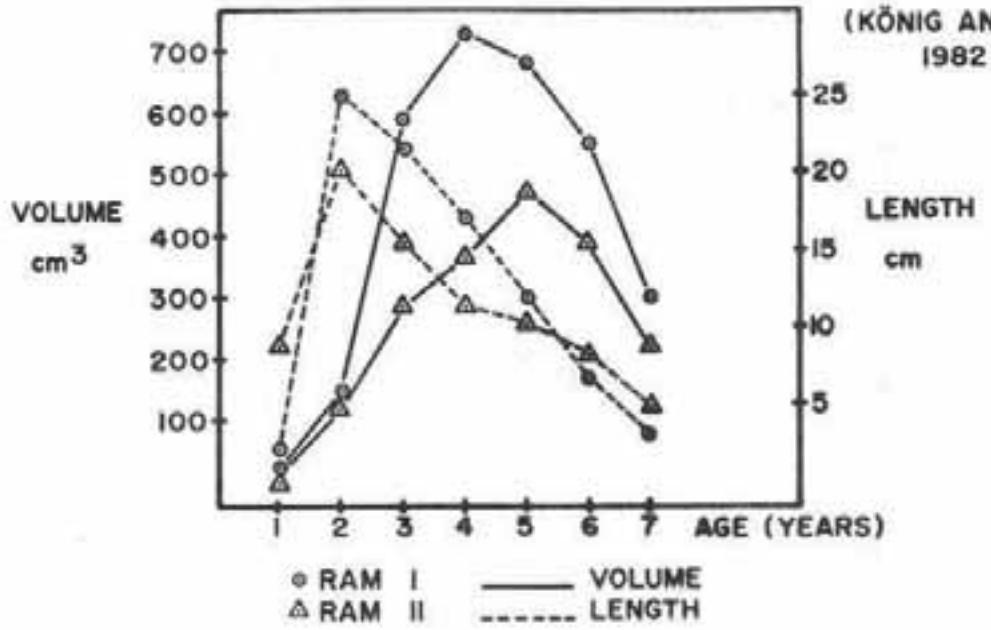


FIG. 5. RELATIONSHIP OF RATIO (CORE / TOTAL VOLUME) TO AGE (MEAN VALUES FOR AGE COHORTS)

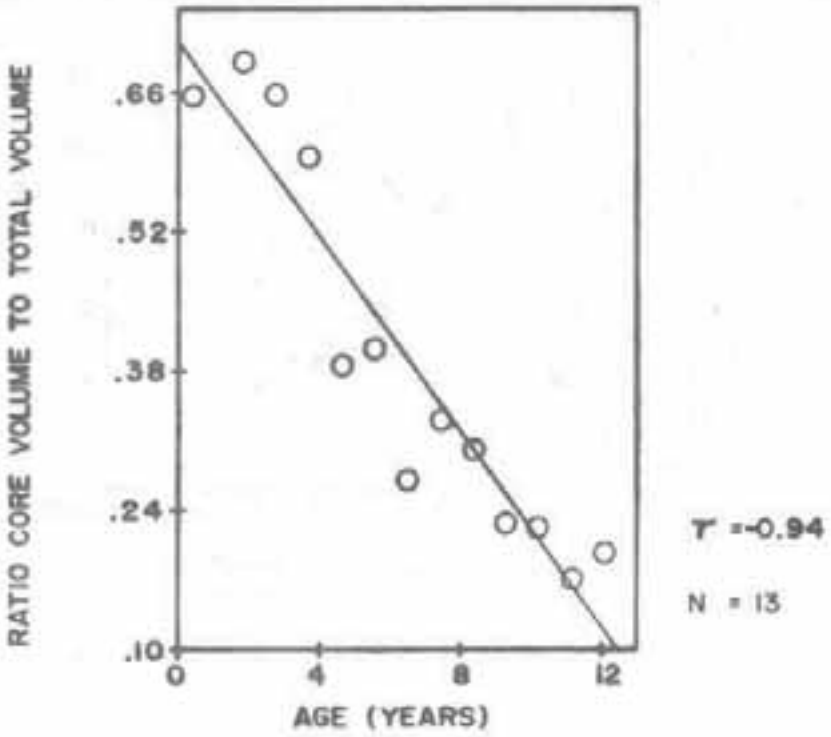


FIG. 6. RELATIONSHIP OF RATIO (CORE / TOTAL VOLUME) TO AGE (INDIVIDUAL VALUES)

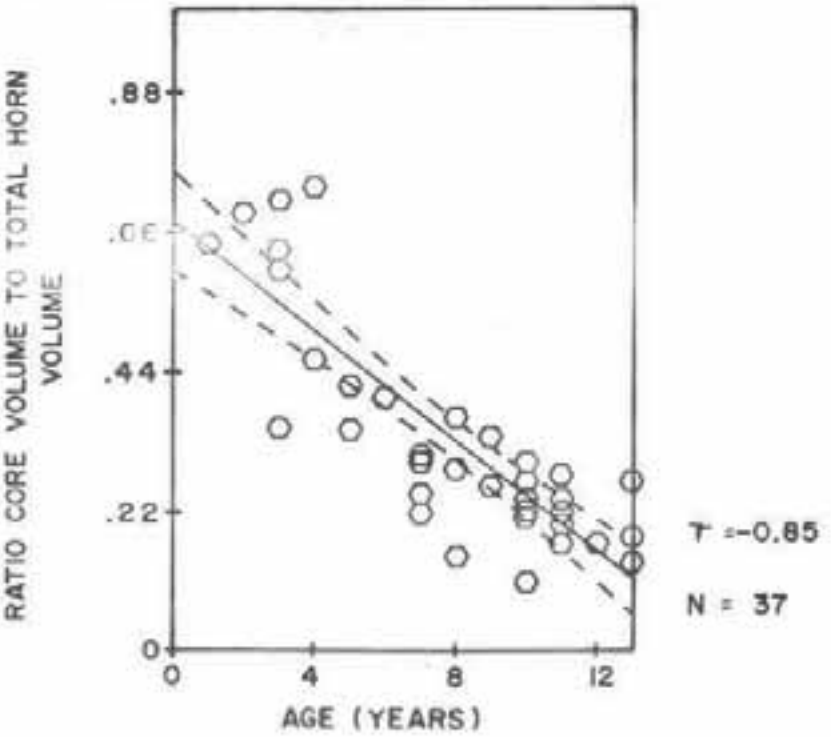


FIG. 7. RELATIONSHIP OF CORE VOLUME TO AGE

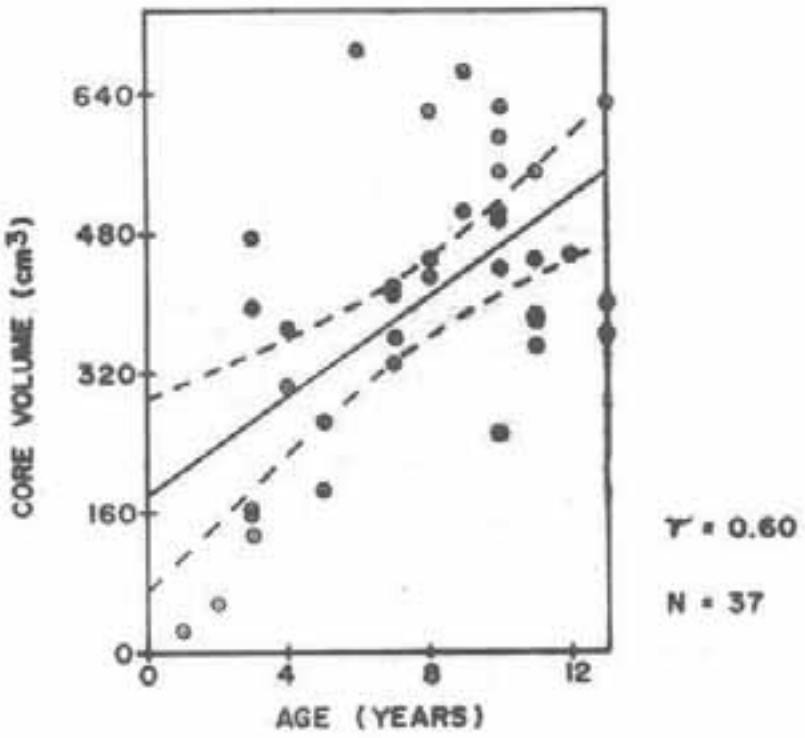


FIG. 8. RELATIONSHIP OF CORE VOLUME TO TOTAL HORN VOLUME

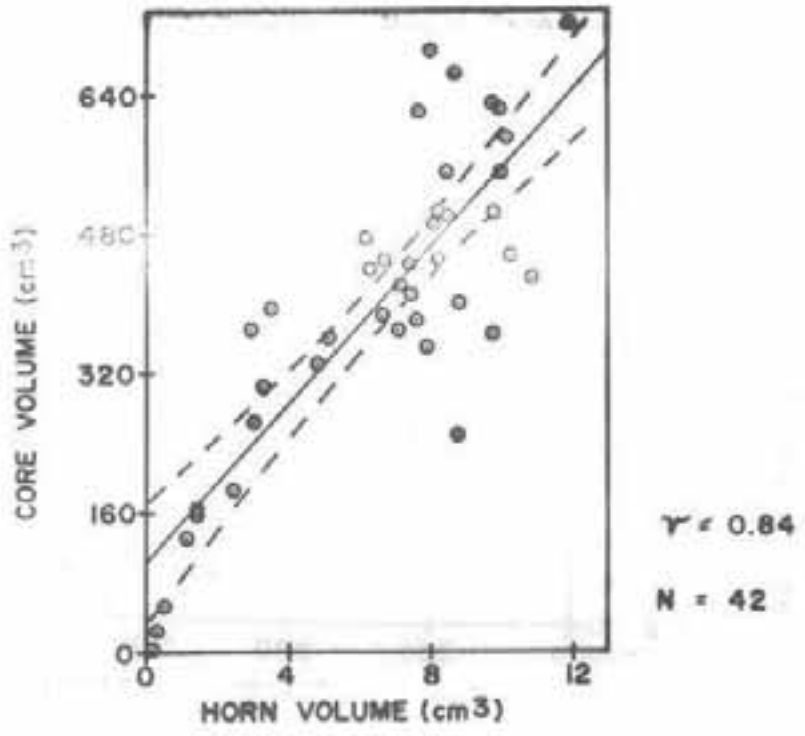


FIG. 9. PARTIAL CORRELATION OF C/T ON AGE (T CONSTANT)

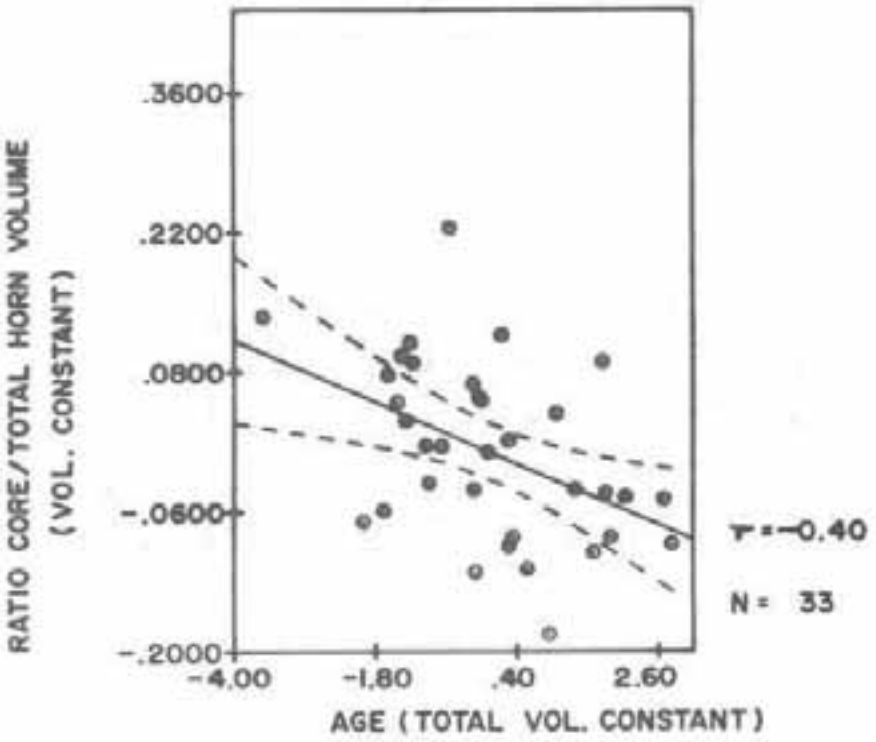


FIG. 10. PARTIAL CORRELATION OF C/T ON TOTAL HORN VOLUME (AGE CONSTANT)

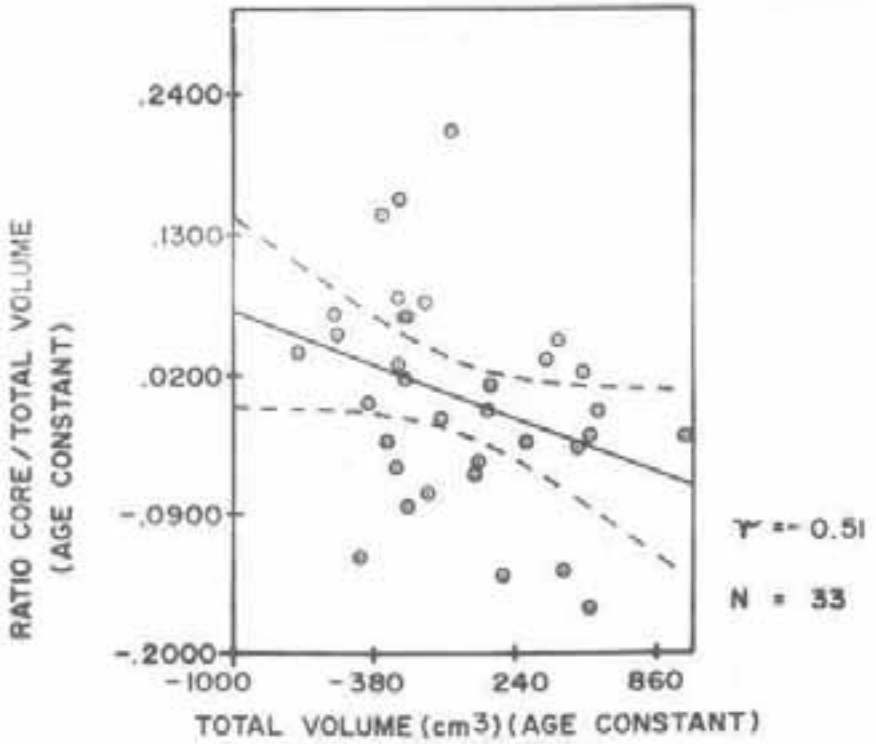
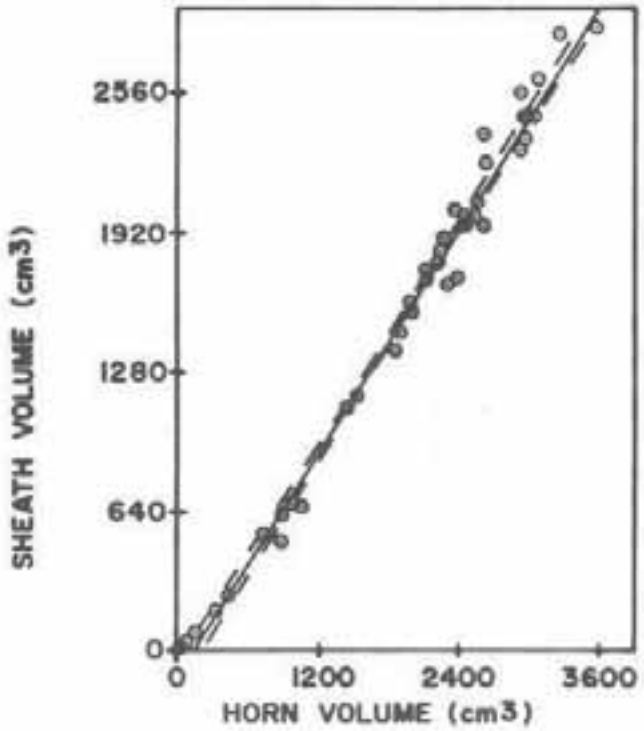


FIG. II. RELATIONSHIP OF SHEATH VOLUME TO TOTAL HORN VOLUME



DISCUSSION AND SUMMARY

The true volume of Dall ram horns increases more uniformly with age, than indicated from measurements of length and circumference, with the latter having been previously applied almost exclusively. The annual increments in volume are substantial from the 2nd year up to and beyond the 10th year.

Wear of the horn tip over time, which may exceed horn growth in length after the 9th year (Hoefs and Nette, 1982) is insignificant in relation to volume change. The volume of the first increment - even in horns with well preserved tips - amounts to less than 4% in 10 year-old rams.

Unfortunately the small sample sizes in certain age classes do not allow an accurate determination of the growth function in horn volume, or the magnitude of the annual increment rates. We know, from detailed measurements of individual horns (Kŏnig and Hoefs, 1982) that the largest growth in volume takes place during the 4th, 5th, and 6th year, which is in contrast to horn growth in length, where the 2nd and sometimes the 3rd years produce the longest increments.

The contribution of the bony core to the total horn volume decreases with increasing volume. This relationship applies to increasing age as well as magnitude of volume growth within an age class. During the first 3 years the core makes up 38% to 42% of the horn volume, it decreases to 18% to 24% in 7-year-old rams, and in the very old age cohorts it may be as low as 12% to 15%.

In the largest horns, with a volume in excess of 3000 cm^3, the core makes up 13% to 20%, in medium sized horns with a volume of 2000 to 3000 cm^3 it contributes 12% to 29%, in horns of 1000 to 2000 cm^3 volume, about 25% of the total volume consists of bony core.

Since the volume of the horn sheath makes up the largest portion of the total horn volume, and since it grows with the latter in a linear manner, each of these volumes can be estimated fairly accurately, if the other one is known (Fig. 11). The regression coefficient between sheath volume and total horn growth is 0.994. Another constant parameter is horn density (1.227 gr/cm^3) which is independent of age or volume. It can be used to calculate sheath volume with little error, once the weight of the sheath has been determined.

It is recommended that volume determination should become part of routine evaluations carried out by many wildlife management agencies or hunting clubs on trophies harvested by hunters. Volume is a more appropriate indicator of trophy value than the linear measurements applied to date, and a more reliable indicator of population quality.

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SEROLOGIC, HEMATOLOGIC, AND BLOOD CHEMISTRY VALUES OF DESERT BIGHORN SHEEP IN SONORA, MEXICO

James R. DeForge, Bighorn Research Institute, Palm Desert, CA

Charles W. Jenner, Bighorn Research Institute, Palm Desert, CA

Peter E. Cyrog, Bighorn Research Institute, Palm Desert, CA

Raul Valdez, Bighorn Research Institute, Palm Desert, CA

ABSTRACT

Blood samples from eighteen desert bighorn (Ovis canadensis mexicana) live-captured in Sonora, Mexico, were collected for serologic, hematologic, and blood chemistry analyses. Significant serologic titers were found to bluetongue, parainfluenza-3, epizootic hemorrhagic disease, and bovine virus diarrhea. Suspect titers were found to contagious ecthyma and Leptospira interrogans serovar pomona. No titers were found to infectious bovine rhinotracheitis or Brucella abortus. Blood chemistry and hematological results are presented.

INTRODUCTION

Eighteen bighorn were captured between January 30 and February 4, 1984, sixteen from the Posada-Pico Johnson range in Sonora, Mexico, and two from Tiburon Island in the Gulf of California. Thirteen of these bighorn were captured by herding the animals into standing linear nets with a helicopter. Two were captured with a net capture gun fired from a helicopter. Three were captured by chemical immobilization from a helicopter using a CO_2 Cap-Chur rifle. Complete capture information is presented in DeForge et al. (1984). Body condition and health of all animals appeared good.

METHODS

Whole blood was collected from each animal by jugular puncture and was transferred into sterile tubes to be used for serological, virus isolation and blood chemistry analyses, into potassium oxalate - sodium fluoride tubes for glucose determination, and into liquid EDTA (K_3) tubes for hematology. Whole blood in sterile tubes was allowed to clot for 2-5 hours at room temperature, then centrifuged for 20 minutes for serum separation. Fecal samples were collected to evaluate parasitic diseases, and nasal swabs were collected to survey respiratory pathogens. All medical samples were flown daily to veterinary laboratories in the United States.

Hematology and blood chemistry analyses were conducted by Veterinary Reference Laboratory, Anaheim, California, as well as hemagglutination inhibition tests for parainfluenza-3 and agar gel immunodiffusion tests for bluetongue. Veterinary Reference Laboratory also ran bacterial cultures from nasal swabs.

Veterinary Laboratory Services, Fresno, California did serological testing for Brucella abortus and Leptospira interrogans serovars pomona, hardjo, grippotyphosa, canicola, and icterohaemorrhagiae by plate agglutination; for bluetongue and epizootic hemorrhagic disease by agar gel immunodiffusion; and for parainfluenza-3, bovine virus diarrhea, and infectious bovine rhinotracheitis by virus neutralization. They also attempted virus isolation from blood clots and nasal swabs, and cultured bacteria from nasal swabs.

Central Animal Health Laboratory, Madison, Wisconsin conducted complement fixation tests for bluetongue, and National Veterinary Services Laboratories, Ames, Iowa, conducted complement fixation tests for epizootic hemorrhagic disease and contagious ecthyma.

RESULTS AND DISCUSSION

Results of serological tests are presented in Table 1. Fifty percent of the sheep were seropositive to parainfluenza-3. These titers were also high (1:64 to 1:256), indicating probable previous infections. Parainfluenza-3 virus destroys the mucociliary cells that line the lower respiratory tract, hindering the clearance of infective agents, and when coupled with stress and bacteria it can trigger fatal pneumonia in both lambs and adults (Heuschele 1981, Salsbury 1981, Dyer 1982). Exposure to parainfluenza-3 has been found in other bighorn populations (Parks et al. 1972, Parks and England 1974, DeForge 1980), and is considered an important factor in a pneumonia complex that is causing high lamb mortality in the Santa Rosa Mountains of California (DeForge et al. 1982). This population should be monitored for signs of disease that could be the result of parainfluenza-3 virus. Parainfluenza-3 is common in cattle and domestic sheep. Cattle were observed in the study area.

Table 1. Results of serological tests for antibodies to selected animal pathogens in 18 desert bighorn from the Posada-Pico Johnson Range in Sonora, Mexico, and on Tiburon Island in the Gulf of California.

	Percent Positive	Percent Suspect
Parainfluenza-3	50	-
Bovine Virus Diarrhea	50	-
Epizootic Hemorrhagic Disease	44	-
Bluetongue	22	-
Leptospira interrogans serovar *pomona*	-	39
Contagious Ecthyma	-	11
Infectious Bovine Rhinotracheitis	-	-
Brucella abortus	-	-

Table 2. Hematologic values for 18 desert bighorn from the Posada-Pico Johnson Range in Sonora, Mexico, and on Tiburon Island in the Gulf of California.

	$\bar{x} \pm s$
Leukocytic series	
Total white blood cells ($10^3/mm^3$)	8.39 ± 3.16
Band neutrophils (%)	0
Segmented neutrophils (%)	61.4 ± 14.8
Lymphocytes (%)	28.1 ± 15.0
Monocytes (%)	2.9 ± 1.8
Eosinophils (%)	7.5 ± 5.9
Basophils (%)	0
Erythrocytic series	
Total red blood cells ($10^6/mm^3$)	12.1 ± 0.8
Total Hemoglobin (g/dl)	16.1 ± 1.0
Packed cell volume (%)	45.6 ± 3.7
Mean corpuscular volume (fl)	38.2 ± 3.0
Mean corpuscular hemoglobin (pg)	13.4 ± 0.9
Mean corpuscular hemoglobin concentration (g/dl)	35.3 ± 1.3

Bovine virus diarrhea is primarily an immunosuppressant disease that attacks white blood cells and reduces an animal's resistance to disease. Infection in pregnant ewes with the bovine virus diarrhea virus can cause abortion and birth defects including mummified fetuses, hydrocephaly, porencephaly, cerebellar hypoplasia and dysplasia, and "hairy shakers" (lambs with abnormal birth coats and incoordination) (Salsbury 1981, Salsbury 1984). Bovine virus diarrhea titers were relatively low (median 1:16). However, similar titers have been found in domestic sheep exhibiting signs of disease (Salsbury 1984). Low bovine virus diarrhea titers have been found in other bighorn populations (DeForge, unpub. data on bighorn in Arizona; David A. Jessup, Calif. Dept. of Fish and Game, Sacramento, unpub. data on bighorn in California), but have not been associated with disease.

Bluetongue and epizootic hemorrhagic disease are both insect borne noncontagious viral diseases that may cause systemic disease and death. Bluetongue has been related to bighorn losses (Robinson et al. 1967, Hailey et al. 1972, Blaisdell 1975, DeForge et al, 1982). Although 4 of 18 samples were positive by agar gel immunodiffusion testing for bluetongue, only one sample had a titer by complement fixation testing (1:20). Complement fixation titers for epizootic hemorrhagic disease were low (median 1:5), probably indicating previous exposure rather than infection.

Titers to Leptospira interrogans serovar pomona were found in 39 percent of the samples; however all titers were at the 1:40 level, which can be considered only suspect (Chilelli et al. 1982). Likewise the two animals with detectable titers to contagious ecthyma were only at a suspect level (1:5). All samples were seronegative to infectious bovine rhinotracheitis and Brucella abortus.

Hematologic values and blood chemistry values are presented in Tables 2 and 3 respectively. Hematologic values are similar to normal values for domestic sheep (Schalm et al. 1975) and published data on desert bighorn (McDonald et al. 1981, DeForge and Scott 1982). Blood chemistry values are also similar to published data on desert bighorn (McDonald et al. 1981, DeForge and Scott 1982) except serum glutamic oxaloacetic transaminase and serum glutamic pyruvic transaminase are lower and phosphorus is higher. These values will help establish normals for desert bighorn sheep.

Aerobic nasal flora cultured from swabs are presented in Table 4. None of these organisms should be considered particularly pathogenic from nasal swabs. No Pasteurella sp. was cultured. This organism has been associated with diseased bighorn (Rosen 1970, Spraker 1977, Spraker and Hibler 1977, Foreyt and Jessup 1982), but it may be part of the normal flora of the upper respiratory tract.

No viruses were isolated from nasal swabs or from blood clots. No fecal parasites were found.

Table 3. Blood chemistry values for 18 desert bighorn from the Posada-Pico Johnson Range in Sonora, Mexico, and on Tiburon Island in the Gulf of California.

	$\bar{x} \pm s$
Serum glutamic oxaloacetic transaminase (U/l)	156.3 ± 45.5
Serum glutamic pyruvic transaminase (U/l)	25.1 ± 20.0
Alkaline phosphatase (U/l)	548.0 ± 469.0
Cholesterol (mg/dl)	84.3 ± 71.8
Glucose (mg/dl)	129.2 ± 36.7
Blood urea nitrogen (mg/dl)	20.9 ± 3.44
Creatinine (mg/dl)	1.8 ± 0.3
Total Bilirubin (mg/dl)	0.32 ± 0.28
Total Protein (g/dl)	7.2 ± 0.6
Albumin (g/dl)	3.9 ± 0.3
Calcium (mg/dl)	9.9 ± 1.5
Phosphorus (mg/dl)	7.3 ± 1.7
Sodium (meg/l)	153.8 ± 5.6
Potassium (meg/l)	5.2 ± 0.9
Creatine phosphokinase (U/l)	369.8 ± 314.8
Lactic dehydrogenase (U/l)	596.3 ± 169.4
Gamma glutamyl transferase (U/l)	66.2 ± 107.2
Cortisol (mg/dl)	4.6 ± 1.6

Table 4. Incidence of aerobic nasal flora cultured from swabs of 17 desert bighorn sampled from the Posada-Pico Johnson Range in Sonora, Mexico, and on Tiburon Island in the Gulf of California.

	Incidence (%)
Acinetobacter anitratus	6/17 (35)
Alternaria sp.	5/17 (29)
Bacillus sp.	4/17 (24)
Citrobacter freundii	2/17 (12)
Corynebacterium sp.	6/17 (35)
Cryptococcus albidus var. *albidus*	1/17 (6)
Enterobacter agglomerans	13/17 (76)
Enterobacter cloacae	7/17 (41)
Hormondendrum (Fonsacaea) sp.	1/17 (6)
Klebsiella ozaenae	2/17 (12)
Micrococcus sp.	1/17 (6)
Pseudomonas fluorescens / putida group	8/17 (47)
Pseudomonas maltophilia	2/17 (12)
Pseudomonas stutzeri	2/17 (12)
Serratia plymuthia	2/17 (12)
Staphylococcus aureus	4/17 (24)
Staphylococcus epidermidis	2/17 (12)

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FECAL NITROGEN AS A DETERMINANT OF ANIMAL CONDITION IN BIGHORN SHEEP

Daryll Hebert, Ministry of Environment, Wildlife Branch, Williams Lake, B. C.

Joyce Hebert, 630 Atwood Place, Williams Lake, B. C.

Marlen Caskey, Ministry of Enviroment, Habitat Section, Nanaimo, B. C.

ABSTRACT

Fecal nitrogen (N) was used as an index of animal condition from 1977-1983 in a captive herd of California bighorn sheep (Ovis canadensis californiana). Comparisons were made with an earlier study (Hebert 1973) and with a free-ranging herd in the Cariboo region of British Columbia. Fecal N indicated a decline in animal and population condition from 1977 to 1982 and a slight recovery during 1982 and 1983. Spring values varied significantly each year while summer and winter values were the most constant. Fecal N was significantly related to other nutritional indices and to seasonal weight change.

INTRODUCTION

Most wildlife range studies (Blood 1961, Demarchi 1968, Harper 1969, Demarchi 1970, Scheffler 1972) have assumed that specific quantitative and qualitative changes in the range have been transmitted to a particular bighorn sheep (Ovis canadensis) herd or population. The magnitude or form of the transmission, in terms of animal response, has not been quantified sufficiently to produce sound range, habitat or animal population decisions.

Recently, research programs utilizing captive animals (Gates 1975, 1980, Mould and Robbins 1981, Westra and Hudson 1981) have attempted to analyze forage-animal relationships. Hebert (1973) utilized captive bighorn sheep to demonstrate nutritional relationships between forage quantity, quality and animal response. In association, Hebert (1978) examined the relationship between bighorn sheep nutrition and blood serum parameters.

However, field studies (Stelfox 1976, Pitt and Wikeem 1978, Hoefs and Cowan 1979, Bunnell 1980, Heimer 1980, Eccles 1981, Shank 1982) have been relatively unsuccessful in establishing significant relationships between

range or habitat measurements and animal population qualitative or quantitative response. Relationships established by Hebert (1973) were further examined with a herd of California bighorn sheep in a 42 ha enclosure (Pitt and Wikeem 1978) at the Okanagan Game Farm, Penticton, prior to field testing with free ranging herds.

Specifically, fecal N techniques (Hebert 1973) were used to determine changes in animal conditon in the captive bighorn herd. Fecal N index methods have been developed to estimate "in vivo" digestibility (Corbett et al 1963, O'Donovan et al. 1967), feed intake (Lancaster 1949, 1954, Milford 1957, Hutchinson 1958, Fels et al. 1959) and feed N (Raymond 1948) in domestic animals. Holechek et al (1982) provide a comprehensive review of methods used to determine the quality of range ruminants diets. Similarly, feed-fecal N relationships, established for bighorn sheep (Hebert 1973) initiated the development of fecal N indices for other species (Gates 1975, incl. 1980, McFetridge 1977, Leslie and Starkey 1982, Janz 1983, Seip 1983). As a result, significant fecal N relationships have been established with plant protein (Hebert 1973, Leslie and Starkey 1982, Janz 1983), protein intake (Hebert 1973), dry matter digestibility (Hebert 1973, Leslie and Starkey 1982, Janz 1983), and body weight change (Gates 1980).

This study explores the reliability of fecal N indices to determine body condition, population condition, forage selectivity among age classes, spring green-up and the nutritional contribution from each season.

Preliminary data from studies in the experimental enclosure at Penticton (Pitt and Wikeem 1978, Eccles 1981, Wikeem in prog.) served as the basis for present data collection systems during 1980-1984.

STUDY AREA

During April, 1977, 20 California bighorn sheep were placed into a 42 ha enclosure adjacent to the Okanagan Game Farm (Fig. 1). The enclosure is on an east-southeast slope and is characteristic of the lower grassland zone dominated by big sagebrush (Artemisia tridentata) and bluebunch wheatgrass (Agropyron spicatum). The enclosure contains facilities that allow trapping and handling of the captive sheep.

Comparable data were obtained from Rocky Mountain bighorn (O. c. canadensis) sheep held in captivity in the East Kootenay during 1968-70 (Hebert 1973). In addition, samples were collected from the Vaseaux herd 15 miles south of Penticton and from the Junction sheep herd at the confluence of the Chilcotin and Fraser Rivers in the Cariboo. Both herds contain California bighorn sheep.

METHODS

Captive sheep were handled every 1-3 months from 1978-1984 in order to obtain fecal samples, body weight and chest girth. During trapping and handling, animals were weighed and measured without the use of immobilizing drugs. In addition, fecal samples were collected during each capture period and in the paddock in the months between capture periods, when possible, immediately after

FIGURE 1. The Okanagan Game Farm, Vaseaux Lake and Junction study areas in British Columbia.

sheep rose and defecated. Fecal samples were obtained at various intervals from the winter fed Vaseux Lake herd which was provided with alfalfa during the winter and from the free ranging Junction herd in the Cariboo.

Hebert (1973) analyzed fecal samples in conjunction with specific feeding experiments for a migratory and non-migratory group of captive sheep.

Nitrogen was analyzed with the macro-Kjeldahl technique at the University of B. C. and Washington State University and autoanalyzer at the Kelowna Soils Lab for the respective studies.

Statistical comparisons were based on standard seasonal periods: winter, December-February; spring, March-May; summer, June-August; fall September-November.

Independent means were compared using the "t" statistic. The relationship between nutritional variables was determined using the correlation coefficient statistic (r).

RESULTS

PLANT NITROGEN

In general, plant nitrogen (N) values for climax bluebunch wheatgrass grasslands cycle in a similar manner on an annual basis. Seasonal N values for grass mixtures from the East Kootenay and Okanagan grasslands were similar for much of the year (Fig. 2). Variation occurs mainly in the spring or during fall greenup. In 1978, spring values at the Okanagan Game Farm were approximately .75 percentage points higher. Fall greenup values at the Okanagan Game Farm were significantly higher (max. of 1.1 percentage points difference) than those in the East Kootenay but also varied significantly between years. Summers were generally wetter during the late 1970's and early 1980's than they were in the late 1960's.

FECAL NITROGEN

The variation in seasonal and annual plant N values is reflected in fecal N values for similar time periods (Fig. 3 - 6). Hebert (1973) developed a significant relationship between fecal crude protein (N x 6.25) and plant crude protein (N x 6.25) for migratory ($Y = -.9400 + 1.034 x \pm 4.58$) and non-migratory ($Y = -6.987 + 1.797 x \pm 2.19$) sheep populations. Leslie and Starkey (1982) and Janz (1983) developed similar relationships for blacktailed deer (*O. h. columbianus*) and Roosevelt elk (*C. e. roosevelti*).

In this study, fecal N values for free-ranging sheep in a paddock (1977) deviated significantly (Fig. 3) from those established for captive sheep fed hand cut forage (Hebert 1973). During May, they differed by 1.6 percentage points of N and in the fall, during greenup they differed by about .9 percentage points. However, the values for sheep fed hand cut forage did not appear to differ from those for captive sheep in 1981-1982 (Fig. 6), when they were close to their poorest condition. Similarly, comparison of fecal N values for 1977 through 1979 (Fig. 4) with those from 1980 through 1983 (Fig. 5) indicated a significant seasonal and annual decline during the initial period.

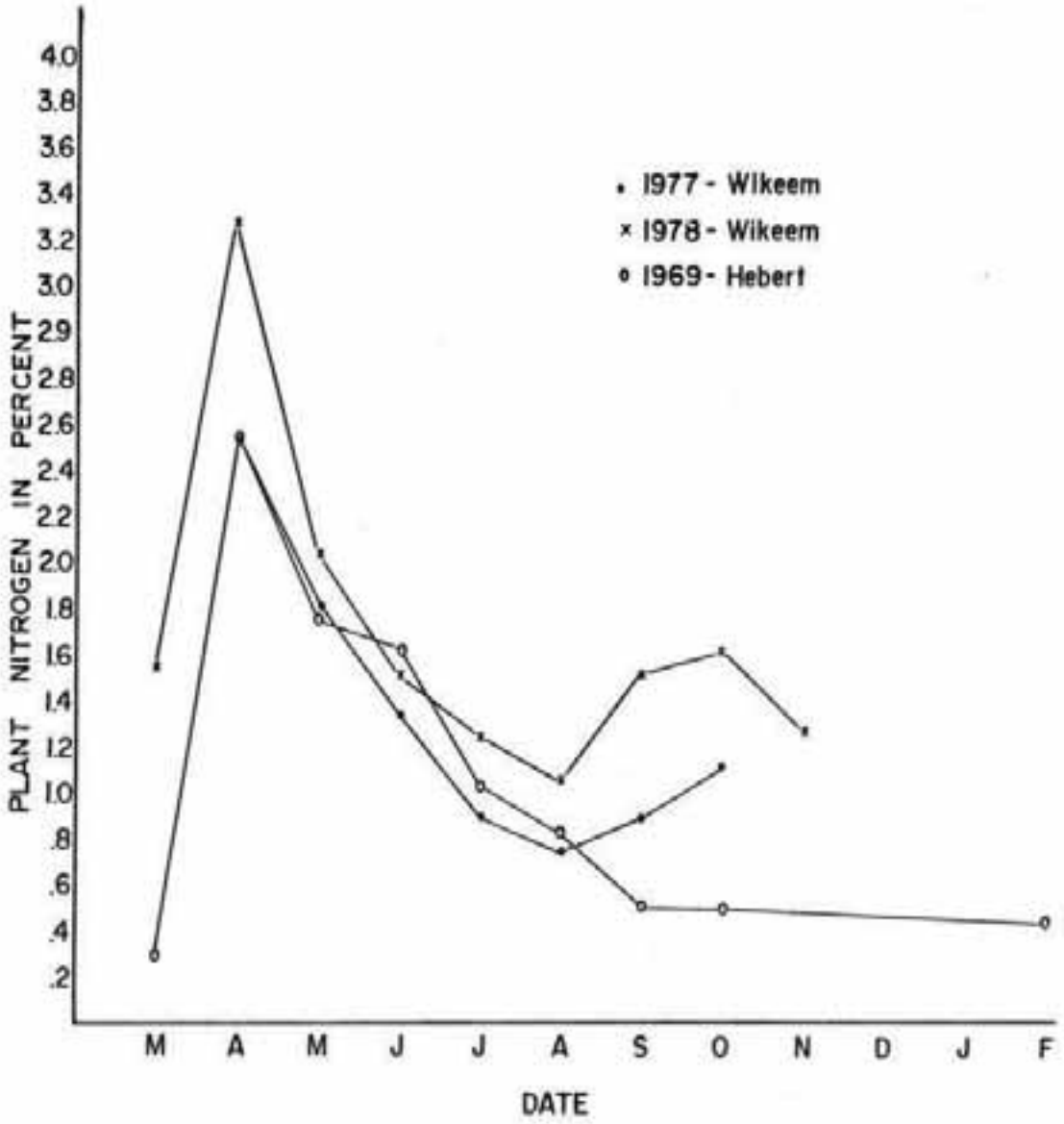

FIGURE 2. Monthly changes in plant nitrogen for the Okanagan and East Kootenay study areas.

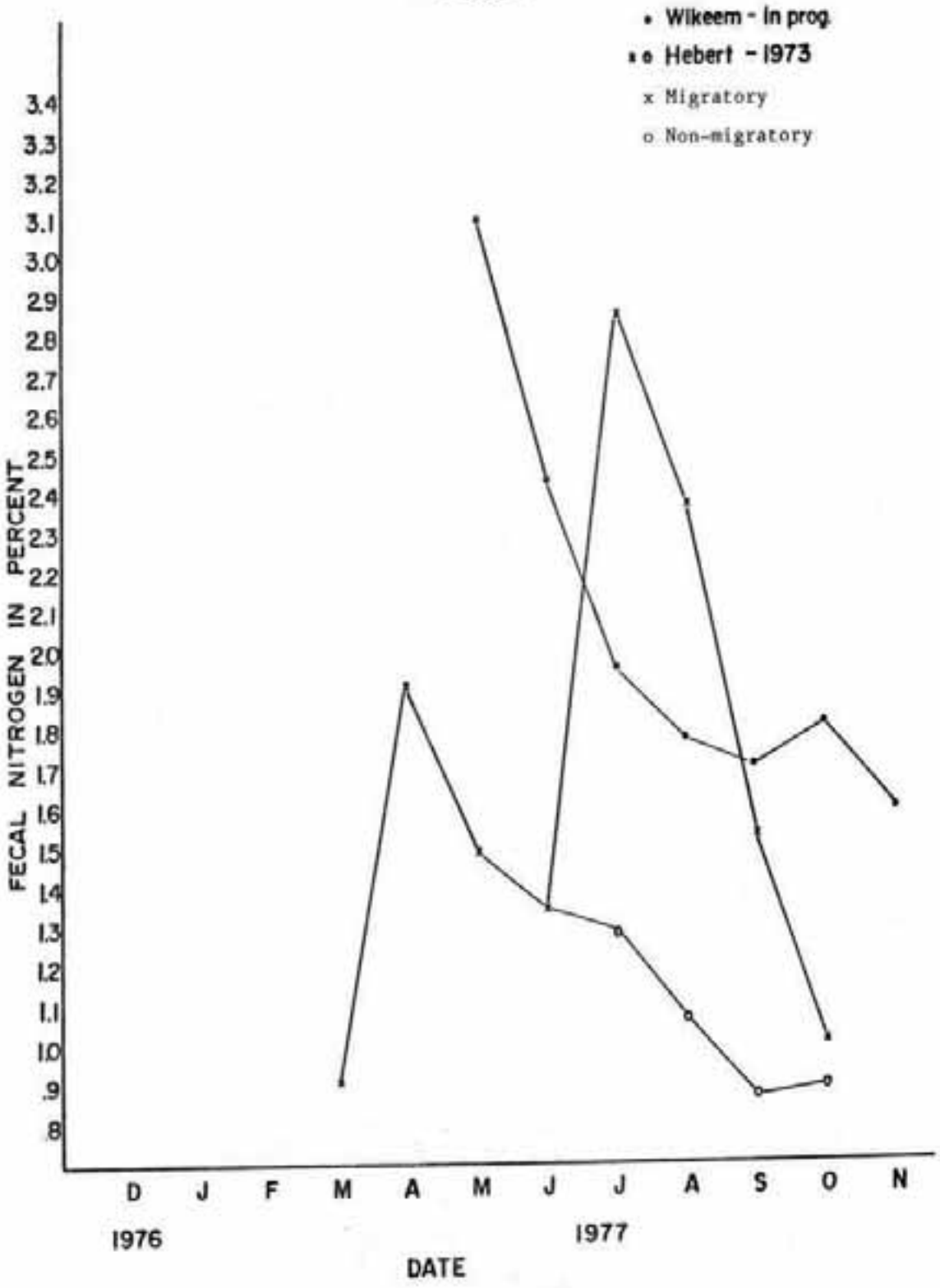

FIGURE 3. Monthly changes in fecal nitrogen for the Okanagan Game Farm (1977) and East Kootenay† captive herds.

†Hebert, (1973)

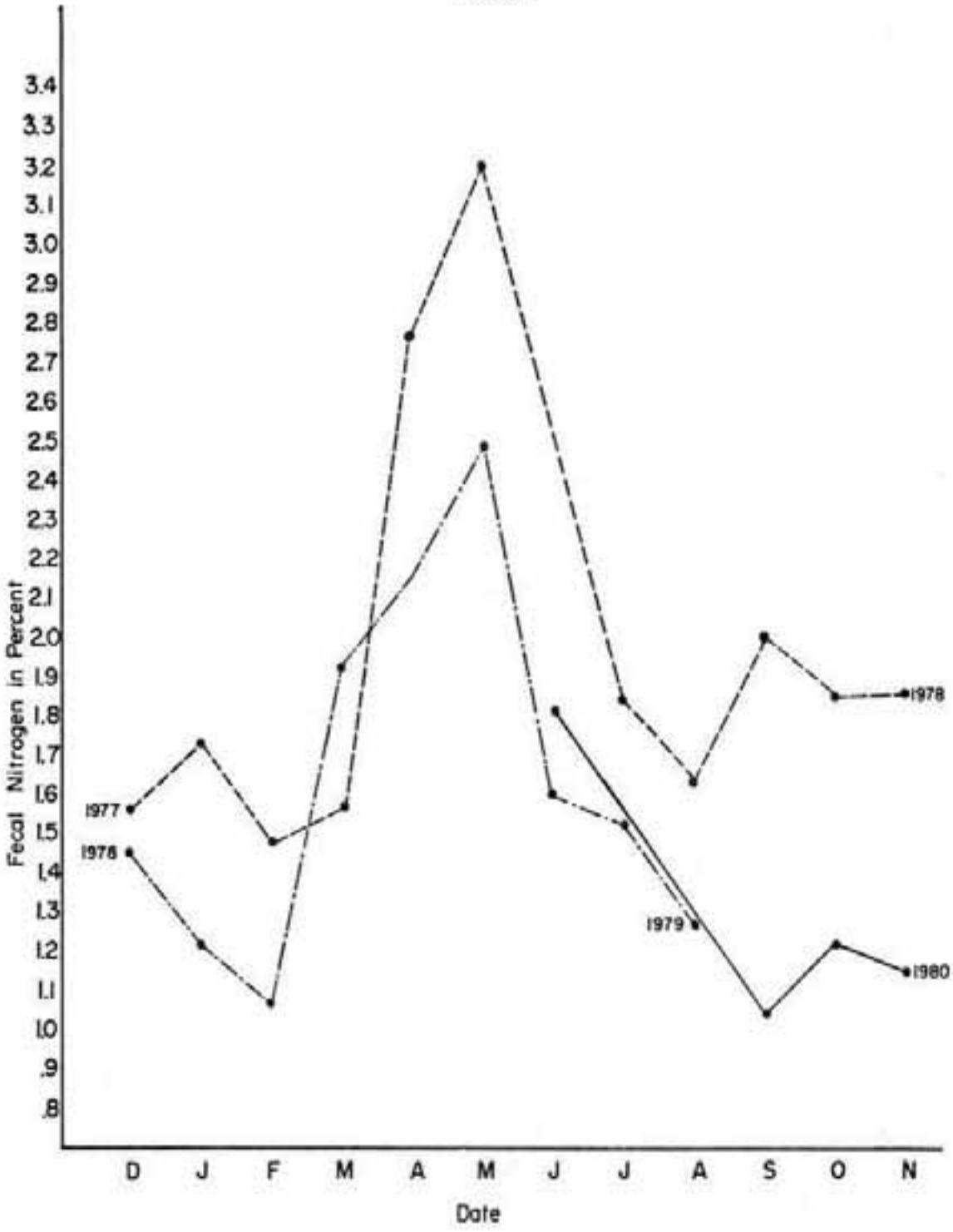

Figure 4. Monthly changes in fecal nitrogen for the Okanagan Game Farm captive herd from 1977 to 1980.

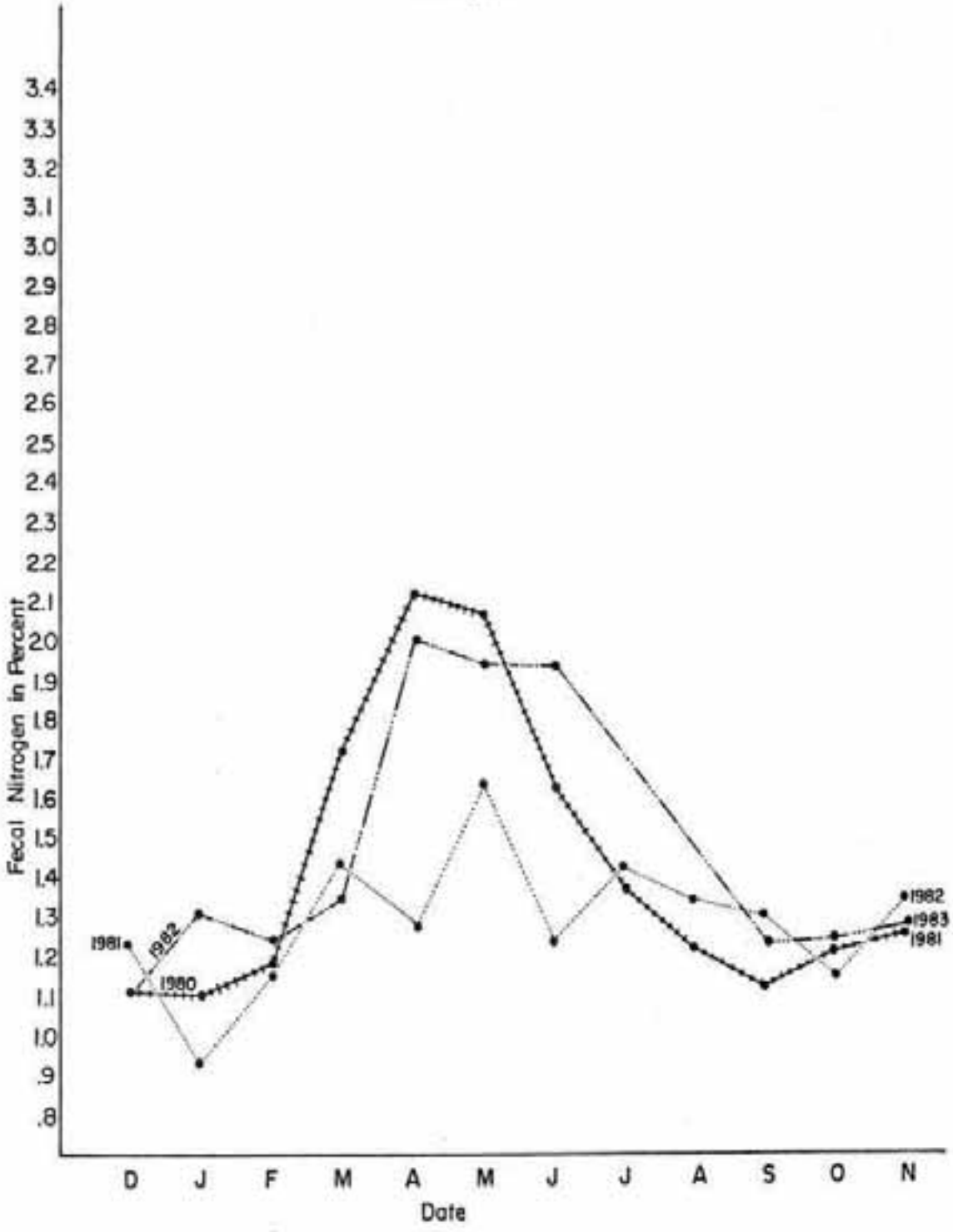

Figure 5. Monthly changes in fecal nitrogen for the Okanagan Game Farm captive herd from 1980 to 1983.

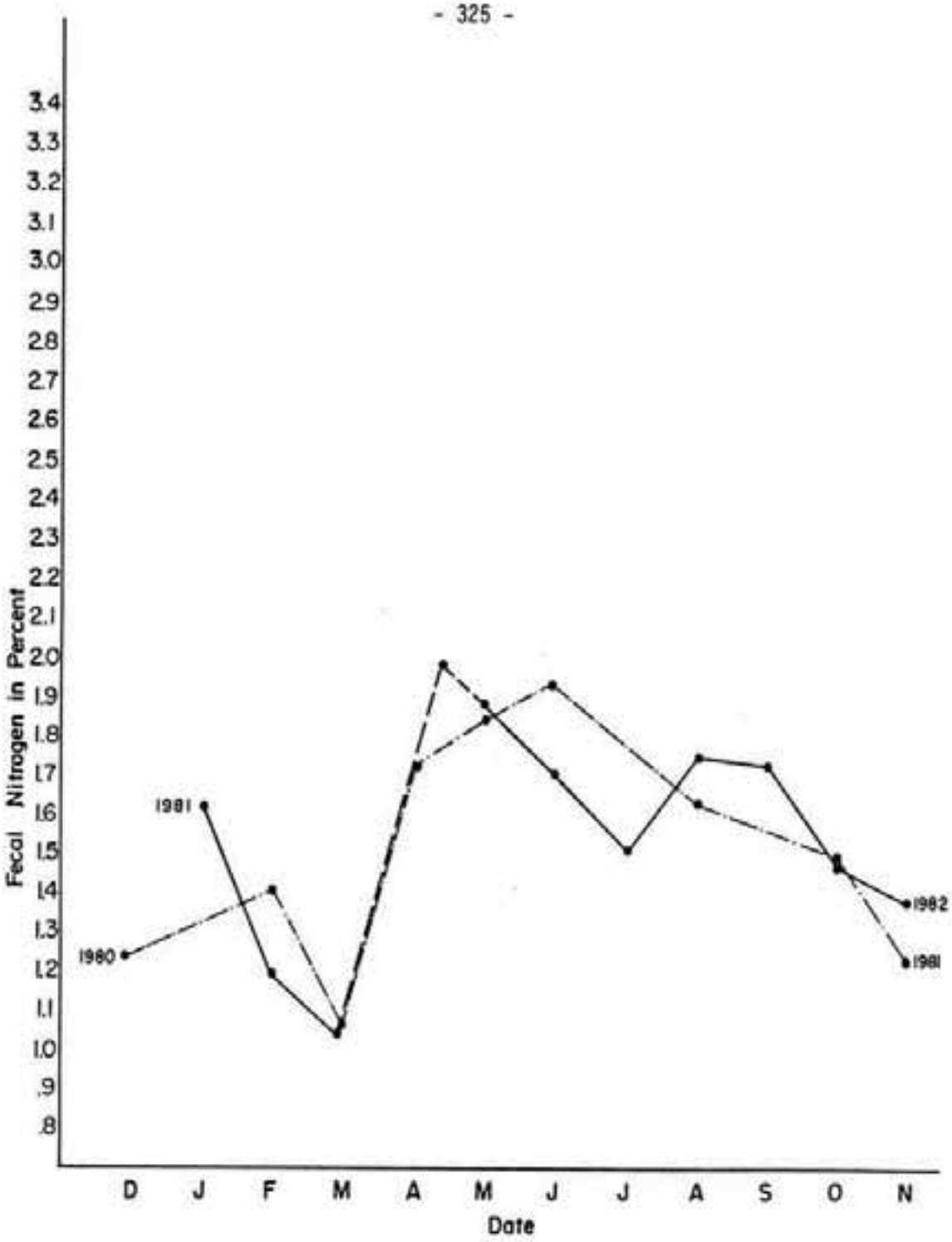

FIGURE 6. Monthly changes in fecal nitrogen for the Junction free ranging herd from 1980 to 1982.

A comparison of various figures indicated that spring and fall greenup periods occurred at similar times each year although the magnitude may differ.

Fecal N curves indicated possible significant differences between seasons and years. Average monthly precipitation was compared to monthly fecal N values using correlation coefficients for all years of the study when data were available. There were no significant relationships for annual or seasonal comparisons.

With captive animals it was possible to compare fecal N values from known animals to those collected randomly in the paddock (Table 1). This comparison was undertaken for 10 collection periods in 1981 and was not significant between methods at each collection period, except in August. One test was undertaken on March 22 to examine deterioration rates (N loss) for fecal samples left on the ground for periods of 2 weeks to 4 months. The March 22 average value was 1.53% N, and the same samples reanalyzed in July contained 1.43% N, a decline of approximately 6.5%.

Seasonal averages of fecal N were calculated in order to examine the seasonal contribution of N to the animal diet (Table 2). With the exception of the fall-winter change in 1980-81 and spring-summer values for 1982, all seasons contributed significantly different levels of N to the nutrition of the animal. Similarly, the fall-winter value for 1983 was just significantly different, indicating a degree of constancy at low levels of N intake for approximately half of each year. The spring-summer values for 1982 did not differ significantly because only March values (initial spring greenup values) represented the spring season. The addition of April and/or May values would increase the average and produce a significant difference.

In order to test the constancy within standard seasons (Table 3), comparisons were made between the beginning and end of each season. The winter season was the most constant while spring periods differed significantly in each of the three years. It appears that summer and fall may differ in some years because of differences in the magnitude of spring and fall greenup and summer dormancy.

Similarly, changes between seasons were significant in all years, with the exception of one fall-winter change and one summer-fall change (Table 4). The winter-spring change in 1983 was not significantly different because the March (1st spring month) collection occurred too early, prior to initiation of greenup. The winter-spring difference was significant, if one deviant point was omitted from the average.

Spring levels of fecal N differed most dramatically between years, winter levels differed the least (Table 5). The summer and fall periods may differ in some years due to above average precipitation in some summers or due to the magnitude of fall greenup in some falls.

During the four year study period, variation in spring greenup in March was examined weekly. Values of 1.35, 1.44 and 1.73 on March 2, 7 and 14, respectively, indicated that although there were minor changes in fecal N in early March, significant greenup did not occur for the animal until March 7-14.

Table 1. A comparison of known and random fecal nitrogen values by month and by season.

Year	Month/Season	Known Mean	n	Random	n	t	p	Signif.
81	January	1.09	(6)	1.10	(8)	.34	.74	x
	February	1.22	(10)	1.19	(7)	.347	.73	x
	March	1.89	(4)	1.73	(15)	1.64	.12	x
	April	2.08	(9)	2.13	(13)	.68	.50	x
	June	1.61	(11)	1.63	(11)	.32	.76	x
	August	1.10	(8)	1.23	(15)	3.19	.004	/
	Aug. 13 - Sept. 7	1.10	(8)	1.13	(11)	.65	.53	x
	Winter (Jan-Feb)	1.17	(27)	1.12	(25)	.84	.59	x
	Spring	2.02	(13)	1.92	(28)	1.29	.20	x
	Summer	1.39	(38)	1.40	(19)	.18	.86	x

Table 2. A comparison of average fecal nitrogen values to show seasonal differences within years.

Year	Season	Mean Season 1	Season 2	t	df	p	Signif.
80-81	f80-w81	1.09	1.14	1.67	(56)	.10	x
1981	w-s	1.12	1.99	-23.19	(90)	.000	/
1981	s-s	1.99	1.39	13.29	(87)	.000	/
1981	s-f	1.39	1.20	5.37	(78)	.000	/
81-82	f81-w82	1.20	1.09	3.28	(89)	.0016	/
1982	w-s	1.09	1.44	-8.67	(76)	.000	/
1982	s-s*	1.44	1.38	1.54	(69)	.12	x
1982	s-f	1.38	1.24	4.90	(74)	.000	/
82-83	f82-w83	1.24	1.15	2.34	(71)	.022	/
1983	w-s	1.15	1.87	-10.35	(67)	.000	/
1983	s-f	1.48	1.24	6.42	(53)	.000	/

*only March value for spring

Table 3. A comparison of fecal nitrogen values to determine within season changes.

Year	Month	Mean Month 1	Mean Month 2	t	df	p	Signif.
80-81	Dec.80-Feb.81	1.11	1.19	-1.31	(22)	.202	x
1981	Mar-May	1.73	2.07	-7.51	(36)	.00000	/
1981	June-Aug	1.63	1.23	9.31	(24)	.00000	/
1981	Sept-Nov	1.13	1.25	-4.50	(38)	.00006	/
81-82	Dec.81-Feb.82	1.24	1.16	2.10	(26)	.046	/
1982	Mar-June[1]	1.44	1.25	2.97	(33)	.006	/
1982	June-Aug.	1.25	1.35	-2.01	(15)	.06	x
1982	Sept-Nov..	1.31	1.35	-1.05	(14)	.32	x
82-83	Dec.82-Feb.83	1.10	1.25	-1.77	(32)	.08	x
1983	March-May	1.35	1.96	-4.40	(13)	.0008	/
1983	May-Aug.[2]	1.96	1.48	6.37	(33)	.000	/
1983	Sept-Nov.	1.24	1.29	1.03	(16)	.32	x

1. Do not have May figures
2. Do not have June figures

Table 4. A comparison of average fecal nitrogen values to determne changes between the end of one season and the start of the next season.

Year	Month	Mean 1	Mean 2	t	df	p	Signif.
1981	Feb-Mar.14	1.19	1.73	-6.77	(20)	.000	/
1981	May-June	2.07	1.61	10.70	(31)	.000	/
1981	Aug-Sept	1.23	1.13	3.63	(24)	.0014	/
1981	Nov-Dec	1.26	1.24	.5092	(27)	.62	x
1982	Feb-Mar.7 & 22	1.16	1.44	-5.20	(36)	.000	/
Aug-Sept		1.35	1.31	.9683	(18)	.34	x
1982	Nov-Dec	1.35	1.10	3.35	(33)	.002	/
1983	Feb-Mar.2	1.25	1.35	-9.29	(10)	.38	x
1983	Feb-Mar	1.25	1.44*	2.43	(9)	.04	/
1983	Aug-Sept	1.48	1.24	4.13	(32)	.0002	/

*left off last point

Table 5. A comparison of average fecal nitrogen values to show seasonal comparisons between years.

Year	Season	Mean 1	Mean 2	t	df	p	Signif.
80-81	Fall	1.09	1.20	-5.03	(66)	.000	/
81-82	Fall	1.20	1.24	-1.57	(74)	.12	x
82-83	Fall	1.24	1.24	-.137	(61)	.90	x
81-82	Winter	1.17	1.09	.61	(62)	.55	x
82-83	Winter	1.09	1.15	-1.31	(86)	.20	x
81-82	Spring	1.99	1.44	13.03	(78)	.000	/
82-83	Spring	1.44	1.87	-6.41	(57)	.000	/
81-82	Summer	1.39	1.38	.1131	(78)	.92	x
82-83	Summer	1.38	1.48	-2.62	(62)	.010	/

Table 6. A comparison of fecal nitrogen values from sheep which were baited or winter fed (alfalfa) with those which were not (1981).

Season	Area: Vaseaux Lake	Area: OK Game Farm	t	df	p	Signif.
January	1.55	1.07	8.21	(14)	.000	/
February	2.22	1.19	9.5	(16)	.000	/
March	1.91	1.73	2.1	(18)	.05	/
April	2.32	2.13	2.58	(21)	.02	/
May	2.30	2.07	3.21	(32)	.000	/
	Feeder	Upper Slope				
January	1.55	1.28	4.74	(15)	.000	/
		Baited	Unbaited			
January		1.25[2]	1.08	6.78	(23)	.000	/
		1.77	1.08	6.75	(25)	.000	/

1. Winter fed
2. Partial baiting

Fecal N can be a valuable tool to assess a variety of feeding regimes. In 1981, the winter fed herd at Vaseaux Lake (about 16 km from the captive herd) was compared to that in the captive paddock (Table 6). In all months the Vaseaux herd was taking in significantly more N. Spring greenup allowed he captive herd to approach the winter fed herd in N nutrition. In January Vaseaux sheep feeding on upper slopes, away from the feeder, were significantly lower in N nutrition than those at the feeder but were higher than those in the captive herd. Similarly, two days of baiting of the captive herd produced significant differences between the unbaited animals monitored at the same time. Prolonged baiting (feeding) produced a dramatic increase in the N nutrition of the captive animals, similar to that of the winter fed herd at Vaseaux Lake. It appeared that fecal N was sufficiently sensitive to detect minor qualitative dietary changes (2 days of baiting).

Fecal N was used to determine diet quality changes between ewes and lambs feeding in the captive paddock (Table 7). In all months, during a four year period there was no significant difference between the fecal N levels of lambs and ewes. This suggests no apparent difference in dietary quality between these two groups.

Table 7. A comparison of known fecal nitrogen values for captive lambs and ewes at the Okanagan Game Farm.

Year	Month	Mean Ewe	Mean Lamb	t	df	p	Signif.
1980	November	1.23	1.22	.18	(15)	.86	x
1981	January	1.44	1.53	.31	(28)	.76	x
1981	March	1.85	2.01	.64	(2)	.58	x
1982	November	1.28	1.23	.63	(4)	.56	x
1983	February	1.44	1.39	.50	(10)	.62	x
1983	April	1.70	1.73	.56	(14)	.58	x
1983	November	1.27	1.41	1.81	(13)	.10	x

Using fecal N, it was possible to determine the initiation of greenup available to the animal in relation to the latitude and elevation at which the population occurs (Table 8). In general, initiation of greenup differed by 1.5 to 2 months with approximately 25° change in latitude and 1000 m change in elevation. Delays in spring greenup at higher latitudes and elevations may be compensated to some degree by reduced summer dormancy periods.

Similarly, fecal N can be used to compare range nutrition and population condition (Fig. 5 and 6, Table 9). The Junction sheep population was significantly (Table 9) but only slightly higher (Fig. 5 and 6) than annual and seasonal N values for the Okanagan Game Farm sheep. The Junction herd is non-migratory, but with a significant fall greenup period it maintained a higher N intake (Fig. 6) than the Okanagan Game Farm herd which was at its lowest nutritional point (highest adult and lamb mortality). The Okanagan Game Farm herd recovered in 1983 (Fig. 5) and approached the level of N nutrition achieved by the Junction herd. Seasonally, the Junction herd did not differ significantly between years (Table 10) with the exception of the fall period (due to exceptional fall greenup of 1982). Spring was almost significantly different between years but the calculation was based on a reduced sample size. Winter and summer values were most constant, similar to the trend at the Okanagan Game Farm (Table 5).

Table 8. Green-up initiation and peak, and fall regrowth initiation compared to latitude and elevation.

Location		Latitude*	Elevation (Type of Range)	Initiation of Green-up**	Peak Green-up**	Initiation of Fall Regrowth
Okanagan[1]	B.C.	49°23' (Approx.)	480-730M (Year Round)	mid-March	mid-May	Aug./Sept.
Junction[1]	B.C.	51°46'	700-1000M(Year Round)	March/April	April	Aug./Sept.
East Koot.[2]	B.C.	49°20'	820-1220M (Winter Range)	March/April	April	None (1969)
		50°	1525-1980M (Summer Range)	May/June	June/July	None
Ya-Ha-Tinda[2]	Alta.	51°42'	1740-2320M (Winter Range)	April/May	(July?)	None
Ram Mtn[2]	Alta.	51°57'	1082-2173M (Year Round)	mid-April	early to mid June	August
Smoky River[3]	Alta.	53°55'-54°	914-2134M (Year Round)	(May?)	end June	None
Maroon Mtn.[3]	B.C.	54°42'	(Approx)600-2066M (Year Round)	March ***	June/July	Aug./Sept

* Latitudes are estimates only
** Dates are taken from fecal N curves
*** Coastal influence

1. California bighorn sheep
2. Rocky Mountain bighorn sheep
3. Rocky Mountain goats (Oreamnos americanus).

Table 9. A comparison of seasonal fecal nitrogen values between the Junction sheep range and the Okanagan Game Farm.

Year	Date/Season	Junction	OK Game Farm	t	df	p	Signif.
1982	Winter	1.42	1.09	3.97	(57)	.000	/
1982	Spring	1.90	1.39	6.72	(33)	.000	/
1982	Summer	1.68	1.38	6.71	(68)	.000	/
1982	Fall	1.55	1.24	7.65	(63)	.000	/
1983	Winter	1.34	1.12	4.23	(48)	.000	/
1983	Spring	1.57	1.87	3.31	(66)	.000	/
1983	Summer	1.79	1.48	5.12	(48)	.000	/
1983	Fall	1.35	1.24	2.77	(52)	.000	/
1984	Winter	1.05	1.11	1.38	(66)	.1692	x

Table 10. A comparison of seasonal fecal nitrogen values between years for the Junction sheep herd.

Year	Season	Mean 1	Mean 2	t	df	p
82-83	Winter	1.42	1.45	-.253	(16)	.80
82-83	Spring	1.90	1.58	1.95	(41)	.06
82-83	Summer	1.68	1.77	-1.50	(54)	.14
82-83	Fall	1.55	1.35	3.94	(54)	.0004

FECAL N - WEIGHT CHANGE

Weight change is a cumulative expression of the bioenergetic balance of an animal. The relationship between fecal N and weight change was explored with captive sheep at maintenance and submaintenance diets (Hebert 1973) and at the Okanagan Game Farm 1977-1982 (Table 11). Although several workers have established relationships between fecal N and digestibility (Coop and Hill 1962, Lambourne and Reardon 1963, Hebert 1973, Holechek et al 1982), few workers have established fecal N - weight change relationships (Hebert 1973, Gates 1980).

In general, weight change was significantly related to fecal N under a variety of conditions (Table 11), yet the relationship was confounded by two variables. In the spring, fecal N rose rapidly while weight change continued to decline (Gates 1980) for 1 - 2 months, especially when the animals were in poor winter condition. This was shown during the period 1977-79 and during 1981 when the correlation was established with and without spring values. Similarly, the relationship established by Hebert (1973) was not significant due to the affect of spring values. When only summer values were used, the relationship improved. The lack of significance for the summer period was attributed to the lower sample size and the fact that digestion trials were not carried out during winter (October - March). In association, the relationship for the migratory group was better than that for the non-migratory group. Low weight change experienced by the non-migratory group (low quality and constancy of diet) may be within the variance of the equipment used and may provide a second confounding factor. The relationship between fecal protein and protein intake per day was highly significant (Table 11). This will allow weight change to be related to absolute protein intake on an instantaneous or cumulative basis (Hebert and hebert in prog.). The relationship between fecal N and weight change was significant for the Okanagan Game Farm sheep when spring values were not included. During 1981 and 1982, the relationship was significant even when spring values were included, probably due to the minor change in spring greenup values.

If weight change is the result of a cumulative expression of bioenergetic balance, the relationship between N and weight change should improve with the specificity of measurement (Table 12). This in fact occurs, if r values are compared for fecal N and weight change and for protein retained (basic N balance) and weight change. The improvement is less obvious when the energy intake (Avg .716), digestible energy (Avg .733) - weight change relationship is compared (Table 12).

DISCUSSION

Since its inception (Raymond 1948), fecal N has seen increasing use (Hebert 1973, Gates 1975, 1980) as an indicator of animal nutrition and condition. Most early studies with wildlife species developed annual curves based on monthly changes (Gates 1975, McFetridge 1977). Later studies (Gates 1980, Leslie and Starkey 1982, Janz 1983) related fecal N values to other measures of nutrition (digestibility) and growth (body weight). However, with the exception of Hebert (1973) and Gates (1980) all relationships were established with free ranging populations, where few variables were controlled.

Table 11. The relationship between fecal nitrogen (protein) and body weight change and crude protein intake for captive sheep (Hebert 1973) and sheep at the Okanagan Game Farm.

CORRELATION	YEAR/SEASON	r Value	n	p
Fecal Protein/Weight	1969	non-migratory .9193	8	<.005
		migratory .0185	8	—
Fecal Protein/ Wt. Change	1969	non-migratory .3612	8	—
		migratory .553	8	>.05
Fecal Protein/ Wt. Change	Spring/69	non-migratory .0340	3	—
		migratory .9535	3	>.05
Fecal Protein/ Wt. Change	Summer/69	non-migratory .48	5	—
		migratory .86	5	<.05
Fecal Protein/ Protein Intake Gm/Day	1969	non-migratory .9031	8	<.005
		migratory .9427	8	<.005
Fecal Protein/ Wt. Change	1977-79 a.	.933	5	<.01
		.24[1]	7	—
Fecal Protein/ Wt. Change	1977-79 b.	.89	5	<.01
		.25[2]	7	—
Fecal Protein/ Wt. Change	1981	.70[3]	8	<.05
		.82[4]	6	<.05
Fecal Protein/ Wt. Change	1982	.9383	3	>.05
Fecal Protein/ Wt. Change	1981-82	.7686	8	<.01

a. All sheep except lambs
b. Eight selected ewes

1. April & June added
2. April & June added
3. Jan-Oct period (Feb. fecal N and March wt.)
4. Removed Spring (Mar & Apr) values

Table 12. Correlation coefficients comparing weight change to various nutritional parameters (Hebert 1973).

r = correlation coefficient

1. % Fecal Protein vs Weight Change in kg.

Control	n=8	r=0.361	Not significant
Experimental	n=8	r=0.553	Not significant

2. % Crude Protein in feed vs Weight Change.

Control	n=8	r=0.541	p=>.05
Experimental	n=8	r=0.677	p=<.05

3. Crude Protein Intake in gm/day vs Weight Change.

Control	n=8	r=.596	p=>.05
Experimental	n=8	r=.646	p=<.05

4. Monthly Crude Protein vs Weight Change.

Control	n=6	r=.703	p=>.05
Experimental	n=6	r=.719	p->.05

5. Digestible Protein in gram/day vs Weight Change

Control	n=8	r=0.612	p=>.05
Experimental	n=8	r=0.640	p=<.05

6. Digestible Protein per kg body weight vs Weight Change.

Control	n=8	r=0.552	p=>.05
Experimental	n=8	r=0.658	p=>.05

7. Protein Retained in gm/day vs Weight Change.

Control	n=7	r=0.924	p=<.01
Experimental	n=7	r=0.736	p=<.05

8. Energy Intake vs Weight Change.

Control	n=8	r=0.678	p=<.05
Experimental	n=8	r=0.754	p=<.05

9. Digestible Energy vs Weight Change/Control

Control	n=8	r=0.785	p=<.05
Experimental	n=8	r=0.681	p=<.05

This study was undertaken to examine the fecal N - nutritional relationships established by Hebert (1973) under controlled conditions, to determine if they applied to semi-controlled (paddock) and free ranging populations. Firstly, it determined that a minimum of 6-15 fresh samples collected from random individuals in the paddock were identical to those collected from known individuals. Preliminary tests suggested minimal changes (6.5%) between fresh and four month old samples. However, more testing is required to determine deterioration rates due to time, site, weather and season. Generally, the random samples were indicative of the nutritional status of the paddock herd. However, in order to accurately assess a wide variety of free ranging populations, more testing of sample size and distribution should be undertaken. At present, a captive, semi-captive, winter fed free ranging and non-migratory free ranging herd have been examined. Gates (1975) has preliminary information on a free-ranging migratory sheep population on the east slopes of the Rockies but little information on free-ranging migratory populations is available for B. C.

During the paddock study, changes in stocking rate were used to produce light to heavy grazing pressure on the range. During this procedure, forbs and browse were reduced in availability or eliminated. Thus, the data show a general decline in forage quality (N) from 1977 to 1982 and a slight recovery in 1983. Similarly, seasonal comparisons of body condition using fecal N were examined during this long term decline. Collection of this type of data will allow examination of fecal N relationships with food habit changes from 1977 to 1982 (Hebert and Hebert in prog.) and the resultant effect on weight change, growth and mortality. Most importantly, fecal N can be converted to crude protein intake (Hebert 1973) by month and/or season in order to examine and/or predict seasonal weight change (Hebert and Hebert in prog.), productivity (Jorgenson and Wishart 1982), winter mortality, maintenance and the effect of grazing by domestic cattle, as well as controlled fire.

The procedure is sufficiently sensitive to identify diet quality changes due to baiting, winter feeding and elevational changes due to chinooks (Gates 1975). Geist and Petocz (1977) hypothesize that young animals (lambs) should consume a higher quality diet than adults due to differences in metabolic rate. The data in this study indicated that there was no significant difference between quality of diets for lambs and ewes. Seip (1983) also suggests that there is no significant difference between the quality of ewe and ram diets for Stone sheep (O. dalli stonei).

During the study (1977-1983), the average body weight of adults declined. Similarly, each generation of lambs grew at a slower rate than the previous generation (age specific weights of each generation decline). Data analysis did not always allow the seasonal and annual changes to be isolated from the longer term decline in overall body condition.

Body weight change has been related to fecal N values in several instances (Hebert 1973, Gates 1980, this study) and indicates that fecal N is capable of estimating the annual condition of an animal. Mould and Robbins (1981) concluded, while using single and simple mixed dietary species trials, that inhibitors (phenols) may reduce digestibility of N and fecal N values may in fact predict arbitrarily high N intakes. Since fecal N is related to body weight change in both bighorn sheep and elk (Gates 1980), this problem appears minimal with multispecies diets, even with browsing species.

Although fecal N and body weight change were significantly related, this relationship is often confounded in the spring when N values increase rapidly while weight change may continue to decline for 1-2 months. Thus, the sample size and sample distribution be season are extremely important variables to consider during the study design. For example, Hebert (1973) conducted the majority of his digestion trials during the spring and early summer when fecal N and weight change correlated the least. Digestion trials were not conducted in late fall and winter due to climatic conditions (freezing urine and water). All r values should improve considerably with a shift in seasonal sampling distribution.

Gates (1980) established a significant relationship between fecal N and young growing elk (calves) (r^2 = 0.89) and yearling bulls (r^2 = 0.89) undergoing a high degree of weight change between seasons. In contrast, Hebert (1973) did not establish a significant relationship for non-migratory sheep given a maintenance diet low weight change for 3 of 4 seasons). The relationship was further confounded by the lag effect between spring fecal N values and weight change. Similarly, the relationship between fecal N and weight change for the migratory group improved over that for the non-migratory group because weight changes were larger. However, it is also confounded by the spring lag effect and a second less pronounced spring lag effect during the change to and from alpine forage. The relationship for the migratory group was greatly improved (r = .86) when only summer and fall values were considered.

Conversion of fecal N to cumulative protein intake (Table 11) will allow evaluation of the N contribution from each season. It is possible that the total annual N intake may be the same between years, however, survival or productivity may differ due to the timing contribution of spring and fall greenup.

Upon establishment of suitable sampling regimes, fecal N could be used as a long term population condition indicator. It could be used to assess differences in population density and total grazing pressure through time. It is possible that it could replace the more traditional plot and clipping procedures which suffer from human variability, sampling design and cost. Similarly, it can be used to assess the nutritional status of pre and post bighorn sheep dieoffs. Most importantly, it can be combined with a variety of fecal techniques (fecal fragments, fecal larval levels, fecal cortisol) that assess the status of the individual or the population.

The data in this paper suggest that it is now possible to assess the nutritional status of most bighorn sheep herds in south central B. C. and Alberta.

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FEEDING HABITS OF MOUFLON (OVIS AMMON MUSIMON) AND CHAMOIS (RUPICAPRA RUPICAPRA) IN RELATION TO THE MORPHOPHYSIOLOGICAL ADAPTATION OF THEIR DIGESTIVE TRACTS.

Reinhold R. Hofmann, Department of Comparative Anatomy of Domestic and Wild Animals, Vet. Anatomy Institute and AKWJ, Justus Liebig University, Giessen, F. R. Germany.

ABSTRACT

The European wild ovids and caprids are highly differentiated ruminant species which are adapted to a feeding cycle based on short montane or very short alpine vegetation periods. They can vary rumen and caecal volume and show extremes of ruminal papillary development or regression all related to seasonal food intake variation and changing plant digestibility. Mouflon are selective grass eaters, ibex selective grass and forb eaters while chamois are intermediate: they are extreme concentrate selectors from June to October but are coping well with high fibre feeds from November to May.

INTRODUCTION

There are two species of caprids (ibex and chamois) and one species of wild sheep (mouflon), which have survived in densely populated, industrialized central Europe. Two of these became almost extinct earlier this century but have been reintroduced and recently built up in many places. All three species are being hunted under strictly controlled conditions, which permitted collection of samples for morphophysiological studies of their digestive tract.

The uniquely rich bovid fauna of East Africa (Hofmann 1969 and 1973) served to establish a comparative grouping of these ruminants, based originally on stomach structure and feeding habits of 29 species. Three feeding types, termed "concentrate selectors", "grass and roughage eaters" and "intermediate" or "mixed feed eaters" were established also for, so far, 23 further ruminant species in Europe, Africa, North America and Asia (Hofmann 1983) and the criteria were extended to anatomical characteristics of all portions of the digestive system. They reflect physiological variations and specialization as first noted by Hungate (1959), extended by Hoppe (1977 and 1983) and recently summarized by Kay et al (1980) and by Van Soest (1982). Specific information on chamois digestive physiology has been provided by Drescher-Kaden (1976 a) and on their anatomical adaptation by Hofmann (1982). Morphophysiological data

Fig. 1: Mouflon ram and sheep during the rut in Central Germany (phot. J. Behnke)

Fig. 2: Young chamois billy, October; Bavarian alps (phot. W. Henkel)

on mouflon were also published by Drescher-Kaden (1976 b) while stomach anatomy and mucosa characteristics of mouflon were established by Geiger et al (1977), their salivary glands were described by Saber and Hofmann (1984), their intestine by von Trott (1983).

METHODS AND MATERIAL

This survey paper summarizes a series of comparative morphological studies which were carried out on 18 free ranging chamois, 3 ibex and 21 mouflon in western and southern Germany, Austria and Switzerland, collected in their natural habitat. In most cases, the digestive system was exenterated and preserved in stages with 10% formalin (4% formaldehyde), either via the esophageal and intestinal lumen or via the blood vascular system. All heads investigated were perfused via the carotid artery while one chamois and two mouflon were preserved in toto in a natural standing position by infusion as described by Hofmann (1966) (Figure 3). For detailed methodical descriptions, the literature cited may be referred to. The morphological results are based on subadult (2-3 years) and adult male and female animals. Chamois weighed 16-34 kg eviscerated (approx 21-46 kg live weight), shoulder height 70-75 cm. Mouflon weighed 16-30 (22-45) kg, standing only 60-65 cm at the shoulder. Ibex weighed 24 (subadult female), 36 (male 4 years) and 76 kg (male 10 years). Of the latter species, only limited sampling (mainly stomach material) was possible. Abbreviations used in this paper are CH for chamois, MF for mouflon and IB for ibex.

RESULTS

The salivary glands are best developed in CH and least in MF. The parotid gland is flat and wide in CH (0,16 - 0,19% of body weight) but flat and narrow in MF (0,06 - 0,08%), where it does not cover the mandibular gland as in CH (Figure 4). Sublingual and ventral buccal glands are better developed in CH than in MF. Total salivary gland weight amounts to 0,22 - 0,30% in CH but only to 0,11 - 0,12% of body weight in MF. Detailed measurements and descriptions are given by Saber and Hofmann (1984).

Stomach shape is similar in all three species. The rumen of MF shows a clearer subdivision than that of IB and CH, but in all three species a relatively small dorsal blindsac is matched by a long and spacious ventral blindsac. Ruminoreticular capacity varies greatly according to season; it ranges in MF from 7,5 to 11,5 litres; in CH from 3,5 litres (rut) to 11,3 litres. During the vegetation period, MF have a relatively greater ruminoreticular capacity than CH (10,2 - 11,5 litres vs 7,6 - 8,9 litres). MF show maximal capacity in late summer and fall, CH in late winter/early spring.

Size sequence of stomach compartments is in all three species rumen - abomasum - reticulum - omasum. The most striking difference is showing in the size of the omasum, which is relatively best developed in MF and least in CH (20 - 25% smaller) (Figure 5).

The forestomach mucosa shows typical variations related to evolutionary adaptation and thus genetically determined feeding type while changes are related to seasonal influences caused by changing forage quality.

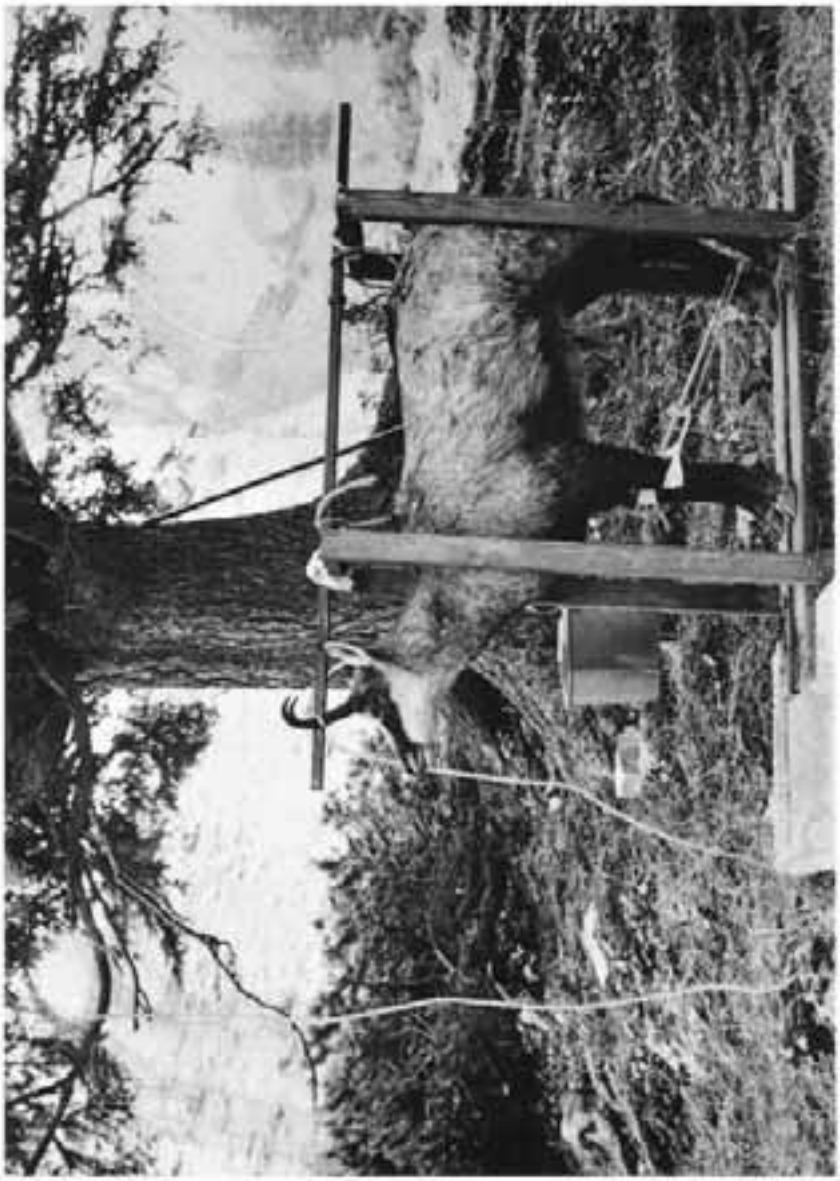

Fig. 3: A six year old chamois billy preserved with formalin after neck shot at c. 3200 ft., September; Austrian alps.

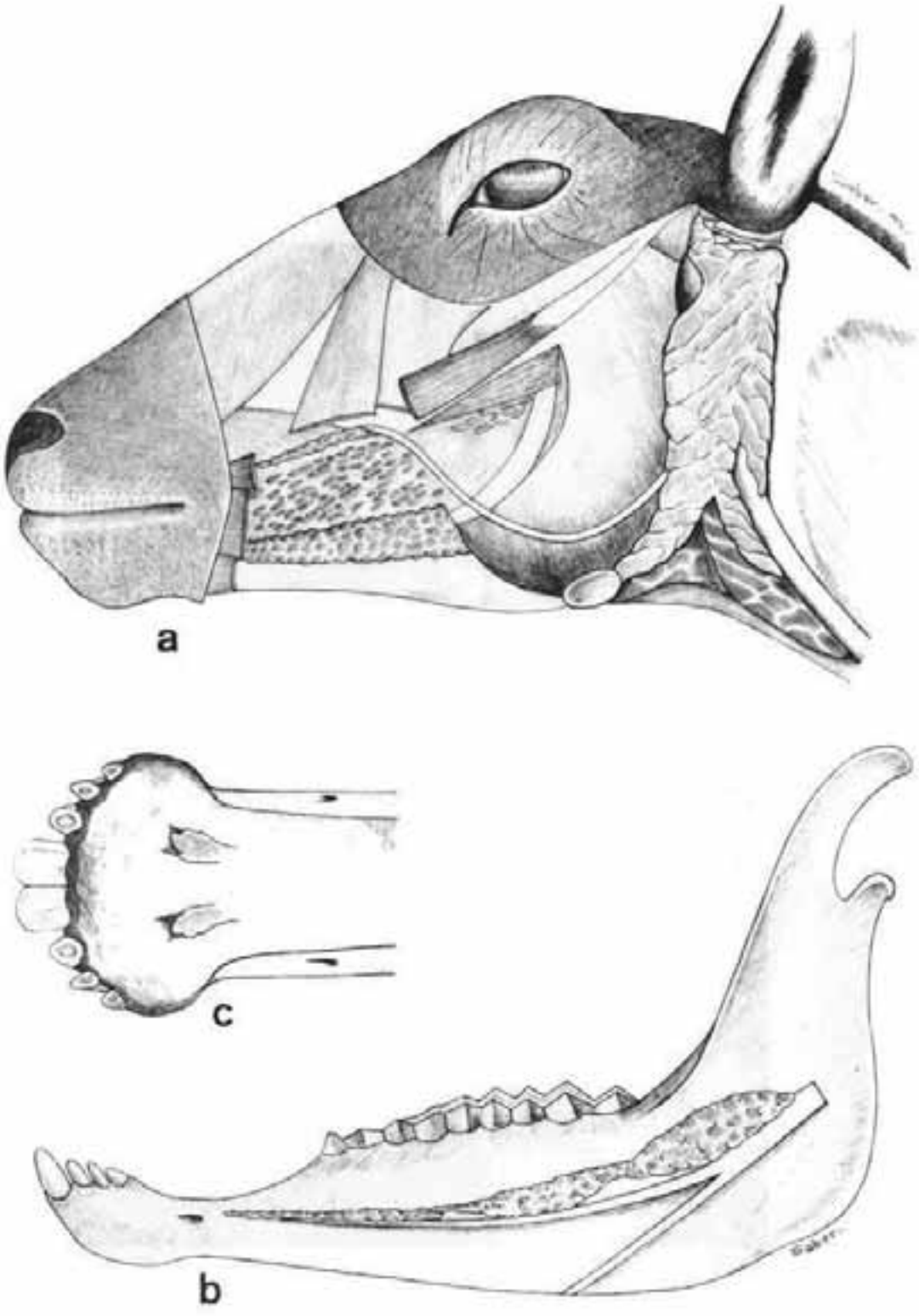

Fig. 4: Dissections showing (a) salivary glands of an adult mouflon sheep (from SABER and HOFMANN, 1984). Buccal glands left, parotid gland upper right, mandibular gland lower right and (b) the sublingual glands at the mandible and (c) the opening of mandibular and sublingual ducts below the tongue (caruncula sublingualis).

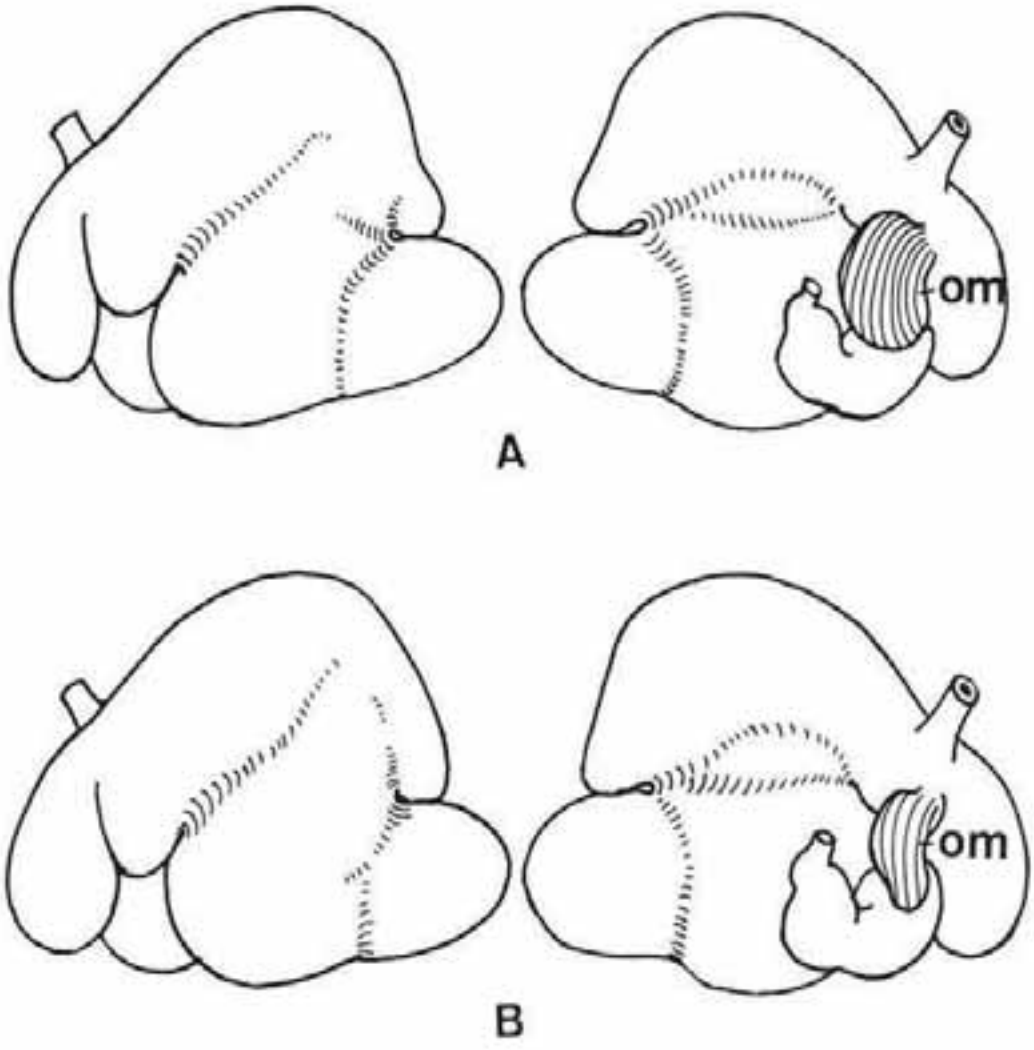

Fig. 5: Stomach shape and compartment relations in (A) mouflon and (B) chamois. Note relative size differences of omasum (om) on right aspect.

The reticular mucosa is most differentiated in MF where higher secondary and tertiary crests are much more pronounced than in CH where spike-like papillae are dominating the reticular cellulae with mainly primary crests.

The ruminal mucosa of MF shows a heteromorphic distribution of papillae which is typical for all grass and roughage eaters. This is similar in IB and extremely variable in CH. Its ruminal mucosa looks evenly papillated as in all concentrate selectors during the short alpine vegetation period but resembles the uneven pattern of grazing ruminants in winter and early spring (Figure 6).

The average surface enlargement factor (SEF) of the ruminal mucosa ranges in MF from 2,6 on the dorsal ruminal wall to 8,6 in the atrium ruminis; in CH from 3,6 on the dorsal ruminal wall to 16,5 in the atrium ruminis. SEF maxima in MF were 20,6, in CH 35,3. Generally, CH offer a greater mucosal surface area for the absorption of solubles and fermentation products, but seasonal variations are much more extreme than in MF. The dorsal ruminal mucosa ("roof of rumen") of CH shows maximal surface enlargement in September/October before the rut: SEF 10,6 on average, up to 12 in optimal cases. It drops dramatically at the beginning of the rut with its minimal food intake about late October/early November to 6,4 and finally even to 2,6 or 1,69 when food intake is reduced to old grass reappearing under melting snow. Average SEF as calculated from four "indicator regions" of the rumen (Hofmann and Saber, in press) range from 14 (20) over 2,5 to 4,5 before it rises again with the onset of a new vegetation period (Figure 7).

The omasal mucosa shows a lower degree of differentiation in CH than in MF. There are basically only two sizes of elongate, narrow laminae while there are three sizes of laminae omasi in MF which have much less long, claw-like papillae than in CH.

The abomasal mucosa shows little differences macroscopically, but there are seasonally varying differences in the microstructure which have not yet been sufficiently evaluated. CH appear to have more parietal cells during their "concentrate period" producing more hydrochloric acid.

MF have a relatively smaller liver (1,1 - 1,2% of body weight) than CH (1,7 - 1,8).

MF have a relatively longer intestine (total length c. 2100 cm) than CH (c. 1680), in relation to very similar body lengths. The proportion of the small intestine to the large intestine is 3,8:1 in MF and 3,1:1 in CH. The average volume of the caecum which is the main portion of the distal fermentation chamber is 310 ml in MF but 630 in CH. There is, however, a striking change of capacity in the chamois' caecum and proximal colon which occurs parallel to the rumen volume changes. During the rut, caecal volume has at 220 ml the annual low, while it reaches 850 or even 1030 early in spring, when old fibrous food only is available. During the vegetaton period, the caecal volume is around 500 - 700 ml. There are, finally, indications of seasonal variations also of the intestinal mucosal microstructure, which are related to seasonally changing forage quality as found in roe deer by Lackhoff (1983). A comparative study is under way.

Fig. 6: Stomach of a six year old chamois in situ, opened from the left side. From left to right: heart, 6th rib, reticulum 8th rib, spleen cut surface; heavily papillated dorsal and ventral ruminal sac, above 13th rib; right below entrance into ventral blindsac. Specimen as in Fig. 3.

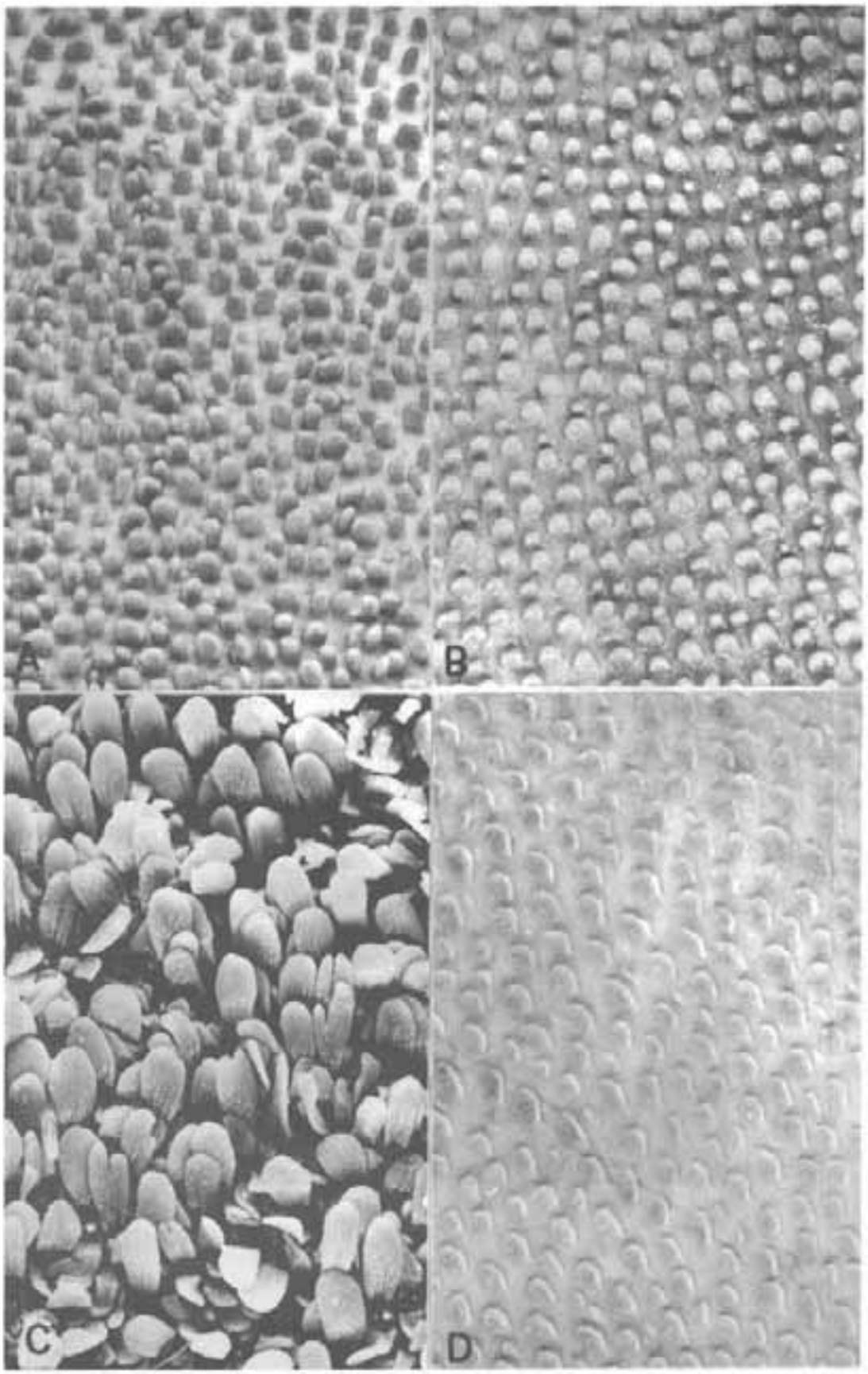

Fig. 7: Mucosa samples from the centre of the dorsal ruminal wall of mouflon (A) under summer, (B) under winter feeding conditions; of chamois (C) in summer, (D) in late winter. Little SEF changes in mouflon, extreme changes in chamois.

DISCUSSION

According to the morphological criteria established (Hofmann 1973 and 1983) the European wild sheep shows the typical evolutionary adaptation within the group of grass and roughage eaters and resembles thus the domestic sheep and, presumably, also other sheep species. It has relatively small salivary glands with a parotid quite dissimilar from concentrate selectors like roe deer (Ramisch 1978), gerenuk or duiker (Hofmann 1973). It has a relatively capacious ruminoreticulum with a distinct subdivision for delayed food passage and an uneven distribution of ruminal papillae. There is only little surface enlargement on the dorsal and ventral wall of the rumen. The margin of seasonal variation through mucosal response and reconstruction (Hofmann et al, 1976; Sakata et al. 1980) is relatively narrow. Main absorption from predominantly slow cellulolytic processes occurs at mid-level of the rumen where papillation is dense and the SEF always higher. The reticular mucosa is subdivided and well suited to separate coarse fibrous food from broken down particles. The medium sized omasum is well developed and offers already a considerable additional mucosal surface for absorption. The liver is relatively small while the intestine is extremely long. The proportion of the large intestine, as calculated by Drescher-Kaden (1976 a,b) and von Trott (1983) is at 19-20% small when compared with ruminants of the concentrate selectors' or intermediate group. This is mainly due to a much smaller caecum. Chamois, on the other hand, which are taxonomically close to the North American mountain goat, show all morphological signs of an intermediate, opportunistic ruminant utilizing a mixed diet but selecting whenever possible for cell content rather than for cell wall, i.e. fibre (Figure 9). This has obviously led to a digestive strategy much different from wild sheep which are well capable to digest poor fibrous food throughout the year. The cyclic changes induced by the limitation of the alpine forage availability are much more dramatic both anatomically and physiologically than in sheep as was shown by Hofmann (1982). Chamois have an extremely high food intake combined with extreme selectivity, optimal nutrient utilization and rapid converson into fat. Their gastro-intestinal tract undergoes remarkable changes of capacity both in the reticulorumen and the caeco-colon. While this distal fermentation chamber is 1:30 in sheep, it is 1:10 in chamois during the vegetation period. While the reticulorumen of CH is at 8-9 litres very capacious at that time, a drastic reduction down to one third occurs during the rut, with only a moderate increase in the subsequent period of moderate food intake and reduced activity during winter. But obviously as a direct result of exhausted energy reserves in late winter and early spring when only poor fibrous food is available, a drastic increase in capacity (from 5 to 10 or 11 litres) is used to compensate lack of nutrient contents by increased intake, which requires adjustment of passage regulating structures.

Similarly impressive and further evidence for this adaptive strategy is the clearly cyclic transformation of the ruminal absorptive mucosa which shows a potential swing of the SEF of 1:7; f.i. during optimal forage availability chamois have an absorptive surface available which is more than seven times larger than during periods of need. Morphological signs of this nature are much more reliable than stomach content analyses which merely inform about a fraction of the animals' year. CH are from the beginning of the alpine vegetation period (after 2-3 weeks of transformation) between June and October, extremely efficient concentrate selectors. They turn fibre digesters during winter and are capable of bridging the dangerous gap between the exhaustion of

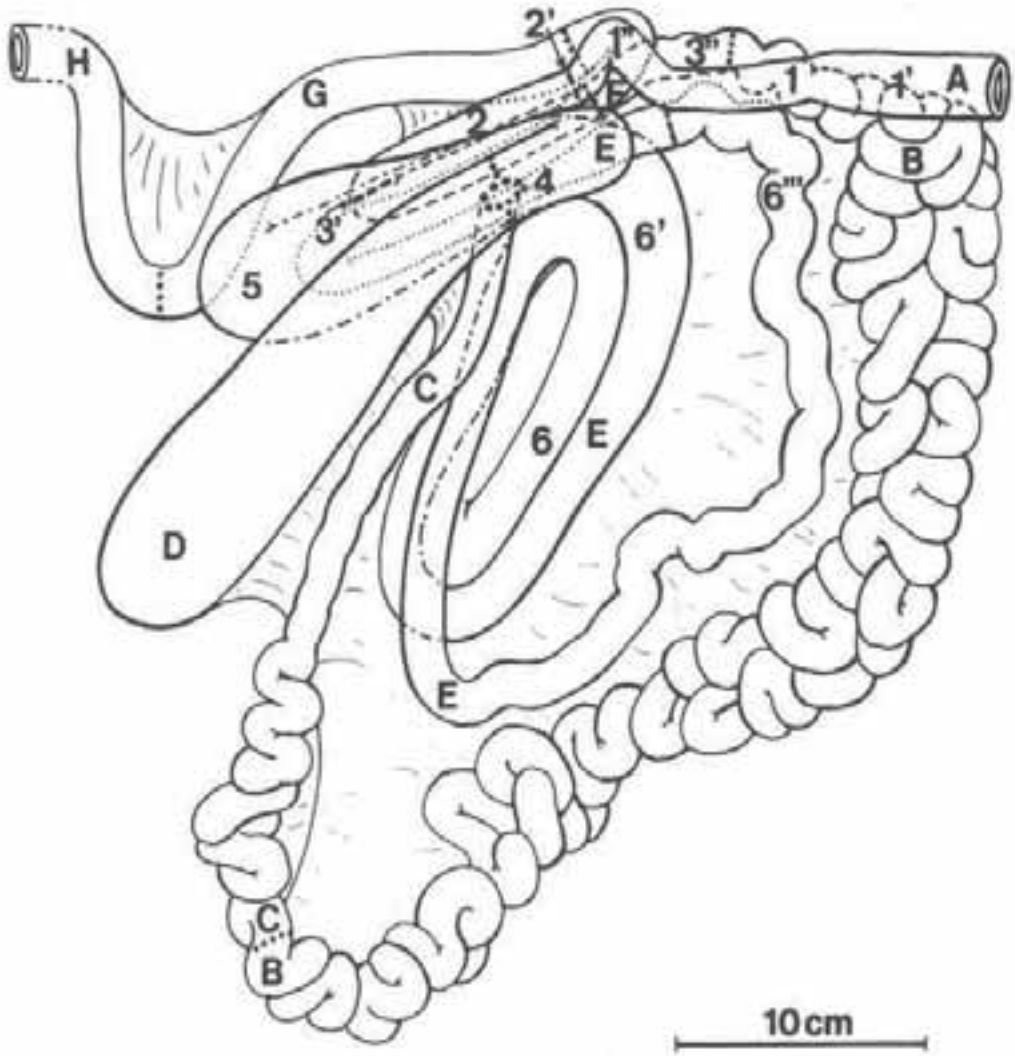

Fig. 8: Schematic diagram of the intestine of mouflon, right aspect. (A) duodenum, (B) jejunum, (C) ileum, (D) caecum, (E) Colon ascendens, (F) Colon transversum, (G) Colon descendens, (H) rectum; 5 widened ansa proximalis coli (part of distal fermentation chamber), 6 spiral colon; from W. von TROTT zu SÖLZ, 1983.

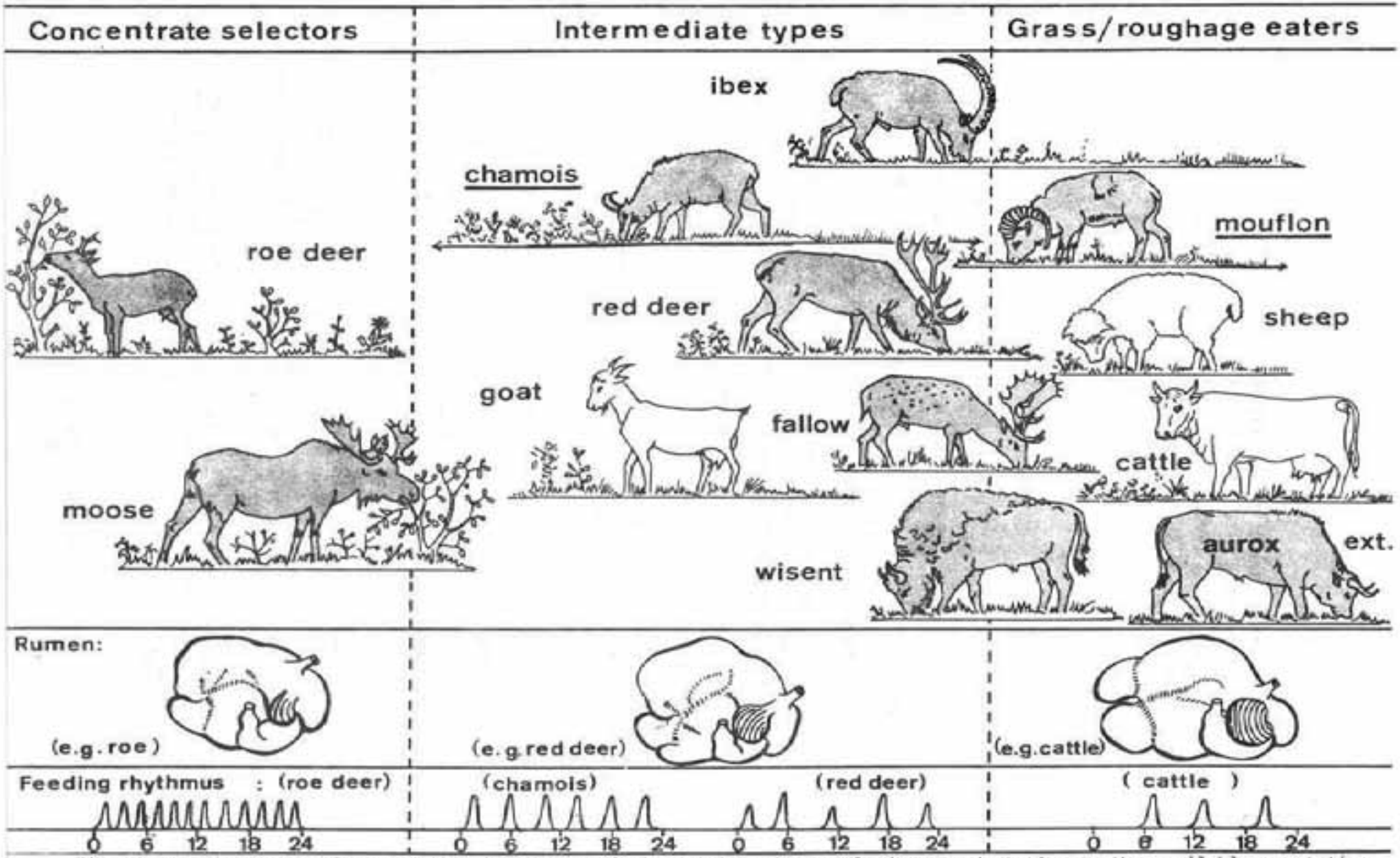

Fig. 9: The European ruminant species in their typical position after evolutionary adaptation to the available vegetation according to feeding habits and morphophysiological specialization of their digestive tract. The further a species is placed to the right, the greater its capability to digest cell wall (fibre; cellulose). (HOFMANN, 1976)

fat deposits and the arrival of new vegetation by maximal intake of low quality forage - a fact which up to now only equids were reputed to do.

Although merely initial work has started on North American species taxonomically related to these European species (Figure 9) it can be stated that the mountain goat will occupy the position similar to that of chamois while the various North American sheep species (Bighorn, Stone, Dall) can be placed in a very similar position as mouflon. This will be verified by detailed studies and published in due course.

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A MAJOR BIGHORN SHEEP DIE-OFF FROM PNEUMONIA IN SOUTHERN ALBERTA

D. K. Onderka, Animal Health Division, Department of Agriculture, 6909-116 Street, Edmonton, Alberta T6H 4P2.

W. D. Wishart, Fish and Wildlife Division, Department of Energy and Natural Resources, 6909-116 Street, Edmonton, Alberta T6H 4P2.

ABSTRACT

The chronological course of a bighorn sheep (Ovis canadensis canadensis) die-off due to pneumonia is charted from southern British Columbia into southern Alberta and northern Montana. Initial losses were primarily breeding age adults followed by poor lamb production from the survivors. The southern Alberta herd was reduced by approximately 65% during the period September 1982 to November 1983. Clinical signs included decreased exercise tolerance, harsh coughing often under severe strain, and sometimes mucoid nasal discharge.

Postmortem examination of sheep found dead or collected revealed acute, subacute or chronic bronchopneumonia, sometimes with extensive pleuritis. A unique Pasteurella hemolytica biotype T was isolated from the lesions. Attempts to isolate other agents on bovine or bighorn cell cultures were unsuccessful. Pasteurella spp. were not found in an extensive culture survey of clinically normal bighorns. There was no correlation between the severity of lungworm infection and the occurrence of pneumonia. Preliminary results of a transmission study using the bighorn Pasteurella sp. isolate in domestic sheep are discussed.

INTRODUCTION

Periodic die-offs of Rocky Mountain bighorn sheep have occurred throughout their range during the past several decades (Buechner 1960, Stelfox 1971). Some of the more recent declines have been attributed to a complex of factors ultimately causing fatal pneumonia (Forrester 1971, Spraker 1979, Wishart et al. 1980). The present report describes an epizootic of bacterial induced bronchopneumonia in bighorns in southern Alberta.

HISTORY AND CLINICAL SIGNS

In December 1981, a die-off from pneumonia was reported in bighorn sheep after they had mixed with a domestic sheep herd on Maguire Creek in southeastern British Columbia (Davidson 1982). By the fall of 1982, the die-off had spread northward up the East Kootenay river to Premier Ridge and eastward across the continental divide into southern Alberta and into Waterton National Park. The northern extent of the die-off in Alberta was the Crowsnest Pass. By early winter 1983, dead and dying bighorns were reported in Glacier National Park, Montana.

In Alberta, the die-off appeared to diminish significantly by the fall of 1983 and the last sick bighorn observed was collected on October 27. Fortunately, a forest barrier north of the Crowsnest Pass may have prevented an interchange of sheep and the continuation of the disease northward.

Affected bighorns were unthrifty in behavior or appearance or both. Various stages of clinical signs observed ranged from animals with a few coughing bouts to animals with labored breathing to the extent that they had difficulty holding their heads up or even standing. Diseased animals were often detected by their inability to keep up with the herd. Generally, the body condition of the affected animals was good, but a few had a scruffy hair coat and some of these were emaciated. On occasion, yellow exudate or clear mucus nasal discharge could be observed in the coughing sheep.

The year following the outbreak (1983) was characterized by a poor and staggered lamb crop. Some unhealthy individuals were observed coughing during the summer and fall.

FIELD SAMPLING PROCEDURES

Following the first reports of a die-off, we initiated intensive ground and aerial surveys to locate diseased sheep and to determine the magnitude of the losses. Bighorns observed suffering from respiratory distress were collected whenever possible. Several dead sheep were located during the culling process. Whole carcasses of collected animals were delivered to the Alberta Veterinary Services Laboratories in Edmonton and Lethbridge and when this was not possible a composite sample of head, trachea, lung, heart, liver, kidney, femur and feces from each specimen was submitted. Also submitted were various combinations of the above body components salvaged from some of the animals that were found dead.

In addition to the culling program, apparently healthy bighorns from within and outside the die-off area were trapped or darted and immobilized to obtain nasal and pharyngeal swabs and blood sera. After sampling, the animals were tagged and released for further observation.

Specimens were obtained in the fall of 1983 when hunters brought in lungs and heads (non-trophy) of bighorn sheep that were shot north of the affected area, that is, from the Crowsnest Pass to the Bow River, a distance of approximately 150 kilometres. In addition to the Alberta samples, we also received a few specimens and samples from the die-off area in British Columbia and Glacier National Park, Montana.

In total, 19 animals were collected and 23 were found dead. Ten of the latter had suitable tissues for laboratory examinations. Nasal and pharyngeal cultures were collected from 22 live bighorns in the die-off area and 176 cultures were obtained north of the die-off area. Cultures were obtained from nasal passages and lungs from 37 animals that were turned in by hunters. Carcasses of two bighorn sheep and one mountain goat were received from Glacier National Park.

MATERIALS AND METHODS

Body condition was assessed by evaluating subcutaneous, mesenteric and perirenal body fat deposits as well as quantification of midshaft femoral bone marrow fat using ether extraction of a preweighed dried sample. The lungworm load was estimated by the size and number of grey nodules in the parenchyma and a rating of very light through moderate, to very heavy was assigned. First stage larvae were quantified in the dried fecal pellets after Samuel and Gray (1982). Kidney, blood and liver were retained frozen for future trace mineral evaluation; sera and fecal samples were collected for future cortisol determinations. Microscopic examination was done on routine formalin fixed tissues stained with hematoxylin / eosin and Masson's trichrome stain.

Swabs for microbiologic examination were obtained using cotton swabs wetted with Stuarts transport media[1]. Pharyngeal swabs were taken through 13 millimetre diameter, 23 centimetre long pre-sterilize plastic tubes inserted into the oral cavity. Culture isolates were exchanged with the Veterinary Laboratory at Abbotsford to compare the organisms isolated from bighorns from British Columbia. Routine cultures were prepared using blood agar and MacConkey plates followed by a series of sugar inoculations to determine biochemical characteristics. Virus isolations were attempted using bovine kidney cells and lung and kidney cell cultures prepared from a young bighorn lamb.

RESULTS

We estimated that approximately 65 percent of a herd of about 400 between Waterton Park and the Crowsnest Pass died during the first year of the outbreak (Table 1). Park wardens estimated a loss of about 150 sheep or approximately 50 percent of the Waterton Park herd. The most remarkable losses were in the older age classes, particularly rams (Table 1, Figure 1). Only four rams were harvested from the die-off area in the fall of 1983 compared to an average annual harvest of 16 trophies during the last decade. Lamb survival and production were low in 1982 and 1983 with less than 20 lambs/100 ewes observed in March, 1984 (Table 1).

Although none of the tagged sheep showed any signs of pneumonia, three tagged ewes lost their lambs over the summer of 1983 while another tagged ewe had a sick lamb with pneumonia which was collected in September (Festa-Bianchet 1983). Most of the animals collected and many of the dead sheep were in good body condition with bone marrow fat of 79 to 91 percent. Some ewes in moderate conditions ranged from 42 to 49 percent while the thin sheep had a fat content

1. Culturettes^{R} - Can Lab.

of 8.5 to 27 percent. Lungworm lesions were usually mild to moderate with few very heavy infections. There was a poor correlation between the estimated lungworm burden and fecal larval output.

Table 1. Numbers of bighorns observed from winter aerial surveys north of Waterton Park to Crowsnest pass (1975-1984).

Year	Total	Lambs	Ewes[1]	Rams <1/2 curl	Rams >1/2 curl
1975	353	81	187	50	35
1979	389	77	248	44	29
1983	123	20	86	4	5
1984	159	19	108	21	3

1. Includes yearling ewes.

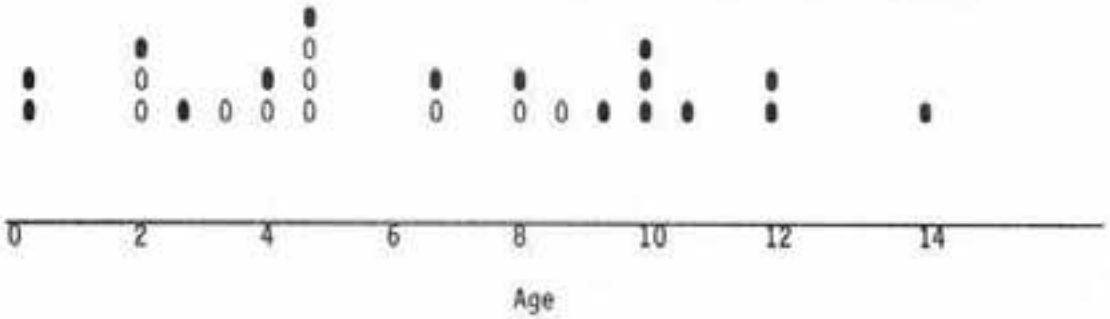

Figure 1. Age distribution of bighorn sheep with pneumonia (● = male, O = female).

The principal lesion was bronchopneumonia expressed as red consolidation of the anterior ventral lung lobes. The tissue was firm and the airway walls were thickened, often containing cream colored mucoid exudate. Pneumonic tissue was usually sharply demarcated from normal lung. There was no overlap with lungworm infected areas. Some animals had severe fibrinous pleuritis with adhesions to the chestwall. Subacute lesions had progressed to necrosis of the lung tissue and some had developed abscesses. In chronically affected sheep, fibrous tissue had formed fusing the anterior and middle lobes as well as causing firm adhesions to the thoracic pleura. These animals were usually in poor body condition.

Microsopic examination confirmed a range of acute to chronic active bronchopneumonias characterized in the subacute phase by proteinaceous alveolar exudate mixed with macrophages, pneumocytes and neutrophils. Bronchioles were often obliterated by a mainly neutrophilic exudate and mucosal infiltrations. Occasionally, a first stage lungworm larva was found trapped in the alveolar exudate. The lungworm nodules consisted of adults, eggs and L_1 larvae causing modest interstitial lymphocyte reaction and some fibromuscular hyperplasia of alveolar septae. Bronchial lymph nodes were enlarged with prominent germinal centers and much neutrophil influx into subcapsular and medullary sinusoids.

Pasteurella hemolytica biotype T of a non-hemolytic variety was isolated from the pneumonic lung tissue in 48 percent of the sheep with bronchopneumonia. In addition, Corynebacterium sp. was recovered from lungs that had progressed to form abscesses. Pasteurella sp. was also recovered from bronchial lymph nodes and nasal swabs in animals with bronchopneumonia.

Virus isolation attempts were consistently negative even from tissues of animals submitted live to the laboratory. Some tissue was suitable for Chlamydia and Mycoplasma cultures but no isolations were made.

Two hundred and forty-five nasal and pharyngeal swabs examined to evaluate the prevalence of Pasteurella spp. in the nasopharyngeal bacterial flora were negative except for one lamb closely associated with a group of sheep affected by pneumonia (Table 2).

Table 2. Apparently healthy bighorn sheep surveyed by culture for Pasteurella spp. in Alberta, 1982-84; includes nasal swabs, pharyngeal swabs and lungs (shot or accidental deaths).

Crowsnest	Sheep River	Banff Park	Ram Mtn.	Jasper Park	Lung Submissions	Total
1/22*	0/33	0/7	0/143	0/3	0/37	1/245

* one lamb (accidental death) positive for P. hemolytica biotype T, variant

DISCUSSION

The pneumonia outbreak spread rather rapidly from B. C. to Montana (1981 to 1983) and was first observed in each jurisdiction in the fall or early winter. The timing of the outbreaks corresponded to the breeding season of bighorns (November and December) when the animals are concentrated and the rams are moving long distances from herd to herd. Festa-Bianchet (1984) reported a linear spread of approximately 100 kilometres between radio-tagged rams from the same herd during the rut at Sheep River, north of the die-off area. The highly mobile component of rutting rams was probably responsible for spreading the disease over such a large area.

Pasteurella sp. has been previously reported in bighorn sheep with pneumonia (Post 1962, Forrester 1971, Spraker and Hibler 1977 and others). The isolates were identified as P. multocida, P. hemolytica or unidentified

species. The biotype isolated in this outbreak was consistently found in affected sheep throughout the die-off area. An interesting cultural feature was the complete absence of hemolysis which made this P. hemolytica type T a variant that was used to trace the spread of the pneumonia. This biotype variant is rarely found in livestock and has not yet been isolated from domestic sheep in Alberta. It must be cautioned not to place too much emphasis on the biochemical characteristics of the bacteria as they could change when the organisms infect a different host species.

Histopathology of the lungs was suggestive of a bacterial bronchopneumonia, although an early viral involvement cannot be excluded even in the face of negative virologic cultures. Some respiratory viruses are extremely labile and may have been destroyed by the host. Nevertheless, it is possible for Pasteurella hemolytica to cause a systemic or pneumonic infection in domestic sheep depending on the biotype (Ellis 1984). Less clear is the role of Pasteurella spp. in shipping fever pneumonia in feedlot cattle. There is little doubt that Pasteurella sp. induced the terminal lung lesions seen in the bighorns, but at the same time one has to keep in mind that Pasteurella spp. are opportunists and other factors may have played a role. The inability to recover Pasteurella sp. from the nasal passages and the pharynx of healthy bighorns may reflect presence of very low numbers or inaccessibility by the swab method if Pasteurella spp. reside in pharyngeal lymph nodes or tonsils.

There was no apparent association of the level of lungworm infection with the bronchopneumonia. It is possible however, that sheep with a high lung parasite load are more susceptible to colonization by opportunistic bacteria and thus may have formed part of the nidus from which the infection may have spread. To reflect a possible multi-etiologic cause, the disease outbreak would best be termed: 'respiratory disease complex of bighorn sheep'.

The question still remains, what was the triggering mechanism that touched off the die-off in the first herd? This problem was discussed by bighorn experts from western North America at a workshop on bighorn die-offs in Cranbrook in May 1983 (Schwantje 1983). The general concensus was that multiple stress factors appear to affect the herds susceptibility through the immunity or resistance level of individual sheep. A triggering factor that started the die-off could have been contact with domestic sheep as in Washington and California (Foreyt and Jessup 1982). However, the workshop participants agreed that there was no solid evidence that domestic sheep could be implicated as the cause of the die-off. Other factors such as inter- and intra-species competition for forage and space, harassment, or inclement weather may have initiated the outbreak. In addition, rutting activity severely drains body reserves of the older, larger rams (Geist 1971) and likely increases their susceptibility to predation, starvation or diseases.

In any event, bacteria would proliferate in the most susceptible sheep and those animals most compromised by stressors would probably die from acute pneumonia. More resistant animals might survive, develop subacute or chronic forms of pneumonia and could serve as transmitters. The possibility that some individuals survive the disease and are carriers seems to be borne out by the fact that poor lamb crops were observed following the die-offs in both British Columbia and Alberta. Festa-Bianchet (1983) noted several barren ewes and a staggered lamb crop during the summer of 1983. He was able to collect two of four coughing lambs in the fall, and both were affected with the Pasteurella

hemolytica type T variant. One of the pneumonic lambs was from a tagged ewe that showed no evidence of the disease throughout the die-off.

Poor lamb production and delayed parturition may have been due in part to a shortage of rams capable of breeding in 1982. Ewes with a subacute infection may not have come into estrus or had a delayed estrus. Subacute or chronic pneumonia may have caused some ewes to abort or to resorb fetuses. It remains to be seen if the disease continues to be manifested by poor productivity.

Experimental work using domestic sheep is underway to test two hypotheses: (a) did disease transmission occur from domestic livestock to a susceptible bighorn sheep population or (b) have opportunistic pathogens overwhelmed bighorns which were stressed by one or more factors to decrease their resistance?

So far, one trial using three sheep has failed to transmit the Pasteurella sp. isolate to domestic sheep using intranasal and intratracheal inoculations and dexamethazone as a stressor. The clinical reaction of these sheep did not go beyond a brief period of fever in response to the foreign bacterial protein. The Pasteurella sp. variant could not be reisolated. However, these sheep were previously found positive for Pasteurella multocida in their nasal flora and may have been refractory to experimental infection. Any antibody response remains to be evaluated. Before any conclusions can be drawn, further experiments will have to be carried out along with an attempt to serotype the bighorn sheep Pasteurella sp. isolate for comparison with isolates from domestic animals.

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LAMB SURVIVAL IN RELATION TO MATERNAL LUNGWORM LOAD IN ROCKY MOUNTAIN BIGHORN SHEEP

Marco Festa-Bianchet, Research Unit, Alberta Fish and Wildlife, and Dept. of Biology, University of Calgary, Calgary, Alberta, T2N 1N4, Canada.

Judith Samson, Dept. of Zoology, University of Alberta, Edmonton, Alberta, T6G 2E9, Canada.

ABSTRACT

The relationship between the output of lungworm larvae in the feces of bighorn ewes and reproductive success was investigated in the Sheep River herd in southwestern Alberta from 1981 to 1983. This herd had a history of high lamb production, but variable lamb survival.

In 1981, the lamb:ewe ratio at birth was 95:100, lamb survival was 90% to November, and mean lungworm larval output for ewes during the March-April period was low. In 1982 and 1983 lamb:ewe ratios at birth were also high, but an estimated 32% and 28% respectively of lambs born each year disappeared before October; average larval output of ewes was higher. Ewes whose lambs survived had significantly fewer larvae in feces than ewes whose lambs died before October. In 1982, lambs that started coughing in July, were never seen playing and behaved in a lethargic manner. Most disappearances seemed to occur between late July and early September. Lambs in 1983 appeared healthier, were rarely coughing, some play was observed and disappearances spanned the entire summer.

Lamb mortality was possibly caused by transplacental transmission of the parasite. A few larvae were recovered from three fetuses collected in 1983. Alternatively, high larval output and lamb death could have been consequences of poor maternal body condition. Since the number of larvae in the feces of all ewes in 1981 were not significantly lower than those of successful ewes in either year of summer lamb mortality, an hypothesis is proposed to explain lamb mortality as a result of the behavior of individual ewes, not a consequence of a factor affecting the entire herd.

INTRODUCTION

Almost all bighorn sheep (*Ovis canadensis canadensis*) in Alberta are infected with lungworms (*Protostrongylus* spp.) (Uhazy et al. 1973; this study). Eggs produced by adult worms hatch into first stage (L1) larvae that leave the host via the feces. L1 output follows a yearly cycle, peaking in late winter and early spring. At this time, fecal samples collected from different sheep usually show a very wide range of larvae per gram of dry feces (LPG) (Uhazy et al. 1973).

Bighorn fetuses can become infected transplacentally in the latter stages of pregnancy. Transplacental infection has been associated with catastrophic lamb die-offs (Hibler et al. 1972, 1974; Woodard et al. 1974; Spraker 1979; Spraker and Hibler 1982). Lamb mortality caused by pneumonia results as a complication of the onset of reproduction among worms acquired transplacentally (Spraker 1979). Infected lambs are characterized by lethargic behavior, rough hair coat and violent coughing. Death usually occurs between late July and September (Woodard et al. 1974; Spraker and Hibler 1982).

Both transplacental infection (Gates and Samuel 1977) and summer lamb mortality (Horejsi 1976) have been reported in Alberta, but a direct link between them has not been established. Summer lamb mortality as high as that reported from Colorado (Hibler et al. 1974) has not been observed in Alberta.

Following an all-age die-off in the Sheep River Wildlife Sanctuary in 1978 (Wishart et al. 1980), a study of the local sheep herd was initiated to determine the relationship between a sheep's area use behavior, lungworm infection and reproductive performance. Here we report on the correlation between maternal lungworm larval output and lamb survival to autumn.

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MATERIALS AND METHODS

The study area is located within the Sheep River drainage in southwestern Alberta. Detailed descriptions can be found in Wishart (1958) and Horejsi (1976). The ewe's winter range has been a Wildlife Sanctuary since 1973, and is semi-protected. The lambing grounds and the summer range are located in the front ranges of the Rockies to the west of the winter range. Hunting for trophy rams and non-trophy sheep (ewes and lambs) on a permit basis is allowed outside the Wildlife Sanctuary.

Sheep were captured using projectile syringe darts loaded with ketamine and xylazine (Festa-Bianchet and Jorgenson 1985) or xylazine only, or in a corral trap baited with salt. Captured sheep were tagged with colored plastic tags and numbered metal tags. A swollen udder was considered to be an

indication that a ewe was pregnant or lactating. Following lambing, survival of individual lambs was monitored through their association with tagged ewes. Exact dates of lamb death were not known, as intervals between ewe sightings varied from a few days to over a month. When a lactating ewe was never seen with a lamb but was sighted within 2-3 weeks following the peak of lambing, it was assumed that the ewe had produced a lamb that had died at or shortly after birth. These events were considered neonatal mortality.

Fecal samples were collected at capture and whenever identifiable sheep were observed to defecate. Samples were air-dried and analyzed for lungworm larvae with a modified Baerman technique (Samuel and Gray 1982). Larval output was measured as larvae per gram of dry feces (LPG). Between-ewe comparisons were made using feces collected when larval numbers peaked (March-April). When more than one sample was collected from the same ewe over this period, the average LPG was used for calculations, so that only one value was used for each individual. The LPG values used were averages of two or more samples in 68% of the cases. Comparisons were made using the Mann-Whitney statistic U, unless otherwise specified. All results reported are relative to marked ewes only. These increased from 40 to 90% of the total ewe herd during this study. Ewes whose lambs survived to October 1st are referred to as successful ewes. Those whose lambs disappeared before this date are referred to as unsuccessful ewes.

RESULTS

Lamb production was high in all three years of the study (Table 1). Although survival to the fall appeared to be greater in 1981, the difference was not statistically significant ($x^2 = 3.49$, $0.1 > P > 0.05$ comparing 1981 to 1982 and 1983). In both 1982 and 1983, lambs disappeared throughout the summer. Neonatal mortality was low, accounting for only 5% of the lamb crop over the two years.

Table 1. Lamb production and survival of the Sheep River herd, 1981-83. All tagged ewes two years of age and older are included.

Year	Lamb:Ewe ratio Birth	(N)[a] October	% lamb survival to October (N) [b]
1981	0.95 (22)	0.86 (22)	90.5 (21)
1982	0.93 (41)	0.63 (41)	68.4 (38)
1983	0.86 (50)	0.62 (47)	72.5 (40)

a. Number of ewes in sample
b. Number of lambs in sample

Table 2 summarizes fecal LI output for all ewes two years of age and older. Differences in LPG were significant only between 1981 and 1982. In 1983, however, the distribution of LPG values was different, so that variance was greater than in 1982 (F-test = 1.943. $P < 0.05$). In both 1982 and 1983, successful ewes had lower LPG values than unsuccessful ones (Table 3). When larval output of successful ewes was examined, no significant differences were found among the three years (Table 4).

Table 2. Protostrongylus spp. L1 output per gram of dry feces for ewes of the Sheep River herd in March-April of 1981-83. Output in years followed by different letters was significantly different (P 0.01, Mann-Whitney U test).

Year	$\bar{X}$	N	(Range)
1981a	417	14	(0-1085)
1982b	776	33	(7-1989)
1983ab	680	51	(6-2811)

Table 3. A comparison of Protostrongylus spp. L1 output per gram of dry feces (LPG) in March-April of ewes whose lambs did and did not survive to October 1st in 1982 and 1983.

	Lamb alive			Lamb dead			
Year	$\bar{X}$	N	(Range)	$\bar{X}$	N	(Range)	p [a]
1982	642	19	(7 - 1718)	967	10	(139 - 1989)	0.025
1983	455	29	(6 - 1542)	1130	10	(160 - 2610)	<0.01

a. Mann-Whitney U test.

Table 4. Summary of statistical comparison of L1 output in March-April of all ewes in 1981, successful and unsuccessful ewes in 1982 and 1983, using the Mann-Whitney U test. (s = successful; us = unsuccessful).

	1981	1982s	1982us	1983s
1982s	>0.05			
1982us	<0.01	<0.025		
1983s	>0.5	>0.1	<0.01	
1983us	<0.01	<0.025	>0.1	<0.01

Lamb behavior was not quantified, but some obvious differences were evident between years. In 1981, lambs behaved 'normally': play was common, lambs appeared healthy and no coughing was observed. In 1982, no play was observed, lambs often displayed lethargic behavior with a tendency for laying down, and many had scruffy, rough hair coats from July onward. Several instances of coughing were observed beginning in mid-July. Coughing was similar to that described in sheep in areas affected by all-age die-offs (Feuerstein et al. 1980; Wishart et al. 1980: Personal observations), and lamb die-offs (Woodard et al. 1974). Lambs sometimes stood for 2-5 minutes with their mouth open, apparently experiencing difficulties in breathing, a symptom noticed also by Woodard et al. (1974). Coughing bouts among lambs were observed up to late October. Since lambs were identifiable only through their association with tagged ewes, it was not possible to know their identity when they were not close to their mothers. As a result, it was not known whether or not those that exhibited coughing and other symptoms most often were the ones that

disappeared. In 1983, some play was observed and coughing was very rare. As in 1981, the subjective impression was that lambs appeared 'normal'.

Three pregnant ewes with high L1 output were collected in 1983. The fetal lungs, liver and several placental cotyledons were dissected and analyzed for lungworm larvae. A few larvae were found (Table 5). Numbers were much lower than those found by Hibler et al. (1974) and Spraker in transplacentally infected fetuses and young lambs. Twelve fecal samples were collected from lambs between late June and August in 1981 and 1982. Some Protostrongylus sp. L1's were found in all (mean = 187 LPG, range 2-881), with no difference between years.

Table 5. First-stage (L1) and third-stage (L3) Protostrongylus spp. larvae recovered from bighorn sheep fetuses collected in 1983.

Date	Ewe LPG	Lungs L1	Liver L1	Liver L3	Cotyledons L1 [b]	Cotyledons (N) [a]
03/31	1641	n/a	0	4	0.0	(10)
04/08	2075	1	2	0	1.2	(9)
04/10	2992	0	0	1	0.0	(10)

a. No. of cotyledons examined.
b. Larvae/cotyledon

DISCUSSION

Spraker and Hibler (1982) discussed three types of pneumonia die-offs of bighorn sheep: all-age, transplacentally induced, and summer lamb mortality following all-age die-offs. The pattern of lamb behavior and mortality observed at Sheep River in 1982 and 1983 is reminiscent of transplacentally induced lamb die-offs. However, there were some differences between this mortality and the lamb die-offs reported in the literature. First, very few larvae were recovered from the three fetuses collected. Second, mortality at Sheep River was not as severe as that documented in other lamb die-offs (Hibler et al. 1974; Woodard et al. 1974). It is possible that rather than a strictly parasitological phenomenon, the summer lamb mortality at Sheep River may have been the result of a combination of heavy lungworm infection and poor condition of the ewe. The total size of the herd increased from 60-70 sheep in the mid 1950's (Wishart 1958) to about 110 in the early 1970's (Horejsi 1976), to over 140 at present. High population density may result in stress, either social or nutritional. Heavy parasite loads may be both a consequence and a contributing cause of stress. Stelfox (1976) found a correlation between range overutilization, low lamb survival and lungworm larval output. If the entire herd was under stress, however, one may expect conception rates to drop, but this did not happen. Lambing rates remained high in the three years of this study, and summer lamb mortality never accounted for more than 32% of the lamb crop. This suggests that, perhaps, rather than an overall stress situation affecting the entire herd, the cause of high lungworm larval output and lamb mortality should be sought within the behavior of individual ewes.

The larval output of successful ewes in 1983 was very similar to that of ewes in 1981 (Tables 2 and 3), a year of negligible summer lamb mortality. The larval output of unsuccessful ewes in 1983, however, was much higher than that of ewes in 1981. Similarly, although output in 1982 was significantly higher than in 1981, this significance disappears if only successful ewes are compared (Table 4). The basic questions to be addressed, therefore, is not what caused an increase in L1 output of the Sheep River herd, but what did some ewes do (or not do) that caused them to experience high L1 output. Major differences in individual behavior have been documented in the course of this study, particularly in the amount of use of the winter and summer ranges from July to mid-October. During this period, forage in the alpine summer range is of higher quality than that available on the winter range (Johnston et al. 1968; Hebert 1973), thus ewes that spend more time on the summer range may be in better body condition than those that remain on the winter range. Wishart et al. (1980) also postulated that summer use of the winter range may lead to heavy lungworm infection, because of a presumably greater availability of infected snails (Boag and Wishart 1982). It is therefore reasonable to suspect that area-use behavior may affect a ewe's larval output and be important to its reproductive success.

At this point, it is important to know what exactly determines how many larvae a ewe will expel with its feces. Forrester and Senger (1964) did not find a correlation between larval output and the area of lungworm lesions in the lungs of mature rams. Uhazy et al. (1973) believed that L1 output was related to the number of adult lungworms in a sheep's lungs. Conclusive data on this relationship, however, are yet to be gathered. An alternative hypothesis (D. Onderka, personal communication), that output is at least partly related to the reproductive performance of adult worms, has not been falsified. If this hypothesis was true, the same number of worms in different sheep may result in widely different numbers of L1's in the feces. It could be speculated that a healthy, vigorous ewe may be able to mount a better immune response and decrease the reproductive performance of its lungworms, while a ewe with inadequate body reserves may not be able to do likewise. The latter ewe may then have higher L1 counts. Because of its poor condition, and perhaps also because of transplacental infection, this same ewe may not be able to raise a healthy lamb that will survive to the winter. An inadequate milk supply may also force the lamb to feed more intensively on vegetation (Horejsi 1976). This behavior should increase the likelihood of being infected by lungworms. Transplacental transmission per se, at the low levels detected in lungworms fetuses from Sheep River, may not be sufficient to cause a lamb's death without the complicating factor of a stressed (nutritionally or otherwise) mother. Therefore, even if low levels of transplacental infection occurred for all lambs, only those born to less vigorous ewes will be likely to die.

If, on the other hand, L1 counts were directly correlated with the intensity of lungworm infection, two possible explanations for the lamb deaths could be proposed. Lungworm infection in itself could be a cause of stress, impairing the ewe's ability to successfully raise a lamb. Alternatively, heavy lungworm infection in the ewe may increase the likelihood and intensity of transplacental infection of the fetus. The very few larvae recovered from fetuses of ewes with high L1 output, however, do not support this hypothesis.

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AN EVALUATION OF PERMIT HUNTING IN THE SOUTHERN YUKON

Norman Barichello, Department of Renewable Resources, Wildlife Branch, Whitehorse, Yukon, Y1A 2C6, Canada.

Manfred Hoefs, Department of Renewable Resources, Wildlife Branch, Whitehorse, Yukon, Y1A 2C6, Canada.

ABSTRACT:

In 1979 permit hunting was established in southern Yukon in response to what was thought to be a declining sheep population, as indicated by surveys and hunter kill statistics. In the following year non-resident hunting in the permit area was discontinued and the full curl rule came into effect.

Permit hunting was designed to reduce and redistribute the kill according to sheep density, in order to (1) increase the number of legal rams, (2) increase hunter success, (3) improve the quality of the hunt and (4) improve the quality of the trophy (average age, horn volume, etc.). Presently, 80 permits are drawn on an annual basis from resident applicants.

Annual surveys to count and classify sheep were carried out in the permit area, an area open to resident and non-resident hunting (no quotas), and an area closed to hunting. Compulsory biological submissions since 1973 provided an evaluation of the hunter kill in the permit area and an adjacent open area (GMZ 7). Four questionnaire surveys in 1982 and 1983 attempted to measure hunter success, hunter effort, hunt quality, and an opinion of the permit system.

Total sheep population numbers, productivity and survivorship demonstrated a strong year effect that was not influenced by permit hunting. Ram numbers in the permit area doubled in three years (16 to 30 per 100 sheep), and the number of legal rams (full curl) increased from 1 to 10 per 100. Meanwhile, legal rams in the open area fluctuated between 0 and 3 per 100.

The resident harvest has nearly doubled since restrictions were imposed. Average age has also increased with permit holders taking significantly older rams than non-permit residents. The total resident harvest of rams with horn volume greater than 2800 cc (on average, 37" rams) has doubled, however there

is no significant difference between permits and non-permits. Horn volume is not correlated to age beyond 7 years.

Hunter success in the permit area is much higher, averaging about 30 animals shot per 100 tags sold compared to 7 per 100 tags, for resident hunters. Permit holders are expending the same effort as residents (4-5 days/hunt). Two independent surveys strongly support (70-80%) the permit system.

INTRODUCTION

In 1979 the Yukon Wildlife Branch proposed restrictive hunting in an area of the Coastal Mountains southwest of Whitehorse. The recommendation followed from a concern that a sheep population appeared to be declining based on helicopter survey results and hunter kill information. The restriction was meant to achieve two results; one, restore the sheep population (numbers) in the area, and two, improve the quality of hunting. It was hoped that hunters would not only enjoy more solitude (reduced hunter-density), but that they would encounter more sheep, enjoy higher success, and take trophy sheep of higher quality. The area chosen had historically produced some of the largest thinhorn sheep trophies in the Yukon; trophies that scored well by North American standards.

Hunting restrictions were imposed in 1979, in an area of about 3140 square kilometres, with a limited number of permits divided evenly between residents and non-residents. In 1980 the outfitter was expelled and permits were allocated to residents only, by subzones within the permit area. The restriction and the allotment served not only to reduce the annual harvest in the area but to redistribute the hunting pressure according to sheep densities and not hunter access. The number of permits increased from 50 to 65 in 1981, and to 80 in 1982. No changes were made in 1983.

Permits were increased in response to what was thought to be an increase in the number of harvestable rams. Presently the number of permits issued represents an estimated 4% of the population (less lambs), while the harvest rate is less than 2%. Data from Sheep Mountain in Kluane National Park indicate that rams attaining full curl (7.5 years) in any one year on average represent about 4.4% of the population (less lambs and rams older than 8 years, Hoefs and Cowan, 1979). If population dynamics of sheep in the permit area are similar to those of the Sheep Mountain population, and the removal of all rams attaining full curl has no detrimental effect on productivity and survivorship of unhunted cohorts, the sheep population could sustain a 4% harvest rate. Presently, then, if sheep are being harvested at less than 2% we should expect a surplus of harvestable rams and consequently an improvement of hunter success and a higher quality of trophies.

In short, the imposition of hunting restrictions and redistribution of hunting pressure was designed to:

(1) increase the number of rams and in particular the number of legal rams in the area,

(2) improve the trophy quality of animals (horn length, horn volume and average age), and

(3) increase hunter success and improve the quality of the hunt.

It should be noted however, that three events occurred simultaneously in 1980.
(1) the number of resident hunters was restricted through permit allocation in the east half of Game Management Zone 7.

(2) Regulations changed to restrict resident hunting to only full curl rams. Non-residents had previously been restricted to full curl rams.

(3) Non-resident hunting was discontinued in the permit area (east half of GMZ 7).

Presently hunting by residents and non-residents is restricted to full-curl rams defined by a jig used by the Yukon Wildlife Branch to measure sheep horns (Merchant et al, 1982). The season runs from 1 August to 31 October and the bag limit is one per year.

STUDY AREA

The permit area is located in the southwest part of Yukon and represents, by area, less than 2% of the territory, encompassing 3140 square kilometres. The area is a part of the Coast Mountain ecoregion (Oswald and Senyk, 1977), characterized by dry rugged mountains to 2709 metres. Three major rivers drain the area; the Wheaton, Watson and Takhini. For management purposes it is divided into 10 game management subzones.

A large portion of the area lies above treeline, (about 1050 to 1200 m a.s.l.), much of it considered excellent sheep range.

Sheep were observed on three distinct blocks, separated by about 40-50 km and topographically and climatically very similar. Hunter-kill data came from the entire Game Management Zone 7, bordered to the south by the Yukon-B.C. border, to the west by the Haines Road, to the north by the Alaska Highway and to the east by the Carcross Road. The permit area is a subset of this larger portion of the Coastal Mountains (figure 1).

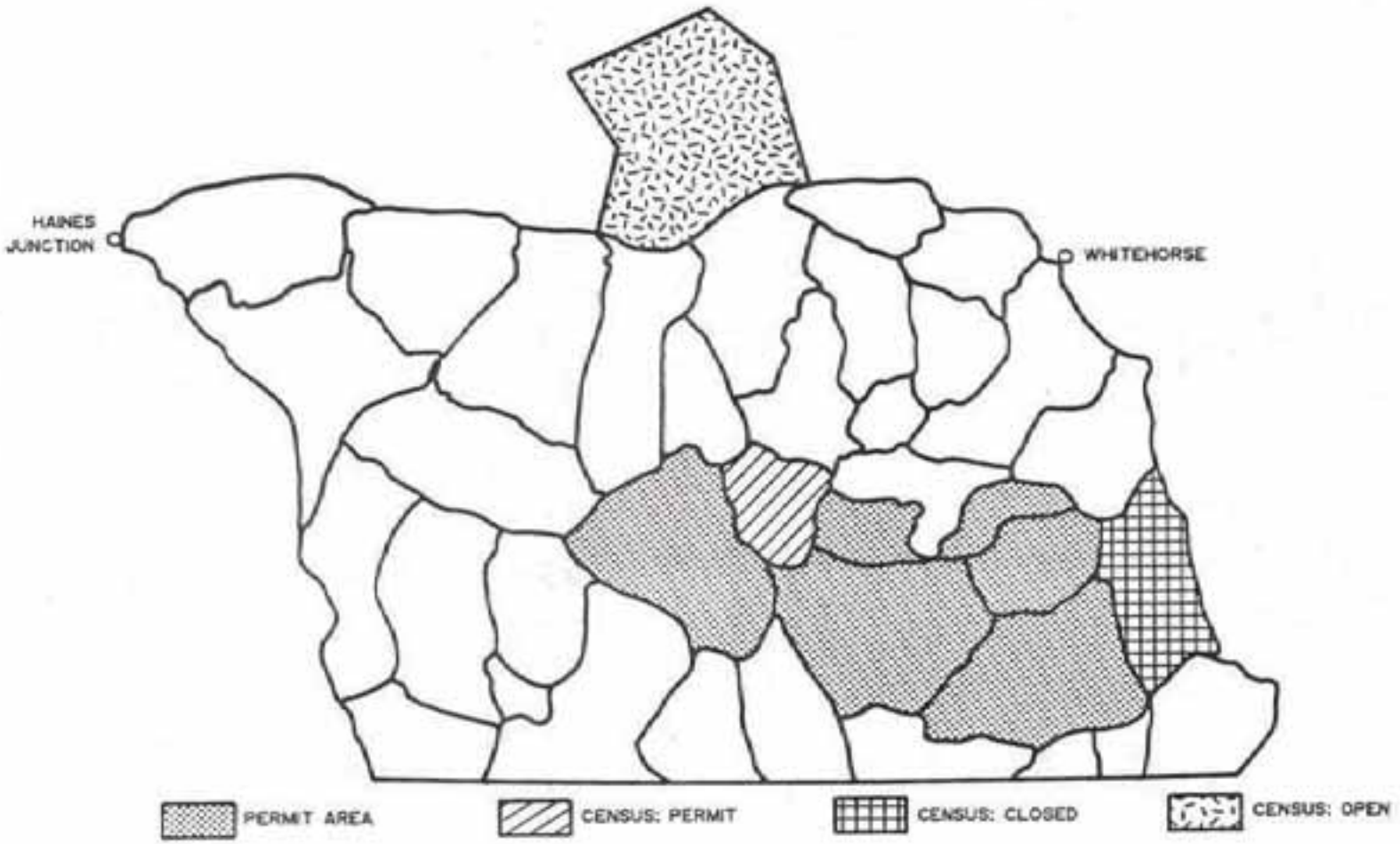
METHODS

POPULATION ESTIMATES AND DEMOGRAPHY

Sheep were counted and classified by aerial census carried out in late June or July. It is assumed that a June-July count is a near-total count, due to the fact that white sheep are on snow-free alpine ranges; very conspicuous, and often concentrated around mineral licks. Replicate counts have been conducted on Sheep Mountain in Kluane National Park revealing only small variations in the count (less than 10%) at this time of year (Hoefs and Cowan, 1979). Helicopters are used to contour mountain blocks above treeline to achieve 100% coverage. Often more than one pass is necessary to get complete coverage. Two observers (not counting the pilot) are used, locations are mapped and sheep are counted and classified as lambs, nursery sheep, and rams

FIG. 1 STUDY AREAS IN SOUTHERN YUKON.

(UNITS REPRESENT GAME MANAGEMENT SUBZONES)



three years and older, which are typed according to horn curl (1/2, 3/4 amd 4/4).

Nursery groups are generally comprised of females, lambs, yearling rams and sometimes 2 year old rams. It was impossible to identify yearlings and 2 year olds with any reliability from a one pass aerial survey conducted in July. An estimate of lamb productivity was calculated as lambs per nursery sheep. This index, however, doesn't allow for a highly variable yearling population that does not reproduce. A high lamb crop of the previous year that enjoys an average survival rate, will result in a low ratio of lambs to nursery sheep, due to the higher than average number of immature individuals in the nursery group. To help minimize this distortion we have calculated productivity as lambs per 100 two-year and-older nursery sheep. The number of 2-year-olds-and-older nursery sheep was derived by subtracting from the nursery count, the yearlings which were calculated by surviving the lambs of the previous year by .65 (this was the average survival rate of lambs in the Sheep Mountain study).

Sheep from three mountain blocks (three different subzones) have been surveyed in most years since 1978. One subzone has been restricted to permit hunting (permit area), one is open to both resident and non-resident hunting with only bag limit, full-curl and season restrictions (open area), and one is closed to hunting and has been since 1979 (closed area). The permit subzone (7-23) has about 210 sq. km. of sheep range and presently carries about 250 sheep, the open subzone (5-49) supports about 200 sheep on about 500 square km. of sheep range and the closed subzone (9-03) supports about 100 sheep on 250 sq. km. The areas are separated by about 50 km (figure 1).

Surveys allow us an area to area as well as year to year comparison.

TROPHY EVALUATION

Since 1973 there has been compulsory inspection of sheep horns shot by resident and non-resident hunters. This has allowed us to determine the number of animals shot, their age and horn growth, by year and location. It is assumed that the unrestricted and unknown native harvest is minimal.

Age has been determined using the horn annuli technique (Geist, 1966). Horn measurements include total length and base circumference of the longest horn as well as the length of each annually grown sheath and circumference of each annuli. An index of horn volume has been calculated using the equation of a cone.

$$\text{Volume} = \pi r^2 * \frac{h}{3}$$

Although this does not account for the curvature of the horn and the shape of the horn cross section, it is probably a very good indication of horn growth. Volume is used as the best index of horn quality. Brooming was not common, and when it occurred it generally removed not much more than the lamb tip. We have excluded broomed horns from the horn volume calculations.

HUNTER SUCCESS AND HUNT QUALITY

Hunter success was estimated in a number of ways. The simplest approach was to measure the number of sheep tags filled. However, this gave us no

measure of the number of sheep tags filled. However, this gave us no measure of effort. Three separate questionnaires have attempted to evaluate hunter effort. One questionnaire was a voluntary response directed to all resident license holders in 1983 to determine days hunted by month, the location of the hunt, and the success. The second was a compulsory questionnaire to all permit holders in 1983 which addressed the same questions. A third questionnaire was a phone survey to all permit hunt applicants in 1982 to determine success rate, an opinion of the permit system and whether or not hunters had enjoyed a high quality hunt. A further evaluation of hunt quality was determined from a voluntary opinion survey of the local fish and game association in 1983. The 1983 opinion survey was directed to all hunters in the organization and not only to permit hunt applicants, as was the case in 1982.

RESULTS AND DISCUSSION

POPULATION CHANGES

The imposition of hunting restrictions appeared to have no influence on either sheep density or productivity. Changes in population number, productivity, and the rate of survival in the three areas (permit, open and closed areas) followed a very similar pattern (figure 2). Population changes appear to be influenced more by lamb production and over-winter survival, both of which are likely dictated by weather and to a smaller degree sheep density than to hunting restrictions. Major fluctuations prior to 1979 could be the influence of less restrictive hunting, notably the allowance of 3/4 curl rams.

Ram numbers have increased in the permit area from 16 per 100 sheep (1+ years) in 1979 to almost 30 per 100 in 1982 (figure 3). Rams in the open subzone have held steady at between 22 and 25 per 100 since 1979. It should be mentioned that the permit subzone is a very accessible area to hunting, most of it above treeline and bordered by two large lakes. The low number of rams observed in 1979 in this area probably reflects its vulnerability to open hunting.

It is only when we look at the number of legal rams that we see a significant area effect. There has been a marked increase in the permit area in the number of legal rams per 100 sheep (1+ years), since restrictions were imposed (figure 4). No such increase has been observed in the open area. The number of full curl rams in the permit area increased to about 10 rams per 100 sheep (1+ years) in 1982. This compares favourably to legal ram counts in both Kluane National Park and an unhunted population in the northern Yukon. The open area has sustained between 1 and 3 legal rams per 100 sheep since 1978.

QUALITY OF THE KILL

Numbers of Animals Shot

The total kill in GMZ 7 (east and west) has ranged from 50 to 87 animals per year in the 10 years since 1973. In 1979 there was a decline in the kill which since imposition of permit restrictions has not increased, but has stabilized to about 50-55 animals. The resident kill, however has shown a substantial increase since 1979 (figure 5). The average resident kill from 1973 to 1979 was 20 animals, and has since increased to 41 animals. In

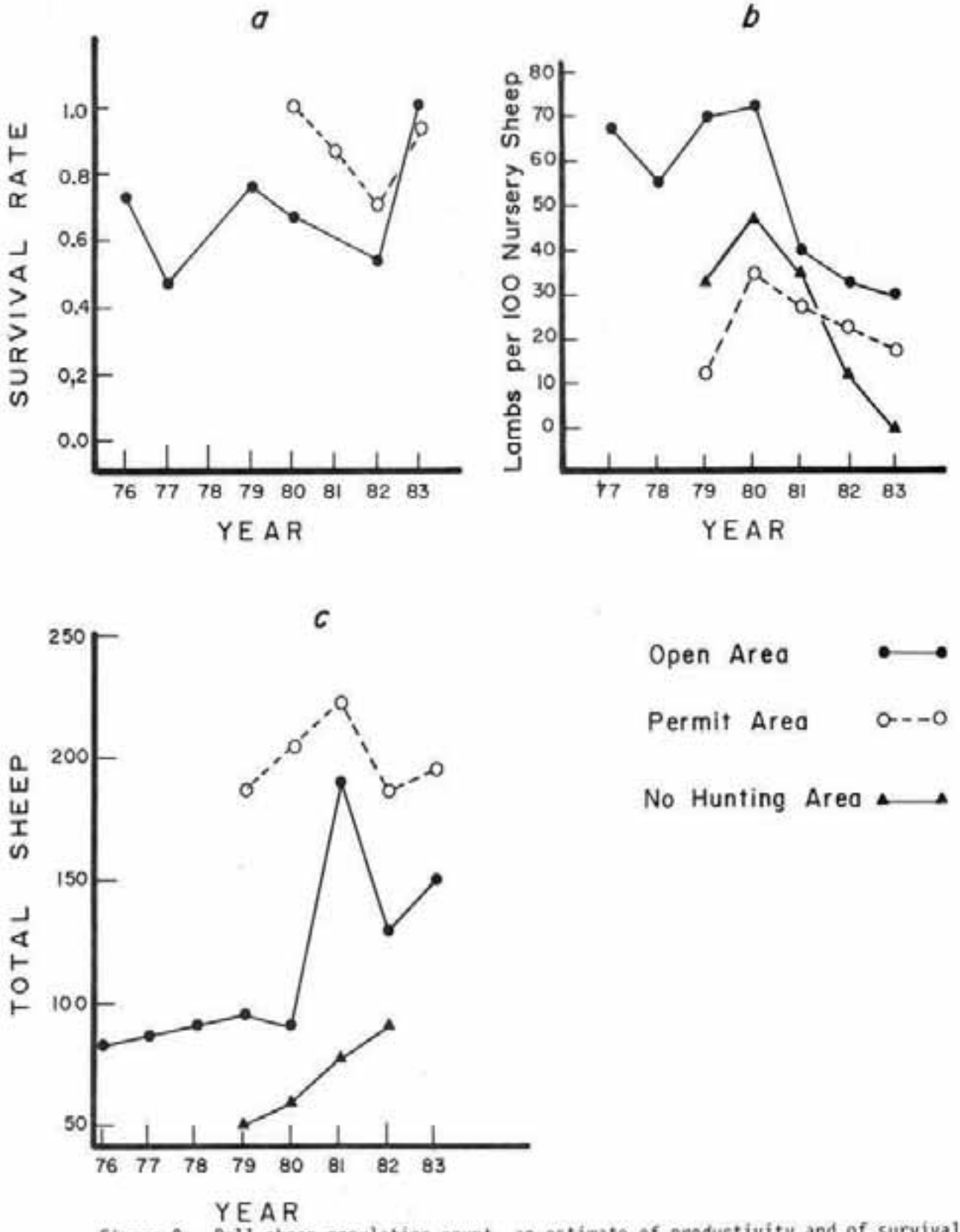


Figure 2: Dall sheep population count, an estimate of productivity and of survival rate against year within three mountain blocks in the southern Yukon.

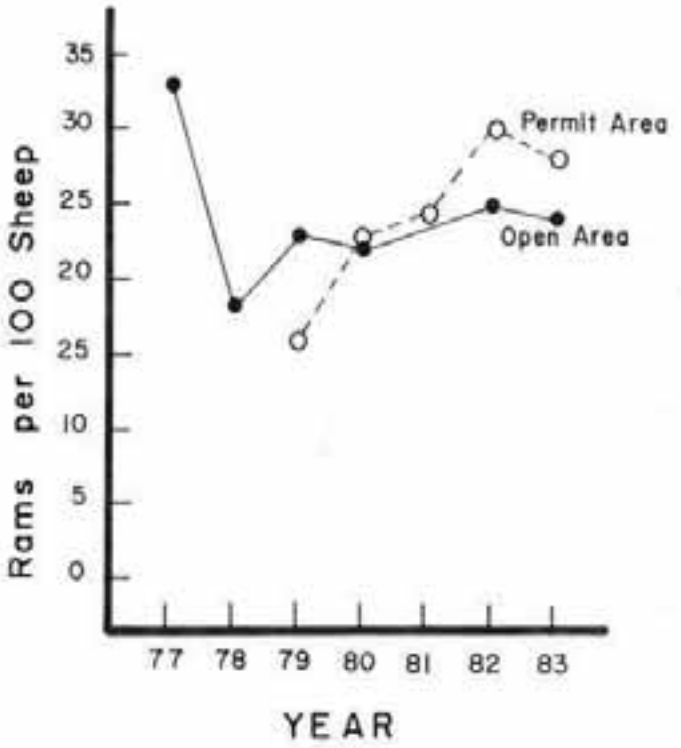


Figure 3: Rams per 100 sheep against year, by area.

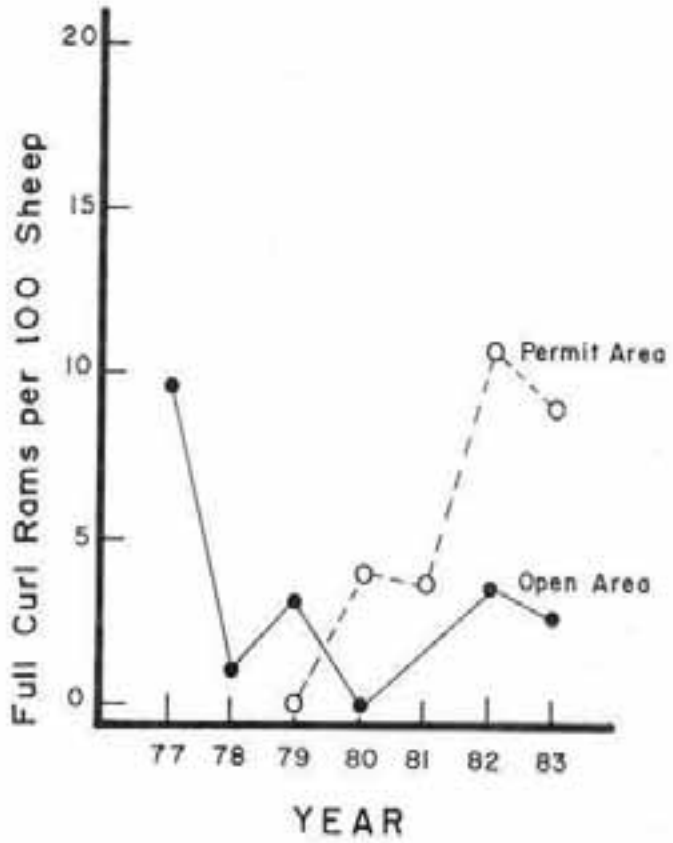


Figure 4: Full curl rams (legal) per 100 sheep against years by area.

fact 29% of all sheep shot by residents in GMZ 7 since 1973 were shot in the last two years.

Average Age

The trend in numbers as well as average age of the kill was used as an index of population viability. The age distribution of all animals shot by residents and non-residents in GMZ 7 since 1973 is shown in figure 6. The average age of rams shot during this period is approximately 8 years.

The average age of resident-shot animals has shown an increase since 1979 (figure 7). Contributing to this most certainly is the imposition of full curl restrictions. However comparing resident (non-permit) to permit holders we see that there has been a recent divergence in average age of the kill. In 1983 rams shot by permit holders were significantly older (at 90% confidence) than resident (non-permit) shot rams. The difference in average age also shows up when we look at the age distribution of the kill since 1979, with the permit harvest shifting to older age animals (figure 8).

The results however are not so clear cut. If we examine the cohort distribution of the kill we see an interesting shift. It was found that certain cohorts were more strongly represented in the kill over time. For instance the 1973 cohort was strongly represented in the kill as 6 year olds in 1979, 7 year olds in 1980, 8 year olds in 1981, etc. The 1983 kill included many 10 year old rams, possibly the influence of a strong 1973 cohort. This should be considered when comparing average age from year to year (figure 9).

The average age of the kill in 1983, by resident and permit hunters is significantly different however, leading us to conclude that average age is more a result of restrictive hunting than the strength of different cohorts (figure 7). Average age is likely an expresssion of the availability of full curl rams. Our survey data support this.

Horn Quality

One might assume that if permit holders were shooting older animals, trophy quality (horn volume) would improve. This has not shown to be the case. There is no significant difference in horn volume between permit and non-permit resident hunters and in fact no significant difference since 1974. Horn length as well has shown no significant difference. If we look at horn volume by age of all rams shot in GMZ 7 since 1973 we see a plateauing at about 8 or 9 years. Older age rams have not produced (on average) significantly larger horns (figure 10). In fact we found that older rams (greater than 9 years old) often suffered poorer early growth and poorer overall horn growth, than younger shot rams.

However if we look at the number of animals shot having horn volume greater than 2800 cc (generally a 37" ram or better) (by all residents), we find proportionally more bigger heads shot since 1980 (figure 11). This probably reflects the regulation change in 1980 to full curl only rams.

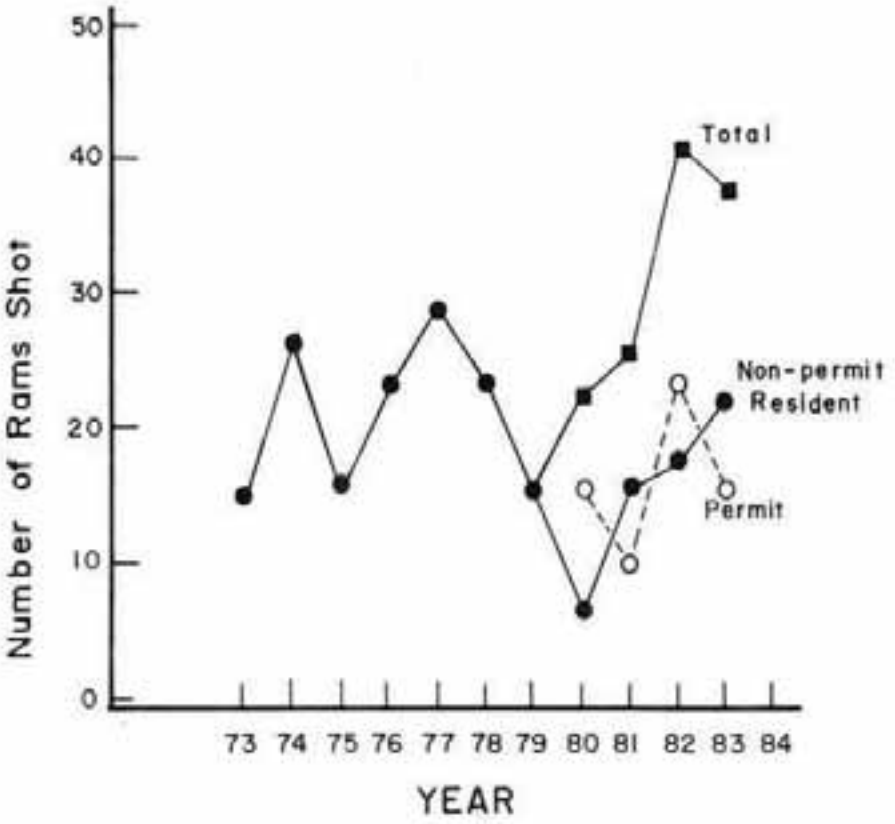


Figure 5: Number of rams shot against year by permit holders and non-permit-resident hunters in GMZ 7.

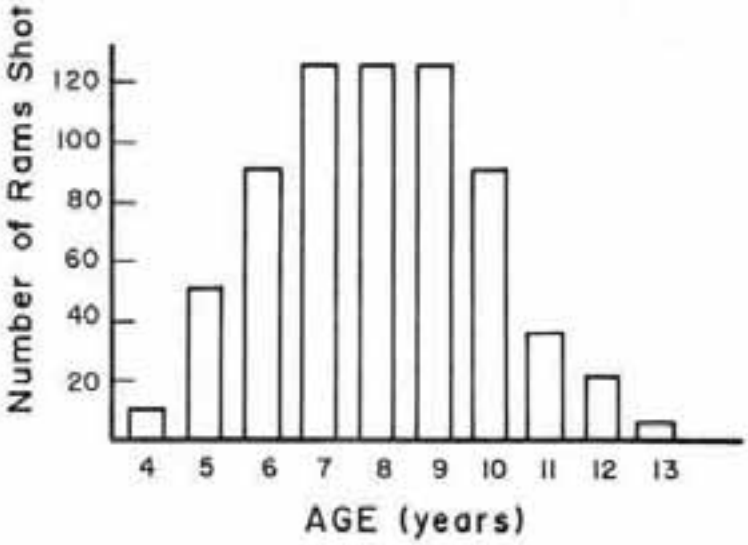


Figure 6: Age distribution of the sheep kill by resident and non-resident hunters in GMZ 7.

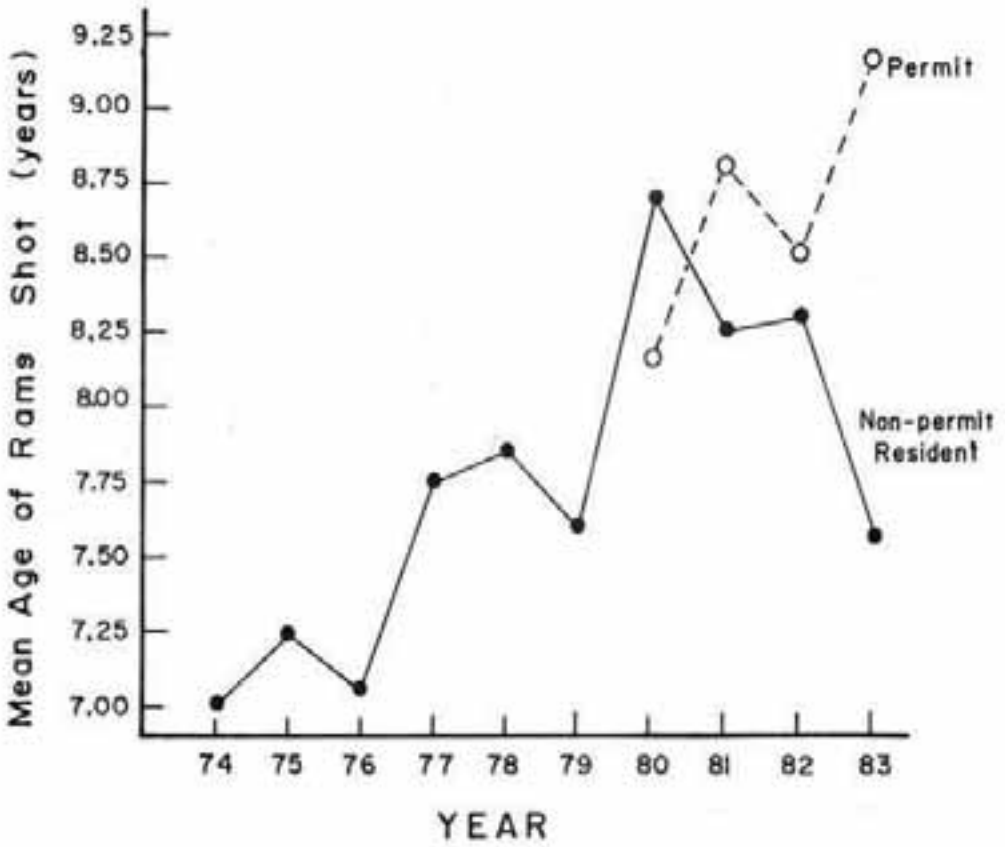


Figure 7: Average age of the resident sheep kill against year by permit and non-permit hunters in GMZ 7.

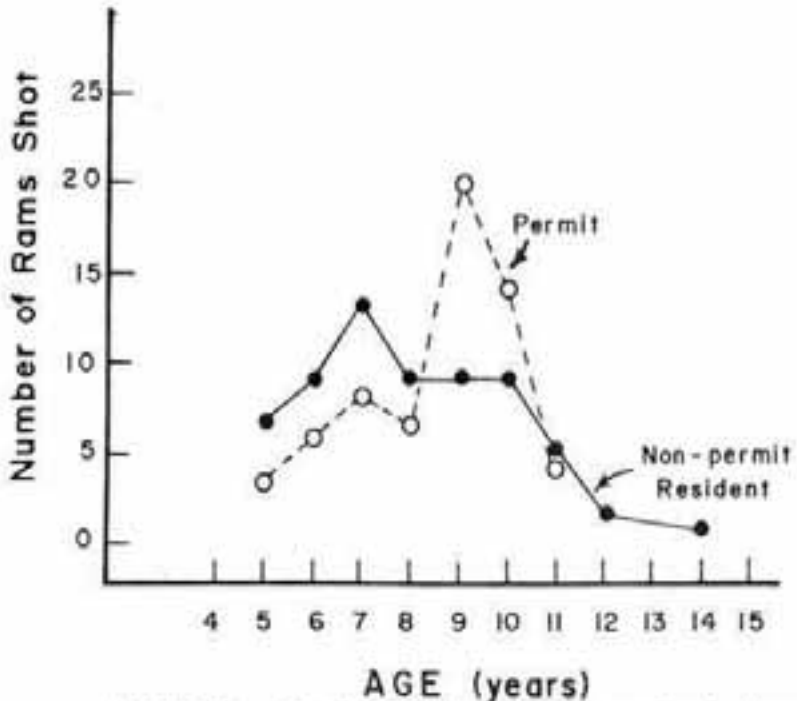


Figure 8: Age distribution of the resident sheep kill against year by permit and non-permit hunters in GMZ 7.

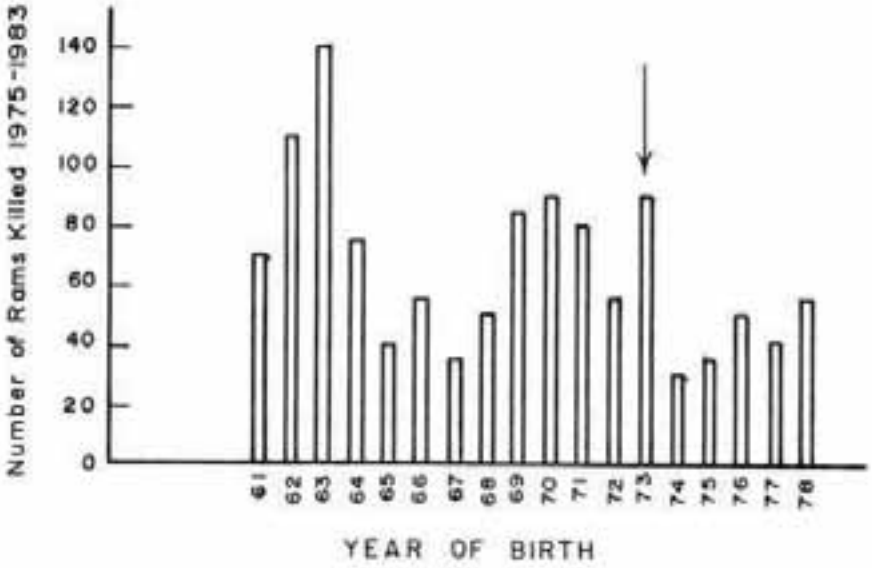


Figure 9: Distribution of the sheep kill by cohorts shot from 1975 to 1983, corrected to allow for cohorts not counted (at both ends of the distribution).

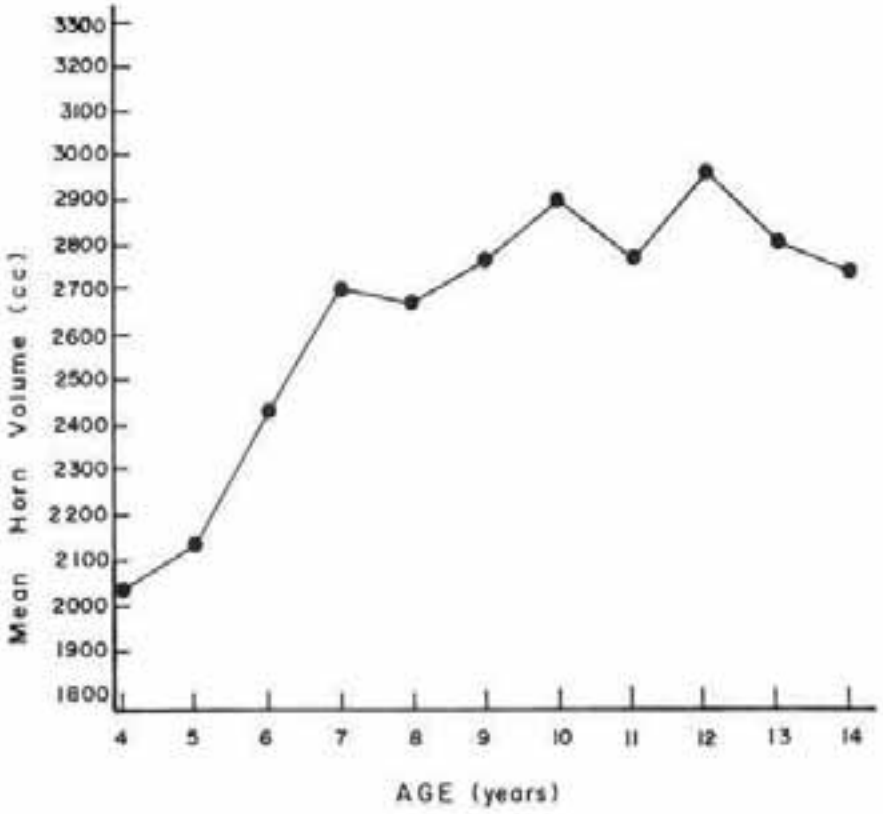


Figure 10: Mean horn volume against age of sheep shot in GMZ 7.

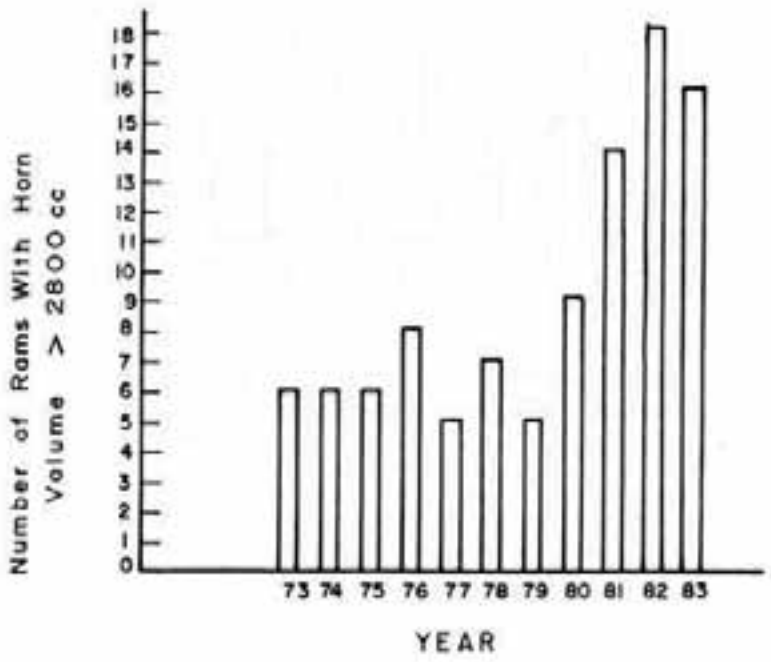


Figure 11: Number of rams with horn volume greater than 2800 cc, against year, in GMZ 7.

Hunter Sucess and Quality of the Hunt

Hunter success is not easy to determine. License sales may not fairly represent effort, and voluntary questionnaires are possibly biased to successful hunters. However three independent questionnaires and calculations based on license sales tell the same story: permit hunters enjoy far better success than resident hunters. Five to ten percent of resident sheep tags are filled compared to 22 to 30 percent of the permits bought (figure 12). From questionnaire data residents in 1983 were 19% successful compared to permit hunters who have been 55 and 35% successful in 1982 and 1983 (figure 13). Contributing to the increase in success could be the expulsion of non-resident hunters in the east half of GMZ 7. This however does not explain the almost doubling of the resident kill since 1979. Resident hunters generally have lower success than non-residents; not surprising since they spend fewer days hunting (on average) and usually do not have the resources (horses, camps, aircraft, etc.) that outfitters provide. The increase in the resident kill is probably the result of an increase in the number of available rams, whether due to the permit system or full-curl restrictions. The redistribution of hunters in the permit area, preventing local concentration of hunters, likely contributes to higher hunter success (more animals shot).

It should be noted that since 1979 the number of residents who purchased sheep tags has not increased, and access into GMZ 7 has not increased significantly. In addition rams subjected to reduced hunting pressure are possibly less wary, and therefore more vulnerable.

Permit hunters are putting in an effort equal to that of resident hunters averaging 4.3 and 4.2 days per successful hunt, and 5.6 and 5.0 days per unsuccessful hunt, respectively.

Since the permit system was adopted, the number of permit applicants has varied between 77 and 136. Eighty permits were issued in 1983; 70% of the applicants were awarded a hunt. In 1984 preference will be given to unsuccessful or first time permit applicants, likely guaranteeing hunters a permit at least once every two years. Based on probability, the odds of success are better for permit hunters hunting every other year than non-permit residents hunting every year (14% vs 8% respectively). With no preference given the odds are still better for permit hunters (10% vs 8%).

Trophy quality has not been a major objective of the permit program. The quality of the hunt has been emphasized, not the quality of the head. Traditional hunters certainly must applaud the efforts to restrict the hunter density. Too many people competing for too few, harrassed sheep must depreciate the experience.

At worst the only cost of the permit program to the resident hunters has been a sacrifice of hunting for one year in two, in the permit area. The advantages are reduced hunter density, higher success, and a higher quality of trophy for those selective hunters.

Opinion of Permit Hunting

The Yukon's permit hunting program has suffered from a lot of criticism. This is partly due to the fact that its justification has been conjecture.

FIG. 12 HUNTER SUCCESS BY YEAR AND LICENCE TYPE
(NUMBER OF RAMS SHOT AS A PERCENT OF LICENCES SOLD)

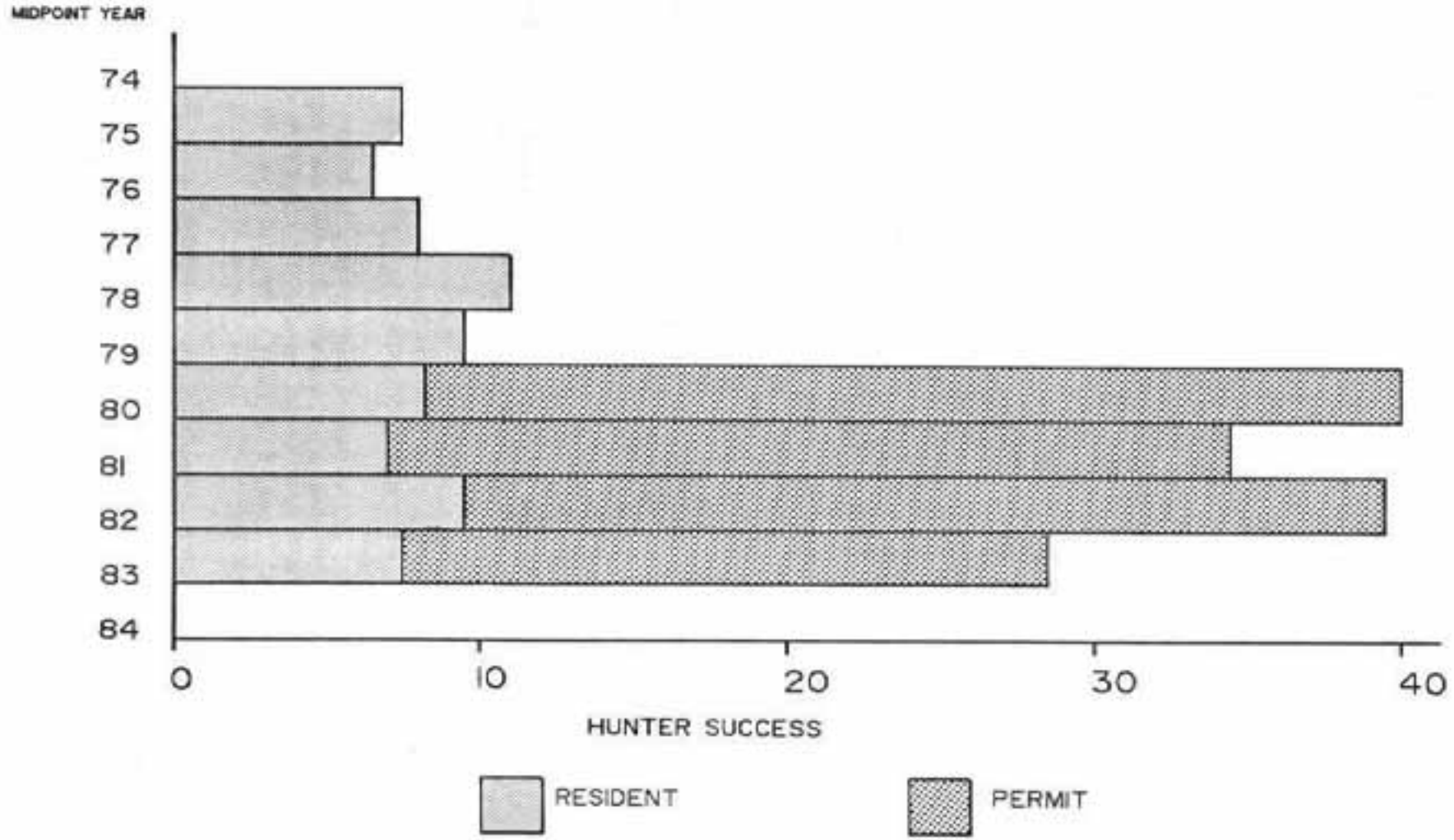
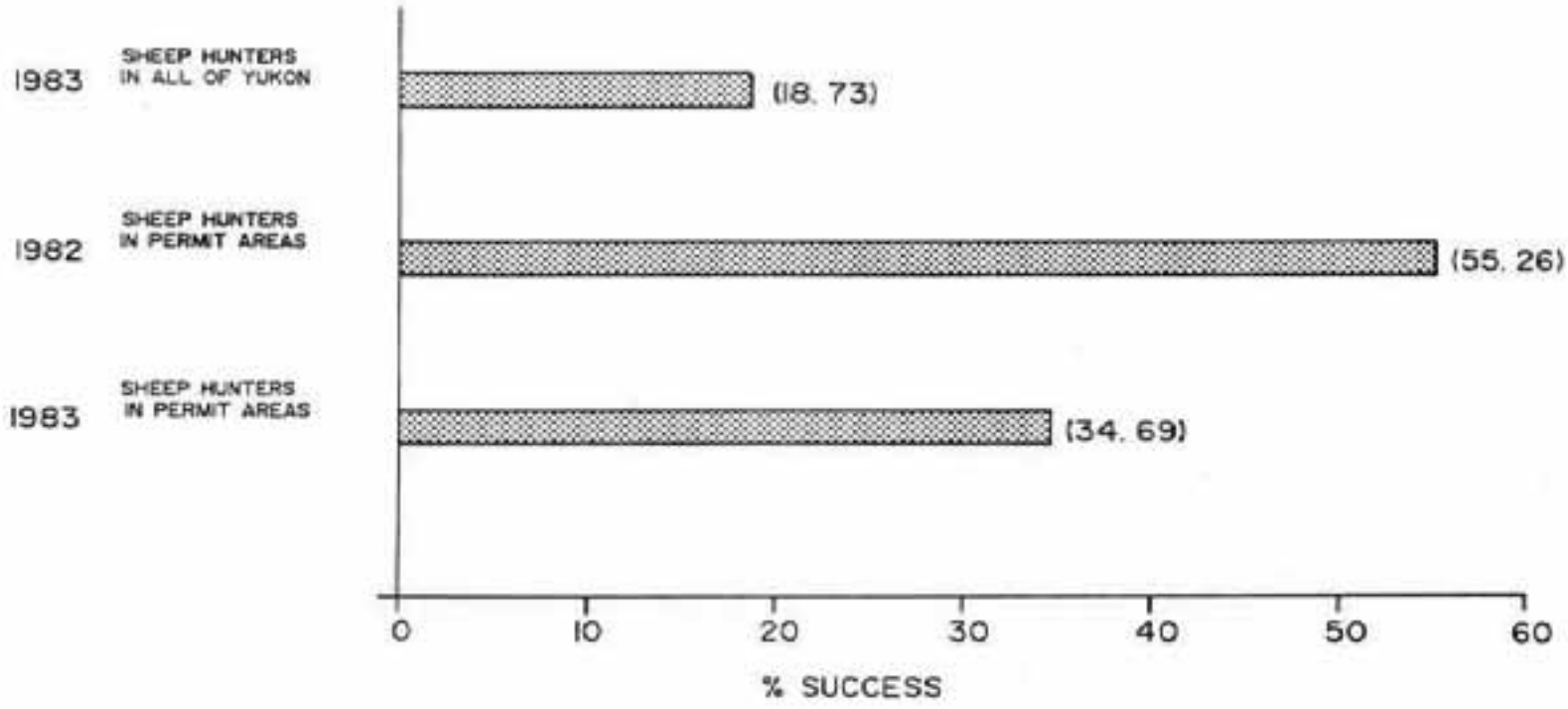


FIG. 13 SHEEP HUNTERS' SUCCESS RATES



Effects of restrictive hunting take time to surface. Many dissenters oppose any form of regulation, others believe that the permit system was imposed only to improve trophy quality, and that sheep should not be managed for trophies.

Two opinion surveys, one conducted on permit applicants, the other on members of the Yukon Fish and Game Association, however, have produced the same results; strong support of the program, 82% and 79% in favour, respectively.

Since permit hunting has been imposed in the southern Yukon:

(1) There has been an increase in the number of legal rams in the population in the permit area; significantly more than an adjacent area offering open-hunting.

(2) There has been an increase in the resident harvest.

(3) The age distribution of the harvest in the permit area has shifted to older animals. The average age of permit shot sheep in 1983 was significantly higher (at 90% confidence) than resident shot sheep in an adjacent area.

(4) Permit hunters enjoy substantially higher success than resident hunters in adjacent areas.

SOME EFFECTS OF A FULL-CURL LAW ON DALL'S SHEEP MANAGEMENT

Lyman Nichols, Alaska Department of Fish and Game, Cooper Landing, AK.

ABSTRACT

Measurements of Dall's sheep (Ovis dalli) ram's horns were converted from linear to cumulative degrees of arc per year. Average degrees of curl-growth were plotted by year for all horns that had reached full-curl; a growth curve was fitted to this data. All horns that had reached 3/4-curl but not full-curl before the ram's death were fitted to similar curves and plotted against age to estimate the number which would or would not reach full-curl had the ram lived to its full potential life span of 14 years. Of those examined, a minimum of 15% would not have reached 360° before death. This, plus loss in curl by natural wear and a natural mortality of 14-43% after 5 years of age, represents the loss in potential rams available for harvest between their average age at 3/4-curl and that at 4/4-curl, and would be the cost in lost hunting opportunity to hunters of a full-curl vs. a 3/4-curl law.

INTRODUCTION

Traditional management of Dall's sheep in Alaska has been by horn curl. For many years 3/4-curl was the legal minimum for rams. This was defined as a horn "...the tip of which has grown through three-quarters of a circle (270°) described by the outer surface of the horn, as viewed from the side." In 1979, this requirement was arbitrarily raised to 7/8-curl (315°) with no proven biological or management justification. The only biological justification postulated was that older rams are needed in a population to assure adequate breeding (Geist 1971). In fact, evidence to the contrary was found on the Kenai Peninsula, where 2 adjacent herds were compared (Nichols 1976). One had been hunted heavily and almost every 3/4 curl ram (and later every 7/8-curl ram) was removed annually, while a second herd was closed to all hunting and contained a nearly natural population of older rams. Over the 14-year period these herds were under observation, there was no statistical difference in ratios of lambs:100 ewes between herds. Stewart (1980), in a study of bighorn sheep, O. canadensis, found no increase in mortality of young rams due to breeding stress and could detect no relationship between dominance and mortality.

Another justification advanced for the 7/8-curl law was that it would produce more large trophies. This was proposed primarily by members of the guiding industry, who at the time were attempting to have a full-curl law passed. The Board of Game compromised upon a 7/8-curl regulation.

Once again a full-curl law is being proposed. Since such a law presently can be justified only on the grounds of producing larger trophies, sheep managers and hunters should be made aware of the cost of such a law in terms of potentially lost hunting opportunity. Not all sheep hunters would prefer to have a full-curl ram (Wishart 1974) especially if such a law would result in significantly fewer rams to hunt.

The natural mortality of rams between the average ages at 3/4-curl, 7/8-curl, and full-curl has been documented by several researchers (Buechner 1960, Murphy 1974, Heimer and Smith 1975, Hoefs and Cowan 1979), but largely ignored by managers. Their literature suggests that from 14-43% of all rams die of natural causes between the ages of 5 years (3/4-curl) and 9 years (4/4-curl). In other words, depending on a variety of factors such as winter weather, predation, herd density, etc., out of 1000 rams available to hunters as 3/4-curls, a range of 140 to 430 would not be available if hunters had to wait for all rams to reach full-curl.

Additionally, Hoefs and Nette (1982) found that loss from natural horn-tip wear, exclusive of brooming, was significant in older rams, and that little or no increase in length could be expected after age 8 in the Yukon. "Brooming" (breaking off of horn tips during clashing) further reduces horn length and curl by an additional and variable amount.

Another factor in loss of hunting opportunity caused by a full-curl law is that a proportion of rams never reach full-curl because of the growth form of their horns. Several studies have been concerned primarily with horn growth by length (Heimer and Smith 1974, Shackleton 1973, Wishart and Brochu 1983). However, management here is by curl, not length. This study re-examines earlier horn measurements and determines the percentage of rams that reached 3/4-curl but would not have been expected to reach full-curl within their lifespan.

METHODS

Measurements of 570 sets of ram horns were made at taxidermy shops in the early 1970's by Erickson (1970), Heimer and Smith (1975), and others. Their data included: total horn curl in degrees, diameter of curl based on horn axis, and annual growth by length. Methods of measurement were described by Heimer and Smith (1974). I converted cumulative annual length measurements from their data on 355 horns into degrees of arc and averaged them by year for all horns which reached or exceeded 360°. A relatively smooth curve was produced by graphing these averages against age, and a curvilinear equation was derived by trial and error using a number of possible formats. A curve of the form $Y=Ae^{B/X}$ (where Y is an estimated point on the curve representing degrees of horn curl, A and B are calculated constants, e is the natural logarithm, and X is a selected age) produced a consistently good fit ($r=0.99+$) for most horns. The constants for this curve were then calculated (Hewlett-Packard HP-67 program #03193D) for each horn which had not yet reached

360° by the time of the ram's death. A curve, using this formula but with constants as calculated for each individual horn, was then generated by computer for each of these horns and plotted against horn-curl and age to estimate whether or not the horn would have reached full-curl within the animal's maximum expected lifespan.

Curves and points were plotted for means of a sample of full-curl-or-better horns from each of the mountain ranges represented in the original data: Alaska Range East of Denali National Park, Brooks Range, Chugach Range, Kenai Mountains, Talkeetna Mountains, and Wrangell Mountains. Each average annual growth in cumulative degrees from age 2 through age 8 was compared between ranges by analysis of variance. There was insufficient data to compare above age 8.

RESULTS

Average cumulative horn-growth in degrees by age was graphed for horns having reached 360° before death, and was plotted against a fitted curve (Figure 1). It can be seen that the curve fits the means for each year's growth very well. Also indicated are the ages at which the curve and the actual data reach 3/4, 7/8, and 4/4-curl. These ages are about 5, 6-7, and 9 years, respectively. Minor differences in growth rate (but not form) were found between the mountain ranges. Although differences existed on an annual basis, the only consistently significant difference ($P < .05$) in horn curl was between the Wrangell Mountains and the Brooks Range, with the latter population exhibiting less cumulative horn growth as rams got older (Figures 2 and 3).

In all of the over 500 original measurements, only 2 horns were found from rams which had lived 13 years. It appears that very few rams reach age 13, and almost none reach 14. Therefore, age 14 was selected as the maximum to which any ram would grow. This is a liberal estimate, but for purposes of this study, I assume that if a ram's horns could not be expected to reach 360° by age 14, they would never do so. Therefore, graphs were generated on a computer with maximum ordinates of 360° for horn-curl (the minimum we are interested in under a full-curl law), and 14 years of age. Any horn-curl growth curve projection reaching 360° before age 14 was considered to have the potential for reaching full-curl. Any not reaching that size by age 14 was assumed not to have that potential.

Curves generated for each of the horns which had not yet reached full-curl by the time of the ram's death showed considerable variation (Figures 4-6) but most reached full-curl within the maximum assumed lifespan. In some cases, the fitted curves forecast that the horns would reach full-curl, but the observed data suggested this would not be so. In all cases, if the forecast growth reached 360°, the horn was considered as having full-curl potential. This assumption produces a conservative estimate of horns unable to reach full-curl within a ram's lifespan (Table 1).

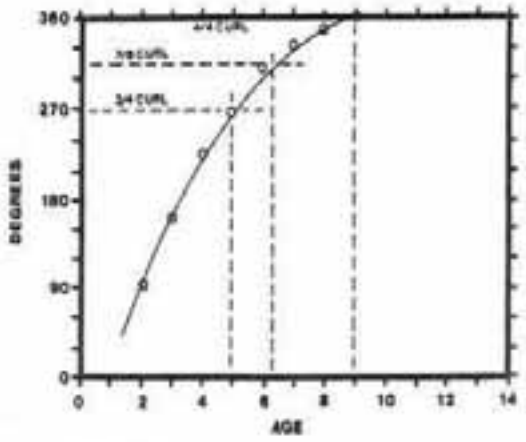


FIGURE 1

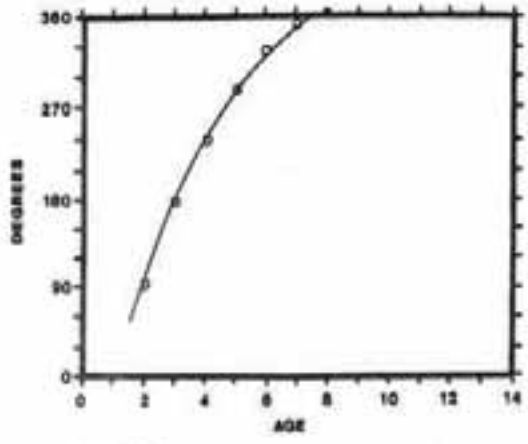


FIGURE 2

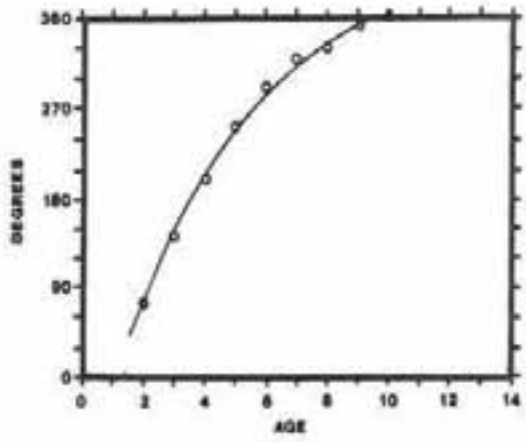


FIGURE 3

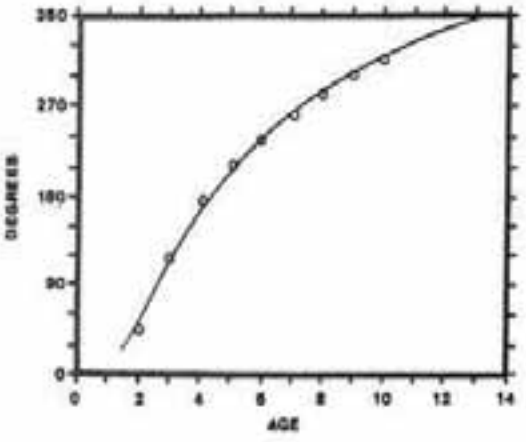


FIGURE 4

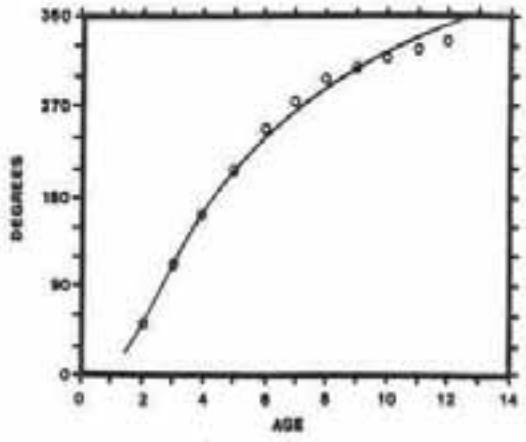


FIGURE 5

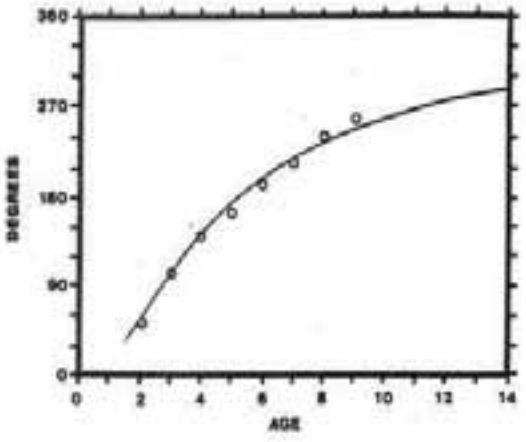


FIGURE 6

Dall's sheep horns by age and degrees of curl.
(Solid lines represent mathematically fitted curves;
circles represent original data points.)

Figure 1. Means of full-curl horns from all areas sampled, with probable ages indicated at specific sizes.
Figure 2. Means of full-curl horns from Wrangell Mountains.
Figure 3. Means of full-curl horns from Brooks Range.
Figure 4. Example of projected horn growth reaching 360° before age 14.
Figure 5. Example of projected horn growth reaching 360° before age 14, while actual data points suggest growth will not reach 360°.
Figure 6. Example of projected horn growth not reaching 360° before age 14.

Table 1. Potential of sub-full-curl Dall's sheep rams' horns to reach full-curl during rams' life span.

Area	Would reach 360°		Would not reach 360°	
	Percent	N	Percent	N
All Alaska	85	165	15	28
Alaska Range E.	80	37	20	9
Brooks Range	63	20	38	12
Chugach Range	92	24	8	2
Kenai Mountains	100	17	0	0
Talkeetna Mountains	87	20	13	3
Wrangell Mountains	96	47	4	2

DISCUSSION

Based on these analyses, I estimate that at least 15% of all rams which have reached 3/4-curl will not reach full-curl even if the ram lived to be 14 years old. This is a conservative estimate for the following reasons: few or no rams actually live to age 14 and those dying earlier would reduce the potential of some horns reaching full-curl before death. The hypothetical growth curves tend to overestimate the potential of horns to reach 360° before age 14. Thus, the actual percentage of sub-full-curl ram horns without the potential to reach full-curl is probably higher than 15%.

Examination of Table 1 shows that the estimated percentage of rams unable to reach full-curl status varies by mountain range. A full-curl law would appear to have less effect on hunting opportunity in some areas, such as the Wrangell and Kenai Mountains (although the small sample size may have biased the estimate for the latter area), than in the Alaska Range or, especially, the Brooks Range, where almost 40% of 3/4-curl rams may not reach full-curl within their lifetime.

On average, of every 1000 3/4-curl rams available to hunters under a 3/4-curl law, a maximum of only 850 would be available under a full-curl law because of horn growth characteristics. This loss in opportunity is in addition to that caused by natural mortality, horn wear, and brooming during the intervening years. While they may not be directly additive (some rams without the potential to reach full-curl would be among those dying of natural causes), these potential losses represent a substantial decrease in hunting opportunity to the public should a full-curl law be implemented.

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EVALUATION AND MANAGEMENT IMPLICATIONS OF LONG-TERM TRENDS IN COASTAL MOUNTAIN GOAT POPULATIONS IN SOUTHEAST ALASKA

Christian A. Smith, Alaska Department of Fish and Game, Ketchikan, Alaska 99901

ABSTRACT

Results of aerial surveys of mountain goat (Oreamnos americanus) populations conducted since 1968 near Ketchikan, Alaska indicate that population reductions of up to 90 percent occurred during the period 1968 - 1975; mean observed rate of increase r, for three populations during this period was -.29. From 1975 to 1983 all populations monitored increased at an average r = .12, range, .03 to .21. During initial recovery, r values were as high as .38 over a 5 year period. Both declining and increasing populations provide limited evidence of correlations between density and rate of increase. Long-term weather patterns are examined as causative forces in trends. Reproductive and mortality data from radio-collared goats provide insight into demographic processes driving the unexpectedly high r values in recent years. Contrary to results of earlier studies of the "coastal" ecotype, results indicate populations can be highly productive. Nevertheless, cyclic weather severity may reverse the trend and populations will decline regardless of management strategies. The limitations of attempting to develop population models and/or harvest guidelines with only a few years' data and static demographic parameters are discussed, and application of a tracking harvest strategy is proposed.

INTRODUCTION

Mountain goat (Oreamnos americanus) populations in south coastal Alaska declined sharply in the late 1960's and early 1970's (Ballard 1977), presumably as a result of the severe winter conditions which were decimating deer (Odocoileus hemionus sitchensis) (Olson 1979) and moose (Alces alces) (Bishop and Rausch 1974) populations during those same years. Because access and, therefore, hunter harvest were limited, the declines in goat herds were not viewed with alarm nor considered cause for drastic management response. During the same period, however, Hebert and Turnbull (1977) documented demographic and behavioral differences between "coastal" and "interior" mountain goat ecotypes and hypothesized that coastal populations were generally less productive and more sensitive to harvest than populations in the intermountain region. In view of the expected low rates of increase for interior goat populations (e.g. r = .11, Youds et al. 1980) and the indication that hunting mortality is additive to other sources of mortality (Kuck 1977), Hebert and Turnbull's findings were viewed with concern by wildlife managers in Alaska.

More recent evaluation of coastal goat population dynamics by Hebert and Langin (1982) indicated that the earlier estimates of potential productivity

and rate of increase were unduly conservative. However, these investigators concluded that their survey data were inadequate to allow determination of the internal dynamics of the study population or to permit development of a sound harvest regime. Hebert and Langin (1982) also implied that their surveys even were of questionable value for assessing trends, in spite of the fact that these data were obtained using relatively intensive helicopter surveys.

The lack of published information on long-term trends in coastal goat populations has, until now, prevented placing the results of work in British Columbia into perspective. The purpose of this paper is to provide such a perspective based on 15 years' aerial trend count surveys conducted near Ketchikan, Alaska and to suggest how future harvest schemes can be established when managers are faced with limited or crude census data, extensive management zones, and relatively limited hunter access. Such conditions exist over much of coastal Alaska and British Columbia where financial constraints largely prohibit detailed censuses of goat populations. I wish to emphasize that some concepts proposed herein may be inappropriate for more intensively managed goat populations.

STUDY AREA

The coastal mountains near Ketchikan consist primarily of granodiorite and quartzdiorite formations reaching elevations up to 2000 meters, heavily modified by glaciation, with sheer faces and rugged terrain extending to sea level in many areas. Bays and fjords intersect most ridge complexes; major river valleys are predominately narrow and steep sided. Vegetation below treeline (7-900 meters) is predominantly old growth western hemlock (Tsuga heterophylla) - Sitka spruce (Piceasitchensis) forest with an understory dominated by Vaccinium spp., ferns, and evergreen forbs(Alaback 1982). Alpine vegetation consists of heath fields and lush forbs-sedge meadows (Fox 1983, Smith 1984).

The climate is maritime with cool wet summers and relatively warm wet winters. Annual precipitation exceeds 400 centimeters per year, much of which falls as snow at higher elevations from October through March. Winter temperature patterns regulate the depth, duration and lower elevational limit of the snowpack, which is consistently of extremely high density.

METHODS

Coastal mountain blocks in the Ketchikan vicinity, divided from each other by bays, fjords or major rivers were stratified into trend count areas ranging from 50 to 280 square kilometers in size (Fig. 1). A fixed contour route, circumnavigating the ridge complexes in each mountain block, was flown in a PA-12 or PA-18 Super-Cub with a pilot and single observer. Both the pilot and the observer searched for goats. The altitude of the flight and distance from the slope were adjusted as necessary to permit a view of the entire slope from treeline to the ridge top.

In view of the variability reported by Ballard (1977) for both fixed wing and helicopter surveys in northern southeast Alaska, results of several

Figure 1. Mountain goat trend count areas near Ketchikan, Alaska.

replicate flights were examined for consistency. For this analysis surveys were categorized on the basis of the weather and visibility at the time of the survey. "Good" survey conditions were considered to occur in early morning or late evening hours during periods of light wind, no glare, often high scattered clouds or thin overcast and cooler temperatures. "Fair" survey conditions occurred at times with intermediate winds, occasional fog and/or warmer temperatures. "Poor" survey conditions were exemplified by limited visibility due to glare, fog or clouds, turbulent winds, high temperatures or excessive snowpack at the survey elevations. These categories parallel those used by Nichols (1980) in selecting optimal periods for goat surveys near Kenai, Alaska.

The stormy conditions typical of the north-Pacific coast prevent rigid scheduling, so survey flights were conducted from mid-August to late September as weather permitted. Recent telemetry studies have revealed that the distribution and sightability of goats is optimal and relatively constant at this time of year (Smith unpubl. data). To the extent possible, flights were timed to correspond with the goats' evening activity period (Fox 1977).

Each goat seen was classified as either a "kid" (i.e. 3-4 months old) or "adult" (any other goat). The location and composition of each observation were recorded on 1:63,360 scale topographic maps and composition was recorded on a standard data form. Following each survey the total number of goats observed, the number of goats counted per hour of survey flight time and the percentage of kids in the herd were calculated. If a survey could not be completed in a single evening due to weather, fog, darkness, etc., the ending point of the survey was noted on the topographic map. In a few cases, incomplete surveys were completed within 2 days and the data from both flights were pooled. Telemetry studies indicate that movements at this time of year are limited, so the potential for double-counting on these pooled surveys is small (Smith unpubl. data).

In trend count areas K-3 and K-8, the annual survey could not be completed in 1982. In area K-4 surveys could not be completed in 1974 and 1980 and in area K-5 the survey could not be completed in 1978. To make the results of all surveys comparable, these incomplete counts were extrapolated as follows. The proportions of adults and kids observed on completed surveys in other years in areas missed on incomplete counts were determined from maps and data sheets. The means of these proportions were used to estimate the number of goats that would have been observed in the unsurveyed portions had the aborted flights been completed. Where regression showed that significant trends in any proportion occurred over time, regression was used to calculate a more accurate estimate of the proportion and number missed than the mean. In all cases, 95 percent confidence limits were used with estimated proportions.

Population trends were determined by regression of the natural log of observed numbers on time. The slope of the regression line, r, represents the mean annual, exponential observed rate of increase (Caughley 1977 p. 109). The antilog of r is λ which can be used to calculate the percentage rate of increase by the formula, $(\lambda-1)*100=\%$ increase.

To test the effect of density on r in this study, density indicies were

calculated by dividing the total number of goats counted on a survey by an estimate of the total area covered by the survey flight line. Because sightability of goats in coastal areas is low (Foster 1982, Smith and Bovee 1984), total survey counts represent only a portion of the population. Furthermore, the survey areas have varying amounts of subalpine and mature timber which were not surveyed, so area figures do not necessarily represent equal proportional coverage. For these reasons, data presented here are indicies only and should not be compared with actual density estimates (e.g. Smith and Bovee 1984).

Information on natality and mortality was available from records of goats captured and radiocollared for habitat use studies (Smith 1983). Natality estimates were based on observations of known females with young or lactating; mortality estimates were based on hunter returns of radiocollars or examination of remains following reception of mortality mode signals from the collars.

Additional information on mortality was provided by spring "carry-over" surveys initiated in 1982. These surveys consisted of fixed wing (PA-18-150) searches of lower elevation cliff/slide areas in April and May. Goats were classified as kids (10-11 months old) and adults. Because such habitat is sparsely distributed over several of the summer/fall trend count areas, all results were pooled to provide an estimate of percent kids in the overall herd.

Several authors have reported correlations between snowfall and goat population dynamics (Bailey and Johnson 1977, Adams and Bailey 1982). Unfortunately, no long-term snowfall records are available within the trend-count areas, and data from Ketchikan, located at sea level on the west coast of Revillagigedo Island (Fig. 1), cannot be considered comparable to conditions on mid-elevations goat winter ranges on the mainland. Thus it was necessary to rely on an indirect method of assessing winter severity on goat populations.

Given the magnitude of precipitation in the coastal region, even a relatively "dry" year has the potential for catastrophic snowfall accumulations if the winter temperatures remain low. This may explain why Merriam (1970) found an inverse correlation between mean winter temperatures at Petersburg, Alaska and over-winter deer mortality. Thus, temperature patterns have been used in this analysis to evaluate the effect of weather on goat populations.

Mean annual temperature at Ketchikan was plotted using a 5-year running mean smoothing formula to assess trends in temperature as Juday (1983) had done for the balance of Alaska. In addition, a 5-year running mean of mean winter (October-March) temperatures was used as an index to winter severity.

RESULTS

Replicate surveys were made in count areas K-4, K-5 and K-11 in 1973, 1975, 1982 and 1983 under varying conditions and with a total of 4 observers (Table 1). The pilot and type of aircraft for all except 1 of these flights were the same. The coefficient of variation (CV) for all replicate surveys

flown in one area in one year ranged from 3.4 to 46.0 percent (x=24.8 percent, SE = 7.8, n=5). However, if only results of surveys conducted under "Fair" or "Good" conditions are considered, the range of CV is reduced to 3.4 to 11.1 percent (x=7.1 percent, S.E.=2.2, n=3). This indicates that the survey methodology is relatively precise (Eberhardt 1978). Furthermore, given sightability levels of 30 to 50 percent for goats on these surveys (Smith and Bovee 1984), the probability that trend lines based on results of surveys conducted under "Fair" or "Good" conditions are accurate to within ±10 percent per year is greater than 90 percent, when at least 3 years' survey results are considered (Harris 1984). Accordingly, unless otherwise noted, all r values reported herein are based on 3 or more counts obtained under "Fair" or "Good" survey conditions.

Table 1. Results of replicate aerial trend count surveys near Ketchikan, Alaska. 1973 to 1983.

Survey area	Survey date	Survey[1] time	Survey[2] conditions	Goats observed	% Kids in herd	Observer
K-4	8-16-73	1.08(a)	Good	103	12	Wood
K-4	9-16-73	1.00(p)	Fair	88	15	Blankenbeckler
K-5	8-13-73	1.45(p)	Poor	29	25	Wood
K-5	9-11-75	1.30(p)	Good	57	30	Wood
K-4	8-13-82	1.07(p)	Poor	43	25	Wood
K-4	9-18-82	1.03(p)	Fair	87	26	Wood
K-4	9-22-82	1.25(p)	Good	99	25	Smith
K-4[3]	9-23-82	1.25(p)	Poor	71	28	Smith
K-4	9-29-82	1.30(p)	Fair	97	26	Smith
K-11	8-29-82	0.22(p)	Poor	28	29	Wood
K-11	9-12-82	0.25(p)	Good	46	31	Wood
K-4	8-17-83	1.75(p)	Fair	122	19	Bovee
K-4	9-08-83	1.40(p)	Fair	118	31	Smith
K-4	9-16-83	1.05(p)	Fair	114	23	Wood

1 Length of survey in hours, (a) = morning survey, (p) = evening survey.

2 Good = high visibility, no glare, light winds, often scattered clouds or high overcast, cooler temperatures. Fair = intermediate visibility, limited glare, moderate winds, occasional fog, warm temperatures. Poor = limited visibility due to glare, fog or clouds, turbulent winds, high temperature or excessive snowpack at survey elevations.

3 Survey conducted in Hughes 500 "D" helicopter, all others conducted in PA-12 (1973-75) or PA-18 (1982-83) with Pilot R.D. Hamlin.

In 1982, portions of trend area K-3 in the Goat Lake drainages and south of Checats Lake were not surveyed due to impending darkness. During previous years approximately 35 percent of the adults, 39 percent of the kids and 38 percent of all goats seen in K-3 were found in these areas (Table 2). It was calculated that, if the 1982 survey had been completed, 16 additional adults and 6 additional kids, or an additional total of 22 goats, would have been seen (Table 3). The precision of the estimates of adults and kids is limited by the small samples and number of surveys.

In area K-4, two years' surveys omitted the Falsegate Creek drainage. Analysis of the proportion of goats observed in this drainage on completed surveys from 1973 through 1982 (Table 4) revealed that a steadily increasing percentage of the count was found here. This trend was highly significant for kids ($p<0.03$), adults ($p<0.01$) and total goats ($p<0.01$) so regression was used to estimate the percent and number of goats that would have been seen in the Falsegate Creek drainage had the 1974 and 1980 surveys have completed (Table 5 and 6).

In area K-5, the 1978 survey omitted the north fork of the Red River drainage. Analysis of results of complete surveys in area K-5 for 1975 through 1982 (Table 7) revealed no trend in proportion of adults ($p<0.5$) or total goats ($p>0.75$), but a significant increasing ($p<0.01$) trend in the proportion of kids in this part of the survey area. Accordingly, the mean values for adults and total goats and regression value for kids were used to estimate the number of goats that would have been seen in the north fork of the Red River in 1978 had that survey been completed (Tables 8 and 9).

In count area K-8, the Grant Creek drainage was not surveyed in 1982. Results of previous surveys indicate that approximately 36 percent of the adults, 25 percent of the kids and 35 percent of all goats seen in K-8 occurred in this drainage (Table 10). Thus, had the 1982 survey been completed, an estimated 30 additional adults, 4 additional kids or 34 more total goats would have been seen (Table 11).

The extrapolated count data for areas K-3, K-4, K-5 and K-8 are presented along with results of complete surveys for these and 4 other areas in Table 12. Two different trends are evident from these results. First, from 1968 through the mid 1970's populations in the 3 areas surveyed each experienced major declines in numbers (Fig. 2). Second, since the mid 1970's, all 8 populations have increased to varying degrees (Fig. 3). These trends are evident in both the total number of goats counted and the number of goats counted per hour of survey time.

Data from trend counts were used to calculate observed rates of increase, (r), for the different count areas (Table 13). The marked declines from 1968 through 1975 or '76 are reflected in negative r values. Since the mid 1970's all the r values are positive, although most areas experienced more rapid growth in the initial 5 years of increase than over the entire period, 1975-83. In fact, following significant initial increases, populations in areas K-4, K-9, and K-10 seem to have fluctuated with no clear trend since 1980.

Table 2. Results of complete surveys of K-3, 1976 and 1980, with breakdown of goats observed in the Goat Lakes area and ridges south of Checats Lake.

Year	Goats observed	Survey time	Goat Lake/South of Checats Lake		
			% Adults	% Kids	% Total
1976	34	1.3	34.6	50.0	38.2
1980	53	1.5	40.5	27.3	37.7
x		1.4	37.6	38.7	38.0
95% C.I.			± 5.8	±22.2	± 0.5

Table 3. Estimated number of goats (and 95 percent confidence interval) that would have been counted in trend area K-3 in 1982 if the survey were completed.

Age Class	Actual count	Estimated Goats missed	Estimated Total
Adults	26	16 (12-20)	42 (38-46)
Kids	10	6 (2-16)	16 (12-26)
TOTAL	36	22 (18-27)	58 (54-63)

Table 4. Results of complete surveys of K-4, 1973-1982 with breakdown of goats observed in Falsegate Creek drainage.

Year	Goats observed	Survey time (Hr.)	Falsegate Creek Drainage had:		
			% of Adults	% of Kids	% of Total
1973	103	1.08	18.9	23.1	19.4
1975	18	0.78	26.7	0.0[1]	22.2
1976	25	0.95	27.8	14.3	33.3
1977	58	0.93	30.8	42.1	34.5
1978	84	0.85	47.7	52.6	48.8
1979	60	1.08	45.5	50.0	46.7
1981	95	0.75	51.5	44.4	49.5
1982	87	1.03	57.5	60.9	59.8
x	66	0.81	38.3	41.1	39.3
S.E.	11	0.04	4.9	6.3	5.0
n	8	8	8	7	8

1 Value deleted from calculations due to small sample size (n=3)

Table 5. Regression equations for % of adults, % of kids and % of total goats found in survey area K-4 that occurred in Falsegate Creek drainage on year for 1973 through 1982.

% of Adults = 4.44 (Year - 1900) - 306.7; r^2 = .93

n = 8; F = 76.73; significant at p<0.01

% of kids = 4.30 (Year - 1900) - 294.1; r^2 = .62

n = 7*; F = 5.47; significant at p<0.03

% of Total = 4.50 (Year - 1900) - 310-11 r^2 = .91

n = 8; F = 45.3; significant at p<0.01

* 1975 value excluded due to small number of kids observed (3).

Table 6. Estimated percentages and number of goats ± 95% C.I. for Falsegate Creek Drainage in 1974 and 1980.

Falsegate Drainage Estimates[1]

	% of Adults	% of Kids	% of Total	# of Adults	# of Kids	# of Total
1974	22.2	24.1	22.9	7	3	10
95% C.I.	+5.1	±16.3	± 6.1	±2	±1	± 4
1980	48.9	49.9	49.9	33	18	53[2]
95% C.I.	± 4.1	±11.6	± 4.9	± 6	± 8	±20

1 Based on regression equations in Table 3.

2 Total may not equal Adults + Kids because this value is based on a separate regression.

Table 7. Results of complete surveys of K-5, 1975-1981 with breakdown of percent of goats observed in the north fork of Red River.

Year	Goats observed	Survey time (hr)	N. Fork Red River Had: % of Adults	% of Kids	% of Total
1975	57	1.30	2.5	0.0	1.8
1976	47	1.65	10.0	0.0	8.5
1977	124	1.67	4.8	4.9	4.8
1980	151	2.08	6.0	5.7	6.0
1981	192	1.83	5.5	8.5	6.3
1982	166	1.58	5.1	6.3	6.0
1983	220	1.95	6.4	8.5	6.8
x	137	1.72	5.8	4.8	5.7
S.E.	25	0.10	0.9	1.3	0.8
n	7	7	7	7	7

Table 8. Regression equations for % of adults, % of kids and % of total goats found in north fork of the Red River portion of survey area K-5 on year for 1975-1983.

% of Adults = 0.04 (Year - 1900) + 2.33; r^2 = .004

n=7; F=0.25; nonsignificant (p>0.50)

% of Kids = 1.04 (Year - 1900) - 77.12; r^2 = .83

n=7; F=22.76; significant at p<0.01

% of Total = 0.27 (Year - 1900) - 15.45; r^2 = .16

n=7; F=1.07; nonsignificant (p>0.75)

Table 9. Estimated percent and number ± 95% C.I. of adults, kids and total goats in the north fork of the Red River in Survey Area K-5 in 1978.

	N. Fork Red River Drainage Estimates					
	% of Adults[1]	% of Kids[2]	% of Total[3]	# of Adults	# of Kids	# of Total
1978	5.8	4.0	5.7	6	1	9
95% C.I.	±1.8	±1.6	±1.6	±2	±1	±2

[1] Based on mean value for 1975-1983, see Table 7.

[2] Based on regression equation for 1975-1983 data, see Table 7.

[3] Total may not equal Adults + Kids because this value is based on a separate calculation.

Table 10. Results of complete surveys of trend area K-8 in 1975 and 1976 with percentage of goats counted in Grant Creek Drainage.

Year	Goats counted	Survey time	Goats in Grant Creek		
			% of Adults	% of Kids	% of Total
1975	40	1.1	41.2	16.7	37.5
1976	51	1.3	31.1	33.3	31.4
$\bar{x}$		1.2	36.2	25.0	34.5
95% C.I.			± 10.0	± 16.3	± 6.0

Table 11. Estimated number of goats (±95% C.I.) that would have been seen in Grant Creek drainage in trend area K-8 in 1982 had the survey been completed.

Age Class	Actual count	Estimated goats missed	Estimated total
Adult	52	30 (18-45)	82 (70-97)
Kid	13	4 (1- 9)	17 (14-22)
TOTAL	65	34 (26-44)	99 (91-109)

Table 12 Results of aerial trend counts of mountain goat populations near Ketchikan, Alaska 1968-1983.

Year	SURVEY AREA K-3 Goats counted	K-3 Goats/Hr survey	K-3 % Kids ± 95% C.I.	K-4 Goats counted	K-4 Goats/Hr survey	K-4 % Kids ± 95% C.I.
1968	79	47	21.3 ± 9.0	265	199	27.0 ± 5.4
1969	-	-	-	-	-	-
1970	-	-	-	-	-	-
1971	94	71	23.1 ± 8.5	220	189	26.5 ± 5.8
1972	-	-	-	-	-	-
1973	-	-	-	103	95	12.3 ± 6.3
1974	-	-	-	44 [a]	54 [a]	23.8 ± 12.8 [a]
1975	-	-	-	18	23	16.7 ± 17.2
1976	34	27	23.7 ± 14.3	25	26	28.1 ± 17.6
1977	-	-	-	58	62	32.9 ± 12.1
1978	-	-	-	84	99	22.5 ± 8.9
1979	-	-	-	60 [b,c]	55 [b,c]	26.5 ± 11.2 [c]
1980	53 [b]	36 [b]	20.6 ± 10.9	106 [a]	131 [a]	34.6 ± 9.1 [a]
1981	-	-	-	95	122	28.6 ± 9.1
1982	58 [d]	41 [d]	27.6 ± 11.5 [d]	87	84	26.5 ± 9.3
1983	-	-	-	114	109	23.1 ± 7.7

Table 12 continued ..

Year	SURVEY AREA					
	K-5			K-7		
	Goats counted	Goats/Hr survey	% Kids ± 95% C.I.	Goats counted	Goats/Hr survey	% Kids ± 95% C.I.
1968	371	194	20.0 ± 4.1	-	-	-
1969	-	-	-	-	-	-
1970	-	-	-	-	-	-
1971	168 [b]	121 [b]	20.6 ± 6.1	-	-	-
1972	-	-	-	-	-	-
1973	81	57	27.0 ± 9.7	-	-	-
1974	30 [e]	25 [e]	20.0 ± 14.3 [e]	-	-	-
1975	57	44	30.1 ± 11.9	48	26	23.1 ± 11.9
1976	47	29	15.3 ± 10.3	-	-	-
1977	124	73	32.9 ± 8.3	-	-	-
1978	140 [f]	81 [f]	25.4 ± 7.2 [f]	-	-	-
1979	-	-	-	-	-	-
1980	151 [b]	72 [b]	23.1 ± 6.7	164	91	21.0 ± 6.3
1981	192	105	24.2 ± 6.1	-	-	-
1982	166	105	29.1 ± 6.9	-	-	-
1983	220	113	21.3 ± 5.4	168	92	21.9 ± 6.3

Table 12 continued ..

Year	SURVEY AREA K-8 Goats counted	K-8 Goats/Hr survey	K-8 % Kids ± 95% C.I.	K-9 Goats counted	K-9 Goats/Hr survey	K-9 % Kids ± 95% C.I.
1968 to 1974	NO DATA			NO DATA		
1975	40	38	15.3 ± 11.1	63	48	17.4 ± 9.4
1976	51	38	11.5 ± 8.8	93	61	21.3 ± 8.3
1977	-	-	-	148	73	29.6 ± 7.4
1978	-	-	-	158	102	23.7 ± 6.7
1979	-	-	-	122 b,c	75 b,c	18.7 ± 6.9 b,c
1980	-	-	-	224	122	29.6 ± 6.0
1981	-	-	-	139	75	28.1 ± 7.5
1982	99 g	83 g	17.2 ± 7.4 g	129	96	19.4 ± 6.8
1983	-	-	-	183	116	20.0 ± 5.8

Table 12 continued ..

Year	SURVEY AREA K-10 Goats counted		K-10 Goats/Hr survey		K-10 % Kids ± 95% C.I.		K-11 Goats counted	K-11 Goats/Hr survey	K-11 % Kids ± 95% C.I.
1968 to 1974	NO DATA						NO DATA		
1975	105		97		29.6 ± 8.7		23	99	21.9 ± 16.9
1976	85		86		23.7 ± 9.0		21	74	23.7 ± 18.2
1977	168		117		32.9 ± 7.1		21	84	28.6 ± 19.3
1978	157		124		23.1 ± 6.6		-	-	-
1979	118	b,c	111	b,c	19.4 ± 7.1	b,c	-	-	-
1980	158		108		26.5 ± 6.9		29	102	24.2 ± 15.6
1981	152		122		21.9 ± 6.6		36	135	19.4 ± 12.9
1982	125		106		20.6 ± 7.1		46	184	30.6 ± 13.3
1983	150		130		20.0 ± 6.4		-	-	-

a. Extrapolated results from incomplete surveys, see text and Tables 4-6.
b. Poor survey conditions, goat count and goats/hr may be unreliably low.
c. Inexperienced observer, results may be unreliable.
d. Extrapolated results for incomplete surveys, see text and Table 2 & 3.
e. Different pilot and aircraft (Cessna 185) results not directly comparable.
f. Extrapolated results from incomplete surveys, see text and Tables 8-10.
g. Extrapolated results from incomplete surveys, see text and Tables 12 & 13.

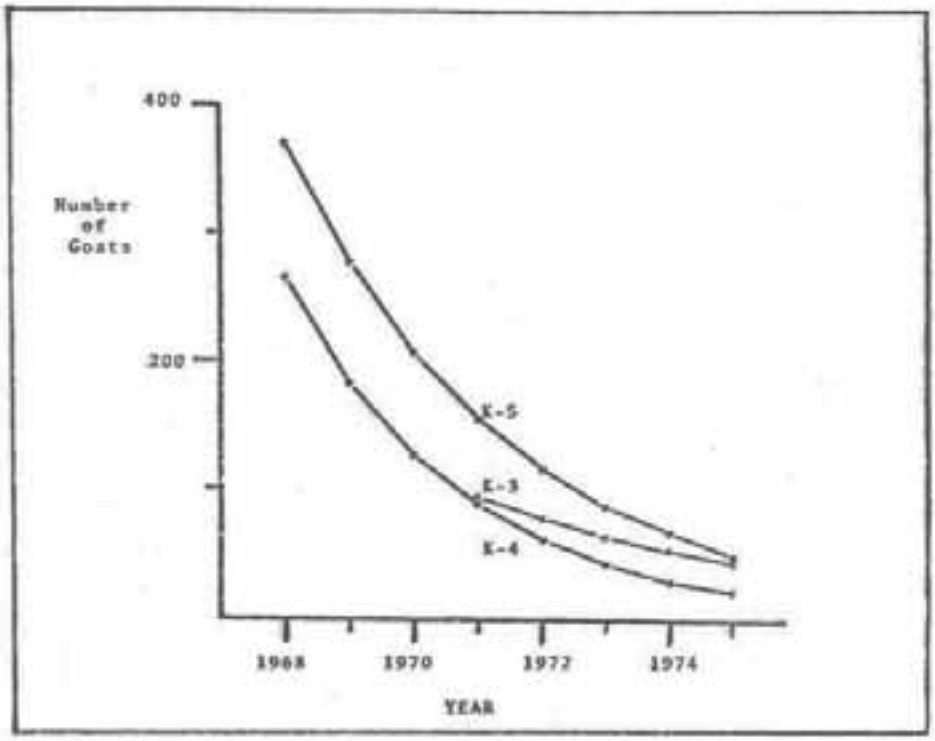

Figure 2. Trends in 3 mountain goat populations near Ketchikan, Alaska, 1968 - 1975, based on the highest pre-decline count and calculated $\bar{r}$ values.

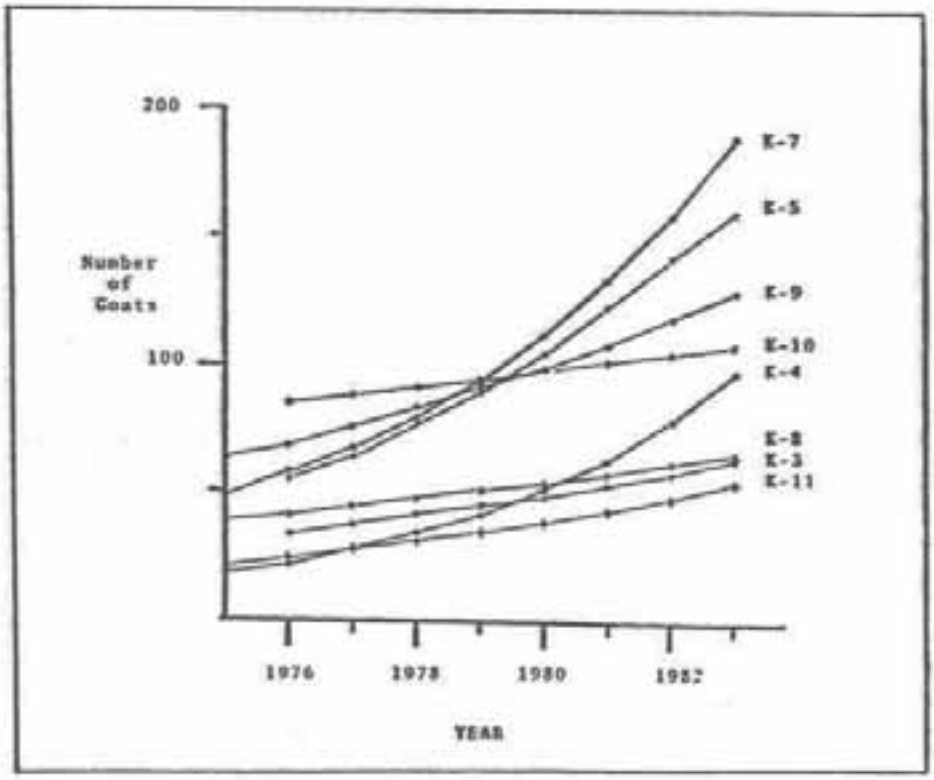

Figure 3. Trends in 8 mountain goat populations near Ketchikan, Alaska, 1975 - 1983

Table 13. Density index and observed rate of increase $\bar{r}$ in 8 mountain goat populations near Ketchikan, Alaska, 1968-1983.

Area	Initial Density Index	Period of decline	$\bar{r}$	Minimum Density Index	Initial Period of Increase	Initial $\bar{r}$	Overall Period of Increase	Overall $\bar{r}$	Current Density Index
K-3	0.99	1971-76	-.20(2) [a]	0.36	1976-80	.11(2) [b]	1976-82	.09(3) [b]	0.61
K-4	5.41	1968-75	-.37(5)	0.37	1975-80	.38(5)	1975-83	.21(8)	2.33
K-5	3.79	1968-76	-.29(5)	0.48	1976-80	.25(4)[b]	1976-83	.16(6)	2.24
K-7	-	-	-	0.45	1975-80	.25(2)	1975-83	.17(3)	1.58
K-8	-	-	-	0.49	-	-	1975-83	.06(3)	1.21
K-9	-	-	-	0.77	1975-80	.26(5)	1975-83	.09(8)	2.23
K-10	-	-	-	1.49	1976-80	.12(4)	1976-83	.03(7)	2.63
K-11	-	-	-	1.11	1975-80	.06(4)	1975-82	.12(6)	2.42

a. (x) = Number of surveys used to calculate $\bar{r}$.

b. Calculation includes results of a survey conducted under "poor" conditions; value may underestimate true $\bar{r}$.

DISCUSSION

Opinions vary as to the influence of density on the dynamics of mountain goat populations. Kuck (1977) and Hebert and Turnbull (1977) did not find the anticipated response of increased productivity in populations following reductions in density due to hunter harvest, but Stevens (1983) found that the rate of increase was inversely correlated with density in subpopulations of mountain goats introduced to Olympic National Park. Adams and Bailey (1982) also implied that r and density were inversely correlated in goats transplanted in Colorado. Results of this study lend limited support to the hypothesis that density and r are related.

Data for the declining period are too limited to permit statistical evaluation of correlation between r and density, but they are consistent with a hypothetical inverse relationship between density and rate of increase (Table 13). Data from the increasing period also indicate the potential for a density dependent relationship inasmuch as the areas with lower densities in the mid 1970's generally had higher r values during the recovery years. However, statistical tests of the significance of the correlation were inconclusive (Spearman's rank coefficient, $\bar{r}_s$=-0.53, n=8, 0.50>p>0.10).

These results are not intended, let alone statistically adequate, to settle the dispute over whether or not goat populations have density-dependent feed-back mechanisms. They are simply presented as indications that density may influence r. Nevertheless, I concur with Kuck (1977) and Hebert (1980) that it would be unreasonable to expect that an exploited goat population will necessarily respond by increasing it's potential r given the nature of goat social behavior and winter range habitat structure (Chadwick 1983).

While the role of density in regulating the magnitude of r may not be clearly indentified by the results of this study, it is obvious from these data that two distinct, and radically different trends have occurred in the goat populations near Ketchikan over the past 15 years.

The differences between the observed population trends are obviously the result of differing natality and/or mortality schedules operating over the years of decline versus the years of increase.

Unfortunately, the only data available from which to draw conclusions regarding these processes during the declining period are the trend survey results, and these provide few insights. Productivity, expressed as % kids in the herd in late summer, during the declining period was not measurably less than during the years of population increase (Fig.4): 1973 being lower, and 1977 higher, than the other years combined. Thus, initial productivity in this area, as measured on the trend counts, may not be as sensitive an indicator of population performance as in some other areas (Adams and Bailey 1982, Stevens 1983).

A major limitation of using kid percentages or kid:adult ratios as a measure of productivity is that changes in productivity per adult female may be masked by changes in proportions of other population segments (e.g. males, juvenile females). For this reason, direct measurement of production per female is a better approach. While no data are available for this parameter

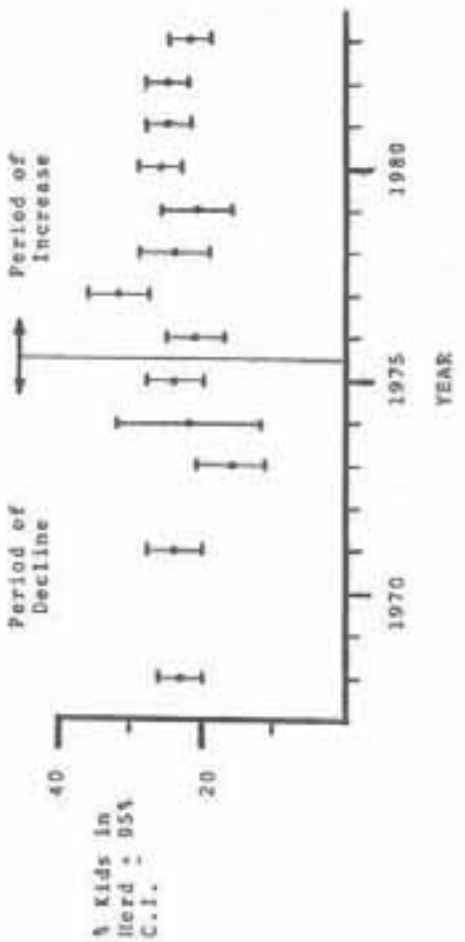

Figure 4. Percent kids in the herd ± 95 % confidence interval in late summer for combined trend count areas near Ketchikan, Alaska, 1968 - 1983.

Table 14. "Jackknife" comparison of kid percentage in the herd + 95% C.I. For individual year vs all other years using pooled data from all trend count areas.

Year	% Kids in herd in year X	% Kids in herd all other years	Deviation of % in year X from all others [1]
1968	22.9 ± 2.8	23.9 ± 1.0	0
1971	23.7 ± 3.9	23.9 ± 1.0	0
1973	17.6 ± 4.5	24.1 ± 1.0	-
1974	21.9 ± 10.1	23.9 ± 1.0	0
1975	23.8 ± 4.3	23.9 ± 1.0	0
1976	20.5 ± 4.2	24.0 ± 1.0	0
1977	31.8 ± 4.0	23.2 ± 1.0	+
1978	23.8 ± 3.6	23.9 ± 1.0	0
1979	20.7 ± 4.6	24.0 ± 1.0	0
1980	25.8 ± 2.9	23.6 ± 1.0	0
1981	24.9 ± 3.4	23.8 ± 1.0	0
1982	24.8 ± 2.8	23.7 ± 1.1	0
1983	21.8 ± 2.5	24.2 ± 1.1	0

[1] Deviation significance determined at $p<0.05$.

Table 15. Age-specific fecundity rates for female mountain goats captured near Ketchikan, Alaska 1980-1983.

Age	% Natality [1]	Sample Size
1	0	5
2	38	8
3	64 [2]	14
4	60	10
5+ [3]	100	33

[1] Based on lactative status upon capture and/or observation following radio-collaring.

[2] Includes 1 nanny captured in June determined to be pregnant by external palpation.

[3] The oldest female captured was at least 10 years old.

from the declining period, such data are available for the years 1980-83. Data representing 70 female goat-years' productivity indicate that among goats near Ketchikan, 38 percent of all 2 year old (n=8), 64 percent of all 3 year old (n=14), 60 percent of all 4 year old (n=10) and 100 percent of all 5 or more year old (n=33) nannies gave birth (Table 15).

A few reports document two-year-old females giving birth in introduced populations (Stevens 1983, Hibbs 1966), but this has not been previously reported in native herds. Thus it appears that the natality rate in goat herds near Ketchikan is currently near optimum levels. Nevertheless, general analyses of ungulate population dynamics (Caughley 1971, 1977) as well as simulation modelling of mountain goat demography (Youds et al. 1980, Adams and Bailey 1982) indicate that changes in mortality patterns are more influential than differential natality in altering r values.

Age-specific mortality data are not available for the declining period so we can only speculate as to the levels of mortality ocurring during those years. Recent spring surveys and radio-monitoring of goats provide data which indicate that mortality is presently low in these coastal goat populations.

The spring surveys which were initiated in 1982 can be compared to the previous summer's survey to provide an estimate of overwinter mortality of kids relative to other goats (Table 16). Results of the last 3 years' surveys indicate that the percent kids in the herd was not declined significantly ($p< 0.05$) over any of the past 3 winters. Thus mortality of kids must be of the same magnitude as mortality of other goats. Data on the life history of radio-collared goats in this area (Table 20) indicates that yearling mortality was approximately 33 percent (n=6) while total mortality for goats aged 2 through 7 was only 4 percent (n=93), and excluding hunter kills, mortality of these goats was nil. Total mortality for all goats over 1 year old was 12 percent (8 percent excluding hunter kills) based on 130 goat-years of radiotracking.

Given the present relatively high natality and minimal mortality in these populations it is not surprising that some have exhibited exceptional rates of increase. The question remains, however, what brought about the initial decline in goat numbers? Hunter harvest was not likely a driving force since these populations are largely inaccessible and, in any case, hunter kill, which currently ranges from 0 to 5 percent of the population in these trend count areas, has been proportionately higher during the increase than during the declining years (A.D.F. & G. unpubl. data). Disease and predation, though contributory to some population declines, have not been reported as the cause of goat declines elsewhere and, if involved in this decline, may have prevented population recovery. The most significant factor influencing these goat populations is believed to be weather.

The influence of winter weather on ungulate survival and abundance is a generally accepted feature in the ecology of high latitude species. The major natural mortality factors which affect mountain goats such as accidental falls, avalanches and starvation (Brandborg 1955, Chadwick 1983) are all exacerbated during periods of high snowfall. Thus it is logical to assume that goat populations should suffer higher mortality during cold, snowy winters. Furthermore, if goats are exposed to regular periods of severe vs

Table 16. Comparison of percent kids in the herd ± 95% C.I. in summer and the following spring for combined trend count areas K-9, K-10 and K-11, 1981 to 1984.

Year	% Kids in Summer	% Kids in Spring
1981-82	24.2 ± 4.6	17.9 ± 8.2
1982-83	21.7 ± 4.7	18.7 ± 5.1
1983-84 [1]	20.0 ± 6.4	17.2 ± 7.7

1. Area K-10 only.

Table 20. Age-specific mortality rates for all radio-collared goats captured near Ketchikan, Alaska, 1980-1983.

Age Class	Number tagged at age x	% Natural mortality [1]	% Overall mortality [2]
1	6	33	33
2	17	0	0
3	25	0	0
4	16	0	12
5	14	0	7
6	9	0	0
7	12	0	8
8	10	10	10
9	11	36	36
10	6	50	50
11	2	0	0
12	2	100	100

[1] % of goats at age x dying before age x+1, excluding human-induced mortality.

[2] Includes hunter kill.

moderate winters, their population should go through "boom" and "bust" cycles as Edwards (1956) demonstrated for deer (O. h. hemionus and O. virginianus), elk (Cervus canadensis) and moose in British Columbia.

Analysis of mean annual and winter temperature at Ketchikan clearly illustrate the magnitude of variation in weather patterns which could effect goat populations. Cycles in mean annual temperatures at Ketchikan appear to follow the same trends Juday (1983) charted for Juneau and Sitka (Fig. 5). The regular and distinct periods of warming and cooling reflect a pattern Juday described for most of Alaska and may occur broadly along the eastern Pacific Rim. A similar analysis of mean winter temperature in Ketchikan (Fig. 6) illustrates that winter temperature cycles parallel annual ones. During the most recent cooling period of 1965 - 1975 several cold, snowy winters occurred in Alaska. The impact of the winters of 1968 - 69, 1970 - 71 and 1971 - 72 on deer (Merriam 1970, Olson 1977) and moose (Bishop and Rausch 1974, Gasaway et al. 1983) have been documented elsewhere. Trend data presented here indicate that the goat populations near Ketchikan responded similarly to adverse winter weather.

Figure 6 presents the trend count results for area K-4 and K-5 along with the trend in mean winter temperature. The relationship between goat numbers and the temperature cycle is evident. As would be expected, initial recovery of the populations lagged behind temperature moderation by several years. Results of trend counts in the other areas reveal the same pattern shown in Fig.6. In addition, data from other studies of coastal goat populations indicate that these trends may have been widespread. Dane (1977) reported that a goat population in the upper Kleena Kleene river in coastal British Columbia declined sharply in the early 1970's during a period of severe winters. Although he attributed much of the decline to reproductive failure, it is obvious from his total count data that adult mortality was also high during the 1972 - 1976 period.

In Hebert and Turnbull's (1977) original discussion of the coastal goat ecotype, populations in the vicinity of Knight inlet were described as being of lower density and less productive than those in the interior. These conclusions were based on surveys conducted in 1974 and 1976, a period corresponding with the low point in the cycle at Ketchikan. Subsequent surveys reported Hebert and Langin (1982) documented recovery of these same populations between 1976 and 1980 at rates of increase comparable to those reported herein for populations near Ketchikan, and far exceeding those presumed possible based on population models developed using data from interior goat herds (Youds et al. 1980).

These results, along with recent re-evaluation of density in coastal goat populations (Smith and Bovee 1984) indicates that the original impressions regarding this ecotype were an artifact of studying a few areas during the "worst" time of their recent demographic history. This reinforces the value of long-term data on trends in developing an understanding of the dynamics of goat populations. Additionally, both short and long-term environmental fluctuations and variations in population parameters must be considered in mountain goat population management.

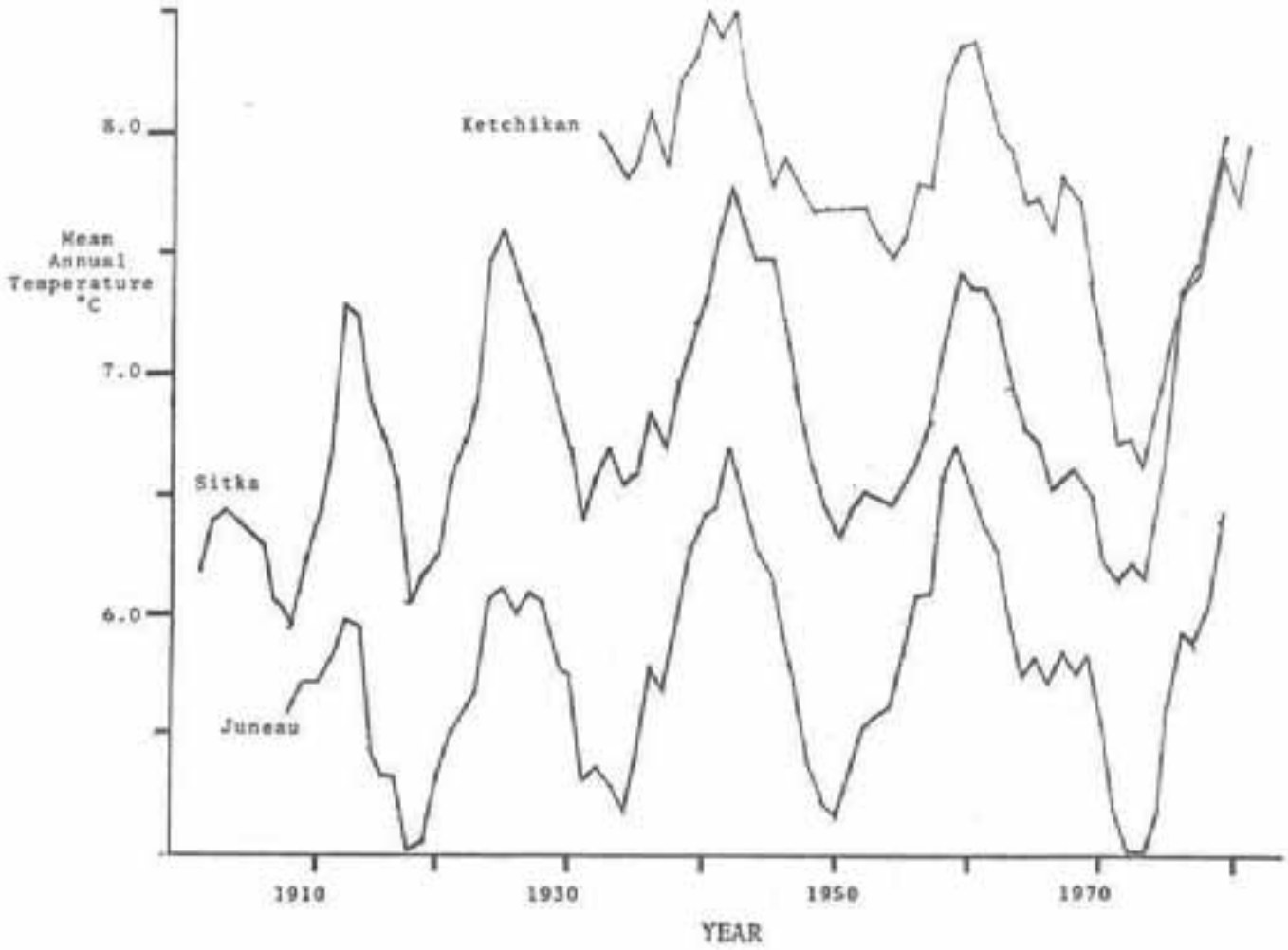

Figure 5. Trends in mean annual temperature at Juneau and Sitka since 1900 (from Juday (1982)) and Ketchikan, Alaska since 1930.

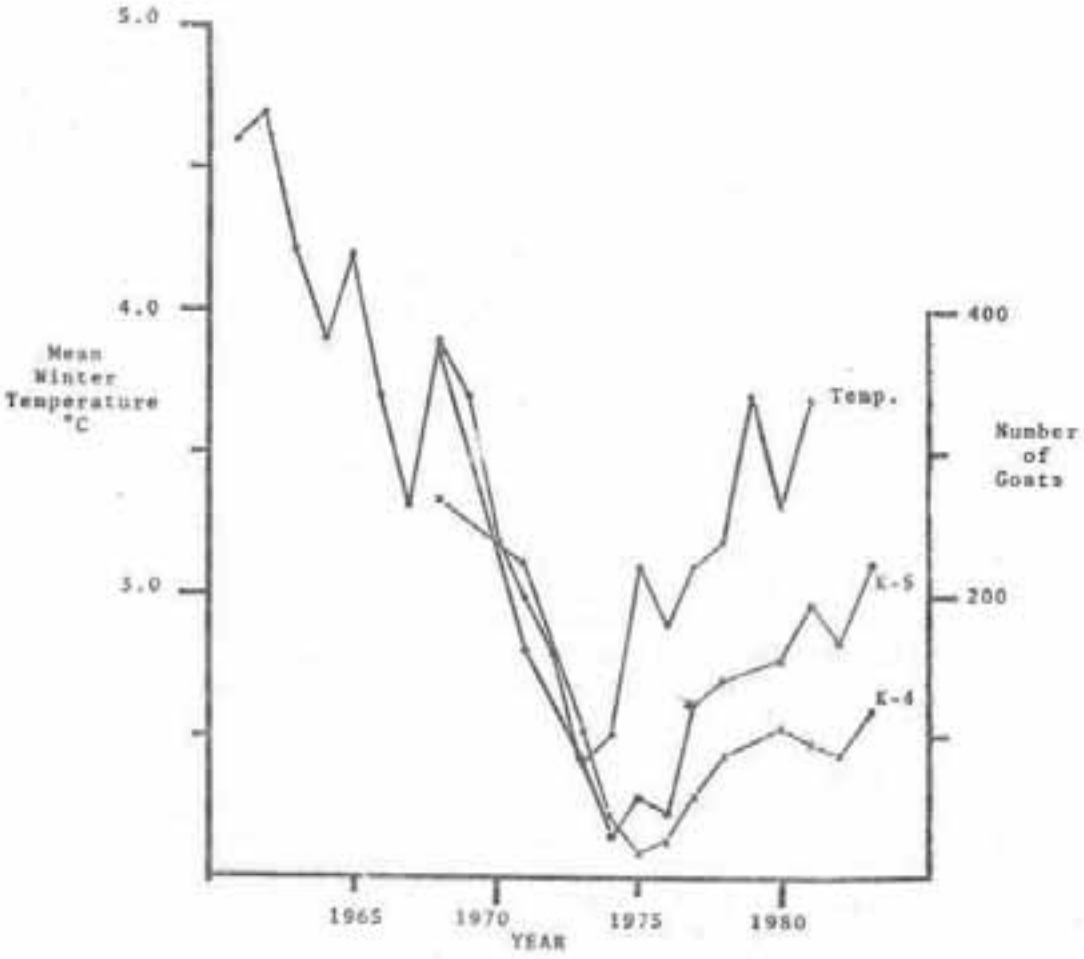

Figure 6. Trends in mean winter temperature at Ketchikan, Alaska and 2 nearby mountain goat populations, 1960 - 1983.

Management Implications

A great deal of time, effort and money has been devoted over the years to gathering detailed information on size and composition of mountain goat populations, yet biologists are still uncertain as to how to go about managing this species (Hebert and Langin 1982, Chadwick 1983). This is particularly frustrating to biologists with small budgets charged with managing large areas where sightability of goats is low and application of the intensive survey methods suggested by Nichols (1980) is not feasible.

In an effort to overcome the deficiencies of available survey results, several investigators have developed goat population models to simulate population dynamics and evaluate the potential effect of hunting on population growth (Kuck 1977, Hall and Bibaud 1978, Youds et al. 1980, Adams and Bailey 1982). As Hebert and Langin (1982) have pointed out, however, these models are non-stochastic and merely plot the trajectory of a population given an initial sex and age composition and fixed natality and mortality schedules. They invariably develop a stable age distribution and constant r. Not only are such models unrealistic, they may create either a sense of false security or unnecessary pessismism regarding goat harvest management depending upon the parameter estimates used in the simulation.

Throughout their range, mountain goat populations are influenced by highly variable biotic and abiotic factors which largely prevent development of either stable age distributions or constant rates of increase. Accordingly no single survey, or even a series of surveys is likely to provide composition data which can be entered into a non-stochastic model with the expectation of accurately predicting the future of the real goat herd. This predicament is what led Hebert and Langin (1982) to conclude that "Annual classification surveys ... produced inconsistent results which were of little value in establishing a harvest management program." They further concluded that survey methodology should be based on the objective of establishing population size, not composition. Caughley (1974) also stressed the need to measure r directly due to the ambiguity of age ratio interpretation.

The need for reliable trend information is reinforced by the fact that mountain goats apparently do not respond to management in the "traditional" way (Hebert 1980). If, as Kuck (1977) and others have concluded, hunting mortality is additive and goats do not increase productivity in response to adult losses, then the application of typical harvest strategies such as Caughley's (1977) maximum sustained yield model is inappropriate. This dilemma is complicated by the variable nature and incomplete understanding of productivity and survival in goat poulations. In short, what is needed is an entirely different philosophy toward goat harvesting; a philosophy which recognizes the fact that goat populations may not be as "resilient" as other ungulate populations, and is cognizant of the fact that there simply may be times when a population can afford additive mortality, and times when it cannot.

During periods of favorable environmental conditions, when goat populations are increasing, harvest can be permitted or increased once the population reaches a predetermined threshold, or management objective level.

When populations are declining toward the objective level, harvest should be curtailed or eliminated until conditions are again conducive to population growth. Caughley (1977) labelled this approach as "tracking harvest strategy." Caughley suggested that it is ideally suited to management of species living in environments subject to major fluctuations with long periodicity, where density and resources are seldom balanced and where little is know about the relationships between population parameters and environmental conditions. It is hard to imagine a better description of circumstances surrounding mountain goat biology and management.

Although application of a tracking harvest strategy to goat management may appear radical, it may actually produce a more stable harvest pattern than past approaches which were far too often characterized by cycles of over-overhunting, closure to allow recovery, resumed harvest based on inappropriate harvest models, etc. In addition, by coupling harvest rates to actual population trajectory relative to pre-set objectives we may be less likely to induce population declines from which herds cannot recover (Caughley 1977).

If a tracking harvest strategy were implimented the essential elements of a management program would be 1) a method of determining population trends, 2) knowledge of the distribution and magnitude of the harvest and 3) establishment of minimum population objectives. Results of this study indicate that aerial trend counts may be adequate to monitor trends. Mandatory harvest reporting can fulfill the second need. Population objectives must be based on improved knowledge of the magnitude and causes of long-term population fluctuations, distribution, amount and productivity of habitat, and the impact of changing access and hunter harvest patterns as development encroaches on currently remote goat populations. It appears appropriate for biologists in coastal regions to concentrate their efforts along these lines, rather than to continue to search for a set of variable sex and age parameters for use in simulation models which will not, in any case, provide a clearer indication of how to go about managing mountain goats in this portion of their range.

ACKNOWLEDGEMENT

Although several biologist collected the data presented in this report, the vast majority was gathered by Robert Wood, Area Management Biologist in Ketchikan from 1971 to the present time. In addition to providing data, Bob participated in discussions which were helpful in refining the ideas presented here. Mr. R. D. Hamlin was the pilot for all survey flights since 1968 and his skill and persistence is largely responsible for the quality of the results. S. D. Miller, R. Flynn, B. Dinneford and D. McKnight reviewed an earlier draft and made several helpful comments. Last, but far from least, I acknowledge the patience and professional performance of Ms. Jennifer Owens who handled numerous re-writes without benefit of a word processor, and without loosing her sense of humor.

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EXCESS RAM MORTALITY IN A HEAVILY HUNTED DALL SHEEP POPULATION

WAYNE E. HEIMER, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701

SARAH M. WATSON, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701

T. C. SMITH III, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701*

ABSTRACT

The basic assumption underlying management of Dall sheep (Ovis dalli dalli) for maximum hunting opportunity and maximum sustainable ram harvest is that heavy harvest of legal (3/4 or 7/8 curl) rams has no effect on the survival of sublegal rams. This assumption was tested by studying Dall ram mortality in a heavily hunted population in interior Alaska. Between 1969 and 1971, 23 legal (at 3/4 curl) and 93 sublegal rams ranging in age from 1 through 5 years were trapped and marked. The population was then monitored through 1983 by aerial survey, hunter reports, ground survey, and mineral lick observation. When marked individuals were no longer observed, they were presumed dead. The age at last observation was recorded as the age at death. A life table for rams which were not killed by hunters was constructed and their survival was compared with that of unhunted rams in McKinley Park, 64 km (40 miles) to the east. Slope of survivorship curves for unhunted rams was nearly indentical to that of the heavily hunted population. However, the age at which increased mortality became evident shifted downward from about 8 years in the unhunted group to about 3 years in the heavily hunted population. This finding indicates the assumptions underlying most ram management are not correct and suggests reevaluation of management philosophy. A behavioral mechanism and a more productive management approach are suggested.

INTRODUCTION

Regulation of mountain sheep hunting throughout North America usually limits harvest to rams in the upper age classes. This practice has been widely applied by wildlife managers because it is presumed to offer maximum opportunity to harvest mountain sheep while providing a horn size acceptable to most hunters.

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*Current Address: P.O. Box 12, Nachez, WA 98937

The underlying assumption of this management scheme is that heavy or even total cropping of rams at 3/4 curl provides the maximum harvest of acceptable trophies. After all, common sense tells us the number of rams in a cohort is highest at birth, after which natural mortality begins to reduce numbers in each cohort. Hence, the highest possible harvest would be immediately following birth, and harvests at later dates would be progressively lower because some individuals had succumbed to environmental resistance along the way. This is correct only if the basic assumption is valid.

Stated in greater detail, the major assumption predicts heavy harvest of legal rams (traditionally 3/4 curl) has little or no effect on the survival of sublegal rams. This assumption has come under increasing scrutiny as more has been learned about mountain sheep behavior. Still, it survives without experimental demonstration. In this paper we report on a test of this basic assumption and its relevance to traditional management of wild sheep in Alaska.

MATERIALS AND METHODS

Twenty-three legal (3/4 curl or greater) and 93 sublegal rams (about 35-40% of the ram population) were trapped and marked in the Dry Creek area of the eastern Alaska Range in 1969, 1970, and 1971. Dry Creek was heavily hunted, and legal, 3/4 curl or greater, rams composed only 3% of the population. Rams were captured at a mineral lick during early summer with a drop net (Erickson 1970) as part of a larger study of Dall sheep movements, mineral lick use, and ewe mortality in the Alaska Range (Heimer 1974). Forty-seven rams were marked with metal eartags in both ears and large canvas neckbands. Thirty-eight rams were marked with rope and pendant collars and plastic and metal eartags. Thirty-three rams were marked with plastic and metal eartags, but no collar.

Marked rams were repeatedly sighted from aircraft. Frequent flights were made to search for these sheep, and to assess their home ranges (Heimer 1974). Marked rams were also repeatedly sighted by investigators on 5 foot trips throughout the area each year. These trips were made during all seasons of the year to enhance resolution of data gathered from aircraft. Marked rams of legal size were available to hunters, and hunters and guides were made aware of the necessity of reporting sightings. Hunters taking legal, marked rams were also required to report their kills to the Alaska Department of Fish and Game. Mineral licks were monitored each year and marked sheep were observed as they returned to the mineral lick each year. The observed return rate for rams (80%) was found to be lower than that for ewes (98%). Heimer (1974) interpreted this as a genuine lack of fidelity to home ranges by rams. However, results of this study suggest it may have been an artifact of mortality. Other mineral licks in the area were also monitored in the course of foot searches for collared rams. Records were kept of all resightings and hunter kills through 1983, the year in which the youngest rams marked would have been 12 years of age.

Mortality of marked rams was determined from harvest reports and failure to resight rams for an entire year. Rams were presumed dead if not sighted for 2 years, and age at death was listed as their age at last observation. Sixteen 1- and 2-year-old rams marked in 1970 and never resighted were deleted from the sample because winter 1970-71 was very severe, and many rams of these age classes probably died during that severe winter. A life table was then constructed for the remaining 100 rams and compared with a similarly constructed life table for rams in an unhunted population. Unhunted population data used were those reported by Murie (1944) form Mt. McKinley National Park 68 km (40 mi) to the east. Once life tables were constructed, the survivorship curve (lx) for each population was plotted. Equations describing the increased mortality phase of each curve (Geist 1971:295) were established by linear least squares fit.

RESULTS

Hunters killed 10 of the 23 rams that were legal when marked: 5 were killed in the first hunting season after they were marked, and 5 during the next hunting season. Of the other 13 legal rams, 1 was found dead of natural causes 2 months after capture; the rest were never seen again. These 12 rams were not reported killed by hunters. They were never found in broad aerial searches of adjacent habitat. They are presumed to have suffered early, natural mortality. Their mean age at capture was 6 years and their mean age when last sighted--at presumed death--was 7.5 years. The known harvest rate of legal rams in the population was 43% (10 of 23 in the marked sample).

Hunters reported killing an additonal 12 marked rams which grew from sublegal to legal size during the study. When harvested, these rams had survived a mean of 5.3 years since being marked

The realized harvest was 16% of the sublegal marked sample. The ages and rate at which the 77 rams not killed by hunters disappeared (or died) are shown in Table 1.

Table 1. Life table for rams disappearing from the observable Dry Creek populations from 1969 to 1982.

Age at death (presumed)	Frequency in sample	Cumulative frequency	% survival of 1,000	% mortality of 1,000	No. alive of 1,000
0	--	135	--	--	1,000
1	2	77	0.570a	0.430	570
2	1	75	0.974	0.026	555
3	9	74	0.987	0.013	548
4	18	65	0.878	0.122	481
5	11	47	0.723	0.277	348
6	14	36	0.766	0.234	266
7	10	22	0.611	0.389	162
8	9	12	0.546	0.454	88
9	3	3	0.250	0.750	22

a 57% was the mean survival from lamb to yearling age in Dry Creek during the study.

DISCUSSION

The life tables for the Dry Creek (Table 1) and McKinley Park (Table 2) populations were compared to test the hypothesis that removal of most 3/4 curl and larger rams has no effect on survival of the remaining sublegal rams. The survivorship curves generated from these life tables show that accelerated mortality of McKinley Park rams begins at about age 8. It is described by the equation, $y = -92X + 1232$. The comparable equation for estimated mortality in Dry Creek rams is $y = -91X + 818$, with the rapid mortality phase beginning at about 3 years of age. This is 5 years earlier than for the unhunted population. The only difference in the survivorship curves for the 2 groups of rams is the age at which increased mortality begins. Young rams in the heavily hunted population exhibit a mortality pattern characteristic of older rams in the unhunted group.

Since data for lamb production and survival are not available from Murie's collections we applied the mean lamb survival (57%) observed between 1972 and 1982 in the Dry Creek study populations to the McKinley National Park data to make the plots comparable. Comparative observations of production and recruitment ratios for the last 10 years indicate these 2 populations are comparable (Heimer, unpubl. data).

The mortality among young Dry Creek rams is about 5 times greater than for ewes of the same ages. Heimer (1973) reported a mean mortality rate of marked ewes younger than 9 years of 7%; once ewes reached age 9 this increased to 50%. The mean mortality rate for marked rams 3 to 9 years of age averaged 37%. In light of these findings an earlier suggestion that ram fidelity to mineral licks is less than that of ewes (Heimer 1974) should be reexamined.

We think the observed differences in mortality patterns result from changes in behavior due to lack of large rams in the Dry Creek population. When socially dominant rams are removed from the population by hunters, younger rams assume the roles of dominant rams and exhibit adult behavior patterns (Geist 1971, Nichols 1971). This places additional energetic stress on young rams before they are physically and behaviorally mature. Geist (1971:349) concluded, "One effect of neoteny is a postpuberal maturation period of 5 to 6 years for rams in which they increase in body and horn size and mature in social behavior." "Promotion" of young rams (which are just entering this period of postpuberal development) by removal of their inhibitory social dominants leads to behavior which apparently increases mortality in young rams just as it does in older rams. We think evidence indicates the presence of a mortality cost associated with social dominance that is independent of age.

These findings show the underlying assumption implicit in mountain sheep management is incorrect. The alternate hypothesis, that social disruption caused by heavy ram hunting significantly reduces survival of the remaining sublegal rams, is consistent with behavioral analysis (Geist 1971) and our data. Managers seeking to provide maximum hunting opportunity through maximum harvest levels should consider the potential advantages afforded by setting legal definitions to select

Table 2. Life table for Dall rams from McKinley Park from Murie 1944.

Age	Frequency in sample (No. skulls)	Cumulative frequency	% survival of 1,000	% mortality of 1,000	No. alive of 1,000
0	--	547[a]	--	--	1,000
1	--	312[b]	0.570	0.430	570
2	5	305	0.978	0.022	557
3	6	300	0.984	0.016	549
4	7	294	0.980	0.020	538
5	8	287	0.976	0.024	524
6	8	279	0.972	0.028	510
7	17	271	0.971	0.029	495
8	26	254	0.937	0.063	464
9	37	228	0.898	0.102	417
10	52	191	0.838	0.162	349
11	75	139	0.727	0.273	253
12	60	64	0.460	0.540	117
13	1	4	0.063	0.937	7
14	3	3	0.750	0.250	5

[a] Calculated from mean survival in Dry Creek from 1972-82.

[b] From findings of Bradley and Baker (1967), Hoefs (1979), and Geist (1971) which show mean survival between years 1 and 2 equals that between ages 2 and 7 years.

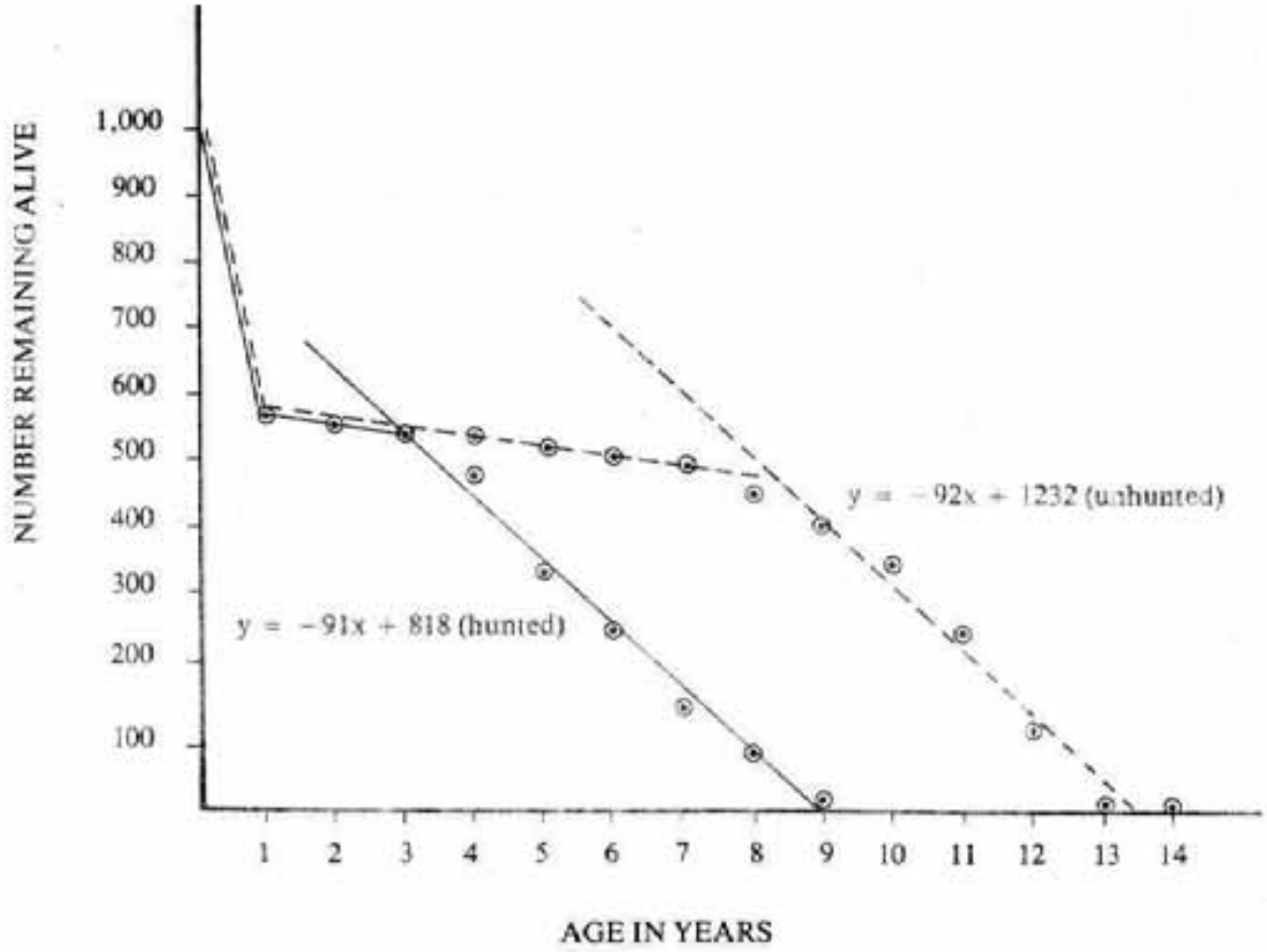

Fig. 1. Survival of Dall Rams in the heavily hunted (Dry Creek) and unhunted (Mt. McKinley Park) sheep populations.

for older rams. This may decrease mortality among young rams and provide for increased ram harvest without adverse effects. Heimer (in prep.) details arguments that show such apparently "conservative" management approaches should increase harvest levels. This has already occurred in southern British Columbia where establishment of a full-curl or 8-year-old legal definition in 1976 was followed by increased harvests (DeMarchi, pers. commun.).

We have suggested a major departure from established sheep harvest management. We believe the data are sufficiently compelling that experiments with changes in harvest regime are in order. Still, we realize that much of what we have offered may be equivocal. Most criticism should be directed at our use of presumptive death when we could no longer locate marked rams. Cessation of resightings does not necessarily demonstrate a given ram is dead. He could have moved, or perhaps we were simply unable to locate him. It is most unlikely that marked individuals moved. All rams located were loyal to established ranges. Furthermore, hunting pressure was very high throughout the entire eastern Alaska Range during the study. Legal rams composed only 3% of a much larger population than that residing in the Dry Creek study area. Virtually all legal rams were being taken from areas up to 40 km on either side of this study area. Still, no marked rams were reported taken by hunters from areas outside of the defined home ranges.

Hunters reported killing only 22 of the 100 potentially available rams. This is less than half of the expected harvest given the observed harvest rate for legal rams in the marked sample. If this light level of harvest really occurred, horn size should have risen dramatically. It didn't. Old rams continued to be scarce in the population through the end of the study period. The remaining explanation is that hunters killed collared rams and did not report them. We find it inconceivable that only half of the successful hunters taking marked rams reported. All hunters who reported were very interested in the study. Some were negative about having shot a marked ram, but no one was disinterested. It is unlikely that marked rams were killed in large numbers and not reported.

We think these alternate explanations are so unlikely that "premature death" is a much more reasonable conclusion. At the very least, these data are sufficient to warrant further investigation of the effects of heavy hunting on survival of postpuberal rams. At most, they indicate that management philosophy should change and that legal definitions relevant to management of rams for maximum harvest and hunting opportunity should be realigned.

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COMPARISON BETWEEN A HUNTED AND AN UNHUNTED DALL SHEEP POPULATION

-A PRELIMINARY ASSESSMENT OF THE IMPACT OF HUNTING-

Manfred Hoefs and Norman Barichello, Yukon Wildlife Branch, P.O. Box 2703, Whitehorse, Yukon Canada

ABSTRACT

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

INTRODUCTION

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

nature of hunter harvest or on the long-term impact on a population through the constant removal of rams with the best developed horns.

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

Specifically this analysis was meant to address the following topics:

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

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

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

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

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

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

METHODS AND MATERIALS

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

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

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

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

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

STUDY AREA

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

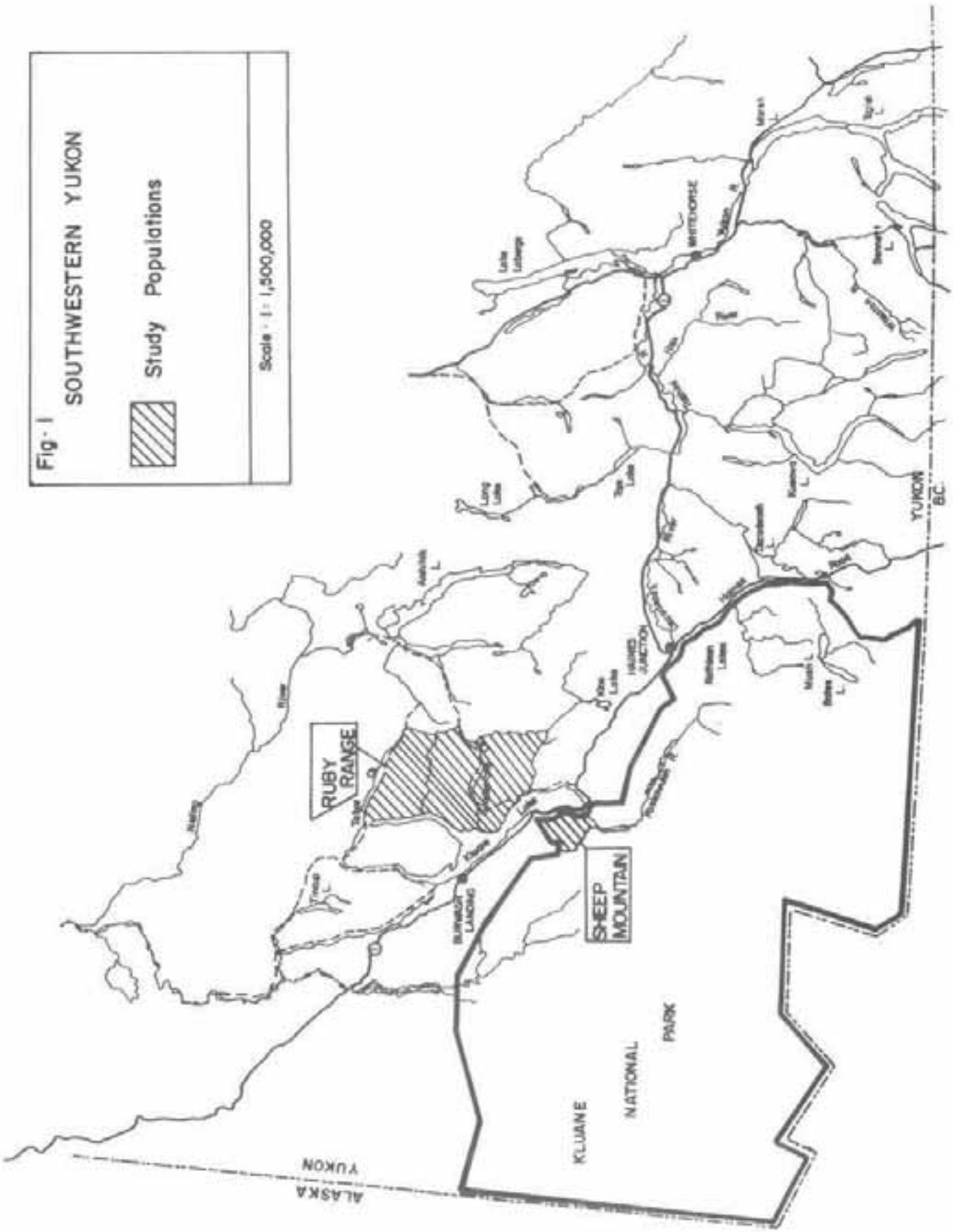


Fig. 1
SOUTHWESTERN YUKON
Study Populations
Scale - 1 : 1,500,000
RUBY RANGE
SHEEP MOUNTAIN
KLUANE
NATIONAL
PARK
ALASKA
YUKON
YUKON
B.C.
WHITEHORSE
BURWASH LANDING
HAINES JUNCTION

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

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

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

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

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

RESULTS

A. Demographic parameters

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

B. Hunting

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

C. Comparison of natural and hunter caused mortality patterns

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

Table: 1 COMPARISON OF POPULATION STATISTICS

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

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

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

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

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

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

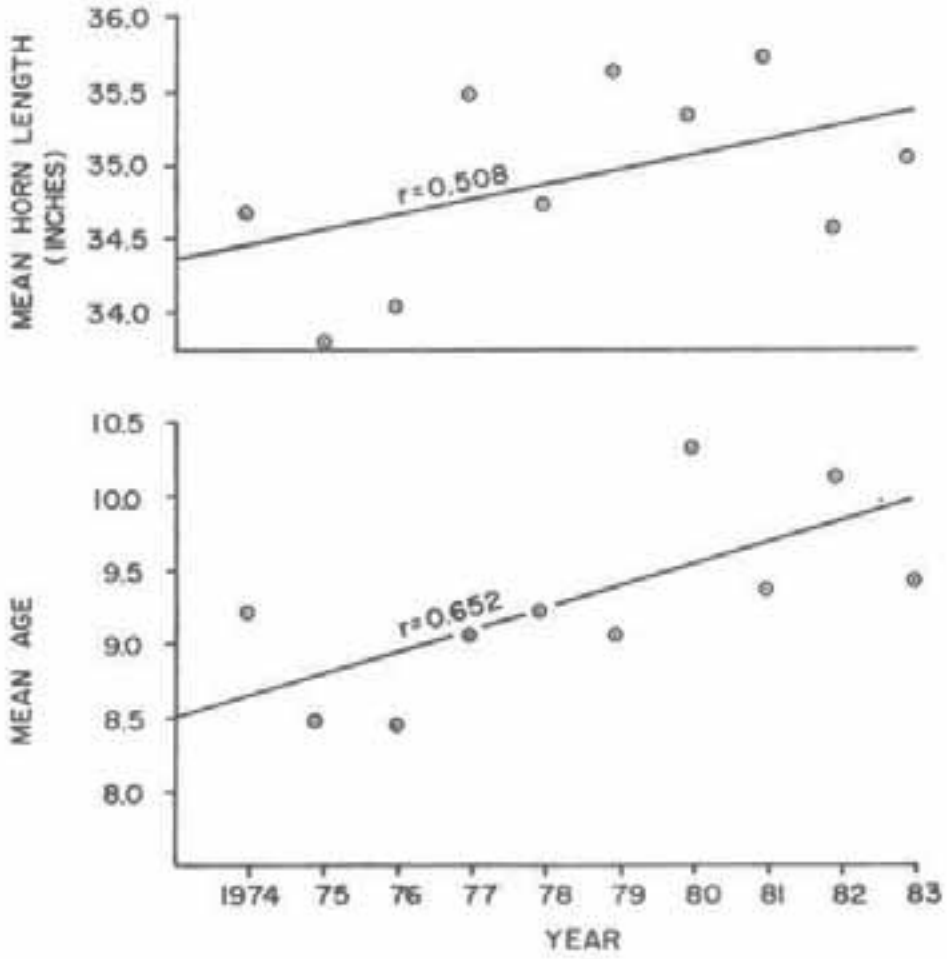
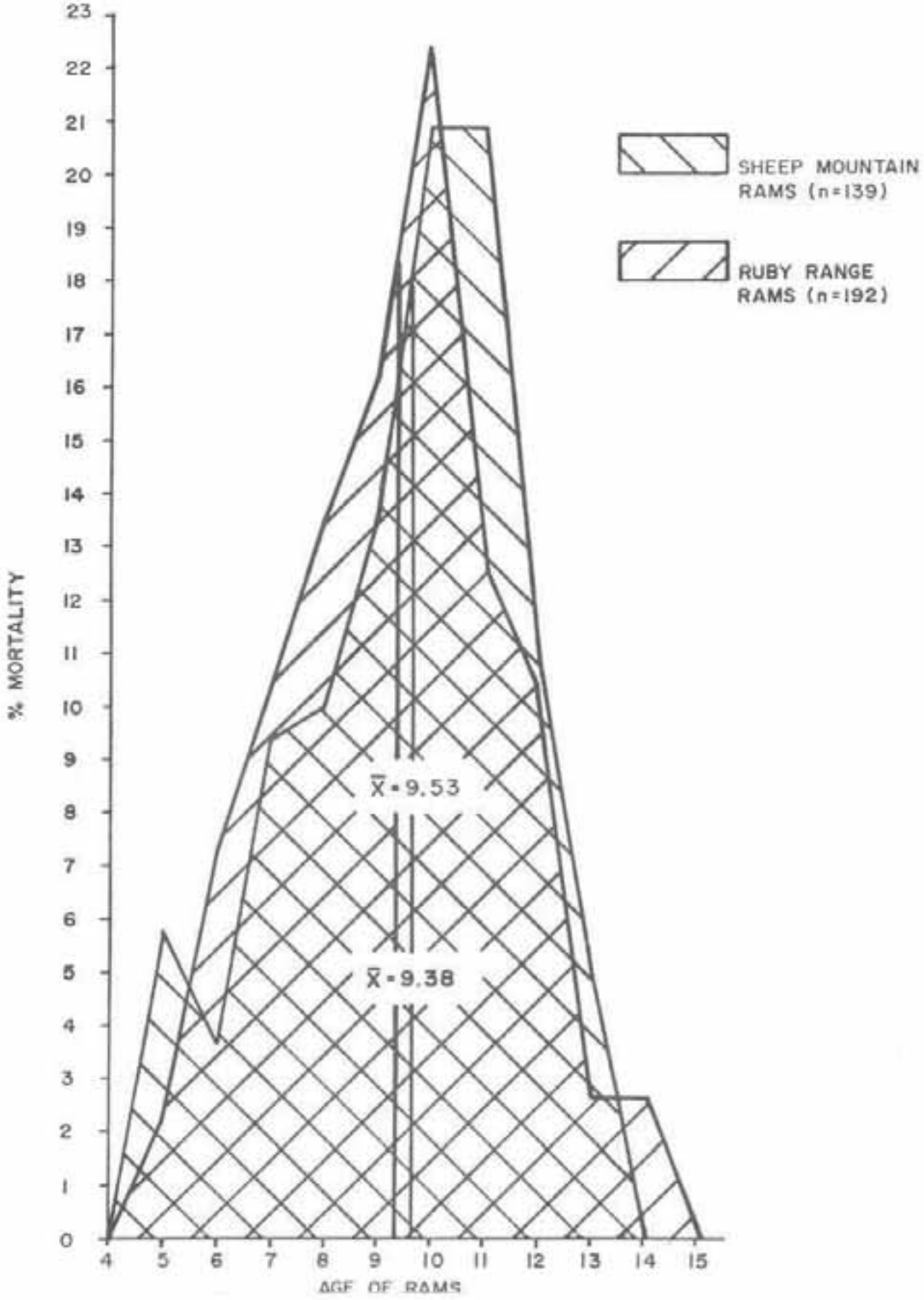


FIG. 3 COMPARISON OF NATURAL AND HUNTER-CAUSED MORTALITY PATTERNS



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

D. Horn growth parameters

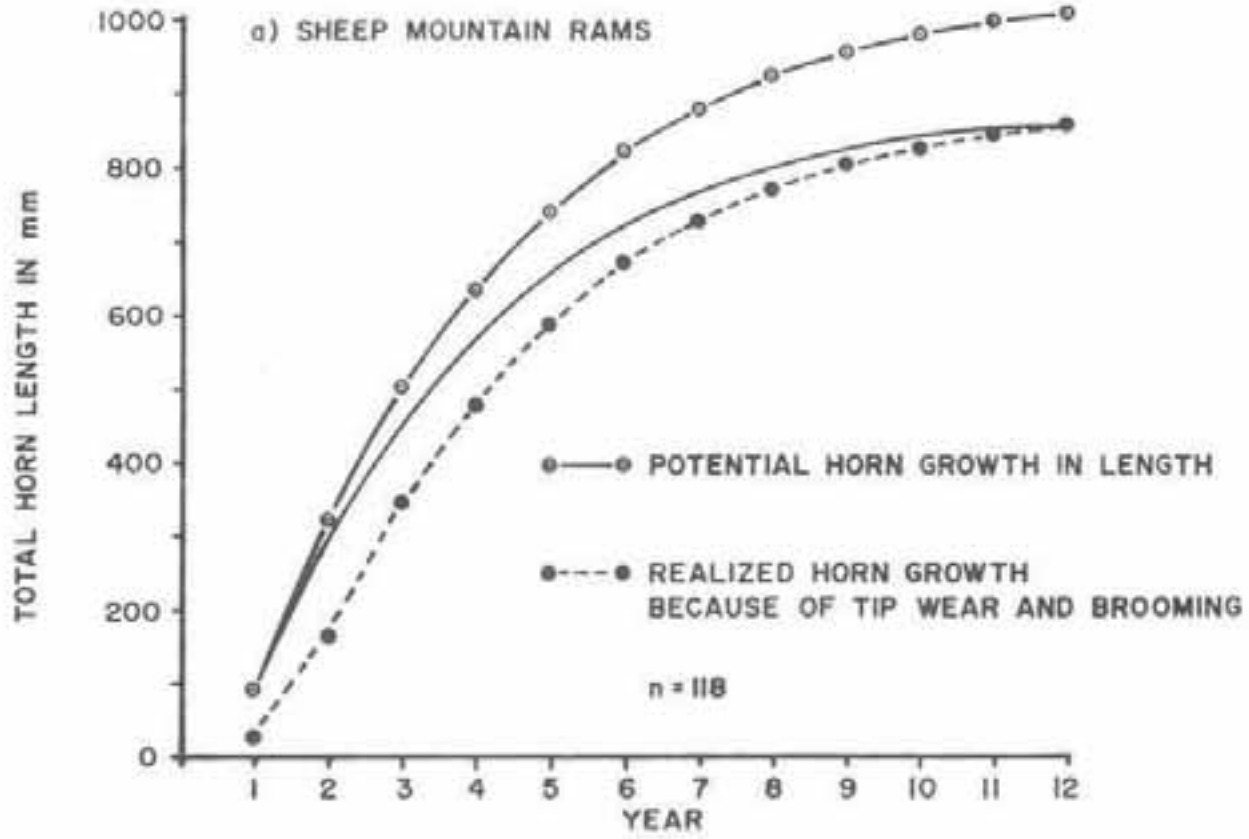
When comparing horn growth characteristics among populations it is essential to point out how data were derived. Horns not only grow with age, they also wear down with age (Hoefs and Nette 1982). Considerable differences exist between population in horn wear rate and brooming, and lack of recognition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

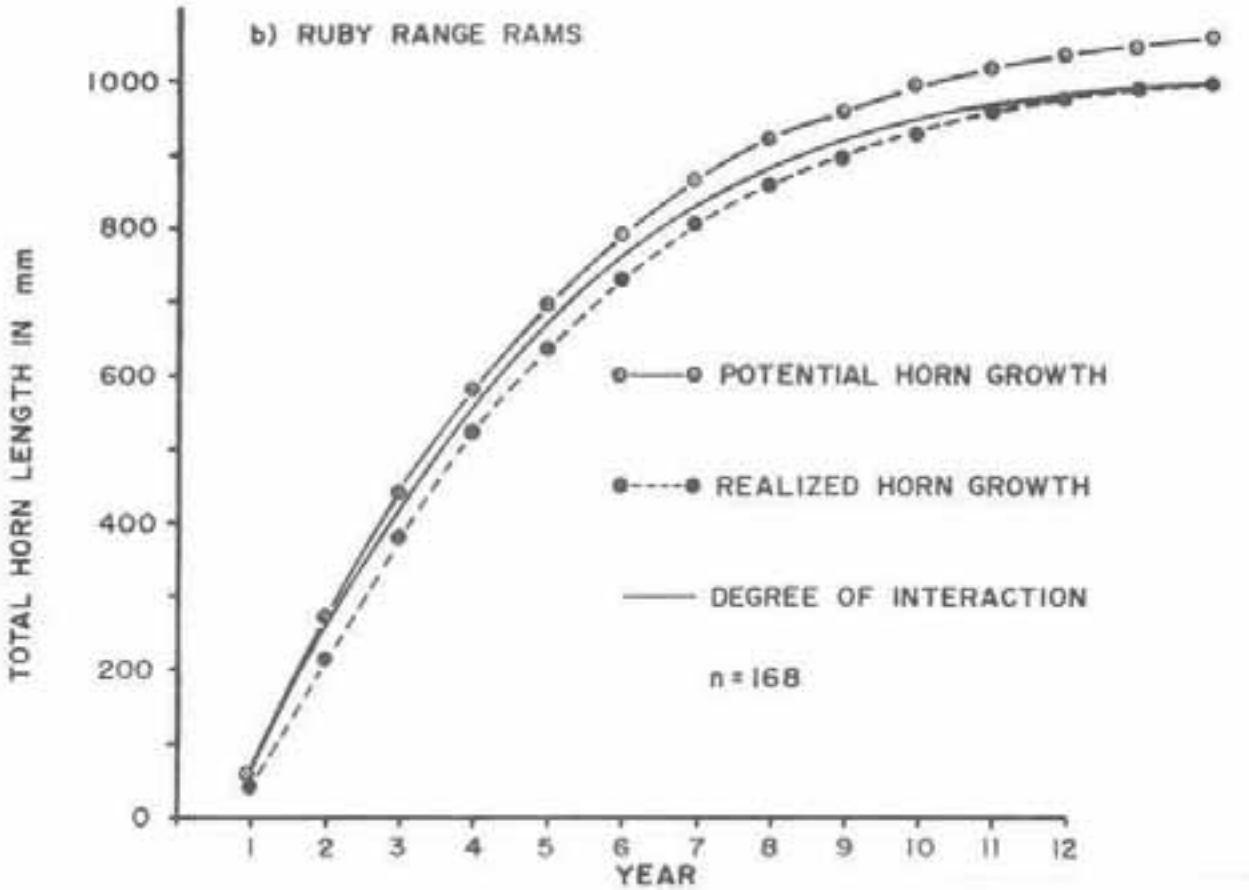
Figure 4 presents two types of horn growth curves, one referred to as "potential" horn growth and the other one as "realized" horn growth for each sheep population. "Realized" horn growth data are the ones usually found in the relevant literature. They treat annual increments that are affected by tip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

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

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

FIG. 4 POTENTIAL AND REALIZED HORN GROWTH IN DALL RAMS





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

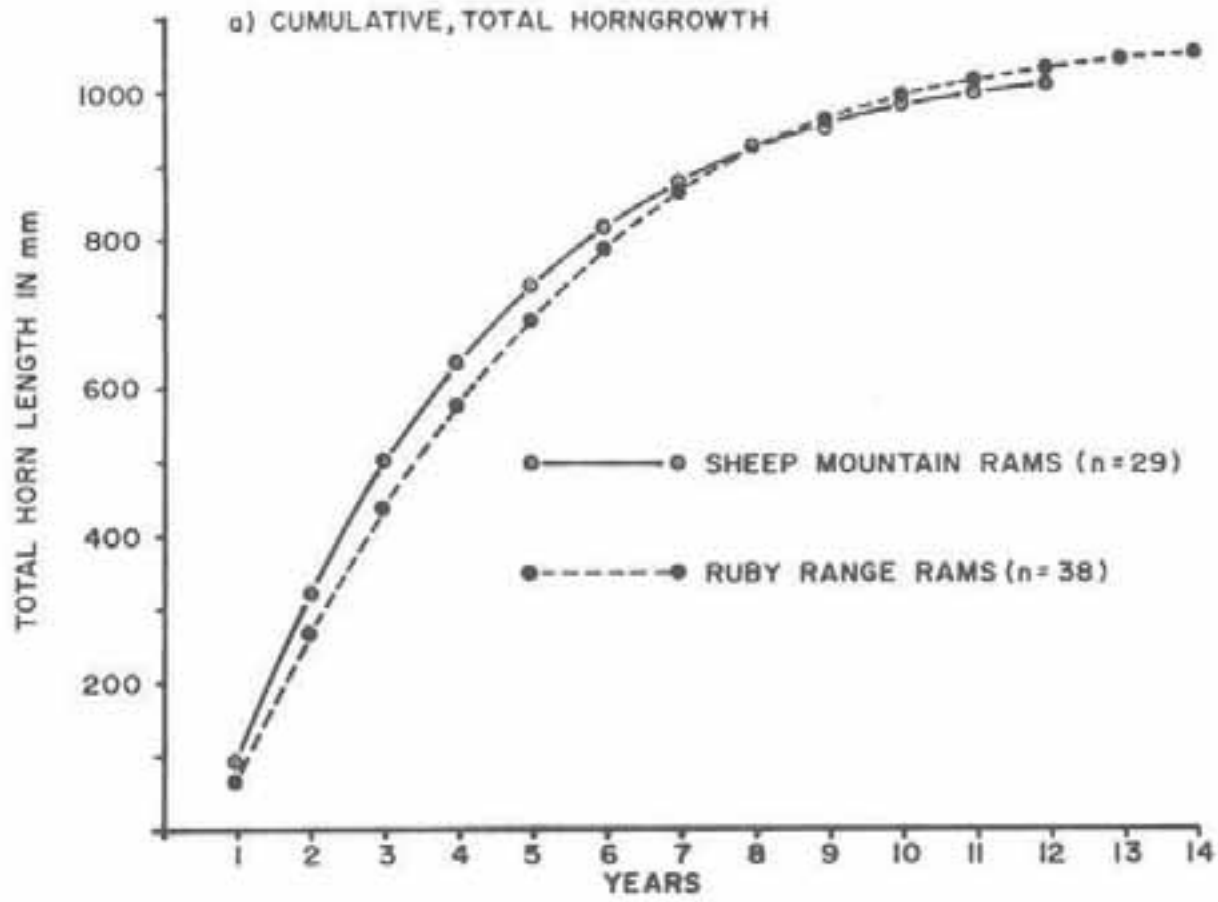
In Fig. 5 and Fig. 6 Sheep Mountain ram horn growth is compared to that of the Ruby Range rams, firstly in respect to potential horn growth and secondly in relation to realized horn growth, to demonstrate the concerns raised in relation to methods of assessment. Fig. 5 shows that the Sheep Mountain rams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

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

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

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

FIG. 5 COMPARISON OF POTENTIAL HORN GROWTH RATES



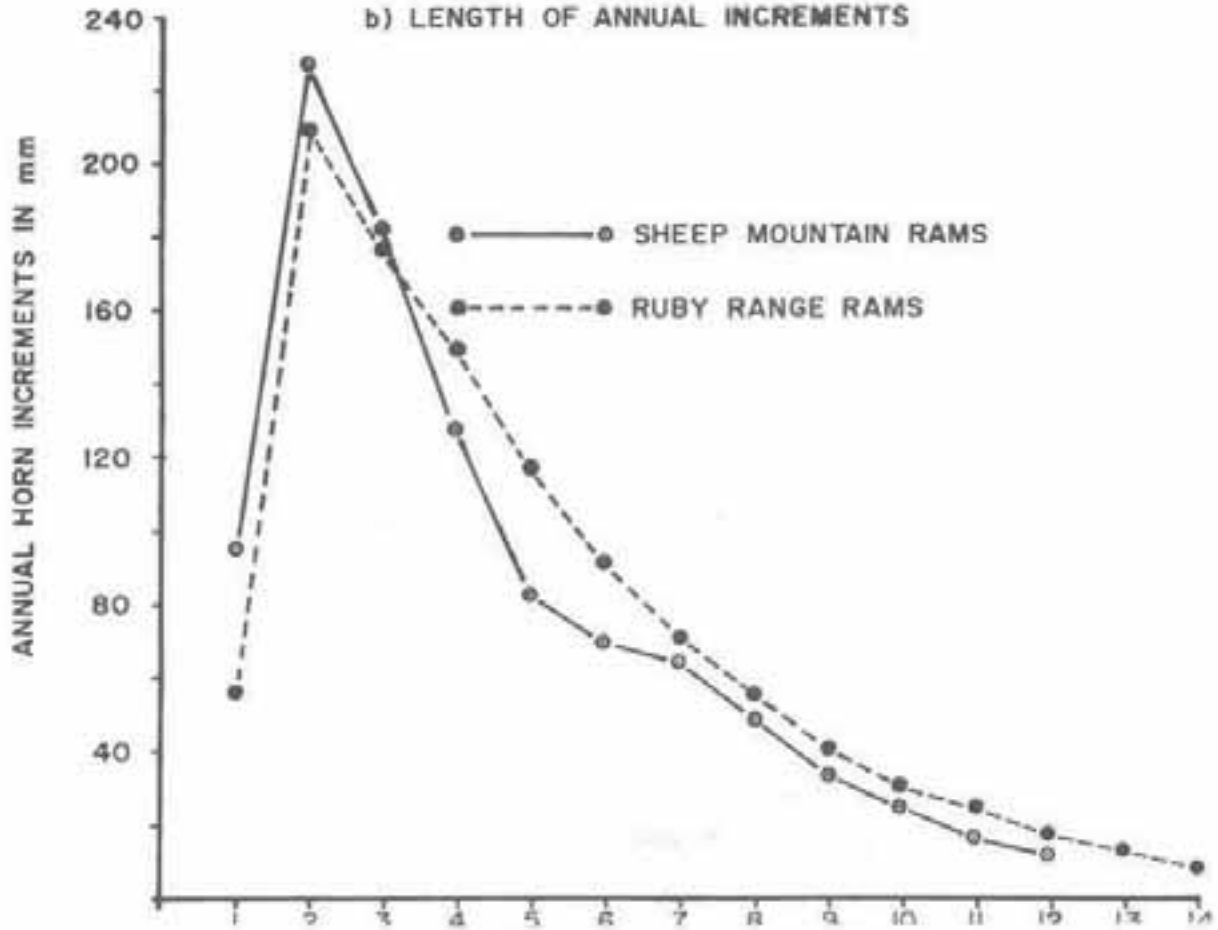
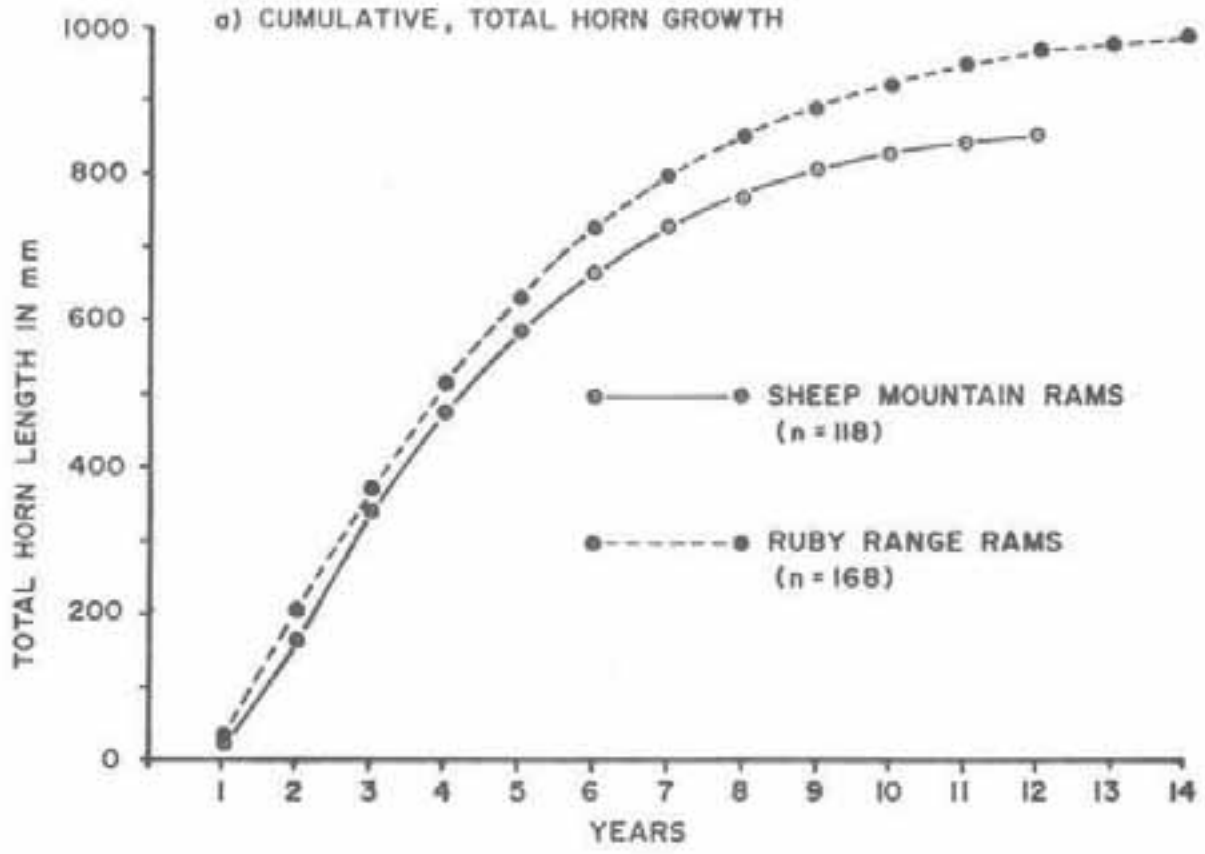
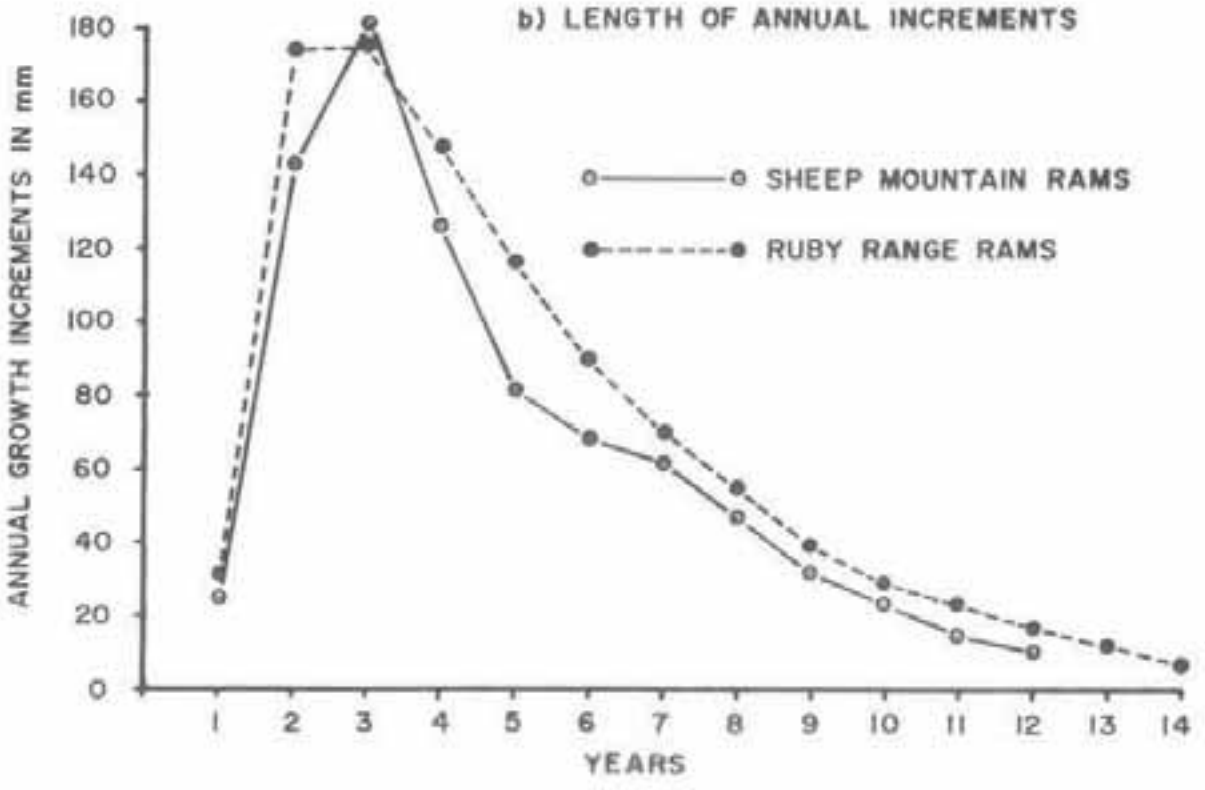


FIG. 6 COMPARISON OF REALIZED HORN GROWTH RATES





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

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

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

FIG. 7 COMPARISON OF HORN GROWTH IN CIRCUMFERENCE

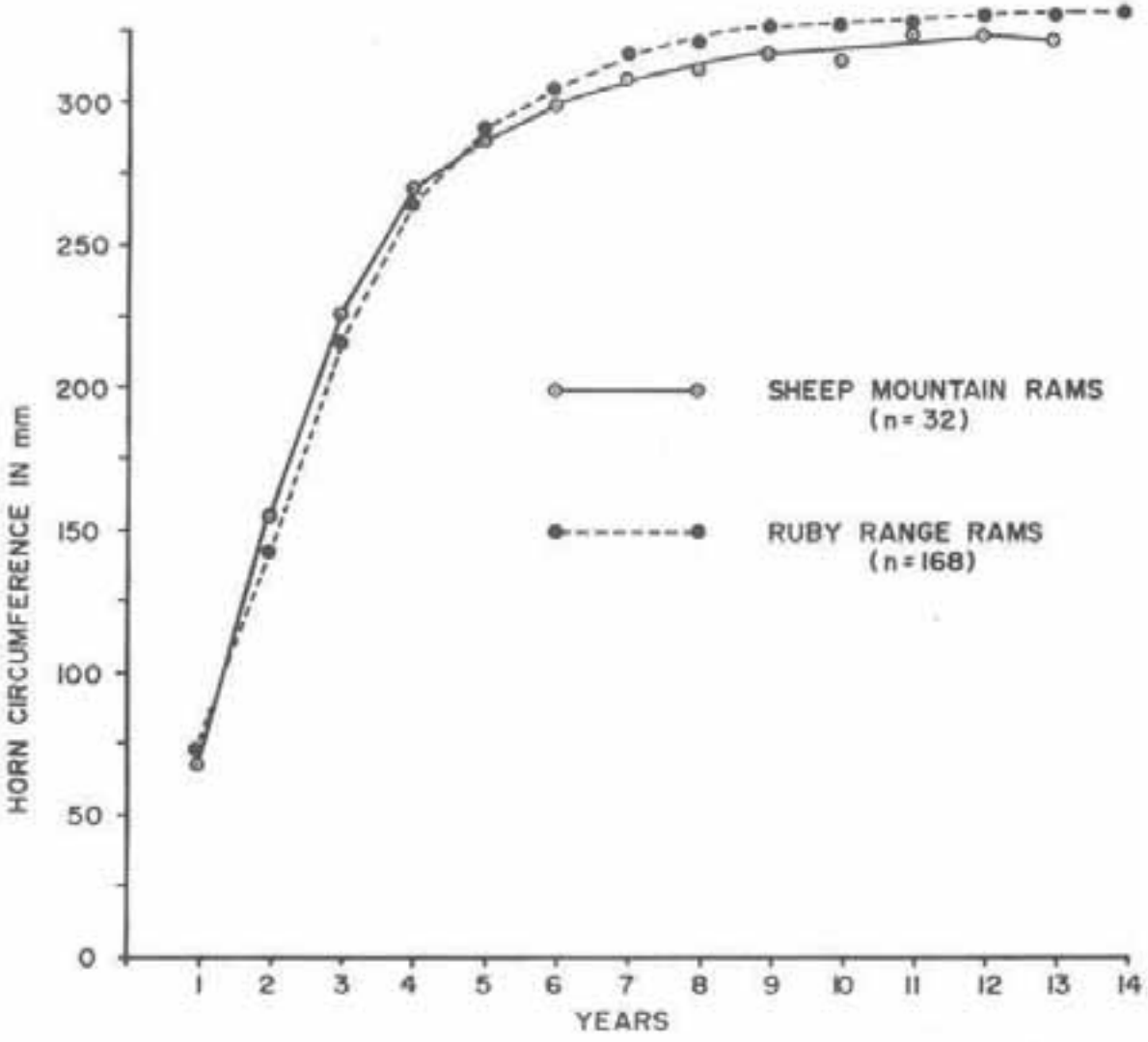


Table: 4 ASSESSMENT OF HORN TIP WEAR AND BROOMING

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

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

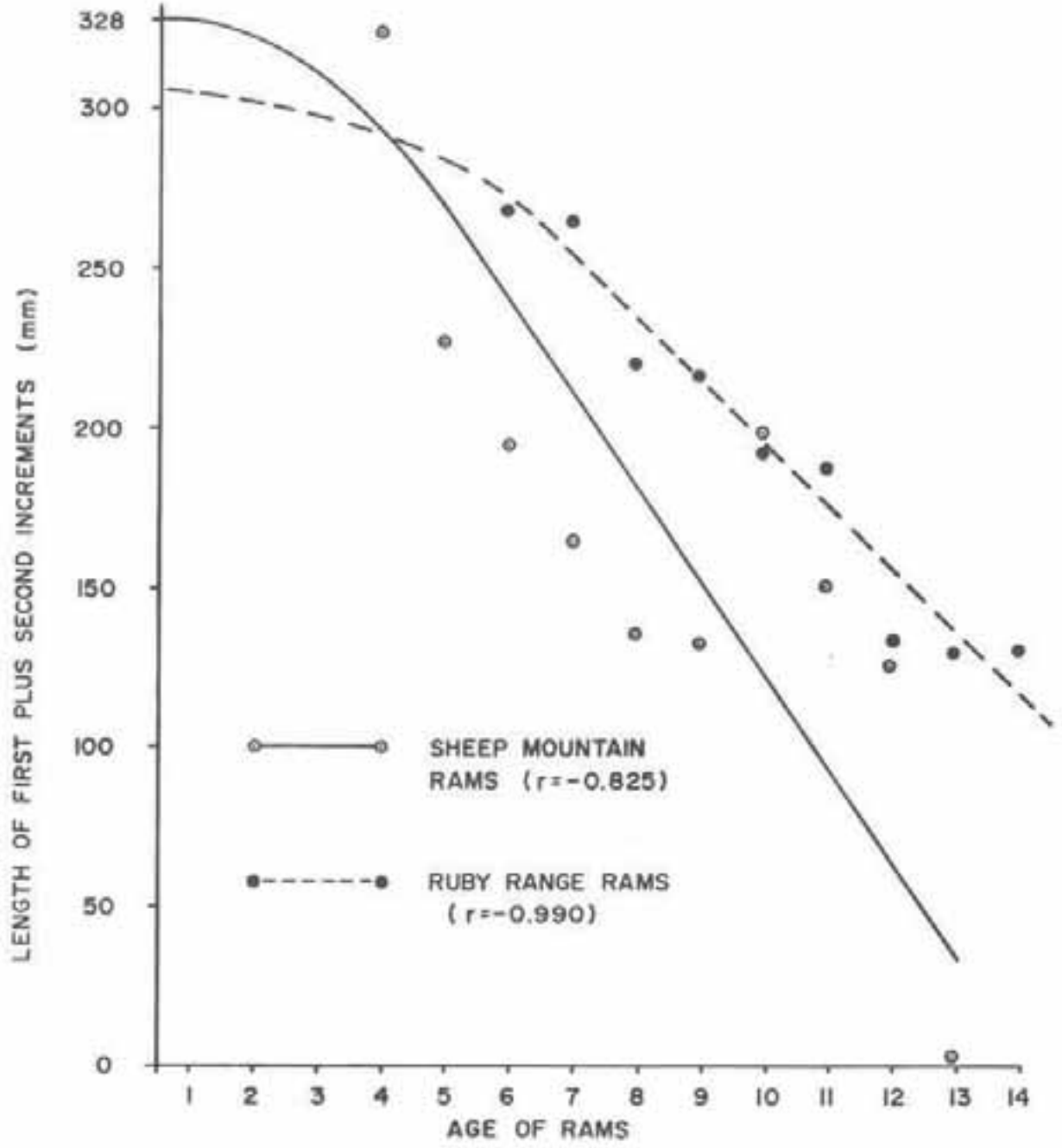
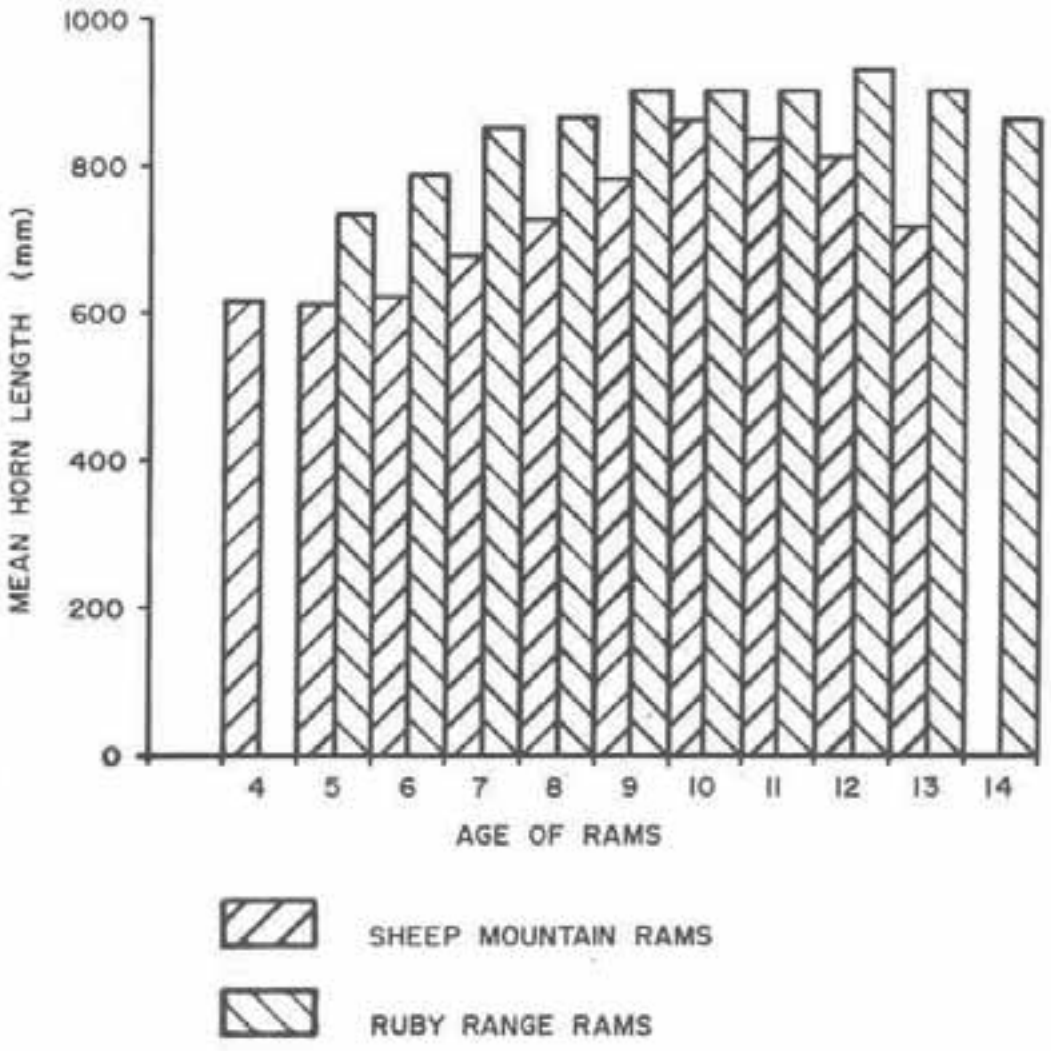


FIG. 9 MEAN HORN LENGTH OBTAINED BY RAMS ON SHEEP MOUNTAIN AND ON RUBY RANGE



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

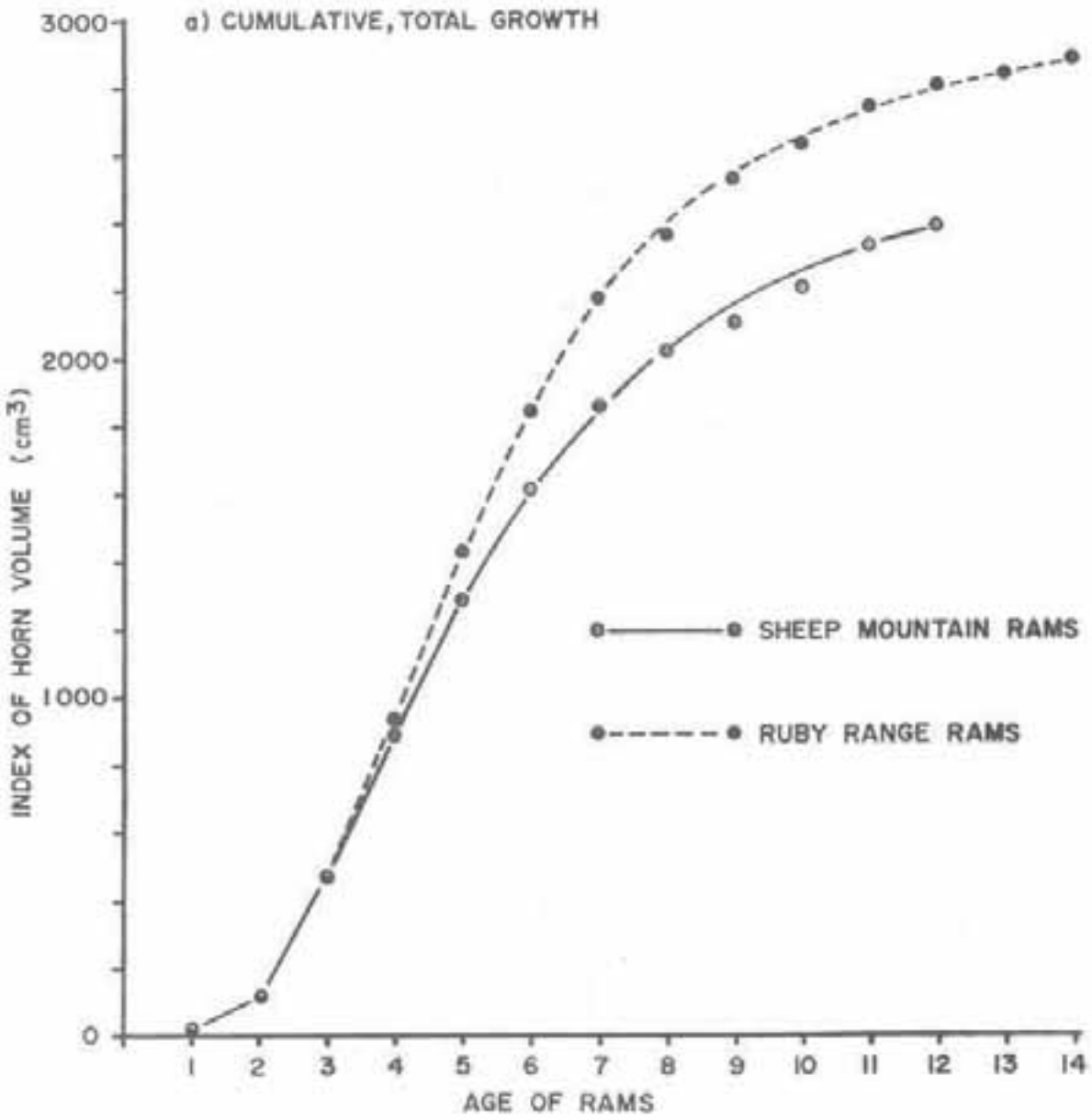
There are many advantages in assessing horn growth in volume. It more appropriately reflects accumulation of mass or tissue than either length or circumference measurements. However, volume determinations are difficult and few attempts have been made (Heimer and Smith 1975, König and Hoefs 1982, Stewart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

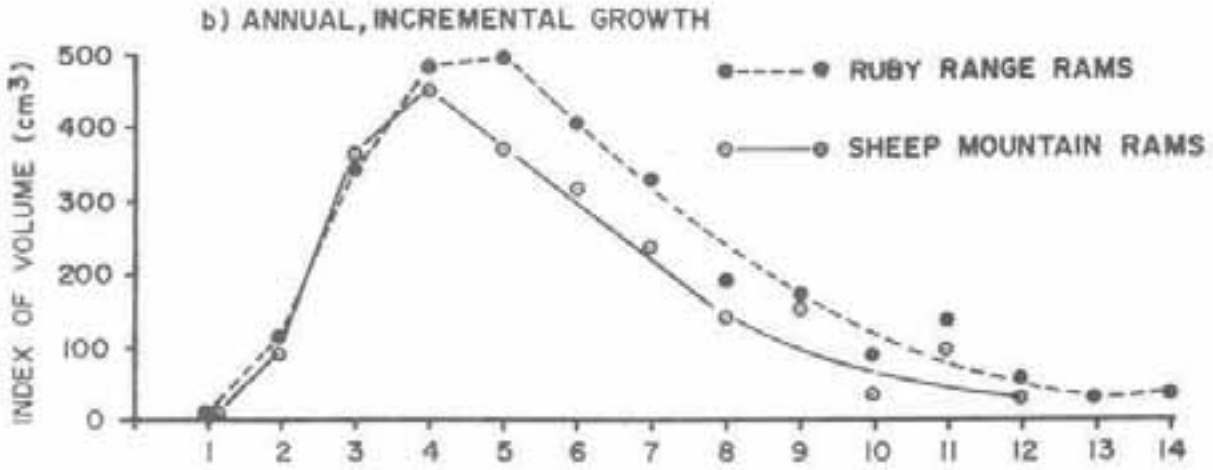
The possibility exists that the differences observed in horn parameters of these two populations may be a reflection of a biased sample. In the Sheep Mountain population the rams died from natural causes and all were included in the sample. Particularly in recent years, the skulls of most rams that died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

Table: 5 COMPARISONS OF HORN GROWTH PARAMETERS

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

FIG. 10 ESTIMATED HORN GROWTH IN VOLUME OF DALL RAMS





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

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

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

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

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

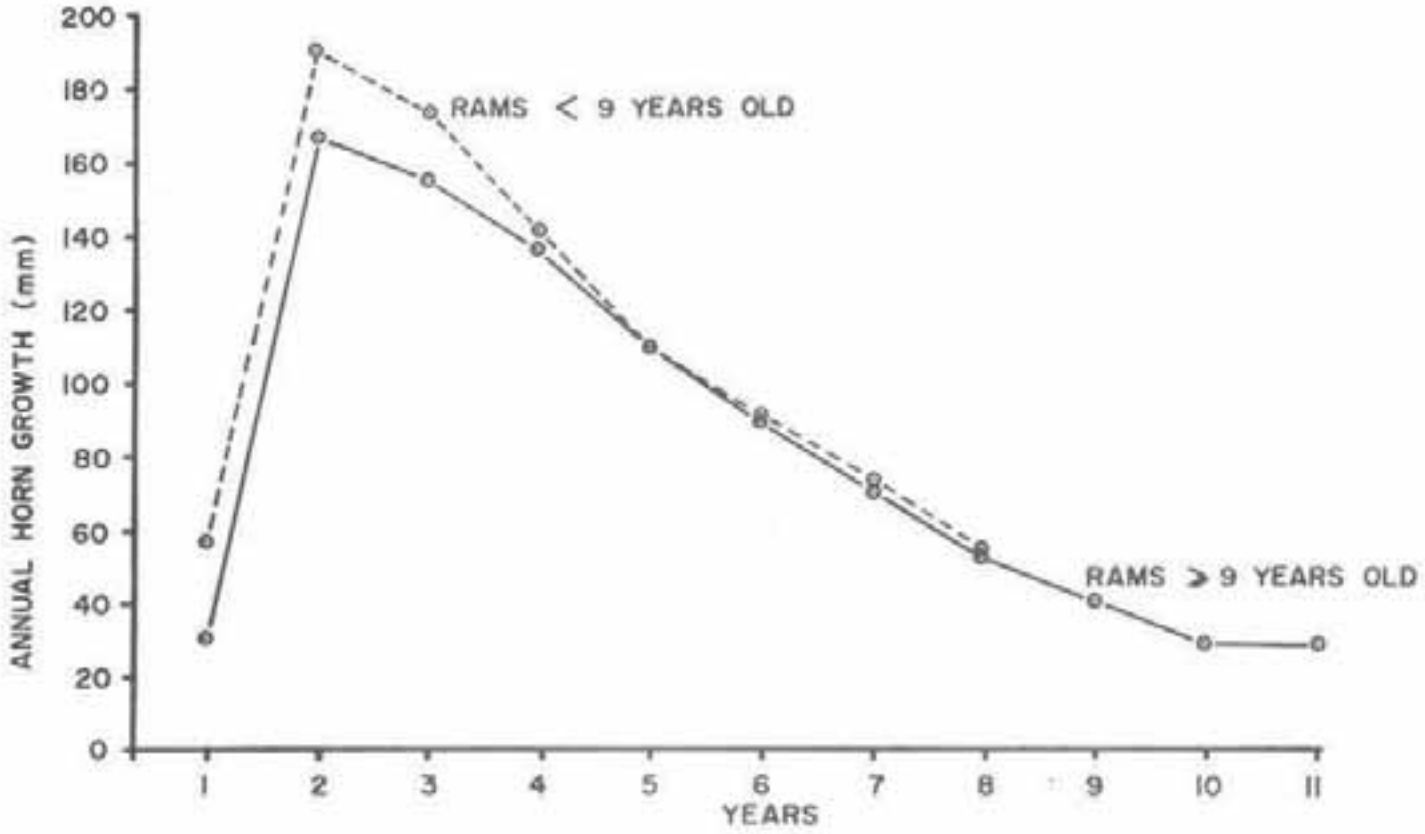
Table 6a Comparison of horn growth in length (mm) of rams shot before and after 9 years of age

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

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

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

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



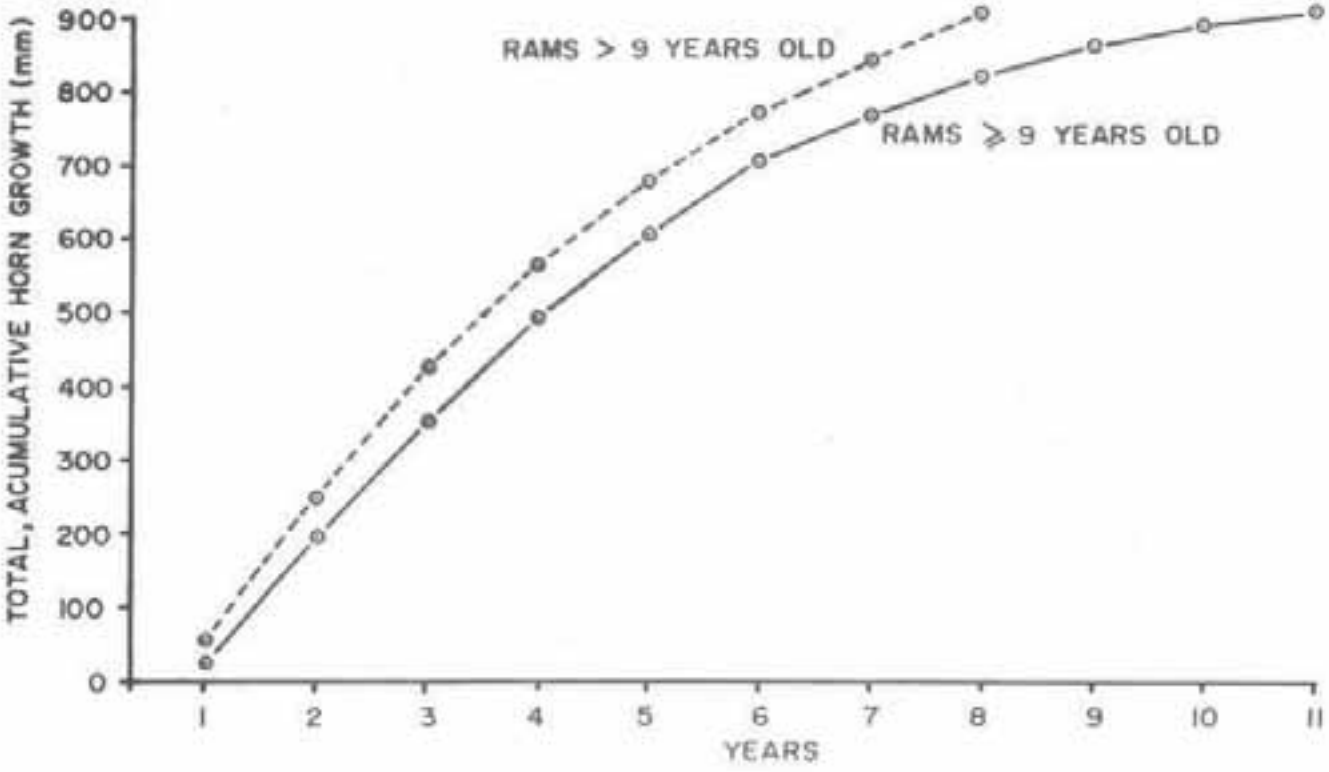


FIG. 12 DIFFERENCES IN HORNGROWTH RATES OF RAMS SHOT AT A GIVEN AGE COMPARED TO THOSE THAT LIVED LONGER

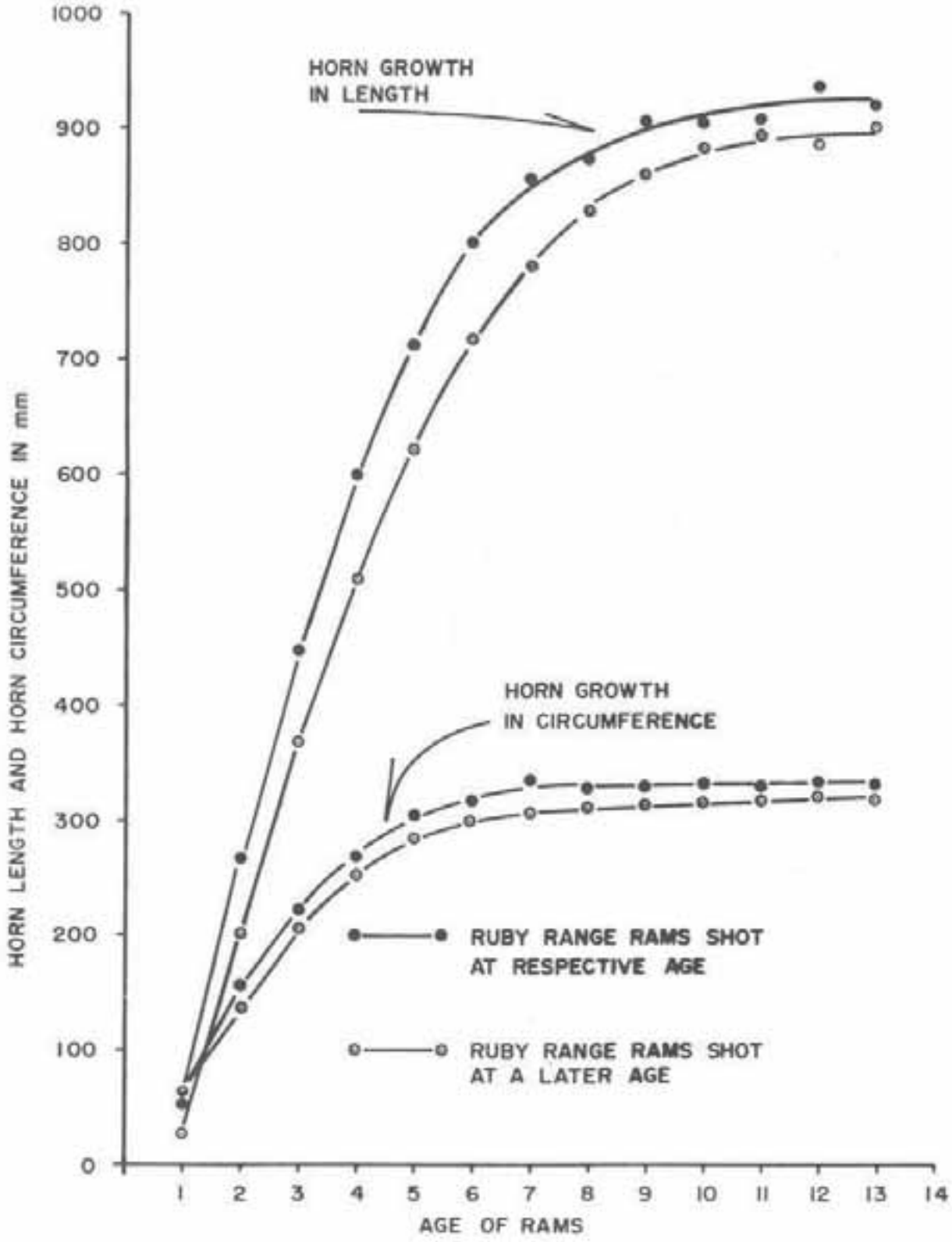


Table: 7a

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

CIRCUMFERENCE AT HORN ANNULI IN mm

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

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

Table: 7b

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

LENGTH OF ANNUAL HORN INCREMENT IN mm

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

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

Table: 8a

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

CIRCUMFERENCE AT HORN ANNULI IN mm

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

Table: 8b

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

LENGTH OF ANNUAL HORN INCREMENT IN mm

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

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

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

E. Assessment of population quality

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

SUMMARY AND CONCLUSION

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

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

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

Horn length (mm)

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

Horn circumference (mm)

1973-74									
$\bar{x}$	153.2	221.9	318.0	326.0	328.0	327.0			
1981-83									
$\bar{x}$	142.9	214.9	300.4	320.7	326.6	331.2			

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

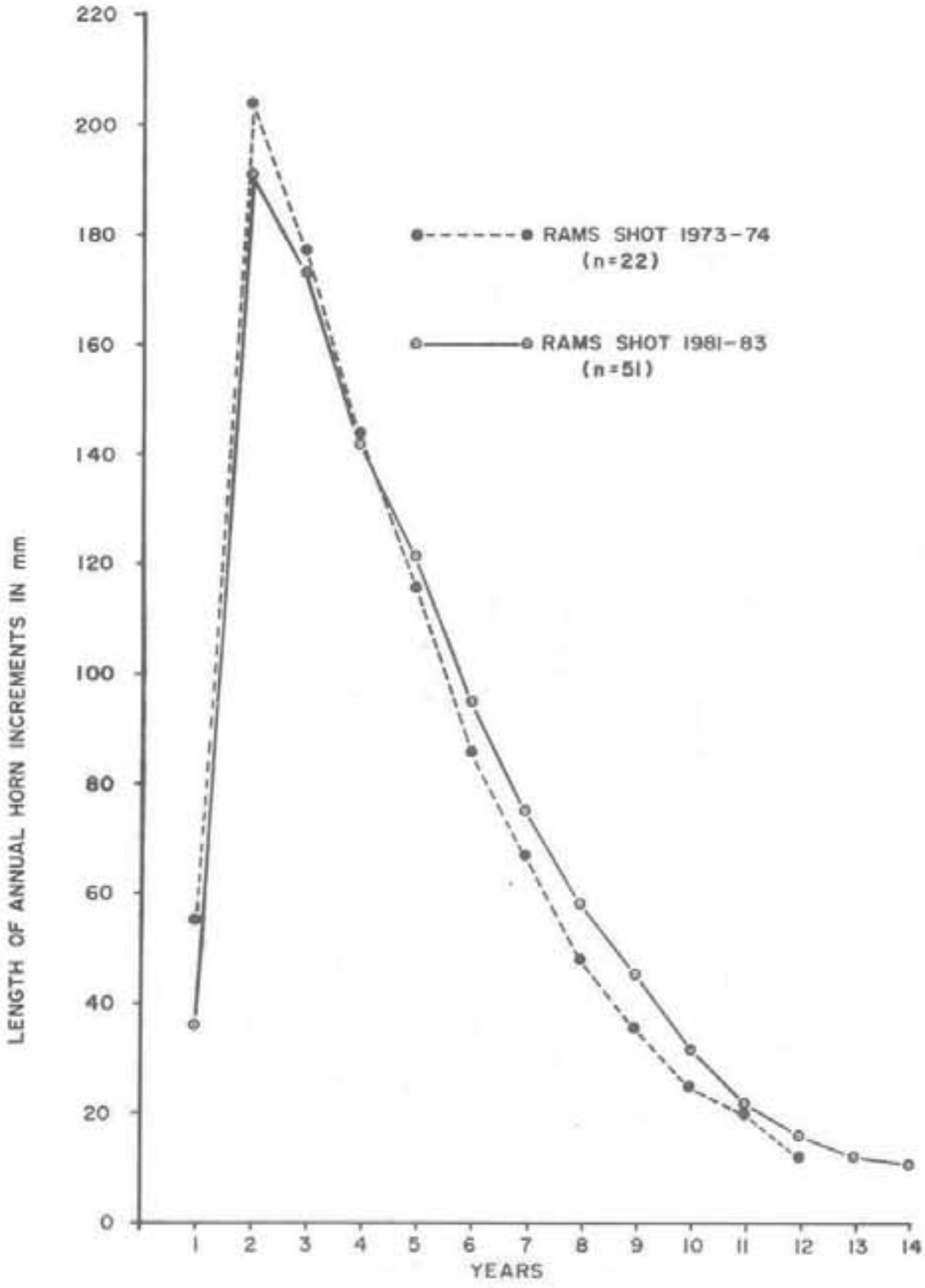


Table 10: Characteristics of population quality

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

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

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MOUNTAIN GOAT TRANSPLANTS IN ALASKA: RESTOCKING DEPLETED HERDS AND MITIGATING MINING IMPACTS

Christian A. Smith, Alaska Department of Fish and Game, Ketchikan, Alaska 99901.

Lyman Nichols, Jr., Alaska Department of Fish and Game, Cooper Landing, Alaska 99572.

ABSTRACT

During June and July 1983, 14 mountain goats (Oreamnos americanus) were captured and transplanted on the Kenai Peninsula to restock a depleted population and 18 mountain goats were captured on the southern mainland near Ketchikan, Alaska and transplanted to Revillagigedo Island to establish a new population. Two male and 10 female goats survived the Kenai transplant, but two females died immediately afterwards and two additional females dispersed from the release site. Dispersing goats showed distinct "homing" directionality. Five male and 12 female goats survived the Ketchikan transplant and no mortalities were documented through March 1984. Lactating females appeared to search for their lost kids and 4 of these females dispersed from the release site in the Ketchikan transplant. Probable breeding of the remaining females was documented. Capture and handling procedures are described and recommendations for future transplants are offered.

INTRODUCTION

A history of successful mountain goat (Oreamnos americanus) transplants in many parts of western North American (Harmon 1944, Lentfer 1955, Burris and McKnight 1973, Denney 1977, Kuck 1977) combined with improved techniques for the capture and handling of goats (Hebert et al. 1980, Nichols 1982) have combined to make the relocation of goats an increasngly attractive tool for re-establishing depleted herds (McCallum 1983) as well as initiating new populations. As basic knowledge of mountain goat biology and habitat

requirements has accumulated, improved methods for predetermining the potential for success of a transplant have been proposed (Gates 1972, Hebert et al. 1980, Guenzel 1980).

The purpose of this paper is to document two recent transplants in Alaska, one designed to replenish a population previously decimated by hunting and the other to establish a new population on vacant range as mitigation for anticipated losses in a nearby herd exposed to mineral development. Because results of the pre-transplant habitat suitability studies are available elsewhere (Culbertson and Walker 1981, Smith 1984a) they will be touched on only briefly here. This paper deals primarily with the mechanics and results of the transplants themselves.

KENAI PENINSULA - REINTRODUCTION

Mountain goats have historically occupied most of the Kenai Mountains (Klein 1953). Development of access to the Kenai Peninsula in the mid 1900's exposed goats to increased hunting pressure. As in many areas in British Columbia (Phelps et al 1975) timely inventory data were unavailable to managers and local, easily accessible sub-populations were occasionally depleted before season closures were invoked. One such area was the ridge complex southwest of Kenai Lake (see Fig. 1) now officially known as Cecil Rhode Mountain (CRM).

During the 1950's CRM was in the Cooper Landing Closed Area and supported a population of at least 22 mountain goats (A.D.F. & G. unpubl. data). Hunting was permitted in the early 1960's and within a few years all but two goats, apparently both males, were killed before the area was again closed. From then until 1982 occasional sightings of 1 to 4 goats were made on the mountain. A survey in spring 1983 found 4 goats, all males, on CRM.

Culbertson and Walker (1981) conducted forage biomass analyses on some areas identified by the junior author as sites used during winter by transient males on CRM, and/or similar in biophysical character to sites used by radiocollared goats on adjacent ridges in the Kenai Mountains. Results of these analyses indicated that CRM winter range could support additional use by mountain goats, so plans were made in cooperation with the USDA-Forest Service to capture from surrounding areas and transplant to CRM 2 male and 10 female goats in the summer of 1983. These animals plus the existing males would provide an initial base populations of 16 goats with a sex ratio of .6 male/female to restock CRM.

KETCHIKAN AREA - NEW POPULATION

Goat populations on the south coastal mainland of Alaska are lightly hunted and major population trends appear to be a function of long-term weather patterns (Smith 1984b). However, in view of expanding timber harvests and mineral development, declines in some populations resulting from habitat loss, disturbance and hunting (legal and illegal) are anticipated (Pendergast and Bindernagel 1977, Smith and Raedeke 1982). Of major concern in the Ketchikan area are the probable effects of activities associated with development of a large open-pit molybdenum mine by U.S. Borax, Inc., at Quartz Hill.

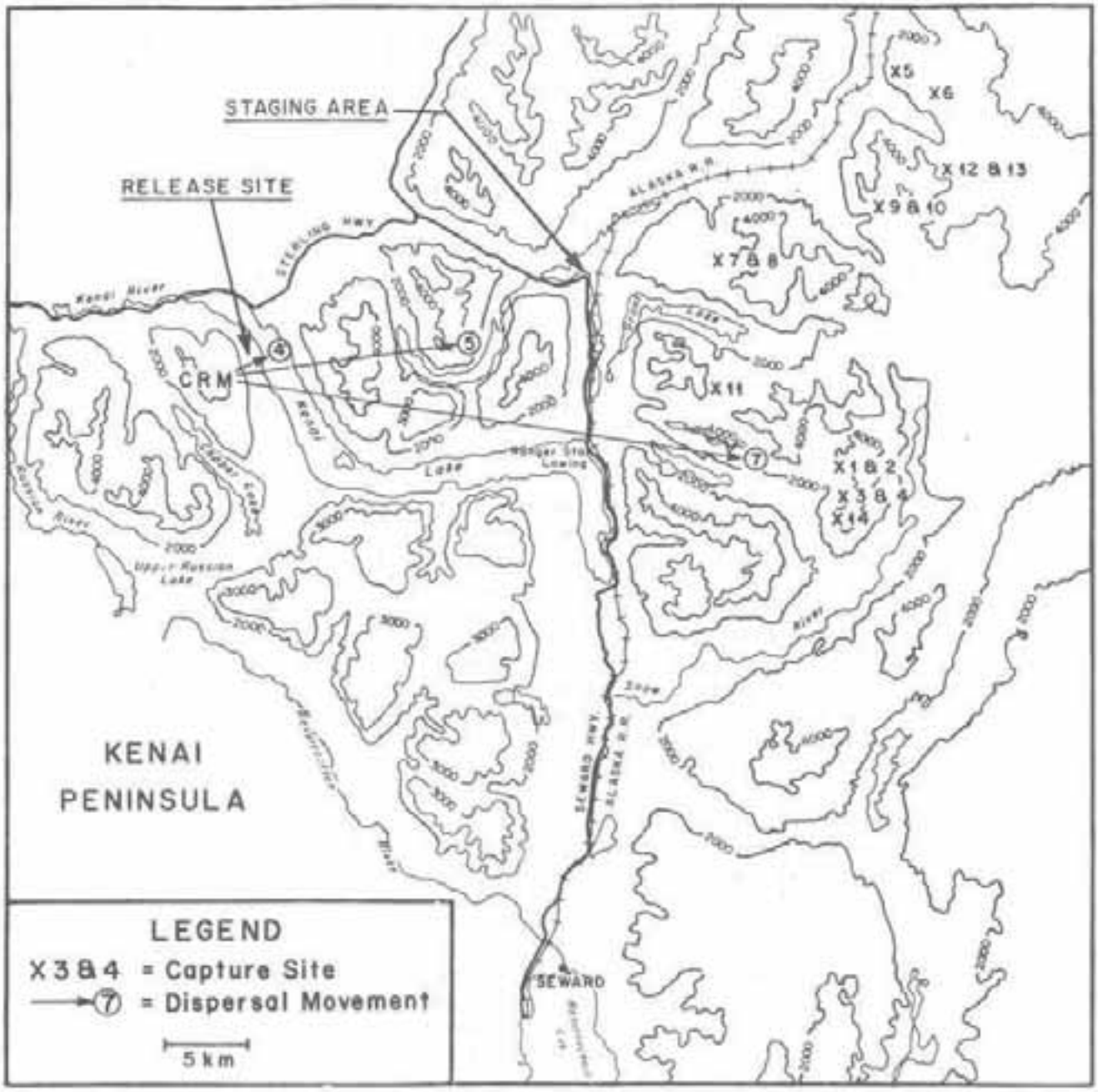

Figure 1. Capture locations, release site and dispersal movements of transplanted goats, Cecil Rhode Mountain (CRM), Alaska, July, 1983.

In evaluating the potential means for mitigating the anticipated losses at Quartz Hill, the possibility of transplanting goats to vacant habitat to create a new population was considered. Because all mainland ridges currently support goat populations, vacant habitat had to be found on one of the larger islands of the Alexander Archipellago.

A preliminary reconnaissance of potential transplant sites in the Ketchikan vicinity indicated that approximately 1000 km^2 on Revillagigedo Island (locally called "Revilla") was similar in biophysical characteristics to mainland ridges across the 2 km wide Behm Canal (Fig. 2). Revilla is part of the Coastal Foothills physiographic division of Southeast Alaska dominated by quartz diorite and granodiorite formations with elevations up to 1500 m and features deepened and accentuated by glacial action (Jacques 1963).

Division of Game policy on introducing species to new areas requires that prior to a transplant, studies must document that adequate habitat exists at the proposed release site to support a viable population of the new species and that the introduction will not adversely affect any resident species.

Smith (1984a) summarized the habitat suitability studies completed on Revilla Island. Major plant communities were sampled for over-and-understory composition and forage biomass, snow depth patterns were compared to those of mainland goat ranges, and topographic and timber types were sampled to provide data for winter range identification. A model of goat winter range based on discriminant function analysis of habitat selection with respect to elevation, slope, aspect, distance to cliff and timber volume derived from data gathered on radio-collared goats on adjacent ranges (Smith 1983) was used to identify potential winter habitat on Revilla Island. Results of these analyses indicated that the northeast third of Revilla Island could support 600-1000 mountain goats at densities comparable to those on adjacent mainland ridges.

Adverse effects of goats on resident species were judged to be minimal inasmuch as all species on the island coexist with goats on the mainland. In fact, goats could potentially benefit one resident species, wolves (Canis lupus), by providing an alernative source of prey.

Plans were made in cooperation with the Forest Service and Ketchikan Sports and Wildlife Club to transplant at least 5 male and 10 female goats between the ages of 2 and 8 years to northeast Revilla Island from the adjacent mainland in summer 1983. This was estimated to be the minimum number of animals capable of becoming established based on simple population models using our best estimates of local productivity and mortality (A.D.F. & G. unpubl. data). These numbers correspond with those found by Guenzel (1980) to be typical for successful transplants.

The release site chosen was a remote ridge complex in the center of the potential habitat area. This choice reflects the desire to keep the newly introduced goats together, avoid human access to the young herd, and allow dispersal of the growing population in all directions.

METHODS

KENAI PENINSULA

Potential transplant stock were located by spotters in a Piper PA-18-150 Super-cub in the mountains north and east of Kenai Lake (Fig. 1). When goats were found, a capture crew in a Bell Jet Ranger was called by radio. Goats were captured using standard helicopter darting techniques (Nichols 1982) with a dose of 4 mg. M99 (etorphine). Use of the fixed wing spotter plane to track a darted goat allowed the helicopter crew to pursue and dart a second goat while waiting for the first animal to go down.

Once the goats were down, the helicopter dropped the 2-man capture crew at the nearest landing site. They would climb to the goat, load it in a sling net and then attach the sling line to the hovering helicopter. The sedated goats were ferried to a staging site at the end of the road near the capture area.

At the staging site, the goats were blindfolded and hobbled, sections of rubber hose were placed over the horns and rectal temperatures were monitored. After being weighed, measured, aged by counting horn annuli and ear tagged, 6 goats were fitted with radiocollars, and 1 with a colored material collar. The remaining 5 goats were uncollared. The goats were loaded into a covered pick-up truck, the bed of which was filled with crushed ice under burlap. After several goats were captured and loaded into the truck they were driven to the base of CRM, a distance of about 70 km.

At the release site the goats were placed in a holding pen constructed of woven wire fence covered with burlap, released from their hobbles, the blindfolds and hoses were removed, and each was then given 8 mg. of M50-50, diprenorphine, intravenously. When all the goats in the pen appeared to have recovered from the drug (usually 1-2 minutes) the gate on the uphill side was opened. Wing fences served to guide the animals upslope toward the nearest cliffy terrain.

Total personnel involved included 6 A.D.F. & G. biologists, 1 USFS biologist and 4 USFS volunteers, a helicopter pilot, and 3 agency PR people.

Following release of the goats, periodic survey flights were made in a PA-18-150 Super Cub equipped with a scanning receiver and twin 3-element yagi antennae to monitor the radio-collared individuals and other goats on CRM.

KETCHIKAN AREA

Potential transplant animals for Revilla were sought on the adjacent mainland north, east and south of the island (Fig 2). No spotter plane was used. A capture crew flying in a Hughes 500 "D" helicopter would locate and dart a goat with 4 mg. of M99. Terrain and vegetation conditions in this area required that the helicopter stay with, and occasionally herd, the goat until it was decumbent. Once down, the goat was approached by the capture crew, sex and age were verified, a blindfold was put on the goat and its ears were plugged with cotton. It was then loaded into a sling net and ferried under the capture helicopter to a nearby staging area, usually a level snowfield. Processing at the staging area consisted of weighing, measuring, ear tagging, blood sampling, placing hose on the horns, radio collaring and securing the

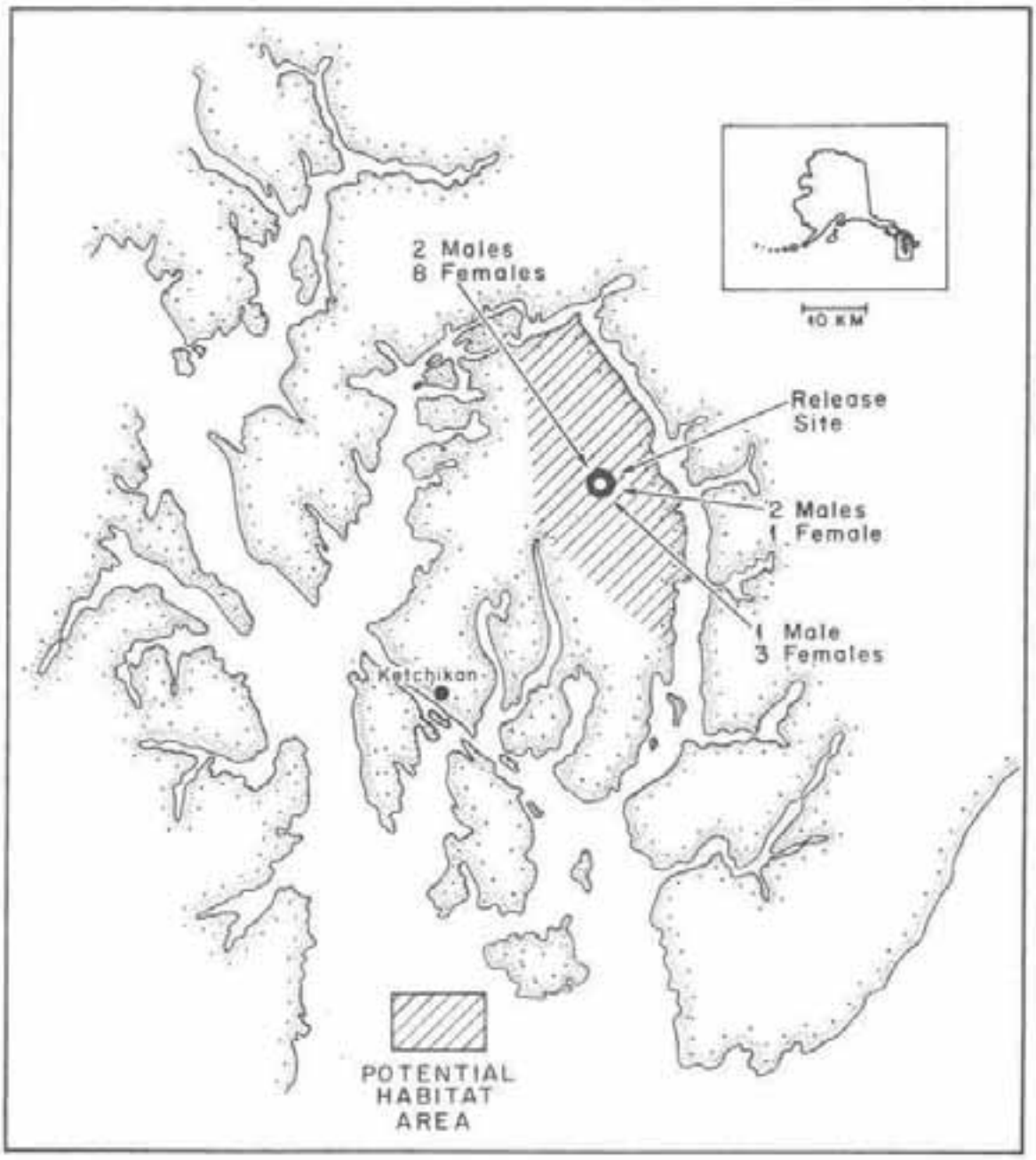

Figure 2. Capture areas, release site and potential habitat for transplanted mountain goats near Ketchikan, Alaska, June-July 1983.

goat in a small "bag" of seine net to restrict movement and facilitate handling. Body temperature, pulse, and respiration were monitored. If the rectal temperature exceeded 105° F, snowmelt water was poured over the goat until body temperature declined.

When 2-4 goats were at the staging site, a second helicopter was called to transport the goats to the release site. The sedated goats were loaded inside the helicopter to allow higher air speeds enroute to the island, 20 to 90 km from the staging areas.

At the release site, an open ridge on the island, hoses, earplugs and blindfolds were removed from the goats and 8 mg's of M50-50 was administered intravenously. No pen was used to confine the goats, but doses were administered quickly to allow all goats released from a single flight to regain consciousness simultaneously.

Total personnel involved included 2 or 3 biologists and 1 technician from A.D.F. & G., 1 biologist from U.S.F.S. and 2 helicopter pilots.

Periodic telemetry surveys were flown following release in a PA-18-150 Super Cub equipped with a scanning receiver and twin 2-element yagi antennae to monitor dispersal and behavior of transplanted goats. Initial mobility of the goats was calculated by dividing the sum of the straight-line distances moved between relocations during the first month by the number of days between release and radio locations. This statistic was also calculated for goats captured in the same areas but not transplanted by Smith (1983) using the capture site as the point of origin. Dispersal distance was calculated as the mean distance between the release site and all subsequent radio locations. Differences between sex-classes and transplanted vs resident goats were calculated using paired t-tests.

RESULTS

KENAI PENINSULA

A total of 14 goats were captured on 25 and 26 July 1983 on the Kenai Peninsula (Table 1). Immediate capture-related mortality resulted in the deaths of two goats. A 5 year old female given two doses of M99 died from complications associated with a bloated rumen during transport in the truck, and a yearling female died of unknown causes, in the sling beneath the helicopter. The day after the transplant was completed, two additional mortalities were detected. A 10+ year old female that responded poorly to both the M99 and M50-50 and was slow to leave the release site was found dead 50m upslope from the pen, and an 8 year old female that went downhill and tried to swim across Kenai Lake drowned. All other goats were found to have moved up onto CRM.

In addition to the 4 goat mortalities, this operation was marred by the serious injury of one A.D.F. & G. biologist who fell from a snowbank/cliff while attempting to reach a sedated goat. The presence of the press, the need to process goats quickly and large number of staff resulted in some confusion. Nevertheless, the operation was generally successful and total operating (i.e. non-salary) costs averaged $714.00 per live goat released on CRM.

Table 1. Results of mountain goat capture and transplant activities, Kenai Peninsula, Alaska 25-26 July 1983.

Goat Number	Date of Capture	Age	Sex	Lactating	Weight (kg)	Status Following Release
1	7/25	7	F	No	-	Alive on CRM[1] thru February 1984.
2	7/25	7	F	No	63.5	Alive on CRM thru February 1984.
3	7/25	1	F	No	36.3	Alive on CRM thru August 1983.
4	7/25	8	F	Yes	61.2	Drowned crossing Kenai Lake 27 July 1983.
5	7/26	3	F	No	65.8	Dispersed from CRM on 9 September, 1983 toward capture site.
6	7/26	1	F	No	38.6	Alive on CRM thru August 1983.
7	7/26	1	F	No	-	Dispersed from CRM in September 1983; seen near capture site in October 1983.
8	7/26	1	F	No	40.8	Alive on CRM thru August 1983.
9	7/26	2	M	N/A	61.2	Alive on CRM thru February 1984.
10	7/26	5	F	Yes	71.7	Died in truck during transport.
11	7/26	1	M	N/A	40.8	Alive on CRM thru August 1983.
12	7/26	10	F	No	73.9	Died near pen after release.
13	7/26	1	F	No	36.3	Alive on CRM thru August 1983.
14	7/26	1	F	No	-	Died in sling under helicopter.

1. CRM = Cecil Rhode Mountain

Unfortunately, the Bureau of Land Management chose the day after the transplant to do some surveying on CRM. Their helicopter activity scattered the goats widely over the mountain and they were still in singles and pairs as of 23 August, the last date prior to snowfall when all 14 goats were seen on CRM.

On 5 September one of the goats, a 3 year old female, swam across Kenai Lake (Fig. 1) and moved into the Crescent Mountain area. Over the next month she moved farther northeast until snowfall apparently halted her movement from the release site toward her former home range. During the same time a non-radioed yearling female disappeared from CRM. Subsequently, a hunter reported seeing a collared goat matching this animal's description on a ridge above Ptarmigan Lake (Fig. 1). As of this writing the other 8 transplanted goats are believed to remain on CRM with the original 4, giving a total population of 6 males and 6 females.

KETCHIKAN AREA

A total of 18 goats, including one pregnant female, was captured on 23 and 24 June and 15-17 July, 1983 in the Ketchikan area for transplant to Revilla Island (Table 2). The only mortality in this group resulted when the senior author attempted to lasso and under-dosed 3 year old female; in the struggle she slipped from a ledge and broke her neck when the rope was snubbed tight. One other goat, also an adult female, was darted but not captured; it fell 1500' from a cliff when the drug took effect. Composition of the surviving goats was 5 males and 12 females, aged 1 to 6 years. All except one yearling of each sex were radio collared.

No human injuries were experienced and the reduced number of people involved helped make this operation less confused. One other significant aid in the Ketchikan operation was the use of 10 x 15 cm mylar data sheets pinned to each goat's blindfold. This kept the record in a convenient, conspicuous form with the goat as it transferred from capture crew to staging crew, to release crew to ensure that data were thoroughly recorded. Careful monitoring of body temperatures and treatment for hypothermia prevented heat stress mortality. Total operating cost for the operation averaged $1100.00 per goat released alive including the price of the radio collars.

Immediately following release each group of goats was observed to move quickly to nearby cliffy terrain. Several sought water from snowmelt streamlets on cliffs and most began feeding within 5 minutes. Within 5 days the goats had dispersed over several kilometers of the ridge.

Radio tracking of the goats following their release revealed that lactating females were significantly ($p < 0.05$) more mobile than males or non-lactating females during their first month on the island (Table 3). No significant difference was found between the latter two classes. Conversely, lactating females which were not transplanted were significantly ($p < 0.10$) less mobile than non-transplanted males or non-lactating females (Table 4). Again, no difference was detected between the latter two classes. Comparisons within classes between transplanted and non-transplanted goats indicated that transplanted lactating females and males were significantly more mobile than their non-transplanted counterparts ($p < 0.05$ and $p < 0.10$ respectively). Although the transplanted non-lactating females also appear to be more mobile

Table 2. Results of capture and transplant of mountain goats near Ketchikan, Alaska, 23-24 June and 15-17 July, 1983.

Goat Number[1]	Date of Capture	Age	Sex	Lactating	Weight (kg)	Time under Sedation (hr:min)	Status on 8 March 1984
1	23 June	1	M	N/A	43.1	3:22	Unknown, not radioed; last seen alive on 20 July.
2	23 June	3	F	Yes	55.3	2:05	Alive on release site ridge.
3	23 June	3	F	Yes	-	N/A	Died of broken neck during capture.
4	24 June	5	M	N/A	79.4	5:10	Alive on release site ridge.
5	24 June	3	M	N/A	56.7	3:46	Alive, across valley south of release site with #7.
6	24 June	5	F	Yes	79.4	3:04	Alive, dispersed to ridge 18 km south of site.
7	24 June	3	F	No[2]	77.1	1:39	Alive, across valley south of release site with #5.
8	15 July	3	M	N/A	61.2	2:22	Alive on release site ridge.
9	15 July	2	M	N/A	72.6	1:54	Alive on release site ridge.
10	15 July	6	F	Yes	65.8	1:14	Alive on release site ridge.
11	16 July	3	F	No	56.7	2:15	Alive on release site ridge.
12	16 July	4	F	Yes	72.6	1:18	Alive, dispersed to ridge 10 km northeast with #17.
13	17 July	3	F	No	70.3	2:55	Alive on release site ridge.
14	17 July	6	F	Yes	72.6	2:24	Alive, across valley west of release site ridge.
15	17 July	1	F	No	31.8	2:51	Unknown, not radioed
16	17 July	3	F	Yes	65.8	2:01	Alive, dispersed to ridge 8 km west.
17	17 July	5	F	Yes	80.7	2:31	Alive, dispersed to ridge 10 km northeast with #12.
18	17 July	2	F	No	57.6	1:24	Alive on release site ridge.

1. One additional goat was darted but fell from a cliff and could not be recovered
2. This female was determined to be pregnant by external palpation.

than non-transplanted ones, the limited sample of such goats (n=2) reduces confidence in this conclusion ($p < 0.15$).

The lactating females' greater mobility on the island resulted in their being more widely dispersed than males or non-lactating females (Table 5). Several of these nannies eventually settled into fall/winter range areas isolated from the rest of the population by one or more low elevation valleys and beyond the movements of any of the collared males.

Radio tracking during the breeding season documented associations of 3 billies with 4 nannies in the vicinity of the release site, and the movement of the billies between relocations indicated that encounters with other females were likely.

Table 3. Mean, standard deviation and range of rate of movement (km/day) of transplanted goats during the first month after release on Revilla Island, summer 1983.

Category	Mean	S.D.	Minimum	Maximum	N
Males	0.22	0.12	0.20	0.39	4
Females					
non-lactating	0.19	0.05	0.14	0.24	4
lactating	0.34[1]	0.09	0.19	0.41	7

1. Significantly greater than non-lactating females and males at $p < 0.05$.

Table 4. Mean, standard deviation and range of rate of movement (km/day) of resident goats during the first month after capture on the mainland adjacent to Revilla Island, summer 1981.

Category	Mean	S.D.	Minimum	Maximum	N
Males	0.11	0.00	0.11	0.11	4
Females					
non-lactating	0.11	0.10	0.04	0.17	2
lactating	0.03[1]	0.03	0.01	0.09	5

1. Significantly less than males at $p < 0.05$; less than non-lactating females at $p < 0.10$.

Table 5. Mean, standard deviation and range of distances (km) between transplant release site and all radio relocations of mountain goats on Revilla Island July 1983 - March 1984.

Category	Mean	S.D.	Minimum	Maximum	N
Males	2.2	0.9	0.0	4.1	28
Females					
non-lactating	2.4[1]	1.0	0.8	5.5	25
lactating	5.0[2]	3.0	0.7	13.9	42

1. Not significantly different from males ($p > 0.20$).

2. Significantly greater than males and non-lactating females at $p < 0.05$.

By mid-December all goats had moved into predicted winter range areas. Weather conditions were mild through March and no mortalities were documented.

DISCUSSION

Helicopter darting was an efficient and effective means of capturing goats for both transplants in areas where other types of capture (e.g. trapping, drop nets, etc.) were impractical. In most cases, with careful monitoring of body temperature and posture, goats survived sedation for up to 5 hours without ill-effect. The number of goat mortalities and the human injury experienced were unusual compared to previous capture operations in Alaska (Nichols 1982, Smith 1983), but were kept to acceptable levels given the conditions and terrain where the work was carried out and the amount of handling to which the goats were subjected.

The major limitation with helicopter darting is that it is virtually impossible to capture nanny-kid pairs, as the goats usually scatter when pursued for a shot. If taking intact family groups is deemed important, some other approach is recommended. Although the "CODA" netgun was not effective for capturing goats in southeast Alaska (Smith 1983), it has been used successfully for this purpose in the Yukon (Barichello, pers. comm.) and may facilitate capture of nannies with kids.

The differential mobility and dispersal of lactating females on Revilla may have been due to "searching" efforts, trying to locate the kid that was left behind. Such movement might be eliminated if intact family units were transplanted. Nevertheless, our evidence indicates that any transplanted goat is likely to be more mobile than its resident counterpart, and the dispersal of several females from the release sites in both areas indicates that it may be necessary to introduce more than the desired minimum number of goats to establish a population.

It will be a number of years before final determination as to the viability of these populations can be made. Nevertheless, in view of our success in the physical translocation of goats and the apparent settlement of most of the goats into their new habitat, we would encourage the reasoned use of transplants after adequate habitat suitability studies are completed to restock depleted herds or establish new populations to mitigate impacts of development on native goat populations.

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AN ECONOMIC STUDY OF DALL SHEEP HUNTING IN ALASKA: CONCEPTS AND METHODS

Sarah M. Watson, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701

ABSTRACT

Economic values of Dall sheep (Ovis dalli dalli) hunting in Alaska are needed for comparison with economic values of competing development alternatives such as grazing, settlement, agriculture and mining. This paper details the concepts and methods used to estimate the economic value of Dall sheep hunting to the State and to the hunter. A mail survey was used to question all 2,517 people who reported hunting Dall sheep in Alaska in 1983. After 8 weeks, over 85% of the questionnaires were completed and returned. Economic values of Dall sheep hunting will be estimated using travel cost, contingent valuation, and gross expenditure methods. These values will be used to demonstrate the value of Dall sheep hunting to the State economy and to Dall sheep hunters. The value of Dall sheep habitat can be inferred.

INTRODUCTION

Since passage of the Alaska Native Claims Settlement Act (1971) and the Alaska National Interest Lands Conservation Act (1980), the question, "Who owns what?" has become "What do we do with it?". Alaska is now confronted with critical resource use decisions ranging from the local level to statewide policy. Together, these decisions will affect the State's future.

The Alaska Constitution mandates that the State's natural resources will be managed "for the maximum benefit of its people" (Article VIII, Section 2). The Alaska State legislature and resource management agencies are faced with determining what constitutes "maximum benefit" in the broad public interest. These bodies recognize the need for information allowing for the objective evaluation of conflicting resource use allocations.

This paper focuses on the concepts and methods of economic valuation, a procedure which is increasingly being used by wildlife managers for determining "maximum benefit". The economic approach recognizes that tradeoffs must be made and provides an objective and consistent basis for comparing different uses of the same resources. This approach does not intend to deny the importance of non-economic considerations. In combination with biological, social, and cultural data, it can be used

to establish management priorities and policies and to improve the allocation of resources.

If economic valuation is to be used in analyzing situations involving wildlife and wildlife habitat allocations, it is especially important for wildlife managers to participate. If no values for wildlife are determined, then wildlife may not be considered among possible resource uses and will probably not be placed highly among competing uses. It is insufficient to say "wildlife is priceless". If we fail to demonstrate the economic values of wildlife, then habitat is likely to be allocated for other uses "for the maximum benefit" of the people of Alaska.

Wildlife managers of the Alaska Department of Fish and Game (ADF&G) have the responsibility to participate in such an economic valuation process. Title 16 of the Alaska Statutes states that employees of ADF&G, as extensions of the duties of the Commissioner, have the responsibility to "manage, protect, maintain, improve, and extend the fish, game, and aquatic plant resources of the State in the interest of the economy and general well-being of the State" (emphasis added). Article II of the State Constitution broadly defines the "State" as the "people".

This study was begun by the Dall sheep research staff of the Alaska Department of Fish and Game in response to the clear need for an economic value for Dall sheep and Dall sheep habitat. Over three-fourths of the Dall sheep in Alaska live outside National Parks and are vulnerable to resource use decisions. Even sheep in National Parks may not be entirely protected from the consequences of resource development as portions of their range may extend beyond Park boundaries. Uses already proposed for Dall sheep habitat that are incompatible with Dall sheep include grazing of domestic livestock, human settlement, agriculture, and mining of major mineral licks.

This study focuses on one use of Dall sheep, hunting, and estimates the contribution of expenditures related to sheep hunting to the State and the value of sheep hunting to hunters. Other uses of Dall sheep such as viewing or "just knowing they are there" certainly have value too, but those values are more difficult to measure. Thus, the economic value obtained will represent a minimum value for Dall sheep. This study will not measure the value of sheep in National Parks and in State-managed closed areas as they are unavailable to hunting.

METHODS

A mail survey was used to question all resident and nonresident hunters who reported (as mandated by law) hunting Dall sheep in Alaska in 1983. Subsistence hunters, who may compose about 2% of the hunters, were not surveyed.

Gross expenditures, travel cost, and contingent valuation were 3 techniques used in the survey to determine economic values of Dall

sheep hunting. More than one method was used so the value of Dall sheep hunting will be comparable to the values of alternative uses obtained through several methods. Additional techniques could have been applied, but they would have required a longer questionnaire, which could have lowered the response rate. The gross expenditures technique sums up the total amount of money spent on the hunt. Expenditure data are useful in estimating monetary costs to the user. It is commonly used as an impressive figure to bolster a point of view. However, it can be misunderstood and misused because it does not consider costs, and it does not estimate net benefits.

Two additional methods were used to measure net benefits. The travel cost method was developed by Knetsch (1963) and numerous revisions have improved the technique (Stoll 1982). It is based on the principle that as the distance traveled to reach a site increases, travel costs increase, and the proportion of people in the associated geographic area willing to make the trip decreases. If people coming from different distances receive the same benefits on the site, then the difference in their travel costs equal the difference in the net benefits they receive (Bart et al. 1979).

Contingent valuation is another suitable technique for measuring net benefits. It asks users to estimate how much more their costs could increase before they would switch to another activity. The amount between what they actually paid and their ceiling amount is the net benefit. Answers to this question are typically constrained by income. Another technique for measuring contingent value is asking for how much a user would sell the activity. These methods are most easily used with goods already exchanged on the market. Users often have difficulty predicting their own willingness to pay or sell for non-market items (Dwyer et al. 1977).

As high response rates in mail surveys tend to reduce nonresponse bias and increase the precision of results (Filion 1978), a number of techniques recommended by Filion (1980) and Linsky (1975) were used to stimulate response from hunters. Pre-contact with sheep hunters was made through newspaper articles and posters displayed to the general public announcing the upcoming survey. The survey was pretested by the Alaska Chapter of the Foundation for North American Wild Sheep who offered improvements in the wording of questions. Length and appearance of the questionnaire were considered important. The final questionnaire contained 18 (for residents) or 20 (for nonresidents) questions on 4 double-sided pages (Watson, 1984 A and B). A cover letter signed by the Director of Game Division, Alaska Department of Fish and Game, explained the purpose of the survey and was printed inside the cover page. Illustrations and colored ink were used to enhance the visual impact of the questionnaire.

Respondents were assured of their anonymity and questionnaires were not individually identified. However, each questionnaires package included a postage-paid return envelope that was numbered to separate respondents from nonrespondents. Once questionnaires were removed from the numbered envelope, it was not possible to identify the respondent.

Questionnaires were mailed with first class postage to ensure return of undeliverable questionnaires. Colorful stamps rather than plain metered stamps were used.

Three weeks after the first mailing, a reminder postcard (Heimer, 1984) was sent to all hunters who had not yet responded. The postcard was an inexpensive means of soliciting additional response. It carried a brief message signed by the sheep research staff and was illustrated and printed on colored paper. Colorful first-class stamps were again used.

After 3 more weeks, the remaining nonrespondents were sent a second questionnaire via first-class mail. The second mailing contained an added letter from the Director asking for the hunter's cooperation (Pamplin 1984). In addition, the numbered and addressed return envelope carried a first-class stamp picturing a mountain sheep.

During the mailings, the study was given some publicity with 2 newspapers carrying articles and radio and television stations featuring it in outdoors reports and news. Public service announcements were sent to all television and radio stations in the State to be aired at their discretion. This publicity was used to remind and encourage hunters to respond.

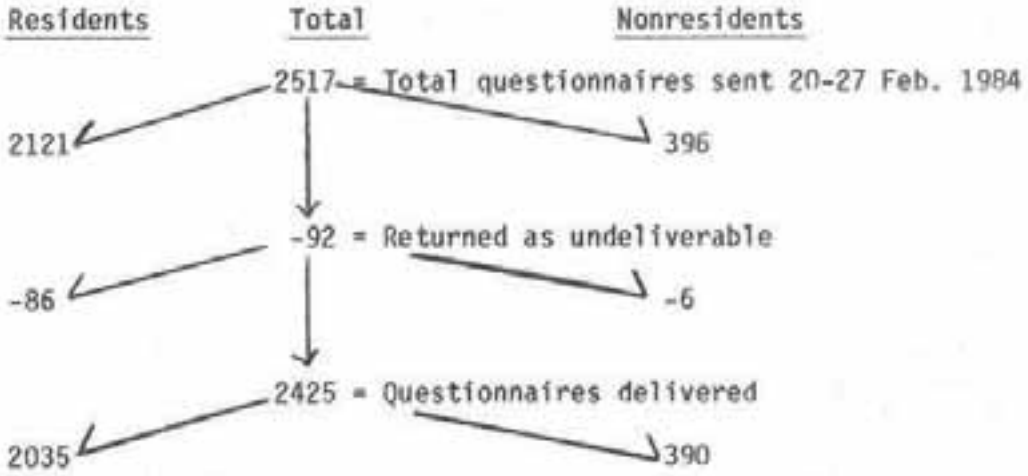
RESULTS

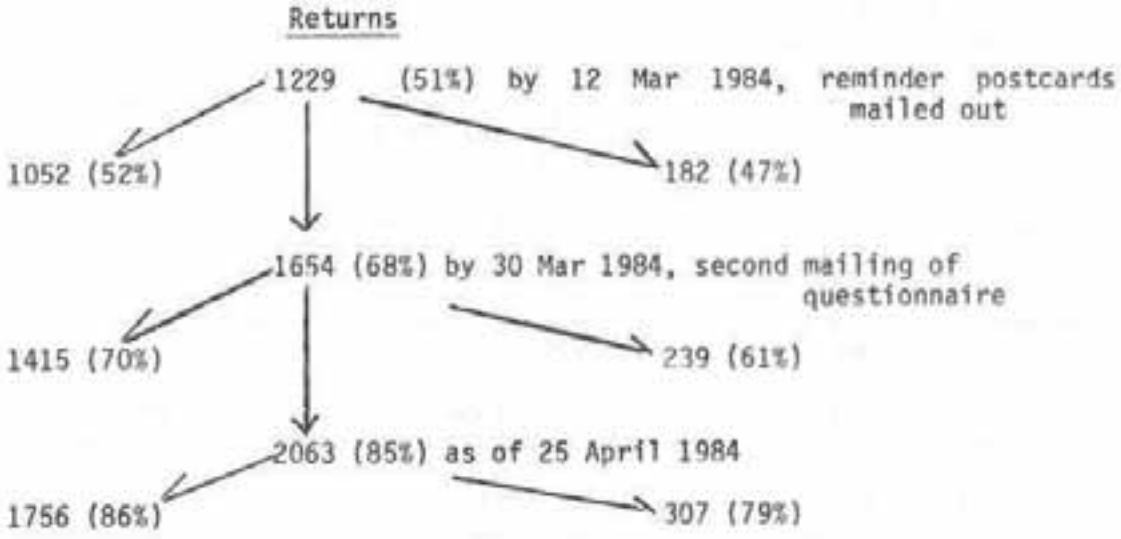
Between 20-27 February, 1984, 2,517 questionnaires were mailed to all hunters who reported hunting Dall sheep in Alaska in 1983: 2,121 were sent to residents and 396 were sent to nonresidents including 26 hunters from foreign countries. Ninety-two were returned as undeliverable reducing the total number of hunters receiving the questionnaire to 2,425 (2,035 residents, 390 nonresidents). After about 3 weeks, 1,229 (51%) had responded and reminder postcards were sent to the nonrespondents. After approximately 3 more weeks had passed, 1,654 (68%) had responded and a second mailing of the questionnaire was sent to nonrespondents. As of 25 April 1984, 2,063 (85%) of the hunters who had received questionnaires had responded, including 1,756 (86%) residents and 307 (79%) of the nonresidents. Twelve (46%) of the hunters from foreign countries had responded. Responses are still arriving in the mail, although at a slow rate. These results are graphically represented in Table 1. Questionnaire return rates are the only results available at this time.

DISCUSSION

The 85% (as of 25 April 1984) return is considered a high return rate for a mail survey (Filion 1980, Linsky 1975). There are probably 2 main reasons why this occurred. First, the survey sampled a relatively homogeneous population with a strong interest in the subject matter--Dall sheep hunting. Dall sheep hunters are consistently the most

Table 1. Flow chart showing the number of questionnaires sent to Dall sheep hunters (both residents and nonresidents) and the number returned. Reminder postcards and a second mailing of the questionnaire prompted additional responses.





responsive group of big game hunters in Alaska, with typically 75% annually reporting harvest data. In contrast, 65% and 30% of moose and caribou hunters, respectively, report harvest data each year. The second probable reason for the high return rate from sheep hunters is that the mail survey strategies for eliciting high response worked. A poorly designed questionnaire with no publicity or additional mailings probably would not have received much consideration by the public.

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A MARK-RECAPTURE CENSUS AND DENSITY ESTIMATE FOR A COASTAL MOUNTAIN GOAT POPULATION

Christian A. Smith and Kent T. Bovee, Alaska Department of Fish and Game, Ketchikan, Alaska 99901.

ABSTRACT

A mark-recapture study was conducted on a mountain goat (Oreamnos americanus) population in southeastern Alaska during September 1982. Thirteen adult goats were captured and fitted with orange radio collars, and 3 aerial samples were taken approximately 60 days after capture. Size of the adult population was estimated using a modified Petersen estimate for the individual samples and a joint probability density function for the combined samples. The resulting estimates (+95% C.I.) were 149 (+70), 103 (+47), and 145 (+68) for aerial samples 1, 2 and 3, respectively and a combined estimate of 145 (+21) adults. The size of the kid portion of the population was estimated by applying the proportion of the kids observed in aerial surveys to the estimated number of adults. The total population was estimated at between 159 and 239 (p=0.90). Densities of goats on winter and year-round range were estimated at 4.4 and 2.3 goats/km^2, respectively. The increasing trend of this population at these densities indicates that coastal ranges may be capable of supporting higher goat densities than previously believed.

INTRODUCTION

Eastman's (1977) survey of research needs for mountain goat (Oreamnos americanus) management concluded that improved inventory methods were the highest priority in many areas. The problems associated with sex and age classification, as well as bias resulting from seasonal and diurnal timing and type of survey (e.g. helicopter, fixed wing or ground count) were cited as difficulties affecting inventory results. The inability to estimate goat numbers and lack of knowledge of habitat use/requirements have limited the development and application of reliable density estimates (Hebert and Turnbull 1977).

Subsequent work by Nichols (1980) and others has led to improved methods for classifying goats, and several authors have made suggestions to improve survey methodology based on behavioral research (Fox 1977, Foster 1982) or

comparisons of various types of surveys (Ballard 1977). To date, however, advanced survey techniques are based on the questionable assumption, either stated (Nichols 1980) or implied, that virtually all goats in the survey area are seen by observers, or that sightability is consistent among all sex/age classes.

In southcoastal Alaska and British Columbia, where goats spend considerable time in forested habitats (Schoen and Kirchhoff 1982, Fox 1983, Smith 1983, Hebert and Turnbull 1977, Foster 1982) goat sightability is generally low. Foster (1982) reported an average sightability of only 42% for ground surveys in west central British Columbia. From fixed wing aircraft even when aided by telemetry, Smith (1983) averaged only 30% sightability in coastal Alaska. Thus, when it became desirable to estimate the actual size of a goat population prior to mineral development in an area southeast of Ketchikan, Alaska, an alternative method had to be employed.

One of the commonly used techniques for censusing hard to observe species is the mark-recapture, or Petersen estimate method (Seber 1982). To date, the only published capture mark-recapture (CMR) census of goats was conducted by Stevens and Driver (1978). Unfortunately, that study population was experiencing a high rate of dispersal and no attempt was made to evaluate the equality of catchability (Caughley 1977) in the population. For these reasons several of the critical assumptions in a CMR census were potentially violated. Nevertheless results indicated that if properly applied this technique might be useful for estimating goat numbers in areas where any single survey is likely to miss a significant proportion of the population.

Goats radio collared as part of a major study of habitat use (Smith 1983) in the vicinity of the Quartz Hill mine impact area provided the opportunity to attempt a mark-recapture census of this population. Monitoring the radioed goats prior to and following the survey permitted detailed evaluation of the assumptions made in the CMR method.

In addition, detailed knowledge of habitat availability in the area provided the opportunity to calculate relatively accurate seasonal density estimates. The purpose of this paper is to report these results.

STUDY AREA

The 197 km^2 study area is located in southeastern Alaska, 80 km southeast of Ketchikan within Misty Fjords National Monument (Figure 1). The portion of the area surveyed is bounded by Smeaton Bay, the Blossom River and Keta River drainages, and is separated from the remainder of the ridge complex by valleys with a maximum elevation of 400 m. The terrain is predominantly steep and broken quartz diorite and granodiorite formations which have been heavily modified by glacial action (Jacques 1963).

Annual precipitation of over 300 cm, the majority of which is rain, allows for dense mixed stands of Western hemlock (Tsuga heterophylla), Sitka spruce (Picea sitchensis), and Alaska cedar (Chamaecyparis nootkatensis) in the valleys. Treeline occurs at elevations of 750 to 900 m and alpine vegetation continues to the summits of the 1200+ m mountain range.

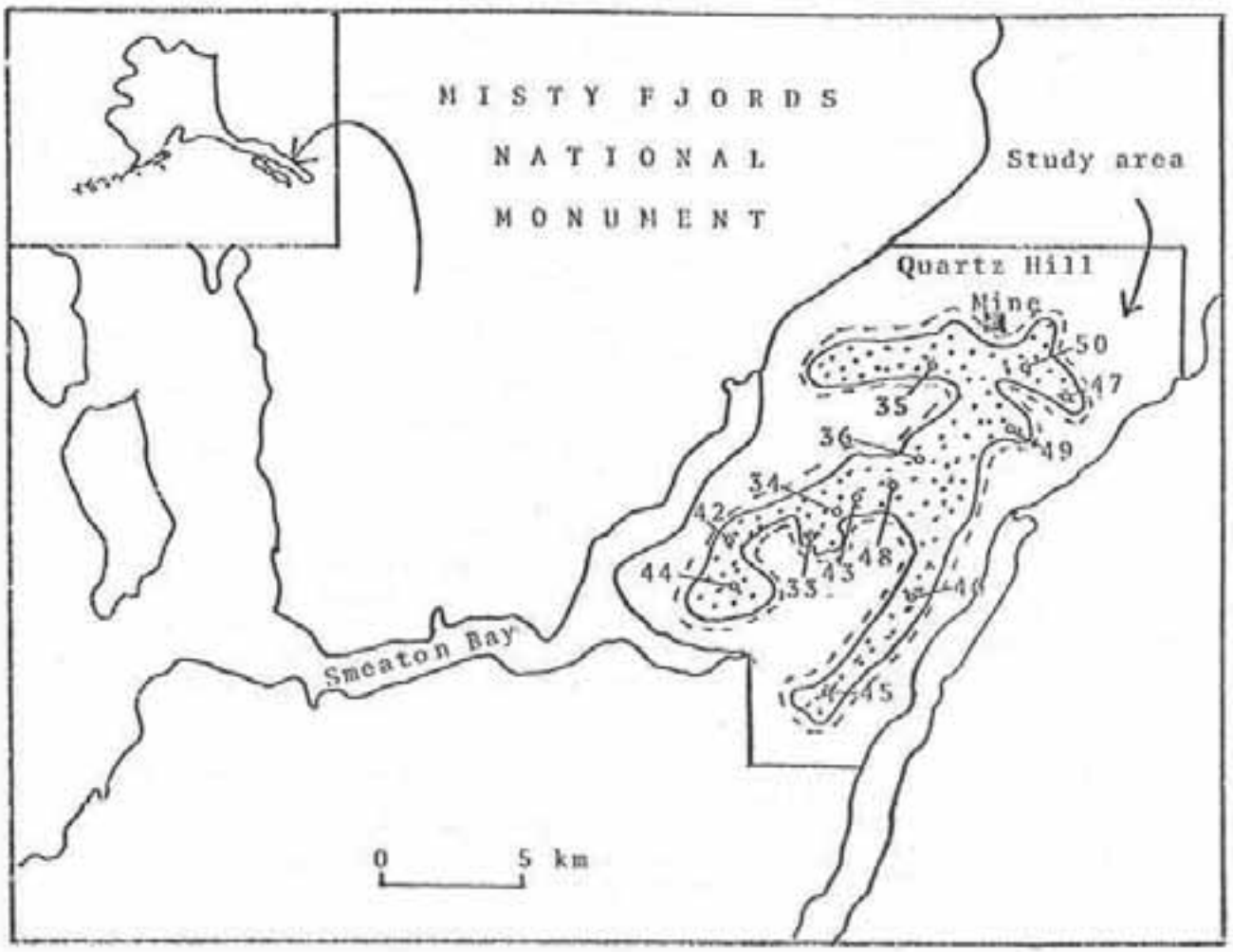

Fig 1. Study area showing alpine region (⁘), flight pattern (- - -) and goat capture locations.

METHODS

POPULATION ESTIMATES

Goats were captured in July 1982 using the helicopter darting technique described by Nichols (1982) with a standard dosage of 4 mg of M99 (etorphine) or by use of a Coda Net Gun (Coda Enterprises, Mesa, AZ), as discussed by Barrett et al (1982). Individuals over one year of age were selected at random as encountered. Ages of captured goats were determined by counting horn annuli, standard horn and body measurements were taken, and general condition of body and dentition, lactative status of females, and presence of ectoparasites or anomalies were noted. Goats were marked with large, orange ear tags and fitted with orange radio collars (Telonics, Mesa, AZ).

During September 1982, 2 aerial surveys were flown in a PA-18-150 Super Cub and a third survey was flown in a Huges 500 "D" helicopter. Each flight began at the northwest end of the ridge complex and kept the ridge to the right of the aircraft. A single contour that permitted viewing the portion of the slope above treeline was flown. All goats seen were identified as either collared or uncollared adults and kids. The location of each goat was recorded on a 1:63,360 topographical map to avoid duplicate counting. When a collared goat was seen it was individually identified by checking its radio frequency.

The critical importance of "equal catchability" of individuals to mark-recapture studies requires that data be analysed for this property before population estimates are made (Caughley 1977). Accordingly, frequency of capture (i.e. resighting of collared individuals) data were evaluated to determine whether or not their distribution differed significantly from an approximation of a zero-truncated Poisson as described by Caughley (1977 p 137).

By noting the location of each goat seen and flying a single contour on each survey, thus preventing duplicate counting, sampling without replacement was assumed. That being the case, use of the hypergeometric distribution model was approriate. For the individual survey results, an approximation of the hypergeometric maximum likelihood estimator:

$$\Pr\left[X_i = x_i\right] = \frac{\binom{m}{x_i}\binom{N-m}{n_i-x_i}}{\binom{N}{n_i}}$$

was calculated using the formula:

$$N^* = \frac{(m+1)(n_i+1)}{(x_i+1)} - 1$$

which has a standard error of:

$$SE = \sqrt{\frac{(m+1)(n_i+1)(m-x_i)(n_i-x_i)}{(x_i+1)^2(x_i+2)}}$$

where m = number of collared goats in the population, n_i = number of goats seen on the survey and x_i = number of collared goats seen (Seber 1982).

To increase the accuracy of the estimate, results of the 3 surveys were combined in a joint probability density function,

$$L(N) = \prod_{i=i}^{k} Pr\ (X_i = x_i)$$

where 'k' was the number of aerial samples and L(N) was the probability of x_i, x_2, and x_3 occurring, given the values of N, m_i, and n_i. This equation was solved by iteration with various values of N and interpreted using calculus in SAS computer programs developed by B. C. Dennis (Department of Statistics, University of Idaho). The first derivative of this equation is the maximum likelihood estimate and the second derivative of this equation is the variance of the estimate.

Because kids are not collared and were classified separately in the surveys, the foregoing analysis provided estimates of the number of adults only. Thus, in order to estimate the total population it was necessary to estimate the total number of kids. This was accomplished by estimating the proportion of kids in the herd from observations from the three surveys and applying this proportion to the estimated total number of adults.

The 95% level was used in establishing confidence limits for the estimates of total number of adults and proportion of kids in the herd. As a consequence of using these estimates to derive the total population figure, the degree of confidence in the estimate of the total population is reduced to 90%.

DENSITY

Smith (1983) identified 51 km^2 of potential goat winter range in the study area based on a discriminant function analysis model. Those results were preliminary, however, and the model used identified approximately 6 km^2 of non-forested alpine slopes as winter range. Inasmuch as goats in this area are rarely found above treeline in winter and no goats or tracks were observed in these areas during 2 winters of radio-tracking (author's unpubl. data), these areas were excluded from the winter range category for the density calculations presented here. Thus total winter range area was estimated at 45 km^2. Year-round habitat was considered to be all areas above the 800 m contour, plus lower elevation winter range. The total was estimated to be 86 km^2. All area figures used represent 2 dimensional map areas measured planimetrically corrected for the third dimension using the arcsine of the mean slope of 33° (A.D.F. & G. unpubl. data).

RESULTS

POPULATION ESTIMATES

Between 21 and 29 July 1982, 6 female and 7 male goats aged 2-9 years old were captured in the study area. Ten goats were captured with the dart gun, 2 with the net gun and 1 with a combination of both. The locations of captures are shown in Figure 1.

The 2 fixed wing aerial samples were taken on 22 and 29 September 1982, with 74 and 72 adult goats being counted, respectively. On each flight 25 kids were seen. On 23 September 1982, 50 adult goats and 20 kids were counted via helicopter. In each of these samples, 6 collared goats were seen and identified (Table 1). The survey conditions varied from poor to excellent. The estimated population sizes (±95% C.I.) from these surveys were 149 (±70), 103 (±47) and, 145 (±68) (Table 2). Using the joint probability distribution function, the combined estimate was 145 (±21). There were no significant differences between these estimates of N. Because the combined estimate is the most precise, it is used in all subsequent analyses.

The estimated proportion of kids in the herd (±95% C.I.) was .262 (±.043). Thus the total population of goats in the study area was estimated to be 197 (145 adults + 52 kids). The 90% C.I. for this estimate is from 159 (124 adults +35 kids) to 239 (166 adults + 73 kids).

Winter range density was calculated to be 4.38 ± .89 goats/km^2 at the 90% confidence level. Year-round habitat density was 2.29 ± .47 goats/km^2, and density of goats over the entire study area was 1.0 goat/km^2 at 90% confidence level.

DISCUSSION

The validity of CMR estimates for N relies upon certain assumptions (Caughley 1977). A discussion of these assumptions follows.

ASSUMPTION 1:

The population was geographically and demographically closed so that N remained constant.

The factors potentially affecting the assumption of closure were natality, mortality, immigration and emigration. Natality does not occur in September and mortality other than hunting, is negligible (A.D.F. & G. unpubl. data). No goats were reported taken by hunters in this area during the study period. The short span of 7 days between samples, geographic isolation of the ridge and limited movement of goats in September (A.D.F. & G. unpubl. data) would have tended to reduce or eliminate biases due to immigration and emigration.

ASSUMPTION 2:

The average probabilities of capturing and sighting collared and uncollared goats were equal (i.e., collared goats were representative of the "true" population).

The validity of every CMR study depends heavily upon assumption 2. If the marked population is not representative, the data gained from the marked individuals will be biased. The composition, behavior and catchability of the marked goats should match those of the population as a whole.

With respect to the composition, the initial sampling and marking of goats were assumed to be done in a random manner. The location, sex and age distribution of captured goats support this assumption. As for behavior, two

Table 1. Results of aerial surveys of mountain goats in the vicinity of the Quartz Hill mine, southeast Alaska, 1982.

Date	Method	Survey Time	Collars Seen	Goats observed Adults/Kids	Survey Condition	Cost
9-22-82	FW	1830-1945h	33 36 45 46 48 49	74/25	Excellent	$380
9-23-82	H	1800-1915h	33 35 42 45 46 48	51/20	Poor	$1002
9-29-72	FW	1810-1930h	42 44 45 46 47 49	72/25	Fair	$360

1. FW - fixed wing, H - helicopter
2. For elabortion see Smith (1984b)

Table 2. Estimated number of adult mountain goats in the vicinity of the Quartz Hill mine, southeast Alaska, 1982.

Sample	m	x	n	N*	SE	95% C.I.
1	13	6	74	149	35.7	79-219
2	13	6	51	103	24.2	55-150
3	13	6	72	145	34.7	76-213
Combined				145	10.6	124-166

1. No significant differences between estimates at $p<.05$.

years' radio tracking data on seasonal movements, home ranges and habitat use suggest that these individuals are representative of goats in the area (Smith 1983, ADF&G unpubl. data).

The re-sightings of collared goats were tested to evaluate the assumption of equal catchability (Caughley 1977). The null hypothesis of equal catchability was not rejected ($p>.05$). Considering the small sample size, however, this does not represent a rigorous test and equal catchability remains the weakest assumption in the analysis.

ASSUMPTION 3:

Collars were not lost.

Monitoring of the goat's radio collars prior to and following the surveys (Smith 1983) assured that the assumption that all collars were retained was valid.

ASSUMPTION 4:

Goats were not counted more than once during a sample.

By recording each goat seen on a topographical map, multiple counting was largely avoided. However, some goats observed on or near the ridgeline may have moved across the divide when disturbed by the aircraft resulting in multiple counts when the flightline contoured the other side of the ridge. This was minimized through careful observation and recording and the senior author's familiarity with the terrain.

ASSUMPTION 5:

No collars on goats were overlooked in the aerial samples.

Considering the experience of the observer, it is reasonable to assume that if a collared goat were visible, its collar was seen and identified correctly. However, for future studies, the visibility of the collar should be increased to further reduce the chance of missing a collar. In addition, if brighter markings were used, the distance of observation could be increased to avoid disturbing goats, thus reducing flight responses which could lead to violation of assumption 4.

ASSUMPTION 6:

Aerial samples were independent.

Independence of samples is a major assumption with multiple sampling. Violation of this assumption will produce deceptively small confidence intervals for N^*, but will not bias N^* if assumption 2 is valid (Rice and Harder 1977). The time span between surveys was adequate to permit "mixing" of the population, and the varying survey conditions contribute further to independence. However, to increase sample independence in future studies, flight patterns, time of day, or observers could be varied (Rice and Harder 1977).

ASSUMPTION 7:

Sample size did not bias the population estimates downward.

The major drawback to the estimates resulting from this study is the possible bias due to the small sample size. Many studies have shown that small values of n/N and/or m/N tend to inflate the estimates (Robson and Regier 1964, Rice and Harder 1977, and Seber 1982). Seber (1982) suggested that the 'x' value should be 10 or greater; 'x' in this study was 6 for the individual studies.

Rice and Harder (1977) have determined minimum values for m/N and k (number of samples) which, with given values for N* and n_1/N^*, will provide estimates that are accurate to within ±10% at the 95% confidence level. Using the values m/N*, N* and n/N* from this study (0.1, 145 and approximately 0.5, respectively), over 20 flights would be required to attain an estimate accurate within 10% at the p=0.95 level. This seems high inasmuch as our results provide an estimate accurate to within 15% at the p=0.95 level for the adult segment and within 20% at the p=0.90 level for the total population with only 3 surveys. Stevens and Driver (1978) indicated an accuracy of only 35% at p=0.95 for their population using multiple ground observations and sampling with replacement. Nevertheless the accuracy of future estimates could be enhanced if a greater number of surveys were flown.

The accuracy of future CMR estimates in this area could also be significantly improved if m/N were increased. Helicopter-darting and radio collaring may be prohibitively expensive, and an inexpensive alternative could be to uniquely mark goats by aerially applying dye. However, this approach would not facilitate evaluation of assumptions 1, 3, 4, and 5.

In spite of the limitations on accuracy and the relatively high cost, in situations where estimates of the actual size of coastal goat populations are needed, some type of CMR census may be required. Given the limited and variable sightability of coast goats to either ground or aerial surveys (Ballard 1977, Fox 1977, Hebert and Langin 1982) no uncorrected count should be taken as more than an index of the actual population size.

As Hebert and Turnbull (1977) indicated, density has been rarely reported in the literature on mountain goats. Furthermore, the variation in how densities are calculated limits comparisons of the published estimates. Some studies report densities for specific habitat types (Hjeljord 1971) and others refer only to general elevational zones or seasonal ranges (Hebert and Turnbull 1977, McCrory et al. 1977, Stevens 1983) or the overall area observed to be used by goats year-round (Foster 1982). Furthermore, the reliability of population estimates is generally undetermined, and often density figures are useful only for relatively crude comparisons between areas of "high", "medium" or "low" density (Hoefs et al. 1977, MacGregor 1977).

Although density estimates from various studies may not be generally comparable for the reasons mentioned, it appears reasonable to compare density estimates from this study with some of those developed in Yoho National Park, British Columbia by McCrory et al. (1977). These authors also used a population estimate corrected for sightability and applied it to their total study area and potential year-round goat habitat. Their values were 0.45 and

1.5 goats/km^2, which are both well below the values of 1.0 and 2.3 goats/km^2 found here. In view of the fact that the Quartz Hill population is rapidly increasing (r=0.21 for 1975-1983), and currently only about 60% of past numbers (Smith 1984), the potential density of this coast population may greatly exceed that of Yoho National Park. This appears to contradict the general theme of Hebert and Turnbull's (1977) evaluation of the differences between "coastal" and "interior" ecotypes, specifically that coastal populations which winter in lower elevation, often forested habitats, are generally of lower density, less productive and more sensitive to harvest than interior ones which have access to higher, wind blown winter ranges. Stevens (1983) also reported phenomenally high densities for goat populations in the Olympic Mountains of coastal Washington.

The high productivity of forage biomass and heavy use by goats of forested winter ranges in coastal Alaska have recently been confirmed (Fox et al. 1982, Fox 1983, Schoen and Kirchoff 1982, Smith 1983). The value of forested winter range in the interior as well is supported by McCrory et al. (1977) who found that those portions of Yoho National Park where goats wintered in timbered areas well below treeline, as well as alpine zones, supported higher densities of goats than mountain blocks without low elevation winter range.

The mountain goat evolved from forest-dwelling ancestors (Schaller 1977, Chadwick 1983) so it should not be surprising that they can successfully utilize such areas, so long as the terrain is steep and broken (Fox 1983). Considering the accelerating human exploitation of timber resources in the range of this species, further assessment of the value of forested winter range to mountain goats is warranted.

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EXPERIENCES IN DARTING DALL SHEEP FROM HELICOPTERS IN ALASKA DURING 1983

Francis J. Singer, National Park Service, Alaska Regional Office, 2525 Gambell Street, Room 107, Anchorage, Alaska 99503-2892.

Kenneth R. Whitten, Alaska Department of Fish and Game, Fairbanks, Alaska 99701.

Lyman Nichols, Alaska Department of Fish and Game, Cooper Landing, Alaska 99572.

ABSTRACT

A total of 20 Dall sheep (Ovis dalli) were darted from a helicopter during June in the Brooks Range and another 6 in the White Mountains of Alaska during April, 1983. Experiences in darting sheep from the two herds were quite variable. No mortalities occurred in the White Mountains, chase times were shorter than 2 minutes, sheep were apparently easier to dart, initial dosages of M99 were only 2.5 mg. and all animals hit were completely immobilized. In the Brooks Range, on the other hand, sheep were more difficult to dart, chase times averaged 8.5 minutes, only 9 of 20 animals were completely immbolized, dosages for completely immobilized sheep were 4.6-6.0 mg of M99, and 3 animals died. The contribution of season, diet, escape terrain, human disturbance and reproductive status to the different capture experiences are discussed.

INTRODUCTION

Dall sheep have received considerably less aerial capture and handling than the other North American sheep, the bighorn (Ovis canadensis). This situation results primarily from their greater remoteness and better population health in comparison to the more southerly and depleted bighorns (Nichols 1975), which are frequently captured and transplanted. Most Dall sheep captures and handlings have occurred using ground techniques at licks or bait stations. Heimer et al. (1980) captured and collar-marked Dall sheep at large, natural mineral licks in Alaska using primarily drop-nets with a few sheep being darted from the ground. Bunnell (1980) captured 145 Dall sheep in baited corral traps on a heavily-used winter range in Yukon Territory.

More mobile methods for capture of Dall sheep are required in remote locales, where the sheep do not frequent natural licks or are not concentrated, where they could be baited. Few capture attempts have been made in these situations. Attempts at darting Dall sheep from helicopters for transplants were made in Alaska in the early 1960's but resulted in high mortality rates; the capture drug was succinyl-chlorine chloride (Burris and McKnight 1973; Nichols 1968). Two of 3 Dall sheep rams gun-netted died (Barrett 1982); however, more recent experiences with net guns in the Yukon have been more successful (G. Lortie, pers. comm.).

Darting of bighorn sheep from helicopters has been attempted more frequently (Jessup at al. 1983; Andryk et al. 1983), although occasional deaths due to capture myopathy persist. We report here on some recent attempts at darting Dall sheep from helicopters in Alaska.

METHODS

Six sheep were captured in the White Mountains, north of Fairbanks, and 20 were captured in the Noatak National Preserve in the Brooks Range of Alaska during 1983. Sheep were darted from a Bell 206B Jet Ranger helicopter with Cap-Chur darting equipment (Palmer Chemical and Equipment Co., Douglasville, Georgia). Only the helicopter pilot and one shooter were involved in most chases; 1-2 assistants were dropped off at a nearby vantage point after a group of sheep was sighted. The ground assistants recorded chase events and times and communicated with the helicopter through hand held transceivers (Motorola, Inc.) in the Noatak. The ground assistants in the White Mountains had no radios, but a Piper PA-18 150 Supercub was used there to help locate sheep, to follow darted sheep, and as a safety precaution. No back-up plane was involved in the Noatak, but the ground crew had radio contact with a base camp in the event of an aircraft failure.

M99 (Etorphine hydrochloride) in the concentration of 1.0 mg/ml (D-M Pharmaceuticals, Inc., Rockville, Maryland) was mixed with Acepromazine (acepromazine maleate, 10 mg/ml, AVECO Co., Inc., Fort Dodge, Georgia) in a ratio of 0.2 cc Acepromazine per 1.0 cc M99 (a ratio of 1:5 in volume and 2:1 in concentration) in the Noatak in 3, 4, 5 or 6 cc darts (2.6, 3.6, 4.6 and 5.6 mg of Etorphine per dart, respectively). In the White Mountains, only 3 cc darts were used (2.5 mg M99, 0.75 cc of Acepromazine). In the Noatak, barbs were shortened off 3/4 inch needles (needle No. NC1) as done for mountain goats (Nichols 1982), but the barbs were not shortened in the White Mountains. All darts were fired with brown (extra low range) propellant charges.

Sheep in the White Mountains were slowly approached and overtaken with the helicopter in all types of terrain and shot as the helicopter tried to match speed with them. Sheep could not always be safely approached on steep terrain in the Noatak. Instead they were slowly herded onto flat terrain, where they were either shot running straight-out across the flats or as they hesitated in tall willow stands. Distances for shots ranged from 2-10 m.

After a dart hit, the helicopter would land 300-700 m away or pick up the ground crew and wait until the drugs took effect. Sheep were rapidly sexed, aged by horn annuli, and instrumented with radio-collars (Telonics Inc., Mesa, Arizona). All animals were then revived with the antagonist M50-50 (2.0 mg/ml,

diprenorphone hydrochloride, D-M Pharmaceuticals), in an amount approximating the volume of M99 given. Induction time was the interval between a hit and immobilization, and recover time was the interval between injection of the antagonist and recovery.

RESULTS

CAPTURE SUCCESS

White Mountains

Six Dall sheep were captured in the White Mountains on April 21, 1983 with 7 hits and 7 darts missed (1 sheep captured per 2.3 darts shot) during 2.2 hours of helicopter time (1 sheep per 0.37 hours of flight time). Two multiple captures of 2 sheep out of groups were made. One sheep was hit in the shoulder and 5 in the hip. The sheep, all adult ewes, were aged at 3, 4, 4, 5, 5 and 9 years. No capture deaths occurred.

Chase sequences were similar to those described for mountain goats (Nichols 1982) with the best success obtained by a slow approach, hovering behind a sheep and only slowly overtaking it. Two sheep actually stopped almost immediately and were easily darted. All the misses were at rapidly running sheep after a rapid helicopter approach. Chase times were 0.5 to 2 minutes. Five ewes were hit once each with 2.5 mg etorphine and the sixth was hit twice. The first dart bounced out, but she was relocated and shot again 2 hours later. Induction times were 6-10 minutes in the first five ewes, but 25 minutes for the ewe darted twice.

Handling time was less than 10 minutes for all 6 ewes. Three cc of M50-50 (6 mg of Diprenorphine) were given as an antagonist, or about 120% of the volume of M99 initially injected. The antagonist was administered intravenously (IV) in the jugular vein. Recovery times were 2 minutes or less.

Noatak

Considerably more difficulty was encountered in capturing sheep in the lower Noatak River in June. Helicopter time totalled 5 hours on June 11, 12, 13, 14, 15, 18 and 21 (.75 hours per sheep capture). Twenty sheep were captured in 58 shots and 23 hits (1 sheep/2.9 shots). Three of the 20 sheep died of capture related causes which equals 1 successfully radio-collared sheep per 1.13 hours of helicopter time, or 1/3 the success of the White Mountains project. Six rams were captured, aged 3, 3, 6, 7, 8 and 8 years, and 14 ewes of which 11 were aged at 2, 2, 2, 3, 6, 7, 7, 7, 7, 9 and 14 years. Multiple captures of 2 sheep per group were made in 2 groups. Shots ranged from 3-10 m.

Helicopter approach time for the 9 sheep (where chases were recorded) that were chased until they had slowed or stopped and then darted was 11.7 $\pm$ 3.4 minutes. These figures include chases of 3 animals that died, which were the longest chases (14.3 $\pm$ 2.1 minutes). Approach times for 4 other animals shot on a full run was 1.3 $\pm$ 0.5 minutes. All of these latter animals were successfully immobilized and reversed in 0.5-4.5 minutes. However, hit success was much lower for the 4 running sheep (4 hits in 20 shots, 20% success versus 50% hit success in animals that slowed or stopped). Overall approach time in the Noatak was 8.5 $\pm$ 5.7 minutes.

Nine sheep in the Noatak were completely immobilized and 11 were partially immobilized. Some mobility and considerable thrashing of the hind legs occurred in the partially immobilized sheep; 3 of these 11 sheep died, but none of the 9 completely immobilized sheep died.

A large initial dose of etorphine was required to immobilize the Noatak sheep. Immobilization was complete in 8 of 9 ewes given the largest M99 dosages (4.6 mg of etorphine), but was complete in only 1 of 5 ewes given smaller dosages (2.5 -3.5 mg of etorphine). Immobilization was complete in 1 ram given 6 mg of etorphine but incomplete in 5 given 3-5 mg. Acepromazine was mixed with M99 in 4 of 8 dosages which resulted in partial immobilization and its presence did not appear to be a critical ingredient. Reaction time was much shorter ($X=5.8 \pm 3.6$ minutes, N=8 timed observations) for sheep that were completely immobilized than for those which were not ($X=14 \pm 10$ minutes, N=6).

Nine sheep were completely reversed and 11 were not (3 of these latter sheep died). Six of those 9 animals completed immobolized were also completely reversed. Intravenous (IV) injection of the antagonist M50-50 seemed to be critical to rapid and complete recovery and was more feasible in a quiet animals. Two animals that seemed to be recovering slowly were reversed in 1.5 and 2 minutes with additional dosages of M50-50. Rapid recovery time was typical of complete reversal. Reversal time was 1.6 ± 1.3 (N=8) minutes in completely reversed sheep, but 79.3 ± 85.3 (N=4) minutes in partially reversed sheep. A volume of M50-50 fully equivalent to the amount of M99 injected appeared critical in total reversal. M50-50 dosage as a percent of initial M99 dosages was 86% in 6 animals incompletely reversed that lived, 70% in 3 others that died, and 117% in 9 sheep completely reversed. The latter amounts over 100% included supplemental IV dosages to animals when the initial reversal was suspected to be intramuscular (IM) or subcutaneous. Handling time averaged 17.8 ± 12.6 minutes for 13 timed handlings. The difficulty in obtaining a full dosage of the antagonist IV resulted from struggling of partially immobilized sheep.

All 3 sheep that died in the Noatak were incompletely immobilized and each was in serious trouble after the reversal drug M50-50 was administered. The sheep all laid down and were unable to easily rise. One sheep stood for about 10 minutes but then laid down again. Each sheep laid its head far back on the ground and hyperventilated. One additional ewe was in this state and also remained bedded at her capture site for 24 hours yet later recovered. We attribute the deaths to some combinations of these factors: chases that were too long resulting in overheating and exhaustion, insufficient intial doses of M99 and insufficient or IM (rather than IV) administration of the antagonist M50-50 due to thrashing of partially immobilized sheep.

As of April 1984, 22 of the 23 sheep successfully captured were still alive and wearing functional radio-collars. One ewe in the White Mountains died, possibly from wolf (Canis lupus) predation. The Noatak sheep have been radio-located 12 times each and the White Mountain sheep 15 times each.

DISCUSSION

WHITE MOUNTAINS - NOATAK DIFFERENCES

Differences in chase times, etorphine dosages required, and overall drugging success (mortality, induction time, recovery time) were quite apparent between the two capture operations. Potential sources of capture variations included: 1) Reproductive status of ewes varied between the 2 herds; White Mountains ewes were pregnant, Noatak ewes were lactating; 2) The White Mountains sheep were on winter forage and Noatak sheep were on spring green-up and possibly their physical condition varied; 3) The White Mountains sheep are subjected to a small sport harvest but the Noatak sheep to both fall sport and late winter subsistence hunts. The winter hunt is often from snowmachines and that harrassment may have caused them to be more responsive to the capture aircraft as has been suggested for caribou that occupy the same general area (Valkenberg and Davis, pers. comm.); 4) Many ungulates require larger drug dosages after longer chases and in summer versus winter seasons; 5) Escape terrain in the Noatak is marginal and scattered, forcing sheep to feed far from safety. Stemp (1982) found a direct relationship between the distance from escape terrain and heart rate (stress) in bighorns. Thus, the Noatak sheep may have been living under more stressful conditions than those in the White Mountains; 6) Shortening of the barbs on the needles in the Noatak as recommended by Nichols (1982) for mountain goats likely did not contribute to the dosage differences since the darts were still retained; and 7) Air temperatures were higher in June during the Noatak capture operation and could have contributed to overheating.

COMPARISONS TO OTHER CAPTURE OPERATIONS

Noatak approach times were longer when compared to successful (no mortalities) darting of bighorn sheep from helicopters in Montana (Andryk et al. 1983). The White Mountains chases were briefer. Chases exceeding 10 minutes and handling times exceeding 20 minutes result in higher mortalities of bighorn sheep (D. Jessup, pers. comm.). Our experience in the Noatak indicated that long chases may contribute to Dall sheep mortality, as well.

Drug dosages for Dall sheep in the Noatak were in close agreement with those found successful for bighorn sheep, i.e. 4.5-5.0 mg of M99 for adult ewes and 5.5-6.0 mg for adult rams. Successful doses in the White Mountains were only 1/2 as large. Smaller required dosages of M99 in the White Mountains may have been due to some combination of different season, diet, excitement level, and/or reproductive status. Longer chase times required increased dosages but for the 6 shortest chases (<2 minutes) in the Noatak, the same high levels of M99 were required for immobilization.

RECOMMENDATIONS

We found that Dall sheep could be successfully captured through darting from a helicopter when certain precautions were taken. Chase times should be less than 10 minutes and preferably less than 5 minutes. Where sheep are nervous, and run and dodge a great deal, we recommend darting them rapidly even if they are on the full run, although this may result in high loss of darts. We achieved handling times of 18 minutes in the Noatak and less than 10 minutes

in the White Mountains and recommend the least amount of handling possible. Injuries due to poor dart placement should be rare when using extra low power propellant charges (brown) and short needles.

High initial dosages of M99 and also equivalent dosages of its antagonist M50-50 given IV appeared critical to survival of Dall sheep. Larger dosages (5-7 cc) would probably ensure rapid immobilization of Dall sheep under most circumstances. However, explosive injection of the drug from Cap-Chur darts causes tissue damage and can be fatal (Valkenburg et al. 1983). Therefore, the smallest darts that appear adequate should be used. More concentrated solutions of etorphine would permit smaller darts. We used Acepromazine in most darts at a rate of 0.2:1 to the M99 with the objective of reducing overall drug and dart size and calming sheep (D. Jessup, pers. corresp. B. Taylor, pers. corresp.). Our observations, however did not clearly verify its necessity. We utilized Jet Ranger II helicopters primarily because of their ubiquitousness across Alaska, however other helicopters such as the Hughes 500 C and D models might prove more maneuverable and enable quicker dart placement and shorter chases.

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A PRELIMINARY ANALYSIS OF INTENSIVE, UNREPLICATED SURVEY DATA FOR MOUNTAIN GOAT POPULATIONS IN BRITISH COLUMBIA

D. Hebert and R. Woods. B. C. Ministry of Environment, Wildlife Branch, Williams Lake, B.C. V2G 1R8

ABSTRACT

Mountain goat (Oreamnos americanus) populations were surveyed at 19 locations throughout the province. Composition data, group size and density were collected or calculated for each location. Density estimates were compared to previous qualitative estimates (Blower 1977) and relationships among density, group size and productivity were examined.

INTRODUCTION

Based on qualitative estimates provided by regional wildlife biologists (Blower 1977), the British Columbia (B.C.) mountain goat population was estimated at approximately 63,000 animals (Macgregor 1977) between 1970 and 1980. Currently the provincial mountain goat species plan (Ministry of Environment 1979) estimated approximately 45,000 (+20 percent) animals in the province, although few populations had been adequately surveyed (Hebert & Turnbull 1977, Hebert 1978). In general, most early surveys (1960-1975) were reconnaissance in nature and did not allow good estimates of total numbers or composition. Intensive surveys began on the south central coast of B.C. in 1974 (Hebert & Turnbull 1977) and increased throughout the province until the present. However, replication of surveys to estimate variance and determine sampling intensity have not been undertaken in B.C.

Intensive surveys were increased because management of mountain goat populations by harvest data led to problems of overharvest in the past (Phelps et al. 1984, Foster 1976, Kuck 1977). The harvest of many mountain goat populations changed from an open season to harvest under a Limited Entry Hunting (L.E.H.) program necessitating better information on total numbers (minimum estimates), composition and distribution.

This paper is an attempt to examine actual survey information and evaluate its use in revising Blower's (1977) estimates. In addition, it examines the relationship between specific population parameters, to determine if management biologists could better evaluate goat populations using these criteria and relationships.

Intensive surveys were conducted throughout the province in a preliminary attempt to gather information from representative mountain blocks. Density estimates from these surveys could be used to extrapolate population estimates for larger areas in order to develop regional wildlife species plans. In association, density was related to other observable population parameters such as group size and productivity in order to develop preliminary provincial ecotype boundaries for mountain goats.

STUDY AREA

The study area consisted of 19 survey locations in the province of British Columbia (Fig. 1). In the southern portion of the province 13 surveys were completed: 3 on the outside of the Coast range, 6 on the inside of the Coast range, 2 in the Rocky Mountains, 1 in the Monashee Mountains and the other in the Cariboo Mountains.

Six surveys were completed in the northern portion of the province: 2 in the Stikine Mountains, 2 in the Omineca Mountains, 1 in the Rocky Mountains and the northernmost one in the St. Elias Range of the Coast Mountains.

METHODS

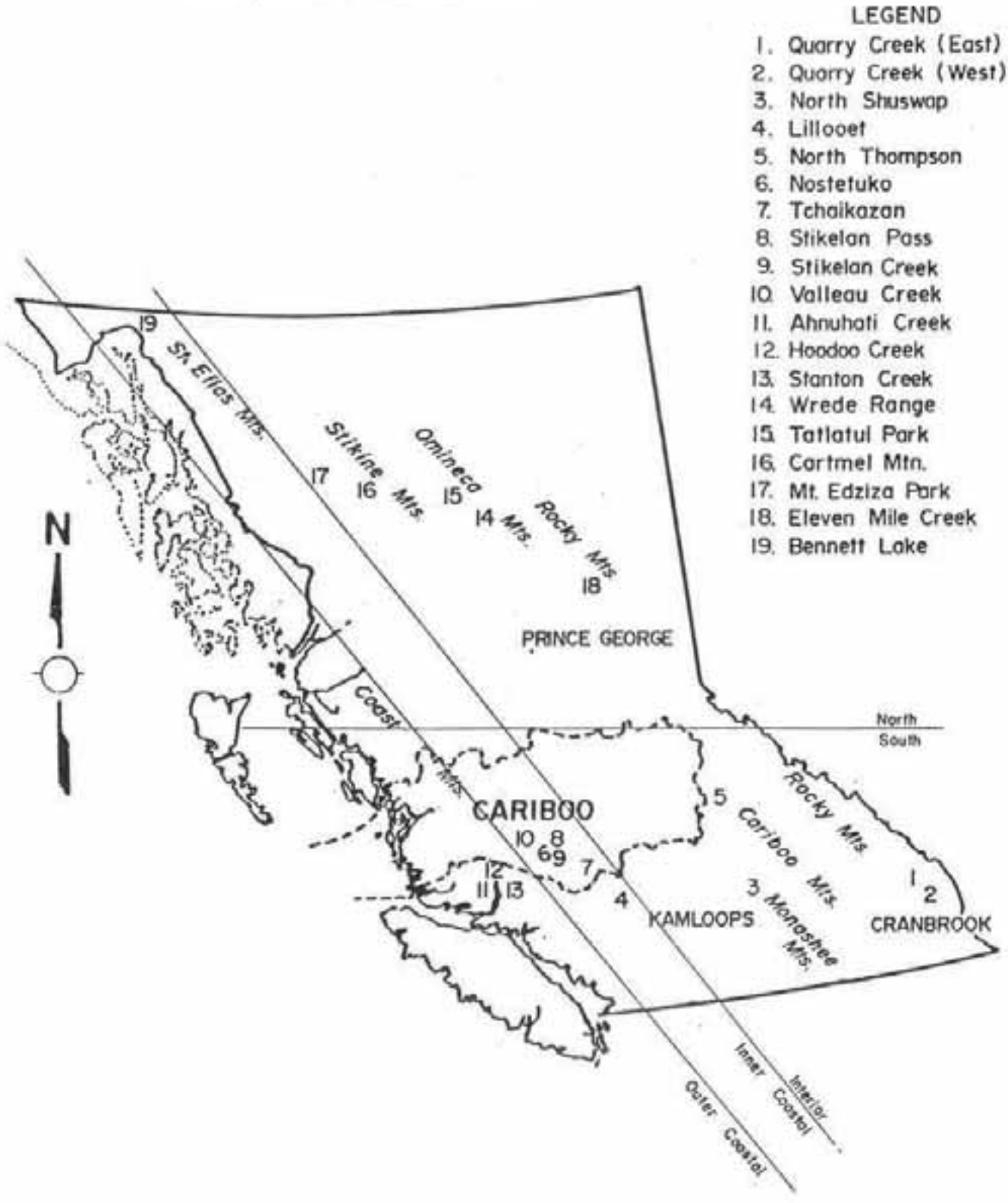
Intensive mountain goat survey data from 19 different areas were obtained from regional Fish and Wildlife Branch offices and the Provincial Parks Branch in Victoria. Surveys varied in detail; 16 with complete classification of all or most goats and 3 with partial classification. All surveys were done using a 206B Jet Ranger helicopter between 1975 and 1983 (Table 1). The majority of surveys were undertaken during 1982 and 1983 (Table 1). Where possible, surveys were standardized according to methodology from Hebert and Turnbull (1977), Hebert (1978), Fox (1972) and Nichols (1980) in lieu of replication.

Seventeen of the surveys were done according to methods standardized by Hebert & Turnbull (1977), primarily during July and August. The North Shuswap and Wrede Range surveys consisted of a single flight transect, while all others had two or more at 150 m intervals.

The area used to calculate population density was determined with an Apple computer and digitizing planimeter, on maps ranging in scale from 1:50,000 to 1:250,000. Difference in scale produced minor differences in the area calculation. Population densities were determined from the area between the 1,250 m contour line (approximate treeline) and height of land in each individual watershed (Hebert & Turnbull 1977). At present, the calculation of density does not account for slight differences in treeline from south to north nor for the amount of rock or nonvegetated area above treeline. Similarly, differences in slope were minimal and differences were not accounted for.

Statistical procedures followed Zar (1974). Correlation coefficients were calculated using the parametric produce-moment and non parametric Spearman rank correlation coefficients for group size, density and productivity for the surveyed areas. Based on statistical theory, kid percentages were initially transformed with the arcsine transformation ($y=\arcsin y$) to better approximate a normal distribution. However, this procedure did not change the results so correlations with untransformed kid percentages were reported.

Figure 1. Locations of Mountain Goat Surveys in various mountain blocks throughout B.C. between 1975 & 1983



RESULTS

Composition

Classification of the majority of goats observed (75 percent) was possible on 11 of the 19 surveys (Table 1). Where possible, at least females with kids were classified on the 8 remaining surveys. The average productivity as measured by observed percent kids was 20.8 and 60.3 kids per 100 females.

Group Size

The average group size for the 19 survey areas (Table 2) was approximately 3.72 (SE = .41). Stratification of the survey areas into North-South and Coast-Interior areas indicated that average group size varied little throughout the province: Coast - 3.5, (SE = .55); Interior - 4.0, (SE = .65); North - 5.2, (SE = .98); South - 3.4, (SE = .42). By comparison, Smith (1977) found group sizes of 2.18 and 1.46 goats during mild and harsh winters in Montana while Smith and Raedeke (1982) found group sizes of 6.4 in southeast Alaska. Similarly, group size for the adjacent north-east portion of B.C. was 6.1 (Bennett Lake).

Density

Population density was calculated for each survey area and ranged from a high of 7.30 goats/sq. km. in East Quarry Creek to a low of 0.08 goats/sq. km. in the Wrede Range, North Shuswap and Ahnuhati (Table 2). The average goat density for the 19 survey areas is 1.03 goats/sq. km. (SE = .47), however, when Quarry Creek densities are removed from the data the average drops to 0.35 (SE = .09) goats/sq. km. Stratification of the survey areas into North-South and Coast-Interior zones indicated major density differences between coastal areas (.35 goats/sq. km., SE = .05) and interior areas (1.79 goats/sq. km., SE = .96) and between north (.41 goats/sq. km., SE = .24) and south areas (1.3 goats/sq. km., SE = .68). Excluding Quarry Creek, densities for the interior area (.36 goats/sq. km., SE = .21) and southern areas (.31 goats/sq. km., SE = .06) are similar to the coastal and northern areas. By comparison, McCrory et al (1977) determined densities of 0.45 goats/sq. km. for the entire area of Yoho Park and 1.50 goats/sq. km. for potential habitat. The interior and southern density calculations were also done excluding Quarry Creek data because this watershed may not be entirely representative of the mountain blocks in the southern Rocky Mountains. It was chosen because of the abundance of goats, in order to adjust the L.E.H. harvest. However, it indicates a possible upper range of goat densities in B.C. habitat.

Additional surveys in southeastern B.C. may produce higher average estimates of both density and group size for the southern and interior sections of the province.

Surveyed densities were compared with densities estimated by Blower (1977) using the sign test. Nine of the densities were higher, 6 were the same or comparable and 4 were lowere suggesting no significant difference (p = >.10). The sign test is not as powerful as other statistical tests and some large discrepancies between surveyed and estimated densities were apparent

(e.g. Quarry Creek). The degree of similarity is largely due to the wide range given to the estimated densities.

Correlations

Correlations were run for the following: (productivity-density), kids-density, percent kids-density, kids/100 females-density; (productivity - group size), percent kids-groups size, kids per 100 females-group size (Table 3).

In general, the relationship between these parameters were not significant for most areas of the province. Parametric and non-parametric statistics indicated a significant relationship exists for number of kids in the population and density (interior) kids/100 females and density (northern and coastal areas) and between kids in the population and group size (south and all populations).

DISCUSSION

Species management is a continually evolving process. Mountain goat population estimates for B.C. have changed from approximately 100,000 (Macgregor 1977) in the early 1960's to 63,000 (Blower 1977) in the early 1970's when based on qualitative estimates, to 45,000 (+20 percent) in the provincial mountain goat species plan (Ministry of Environment 1979). Regardless of the estimate or the process used to derive the estimate, hunter harvest has been a significant mortality factor on many if not most mountain goat populations in B.C. (Phelps et al. 1984, Foster 1977). Thus, it is imperative that precise and accurate population estimates be derived as soon as possible. Unreplicated, intensive standardized surveys are but an interim step in the process. They allow new estimates to be developed by extrapolating densities from specific surveys to larger mountain blocks which they may represent and allow population characteristics to be examined in order to identify general ecotype boundaries.

At present there are no specific criteria which allow a standard, comparable calculation of population density. Blower (1977) varied his watershed base (include minor or major watersheds) throughout the province for his density calculation. Hebert (1977) examined density for an entire watershed, the area between 305 and 1525 m, the area above 1525 m and that for south slopes only. McCrory et al (1977) calculated density based on a qualitative definition of potential habitat. It is obvious and imperative that definitions and standardized measures of density be established as soon as possible.

Due to the extent of mountain goat habitat in B.C. and its diverse and rugged nature, only general population indices will be available to management biologists for the foreseeable future. Thus, density estimates, derived from unreplicated, standardized surveys of representative mountain blocks will be used to develop population estimates for mountain blocks, management units, regions and the province, in order to set reasonable harvest rates. The harvest of mountain goats has and will continue, with or without adequate information. Improvements in establishing estimates (minimum estimates) can only improve the level of management.

The current density estimates for B.C. vary from .08 to 7.3 goats/sq. km. due to the diversity of goat habitat surveyed. However, the average density (1.03/sq. km.) in B.C. is lower (average .35 without Quarry Creek) than several other density estimates (McCrory and Blood 1977, Stevens 1983, Smith 1984). Also, since replication of surveys of large scale mountain blocks or management units, necessary for management purposes is impossible at this time, due to budget constraints, these population estimates are minimum estimates, useful in the evolving calculation of a provincial estimate and in the calculation of approximate harvest.

A preliminary comparison of southern interior and outer coastal goat populations suggested that productivity and group size may be related and indicated that these parameters (prod. = 34 kid/100 fem., 13.9 percent kids; group size = 1.69) (Hebert and Turnbull, 1977) may be lower for this outer coastal population than for the southern portion of the province. The low number of significant correlations between productivity and density and group size may result from inadequate definition of ecotype boundaries and individual samples which may not be representative of ecotypes. Larger samples within ecotypes may aid in the determination of these relationships. A comparison of data from Hodoo and Stanton Creek with that from all surveyed areas in the province suggests that productivity and group size are lower on this portion of the outer coast than for almost all areas throughout the province. Comparison of these criteria indicates that there is considerable overlap among southern, northern and inner coastal populations.

The reality of annual harvest and high hunter demand necessitate improvement in survey techniques and continual analysis of available data. Stratification of B.C. mountain goat populations into appropriate ecotypes is necessary in order to develop harvest strategies.

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