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POPULATION DYNAMICS AND BEHAVIOR OF MOUNTAIN GOATS USING ELLIOTT RIDGE, GORE RANGE, COLORADO

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Abstract: The Gore Range mountain goat (Oreamnos americanus) population started from 15 animals released between 1968 and 1972. Maximum population was estimated to be 120 in 1979. During the summers of 1990 and 1991, mountain goats were observed on Elliott Ridge, an area they began using in 1981. This alpine ridge lacks escape cover. Goats are attracted to 10 mineral licks on the ridge, regularly traveling at least 24 km, round-trip, to them. A radio collared nanny with kid moved >84 km from 2 July to 5 September 1991, primarily because of repeated visits to the licks. Group size averaged 26 animals for the 2 summers (Maximum = 69). Adult billies were absent from the ridge in late summer. During 1977-1991, the number of kids per 100 older animals ranged from 14 to 48, averaged 29.6, and negatively correlated to May snowfall and maximum snow depth. The population of 128 animals appears to be stable or increasing slightly. Hunter harvest averaged 6.9 adults since 1978 (range 1-12). Because of the large number of mountain goats congregating at licks, aggressive behaviors occurred at high rates. Large separations of >30 m between nanny and kid were often observed and the number of successful suckling attempts was low.

Between 1968 and 1972, 15 mountain goats were introduced into the Gore Range-Eagles' Nest Wilderness Area in Summit County, Colorado. The population was estimated at 120 animals in 1979 (Thompson 1981). Since then, there has been some concern over a possible population decline.

Thompson (1981) evaluated habitat use, food habits, distribution, and population dynamics of the Gore Range mountain goats. At that time, the Gore Range population exhibited one of the highest "r" (rate of growth) values reported for introduced mountain goats (Guenzel 1980).

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The population has been hunted since 1978. Hunting has varying impacts on mountain goat herds. Hebert and Turnbull (1977), Kuck (1977), Chadwick (1983), and K. Smith (1988) reported hunting being additive to mountain goat mortality in native populations. Adams and Bailey (1982), Stevens (1983), and Swenson (1985) observed density-dependent reproduction in introduced populations.

Since Thompson's (1981) study, Gore Range mountain goats began making extensive summer use of the relatively flat Elliott Ridge which has little of the typical steep goat habitat described by Hebert and Turnbull (1977), Kuck (1977), and Chadwick (1983). The area lacks significant escape cover, usually important to mountain goats (Brandborg 1955, Fox 1983, von Elsner-Schack 1986). However, Adams et al. (1982b) noted goats using habitat far from escape terrain in Colorado. The first report of goats using Elliott Ridge was 1981. Presumably they use this Ridge for its mineral licks.

We (1) review the status of Gore Range mountain goats and how different factors such as hunting and snow depth may affect kid production; (2) discuss mountain goat summer use of Elliott Ridge and goat behaviors at lick sites; and (3) document changes in summer range and habitat use by mountain goats in the Gore Range.

STUDY AREA

In north-central Colorado, the Eagles Nest Wilderness Area (542 km^2) encompasses most of the Gore Range. The range's highest peak is Mt. Powell (4125 m). The north end of the range forms an 8.6 km long, alpine ridge called Elliott Ridge. The Ridge descends northward from Meridian Peak (3787 m) to 3400 m at Blue Lake. Blue Lake is a major trailhead. Snow conditions preclude access until late June - early July. Elliott Ridge is relatively flat, averaging 0.6 km wide, with steep flanks east and west. The flanks have only a few rocky cliffs, potential escape cover. The Ridge supports alpine vegetation. Tufted hairgrass (Deschampia caespitosa), sheep fescue (Festuca ovina), sedges (Carex spp.) and clovers (Trifolium spp.) are dominant plants with some dense willow (Salix spp.) in wetter areas. More than 90% of Elliott Ridge is above treeline. Ten mineral licks occur along the ridge-top. The licks may be natural or could be areas where past herders have salted. About 800 domestic sheep annually grazed the Ridge from at least 1953 until 1989, primarily in the early fall.

METHODS

We used weather data from the National Oceanic and Atmospheric Administration station at Climax, CO (3460 m) which is 45 km southeast of the study area. Climax approximates the terrain and elevation at the study site.

Four mountain goats were captured and radio-collared during 1991. Collared goats were relocated from the ground and in monthly fixed-wing flights. Home ranges were calculated from the 3 most distant locations for each goat.

The field season lasted from 6 July to 2 September in 1990 and from 28 June to 5 September in 1991. On 54 days (1990:15; 1991:39), mountain goats were observed for a total of 242 hours. We made all observations at mineral licks using a 12x-36x spotting scope. On some days, randomly chosen nanny-kid diads were observed in 10-minute sessions. Activities and interactions were recorded during 22 separate sessions in July and August, 1991. Group size with each diad was recorded.

Mountain goats on Elliott Ridge were counted and classified, based on B. Smith (1988). Final ratios for each year were determined by averaging the daily counts. On most days, some goats were not classified and the final ratios do not include days when more than 50% of the total were unclassified. Kid:100 older animal (K:100 OA) ratios are considered most reliable when estimating production of goats classified while in large herds (Lentfer 1955; R.D. Schultz, unpubl. rep., Colo. Div. of Wildl., Fort Collins, 1973). The "older animal" classification lumps yearlings, subadults, and adults.

Data from past Colorado Division of Wildlife (CDOW) ground and flight observations were converted to K:100 OA ratios. Flights covered the entire Gore Range in some years (1976-79, 1982, 1985, 1989). During 1982 and 1986, there were coordinated ground counts by volunteers. The "minimum observed population" was the largest number of mountain goats seen on any day. "Minimum calculated population" size was computed by the cohort completion method (Smith 1976, Hayden 1984).

Soil samples were collected by hand from each of the mineral licks. Control samples from each of the different parent materials on Elliott Ridge were also collected. The Soils Laboratory at Colorado State University analysed soil samples from lick and non-lick (control) areas.

Spearmann and Pearson correlations were used to evaluate relationships between variables (Steel and Torrie 1980).

RESULTS

Movements

Mountain goats in the Gore Range often made 24 km round-trips to mineral licks on Elliott Ridge. Animals typically came from near Mt. Powell, travelled out the ridge to a lick, and often, after several hours moved back to the Mt. Powell area, completing a 24 km circuit.

In 1991, 4 radio-collared goats were relocated on 3 days from fixed-wing aircraft (18 Jul, 12 Aug, 27 Sep) and on 3 - 11 days from the ground. The collared adult nanny with kid travelled extensively, moving at least 84 km during 2 July - 5 September, including many trips out Elliott Ridge. On one occasion, she was relocated 16 km south of the Ridge, the furthest that any collared animal moved from the mineral licks. Her summer home range size was estimated at 48 km^2.

The adult collared billy moved a minimum of 32 km during the summer of 1991. Observations of the billy were few because he retired to steep terrain that prohibited location of his radio signal from Elliott Ridge. The billy's home range was estimated from flight and ground data to be 4.9 km^2 between 2 July and 27 September.

The 2 collared yearling billies spent the whole month of August and early September on Elliott Ridge or in the area nearby. Their home ranges were both estimated to be 5.3 km^2 between 2 August and 27 September.

Population Dynamics

Group size and composition.--On Elliott Ridge, group size averaged 26 animals (27.4 in 1990, 24.2 in 1991). Maximum observed group sizes were 53 in 1990 (12 July) and 69 in 1991 (29 July). The maximum number of goats seen on Elliott was 100 on 28 July 1991.

On some days (36% in 1990; 45% in 1991), at least 1 adult billy was observed on Elliott Ridge. However, adult billies were rarely seen on the Ridge after 17 July.

Group size on Elliott Ridge decreased as the summer progressed in both years (1991: Fig. 1; 1990: $r = -0.05$, $P = 0.08$, $n = 13$).

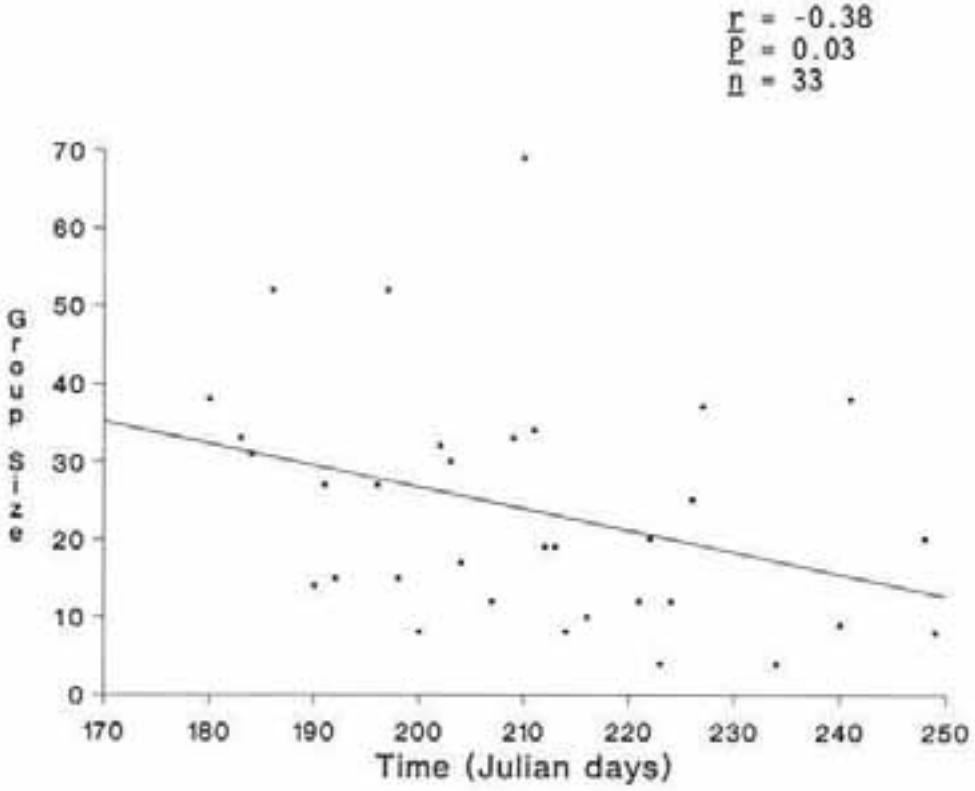

Fig. 1. Group sizes of mountain goats observed on Elliott Ridge, summer 1991. (11 Jul = day 192; 29 Aug = day 241).

Totals and ratios.-- Data from counts made in previous years for the entire Gore Range, including Elliott Ridge, are shown in Table 1. K:100 OA ratios from 1977 to 1991 ranged from 14 to 48 (avg. = 30). Minimum calculated population sizes for 1990 and 1991 were 76 and 128, respectively.

Table 1. Minimum observed population of mountain goats and calculated kid to 100 older animal (K:100 OA) ratios in the Gore Range, including Elliott Ridge, from 1977 to 1991. Minimum population size represents the largest number of mountain goats observed at one time.

Census Date	Minimum population	K:100 OA	Mode
Sep 1976	53	47[a]	Flight
Summer 1977	77	48	Flight
Summer 1978	92	20	Flight
Summer 1979	89	14	Flight[b]
Aug 1981	49	34	Ground[b]
Aug 1982	57	30	Ground
Aug 1982	75	24	Flight[b]
Jun 1984	60	20	Ground[b]
Jun 1984	49	26	Ground[b]
Aug 1985	75	44	Flight
Aug 1986	73	40	Ground[b]
Jul 1987	53	33	Ground[b]
Aug 1989	65	18	Flight[b]
Summer 1990	53	31	Ground[b]
Summer 1991	100	32	Ground[b]

[a] Yearlings were lumped with kids.
[b] Counts made only from Elliott Ridge.

Weather effects on kid production.--Increasing snowfall and snowdepth during winter and early spring (especially in May) had negative effects on K:100 OA ratios (Figs. 2, 3). Cumulative November thru May snowfall showed a close-to-significant negative relationship with K:100 OA ratios (r = -0.55; P = 0.06; n = 12).

Hunting.--During 1978-1991, hunters averaged 66% success in the Gore Range and nannies comprised an average of 52% of the harvest (Table 2). No gender data was available for 1986. Success has not changed significantly since 1978 (r = -0.26; P = 0.93; n = 14). Ages of the harvested mountain goats in 1989-1991 (CDOW) averaged 4.3 years (range 1-8). There was a negative, but not significant (r = -0.33; P = 0.35; n = 10) trend between the number of animals taken in the fall harvest and the K:100 OA ratio of the following spring.

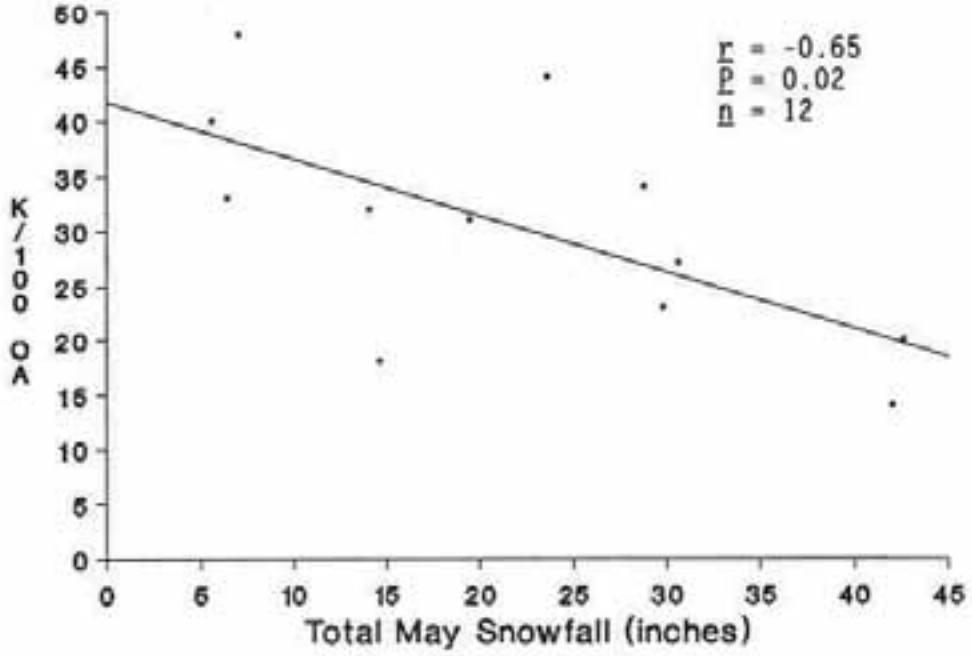

Fig. 2. The number of kids per 100 older animals in the Gore Range mountain goat herd in relation to total snowfall in May of the same year as the birth of the kids.

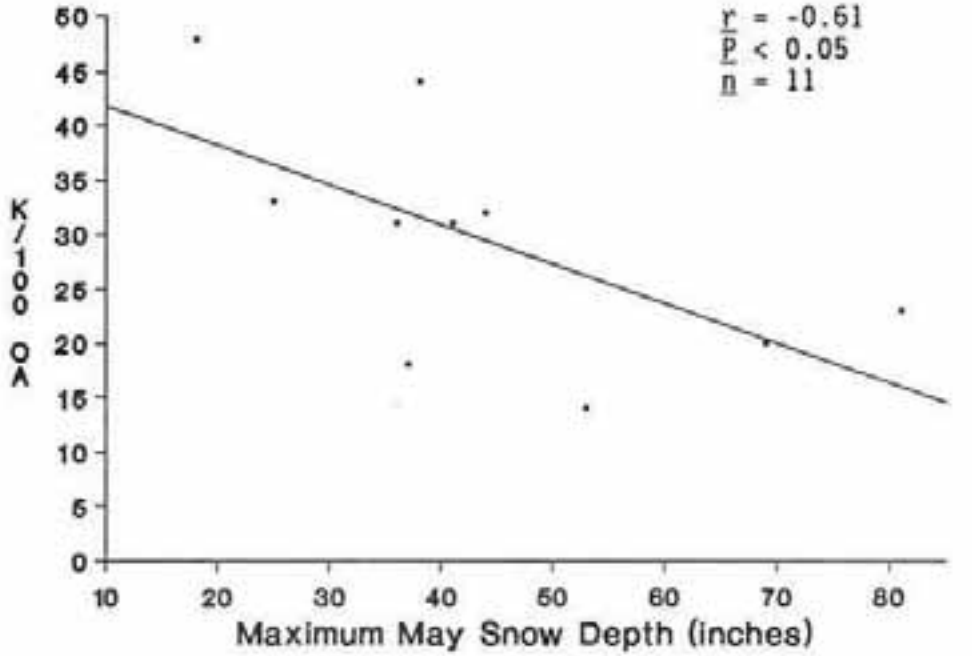

Fig. 3. The number of kids per 100 older animals in the Gore Range mountain goat herd in relation to maximum snow depth in May of the same year as the birth of the kids.

Table 2. Harvest statistics for mountain goats, Gore Range, 1978-1991 (CDOW). B = billy; N = nanny; Res = resident; Non-res = non-resident.

Year	Licenses Issued		Harvest		Total harvest	% Success	% Nannies killed
	Res	Non-res	B	N			
1978	4	0	2	2	4	100	50
1979	8	0	4	1	5	63	20
1980	8	0	2	5	7	88	71
1981	8	0	3	4	7	88	57
1982	12	0	2	2	4	33	50
1983	10	0	4	3	7	70	43
1984	9	1	1	1	2	20	50
1985	9	1	1	0	1	10	0
1986	9	1	-	-	5	50	-
1987	11	1	5	7	12	100	58
1988	11	1	2	4	6	50	67
1989	11	1	4	5	9	75	56
1990	9	1	4	5	9	90	56
1991	9	1	5	3	8	80	38
Totals:	128	8	39	42	86	Averages: 66	52

For 1990 and 1991, kill locations for 13 of 17 harvested mountain goats are known. One (8%) was killed on Elliott Ridge, 9 (69%) within 2 km of Mt Powell, 2 (15%) near Slate Lake 8 km southeast of Mount Powell, and 1 (8%) near Deluge Lake 18 km southeast of Mount Powell. Ninety-two percent of the 13 known kill sites were in the northern-most portion of the Gore Range, within an area of approximately 14 square miles (36 square kilometers).

Behavior

Aggression.--While observing nannies and kids, 153 aggression events, as described by Geist (1964), DeBock (1970), and Chadwick (1977), were recorded (Table 3).

Aggression involving bodily contact between nannies and kids was recorded at least 20 times. In all but one of these interactions, the aggression was addressed towards the nanny's own kid. Nannies would butt and push their own kids out of the way when it interfered with the nanny's access to a lick.

Aggression occurred more frequently as summer progressed (Fig. 4) and as group size increased (Fig. 5). The rate of aggressive events at licks averaged 41.7 per hour or 0.7 per minute.

Suckling.--Twenty-four suckling attempts and 1 successful suckle were observed in 10 observation periods. This is a rate of 0.24 attempts per minute or 14.4 per hour. The overall success ratio (number of successful

Table 3. Aggressive threat behavior between mountain goats at mineral licks, Gore Range, Colorado, summer 1991. Data were recorded during 10-minute observation periods of nanny-kid diads. Nan = adult nanny; Bil = adult billy; Sa = subadult.

Threat Behavior	Percent of 153 Observed Threat Interactions					
	Nan-Bil	Nan-Nan	Nan-Sa	Nan-Kid	Sa-Kid	Total
Present	0.5	4	0	0	0	4.5
Weapon	0	0.5	0	5	0	5.5
Rush	1	3	7	5	2	18.0
Orientation	1	28	16	18	9	72.0
Totals	2.5	35.5	23	28	11	100.0

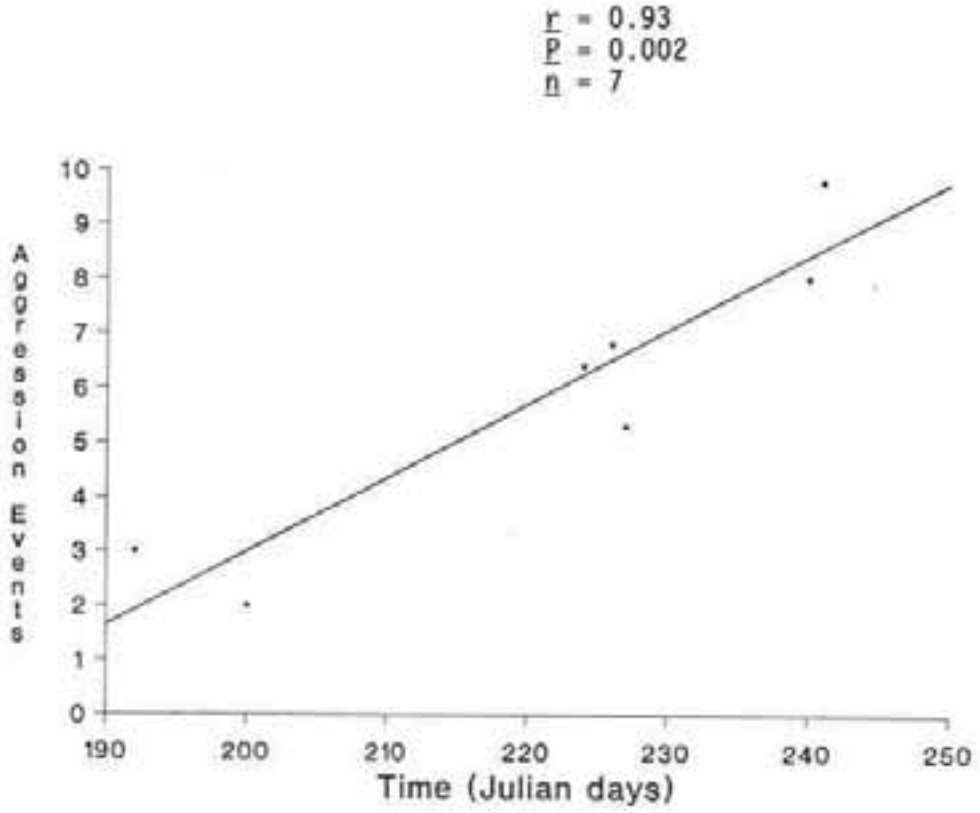

Fig. 4. The average number of aggressive events occurring between mountain goats at mineral licks during 22 10-minute observation periods on 7 days in the Gore Range, summer 1991. (11 Jul = day 192; 29 Aug = day 241).

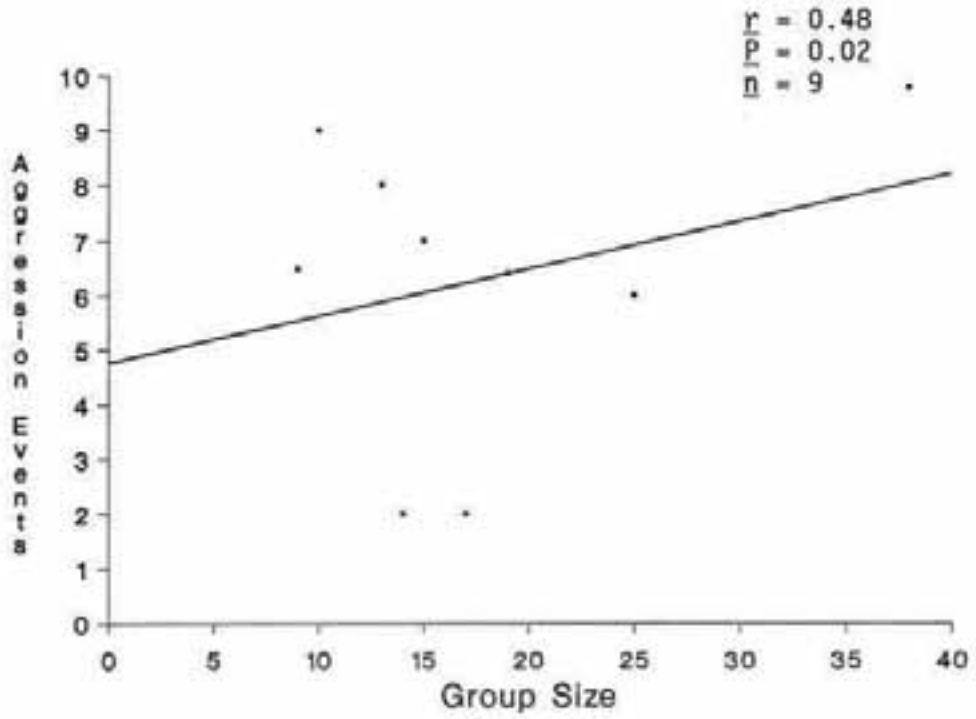

Fig. 5. The average number of aggressive events occurring between mountain goats at mineral licks during 22 10-minute observation periods in the Gore Range, summer 1991 in relation to the number of mountain goats in the group.

attempts/total number of attempts) is 0.04 for the observation periods. The average duration of a suckling event was 9.2 seconds (range 1-35).

Proximity.--Kids were often separated from their nannies. Kids were >30 m from their nannies at least 20 times. Once separated, the kid often vocalized. Upon reunion, the nanny and kid touched noses 10% of the time and the kid attempted to suckle 35% of the time. Maintenance of proximity is the kid's responsibility because a nanny will move off without looking at the kid (DeBock 1970, Hutchins 1984). Chadwick (1973) noted that kids maintained distances of <5 m from their nanny, but playing or exploring youngsters strayed 9-15 m and occasionally up to 30 m.

Mineral Lick Use and Soil Analysis

All age and sex classes used mineral licks. Relative use of the 10 licks differed between 1990 and 1991 (Table 4). All lick sites on Elliott Ridge, except number 10, contained much higher concentrations of Na and K than do the corresponding control areas (Table 5). In the Gore Range, Thompson (1981) noted a significant decline in Na and K concentrations on Dora Mountain. Analysis of soil from a Dora Mountain lick during my study showed lower mineral concentrations than he recorded and lower levels than most samples from Elliott Ridge.

Table 4. The number of days of use of 10 mineral licks on Elliott Ridge, Gore Range, by mountain goats, 1990 and 1991.

Lick	Days of use (%) 1990	1991
1	0	12 (34)
2	0	5 (14)
3	2 (15)	14 (40)
4	2 (15)	6 (17)
5	5 (39)	10 (29)
6	4 (31)	10 (29)
7	2 (15)	5 (14)
8	0	6 (17)
9	2 (15)	4 (11)
10	2 (15)	12 (34)

Table 5. Sodium (Na) and potassium (K) concentrations in licks 1-10 on Elliott Ridge, a lick on Dora Mountain, and Elliott Ridge control (non-lick) areas (C1-C4) in the Gore Range in 1991. Parent soil materials on Elliott Ridge: SS = sandstone; LS = limestone; B = basalt; G = gneiss.

Lick No.	Parent Material	Na (ppm)	K (ppm)
1	SS	352	184
2	SS	295	125
3	SS	229	1147
4	LS	561	92
5	SS	298	500
6	SS	324	482
7	LS	158	89
8	B	138	384
9	G	193	181
10	G	24	152
Dora Mt.	G	4	87
C1	SS	28	93
C2	LS	22	67
C3	G	31	129
C4	B	51	67

DISCUSSION

Movements

Mountain goats in the Gore Range move unusual distances in summer. Multiple trips to and from mineral licks on Elliott Ridge comprised much of the mileage (4-24 km round-trip). These represent greater distances and more frequent visits to mineral licks than in previous studies (Hebert and Cowan 1971; F. J. Singer, unpubl. rep., Natl. Park Serv., West Glacier, Mont., 1975; Bansner 1976). Hebert and Cowan (1971) reported goats travelling 3-24 km to mineral licks but only once per summer. In Colorado, Adams et al. (1982a) reported the average greatest linear distance between any 2 observations of a mountain goat was greater in summer (6.4 km) than in winter (1.7 km). In this study, the average greatest linear distance between any 2 observations for the 4 collared mountain goats in summer was 10.8 km.

The home-range sizes of the collared yearling (5.4 km^2) and adult (4.9 km^2) billies are similar to those of previous studies of mountain goats where yearly home range size was generally less than 25 km^2 (Wigal and Coggins 1982), but the collared nanny with kid's summer range (48 km^2) is much larger.

Habitat

Mountain goat behavior, in terms of use of Elliott Ridge, contradicts studies suggesting that goats' primary consideration in choosing habitat is proximity to escape terrain (Fox 1983, von Elsner-Shack 1986). Mountain goats in the Gore Range use open terrain on Elliott Ridge, up to 8 km from escape terrain, despite considerable human recreational use, which does disturb them according to our observations. The reasons for the frequent mineral lick visitation in the Gore Range are unclear. The abundant alpine vegetation on Elliott Ridge may play a role in attracting mountain goats. Together, vegetation and minerals, may serve as strong enough attractants to warrant the expenditure of energy and the risk of moving from escape cover to get to the Ridge. The absence of wolves in the Gore Range may reduce goat dependency on escape cover, although eagles and coyotes do frequent the area.

Population Dynamics

There does not seem to have been a great decline in kid production or change in the number of mountain goats in the Gore Range herd since the late 1970's (Thompson 1981). There were over 100 goats in the Gore Range in summer, 1991, with an estimated minimum calculated population size of 128 animals. This compares favorably with minimum estimated population of 89 and maximum of 116 in summer, 1979 (Thompson 1981).

The K:100 OA ratios for 1990 and 1991 (31:100 and 32:100, repectively) are near the average reported for native herds and herds established at least 16 years (28 kids:100 OA) (Bailey and Johnson 1977). The average ratio for 1977-1991 for the Gore Range herd is 30:100. Two populations in Colorado, 18-31 years after introduction,

had higher averages. The Mt. Shavano average was 42:100 (R. F. Smith, unpubl. rep., Colo. Dep. Fish and Wildl., Fort Collins, 1979); at Sheep Mountain, the average was 41:100 (Adams and Bailey 1982).

Thompson (1981) and Adams and Bailey (1982) also reported spring snow depth negatively affecting reproductive success. Other studies have found lower kid production after severe winters (Brandborg 1955, Chadwick 1973, Hjeljord 1973, Rideout 1974, Smith 1984).

Although not significant, the trend that hunting negatively affects kid production is important. Others have reported that mountain goat populations are sensitive to over-harvest (Hebert and Turnbull 1977, Kuck 1977, Adams and Bailey 1982, Chadwick 1983, K. Smith 1988). Conservative harvesting of mountain goat herds seems justified.

Behavior

Behavior of mountain goats on Elliott Ridge is somewhat different from that reported by DeBock (1970), Chadwick (1977), Thompson (1981), and Hutchins (1984). Average group size is high compared to other areas, where it ranges from 2.5 - 6.4 (Brandborg 1955, Lentfer 1955, Smith 1976, Chadwick 1977, Smith and Raedeke 1982). On Elliott Ridge, average group size was 27.4 in 1990 and 24.2 in 1991. Adams et al. (1982b) found that Colorado goats tended to congregate in large groups, with a maximum summer group size of 83. Large group sizes on Elliott Ridge may provide numerical security from human disturbance or natural predators, such as eagles, as the goats travel far from escape terrain.

A behavioral cost of using Elliott Ridge licks in large groups is a high rate of aggression between animals. Pedevillano (1986) reported 3.2 aggression events/hour at a lick. We observed 41.7/hour. This difference is likely due to group size, as aggression increases with group size (this study, Chadwick 1977, Masteller and Bailey 1988). When groups were larger than 20, Singer (1977) and Dane (1977) found high rates of aggression (1 every 20 sec. or 180/hr.). Chadwick (1977) reported a rate of 6.1 agonistic encounters/goat/hour at salt licks with a group size of 8.

Kids on Elliott Ridge had a low overall suckling success ratio in comparison with a herd studied by Hutchins (1984) for several summers. This may be due to the sample size in this study, the higher number of aggressive interactions we observed, or the increase in nanny-kid separations in large groups.

Mineral Licks

Although Hebert and Cowan (1971) noted mountain goats using mineral licks only once in a summer, Singer and Doherty (1985) reported multiple trips to licks. At Elliott Ridge, the radio-collared mountain goats and other recognizable goats made several trips to licks. Most adult billies retired to remote areas after making visits to mineral licks during early summer.

Soil compaction may explain the variance between years in the use of licks on Elliott Ridge. Some licks which received high use in 1990 were so compacted in 1991 that we could barely obtain a soil sample. This might sometimes deter goats from intensely using a lick for 2 consecutive years. Compaction of the Dora Mt. licks, and their low levels of Na and K, may explain the onset of use of the licks on Elliott Ridge.

Management Recommendations

Using the calculated minimum population from this study (128 animals), current harvest levels in the Gore Range are 8% of the herd. However, if the average harvest for the last 14 years (6 animals) is used, harvest levels are at 5%, the recommended rate. Hebert and Turnbull (1977) suggested a harvest of 4% of the total population or 5% of the adults (2 year-olds and older) in native goat populations. Youds et al. (1980) and Smith (1986) stated that a 5% harvest of adults would be sustainable given moderate production (57 kids per 100 females). Bailey and Johnson (1977) and Guenzel (unpubl. rep., Univ. of Wyoming, Laramie, 1978) suggested similar management for goat populations that have been established for more than 15 years. In Colorado, Adams and Bailey (1982) suggested a harvest of 7% of the late summer population for the Sawatch Range herd.

As Thompson (1981) suggested, the survival of the previous year's kid crop and a reliable estimate of kid production should be 2 important management considerations. For the Gore Range population, present and historical census data shows an average K:100 OA ratio of 30:100 suggesting that present kid production is moderate and warrants a 5% harvest. Harvest levels should not be increased from current levels.

It is also important that, based on 1990 and 1991, most of the mountain goats in the Gore Range are being harvested in a 36 square kilometer area of the northern portion of the range, near easy access via Elliott Ridge. If numbers of permits remain at present levels it may be wise to allocate licenses on a drainage basis. Others have found that increased access into mountain goat range leads to over-harvesting in accessible areas (Chadwick 1973, Foster 1977, Hoefs et al. 1977, Johnson 1977, MacGregor 1977).

Yearly inventories are suggested to monitor the growth and sex-age composition of the Gore Range mountain goats. These censuses would be most effective if aerial surveys are combined with ground observations. As Risenhoover and Bailey (1982) suggested, the survey method must be standardized so biases are consistent and accurate trends in population changes may be determined.

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