INFLUENCE OF SNOW CONDITIONS ON WINTER DISTRIBUTION, HABITAT USE, AND GROUP SIZE OF MOUNTAIN GOATS

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Abstract: Habitat relationships of mountain goats (Oreamnos americanus), native to the Bitterroot Mountains of western Montana, were studied from January 1973 to June 1975. Distribution and habitat use on winter ranges were evaluated in terms of elevation, exposure, slope inclination, terrain types, vegetative associations, and size of winter range used by goats. Observed variations during and between three winters were related to snow conditions. When snow depths were greatest, lower elevations, southern exposures, and cliff terrain were used a greater percentage of the time. Mean group size declined and amount of winter range occupied increased during two severe winters versus a mild winter. Adult females exploited snow-free portions of cliffs while subdominants used less optimum habitat. Successful exploitation of optimum habitat, where energy expenditures are minimized, likely promotes survival of females and their offspring.

Mountain goats have evolved many unique adaptations which permit them to occupy an uncrowded niche. Few other North American mammals can survive in the mountainous environment inhabited year-round by goats. As a result, serious predators upon the species are relatively few and mountain goats experience little competition for food and space from other herbivores. Previous investigators examined the daily and seasonal movements, food habits, behavior, and activity patterns of goats to understand their means of coping with their environment and to determine what constitutes good habitat for goats (Brandborg 1955, Chadwick 1973, Kuck 1973, and Rideout 1974). In these studies, the terrain and vegetational features of goat range were combined into four to eight habitat types used to document habitat use. Such broad classifications could preclude accurate measurement of those habitat characteristics which mountain goats prefer.

During January 1973, I initiated an ecological investigation of mountain goats native to the Bitterroot Mountains of western Montana. Part of that study focused on documentation of winter distribution and habitat use. Data were obtained during three winters to investigate year-to-year climatic influences.

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STUDY AREA

This study was conducted 40km south of Missoula, Montana in the Bitterroot Mountains (between 46°16'N and 46°31'N latitude and 114°12'W and 114°28'W longitude), the crest of which forms the Montana-Idaho state line. Seven parallel, steep-walled, glacial canyons, which drain eastward to the Bitterroot River, constituted the study area. The canyons are 10 to 16km in length. Elevations range from 1280 to 2800m (4200 to 9200feet). The eastern half of the south-facing canyon wall in six of the drainages provides winter range for mountain goats. Winter range in each canyon is continuous and characterized by steep, broken terrain in which tiered cliffs, skirted by talus, and dissected by couloirs predominate. Parent material is granite and gneiss. Winter ranges lie within the montane forest zone, where scattered ponderosa pine (Pinus ponderosa) and Douglas-fir (Pseudotsuga menziesii) overstory grows on moderate slopes and cliff ledges. A mixed understory of native grasses, forbs, and shrubs flourishes on ledges, talus, and couloirs where a soil mantle has developed. Common species include: bluebunch wheatgrass (Agropyron spicatum), elk sedge (Carex geyeri), yarrow (Achillea millefolium), stonecrop (Sedum stenopetalum), currant (Ribes spp.), and serviceberry (Amelanchier alnifolia). Forests of lodgepole pine (Pinus contorta), subalpine fir (Abies lasiocarpa), whitebark pine (Pinus albicaulis), and alpine larch (Larix lyallii) grow on the cooler north-facing canyon walls and at higher elevations.

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The climate is typically warm and dry in summer, cold and wet during winter. Precipitation increases from 100cm annually at the canyon mouths to 250cm along the Bitterroot Divide. The majority falls as snow.

METHODS

I censused mountain goats from 1 January 1973 to 10 June 1975. They were spotted and observed from trails in each of the canyon bottoms during fall, winter and spring. Modes of travel used to conduct censuses included hiking, snowshoeing, skiing and, in Fred Burr Canyon (winter 1974-75), snowmobile. Summer censuses were conducted along interfluvial ridgetops. Data from aerial censuses were not included in habitat use analyses as identification of habitat characteristics was difficult from aircraft.

Upon initial observation, habitat characteristics, general behavior, and age and sex composition of each sighting were determined with a 15-60 variable spotting scope and recorded on a datum form. Only one record per day was made of each group. Goats were classified in one of six sex and/or age cohorts: kid (K), yearling (Y), 2-year-old male (2M), 2-year-old female (2F), adult male (AM), and adult female (AF) (Brandborg 1955, Smith 1976).

Throughout the study, each sighting was plotted on U. S. Geological Survey 7.5 minute topographic maps. Elevation, slope inclination, and exposure were recorded. Slope was measured over a 61m (200 f) interval of elevation from 10.2cm:1.6km (4in:1mi) topographic maps. Exposure was determined for an area with a 13.7m (15 yard) radius of each sighting. Furthermore, I devised a dual system for describing the habitats occupied by goats whereby I classified the terrain type and vegetative association separately within a 13.7m radius of each sighting. The final, modified version was used from July 1974 through June 1975. Ten terrain types described the predominate geomorphic features of goat range in the study area. Vegetation was classified in a two-component scheme (understory and overstory) paralleling that developed by Daubenmire and Daubenmire (1968). However, existing plant cover, regardless of successional stage, constituted vegetative associations. Ten overstory and 14 understory types were described. This habitat system was outlined previously (Smith 1976). A dual system was employed to determine whether terrain or vegetation might better preduct habitat utilization.

Snow depth was estimated at the location of each goat sighting according to the technique described by Geist (1971:269). Chest height (47cm for adults) and other reference points on goats were used as a measuring stick.

RESULTS

Seasonal Distribution

Mountain goats in the study area occupied different summer and winter ranges. Snow depths limited goat distribution, from mid-November through May, to the eastern 7km of the canyons. Steep slopes, southerly exposures, and the action of westerly winds afforded the eastern south-facing canyon walls with excellent snow shedding properties. Elsewhere, snow accumulated to depths of 1.5-4.5m in winter and remained into spring (Table 1). Six of the seven canyons supported a goat herd during winter.

The fall migration to winter ranges was a gradual process. During mid-Octobers of 1973 and 1974, a few goats began appearing on south-facing canyon walls west of winter ranges. This section of each trunk canyon constituted a transitional range utilized for about one month. The movement to the Fred Burr Canyon winter range was abrupt during 1973, and it followed a storm which produced 75cm of snowfall across the study area on 31 October and 1 November. During the exceptionally mild fall of 1974, the movement of goats onto winter range was less synchronous but also occurred during early November. Mountain goats remained on their respective herd winter ranges until the migrated to high elevational summer ranges along interfluvial ridges and the Bitterroot Divide during mid-June. Movements between winter ranges did not occur.

Habitat Use

During the study, I observed groups of goats 717 times on winter ranges accounting for 1,138 goat observations. "Group" and "sighting" are used interchangeably throughout the text to denote either a single goat or several interacting in close proximity to one another for a period of time. Of these totals, 594 groups accounting for 960 goat-observations were in Fred Burr Canyon, where winter ecology was studied most intensively. These 717 sightings are the basis for analysis of habitat use.

Elevation From 1 January through 27 Mary (which henceforth is referred to as "winter period" while "winter" includes only the months January through March), mountain goats used elevations below 2,225m (7,300f). Over 94 percent were observed on the lower 594m (1,800f) of south-facing canyon walls between 1,366 and 1,981m (4,480 and 6,500f) elevation. A complete altitudinal switch occurred in summer when 98 percent of observed goats were above 2,225m (7,300f) elevation (Fig. 1). The

Table 1. Annual precipitation and snow depths at a USDA Soil Conservation Service collecting station 15 km south of the study area and 1.5 km east of the Bitterroot Divide.[a]

Precipitation in Centimeters													
Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1968-1972 Average	15.49	15.80	24.05	41.17	21.74	16.18	15.04	8.76	11.79	3.07	3.30	11.38	187.76
1973	4.09	8.99	29.18	17.78	7.47	11.89	6.96	6.68	10.03	4.78	1.45	11.91	121.21
1974	12.95	24.33	30.07	40.26	26.62	22.00	18.97	9.55	11.99	9.96	5.00	3.96	215.67
1975	1.75	12.42	2.43	45.64	20.14	17.37	15.44	7.16	11.46	5.82	14.86	2.82	179.22

Snow Depth in Centimeters						
Year	Jan.	Feb.	Mar.	Apr.	May	June
1960-1972[b]	165	196	277	284	277	163
1973	142	--	198	203	183	63
1974	201	--	345	358	338	274
1975	163	--	297	325	333	267

[a]Twin Lakes, Montana, Station No. 14CD8P, 1948m; Sec. 32 T 05 N R 23W (Latitude 46° 09' Longitude 114° 30'); Bitterroot River of Columbia Basin.

[b]January data collected 1968-72, February data in 1968, and June data 1965-72.

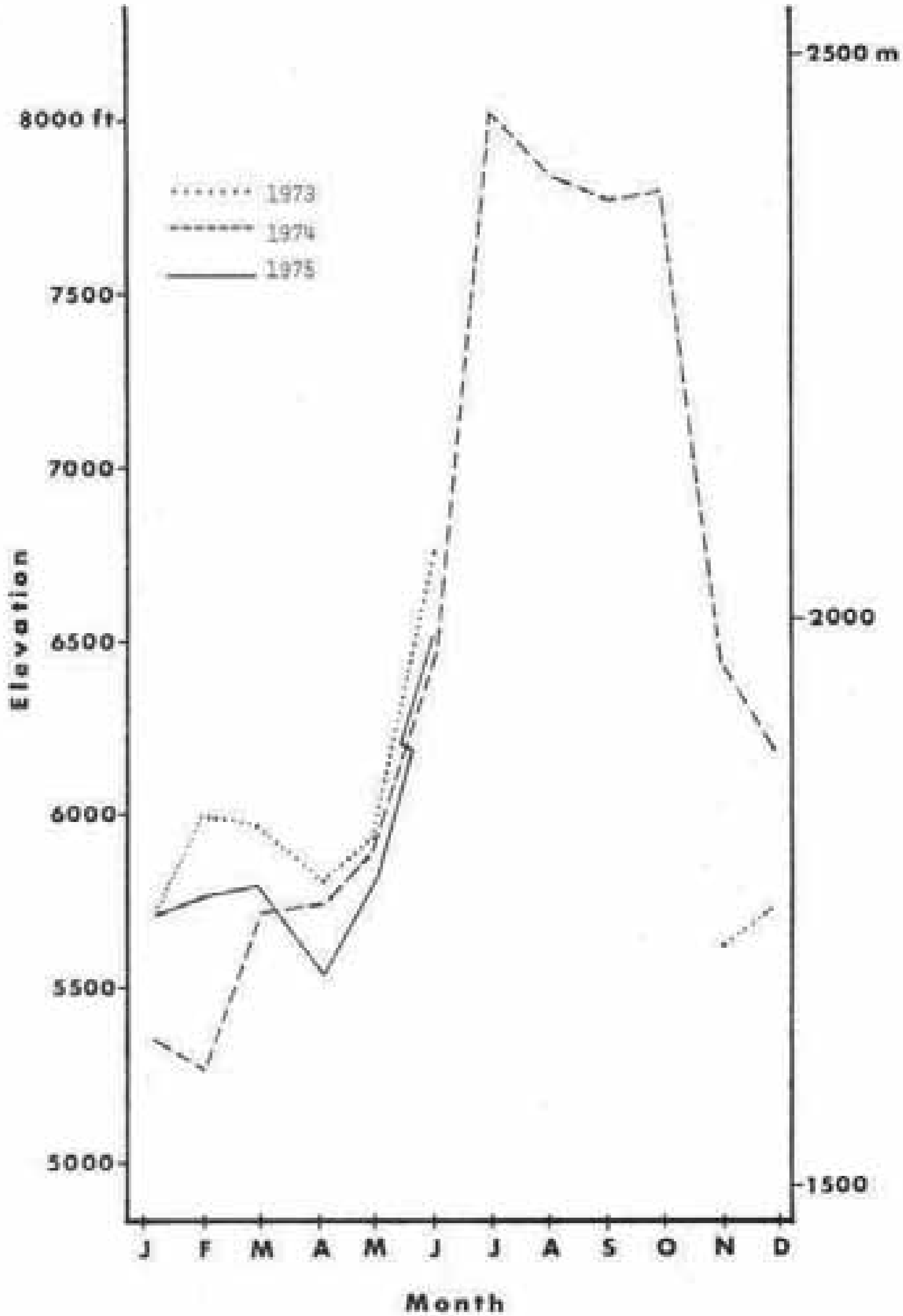


Figure 1. Monthly mean elevation of goat sightings from 1973 to 1975.

alpine cirques used extensively in summer by goats begin at 2,225m (7,300f).

During the winter period of 1974 and 1975, goats utilized mean elevations of 1,735m (5,693f) and 1,741m (5,712f) respectively, compared to 1,786m (5,858f) during winter period of 1973 when snow depths were below normal. The mean elevations used in 1974 and 1975 were significantly less ($p < 0.05$) than in 1973, based on the Student-Newman-Keuls multiple comparison test (Sokal and Rohlf 1969:239). Table 1 shows monthly snow depths recorded at a Soil Conservation Service collecting station 13km south of the study area. Because goat winter ranges lay at lower elevations and farther east of the Bitterroot Divide than the S.C.S. station, they accumulated less snow during winter and retained large patches only on shaded exposures by June. However, the annual trends shown in Table 1 are applicable to goat winter ranges.

The monthly elevations used by goats fluctuated with snow depths (Fig. 1). Deep accumulations of snow during fall 1973 forced goats to lower portions of winter ranges than during the succeeding fall. Below normal daytime temperatures from February through May 1975 delayed spring snowmelt. Consequently, goat sightings were at lower elevations during April and May 1975 than during the preceding two years.

There were no significant differences ($p < 0.05$) between the mean elevations used by feeding and bedding groups (the daily activities at which mountain goats spend 37 and 47 percent of their time, respectively) during each of the three winter periods.

Exposure From the time goats reached transitional ranges in October until the spring migration, all sighting were on E, SE, S, SW, and W exposures. Sixty-three percent were on S exposures which shed snow more readily than others due to favorable sun angle (Table 2). Goats used SE and E exposures more than SW and W, largely because of winter range geomorphology. West exposures of outcrops and cliffs were much steeper, supported less forage, and received full force of prevailing winds, in contrast to E exposures.

From January through April, when snow depths were greater on winter ranges, goat frequented S exposures 56 percent of the time in 1973 compared to 73 and 71 percent of the time in 1974 and 1975. There were no significant differences ($X^2 = 6.52$, 4df, $p < 0.05$) between exposures used by feeding and bedding groups during each of the three winter periods.

As winter snowpack began receding in late May and June, use of S exposures declined and sightings on SE and E exposures increased (Table 2). This shift correlated with the appearance and accessibility of new plant growth on all exposures and rising daytime temperatures. During May and early June, when mountain goats had only partially shed their heavy winter pelage, afternoon temperatures often reached 15.5 to 27 degrees C. Easterly exposures were shaded and cooler during the warm afternoon and evening hours.

Slope From January through June, the average slope used by mountain goats was 47, 49, and 48 degrees respectively in 1973, 1974 and 1975. There was little monthly variation. Although goats displayed no significant ($p < 0.05$) difference in year-to-year preference for slopes, they favored slopes considerably steeper than the average angle (23, 25, 27 and 27 degrees) which Beaty (1962) calculated for the south-facing canyon walls of four representative canyons in the study area. This implied that goats preferred the steepest slopes practical regardless of snow conditions. As specialized rock climbers, goats found snow-free feeding sites and secure bedsites on steep slopes (Fig. 2).

Vegetative Associations From November 1974 through 10 June 1975, goats used the bunchgrass type 62 percent of the time followed by 23 percent in scattered herb. Plant composition was similar in both understory types, but total biomass was greater for the bunchgrass types (Smith 1976). The bunchgrass type covered much of winter ranges and lower transitional ranges on cliff ledges, and parkland and forested colluvial slopes. Scattered herb occurred on sites with thin soils such as cliffs, talus, and broken rock terrain types. Use of vegetative associations was distributed most evenly during November, May and June when snow depths were least (Table 3).

Vegetative associations without overstory were increasingly selected from December through April (0 to 36 percent), then decreased abruptly in importance during May and June. The sites frequented by goats from February through April were wind-swept cliffs capable of supporting only sparse tree growth.

During the winter period of 1975, the observed occurrence of feeding and bedding groups in understory types differed significantly ($X^2 = 16.00$, df = 5, $p < 0.01$) from their expected frequencies. Feeding and bedding groups within the bare rock and scattered herb types contributed 32.5 and 36.3 percent, respectively, to the chi-square value. Groups of goats bedded more than they fed in bare rock and fed more than they bedded in scattered herb.

Terrain Types From November 1974 through 10 June 1975, 70 percent of all goat sightings occurred on cliffs (Table 4). Feeding and bedding activities were similarly distributed with 70 percent of feeding and 71 percent of bedding groups observed on cliffs. Herbaceous forage remained available

Table 2. Monthly percent use of exposures by mountain goats on transitional and winter ranges (November to June 1973-1975). Trace (T) amounts are less than 0.5 percent.

Month	No. of Groups	Exposure								
		NE	N	E	NW	SE	W	S	SW	I[a]
Nov.	26					27		69	4	
Dec.	32			6		25		69		
Jan.	57					16		80	4	
Feb.	51			4		33		59	4	
Mar.	100			4		15	1	73	7	
Apr.	225			5		20	2	67	5	T
May	194			9		26	2	53	9	2
June	32			16		44		31	6	3
Total	717									
Averages				6		23	1	63	6	1

[a]I = Indifferent, no exposure.

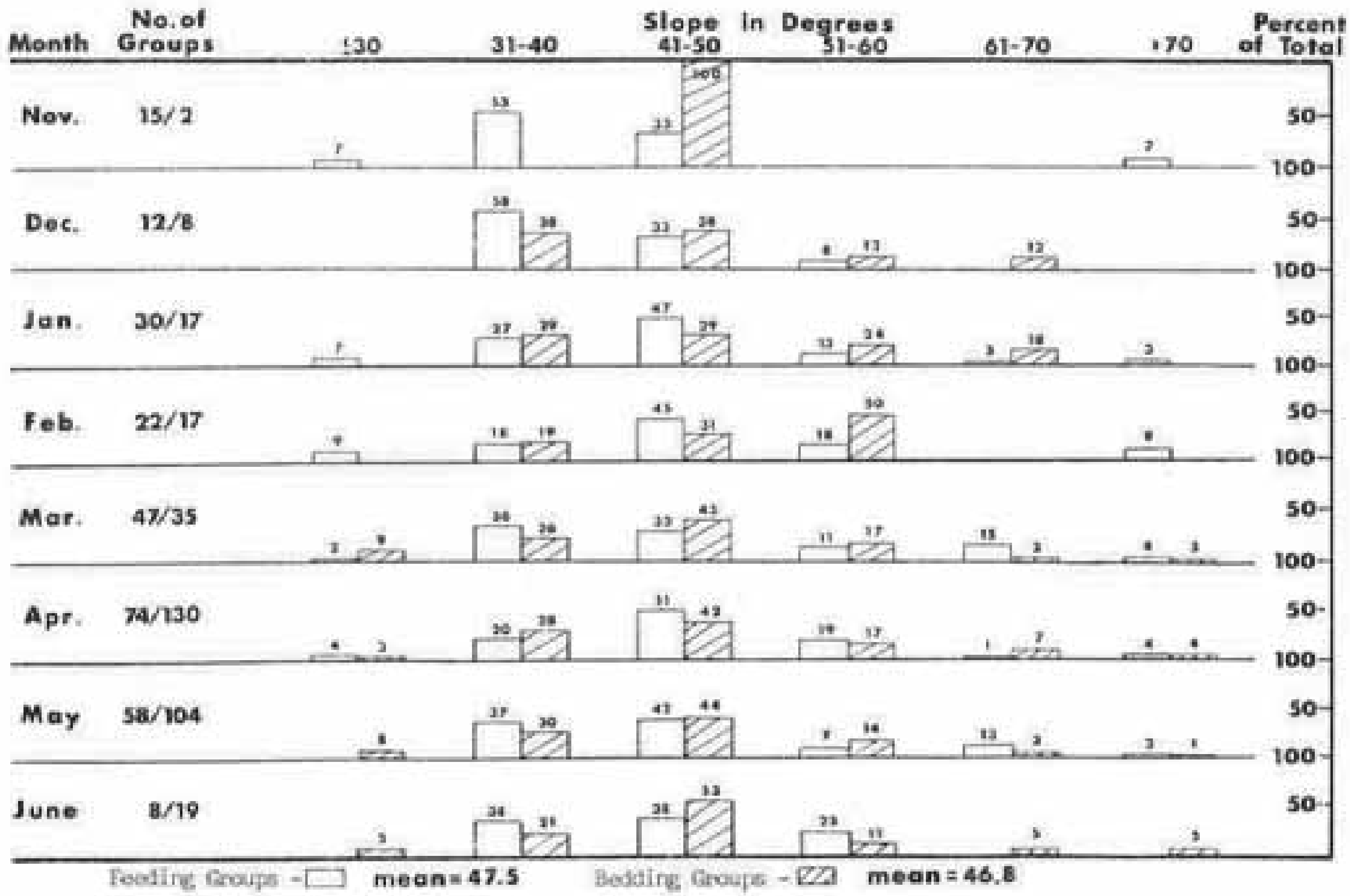


Figure 2. Monthly distribution of feeding/bedding groups on slopes of transitional and winter ranges from January 1973 to June 1975.

Table 3. Monthly percent use of vegetative associations on transitional and winter ranges from November 1974 to June 1975. Trace (T) amounts are less than 0.5 percent.

Month	No. of Groups	Bare rock[a]				Snowfield[b]	Bunchgrass					Beargrass-herb			Deciduous shrub		Scattered herb				Senecio-sedge		
		01	02	03	04	03	01	02	03	04	07	01	03	07	01	04	01	02	03	04	01	03	04
Nov.	17						6		41		6		6	12	6				12		6	6	
Dec.	11			9					55	27									9				
Jan.	22						5	18	18	41			5				5		9				
Feb.	37						11	5	24	41							5		8		5		
Mar.	64	5	2				6	3	27	33			5				9	2	8	2			
Apr.	148	2			2		16	10	10	32			2		1		17	1	5	2			
May	96	7		3	8			8	10	24	1	1				4	5	3	10	13		1	
June	22	14		5	5	5			27	14							5		14			9	5
Means	52	4	T	1	3	T	8	7	18	29	T	T	2	T	T	1	10	1	8	4	1	1	T
Composite Understory Means		9				T	62					3			1		23				2		
Total	417																						

[a]Each written understory type is subtended by the numbers of associated overstory types: 01 - no overstory; 02 - ponderosa pine; 03 - Douglas-fir; 04 - ponderosa pine/Douglas-fir; 07 - subalpine fir.
[b]Pertinent only to May and June.

on cliff ledges in the Bitterroots throughout the winter period due to snow slides and wind action. Mountain goats generally avoided areas of chest-deep snow (approximately 47cm) unless it was sufficiently dense or crusted to support their weight.

During 1975, I estimated the snow depth at each group location. Fig. 3 and Table 4 demonstrate that those terrain types which remained most snow-free also accounted for most sightings. Most parkland colluvial slopes used by goats were essentially very bad ledges. Their use peaked during fall and early winter when snow was fluffy and relatively easy to paw and travel through. The persistence of snow on these shaded, gentle slopes probably reduced their attractiveness to goats in spring. Conversely, cliffs without prominent ledges received no use until February but served as important snow-free feeding sites through spring. As snowbound couloirs and sliderock became snow-free in late spring, their importance increased.

During the winter period of 1975, frequencies of feeding and bedding groups observed in each terrain type did not differ significantly from the expected frequencies (X^2 = 9.92, 6 df, $p > 0.05$). Goats were synchronizing their daily activities on the same terrain types.

There were five caves on the Fred Burr winter range and others were located in adjacent drainages. Carpets of pellets, shed hair, and tracks indicated those caves were important to mountain goats. Few goats were seen on days when wind-driven rain or sleet would have soaked their pelage. I believe that caves, overhangs, and the lee side of cliffs provided refuge for goats during such weather.

Size and Distribution of Groups

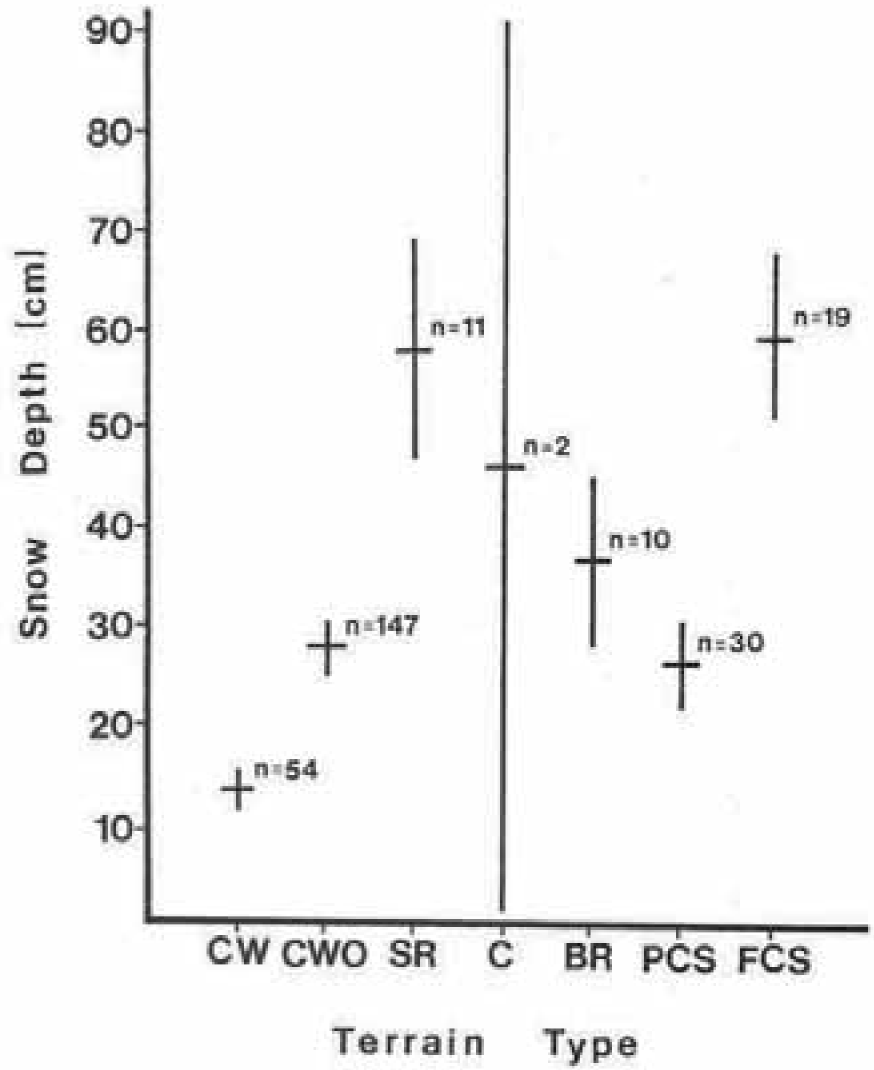
Data from three winter periods indicated that snow conditions affected groups size and distribution of goats on the Fred Burr winter range. During 1973, an estimated herd of 36 goats was distributed across 5km of winter range (Fig. 4 and Table 5). Forty-seven percent of groups were single animals. During the winter period of 1974, snow covered much of the winter range for extended periods. The amount of the south-facing canyon wall occupied by a smaller herd increased to 6.8km. Whereas adult females were distributed similarly to the previous year, 83 percent of adult male sightings were on the western 1.6km of range where snow depths were greater (Fig. 4). Consequently, the mean distances from AM groups (groups containing one or more AMs but no AFs) to their nearest neighbors (closest group regardless of composition) and to the nearest AF groups (groups containing one or more AFs but no AMs) were greater in 1974 than in 1973. This happened despite the fact that the average number of groups on the winter range in 1974 exceeded the average number in 1973 (Table 5).

Tabel 5. Distribution-related data for mountain goats on the Fred Burr range from January to 27 May 1973-75. Distances (m) from AM groups to nearest-neighbors (N-N) and to nearest AF groups were measured on a census by census basis, then averaged for all censuses during a winter period. Distances were measured from topographic maps and not adjusted for elevational change.

Year	1973	1974	1975
Herd Size	36	32	27
Mean Group Size	2.18	1.45	1.47
Largest Group	8	5	6
Average Number of Groups on Winter Range[a]	16.4	22.0	18.4
Linear Area of Winter Range Used	5 km	6.8	6.8
Mean Dist. to N-N of AM Groups	347	411	517
Mean Dist. to Nearest AF Group from AM Groups	621	1263	1083

[a]Herd size÷mean group size; the herd sizes were calculated by Smith (1976).

The winter period of 1975 was another with persistent snow cover. A herd of 27 goats occupied 6.8 km of Fred Burr Canyon. Groups were homogeneously distributed with a clump of AF sightings on the eastern 1.6 km of winter range and a clump of AM sightings on the western end. The distinct east-west segregation of 1974 disappeared. Nevertheless, mean distance from AM groups to their nearest neighbors increased over the previous two years. Group size remained small.



CW = cliffs with prominent ledges; CWO = cliffs without prominent ledges; SR = slide rock; C = couloirs; BR = broken rock; PCS = parkland colluvial slopes; FCS = forested colluvial slopes; and N = 273.

Figure 3. Mean ± standard error of snow depths estimated at the locations of goat sighting within each terrain type on winter ranges.

Table 4. Monthly percent use of terrain types on transitional and winter ranges (November 1974 to June 1975).

Month	No. of groups	Terrain Types: Cliff w/o prominent ledges	Cliff w/ prominent ledges	Slide rock	Couloir	Broken rock	Parkland colluvial slope	Forested colluvial slope
Nov.	17		47		12	6	29	6
Dec.	11		45	9		9	36	
Jan.	22	5	55	5	5		23	9
Feb.	37	11	54	3		5	16	11
Mar.	64	19	53	5		2	14	8
Apr.	148	23	55	4	1	5	7	5
May	96	24	43	11	3	6	3	9
June	22	18	50	9	14	5	5	
Means		19	51	6	2	5	10	7
Total	417							

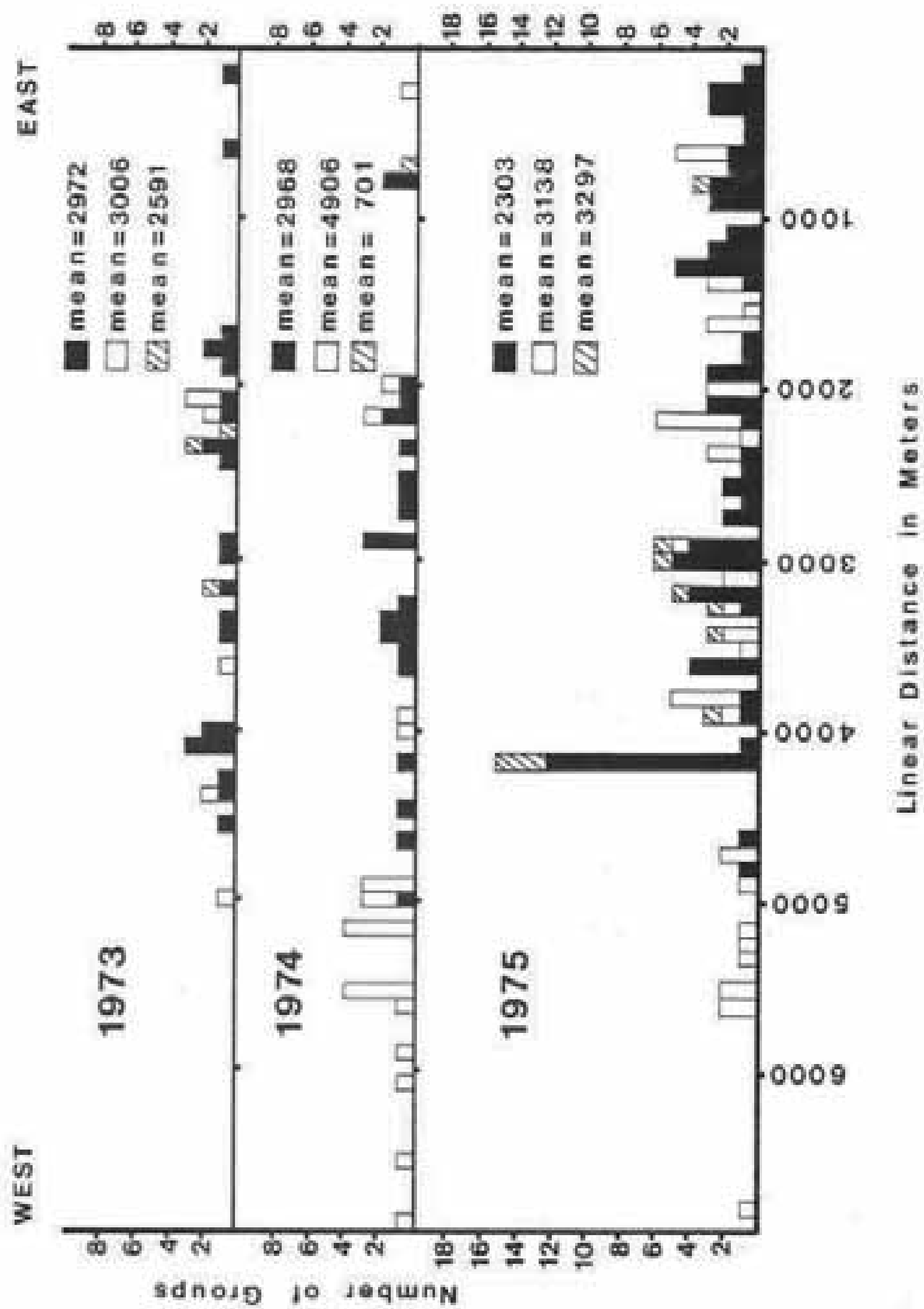


Figure 4. Linear distribution of goat sightings across the Fred Burr winter range from January through May 1973 - 1975. The 0 meter reference point coincides with the eastern most location at which any goat was seen.

A chi-square test revealed that observed groups of goats, categorized as AM, AF, and subadult (groups containing one or more Ks, Ys, 2Ms, and 2Fs but no AMs or AFs) groups, differed significantly from their expected occurrence in various snow depths ($N = 246$, $X^2 = 19.34$, 4df, $p < 0.05$). A Bonferonni multicomparison test (Neu et al. 1974) demonstrated that AF groups used areas with 0-16cm snow depths significantly more than expected ($p < 0.05$) as compared with AM and subadult groups (Table 6).

Table 6. Occurrence of AM, AF, and subadult groups of mountain goats by snow depth in the Bitterroot Mountains, Montana, January through April 1975.

Hierarchical groups	Snow depth category in centimeters	Observed proportion (number) of groups $\hat{p}$	Expected proportion (number) of groups $E(p)$[a]	Confidence interval on proportion of occurrence (95%)[b]
AF				
	0-16	0.635 (73)	0.508 (58.4)	0.526 E(p) 0.744
	17-47	0.226 (26)	0.280 (32.3)	0.132 E(p) 0.320
	48+	0.139 (16)	0.211 (24.3)	0.060 E(p) 0.218
TOTAL		(115)	(115.0)	
AM				
	0-16	0.379 (25)	0.508 (33.5)	0.233 E(p) 0.525
	17-47	0.273 (18)	0.280 (18.5)	0.203 E(p) 0.343
	48+	0.348 (23)	0.211 (14.0)	0.203 E(p) 0.493
TOTAL		(66)	(66)	
Subadult				
	0-16	0.415 (27)	0.508 (33.0)	0.264 E(p) 0.566
	17-47	0.385 (25)	0.280 (18.2)	0.236 E(p) 0.534
	48+	0.200 (13)	0.211 (13.7)	0.077 E(p) 0.323
TOTAL		(65)	(64.9)	
GRAND TOTAL		(246)	(245.9)	

[a] $.508 = \frac{73+25+27}{246}$ The null hypothesis states that hierarchical groups of mountain goats occur in the three categories of snow depths in equal proportions.

[b] $\hat{p} \pm Z\sqrt{\hat{p}(1 - \hat{p})/n}$

AF groups accounted for 66 percent of a-1 sightings on cliffs without prominent ledges--the most snow-free terrain type. (Cliffs without prominent ledge, which provided adequate forage and were navigable by goats, were not abundant on the study area). No significant differences were found at depths exceeding 16cm.

DISCUSSION

Winters of above normal snowfall probably increase intraspecific competition for food and space, in comparison to mild winters, and alter habitat use of mountain goats. Goats in the study area utilized lower elevations and more southerly exposures, which were generally more snow-free, during 1974 and 1975 than during 1973 when snow depths were below average. Goats in the Sapphire Mountains, 25km east of the Bitterroots, likewise sought lower elevations during the severe winter of 1972 than during 1973 (Rideout 1974). Similarly, Hjeljord (1973) found that goats in Alaska wintered above timberline on windswept ridges, when their subalpine winter range of the following mild winter became laden with 60 - 90cm of crusted snow.

Within their 1975 winter range, goats generally avoided areas of chest-deep snow unless it supported their weight. Kelsall (1969) and Gilbert et al. (1970) found that movements of moose (*Alces alces*), and white-tailed (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) were severely restricted by snow which exceeded two thirds of chest height. In deep snow, energy expenditures are high during travel and feeding because movements are cumbersome and animals must paw for herbaceous forage. Geist (1971:266-268) felt that pawing frequencies of Stone's sheep (*Ovis dalli stonei*) and mountain goats reflected the relative effort being expended. He observed that both pawing frequency and number of scratches per bout increased with snow depth. Either one or both of the two most frequented vegetative understory types, bunchgrass and scattered herb, grew on all seven terrain types on winter ranges. Yet two of those terrain types, cliffs with prominent ledges and cliffs without prominent ledges, received over 70 percent of all goat use. In the Bitterroot Mountains, cliff ledges supported considerable forage, provided secure bedsites, and shed snow more readily than other terrain types. Parkland colluvial slopes received heavy use only in fall and early winter when snow was fluffy, and easily blown off that terrain type. Thus, winter habitat use was concentrated on terrain types with shallow snow and accessible forage. During winters of below normal snow accumulations, vegetation composition, biomass, and/or palatability may play a larger role in habitat use.

The similarity in elevations, slopes, exposures, and terrain types chosen for both feeding and bedding, suggests that these activities were synchronized on the same topographic locations to conserve energy. In many cases during the winter period of 1974 and 1975, feeding bouts ceased as goats reached prime bedding sites. Vaughan (1975) hypothesized that the low reproductive success of nannies in the Wallowa Mountains resulted from the inadequacy of winter range. He observed that goats travelled twice daily between removed feeding and bedding sites and that those travels adversely affected gravid females.

The variable effects of hardness and density as well as depth of snow on habitat use were reported for moose (Peek 1971) and various mammals of Russia (Formozov 1946). Snow which is dense and/or crusted, but incapable of supporting an animal's foot load, poses obvious feeding and locomotional difficulties for ungulates. Measurements of these snow characteristics were not obtained during this study. However, Gilbert et al. (1970) demonstrated the effectiveness of snow depth in altering the monthly and annual distribution of mule deer on mountainous winter range. Annual snow depths affected distribution and size of winter range occupied by mountain goats in the Bitterroot Mountains. During the winter period of 1973, the Fred Burr herd exploited a variety of habitats. Of the 77 groups recorded from January through May, no two were at the same location. During the succeeding two years, the herd occupied 25 percent more linear winter range. Sightings were clumped on more snow-free cliff areas.

The explanation to this relates to the social interactions of goats in the study area. On winter ranges, small groups appeared to be selectively adaptive since:

1) The broken nature of winter habitat and dispersed food base favored small foraging groups. Evenly distributed small groups maximized use of available food while reducing intraspecific competition and the potential for degradation of small areas.

2) Lower rates of agression in small groups promoted individual conservation of energy under adverse conditions.

3) Large groups would likely increase the potential for accidents resulting from crowding on narrow cliff ledges.

During winters with deep and persistent snow, as in 1974 and 1975, heightened intraspecific competition for feeding sites probably reduced group stability. Mean group size declined. With less snow-free habitat available on the eastern 5 km, groups typically comprised of one to three animals exploited all relatively snow-free patches along a greater length of winter range.

Apparently different social strategies have evolved in other goat populations. Casebeer et al. (1950) reported that goats in the Red Butte area of Montana ranged in large groups during winter. He felt this was advantageous in deep snow as the goats developed well-trodden trails between scattered open areas of available feed. Chadwick (1973) reported group sizes averaging three to six animals in the Little Creek drainage of Montana. There, 3.5 ha of windblown ridgetops constituted the primary winter range for 17 mountain goats. Groups averaging six to seven animals in January and February occupied the Mt. Wardle winter range in Kootenay National Park (Holroyd 1967). DeBock (1970) found that from January to May in Kootenay Park, AM groups averaged about three goats, and female-young groups averaged over nine. Reporting on an introduced population of goats in the Crazy Mountains of Montana, Lentfer (1955) noted that group sizes were larger during winter than summer or fall, but gave no figures. Foss (1962) reported group sizes averaging 2.0 for June, August, and September, and 4.5 for July in the Crazy Mountains. Saunders (1955) regarded windswept ridgetops and slopes as important winter habitat for goats in the Crazy Mountains. All four of these goat populations inhabit winter ranges less broken than those in the Bitterroot Mountains. Windblown slopes or ridgetops provide relatively large patches of habitat over which groups of five or six goats can easily feed without directly competing with one another. Intragroup agonistic behavior does not jeopardize the lives of group members as it may on steep cliffs. Such cliffs characterized goat winter ranges in the Bitterroots, and along the Salmon River (Brandborg 1955) and Lemhi Range (Kuck 1973) of Idaho where group sizes averaged 3.5 and 2.0, respectively. The nature of available habitat apparently dictates winter social strategies.

Winters with deep and persistent snow would further encourage grouping on ranges characterized by windblown slopes and ridgetops as goats become aggregated on less range. Goats in Banff National Park formed larger groups during period of deep winter snow (Petocz 1973).

The distribution of AMs was more variable between years than that of AFs. My observations concur with those of Geist (1964) and Chadwick (1973) that outside the rut, AFs are socially dominant to other classes and that AMs are subordinate to all others. In Fred Burr Canyon, AFs successfully exploited optimal winter habitat. In particular, AFs monopolized favorable cliffs without prominent ledges. AMs generally avoided those areas occupied by other goats, especially AFs. Geist (1971:257-260) observed that Stone's sheep rams were more solitary in winter than other seasons, and reduced social activity then. He felt this reduced energy expenditures. During winter 1974, AF and AM groups were segregated east-west on winter range, but in 1975, linear segregation was not apparent. Instead, AMs used suboptimal habitat on the eastern 4 km of winter range. Lower herd density and reduced likelihood of confrontations with other groups may have permitted the changed distribution of AMs in 1975. DeBock (1970), Chadwick (1973), and Rideout (1974) observed AMs occupying winter areas peripheral to AFs and subadults.

This distribution of hierarchical groups may be evolutionarily selective in maintaining herd numbers. If AFs survive the winter period and are healthy in spring, their changes of producing viable offspring increase. Edward (1956) linked declines in Canadian goat populations during the mid-1940's to harsh winters with excessive snowfall. The reproductive rate of the Fred Burr herd during 1973 exceeded the rate following the winters of 1974 and 1975 (Smith 1976). In addition, it seems reasonable that Ks, which follow their nannies for the first ten or eleven months of life, would experience higher winter survival in relatively snow-free habitat. Avoidance of AFs by AMs limits forage competition between those classes and diminishes nonessential energy expenditures in the form of agonistic behavior. Although AMs generally respond submissively to AFs, their reluctance to associate with AFs neutralizes the potential for injurious encounters between AMs and AFs and their offspring.

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