MOUNTAIN GOAT BEHAVIOR AT THE WALTON LICK AND HIGHWAY 2 UNDERPASSES IN GLACIER NATIONAL PARK

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AUTHORIZATION TO PROCEED WITH THE FINAL DRAFT

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ABSTRACT

Mountain goat use of the Walton lick and adjacent Highway 2 underpasses in Glacier National Park, Montana, was monitored May to September, 1983 and 1984. Greatest lick use occurred early June to mid-August of both years. Billies and subadults visited the lick earlier in the season than nannies and kids. Daily lick use followed a crepuscular pattern. Snowslide Gulch Bridge underpass, larger with greater visibility across the highway, was used more frequently and by more goats than Goat Bridge underpass which was smaller in size, had more forested approach routes, and higher sound levels. Mountain goats exhibited runbacks (24% of crossings), erect tails (55% of crossings), altered routes, and delayed crossings in response to passing vehicles and visitors on the highway. All mountain goats observed eventually crossed the highway successfully via the underpasses. Most crossings occurred between 0500 and 0700 hours when traffic and visitors were least and lick use was greatest. Mountain goats on the lick engaged in 3.2 agonistic interactions per hour, and the number of interactions increased as the number of goats on the lick increased.

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I. USE OF WALTON LICK AND HIGHWAY 2 UNDERPASSES.

INTRODUCTION

Mountain goat (Oreamnos americanus) use of the Walton lick has been reported since the early 1920's (Singer 1975). In 1930, U.S. Highway 2 was constructed as the only northern Montana route across the Continental Divide. It borders the southern tip of Glacier National Park and extends along the Middle Fork of the Flathead River past the Walton lick. Mountain goats must cross the highway to get to the lick. By 1966, all sections of the road were widened and reconstructed except the Park section, which remained narrow and winding. Winter maintenance problems, a higher vehicle accident rate, and slower speeds along the Park section prompted the Montana Department of Highways and the Federal Highway Administration to propose reconstruction of that portion of the highway.

In 1975, a study was conducted to determine the extent of mountain goat use of the area as well as their response to traffic and park visitors (Singer 1975). A construction plan was approved by the U.S. Department of Transportation and the Federal Highway Administration in 1977; it included various design options to accomodate mountain goats crossing the highway. These options included construction of a goat underpass, modification of an existing bridge over Snowslide Gulch to serve as a second underpass, restrictive fencing and walls between underpasses, and movement of a visitor viewing exhibit from the goat crossing zones to a new off-highway parking area. In 1979, an avalanche destroyed the existing

Snowslide Gulch bridge thereby prompting an immediate need to reconstruct the highway.

Road reconstruction extended from May, 1980 to October, 1981. Mountain goat responses to the construction activities were monitored from April to August of 1980 and 1981 (Singer and Doherty 1985b). Construction of the Goat Bridge and visitor viewing area was delayed until August 15, 1980 and September 1, 1981, respectively, to avoid the peak periods of goat visits to the lick in June and July. Road work was restricted during the peak goat crossing hours and equipment and passing vehicles were stopped for goats attempting to cross the highway.

This study was initiated in May of 1983 to monitor lick activity and assess the effectiveness of the goat crossing facilities following the completion of all construction. Specific objectives were to: (1) document seasonal and daily patterns of lick use by mountain goats; (2) quantify goat use of the two newly-constructed highway underpasses; (3) document crossing behavior; (4) quantify possible factors associated with crossings and lick use such as hourly rates of traffic flow, sound levels at each underpass, visitor use of the area, and daily weather patterns.

BACKGROUND

Lick Use

Use of natural mineral licks by mountain goats has been reported in various areas of Canada (Cowan and Brink 1949, Holroyd 1967, DeBock 1970, Hebert and Cowan 1971) and the U.S. (Stockstad et al. 1953, Brandborg 1955, Singer 1975). Lick use has also been observed in other ungulate species such as white-tailed deer (Odocoileus virginianus) (Weeks 1978), mule deer (Odocoileus hemionus) and elk (Cervus elaphus) (Carbyn 1975), moose (Alces alces) (Tankersley 1981), barren-ground caribou (Rangifer tarandus) (Calef and Lortie 1975), dall sheep (Ovis dalli) (Heimer 1974), bighorn sheep (Ovis canadensis) (Hamilton 1982), and African big game (Henshaw and Ayeni 1971). In all species, lick use usually occurs seasonally, during spring and early summer.

In some licks, sodium appears in high concentrations and is thought to be the main element attracting big game species (Knight and Mudge 1967, Hebert and Cowan 1971, Weeks and Kirkpatrick 1976, Tankersley 1981, Fraser et al. 1982). Free-choice selection experiments with ungulates show a preference for sodium compounds (Stockstad et al. 1953, Fraser 1980), and salt has been used as a big game attractant (Dalke et al. 1965). Mountain goats approach humans to lick salty sweat in Glacier National Park (Banser 1976) and Olympic National Park (Stevens 1983). Moose seasonally use aquatic plants as a source of sodium (Jordan et al. 1973) and switch from use of licks to aquatics when aquatic plants reach their peak in sodium content in June (Fraser et al. 1982).

One theory attributes this seasonal drive towards sodium sources to excessive sodium loss in urine and feces after ingesting large quantities of potassium and water in new-growth forage (Weeks and Kirkpatrick 1976, Hebert and Cowan 1971). This is contrary to evidence that physiological mechanisms promote sodium retention when there is a deficit of this mineral in the body (Comar and Bronner 1962). An acquired taste for salt could also cause sodium-seeking behavior (Denton 1982). Increased mineral demands during spring and summer may result from depletion of nutrient reserves after ingesting low quality winter forage, and increased demands due to shedding and growth. (Dixon 1939, Weeks 1978). Pregnancy and lactation also increase sodium requirements since it is needed for fetal growth and milk production (Robbins 1983:42).

Other elements have been found in high concentrations in natural mineral licks. Dixon (1939) found high levels of calcium phosphate in an Alaskan lick. Calcium and magnesium were high in natural licks in Ohio (Chapman 1939) and California (Hamilton 1982). Chamberlin et al. (1977) found large amounts of calcium and potassium to be common in licks in Ontario. Cowan and Brink (1949) suggest that trace elements may be the critical constituents of some licks. Conflicting results among many lick studies may be due to inappropriate sampling techniques (Fraser et al. 1980) which overestimate sodium levels because of urine contamination and underestimate trace metals due to poor field-filtration of samples. Theories of mineral lick use by mountain goats and other ungulates remain speculative and require further research.

Underpass Use

Mountain goat use of highway underpasses has been documented only in Glacier National Park where Highway 2 crosses a major goat movement route to a natural mineral lick. Goats initially adapted quickly to man-made lead trails and to the underpasses themselves, but passing traffic and visitors were a disturbance (Singer and Doherty 1985b).

Underpass use has been studied in other ungulate species. Mule deer in Colorado used an underpass built along Interstate 70 while migrating between summer and winter range (Reed et al. 1975). In Wyoming, mule deer and elk crossed6665hway underpasses but pronghorn antelope (Antilocapra americana) did not (Ward et al. 1980). Barren-ground caribou were reluctant to use underpasses to traverse the Trans-Alaska Oil Pipeline and preferred to use gravel ramps (Child 1974). Klein (1980) concluded that the responses of caribou and reindeer to man-made barriers depends on the season of year, sex and age of individuals, group size, and intensity and type of disturbance.

Remote, hunted populations of mountain goats have been observed to respond more negatively to human disturbance than those in national parks. This coincides with Geist's (1971) theory that ungulate behavior towards humans is largely a consequence of human behavior towards them. In Glacier and Olympic National Parks, mountain goats have become habituated to visitors and approach them seeking salt (Banser 1976, Stevens 1983). Hydroelectric exploration activities in British Columbia severely disturbed 83% of all mountain goats in the vicinity (Foster and Rahs 1983). Logging and mining activities caused declines in nearby goat populations through increased hunter access and construction-related disturbance (Chadwick 1973, Pendergast and Bindernagel 1977).

It seems essential to study the behavioral responses of ungulates to disturbance and to develop ways of lessening human impacts since optimum production from a population and utilization of a habitat can only be realized in a known and predictable social and physical environment (Cowan 1974).

STUDY AREA

The study site is located at the southern tip of Glacier National Park, Montana. It consists of the Walton mineral lick, located on the banks of the Middle Fork of the Flathead River, portions of Running Rabbit Mountain, U.S. Highway 2 and the associated underpasses, and an off-highway visitor parking area (Fig. 1). Another mineral lick is located across the river from the Walton lick in the Flathead National Forest. The Burlington Northern Railroad passes through the National Forest, paralleling the river.

The Walton goat lick, elevation 1025 m, is located 100 m downslope of U.S. Highway 2 and is an exposure of the Roosevelt Fault. It is situated along fault lines of four major rock formations, Snowslip, Helena, Empire, and Grinnell, which are part of a stratigraphic sequence called the Middle Proterozoic Belt Supergroup (Whipple et al. 1984). Various seeps are apparent in the rock, and free water flows down a small ravine on the east side of the lick.

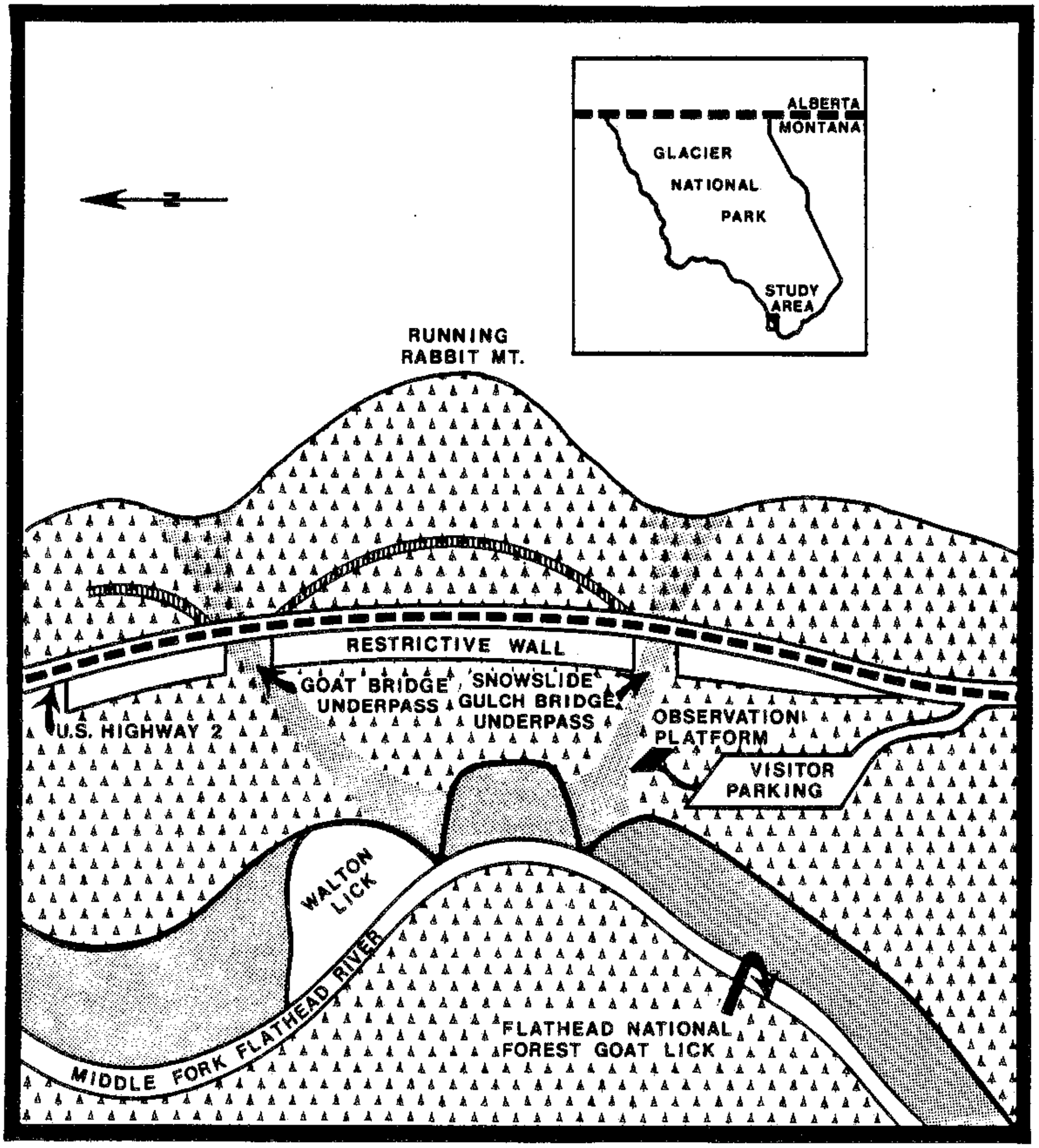

Figure 1. Map indicating location of study area in Glacier National Park, Montana.

The Highway 2 underpasses consist of a specially-designed Goat Bridge (GB) 100 m upslope from the Walton lick, and the modified Snowslide Gulch Bridge (SSGB) east of the lick (Fig. 2). The GB is 4-9 m high, 13 m wide, and 27 m in length with 1.2 m high metal screening on the side abutments of the bridge. Conifer saplings were planted along the approach trails to the GB in 1981 for additional cover. SSGB facilitates mountain goat passage underneath by a wide earth benches along both sides of Snowslide Gulch, 4 m high and 8 m wide, and the bridge extends for 55 m in length. Man-made trails lead to the approaches of both bridges.

The highway between both bridges, and extending 100 m west of the GB, restricts goat movements with a sheer reinforced-earth wall on the downhill side and cyclone fencing on the uphill side. The 2.1 m high cyclone fence parallels the highway between the bridges and funnels down to connect with the sides of the underpasses. Two one-way gates are installed in the fencing to allow goats trapped on the highway side to escape. The earth wall, 2.1 to 8 m high is parallel to and downhill from the highway and forces goats moving upslope from the lick to use the underpasses.

The off-highway visitor viewing area is situated south of the highway 100 m east of SSGB. The oval-shaped parking area accommodates up to 30 vehicles. An interpretive sign overlooks the river and the Flathead National Forest goat lick on the opposite bank. An asphalt trail, 30 m long, heads west towards the Walton lick, terminating in a square, wooden observation platform with railings enclosing two sides. A clear view of the Walton goat lick can be seen from here. The visitor viewing area includes two restrooms. Highway signs along the east and west-bound approaches indicate "Goat Lick Parking" and the direction to turn off the highway.

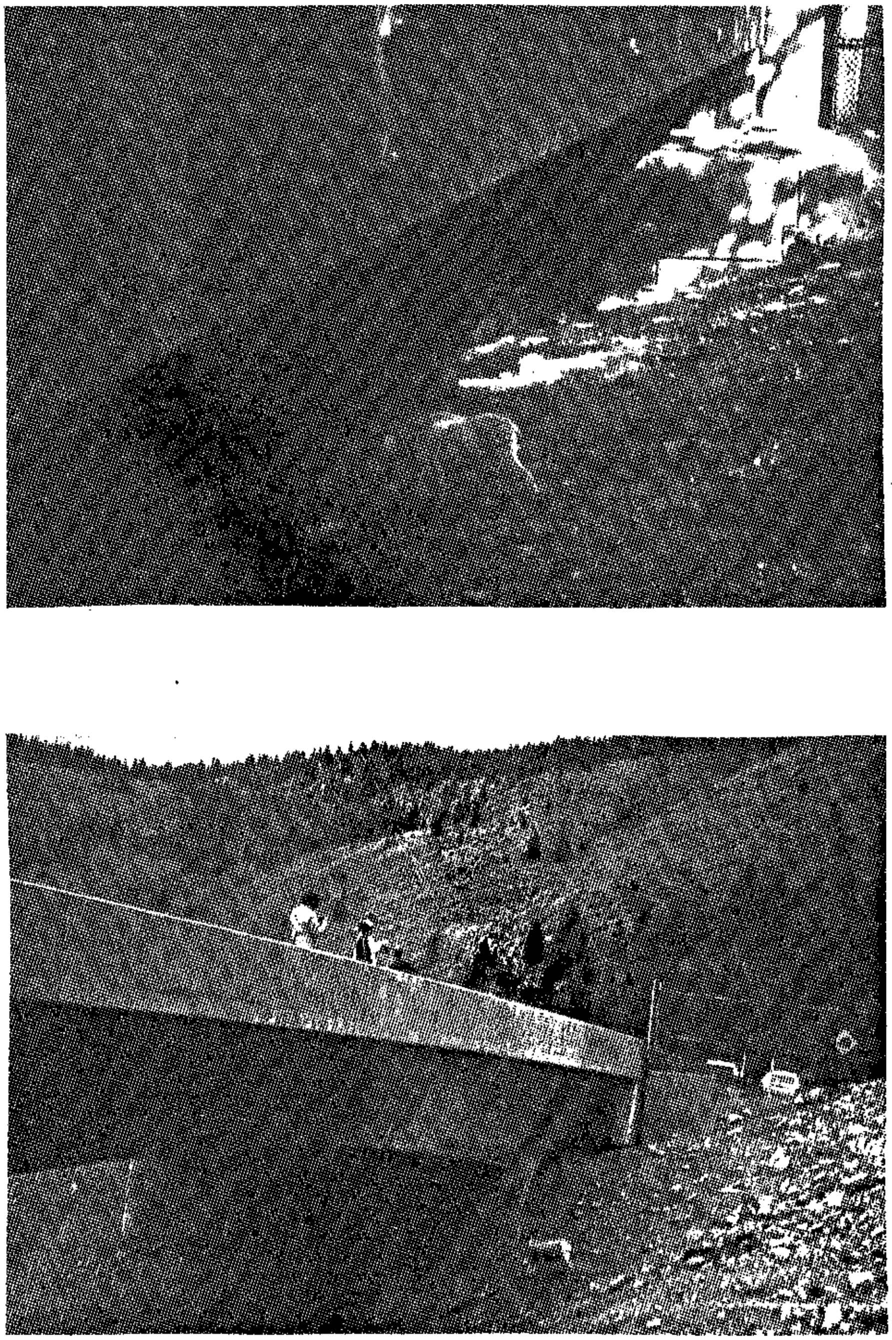

Figure 2. The Goat Bridge (top) and Snowslide Gulch Bridge underpass beneath Highway 2 in Glacier National Park which facilitate mountain goat crossings to the Walton lick.

METHODS

Lick Use

Mountain goat use of the Walton lick was monitored from May through August of 1983 and 1984. Sightings of goats on the lick were recorded when observed, with 7 X 50 power binoculars and a 20-60 power spotting scope, noting sex and age class where possible. Instantaneous scan sampling (Altmann 1974) was used to quantify numbers, locations, and distances between goats on the lick. Scans of the lick were taken at 5-minute intervals for 1-hour time blocks between 0500 and 2200 hours which were randomly assigned to different days. Prior to the 5 minute mark, all goats on the lick were classified by sex and age (Table 1), location, and distance to nearest neighbor, and on the 5 minute mark this information was relayed into a tape recorder. The lick was divided into nine zones for ease of recording goat locations (Fig. 3). Data from scan sampling and incidental observations were used to determine the daily maximum number of each age and sex class goat on the lick.

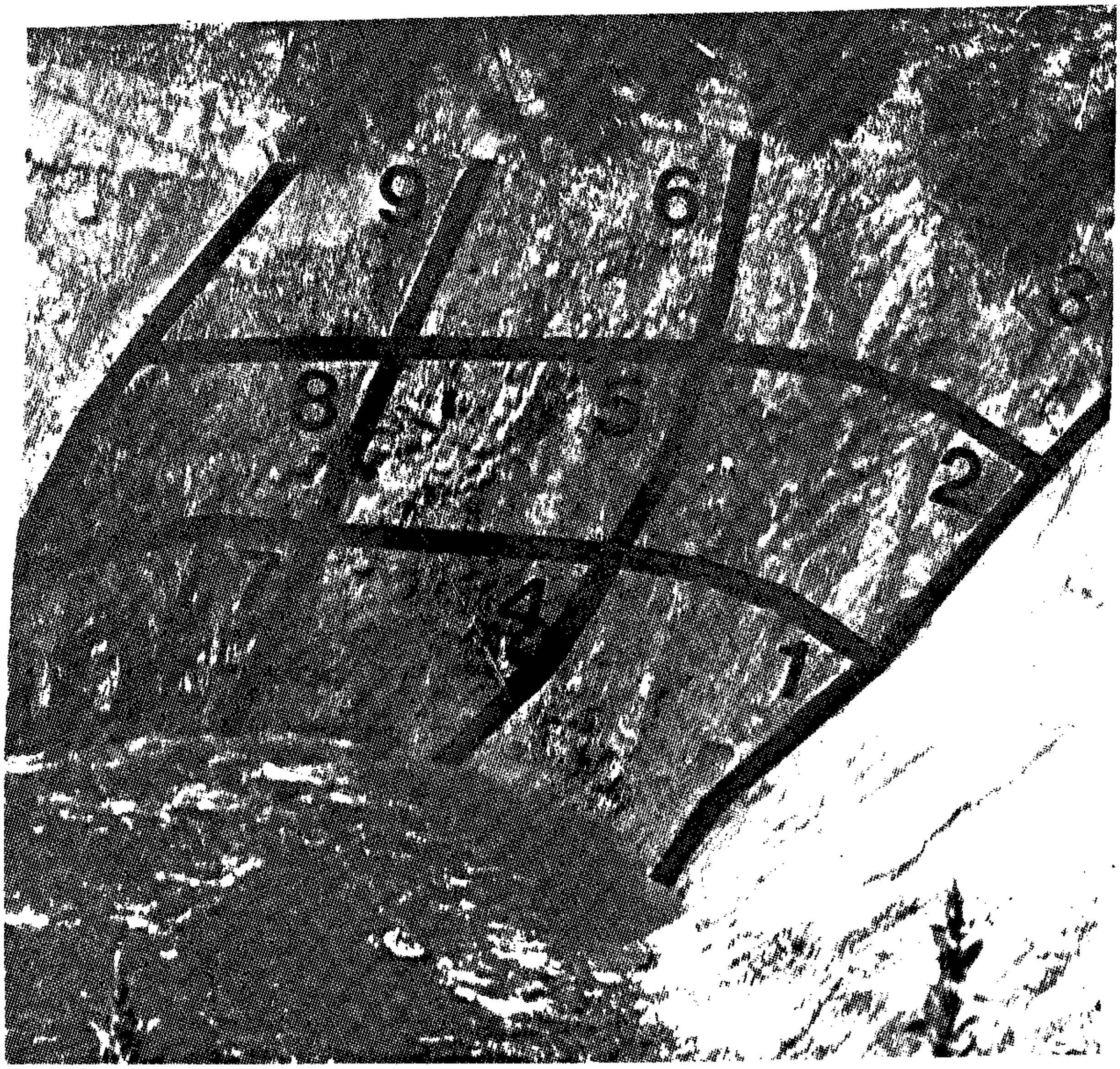

Figure 3. Zones used to deliniate mountain goat locations on the Walton lick in Glacier National Park, Montana.

Table 1. Age and sex classes used to classify mountain goats using the Walton lick in Glacier National Park, 1983 and 1984.

Goat Type	Definition
Nanny	Adult female greater than 3 years of age
Billy	Adult male greater than 3 years of age
Subadult	Male or female between the ages of 1 and 3
Yearling	Male or female approximately 1 year of age
Kid	Male or female less than 1 year of age

Underpass Use

Mountain goat crossings of the highway underpasses were documented from May 15 to August 15 1983, and May 25 to August 25 1984. Intensive observation of the crossings was done in 1984, sampling each hour of the day from 0500 to 2200 at each underpass. Sampling effort was allocated so as to concentrate more effort on evening hours when the most goats were predicted to travel to and from the lick. Observation periods were divided into time blocks; 0500 to 0900, 0900 to 1300, 1300 to 1800, 1800 to 2200, allocating 2 hours to each underpass within each block. Time blocks were randomly assigned to days throughout the season so that each hour at each underpass was sampled sufficiently. A total of 256 hours were spent observing mountain goat crossings of the underpasses in 1984, 111 hours at the GB and 145 at SSGB.

Crossing Behavior

Mountain goats using the highway underpasses were observed from blinds. A cross attempt was considered to be when one or more goats reached a pre-defined area near each underpass and were oriented in the direction of the underpass. For each cross attempt, the number of goats, sex and age classes, time of day, underpass, and direction of travel were recorded. Behaviors such as hesitating to cross, running back from the underpass, or switching from one underpass to another were also noted. Tail positions of crossing goats were classified according to Table 2, and follow the definitions of Banser (1976) of totally erect tail indicating high intensity fear response, and semi-erect tail indicating low intensity fear response. Leadership during crossings was noted by the sex and age of that goat out of a group (greater than one) which first attempted to cross and was subsequently followed by the rest of the group.

Crossings were considered successful when the mountain goat attained a position underneath the underpass. Total elapsed time in minutes from first attempt to successful crossing was recorded for each goat. This was converted to a measure of velocity for comparison between underpasses which were unequal in the distance goats had to travel to reach the underpass.

Table 2. Tail positions of mountain goats crossing Highway 2 underpasses in Glacier National Park, Montana, 1983 and 1984.

Tail Position	Definition
Totally erect	Tail held straight up, perpendicular to horizontal plane of animal's body
Semi erect	Tail held straight out, parallel with horizontal plane of animal's body
Down	Tail hanging downward in free position

Factors of Underpass and Lick Use

Traffic. Flow of traffic along Highway 2 was measured by direct counts simultaneous with monitoring of underpasses during June (N=116 hours) and July (N=140 hours) of 1984. Number of vehicles per hour heading east and west between 0500 and 2200 hours were tallied on random days for both weekdays and weekends.

Sound. A digital sound meter was used to record noise level underneath each underpass when no vehicles were present and when vehicles passed overhead. Hours between 0500 and 2200 were randomly sampled in 1984.

Visitors. Number of visitors present on the highway in the vicinity of the underpasses and their length of stay were recorded during underpass sampling periods in 1984. Visitor use of the off-highway parking area was monitored in 1983 and 1984. Vehicle counts were recorded daily by a traffic meter placed across one lane of the pull-off. Visitor activities in this area were directly observed in 1983. Each hour between 0600 and 2200 was randomly sampled four times for a total of 64 observation hours. During each hour, the number of vehicles, number of visitors per vehicle, activity of each visitor, and length of stay were recorded. Activities were classified as using the observation trail to view goats on the Walton lick and stopping at interpretive sign and looking across to the Flathead National Forest lick.

Scan sampling (Altmann 1974) was used to quantify the number of visitors using the observation platform and the number of goats on the Walton lick at the same time. Incidental observations of visitors near the parking area interacting with mountain goats using the underpasses were also recorded.

The responses of mountain goats on the Walton lick to rafting parties floating past were documented whenever observed. Number of goats on the lick, sexes and ages, and behavior while the raft went by were recorded. Number of rafts, time of day, number of people on the rafts, and behavior of the floating party was also noted.

Weather. Daily weather data was recorded at the Walton Ranger Station, 3 miles from the Walton lick. This included maximum and minimum temperature, precipitation, and cloud cover.

RESULTS

Lick Use

Mountain goat visits to the Walton lick in 1983 began in April and extended through October, with greatest use occurring early June to mid-August. A high count of 47 goats on the lick occurred on 7 June. The first nanny-kid pair appeared on 5 June and the overall kid:nanny ratio was 58 kids:100 nannies for the 1983 season. Appendix 1. shows the daily maximum numbers of mountain goats visiting the Walton lick in 1983.

In 1984, mountain goats visited the Walton lick from February until October, with most use occurring from late June to mid-August. A high count of 77 goats on the lick occurred on 25 June. The first nanny-kid pair appeared on 27 May and the overall kid:nanny ratio was 76 kids:100 nannies. Appendix 2. shows the daily maximum numbers of mountain goats visiting the Walton lick in 1984. More mountain goats used the Walton lick in 1984 than in 1983 (Fig. 4). Billies and subadults visited the lick earlier in the season than nannies and kids during both 1983 and 1984 (Fig. 5).

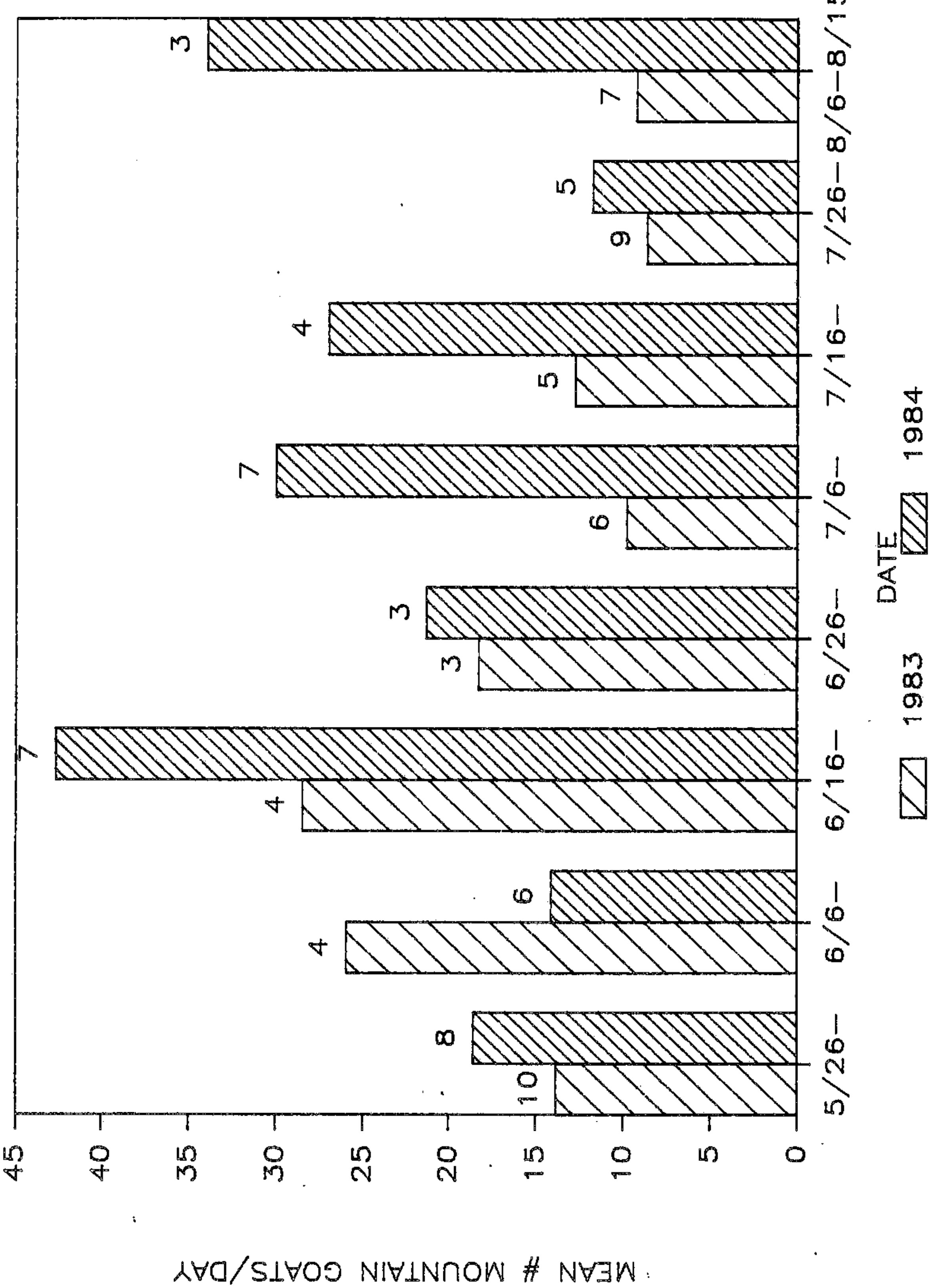

Figure 4. Mountain goat use of the Walton lick from May through August of 1983 and 1984.

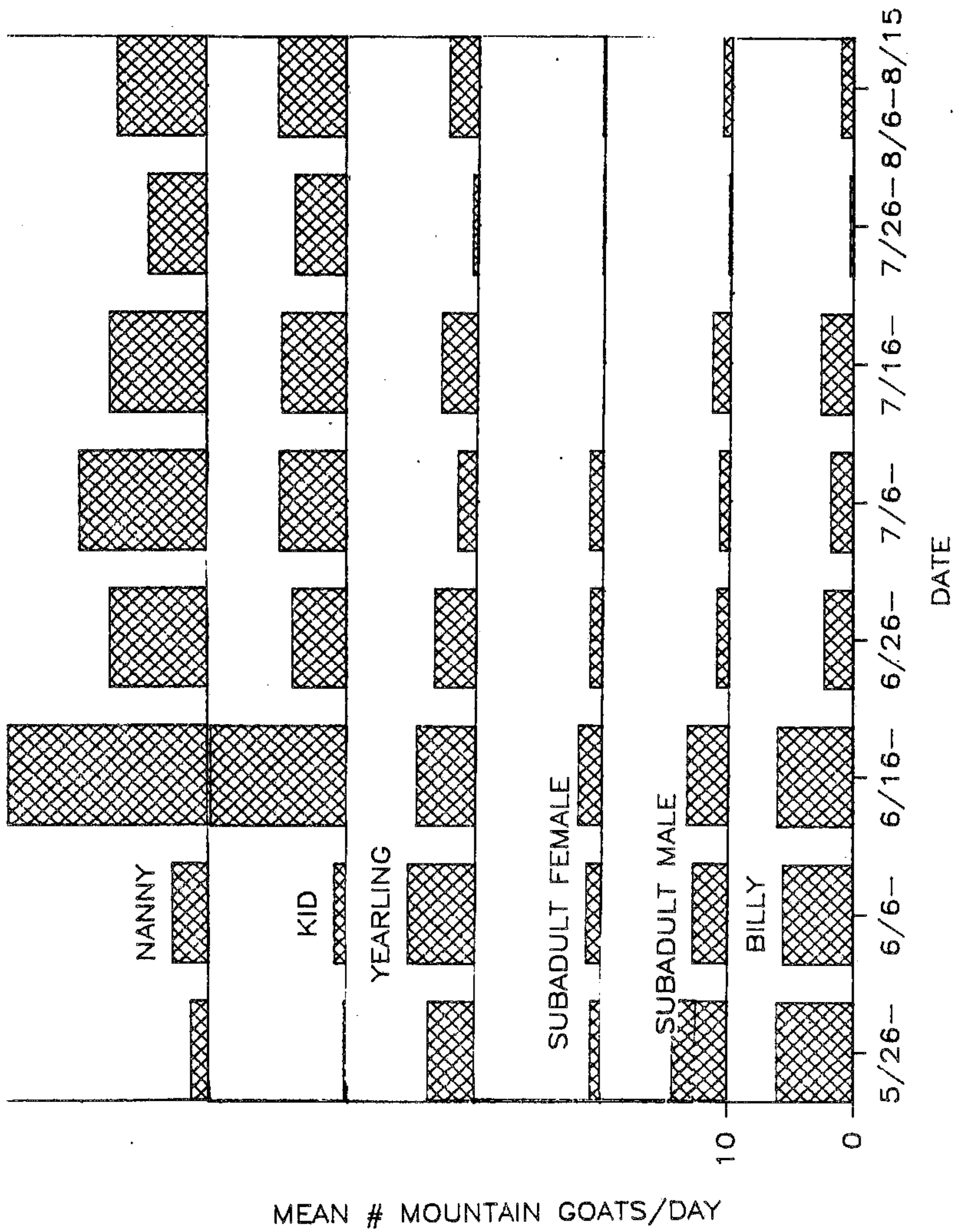

Figure 5. Mountain goat use of the Walton lick by age and sex class from May through August of 1983 and 1984 combined.

Mountain goats were observed more frequently in zone one of the lick which was adjacent to a running seep. Other wet areas, zones three, four, and five, were also used more than drier areas such as zones six to nine (Table 3). The mean distance between mountain goats on the lick was 14.2 (SE=6.3) meters.

Table 3. Mountain goat use of the Walton Mineral Lick in Glacier National Park by zones, 1983.

Zone	#Scans	Percent of Total
1	1201	29.00
2	678	16.31
3	925	22.30
4	678	16.31
5	589	14.20
6	0	0.00
7	46	1.11
8	29	0.70
9	3	0.07

Stepwise regression was used to investigate the predictive value of the factors date, weather, number of vehicles per day, and number of visitors per day on daily maximum numbers of goats on the Walton lick (Appendix 3). None of the variables were significant at the .05 level for entry into the model.

The total number of goats observed in the study area each day in the 1984 season was used to examine potential correlations with the respective date, maximum and minimum daily temperature, precipitation level, and cloud cover (Appendix 4). Date was the only significant variable (R^2 = .44, $p < .0001$) in a stepwise regression model. The number of goats sighted decreased as the date increased from 6 June to 26 August (Figure 6). The maximum plus minimum daily temperature had a significant effect on the number of goats sighted (R^2 = .16, $p < .0002$) in a regression model with the date removed. As maximum temperature increased (52 to 96°F), and minimum temperature increased (30 to 59°F), the number of goats sighted decreased.

MOUNTAIN GOATS BY DATE

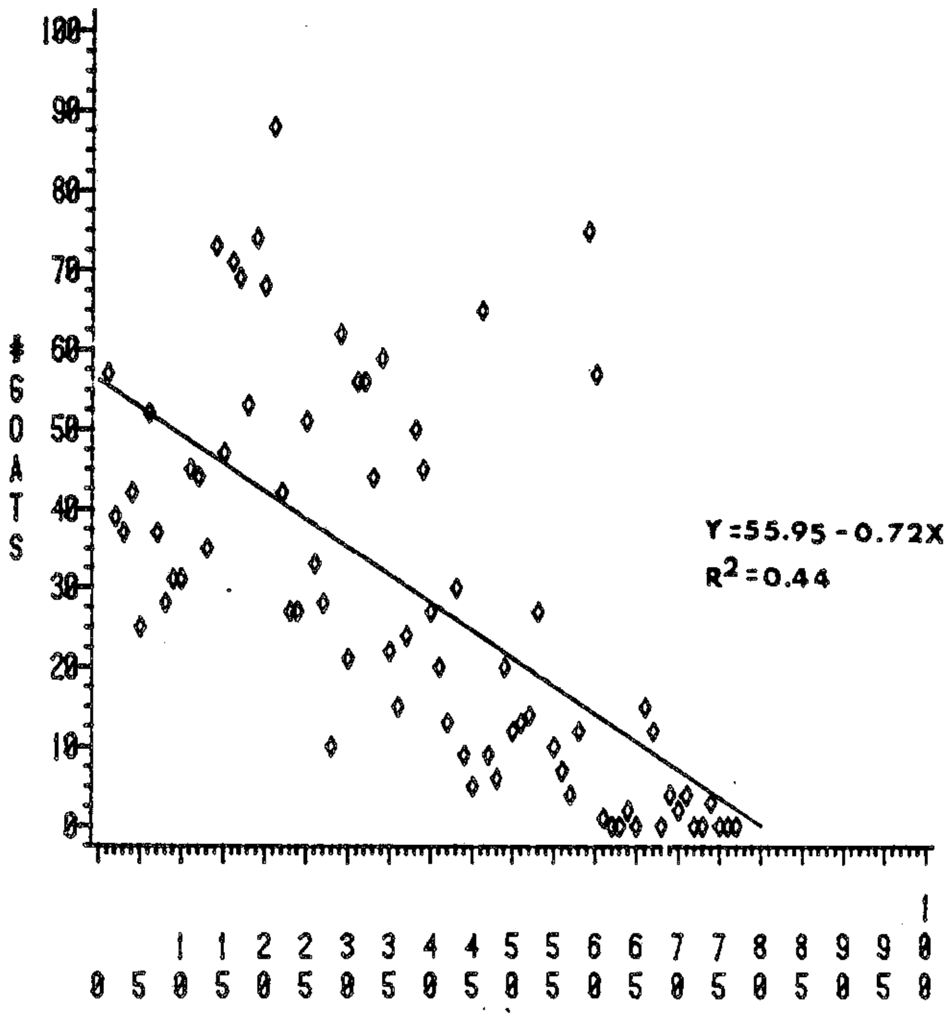

Figure 6. Maximum number of mountain goats observed at or near the Walton lick from June through August of 1984.

Underpass Use

A total of 333 crossings by mountain goat groups through the Highway 2 underpasses were recorded in 1984 in 256 hours of observation. Table 4. shows the number of crossing groups per hour using each underpass. SSGB had significantly higer rates of crossing (paired t-test, $t = 3.03$, $p < .05$) than GB. There was a significant difference in rates of underpass crossings between hours of the day (ANOVA, $\alpha = .05$, df = 15, $p < .025$). Rates from 0500 to 0700 were higher than those during all other two-hour intervals (Duncan's Multiple Range Test, $\alpha = .05$, df = 16). No mountain goat crossings were observed between the hours of 1300 and 1400.

Table 4. Crossing rates (#groups/#observation hours) for mountain goats using two highway underpasses in Glacier National Park, Montana, May-August 1984.

Hour	GB		SSGB		Combined		
0500-0600	(11/5)	2.20	(33/6)	5.50	(44/11)	4.00	A
0600-0700	(9/5)	1.80	(28/8)	3.50	(37/13)	2.85	AB
0700-0800	(0/6)	0.00	(7/7)	1.00	(7/13)	0.54	C
0800-0900	(1/5)	0.20	(7/9)	0.78	(8/14)	0.57	C
0900-1000	(5/5)	1.00	(6/9)	0.67	(11/14)	0.79	BC
1000-1100	(1/4)	0.25	(4/7)	0.57	(5/11)	0.46	C
1100-1200	(2/5)	0.40	(7/7)	1.00	(9/12)	0.75	BC
1200-1300	(0/5)	0.00	(2/7)	0.29	(2/12)	0.17	C
1300-1400	(0/5)	0.00	(0/3)	0.00	(0/8)	0.00	
1400-1500	(1/4)	0.25	(1/6)	0.17	(2/10)	0.20	C
1500-1600	(1/4)	0.25	(3/6)	0.50	(4/10)	0.40	C
1600-1700	(2/6)	0.33	(4/5)	0.80	(6/11)	0.55	BC
1700-1800	(7/7)	1.00	(11/5)	2.20	(18/12)	1.50	BC
1800-1900	(23/10)	2.30	(14/10)	1.40	(37/20)	1.85	BC
1900-2000	(17/15)	1.13	(32/12)	2.67	(49/27)	1.80	BC
2000-2100	(14/11)	1.27	(38/23)	1.65	(52/34)	1.53	BC
2100-2200	(6/9)	0.67	(36/15)	2.40	(42/24)	1.75	BC

Means with the same letter within a column are not significantly different (Duncan's Multiple Range Test, df = 16, α = .05)

A total of 994 mountain goats were observed using the highway underpasses in 1984. More mountain goats were observed to cross SSGB per hour than GB (Table 5) (paired t-test, $t = 2.607$, $p < .05$). The greatest number of goats crossed between 0500 and 0600 hours.

Larger groups of mountain goats used SSGB than the GB underpass (Table 6) (paired t-test, $t = 2.566$, $p < .05$). The largest groups occurred from 0600 to 0700 at SSGB and 2100 to 2200 at the GB underpass, but no significant differences between hours were found.

Table 5. Crossing rates (#goats/#observation hours) for mountain goats using two highway underpasses in Glacier National Park, Montana, May-August 1984.

Hour	GB		SSGB		Combined	
0500-0600	(25/5)	5.00	(141/6)	23.50	(166/11)	15.09
0600-0700	(18/5)	3.60	(127/8)	15.88	(145/13)	11.15
0700-0800	(2/6)	0.33	(29/7)	4.14	(31/13)	2.39
0800-0900	(2/5)	0.40	(28/9)	3.11	(30/14)	2.14
0900-1000	(11/5)	2.20	(21/9)	2.33	(32/14)	2.29
1000-1100	(2/4)	0.50	(9/7)	1.29	(11/11)	1.00
1100-1200	(3/5)	0.60	(30/7)	4.29	(33/12)	2.75
1200-1300	(0/5)	0.00	(1/7)	0.14	(1/12)	0.08
1300-1400	(0/5)	0.00	(0/3)	0.00	(0/8)	0.00
1400-1500	(2/4)	0.50	(1/6)	0.17	(3/10)	0.30
1500-1600	(1/4)	0.25	(7/6)	1.17	(8/10)	0.80
1600-1700	(4/6)	0.67	(9/5)	1.80	(13/11)	1.18
1700-1800	(21/7)	3.00	(22/5)	4.40	(43/12)	3.58
1800-1900	(45/10)	4.50	(25/10)	2.50	(70/20)	3.50
1900-2000	(39/15)	2.60	(76/12)	6.33	(115/27)	4.26
2000-2100	(36/11)	3.27	(115/23)	5.00	(151/34)	4.44
2100-2200	(23/9)	2.56	(119/15)	7.93	(142/24)	5.92

Table 6. Mean group size (#goats/#observed crossings) of mountain goats using two highway underpasses in Glacier National Park, Montana, May-August 1984.

Hour	GB		SSGB		Combined	
0500-0600	(25/11)	2.27	(141/33)	4.27	(166/44)	3.77
0600-0700	(18/9)	2.00	(127/28)	4.54	(145/37)	3.92
0700-0800	(0/0)	0.00	(29/7)	4.14	(31/7)	4.43
0800-0900	(2/1)	2.00	(28/7)	4.00	(30/8)	3.75
0900-1000	(11/5)	2.20	(21/6)	3.50	(32/11)	2.91
1000-1100	(2/1)	2.00	(9/4)	2.25	(11/5)	2.20
1100-1200	(3/2)	1.50	(30/7)	4.29	(33/9)	3.67
1200-1300	(0/0)	0.00	(1/2)	0.50	(1/2)	0.50
1300-1400	(0/0)	0.00	(0/0)	0.00	(0/0)	0.00
1400-1500	(2/1)	2.00	(1/1)	1.00	(3/2)	1.50
1500-1600	(1/1)	1.00	(7/3)	2.33	(8/4)	2.00
1600-1700	(4/2)	2.00	(9/4)	2.25	(13/6)	2.17
1700-1800	(21/7)	3.00	(22/11)	2.00	(43/18)	2.39
1800-1900	(45/23)	1.96	(25/14)	1.79	(70/37)	1.89
1900-2000	(39/17)	2.29	(76/32)	2.38	(115/49)	2.35
2000-2100	(36/14)	2.57	(115/38)	3.03	(151/52)	2.90
2100-2200	(23/6)	3.83	(119/36)	3.31	(142/42)	3.38

Crossing Behavior

Average group size was 3.0 goats, and 83% of all groups contained between 1 and 5 goats (Table 7). A group size of 2 was observed most frequently. Mountain goats classified as leaders initiated 28% of all crossings observed. Adult females were 69% of the leaders, adult males 25%, subadult males 4% and yearlings 2%.

Table 7. Group size of mountain goats crossing two highway underpasses in Glacier National Park, Montana, May-August 1984.

Number in Group	Number of times observed	Percent of total groups observed
1	38	11
2	95	28
3	41	12
4	71	21
5	37	11
6	14	4
7	20	6
8	4	1
9	3	1
10	10	3
11	3	1
12	4	1

Mountain goats using the underpasses to cross Highway 2 sometimes turned around and ran back from the highway in response to visitors and passing vehicles. Of the observed crossings, 24% resulted in this behavior; 17% in response to passing vehicles, and 7% in response to visitors on the highway. Frequency of runbacks differed by age and sex class ($\chi^2 = 35.8$, df = 5, $p < .05$) (Table 8). Nannies performed runbacks significantly more ($\chi^2 = 21.3$, $p < .05$) and subadult males significantly less ($\chi^2 = 5.6$, $p < .05$) than other goats. During crossings, 55% of goats showed erect tails; 37% totally erect and 19% semi-erect.

Table 8. Runbacks exhibited by mountain goats crossing the Highway 2 underpasses in Glacier National Park, Montana 1983-1984.

Goat Type	Number of Runbacks	Percent of Total
Nanny	31	37
Billy	8	10
Subadult Male	5	6
Subadult Female	7	8
Yearling	12	15
Kid	20	24

Mountain goats altered their crossing route six times, five times from SSGB to the GB while heading to the lick, and once from the GB to SSGB while coming from the lick. All instances of altered routes occurred when 20 or more people were on the highway bridges.

Mean velocity of goats crossing SSGB, 20.6 m/min, was significantly higher than that of goats crossing the GB, 12.42 m/min (Table 9) (ANOVA, $\alpha = .05$, df = 1, $p < .0009$). Hour of the day had no effect on mean velocity of mountain goats using the underpasses.

Table 9. Mean velocity (meters/minute) of mountain goats crossing two highway underpasses in Glacier National Park, Montana, 1984.

Hour	GB	SSGB	Combined
0500-0600	10.00	00.00	10.00
0600-0700	7.50	37.50	27.50
0700-0800	00.00	00.00	00.00
0800-0900	10.00	50.00	40.00
0900-1000	7.83	13.75	10.20
1000-1100	30.00	18.75	24.38
1100-1200	6.75	17.50	13.20
1200-1300	00.00	37.50	37.50
1300-1400	00.00	00.00	00.00
1400-1500	7.50	37.50	22.50
1500-1600	15.00	21.88	19.58
1600-1700	00.00	15.00	15.00
1700-1800	9.93	14.58	12.79
1800-1900	15.90	30.48	22.67
1900-2000	11.81	25.63	20.35
2000-2100	10.64	18.77	16.58
2100-2200	13.21	10.79	11.21

Factors of Underpass and Lick Use

Visitors. The number of visitors on SSGB during a crossing by a group of mountain goats and the average time it took the group to successfully cross are shown in Appendix 5. As the number of visitors on the highway increased, the time it took goats to complete a successful crossing increased (R^2 = .31, $p < .0001$) (Figure 7). Number of visitors on the highway during a crossing ranged from 1 to 25, and goat crossing times from 1 to 40 minutes.

Average length of stay for people on the highway bridges was 9.1 minutes (SE=6.96, range 1 to 80). A total of 1078 visitors were observed, averaging 4.2 visitors per hour of observation. Number of visitors observed was greatest between 1600 and 1700 (Table 10).

NUMBER OF VISITORS VERSUS CROSSING TIME

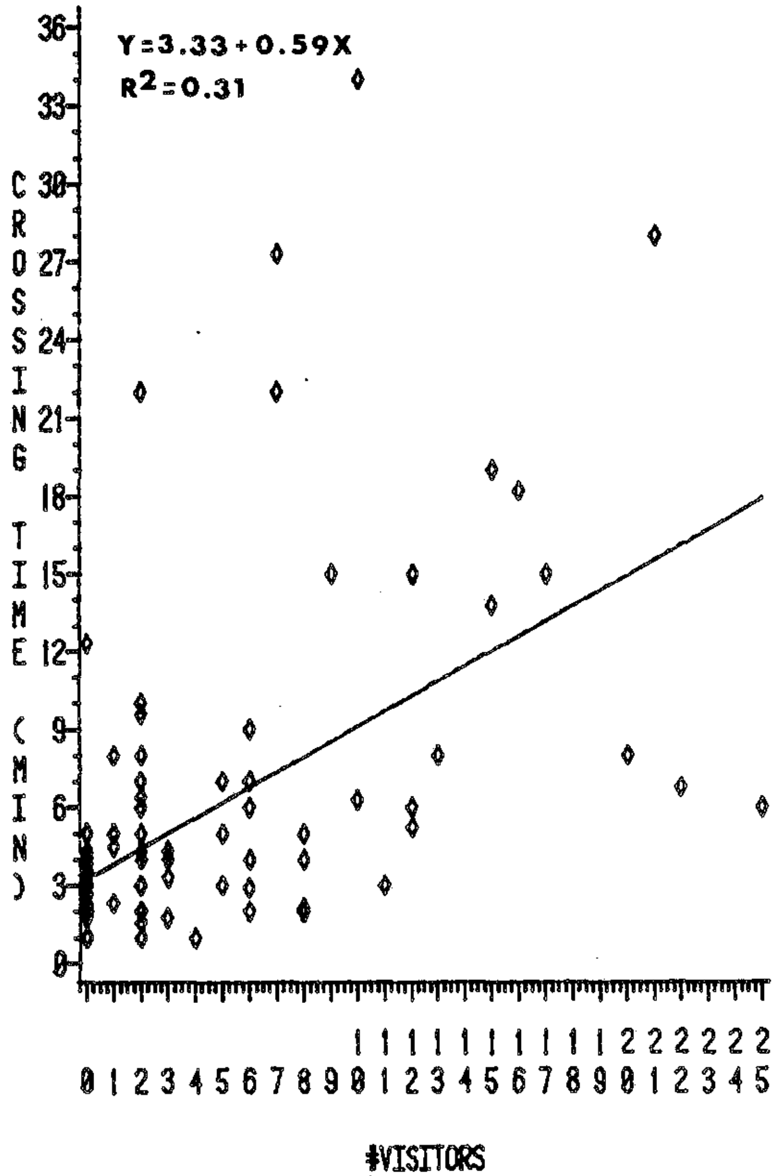

Figure 7. Number of Glacier Park visitors on SSGB versus the time it took mountain goats to successfully cross the highway underpass in Glacier National Park, Montana, 1984.

Table 10. Mean number of visitors stopping on Highway 2 to view mountain goats using the underpasses in Glacier National Park, Montana, 1984.

Hour	#Visitors	Hour	#Visitors
0500-0600	0.03	1300-1400	0.00
0600-0700	0.08	1400-1500	4.75
0700-0800	1.33	1500-1600	3.00
0800-0900	0.57	1600-1700	6.11
0900-1000	0.91	1700-1800	1.76
1000-1100	1.75	1800-1900	2.06
1100-1200	6.00	1900-2000	2.81
1200-1300	0.00	2000-2100	2.51
		2100-2200	0.00

Traffic.

Mean number of vehicles travelling Highway 2 per hour in July, 46.28, was significantly greater than the overall June average of 34.64 (ANOVA, df = 1, $p < .0001$). There were significant differences in traffic flow between hours of the day for June and July (ANOVA, df = 16, $p < .0001$). Traffic flow was least between 0500 and 0600, increased to a peak from 1400 to 1700, then declined (Fig.8)

There were no significant differences in traffic flow between east- and westbound traffic (Appendix 6). The mean number of vehicles per hour travelling Highway 2 on weekends, 63.40, was significantly greater than weekday mean, 46.28 (ANOVA, df = 1, $p < .0001$) (Appendix 7).

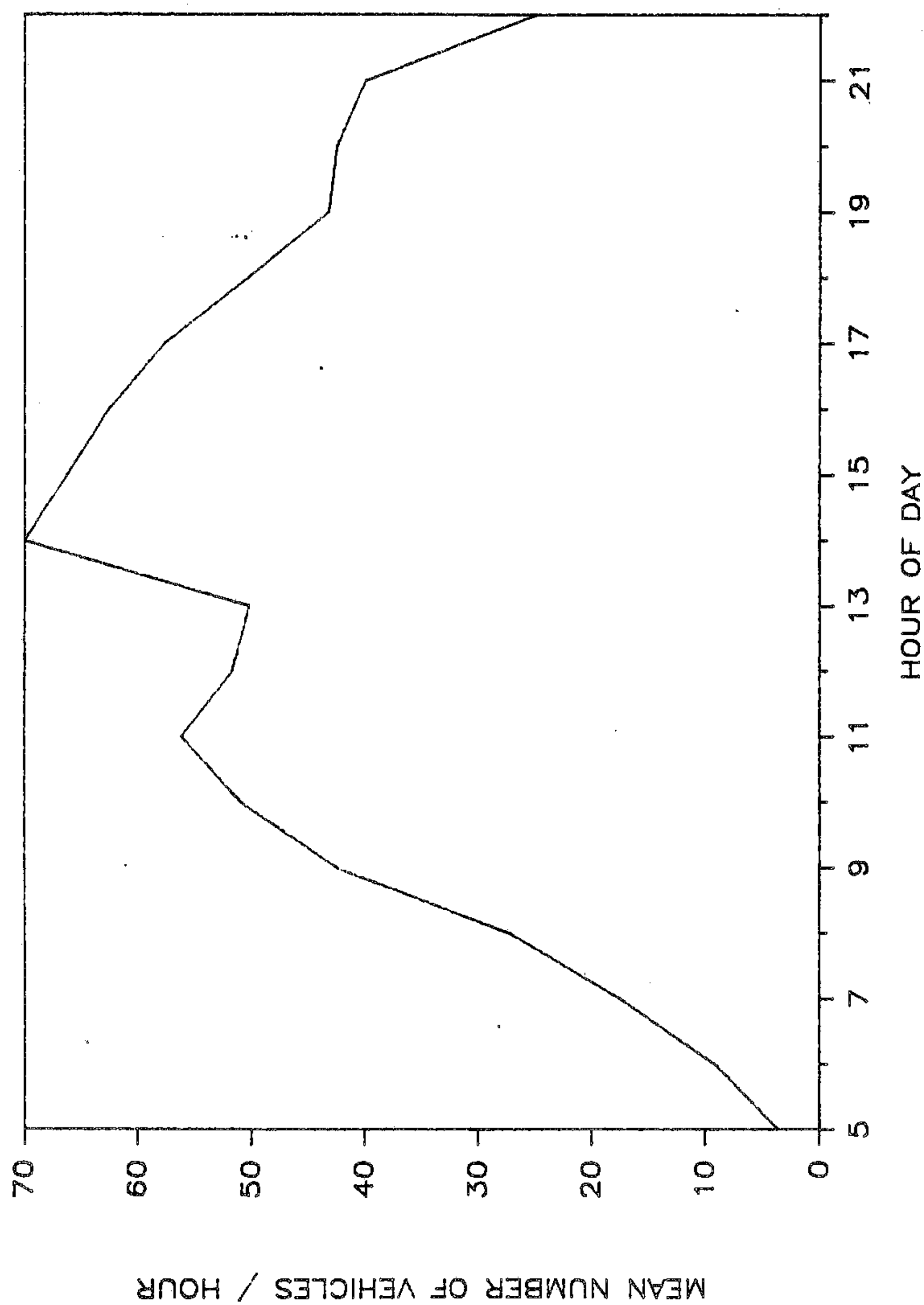

Figure 8. Hourly trends in traffic flow along Highway 2 in Glacier National Park, Montana, June and July, 1984.

Sound. The level of background noise at the GB ($\bar{x}$=48.80 decibels, SE=.17) was significantly greater than that of SSGB ($\bar{x}$=40.70, SE=.09) (Student's t-test, $t = 37.97$, $p < .05$) (Appendix 8). Sound levels at the GB was significantly higher than that of SSGB (ANOVA, df = 1, $p < .0001$) after subtraction of background noise levels (Appendix 9).

Stepwise regression was used to investigate the value of traffic flow rate, visitation rate, and sound rate in predicting the rate of mountain goat crossings during hourly intervals. Traffic flow was the only significant variable in the regression model ($R^2 = .52$, $p < .001$) such that as the number of vehicles per hour increased, the number of mountain goat crossings per hour decreased (Fig 9.).

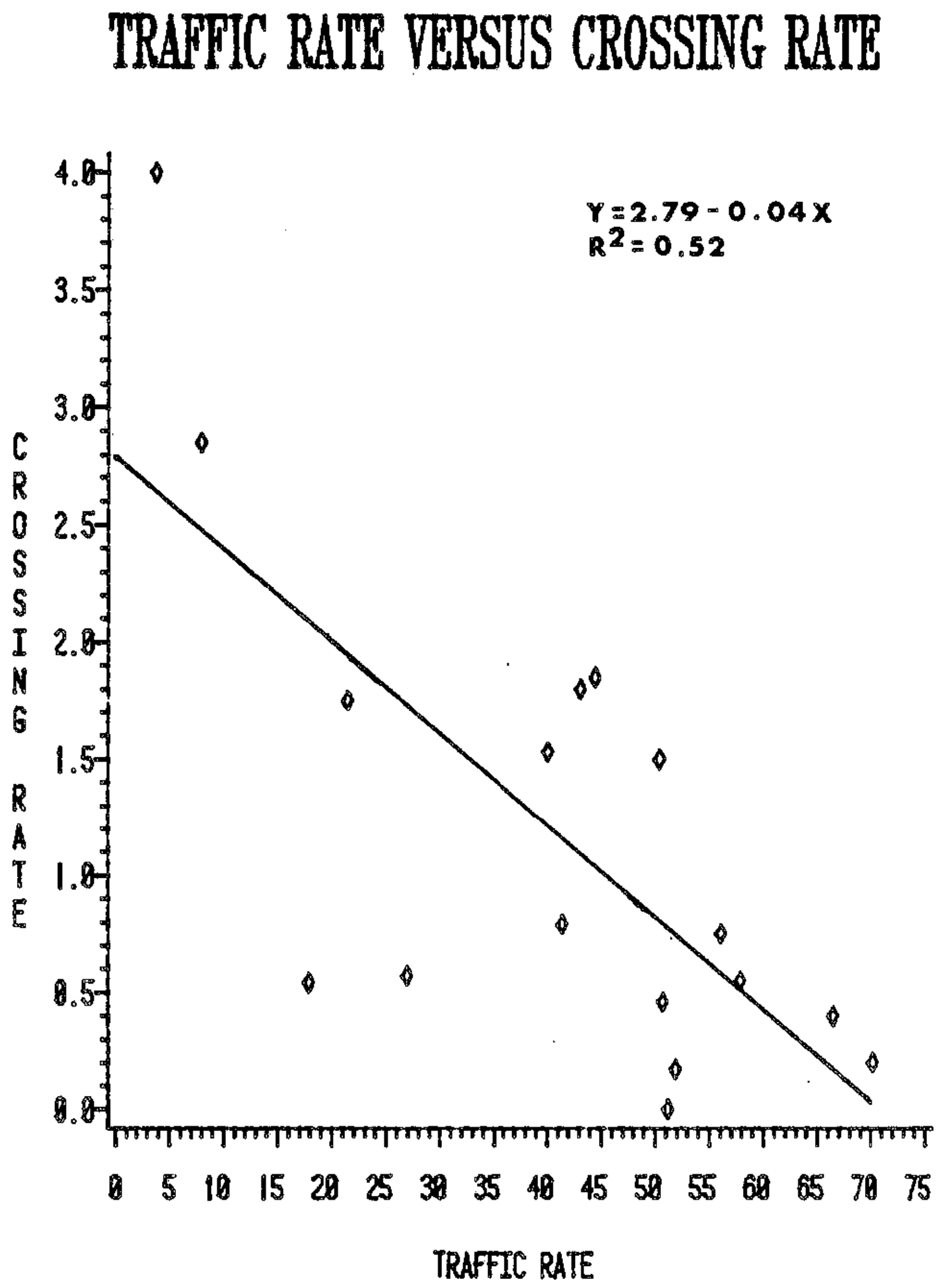

Figure 9. Traffic rate (#vehicles/hr) along Highway 2 versus the rate of mountain goat crossings (#groups/hr) of the highway underpasses in Glacier National Park, Montana, June and July, 1984.

Visitor Use of Goat Observation Area

The mean number of vehicles per day entering the mountain goat observation area during June, July, and August of 1983 and 1984 is shown in Table 11. Peak use was in July of both years, and there was no significant increase between years. An estimated 34% of all vehicles travelling Highway 2 pulled off the highway into the goat observation parking area.

Table 11. Mean number of vehicles per day entering the goat observation area in Glacier National Park, Montana, during 1983 and 1984.

	#Vehicles/day	
	1983	1984
June	190	215
July	210	238
August	167	185

The mean number of visitors per hour at the goat observation area was calculated for each activity (Table 12). Number of visitors was greatest from 1300 to 1400 ($\bar{x}$= 226) and least from 0600 to 0700 ($\bar{x}$=1). Number of vehicles in the parking area was greatest from 1600 to 1700. Approximately 64% of the visitors observed took the observation trail to view mountain goats on the Walton Lick and 67% stopped at the interpretive sign which overlooks the Flathead National Forest goat lick. There were 4.3 visitors per vehicle, and the average length of stay was 12.0 minutes.

The maximum number of mountain goats on the lick and visitors on the observation platform during hourly intervals is shown in Appendix 10. These two variables were not significantly correlated.

Displacement of mountain goats using the Walton lick was caused by 60% of all rafting parties observed (Table 13). Goats displayed erect tails in response to 87% of the rafting parties floating past the lick.

Table 12. Hourly distribution of visitor activities at the mountain goat observation area in Glacier National Park, Montana, July, 1983.

Hour	Ave# Veh/hr	Ave# Vis/hr	Ave # Vis/hr At: Sign	Trail	Ave Stay (min)
0600-0700	1.0	0.5	0.5	0.0	0.0
0700-0800	2.3	5.3	4.8	4.0	8.1
0800-0900	3.3	9.3	8.3	8.8	9.2
0900-1000	13.3	51.0	48.3	45.8	12.4
1000-1100	16.3	54.8	50.0	50.8	13.6
1100-1200	17.5	52.5	43.8	45.3	10.3
1200-1300	10.8	34.0	29.0	27.3	9.0
1300-1400	16.5	225.8	47.5	44.3	14.4
1400-1500	13.5	36.8	34.5	33.8	13.1
1500-1600	15.3	62.8	52.5	47.0	12.7
1600-1700	19.3	60.3	49.5	43.3	12.3
1700-1800	15.0	46.5	43.5	39.0	13.5
1800-1900	8.0	26.3	22.0	19.5	13.3
1900-2000	9.3	26.3	21.3	20.3	13.0
2000-2100	7.3	24.3	23.5	19.0	9.0
2100-2200	1.0	1.5	1.0	1.5	3.1

Table 13. Reactions of mountain goats to rafters floating the Middle Fork of the Flathead River past the Walton lick in Glacier National Park, Montana, from May to August of 1983.

Goat Reactions	No. of Rafts	Percent of Total
All ran off lick, erect tails	5	33
Some ran off, others stayed and moved up on lick, erect tails	4	27
All stayed and moved up, erect tails	3	20
All remained in same positions, erect tails	1	7
All remained in same position, no visible reaction	2	13

DISCUSSION

Lick Use

Seasonal. Mountain goats in Glacier National Park used the Walton lick intensively from May through August of 1983 and 1984 with peak use in June. Singer (1975) and Singer and Doherty (1985a) reported similar patterns of use of the Walton lick by mountain goats. Seasonal use of mineral licks by mountain goats has also been observed in Jasper National Park, Canada (Cowan and Brink 1949), Kootenay National Park (Holroyd 1967 DeBock 1970) and other areas of British Columbia (Hebert and Cowan 1971).

Lick visitation during spring and summer could be attributed to various factors. One impetus for lick use may be seasonal physiological requirements for elements found in the licks. Sodium has been postulated as the element ungulates are seeking in licks (Hebert and Cowan 1971, Weeks and Kirkpatrick 1976, Tankersley 1981, Fraser et al. 1982) where it is in much higher concentrations than other elements. Hebert and Cowan (1971) believe that mountain goats visit natural licks in spring to compensate for a sodium deficiency resulting from low levels of sodium in spring forage. Sodium was in lower concentrations than calcium, magnesium, and potassium in analysis of 14 plant species located in mountain goat feeding areas near the Walton lick (Appendix 11). Mountain goats may be seeking sodium in the Walton lick, but analysis revealed that levels of sulfates, calcium, and magnesium were similar to sodium (Appendix 12). It may be a combination of both macronutrients and micronutrients that attracts goats to the Walton lick. A rich mineral source would be valuable at this time of year to supplement the demands of pregnancy, lactation, shedding and growth, and would offset any mineral deficits incurred by ingesting low quality winter browse. Little is known of seasonal mineral requirements for mountain goats.

Spring and summer lick use may also be due to easier access to the lick during snow-free periods and easier consumption of lick soil moistened by spring rains. Mountain goats were seen to concentrate in wet areas on the Walton lick. This was also observed in lick use by white-tailed deer (Weeks 1978) and moose (Chamberlin et al. 1977). Henshaw and Ayeni (1971) reported big game use of mineral licks in Nigeria to increase during the rainy season.

Spring use of licks could also coincide with movements from winter to summer range. Singer and Doherty (1985a) found that some mountain goats using the Walton lick occupied habitats in close proximity to the lick during summer. Goats either established summer ranges close to the lick for ease of frequent visits or used the lick coincidentally with their movements. Heimer (1974) found that the time of maximum lick use by Dall sheep in Alaska corresponded to the time of movement from winter to summer range and sheep went out of their way to use the lick. Moose in Alberta detoured from the most direct route between their winter and summer range to use mineral licks in Alberta (Best et al. 1977).

Daily. The daily pattern of use at the Walton lick was mainly crepuscular with frequent night use. This may correspond to normal mountain goat summer activity patterns which have been found to peak at sunrise and sunset (Chadwick 1973, Fox 1978). Weeks (1978) also found lick use by white-tailed deer to correspond to their daily crepuscular activity patterns. Peak use of licks during nocturnal hours was also reported in moose (Tankersley 1981) and Dall sheep (Heimer 1974), both in Alaska.

The location of the Walton lick on a steep southerly exposure may influence daily patterns of use. Mountain goats seem to avoid using the lick when it is hot. Mountain goats were found to select rock outcrops to avoid direct sunlight from June through August (Singer and Doherty 1985a), and Chadwick (1973) observed goats to shift their bedding sites to shaded areas as the sun's angle moved. Fox (1978) reported increased use of northerly aspects by mountain goats on warm days in Alaska.

Crepuscular use of the Walton lick by mountain goats corresponds to the hours when highway traffic and visitors in the area are at their lowest levels. This may indicate avoidance of the lick during hours when human disturbance was highest. Bighorn sheep were found to use a mineral lick subjected to human disturbance only when people were absent from the immediate vicinity (Hamilton 1982). The maximum number of mountain goats using the Walton lick each day fluctuated widely, and neither the number of vehicles, visitors, weather, or date could predict daily use. High counts resulted from several herds arriving at and leaving the lick simultaneously. Dates when this would occur could not be predicted from the variables tested.

Though predation was believed to influence the daily pattern of elk use of a natural lick (Carbyn 1975), it does not seem to be a pertinent factor in mountain goat use of the Walton lick. The steepness of the lick terrain, its location on the river, and its close proximity to Highway 2 may isolate it from access by most predator species.

Weather. Weather patterns may dictate both daily and seasonal use of mineral licks. Mountain goat visits to the Walton lick were initiated in February of 1984 during a mild winter with early snowmelt, but the harsher winter of 1983 delayed lick use until April. Singer and Doherty (1985a) found that mountain goats initiated movements to the Walton lick most often after a recent clearing trend with peak visits in clear weather. Dall sheep also showed greater use of licks during favorable weather (Heimer 1974). Increases in maximum and minimum daily temperatures were negatively correlated with mountain goat sightings in the vicinity of the Walton lick in 1984. Heimer (1974) also found that as temperatures increased in July, Dall sheep use of licks declined. There may be an optimum temperature at which ungulates prefer to visit licks and decreased lick use in July may be due to the negative effects of very warm temperatures on thermoregulation.

Other weather variables that have been correlated with mineral lick use by other ungulates are humidity (Carbyn 1975), maximum wind speed (Tankersley 1981), and barometric pressure (Heimer 1974).

Sex and Age. Daily and seasonal patterns of mineral lick use also depend on the sex and age class of the individual. Billies and subadults used the Walton lick more during April and May, before peak use by nannies and kids in June. Similar patterns of lick use by different sex and age classes have been observed in other herds of mountain goats (DeBock 1970, Hebert and Cowan 1971), in moose (Tankersley 1981), bighorn sheep (Hamilton 1982), and Dall sheep (Heimer 1974). The delay in lick use by nannies and kids has been attributed to females remaining on higher, more remote ranges until the young are born (Hebert and Cowan 1971). Lactating mountain goats (DeBock 1970, Singer and Doherty 1982), moose (Tankersley 1981), and

Dall sheep (Heimer 1974) also have been found to make more frequent lick visits and spend more time licking.

The temporal segregation in lick use by adult male and female mountain goats may be a strategy of resource use similar to the spatial segregation between the sexes observed during the non-rut period (DeBock 1970, Stevens 1983) where males and females have been observed to occupy different ranges. It has been hypothesized that males tend to segregate from females and young so as to lessen competition for limited resources such as food, and thereby insure the survival of offspring (Geist and Petocz 1977).

Male mountain goats also may have less of a physiological requirement for minerals found in the licks than females. Earlier lick visits of shorter duration may be sufficient to supply their mineral need. Since billies begin to shed earlier in the season than nannies, their demand for mineral supplements would also begin earlier. Spatial segregation between male and female red deer was attributed to different nutritional requirements between the sexes (Clutton-Brock et al. 1982), and segregation increased when food supplies were short. Since the mineral lick is a limited resource, the goat's strategy of use may be similar to times of food shortage. Billies may be allowing nannies and young the full benefit of the lick by arriving earlier and leaving when nannies and kids arrive. Pregnancy and lactation would increase mineral demands for nannies. Watson and Staines (1978) observed red deer hinds to occupy higher quality habitats than stags which was attributed to different nutritional requirements between the sexes and to altruistic behavior of stags toward calves by allowing hinds access to better areas. Sexual segregation may be an adaptive strategy of mineral lick use which optimizes the duration of lick visits according to individual need.

Underpass Use

The Highway 2 underpasses in Glacier National Park were very effective in channelling mountain goat movements under the highway. In 1975, prior to underpass existence, mountain goats were successful in crossing the highway in only 74% of their attempts (Singer 1975). During construction activities, 86% of attempts were successful (Singer and Doherty 1981). During this study, all mountain goats observed using the underpasses to cross the highway were eventually successful. The effectiveness of these underpasses may in part be due to use by unhunted mountain goats that were previously habituated to traffic and humans, and that were crossing the highway in route to a mineral lick.

Greater use of the Snowslide Gulch Bridge underpass by mountain goats could be due to several factors. The larger dimensions of this underpass afforded more room for crossing and greater visibility across the highway. The approach trails were more sparsely vegetated than those of the Goat Bridge, increasing visibility as goats were coming to cross. Mountain goats preferred more open routes when crossing Highway 2 before the underpasses were built but would switch to a more forested route when visitors were present (Singer 1975). During underpass construction, they also used a more open route for crossing (Singer and Doherty 1981).

Reluctance to cross structures that obstruct their view has been observed in other ungulates. Mule deer hesitated to cross a highway underpass in Colorado due to its small dimensions and poor visibility across the roadway (Reed 1981). Greenwood and Dalton (1984) observed that mule deer avoided crossing beneath and overland coal conveyor in Utah when the crossing clearance was less than 50 cm. Barren-ground caribou would not cross roadways and pipelines which presented a visual barrier to them (Hanson 1981), and white-tailed deer selected an area to cross a highway where visibility across the road was greatest (Carbaugh et al. 1975).

The level of highway sound may have influenced the mountain goats' choice of crossing routes, since background noise and vehicle noise were greater at the GB than SSGB. This was probably due to the smaller dimensions of the GB which magnified the sound of passing vehicles. Although Singer and Doherty (1981) reported little reaction by mountain goats to construction-related noise, Brandborg (1955) noted that mountain goats reaction to noises varied with the familiarity of the auditory stimulus. Goats appeared most disturbed by passing vehicle noise when they were approaching the GB where forest cover obscured their view of the road. In this situation, vehicle sounds were unanticipated and thereby elicited more of a response from the goats. Unanticipated noises from helicopters caused mountain goats to exhibit intense avoidance reactions (Chadwick 1973, Foster and Rahs 1983).

The greater use of Snowslide Gulch Bridge underpass by mountain goats may also be a factor of tradition. The strong following tendencies elicited by older goats (Chadwick 1973, Singer 1977) may be responsible for younger goats learning the use of one particular trail which was then perpetuated in successive years. Migrational paths of caribou are traditional and learned by the animals when they associate with older members of their population (Miller et al. 1972). Learning a particular crossing route could also occur by olfaction whereby scent deposited on well-used trails could be picked up by goats arriving later in the season who were unfamiliar with the crossing area. This is a possibility at Snowslide Gulch Bridge where more goats used the underpass.

Mountain goats using SSGB crossed faster than those using the GB. This could be due to their greater familiarity with the underpass and crossing trails from more frequent use. The lack of available forage adjacent to SSGB eliminated time spent stopping and feeding which often occurred at the GB.

Mountain goats used the Highway 2 underpasses most in the early morning when traffic was least. Traffic rate was the only variable measured which accounted for variation in the rate of mountain goat crossings. As the number of vehicles per hour travelling Highway 2 increased, the number of goat groups crossing per hour decreased. Singer (1975) also found a correlation between increased traffic flow and fewer successful highway crossings by mountain goats. Elk in Rocky Mountain National Park also showed a response to traffic by moving from view earlier on mornings with greater traffic flow (Schultz and Bailey 1978).

Though traffic rate may be a proximate factor determining time of underpass use, lick use would be the ultimate factor since the underpasses are used strictly for travel to and from the lick. Early morning crossings correspond to the crepuscular pattern of use of the Walton lick, and also coincide with a daily activity peak between 0500 1000 for mountain goats not using licks (Chadwick 1973, Singer and Doherty 1985a). Early morning crossings of the underpasses could also be in response to low levels of visitors in the area although this was not found to be a significant predictive factor. Visitor presence on the highway increased the time it took mountain goats to cross, and goats were found to alter their crossing routes from SSGB the GB in all instances when 20 or more people were on the highway bridge. Singer (1975) also found that 54% of altered crossings were due to visitors present in the crossing zone.

Crossing Behavior

Several factors must be considered when evaluating the behavior of mountain goats using the highway underpasses, such as sex and age of the individual, group size, and degree of visitor or vehicular disturbance in the crossing zone. An individual's previous experience with the crossing area also may influence its response. Some goats seemed more sensitive to visitor and vehicle disturbance, perhaps because they were from herds occupying more remote ranges of the park where there was little human contact. Greater sensitivity to traffic by elk arriving later on winter range in Rocky Mountain National Park was thought to be because they summered highest in the park where human contact was least (Schultz and Bailey 1978). Leslie and Douglas (1980) found that bighorn sheep habituated to human presence were less sensitive to construction activities and traffic than herds from isolated areas.

Mountain goats ran back from the highway in 44% of their crossings before underpass construction (Singer 1975), in 30% during construction (Singer and Doherty 1981), and in 24% after construction was completed. Crossing the highway via the underpasses may be less disturbing to mountain goats than was crossing the highway and contending directly with vehicles and visitors. The underpasses create a more predictable situation with visitors and vehicles usually remaining in specific areas.

Nannies ran back from the highway more and subadult males less while crossing than all other goats perhaps because of greater sensitivity of nannies with kids to disturbance. Adult female caribou were also found to be more sensitive to disturbance as they avoided the Trans-Alaska Pipeline haul road more than bulls (Cameron et al. 1979). Caribou bulls were also more accepting of the pipeline structure itself than cows (Hanson 1981).

Mountain goats ran back more frequently in response to passing vehicles than to visitors on the highway before construction (Singer 1975), during (Singer and Doherty 1981), and after. Fast, loud vehicles elicited the strongest response from crossing goats perhaps because they represented a more unique situation than those travelling at a moderate speed. Caribou were also more disturbed by fast-moving vehicles than slow-moving ones (Klein 1980). Horejsi (1981) concluded that the intensity of caribou responses to a moving vehicle was determined by the rate at which the vehicle approached. Moving vehicles elicited heart rate responses in bighorn sheep within 25 m of the road in 74% of all vehicle passes, and heart rate increased on all sheep activities as distance to the road decreased (MacArthur et al. 1979). Passing vehicles may cause physiological stress to nearby animals which may not be shown by overt behavioral reactions.

The display of an erect tail posture may be a sign of disturbance in mountain goats. Banser (1976) observed different degrees of tail erection in mountain goats according to the intensity of human interaction, with totally erect tails being the highest intensity response. African ungulates such as greater and lesser kudu, reedbuck, giraffes, elephants, and rhinos raise or curl their tails when alarmed (Leuthold 1977:90). Walther (1984) concluded that display of erect tails by ungulates may be an alarm signal which precedes the actual flight response. A decline in the incidence of erect tails exhibited by mountain goats crossing Highway 2 occurred after underpass construction. Erect tails were observed in 70% of mountain goat crossings before the underpasses existed (Singer 1975), in 42% of the crossings during underpass construction (Singer and Doherty 1981), and in 55% of the goat crossings after the underpasses were completed. The lowered incidence of erect tails after underpass completion may indicate a less disturbing situation, or gradual habituation to the crossing areas by some goats. The low incidence during construction might have been due to slower vehicle speeds and less traffic through the crossing areas. Caribou were also found to show erect tail postures 88% of the times they were subjected to a moving vehicle (Horejsi 1981).

Visitor Use

Peak visitor use of the off-highway goat observation area occurred in July of 1983 and 1984. Singer (1975) also observed peak visitor activity at the lick exhibit to be in July. The time of day most visitors stopped to view goats, 1600 to 1700 hours, was also similar before and after construction of the underpasses and observation area. The length of stay of visitors increased from 3.3 minutes at the lick exhibit (Singer 1975) to an average of 12.0 minutes in the off-highway observation area. This increased duration could be attributed to the greater number of activities available in the observation area such as walking down the trail to the observation platform to view goats on the Walton lick, looking across the river to the Flathead National Forest goat lick, and visiting the restrooms.

Visitors using the observation platform apparently did not disturb mountain goats on the Walton lick. The platform is far enough away from the goat lick and surrounded by sufficient cover that is doesn't seem to elicit reactions from goats on the lick. Visitors not remaining on the observation trail and platform apparently disturbed goats crossing SSGB, created trails and destroyed vegetation. Mountain goats fed near the platform and trail in early morning and late evening hours when few or no visitors were present. Continual erosion of this area by off-trail visitor use will decrease its value as a feeding site for mountain goats.

The peak in traffic flow along Highway 2 was similar before and after construction; occurring from 1600 to 1700 hours in both 1975 and 1984. Approximately 40% of the vehicles travelling Highway 2 pulled off to view goats on the Walton lick from the lick exhibit (Singer 1975), and 34% of the vehicles pulled off into the goat observation parking area in 1983 and 1984. This latter figure under-represents the number of vehicles and visitors stopping to view goats since people continued to pull off onto the highway shoulders near both bridges to get better views of mountain goats using the underpasses and mineral lick. An average of 4.2 visitors per hour stopped on the highway bridges and stayed an average of 9.1 minutes. This represents a fairly large segment of visitor use outside of the off-highway parking area.

River rafters disturbed mountain goats using the Walton lick when they passed by. Singer and Doherty (1981) also observed mountain goats to be displaced from the lick by rafters, with the goats displaying erect tails in all cases. The high intensity disturbance reaction of mountain goats to river rafters may be due to the uniqueness of the situation and the unanticipated approach of the raft.

MANAGEMENT RECOMMENDATIONS

Underpasses

Several steps can be taken to reduce the problems created by visitors stopping on the highway bridges to view mountain goats using the underpasses and mineral lick. Since this situation exists only from May through August when both goat use of the lick and visitor use of the park are high, some measures need only be taken seasonally.

(1) Near each bridge, eliminate the highway shoulder areas which create easy access for vehicles to pull off. This could be accomplished by extending the existing guardrail between both bridges, and to the west of the Goat Bridge and east of Snowslide Gulch Bridge.

(2) The GB has 3 m high metal screening on both sides which could also be used at SSGB especially on the north side. Sloped terrain there puts goats in close proximity to passing vehicles and visitors when the goats approach the underpass to cross.

(3) Fencing should be placed on the northeast end of Snowslide Gulch Bridge to continue the funnel-like fencing design which leads mountain goats to the underpasses. This is the only area where goats were seen close to the road surface creating a potential for goat-vehicle collisions. This area also receives much visitor use when people try to get closer views of mountain goats crossing under the highway.

(4)The existing "No Parking" signs near the highway bridges are too small and should be made larger. It would also be helpful to paint "No Stopping or Standing" in bold yellow letters along the sides of the bridge abutments and on the pavement shoulders of both bridges.

(5) Additional signs are needed in the area to warn fast oncoming traffic that there may be vehicles slowed or stopped and people on the highway. Several close calls were witnessed where fast drivers had to brake quickly to avoid hitting slow vehicles or pedestrians on the bridges. Signs such as "Slow Speeds--Mountain Goat Viewing Area" or "Slow Down--Mountain Goat Crossing Zone" placed at the east and west approaches to both bridges might help alleviate this safety hazard.

(6) Stricter enforcement of the No Parking regulations by park rangers is essential in combatting this problem. A park employee could be assigned to monitor this area during the critical months of June and July. Visitor control is especially needed on weekends during late evening hours from 1800 to 2200 when large numbers of mountain goats are coming to cross and many visitors are passing through the area.

Visitor Parking Area

(1) The highway turn-off should be widened to accommodate incoming and outgoing vehicles. Several near-misses were witnessed because of inadequate room to make the turn off the highway, especially when entering from the westbound lane of Highway 2.

(2) A wooden fence is needed along the edge of the parking area where the interpretive sign overlooks the river and National Forest goat lick. Visitor use is eroding trails along the embankment of this steep drop off; this could be curtailed by a fence. This fence could also extend along the observation trail to the platform to ensure visitor safety while on the trail.

(3) If visitors continue to go off the observation trail and platform and hike up to Snowslide Bridge in the goat crossing zone, fencing will be needed extending from the underpass down the gulley to the visitor platform. This would lessen human disturbance of mountain goats trying to use the underpass.

Provisions for Monitoring

The Highway 2 underpasses should be monitored in future years to determine if any additional factors such as increased visitation or traffic flow are affecting mountain goat use of the area. Hourly counts of the number of goats crossing each underpass, number of people stopping and vehicles travelling the highway could be done twice a week June and July. Comparing the results of these counts to data collected during 1983 and 1984 would reveal any sharp increases or decreases in mountain goat use of the underpasses or visitor use of the area. The best hours to conduct these counts would be from 1800 to 2200 when goat crossings and visitor use are at high levels.

The Walton lick is an ideal place to monitor herd composition and productivity of mountain goats in the park. Early mornings between 0500 and 0900 and evenings from 1800 to 2200 are the hours when most goats visit the lick. Sex and age of goats on the lick are most accurately determined through a spotting scope. A more precise method of determining sex and age composition of goats visiting the lick would be to sit under SSGB along the east embankment from 0500 to 0900 the morning after a large number of goats were seen on the lick in the evening. One person remaining quietly in a stationary position can sometimes go unnoticed by crossing goats. The goats usually file past slowly and close enough to accurately sex and age individuals.

Use of the off-highway parking area could continue to be monitored by a traffic meter placed across one lane of the pull-off. Frequent checks to evaluate visitor use of the area should be made. If visitor use and traffic continue to increase in the area, additional modifications may be required to keep mountain goats and park visitors apart.

River rafter use of the Middle Fork of the Flathead River past the Walton lick should be monitored in future years since it disturbed mountain goats using the lick. Counts of rafts per day during June and July and observations of goat responses could determine an increase of this visitor activity and the degree of habituation displayed by the goats.

II. AGONISTIC BEHAVIOR AT THE WALTON LICK.

INTRODUCTION

Social behavior of the mountain goat (Oreamnos americanus) has been observed infrequently. Documentation of the behavioral repertoire of this species has been difficult due to the inaccessible terrain it inhabits. Nevertheless, several aspects of mountain goat sociality have been reported. Geist (1964) observed rutting behavior in mountain goats and categorized various threat and submissive postures. Chadwick (1977) recorded sexual, agonistic, and leadership relationships among free-ranging mountain goats and their influence on population size and distribution. DeBock (1970) described various aspects of mountain goat sociality, and Singer (1977) observed dominance, leadership and group cohesion. Petocz (1973) investigated the effect of snow cover on mountain goat social behavior. Other studies have referred to social interactions among mountain goats (Banser 1976, Thompson and Guenzel 1978, Dane 1977) but few have attempted to quantify rates of interactions.

It is important to document not only the existence of a specific behavior in a species but how frequently it occurs in different situations. This may aid in understanding the mechanisms by which behaviors evolve and persist by determining the optimality of the behavior under different contexts. Since agonistic interactions require an energy investment (MacArthur et al. 1982b), they should only occur in those situations where the benefit from gaining access to the resource outweighs the cost. Under this premise, high rates of aggression would occur in situations which contain high-valued resources such as mates, food, or in this case, a mineral lick.

This study was undertaken to measure rates of agonistic interactions between mountain goats utilizing a natural mineral lick in Glacier National Park where large numbers of goats seasonally concentrate.

METHODS

Social interactions among all sex and age classes of mountain goats using the Walton lick were observed in June and July of 1983. Behavior was quantified using an all occurrences sampling technique (Altmann 1974). All instances of dominant and subordinate acts observed within a sampling hour were recorded. Sampling hours were assigned to random days for a total of 84 observation hours. The dominant goat and activity, subordinate goat and activity, and displacement distance were noted. All observations were dictated into a portable tape recorder. Aggressive behaviors were classified according to Table 14.

Table 14. Activities used to classify dominance and subordinance in mountain goats using the Walton lick in 1983 and 1984.

Dominant	Subordinate
Presentation = broadside orientation toward opponent, arched back, dorsal ridge pelage erect, tense, exaggerated movements, tail tucked between legs	Withdrawal = withdrawal from confrontation by crouching and/or slowly moving away
Butt = display or actual use of horns aimed by lowering the head and delivering quick upward or lateral swipes	Butt Avoidance = crouching or squatting to position rump and flank away from horns of opponent
Joust = butt with head-on orientation toward opponent	Joust Avoidance = positioning head away from horns of opponent
Rush = leaping, galloping, or trotting toward opponent	Rush Avoidance = leaping, galloping or trotting away from opponent
Orientation = walking, turning, or staring fixedly towards opponent	Orientation Avoidance = walking, turning, or staring fixedly away from opponent

RESULTS

A total of 266 agonistic interactions between mountain goats on the Walton lick were observed over 84 hours of observation, averaging 3.2 interactions per hour. The number of interactions observed during hourly intervals was significantly positively correlated with the number of goats using the lick during those hours (Appendix 13) ($r = .60$, $p < .0001$).

Appendix 14. lists the rates of interactions between goats of different age and sex classes while on the lick. Rates (R) for each dominant- subordinate pair were calculated as:

$$R = \frac{\Sigma \text{ \#Dom-sub acts observed between the pair}}{\Sigma \text{ \#Pair-hours}}$$

and were summed over the number of observation hours that contained both members of the pair. The number of pair-hours was determined by the number of members of each pair on the lick during that hour (e.g. 6 nannies and 4 yearlings present yields 24 nanny-yearling hours). There were no significant differences between sex and age classes in the distribution of agonistic interactions ($\chi^2 = 4.50$, $df = 25$, $p > .05$) (Table 15).

Table 15. Mean rates of agonistic interactions (Acts/pair-hour) between mountain goats on the Walton lick in Glacier National Park, Montana, May-August 1983.

	Nanny	Subad. Female	Subad. Male	Billy	Yrling	Kid
Nanny	0.51					
Subad. Female	0.52	0.00				
Subad. Male	0.33	0.67	0.36			
Billy	0.54	1.00	0.25	0.00		
Yrling	0.36	0.49	0.16	0.37	0.24	
Kid	0.39	0.00	0.00	0.25	0.40	0.00

Table 16. shows the rates of the various dominant and subordinate activities performed by mountain goats in each age and sex class. Significant differences were found only between rates of performance of dominant activities (ANOVA, df = 4, $p < .01$). Rush and orientation were performed at significantly higher rates than all other dominant activities (Duncan's Multiple Range Test, $\alpha = .05$, df = 25).

Nannies displayed the highest proportion of dominant to subordinate acts than other age classes while on the lick and kids displayed the lowest proportions (Figure 10).

Table 16. Rates of dominant and subordinate acts (Acts/goat-hour) performed by mountain goats on the Walton lick in Glacier National Park, Montana, May-August, 1983.

	Dominant Activities					
	Presentation	Butt	Joust	Rush	Orientation	Totals
Nanny	0.03 (2/69)	0.23 (16/69)	0.02 (2/69)	1.30 (90/69)	0.77 (53/69)	2.34 (163/69)
Billy	0.04 (1/23)	0.09 (2/23)	0.00 (0/23)	0.61 (14/23)	0.65 (15/23)	1.39 (32/23)
Subad. Male	0.00 (0/25)	0.16 (4/25)	0.04 (1/25)	0.60 (15/25)	0.52 (13/25)	1.32 (33/25)
Subad. Female	0.00 (0/11)	0.09 (1/11)	0.00 (0/11)	0.09 (1/11)	0.27 (3/11)	0.46 (5/11)
Yrling	0.00 (0/49)	0.27 (13/49)	0.02 (1/49)	0.29 (14/49)	0.08 (4/49)	0.65 (32/49)
Kid	0.00 (0/58)	0.02 (1/58)	0.00 (0/58)	0.00 (0/58)	0.00 (0/58)	0.02 (1/58)
Totals	0.08 C	0.85 BC		0.08 C	2.89 A	2.30 AB

Means with the same letter are not significantly different (Duncan's Multiple Range Test, df = 4, = .05).

	Subordinate Activities			
	Orientation Avoidance	Rush Avoidance	Butt Avoidance	Totals
Nanny	0.32 (22/69)	0.38 (26/69)	0.15 (10/69)	0.84 (58/69)
Billy	0.13 (3/23)	0.00 (0/23)	0.00 (0/23)	0.13 (3/23)
Subad. Male	0.56 (14/25)	0.16 (4/25)	0.00 (0/25)	0.72 (18/25)
Subad. Female	0.73 (8/11)	0.55 (6/11)	0.00 (0/11)	1.27 (14/11)
Yrling	0.76 (37/49)	1.78 (87/49)	0.45 (22/49)	2.98 (146/49)
kid	0.14 (8/58)	0.19 (11/58)	0.14 (8/58)	0.47 (27/58)
Totals	2.63	3.05	0.73	

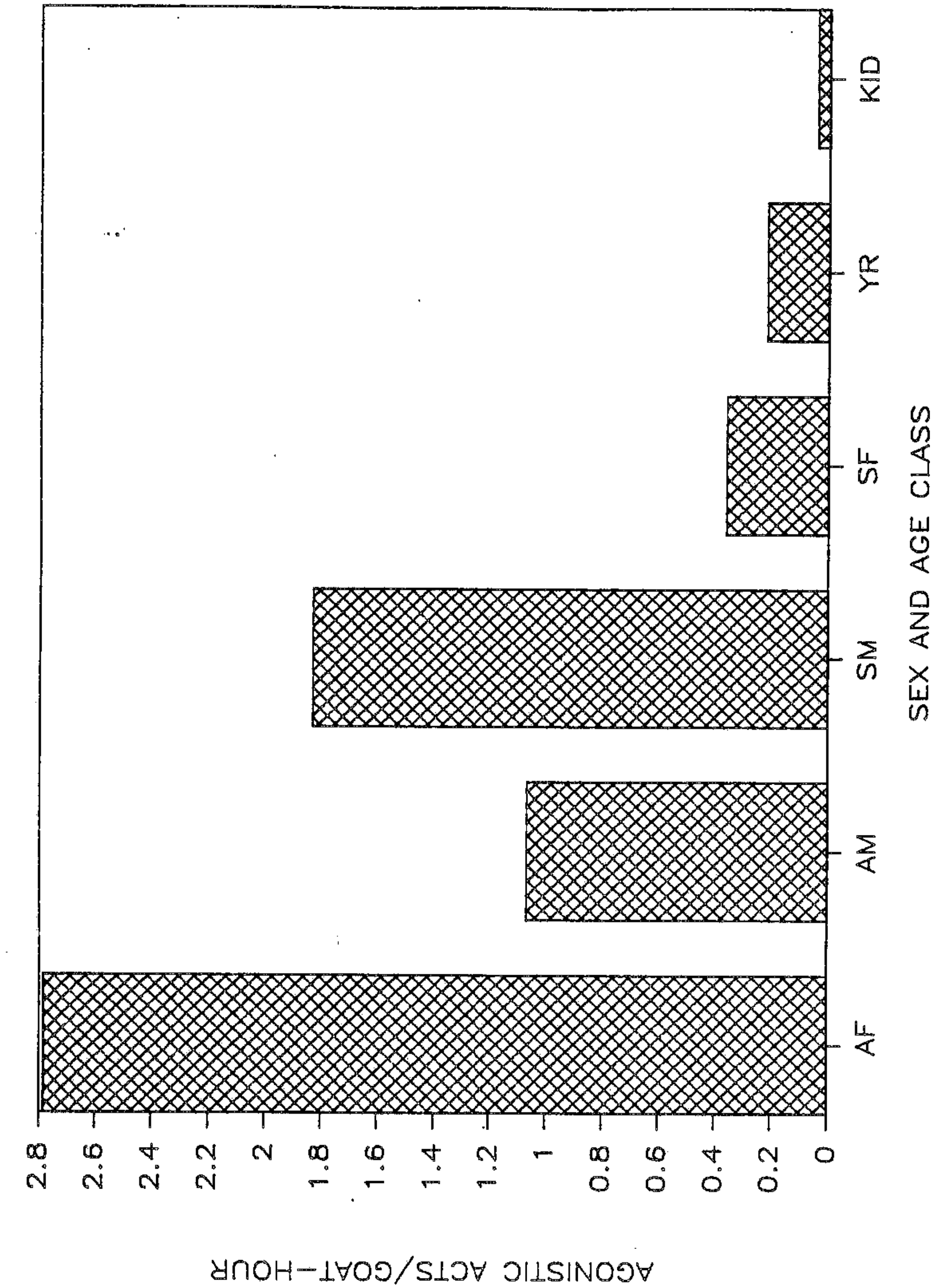

Figure 10. Proportion of dominant to subordinate activities performed by mountain goats on the Walton lick June and July, 1983.

DISCUSSION

Mountain goats contested access to space on the Walton lick at relatively high rates of 3.2 threats/hour compared to rates of 1.06/hr recorded when feeding and 0.48/hr when bedded (Chadwick 1977). Banser (1976) reported aggressive encounters in mountain goats to be 7 times more frequent when licking salt than when feeding. Since the mineral lick is only encountered seasonally, goats have to concentrate their licking effort in a limited amount of time and space. This may increase rates of aggression. The frequency of aggressive interactions in red deer was also found to increase when they were competing for a limited resource in a restricted area (Hall 1983a).

The greater frequency of agonistic encounters with greater numbers of goats on the lick may be due to several factors. Threats may occur more often to insure sufficient personal space as the number of goats on the lick increases. The rates at which red deer threatened others also increased with larger group size (Clutton-Brock et al. 1982). With greater numbers of mountain goats using the lick, there is a greater opportunity for interactions between different age and sex classes. Chadwick (1977) found higher agonistic rates in mixed sex groups and higher intensity threats between goats of similar rank. Petocz (1973) also observed an increase in the frequency of agonistic behavior when deep snows forced mountain goats to aggregate into mixed groups and compete over limited food resources.

The mixing of mountain goats from different herds on the lick also may contribute to increased rates of aggression. Mountain goats regularly associating were found to have lower rates of aggression than those who were unfamiliar (Chadwick 1977), as were red deer (Clutton-Brock et al. 1982) and white-tailed deer (Ozoga 1972)

Agonistic behavior between mountain goats on the Walton lick was distributed fairly evenly among all age and sex classes. No two age and sex classes interacted more frequently than any other. Mountain goats on the lick may have threatened their nearest neighbors, regardless of age or sex, because space was limited and the resource was in such high demand.

Mountain goats performed rush and orientation activities more frequently than any other acts while on the lick. Chadwick (1977) suggests these are the lowest intensity threats in terms of probability of leading to an escalated fight, but no data are presented. Fighting might be risky on the precipitous lick terrain. It may be advantageous to use low intensity threats to minimize fighting, lessen risk, and optimize the amount of time spent licking.

Nannies performed rushes more often than any other age class. This was also found by Chadwick (1977). A rush may be a fast, effective way for nannies to defend their kids from the approach of other goats while still maintaining their licking spot. DeBock (1970) observed that first meetings of lactating females with unfamiliar kids resulted in females repelling kids with a short rush threat. This may also account for the high incidence of rushes among nannies on the Walton lick.

Adult females displayed a higher proportion of dominant to subordinate acts than other age classes. This could be due to defense of their young or perhaps nannies having a stronger desire for lick contents and were more willing to challenge other goats for space on the lick. Adult females have been reported to be the dominant class in mountain goats (Chadwick 1977, Singer 1977, DeBock 1970) which, if true, would require performing acts to establish and maintain their position. The advantages of dominance have been shown in red deer where it may influence access to food, (Appleby 1980), lead to more frequent social grooming and mounting behavior, and influence associations between individuals (Hall 1983b).

Mountain goat kids showed the smallest proportion of dominant to subordinate activities. This concurs with Chadwick (1977) who reports kids to be recipients of the most agonistic behavior and express the least of all age classes.

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APPENDICES

Appendix 1. Maximum daily counts of mountain goats on the Walton lick in Glacier National Park, Montana, May-August, 1983.

Date	B	SM	Y	SF	N	K	Total
526	5	2	4	2	1	0	14
527	7	5	5	0	2	0	19
528	9	4	9	1	3	0	26
529	3	1	2	0	0	0	6
530	5	2	2	1	1	0	11
601	3	2	7	1	3	0	16
602	0	0	2	0	1	0	3
603	1	1	2	0	0	0	4
604	1	1	0	0	0	0	2
605	12	7	10	2	5	2	38
606	10	6	9	3	6	3	37
607	12	6	11	4	10	4	47
608	1	3	4	1	3	0	12
610	1	0	5	0	2	0	8
703	1	2	5	0	8	5	21
704	2	0	5	0	11	6	24
705	1	0	3	2	14	0	10
707	0	2	0	1	2	1	6
708	0	0	0	0	4	4	8
709	0	1	3	2	13	4	23

710	0	0	0	0	1	1	2
711	0	0	0	2	3	2	7
713	0	0	3	0	6	4	13
717	0	2	8	0	18	11	39
719	1	0	2	0	7	3	13
720	0	1	0	0	0	0	1
722	0	1	3	0	3	2	9
725	0	0	0	0	1	1	2
726	1	0	0	0	1	1	3
727	0	1	0	0	1	1	3
728	0	0	0	0	1	1	2
729	0	0	0	1	1	1	3
730	0	0	2	0	5	4	11
801	0	0	1	0	15	11	27
802	0	0	0	0	5	4	9
803	0	0	0	0	8	6	14
804	0	0	1	0	3	3	6
806	0	1	1	1	4	4	11
807	1	0	1	0	2	1	5
808	0	0	1	0	1	0	2
809	0	0	2	0	1	0	3
810	1	1	5	0	10	8	25
811	1	1	7	0	3	1	13
812	1	1	2	0	1	1	6

Appendix 2. Maximum daily counts of mountain goats on the Walton lick in Glacier National Park, Montana, May-August, 1984.

Date	B	SM	Y	SF	N	K	Total
527	7	5	1	0	1	1	15
528	7	3	1	0	1	0	12
530	9	3	6	2	3	1	24
601	6	13	10	1	1	0	31
602	10	6	3	1	1	0	21
603	11	9	3	1	1	0	25
604	9	5	0	2	1	0	17
605	5	5	1	1	1	1	14
606	8	0	1	0	1	1	11
609	2	2	4	1	1	1	11
610	5	1	4	1	1	0	12
611	12	8	6	2	4	1	33
612	3	0	4	0	0	0	7
616	4	2	6	2	12	8	34
617	2	3	5	1	11	8	30
619	3	2	4	3	15	9	36
622	8	2	3	2	10	7	32
623	0	1	2	0	13	12	28
624	13	7	2	0	24	16	62
625	12	6	11	5	25	18	77
626	6	3	5	2	15	12	43
628	2	1	1	1	4	3	12
701	2	0	1	1	5	0	9

707	3	1	0	0	5	3	12
708	6	2	5	2	22	9	46
709	4	0	1	0	10	6	21
710	2	2	3	3	20	10	40
712	1	1	0	1	5	4	12
714	3	1	2	2	29	13	50
715	4	1	3	1	12	8	29
716	1	1	3	0	10	7	22
719	1	1	1	0	9	8	20
723	14	6	8	0	20	12	60
724	0	1	1	0	2	2	6
727	0	0	0	0	2	3	5
728	1	1	0	0	6	5	13
730	0	1	0	0	7	8	16
801	0	0	2	1	8	7	18
802	2	0	1	0	2	2	7
808	6	3	5	1	34	26	75
814	0	0	0	0	8	7	15
815	0	0	0	0	6	6	12

Appendix 3. Daily maximum numbers of mountain goats on the Walton lick, visitors, and vehicles on Highway 2 in Glacier National Park, Montana, and weather information June through August, 1984.

Date	#Goats	Max Temp	Min Temp	Ppt	Cld	#Veh	#Visitors
601	31	55	35	.01	08	147	32
602	21	60	30	000	00	153	21
603	25	65	30	000	04	230	20
604	17	66	35	000	10	126	15
605	14	66	40	.12	00	111	17
606	11	57	34	.05	08	111	23
607	12	60	36	.03	10	111	37
608	11	61	40	.05	10	164	25
609	11	53	37	.13	10	166	21
610	12	62	35	.04	05	280	15
611	33	62	40	.01	08	191	28
612	07	59	36	.01	05	191	30
616	34	74	44	000	05	191	34
617	30	75	43	000	05	191	37
619	36	75	39	000	00	203	39
622	32	52	41	.97	06	243	24
623	28	55	39	000	04	243	10
624	62	77	38	000	08	130	34
625	77	84	44	000	10	130	25
626	43	81	44	000	00	130	28
628	12	79	42	000	00	232	38

701	09	66	39	000	10	210	40
707	12	89	37	000	05	271	46
708	46	87	35	000	05	271	41
709	21	76	40	000	00	207	45
710	40	75	41	000	00	314	38
712	12	89	44	000	00	272	39
714	50	82	45	000	00	281	47
715	29	81	42	000	00	281	42
716	22	85	44	000	00	275	40
719	20	90	47	000	00	183	41
723	60	78	49	000	00	177	43
724	06	79	47	000	00	188	59
727	05	97	54	000	00	192	54
728	13	78	52	.02	10	233	63
801	18	83	50	.01	05	190	51
802	07	78	55	000	05	130	57
808	26	79	43	000	00	268	42
814	15	86	40	000	00	307	48
815	12	82	38	000	00	307	50

Appendix 4. Maximum number of mountain goats observed in the vicinity of the Walton lick in Glacier National Park and daily weather information.

Date	#Goats	Max Temp	Min Temp	Ppt	Cloud
601	57	55	35	0.01	08
602	39	60	30	0.00	00
603	37	65	30	0.00	04
604	42	66	35	0.00	10
605	25	66	40	0.12	00
606	52	57	34	0.05	08
607	37	60	36	0.03	10
608	28	61	40	0.05	10
609	31	53	37	0.13	10
610	31	62	35	0.04	05
611	45	62	40	0.01	08
612	44	59	36	0.01	05
613	35	71	40	0.00	05
616	73	74	44	0.00	05
617	47	75	43	0.00	05
619	71	75	39	0.00	00
622	69	52	41	0.97	06
623	53	55	39	0.00	04
624	74	77	38	0.00	08
625	68	84	44	0.00	10
626	88	81	44	0.00	00

627	42	84	51	0.03	00
628	27	79	42	0.00	00
629	27	92	43	0.00	00
630	51	82	43	0.00	10
701	33	66	39	0.00	10
702	28	74	45	0.04	05
703	10	77	43	0.00	03
705	62	79	47	0.00	00
706	21	87	47	0.04	10
707	56	89	37	0.00	05
708	56	87	35	0.00	05
709	44	76	40	0.00	00
710	59	75	41	0.00	00
711	22	82	43	0.00	00
712	15	89	44	0.00	00
713	24	83	47	0.00	00
715	45	81	42	0.00	00
716	27	85	44	0.00	00
717	20	85	44	0.00	00
718	13	88	45	0.00	00
719	30	90	47	0.00	00
720	09	87	43	0.00	00
722	05	76	39	0.00	00
723	65	78	49	0.00	00
724	09	79	47	0.00	00
725	06	90	47	0.00	00
726	20	95	54	0.00	00
727	12	97	54	0.00	00

728	13	78	52	0.02	10
729	14	85	59	0.10	10
730	27	76	52	0.05	10
731	03	71	47	0.00	00
801	10	83	50	0.01	05
802	07	78	55	0.00	05
803	04	83	46	0.00	00
806	12	85	48	0.14	10
807	75	75	40	0.13	00
808	57	79	43	0.00	00
809	01	84	48	0.00	00
810	00	91	49	0.00	05
811	00	91	49	0.00	10
812	02	77	49	0.00	00
813	00	88	51	0.10	10
814	15	86	40	0.00	00
815	12	82	38	0.00	00
816	00	88	46	0.00	00
817	04	85	50	0.00	00
818	02	90	50	0.00	00
819	04	86	49	0.27	10
821	00	75	37	0.00	00
822	00	78	38	0.00	00
823	03	76	45	0.00	00
824	00	89	47	0.00	00
825	00	88	38	0.00	00
826	00	82	43	0.00	00

Appendix 5. Number of visitors on SSGB underpass in Glacier National Park, Montana, 1984, and the mean crossing times of mountain goats in their presence.

No. of Vis	Time (min)						
8	2.0	0	1.0	5	3.0	2	6.4
0	4.3	2	2.0	6	2.0	2	8.0
0	4.2	5	5.0	0	1.0	2	9.6
0	3.0	17	15.0	0	3.0	0	3.8
0	1.8	0	3.2	0	12.3	0	3.0
0	4.2	0	2.0	2	1.0	6	4.0
0	1.8	0	5.0	5	7.0	6	4.0
0	4.0	0	3.3	0	2.0	0	2.0
1	2.3	0	3.5	0	1.0	0	3.0
2	3.0	0	2.0	0	3.0	0	3.5
0	5.0	0	2.0	8	2.0	0	5.0
0	3.0	11	3.0	8	2.0	0	3.0
0	5.0	13	8.0	8	4.0	0	2.0
0	3.0	7	22.0	0	5.0	0	2.0
0	2.0	7	27.3	0	2.0	0	3.0
0	5.0	2	5.0	0	3.0	25	6.0
3	4.3	9	15.0	0	3.0	0	3.0
8	5.0	0	3.0	3	3.0	0	3.0
1	8.0	0	1.0	0	2.0	0	3.0
1	5.0	2	1.6	15	19.0	2	2.0
1	4.5	0	1.8	2	7.0	0	3.0

0	4.0	0	3.0	1	5.0	0	1.0
6	2.0	0	2.0	0	2.0	0	3.0
0	3.0	0	2.0	0	1.0	0	2.0
0	2.0	0	3.0	0	7.0	2	6.0
1	1.0	0	2.3	0	2.0	6	6.0
16	18.2	0	2.0	0	4.0	6	7.0
2	3.0	0	2.0	0	1.0	0	3.0
3	4.0	3	1.8	0	3.0	0	2.0
3	5.0	0	5.0	21	28.0	0	3.0
2	3.0	0	3.0	0	3.0		
0	2.5	0	4.0	6	9.0		
0	2.6	0	3.0	2	10.0		
6	7.0	1	4.0	22	6.8		
3	3.3	0	7.0	15	13.8		
2	4.0	2	22.0	6	4.0		
6	2.9	12	5.3	0	2.0		
4	1.0	10	34.0	20	8.0		
8	2.1	1	5.0	12	15.0		
0	2.7	10	6.3	12	15.0		
0	3.0	12	6.0	2	4.3		

Appendix 6. Mean number of vehicles per hour travelling eastbound and westbound on Highway 2 past the Walton goat lick during June and July, 1984.

Hour	Eastbound	Westbound
0500-0600	4.50	3.00
0600-0700	11.20	4.80
0700-0800	20.50	15.17
0800-0900	32.00	21.83
0900-1000	43.00	39.80
1000-1100	52.67	49.25
1100-1200	57.80	54.20
1200-1300	52.60	51.20
1300-1400	52.00	50.33
1400-1500	64.40	75.80
1500-1600	58.60	74.20
1600-1700	54.00	61.60
1700-1800	48.25	52.50
1800-1900	41.20	47.60
1900-2000	34.56	51.56
2000-2100	36.33	42.20
2100-2200	24.17	19.70

Appendix 7. Mean number of vehicles per hour travelling Highway 2 past the Walton goat lick during weekdays and weekends in July, 1984.

Hour	Weekday		Weekend	
0500-0600	4.50	G	3.00	F
0600-0700	10.25	G	9.50	EF
0700-0800	19.50	FG	23.50	DEF
0800-0900	33.50	EF	34.00	CDEF
0900-1000	51.50	ABCD	62.00	ABCD
1000-1100	47.50	CD	76.00	ABCD
1100-1200	62.25	ABC	77.00	ABCD
1200-1300	65.25	ABC	91.00	AB
1300-1400	55.50	ABCD	109.50	A
1400-1500	74.17	A	106.50	A
1500-1600	73.17	AB	81.50	ABC
1600-1700	64.75	ABC	62.50	ABCD
1700-1800	64.00	ABC	76.00	ABCD
1800-1900	49.83	CD	106.50	A
1900-2000	50.50	BCD	78.17	ABCD
2000-2100	45.20	CDE	57.38	ABCDE
2100-2200	25.20	EFG	39.88	BCDEF

Means with the same letter within a column are not significantly different (Duncan's Multiple Range Test, df = 16, $\alpha = .05$).

Appendix 8. . Mean sound levels (decibels/hour) at two highway underpasses in Glacier National Park, Montana from June to August, 1984.

Hour	Goat Bridge	Snowslide Bridge
0500-0600	58.52	59.49
0600-0700	56.24	57.21
0700-0800	58.32	54.79
0800-0900	57.02	54.53
0900-1000	57.61	55.08
1000-1100	58.25	55.59
1100-1200	58.07	55.22
1200-1300	55.51	55.02
1300-1400	55.68	57.00
1400-1500	57.19	54.96
1500-1600	57.56	53.71
1600-1700	57.33	54.65
1700-1800	57.87	54.53
1800-1900	58.81	55.07
1900-2000	57.48	52.92
2000-2100	56.63	53.44
2100-2200	57.39	53.28

Appendix 9. Mean sound levels (decibels/hour) minus background noise levels at two highway underpasses in Glacier National Park, Montana, from June to August of 1984.

Hour	Goat Bridge	Snowslide Bridge
0500-0600	17.84	10.68
0600-0700	15.56	8.41
0700-0800	17.64	5.99
0800-0900	16.35	5.73
0900-1000	16.94	6.28
1000-1100	17.58	6.79
1100-1200	17.39	6.42
1200-1300	14.83	6.22
1300-1400	15.01	8.20
1400-1500	16.52	6.16
1500-1600	16.88	4.91
1600-1700	16.66	5.84
1700-1800	17.20	5.73
1800-1900	18.14	6.27
1900-2000	16.80	4.12
2000-2100	15.96	4.63
2100-2200	16.72	4.48

Appendix 10. Mountain goats using the Walton lick and visitors using the observation platform simultaneously in Glacier National Park, Montana, July, 1983.

#Vis	#Goats	#Vis	#Goats
26	6	30	15
1	8	0	0
14	7	2	0
17	8	44	1
3	5	18	1
61	6	57	2
35	9	2	0
20	10	5	1
12	7	12	1
0	8	20	1
0	6	11	1
0	6	32	4
5	5	2	0
0	2	0	1
6	8	23	1
0	16	0	0
2	0	28	5
13	12	26	9
16	5	81	25
24	13	66	18
14	3	10	9
0	35	10	13

0	7	36	8
0	8	9	6
0	8	6	1
7	2	11	0
12	3	31	0
7	3	26	0
12	3	0	8
7	3	5	5
7	4	21	0
36	7	30	3
31	10	82	5
23	4	48	7
2	8	16	2
1	3	0	2
27	20	0	2
36	5	0	4
76	4	5	3
77	9	0	0
40	5	14	3
59	6	22	0
34	9	24	1
44	2	49	5
53	7	73	8
28	14	17	13
12	2		

Appendix 11. Mineral contents of plant species found in mountain goat feeding areas on Running Rabbit Mountain in Glacier National Park May through August of 1984 (Mean percentage +-SD).

Species	Ca	K	Mg	Na
Acer	0.45	1.45	0.18	0.05
glabrum	(.11)	(.21)	(.07)	(.02)
Amelanchier	0.71	1.25	0.32	0.06
alnifolia	(.04)	(.26)	(.04)	(.05)
Arctostaphylos	0.44	0.58	0.36	0.02
uva-ursi	(.03)	(.22)	(.28)	(.01)
Berberis	0.19	0.57	0.14	0.05
repens	(.09)	(.45)	(.03)	(.01)
Betula	0.53	0.67	0.36	0.03
glandulosa	(.08)	(.46)	(.08)	(.01)
Ceanothus	0.53	0.74	0.17	0.05
velutinus	(.12)	(.15)	(.03)	(.02)
Rubus	1.35	1.33	0.81	0.06
parviflorus	(.18)	(.06)	(.23)	(.02)

Salix	0.63	1.24	0.32	0.05
spp.	(.05)	(.37)	(.04)	(.02)
Shepherdia	0.29	1.31	0.14	0.05
canadensis	(.09)	(.23)	(.04)	(.02)
Sorbus	0.44	1.77	0.38	0.06
scopulina	(.26)	(.39)	(.04)	(.03)
Spiraea	0.36	1.26	0.23	0.06
betulifolia	(.11)	(.28)	(.10)	(.05)
Symphoricarpos	0.53	2.02	0.41	0.08
albus	(.16)	(.52)	(.10)	(.04)
Vaccinium	0.54	0.45	0.22	0.03
globulare	(.06)	(.20)	(.04)	(.01)
Xerophyllum	0.18	0.74	0.08	0.07
tenax	(.04)	(.22)	(.01)	(.04)

Appendix 12. Concentrations (ppm) of minerals found in the Walton lick, Flathead National Forest lick, and other licks in Glacier National Park, Montana, 1984.

Sample	Mg	Ca	Na	Cu	Fe	Cd	Zn	Li	K	F-	Cl-	No3-	So4=
Walton	6.4	7.6	17.9	.0027	.02	.0004	.007	.04	5.5	.46	3.6	1.0	2.2
Walton	31.4	53.1	18.9	.0036	.02	.0005	.005	.13	13.1	.31	1.3	----	238.0
Walton	85.3	136.3	237.4	.0095	.03	.0018	.013	1.19	70.0	1.63	22.1	----	1028.0
F.N.F	4.2	11.1	23.8	.0120	.02	.0004	.008	.12	6.7	.26	1.5	26.9	37.1
F.N.F	3.6	9.6	22.5	.0079	.02	.0004	.008	.11	6.3	.26	1.0	24.2	26.9
Blue Lk	169.9	302.2	14.8	.1463	76.40	.0108	1.520	.60	20.6	2.48	1.5	8.9	1612.6
Red Lk	1.5	3.2	37.3	.0225	.82	.0005	.042	.01	3.1	.41	2.0	9.2	10.2
Park Lk	2.2	6.3	72.6	.0141	.15	.0007	.020	.06	8.5	.81	13.4	2.1	6.7

Appendix 13. Number of agonistic interactions performed by mountain goats during hourly intervals while on the Walton lick in Glacier National Park in 1983.

Date	#Goats on Lick	#Agonistic Interactions	Date	#Goats on Lick	#Agonistic Interactions
530	10	0	708	2	2
530	10	12	708	8	6
601	16	9	709	7	3
606	8	10	709	7	4
606	10	8	709	17	20
606	12	8	709	21	2
606	8	0	709	4	0
606	3	0	709	16	15
607	19	15	710	0	0
607	14	14	710	0	0
607	13	7	710	2	0
607	11	0	710	2	0
607	21	4	710	2	0
607	4	0	710	0	0
607	40	16	711	0	0
608	11	11	711	2	0
610	7	13	711	2	0
610	8	22	711	2	0
610	2	0	711	2	0
703	3	0	711	2	0
703	6	1	713	0	0

703	6	0	713	3	0
703	9	3	713	3	0
703	5	0	713	0	0
703	10	4	713	5	0
704	8	0	713	6	3
704	25	6	717	20	1
704	8	3	719	12	15
704	8	0	719	15	4
704	9	5	719	9	2
704	6	1	719	5	0
705	10	4	720	1	0
705	6	5	720	0	0
707	5	0	720	0	0
707	4	0	720	0	0
708	0	0	722	8	16
708	4	0	722	9	3
708	0	0	722	0	0
708	4	0	722	2	2
			722	6	0
			722	9	0
			725	2	0
			725	2	0
			726	3	0
			726	2	0

Appendix 14. Rates of agonistic interactions (acts/ pair-hour) between mountain goats utilizing the Walton lick in Glacier National Park in 1983. (N = Nanny, B = Billy, SM = Subadult Male, SF = Subadult Female, Y = Yearling, K = Kid)

N-B	N-SM	N-SF	N-Y		N-K	N-N	B-SM
1.50	0.08	1.00	0.33	0.17	1.00	1.00	0.33
0.67	0.67	0.20	0.04	0.17	0.50	0.20	0.25
0.33	0.40	1.00	1.00	0.20	0.20	0.20	0.25
0.17	0.10	0.33	0.33	0.17	0.13	3.00	0.25
0.67	0.33	0.67	0.28	0.67	0.01	0.02	0.17
0.30	0.25	0.33	0.25	0.11	1.00	0.33	
0.17	0.67	0.09	0.03	0.03	0.25	0.33	
	0.25		0.25	0.19	0.17	0.07	
	0.20		0.70	0.50	1.00	0.11	
			0.80	0.07	0.33	0.03	
			0.33	1.25	0.27	0.60	
			0.50	0.38	0.02	0.05	
			0.08	0.33	0.25	0.17	
			0.50			1.00	

B-SF	B-Y	B-K	SM-SF	SM-Y	SF-Y	Y-K
1.00	0.50	0.33	0.67	0.33	0.67	0.33
	0.20	0.17		0.14	.067	0.50
	0.67			0.02	0.14	0.38
	0.13			0.13		
				0.03		
				0.08		
				0.25		
				0.33		

SM-SM	Y-Y	SF-SF	K-K	SM-K	SF-K	B-B
0.33	0.33	0.00	0.00	0.00	0.00	0.00
0.07	0.24					
0.67	0.07					
	0.03					
	0.04					
	0.17					
	0.02					
	0.30					
	1.00					
	0.17					