Mountain Goat (Oreamnos americanus) Habitat Utilization in Olympic National Park

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MOUNTAIN GOAT (*Oreamnos americanus*)

HABITAT UTILIZATION IN OLYMPIC NATIONAL PARK

by

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Master's Thesis

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CHAPTER 1

Introduction

The Olympic Peninsula is dominated by a range of mountains that is isolated from the rest of the mountainous terrain on the North American continent by salt water on three sides and the Chehalis River lowlands on the fourth. This isolation has been in effect at least as long as the Pliocene -Pleistocene eras when both the Olympics and the neighboring Cascades were uplifting. As a result, gene pools have been isolated and dispersing species of both plants and animals have sometimes stopped short of reaching this otherwise favorable habitat. Among the mammals to have been excluded by intolerance of lowlands are the Cascade red fox, (Vulpes fulva cascadensis), pika, (Ochotona princeps), wolverine, (Gulo luscus), golden manteled ground squirrel, (*Callospermophilus saturatus*), and the mountain goat, (*Oreamnos americanus*) , the subject of the present report.

During the 1920's, ecological consciousness in Washington State was not as acute as it is today and the introduction of a non-native species, especially a game species, into a seemingly unused habitat was considered an enrichment of the fauna. To this end, between 1925 and 1929, the Clallam County game commissioner and a local sportsman's club arranged the exchange of several elk calves from the Hoh River Valley with mountain goats from Alaska and the Selkirks on the British Columbia - Alberta border. All together, a total of from eight - fifteen goats with representatives of both sexes were transplanted just off highway 101 near Lake Crescent on what is now the far northern boundary of Olympic National Park, (Figure 1). By 1933 goats were seen on Klahhane Ridge and gradually the population grew and dispersed throughout the mountainous regions of the peninsula. From the dispersal pattern it appears that two major corridors were used (Moorhead, 1976). One leads down the east side of the range and the other across the Bailey Range to Mt. Olympus (Figure 1). By the 1940's goats were common in the Lake Constance area and in the 1960's goats were seen outside the park to the south.

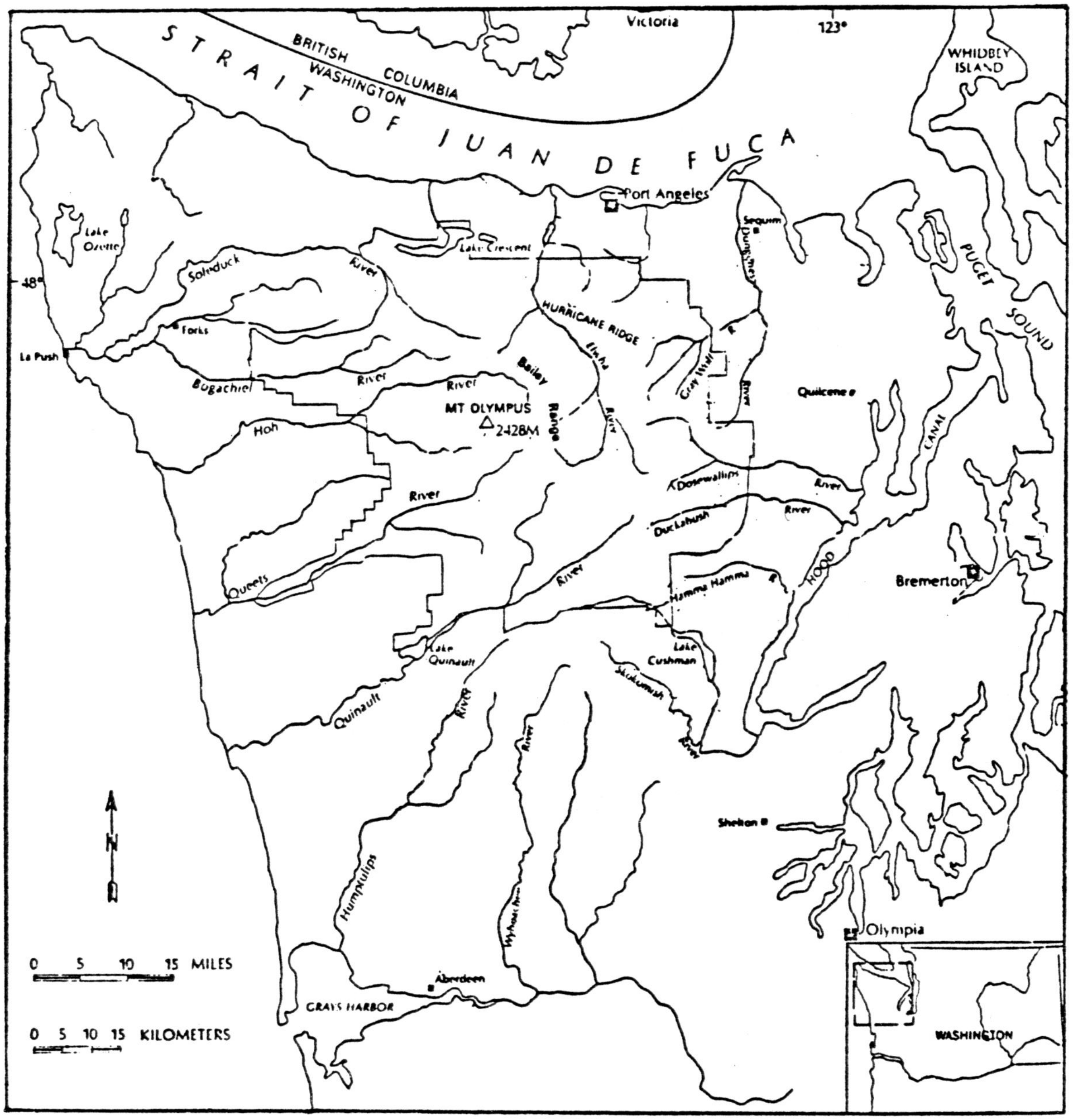


Figure 1. The Olympic Peninsula, Washington, showing the location of Olympic National Park.

The introduction was a qualified success. From the hunter's viewpoint the presence of an expanding goat population was not worth celebrating. Before the population reached a huntable size most of the goat habitat on the peninsula was closed to hunting with the transfer of Olympic National Monument from Forest Service to Park Service jurisdiction in 1933. Five years later, on June 29, 1938, the area achieved National Park status. It was not until decades later (1967) that goat distribution was wide enough so that a huntable population overflowed onto national forest land and an archery unit could be established.

Although goats in Olympic National Park are popular with visitors, the mandate of the Park Service is to preserve native ecosystems. If goats, as exotic animals, damaged plant/soil communities significantly, their continued presence would be contrary to park policy (Leopold et al. , 1963). Therefore it has become necessary to determine the nature and extent of goat impact on natural park ecosystems.

Over the last decade the population has continued to grow and a noticeable increase in bare ground and erosion has resulted from goat use in areas of high density. Such effects are not uncommon in the regions subjected to exotic ungulate introductions. Introduced reindeer, (*Rangifer tarandus*) on St. Matthew Island increased dramatically until their food source, lichens, was decimated and then crashed (Klein, 1968). The decimation resulted from a "combination of winter grazing, trampling, and shattering, and actual removal of the dry, shattered pieces of lichen by the persistently strong winds" (Klein, 1960). Mountain sheep, (*Ovis canadensis*) on Flathorse Island, Montana, have a similar history (Woodgerd, 1964). The natural regulation of such populations eventually occurs at the expense of the plant community. Since national parks are managed "... to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations," (Congressional Act of 1916), the integrity of plant communities is a matter of continuing management concern.

Although national park status is sufficient reason to preserve native ecosystems, there is now additional impetus under UNESCO's "Man and the Biosphere" (MAB) program. Olympic National Park has been designated a Biosphere Reserve. These reserves have three objectives: 1) conservation and preservation, 2) research and monitoring, and 3) education. Among the outstanding features for which Olympic National Park attained Biosphere Reserve status are the alpine ecosystems (Franklin, 1977).

Several exotic ungulates have been introduced into U. S. national parks. Their control or eradication, where necessary has proven difficult (Schectman, 1978). Burros, introduced into North America by Spaniards in the 16th century and spread throughout the Southwest by prospectors, are now well established in several National Park System areas including Grand Canyon National Park, Death Valley National Monument and Bandolier National Monument. They foul watering areas, compete with native deer, (Odocoileus hemionus), and desert bighorn, (Ovis canadensis) and influence the plant communities by trailing, wallowing and foraging (Anon. 1979). Efforts to remove burros from these areas have resulted in outcries from those who feel the burros are an historical symbol of the area and those who object to any killing of animals. These special interest groups have succeeded in halting control programs, at least temporarily.

The wild boar in Great Smokey Mountains National Park has also affected the native vegetation (Bratton, 1974, 1975; Howe and Bratton, 1976; Huff, 1977). Successful opposition to eradication of boars has come from hunters who believe that the unhunted national park population is providing an endless supply of boars to the neighboring areas (Anon., 1978).

On the other hand, a success story comes from Hawaii Volcanoes National Park where feral goats have consumed vegetation that evolved free from large grazing animals and that provided important habitat components to many native species. "First introduced in Hawaii in the late 18th century, goats have been a major contributor to the endangerment or extinction of hundreds of endemic plants and birds." (Reeser, 1976). Between 1922 and 1972 than 100,000 goats were removed from the park, but the remaining population was sufficiently large to maintain an excessive pressure on the plant/soil complex. This continuing failure led the Park Service to undertake a systematic eradication. By January, 1979 the census showed 448 goats (Annual Report from Hawaii Volcanoes National Park, 1978), a decrease of more than 13,500 from 1970 (Baker and Reeser, 1972).

The present study is part of the National Park Service effort to evaluate the effects of introduced mountain goats on Olympic ecosystems. A management plan based on this evaluation will include a determination of acceptable levels of mountain goats in all parts of the park and will detail methods of obtaining those levels. The biological basis of this management plan will include data on current distribution, abundance and relation to habitat, as well as potential distribution and abundance. The present study was undertaken to provide this basic biological data. The specific objectives were:

1. To determine the spatial and temporal use patterns of summering goats,

2. To determine distribution and relative densities of goats on summer habitat in sample areas of the whole park, and

3. To make predictions of potential goat use throughout the park based on the extrapolation of landscape use data from objective one on the landscape information from LANDSAT spectral signatures, aerial photos and maps.

As with all organisms, the structure, biology, and habitat choices made by mountain goats have been honed by the evolutionary process to create the most efficient life strategy possible. The central feature of this strategy is the use of steep, rocky terrain for protection. Goats select suitable cliffs or bluffs, and then feed on the most suitable plants available in that vicinity (Chadwick, 1976). Thus, different sub-populations differ widely in their diets (Brandborg, 1955; Saunders, 1955; Hjeljord, 1971; Hebert and Turnbull, 1977; Smith, 1978).

Within Olympic National Park, the largest sub-population of mountain goats summers on Klahhane Ridge. Therefore Klahhane Ridge was selected for a detailed study of summer goat ecology, emphasizing the analysis of choice and use of habitat (landscape) components. Goats were first seen in this area in 1933, and since that time the sub-population has increased to about 200 (Stevens and Driver, 1978).

The primary purpose of determining essential habitat features for goat summer range has been to make possible the testing of the following hypotheses.

1. The distribution and relation between important components of goat summer range on the Olympic Peninsula are correlated with the relative densities of goats throughout the area.

2. Klahhane Ridge is a unique goat "mecca" where the important habitat features are abundant and closely associated. This has resulted in rapid growth of the goat population. This ideal combination of abundance and

proximity does not occur elsewhere and therefore the goat density on Klahhane Ridge will not occur now or in the future in other parts of the park.

Inasfar as possible these hypotheses were tested using ground surveys, aerial photos, and remote Landsat imagery, which has been used to describe levels of quality in wildlife habitat for white-tailed deer in Mississippi (Joyce *et al.* , 1977).

CHAPTER 2

Study Area

Because this study involved both an overview of goat density throughout the park and a detailed analysis of landscape use in one area, each section describing the study area will have general descriptions of the entire peninsula as well as a closer look at Klahhane Ridge.

2.1 Location and Accessibility

Olympic National Park is located in the center of the Olympic Peninsula, in the northwest corner of Washington State (Figure 1). The park comprises about one third of the 10,400 square km. of the peninsula and practically all of the mountainous terrain. Klahhane Ridge runs east-west about four km. inside the park boundary in the northeast corner (Figure 2). It is defined by Mt. Angeles on the west and Rocky Peak on the east. The Hurricane Ridge Road, completed in 1957, provides easy access to Klahhane Ridge, as it parallels the length of the ridge from 700 - 500 meters below the crest. A maintained trail (Switchback Trail) leads from the road to the top of the ridge (3 km.) and about two km. along the crest.

2.2 Geology and Topography

Geologically the peninsula can be separated into two assemblages, the peripheral rocks and the core rocks. The peripheral rocks are in a horseshoe configuration surrounding the core and delineated by faults (Figure 3). The oldest formation is oceanic basalt of the Eocene known as the Crescent Formation which is a large component of the peripheral rocks. This formation is visible from the Hurricane Ridge Road and the Dosewallips Road in the form of pillow lavas. In places the basalt may be 16 km. thick, one of the thickest basalt strata in the world (McKee, 1972). The core rocks are mostly shale, siltstone and sandstone and are characterized by complex folding and faulting (Tabor and Cady, 1978). This disruption was probably caused by squeezing as the oceanic plate moved under the continental plate. When the movement stopped the sedimentary rocks in the core began to bob up because

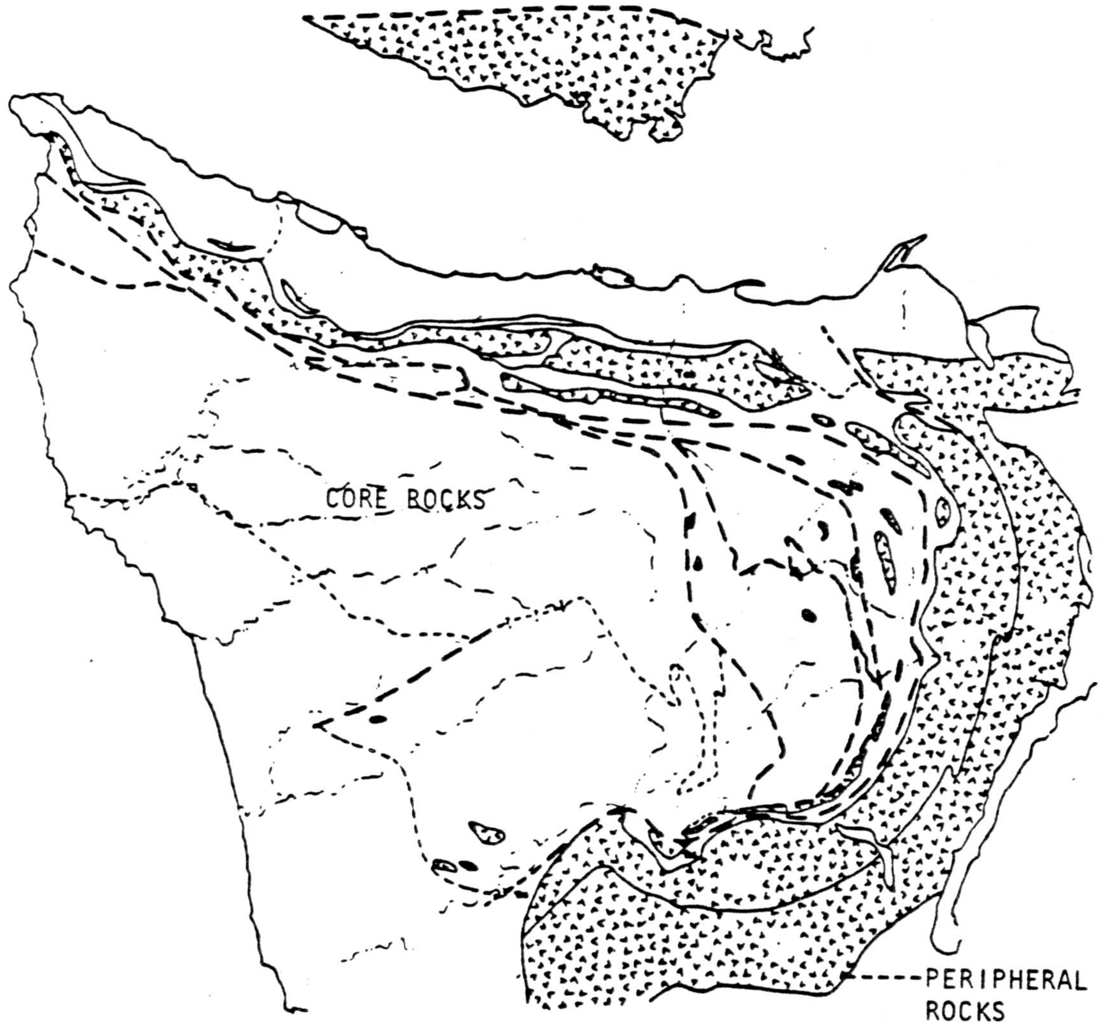


Figure 3. The basic geological structure of the Olympic Peninsula.

of their low density (Tabor, 1975). This rebound which began in the Pliocene created the central Olympic Mountains which are still rising at the rate of about one cm./year (Lee Fairchild, pers. comm.). Glaciers also lent a hand in shaping the Olympics. The region was glaciated at least four times (Crandell, 1964), the last two being about 100,000 and 10,000 years ago. Glaciers caused shearing along the tops of folds in the core area and deposited large granitic erratics, the only granite now found in this region. Today the Olympic Mountains appear as a mass isolated on all sides by lowland. Eleven major rivers radiate from the center of this mass.

Klahhane Ridge is within the area of peripheral rocks. It is composed mainly of basalt and breccia, but is bisected in two areas by sedimentary rocks. One of these areas is Mt. Angeles where the alternate layers of sedimentary and volcanic breccia can be seen from the ridgetop, tilted and tipped from their original horizontal position.

2.3 Climate

The climate of the Olympic Peninsula cannot be characterized as a unit. At one extreme is the rain forest on the west slope of the mountains which receives over 140 inches (360 cm) of rain annually. In the northeast corner, which falls in the rainshadow of the mountains, the annual precipitation is only around 17 inches (43 cm). This area is known fondly as the banana belt and agriculture thrives with the aid of irrigation (Fagerlund, 1965). Another cline exists altitudinally. In the interior mountains, glaciers are fed by high snowfall during much of the year, while on the coast a maritime climate prevails with temperatures averaging 3.7 degrees C. (38.6 degrees F.) during January, the coldest month of the year (NOAA, 1978).

Klahhane Ridge is an alpine area somewhat in the rainshadow. Although there is no weather station there, the weather is similar to that of nearby Hurricane Ridge, where an informal recording of hign and low temperatures is made by Park Service personnel. Winter temperatures are consistently below freezing with a record low of -22 degrees C. (-8 degrees F.) on December 31, 1978. Highest temperatures occur in July and August, sometimes going over 32 degrees C. (90 degrees F.) during the day, although nights are always cool. The nearest official weather station is at Port Angeles, 16 km. north and 2,000 meters lower than Klahhane Ridge. A daily comparison of the high and low temperatures from Port Angeles and those from Hurricane Ridge when available show that the average daily minimum temperature is lower on Hurricane Ridge by 6.9 degrees C. (12.4 degrees F.) and the daily maximum is lower by 8.5 degrees C. (15.3 degrees F.) or about 1 degree C. For every 195 meters (643 feet) in elevation.

From November through March precipitation on the ridge is usually in the form of snow. Although no measurements have been taken on top of Klahhane Ridge, snow depth is recorded for Cox Valley on the south side of the ridge and 450 m. (1500 ft.) lower in elevation and provides a relative measure for comparisons between months or years (Table 1). Snow remains in places on the ridge throughout the year except when exceptionally warm summers follow winters of light snow as occurred in 1978.

Table 2 shows monthly precipitation in Port Angeles for 1977 and 1978 as compared to the 15 year average. The precipitation on Klahhane Ridge probably parallels these figures, which show that overall precipitation has been lower than average during this study.

Table 1. Snow depth and water content in Cox Valley, Olympic National Park.

MONTH[1]	1977		1978		1979		AVERAGE (1968-1979)	
	snow depth	water cont.	snow depth	water cont.	snow depth	water cont.	snow depth	water cont.
January	0	0	60	22.6	81	14.8	82.25	29
February	31	6.3	69.6	27.4	97	27	106.47	34.6
March	69.35	22.2	71	28	74.8	30.8	106.43	40.95
April	34.3	16.5	71	30.5	78	36	93.28	41.49

[1] measurements were taken at the end of each month.

Table 2. Monthly precipitation for Port Angeles in 1977 and 1978.

MONTH	1977(in.)	1978(in.)	AVERAGE(in.)
January	1.51	2.35	4.01
February	1.14	1.88	2.39
March	4.45	1.39	2.04
April	0.71	1.54	1.33
May	2.04	1.52	1.48
June	0.31	0.17	0.91
July	0.50	0.51	0.49
August	1.86	1.09	0.73
September	0.97	1.93	1.20
October	2.47	----	2.68
November	3.87	----	3.79
December	3.65	----	3.97

2.4 Vegetation

Goats commonly summer above treeline, so the areas of concern to this study were those over 1500 meters (Easterbrook and Rahm, 1970). For regions above this elevation in Olympic National Park Kuramoto and Bliss (1970) have described eight plant community types (Appendix A).

The major clines along which community variation occurs are altitude, aspect, slope, soil substrate, moisture gradient and growing season length. The broken character of the landscape above tree line with respect to most of these features creates a mosaic of plant communities with sharp ecotones.

Klahhane Ridge has examples of several of these communities. The cushion plant type occurs in small areas along the top of the ridge and, the mesic grass type is a favorite goat foraging area on the south side of the ridge near Mt. Angeles. At lower elevations on the south side of the ridge the _Saussaurea_ forb type is evident along the Switchback Trail. The north bowl at the far east end of the ridge is a good example of the heath-shrub type. It is later to melt out than higher areas on the south side.

The Olympics have a number of endemic species and varieties as a result of isolation and glaciation (Table 3). Most of these are alpine species and have a range overlapping that of the goat. Of note are _Viola flettii_ , a small violet that grows in cracks in rock and is occasionally seen on steep undisturbed scree slopes; _Campanula piperi_ , a blue (rarely white) bell-flower that grows in areas similar to the violet; and _Senecio neowebsterii_ , a late blooming yellow composite which

Table 3. Endemic plants of Olympic National Park.[1]

SPECIES	COMMENTS
Astragalus cottonii	very limited population, has been reported in prime goat habitat, northeast of Mt. Angeles. Likely to be a preferred forage species
Campanula piperi	wide population distribution within prime goat habitat, including Klahhane Ridge. Trampling effects reduced by its rock crevice habitat; although forage preference is unknown, it is apparently low.
Campanula piperi f. sovereigniana	questionable endemic status, unknown population
Castilleja parviflora var. olympica	fairly wide distribution in goat habitat. Castilleja is not a highly preferred genus on Klahhane Ridge. Extent of utilization of this species is unknown. Some question of variety-endemic status.
Erigeron flettii	very limited population, and is found in prime goat habitat. Extent of goat forage preference unknown, but likely to be high.
Erigeron peregrinus ssp. callianthemus var. thompsonii	questionable endemic status.
Erysimum arenicola var. arenicola	questionable endemic status, widespread distribution, especially in prime goat habitat, but apparently not a preferred forage species.
Pedicularis bracteosa var. astrosanquinea	only goat use possible in winter range.
Petrophytum hendersonii	limited populations in best goat habitat, apparently larger populations exist in areas of reduced goat use (the Bailey Range), amount of foraging unknown. Restricted to rock crevices in areas of heavy goat use - formerly more widespread?
Senecio flettii	questionable endemic status, widespread distribution - in good habitat, but also possibly found east of the Cascades.

Table 3. cont.

SPECIES	COMMENTS
Senecio neowebsteri	populations in prime goat habitat on Klahhane Ridge and other areas. It is a preferred forage species.
Syntheris pinnatifida var. lanuginosa	rare within goat habitat: Klahhane Ridge and Obstruction Point.
Viola flettii	secure population, reduced in areas of moving scree due to trampling, but not a preferred forage species.

[1]Compiled by Douglas Pike, College of Forest Resources, University of Washington.

grows on unstable, commonly north facing scree slopes.

CHAPTER 3

Methods

The approach to the objectives in this study was sequential. The results from the first and second were necessary before the solution to the third could be attempted. The first, to determine spatial and temporal use patterns of summering goats, involved an intensive, quantitative analysis and resulted in an ecological description of preferred goat habitat. The second, to determine distribution and relative densities of goats on summer habitat, involved an extensive ground survey of six areas throughout the park and resulted in a comparison of goat density as related to habitat characteristics already described in ecological terms in the Klahhane Ridge study. The final objective required input from objectives one and two and involved extensive remote sensing. It was to make predictions of potential goat use throughout the park. The methods used will be presented in the same order.

3.1 Habitat Utilization

Describing goat habitat quantitatively involved 1. the capture and marking of goats in that area, 2. systematic data collection, and 3. analysis of the data.

3.1.1 Capture and Marking

Marked animals were used exclusively as subjects for landscape use data collection so that the age and sex of the subject would be known for analysis of differential use. Tagging began in June, 1977 and continued through August, 1978. Therefore, the number of marked animals was increasing throughout the 1978 field season when the landscape data were collected. As the data were not used in any way to correlate the numbers marked with the numbers unmarked, this increase should have no effect on the analysis.

Initially, goats were captured by immobilization with succinolcholine chloride, a drug which has been used with success on elk (Paige, pers. comm.; Jenkins, pers. comm.).

A powdered form of the drug in premeasured doses (Pneudarts) was fired from a rifle using the lightest charge available (gray) as approaching to a distance of 15 feet was not uncommon.[1] Our success rate was not outstanding. Of 26 goats darted, 10 were successfully immobilized, 1 stumbled but did not go down, 11 did not react to the drug and 4 died (Table 4).

Near the end of June, 1977, the capture technique known as "goat roping" was perfected. In this method a slip knot is tied at the end of an eight meter section of rope (both nylon and manila have been used) and the resulting loop (about 44 cm. in diameter) is placed near salt in an area where it is likely for a hind foot to be placed. The capturer waits at the other end of the rope ready to pull when the correct moment arrives. A pull which is back and up simultaneously has been found to be most successful in closing the loop just above the hoof and therefore making it difficult for the goat to escape.

[1] Pneudart, Inc. P. O. Box 388. Williamsport, Pennsylvania 17701. Availability as of February, 1978 was limited to persons who accept the responsibility for being clinical investigators under Title 21 CFR 511. (B) (7). This responsibility entails keeping clinical records for the Pneudart Company files.

Table 4. A record of mountain goats darted in Olympic National Park with succinylcholine chloride during the field season, June - September, 1977.

DATE	AGE	SEX	DOSE(mg)	CHARGE	DISTANCE(yd)	TIME DOWN	TIME UP	COMMENTS
6-11	A	M	18	brown	25	--	--	no reaction
6-11	2-3	M	18	brown	20	--	--	no reaction
6-11	A	F	20	brown	20	--	--	no reaction
6-11	A	M	20	brown	20	--	--	no reaction
6-12	3	M	25	brown	15	12 min.	27 min.	tagged
6-12	A	F	25	brown	20	-	--	no reaction
6-12	3	M	25	brown	--	--	18 min.	tagged
6-12	5	M	25	brown	--	--	--	stumbled at 6 min.
6-12	2	M	25	brown	--	12 min.	--	tagged
6-12	2-3	F	25	brown	--	12 min.	34 min.	tagged
6-12	1	?	20	brown	--	--	--	no reaction
6-12	1	M	20	brown	--	--	--	no reaction
6-17	2-3	F	25	brown	20	--	--	no reaction
6-18	1	F	20	brown	15	2 min.	15 min.	tagged
6-18	1	M	20	brown	15	--	--	no reaction
6-18	2	F	25	brown	15	7 min.	--	died
6-18	1	M	25	brown	15	2 min.	--	died (10 min.)
6-19	A	F	25	gray	15	--	--	no reaction
6-19	2	M	20	gray	15	--	--	no reaction
6-19	1	F	20	brown	15	--	--	died
6-19	3	F	25	gray	15	6 min.	29 min.	tagged
6-19	3	F	25	brown	15	12 min.	30 min.	tagged
6-20	3	F	25	gray	15	5 min.	--	died (9 min.)
9-8	1	M	22	gray	--	15 min.	30 min.	tagged
9-9	2	F	25	gray	--	9 min.	25 min.	tagged
9-9	5	F	25	gray	--	30 sec.	25 min.	tagged

While tension is held in the rope, a second person approaches the goat from behind and knocks it over. When the goat is down a covering is placed over its eyes and it is held while measurements and tagging take place. With the exception of large males, two people can perform the above procedure. When only two people were available it was found to be helpful to tie off the rope to a tree, rock or shrub in a manner which kept tension on the rope. Once down, the animal was aged by counting horn rings, and sexed, standard measurements were taken and a large plastic Y-Tex tag developed for cattle was placed in the right ear of a male and the left ear of a female.[1] In the summers of 1977 and 1978 goats were captured and handled in this way with no fatalities. It seems well suited to park conditions, where goats are attracted to salt, especially in early summer, and tolerate the close approach of humans.

An example of the data sheet used during this procedure is in Appendix B. The adult tags were 75 X 78 mm. with numbers 42 mm. high on both sides and the tags for kids were 53 X 56 mm. with numbers 25 mm. high. The numbers on the large tags were visible from a kilometer

[1] Y-Tex Corporation, P. O. Box 1450, Cody, Wyoming 82414.

away with a 60 power spotting scope. There has been no apparent tag loss. In 1978 all but 4 of the 54 goats tagged the previous summer were accounted for. In 1978, 34 animals were double tagged to check for tag loss. To date, no tag loss has been reported. Therefore it seems most likely that the goats disappearing between the 1977 and 1978 summer season died or emigrated.

3.1.2 Data Collection

Data were collected systematically on the Klahhane Ridge population from June 24 - September 4, 1978. The system was designed to include enough information on individuals of known age and sex to compare landscape use between age and sex classes under a wide variety of environmental conditions, between days throughout the summer, and between times during a day. The large number of tagged goats on the ridge made possible accurate identification of the age and sex of 100 percent of the goats used for observation.

A similar, but less comprehensive study was conducted by McFetridge (1977) in Alberta. He recorded habitat use by nursery groups throughout the summer and fall. The primary difference between his study and the present one is the addition to the latter of the variable, time within a day, and the inclusion of all sex and age classes.

Each systematic observation focused on a tagged individual which was either an adult male or an adult female. Since the adult females tended to associated with the other 3 cohorts (yearling males, yearling females and kids), all 5 cohorts were represented in the sample by the system of focusing on adult males and adult females. This approach avoided the confusion inherent in attempting to study goat groups per se. The focus individual was followed throughout an observation period during which the group composition often changed.

During each observation period, comparable data were collected on every tagged individual in the same group. A series of environmental parameters was measured and noted every five minutes along with total group composition, general location on a topographical map and the activity and specific landscape type location of each tagged goat in the group. Altogether, 5,589 cases were recorded during 50 observation periods over 36 days distributed in three distinct segments throughout the summer. The average observation period was 4.19 hours with none shorter than 30 minutes or longer than 11 hours. The data were recorded on data sheets, designed to eliminate intermediate handling of the data before keypunching (Appendix C).

The data were keypunched by the College of Fisheries, University of Washington and analysed from a permanent file on the CDC 6400 at the University of Washington Academic Computer Center. The Crosstabs program from SPSS (Statistical Package for the Social Sciences) (Nie, 1975) was used to correlate landscape use, activity, age and sex with each other and with environmental and physiographic parameters.

3.2 Goat Density

To sample the distribution and density of goats throughout the eastern portion of the park a one kilometer squared grid system was superimposed on a map of the area. The sampling area included every other six kilometer strip running east to west. The 112 one kilometer cells which were both above 1524 meters (5000 feet) and in the sampling area, constituted the extensive survey sample. Each cell was visited and checked for direct evidence of goats (sightings, tracks, pellets, wallows). Six areas were sampled: Klahhane Ridge (27), Grand Valley (21), Grey Wolf Ridge (19), Mt. Constance - Mt. Mystery (27), LaCross

Pass - Marmot Lake (13), and Sawtooth Ridge (6). A subjective density rating from 0 (no evidence of goats) to 4 (heavy goat use) was assigned each cell using the top of Klahhane Ridge as the type cells for 4, the area around Lake Constance as the type cells for 3 and the Sawtooth Ridge area as the type cells for 2.

Since goats do not confine themselves to one kilometer cells, a number (D), was estimated for each area, representing the total relative density.

$$D = \frac{4(a) + 3(b) + 2(c) + 1(d)}{a + b + c + d}$$

Relative density categories were: highest (a) moderate (b) light (c) and sporadic (d).

3.3 Potential Goat Habitat

The analysis of Landsat satellite remote imagery was correlated with specify the distribution and associations of important mountain goat habitat elements. The raw satellite data were available on computer tape through the Washington State Computer Center, Pullman, via the Oregon State Computer Center, Corvallis, for reformatting. The available tape was for October 11, 1977. This was fortuitous as a pre-snowfall autumn scene reflects the largest snow-free areas while still showing the areas with snow patches which have been available throughout the summer. The date is also close enough to the date when the aerial photographs were taken (September 4, 1976) so that the phenology of the vegetation is similar and direct comparisons could be made with confidence.

The Landsat satellite can distinguish a unit of area called a picture element or pixel. For Landsat II which is the source of the tape used in the present study, a pixel is 1.1 acres or 50 meters squared. There are 400 pixels in each one kilometer squared cell. The recorded data is the reflected intensity of each pixel on four bands of the light spectrum.

The habitat classification was accomplished with the University of Washington Image Processing System (UWIPS) developed by Muller (1979) from the Remote Sensing Applications Laboratory, University of Washington. The system cuts out a user specified area (window) from the whole Landsat scene, (184 kilometers squared or 115 miles squared), learns to identify ground cover by comparison with user specifed areas (Training sites) and classifies large areas according to a system developed by the user.

In the present study a few broad categories of ground cover or landscape types were chosen to characterize good goat habitat according to the findings from the habitat study on Klahhane Ridge . They were rocky bluffs, open meadows and snow. Three cover types were also classified to make the identification of map locations more accurate. These were standing water, dense coniferous forest and open coniferous forest. The above classes were developed for the Klahhane Ridge area where aerial photographs and a previous knowledge of the ground cover were used to refine the system's ability to distinguish between them. When the classification for the Klahhane Ridge area was satisfactory a larger "window" including all six of the sampling areas was classified using the same system. The output was a map 3 by 3.2 meters which was tacked to a wall for examination. A comparison was then made between how the satellite perceived Klahhane Ridge , the ideal area for goats, and each of the other five areas. The bases for comparison were,

1. The presence of all 3 "essentials" of good goat habitat: steep rocky terrain; open meadows; and cool areas represented by snow.

2. The proximity or juxtaposition of the 3 "essentials."

3. The amount of unclassified area intermixed with good goat habitat,

4. The orientation of the ridge.

Justification for the inclusion of the last two items is as follows. Item 3 - the areas which appeared to have pixels of concern to goats mixed liberally with unclassified pixels were unpredictable. Examples are the Port Angeles area (residential and industrial) and the dry lake bed of Lake Cushman. Item 4 - the orientation of the ridge is thought to be important because of the wide array of micro climates available when the ridge has an east - west orientation, like Klahhane Ridge, as compared to one with a north - south orientation.

CHAPTER 4

Results

4.1 Habitat Utilization

The two most important (i. e. most frequent) observed goat activities were feeding and bedding. Eighty-two percent of all observations were of feeding (40 percent) or bedding (42 percent). Averaged over the entire field season, there were distinct peaks in both activities which complemented each other (Figure 4). Peaks of feeding occurred in the morning between 0500 and 0600 (70 percent of the observations were of feeding) and between 1800 and 2100 (70 percent). With few exceptions formal observations did not start before sunrise or go beyond sunset. The rather sharp morning peak of feeding occurred

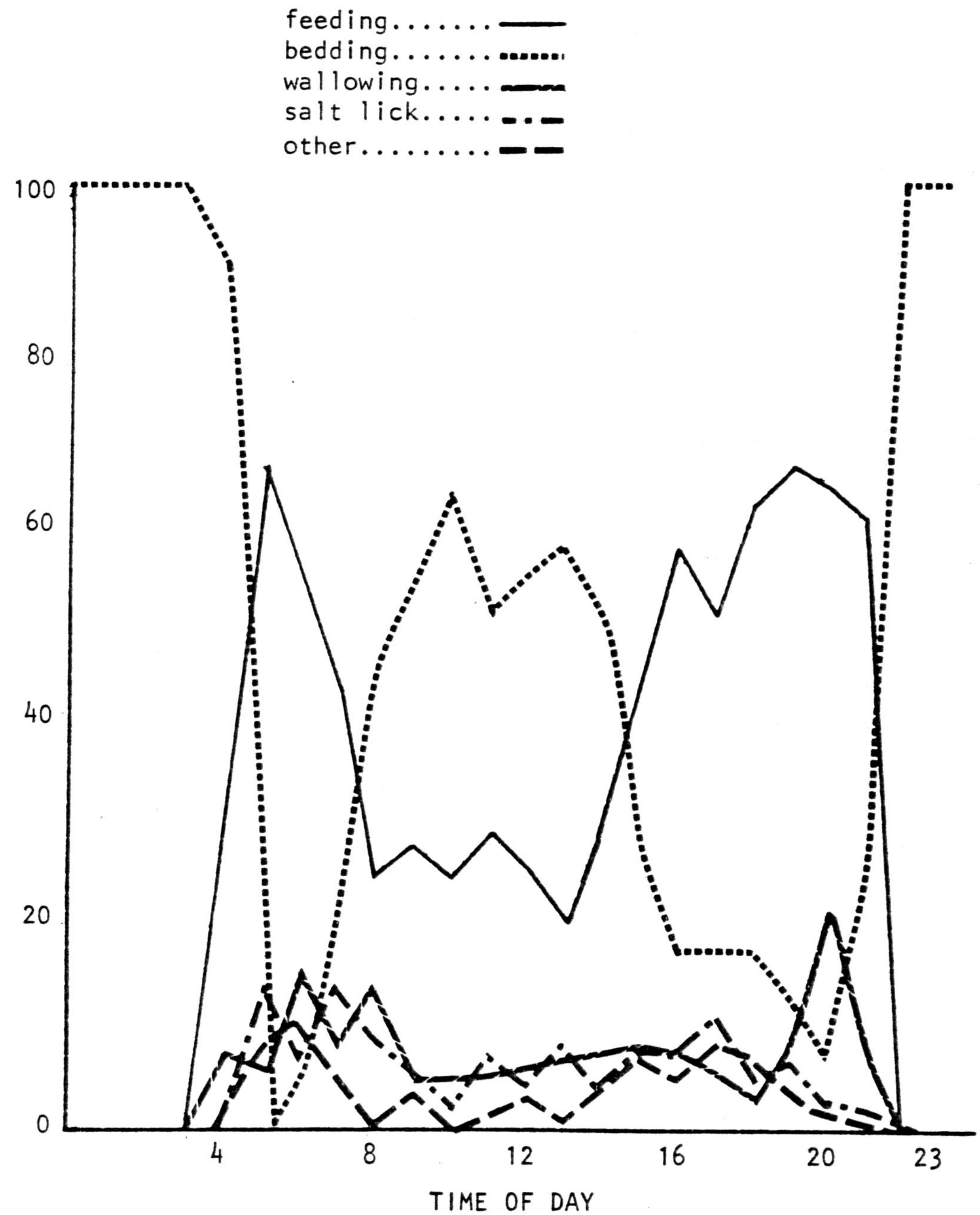


Figure 4. Percent of observations of each activity by hour throughout the summer.

in the hour following sunrise and the more prolonged evening peak occurred in the several hours prior to sunset. During daylight hours the level of feeding never dropped below 22 percent. Data on night activities are limited to a single full night of observations of five goats. They bedded on a rocky bluff at approximately 2000 and didn't move other than to shift positions until 0445. However, on two other occasions during the summer observations on the ridge at midnight showed adult males feeding in the open meadows on the south side of the ridge. More observations are needed in order to quantify nocturnal activities.

Bedding peaked during the night (100 percent) and the four hours in the middle of the day (55 - 67 percent). All other activities, (licking minerals, traveling, agonistic behavior, eating snow), roughly followed the peaks and dips of feeding, beginning with a flurry of activity in the morning, dropping to a low but fairly steady rate in the middle of the day and increasing slightly just before dropping to zero for the night. Traveling had a more pronounced peak just before dark, presumably because goats were moving to protected, safe bedding sites for the night.

4.1.1 Seasonal Activity Patterns

The data for the whole summer, taken together, obscure many of the variations due to day length, forage quality, and weather, which change throughout the summer. In an effort to analyse the change in the goats's response to changes in the season, the observation periods were separated into three segments of the summer: Period I, June 24 - July 4; Period II, July 11 - August 4; Period III, August 22 - September 4. A comparison of the temperatures in each period is shown in Figure 5. During the first two periods when the average daytime temperatures were quite high, feeding dropped dramatically during the middle of the day (to 5 percent of observations) as compared to the cloudy, wet period near the end of summer when feeding never dropped below 30 percent of the observations during the day (Figure 6).

The temperatures were recorded with respect to the location in which the goats were found and thus reflect the goat's attempt to damp the extremes of temperature by habitat selection. During the cool early or late summer days the warmer south slopes are selected and during the hot mid-summer days the goats tended to be on the cooler north slopes.

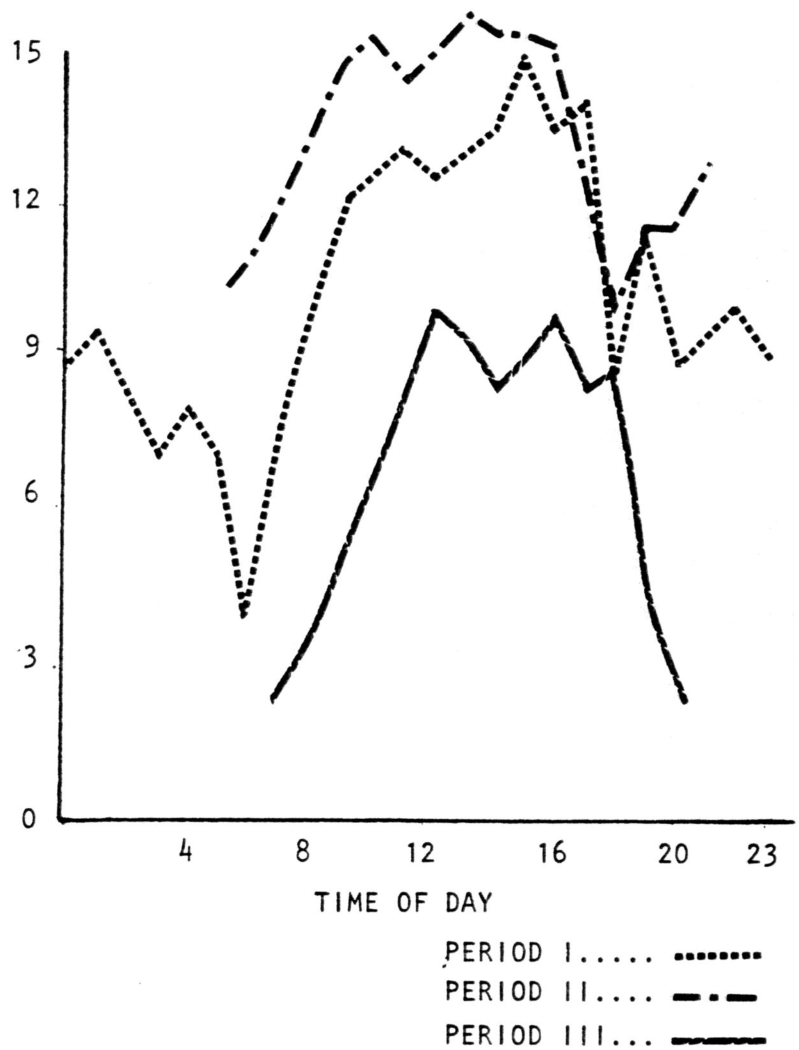


Figure 5. A comparison of hourly temperature for each period.

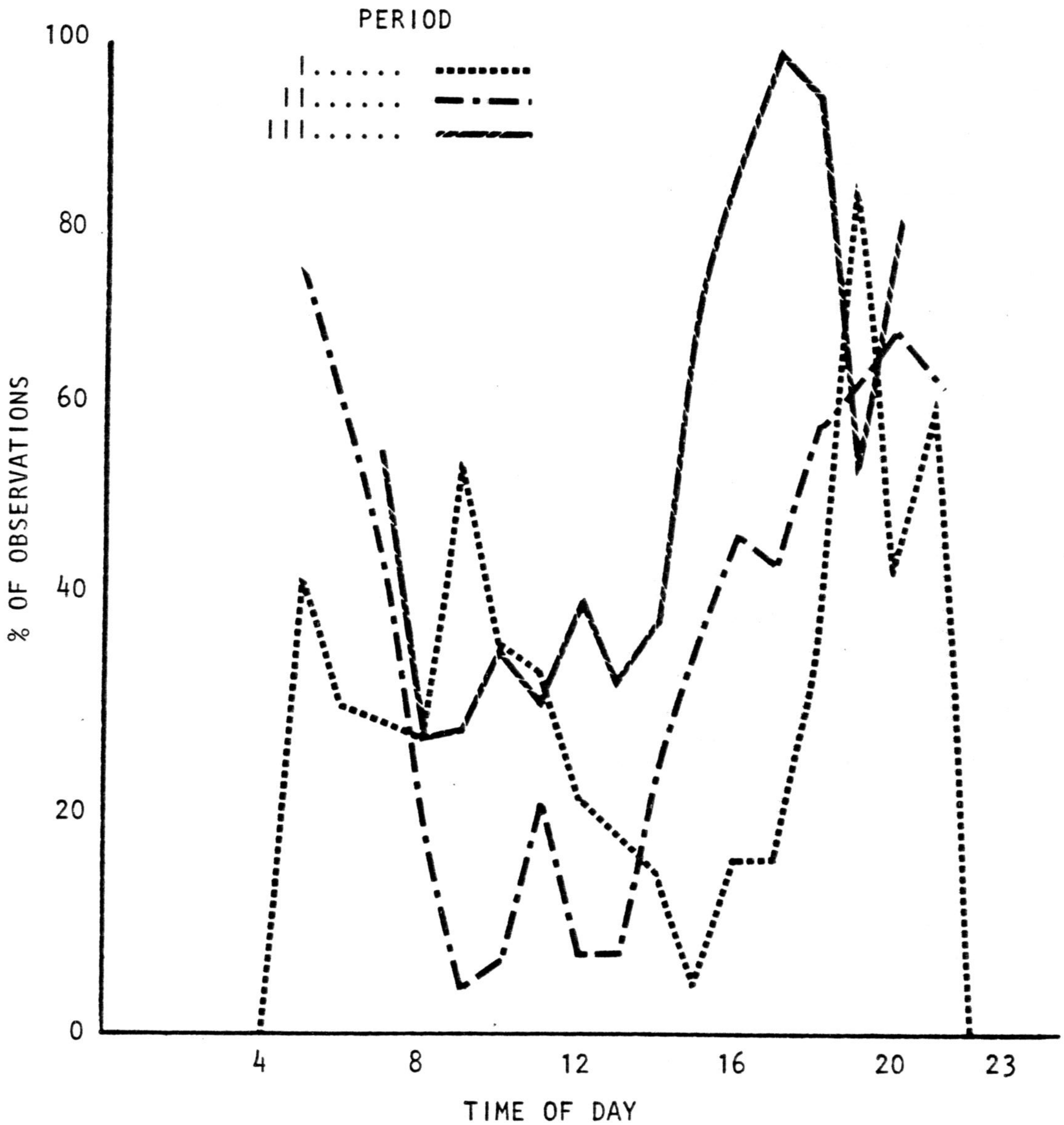


Figure 6. A comparison of the percent of observations of feeding each hour during three periods of the summer.

Forage quality, reflected in low fiber content, is highest when the vegetation is growing at its maximum rate, which is in early summer on Klahhane Ridge. Nitrogen levels in fecal pellets collected monthly on Klahhane Ridge appear to parallel forage quality (Figure 7, Appendix D). Daily foraging time is summarized in Figure 8. These data show that more time was spent foraging in period III (late summer) than in period I (early summer) when the forage quality is highest.

When forage is high in quality it tends to be more succulent and more easily digested (Nelson and Leege, 1979), and therefore to pass through the digestive tract more rapidly. Therefore more food can be processed daily. Assuming that the individual will eat as much food as it can process daily, we would expect that feeding would occupy more time when forage is excellent and less time when forage is poor, and moves slowly through the digestive tract.

Analysis of feeding behavior shows that foraging time has two components, searching time and feeding time. As forage quality declines, feeding time declines, but searching time increases. This is due to the patchiness of the resource. The forage species vary not only in their average quality, but also in their phenology, which

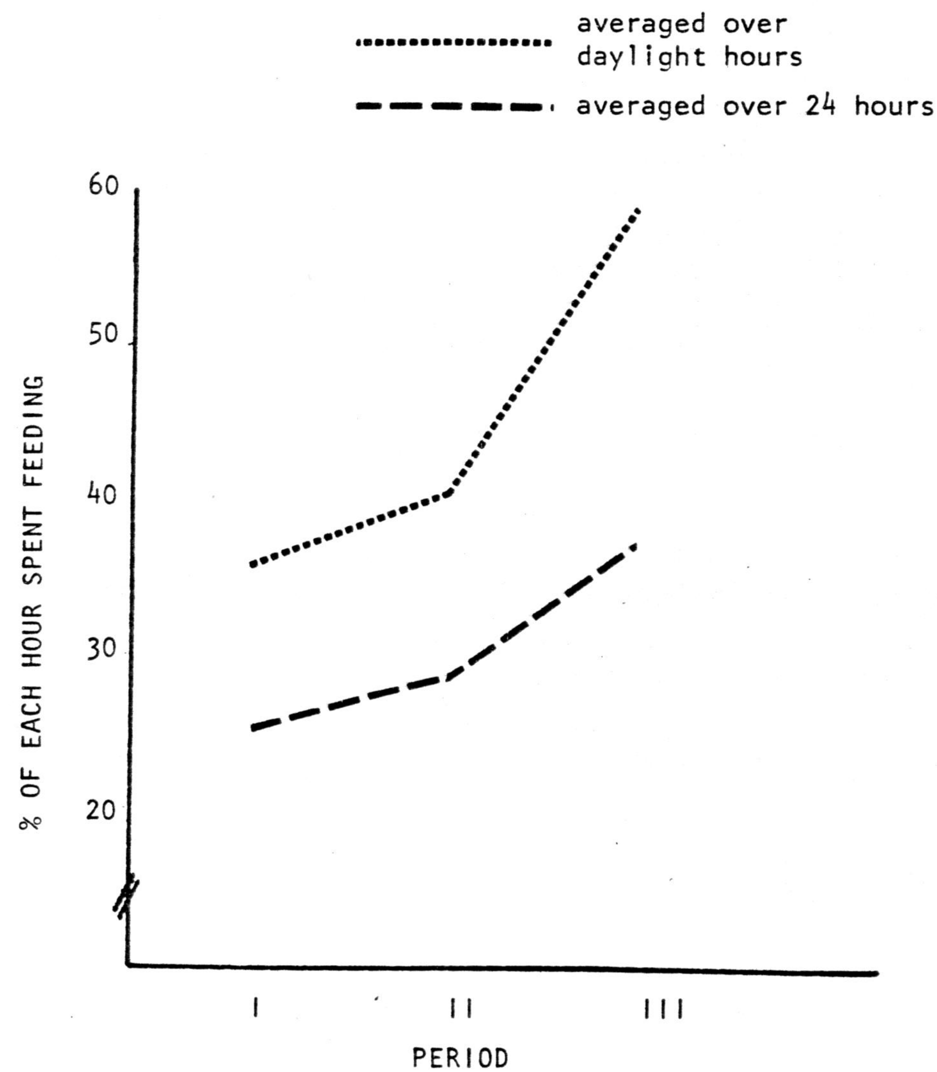


Figure 8. A comparison of the total time spent feeding per day for three periods of the summer.

may magnify the quality differences. As the overall quality of the forage decreases, the goats must spend more time searching to get the highest quality diet. Stated in another way, it is worth the goat's time to look for the higher quality forage and it takes a greater percentage of the goat's time in the late summer when the forage quality is generally poorer than in early summer.

Behavior with respect to the salt lick also proved to be seasonal (Figures 9 and 10). Averaged over a 24 hour day, the goats during the last period were spending only 9 percent as much time at the salt lick as they were during the first period. This indicates that the physiological craving for salt is much stronger during the early period. In spite of the drop in interest, it was still possible to bait goats successfully with salt through August. Hebert and Cowan (1970) give evidence suggesting that the craving for sodium during late spring and early summer is a result of sodium loss through the feces. The fecal material becomes soft when the goats are eating the new, succulent growth and soft feces hinder sodium retention.

Wallowing was recorded as an activity distinct from bedding in a wallow. A goat was recorded as wallowing when it was actively throwing dirt over itself. Wallowing appeared to be most closely tied to temperature, being

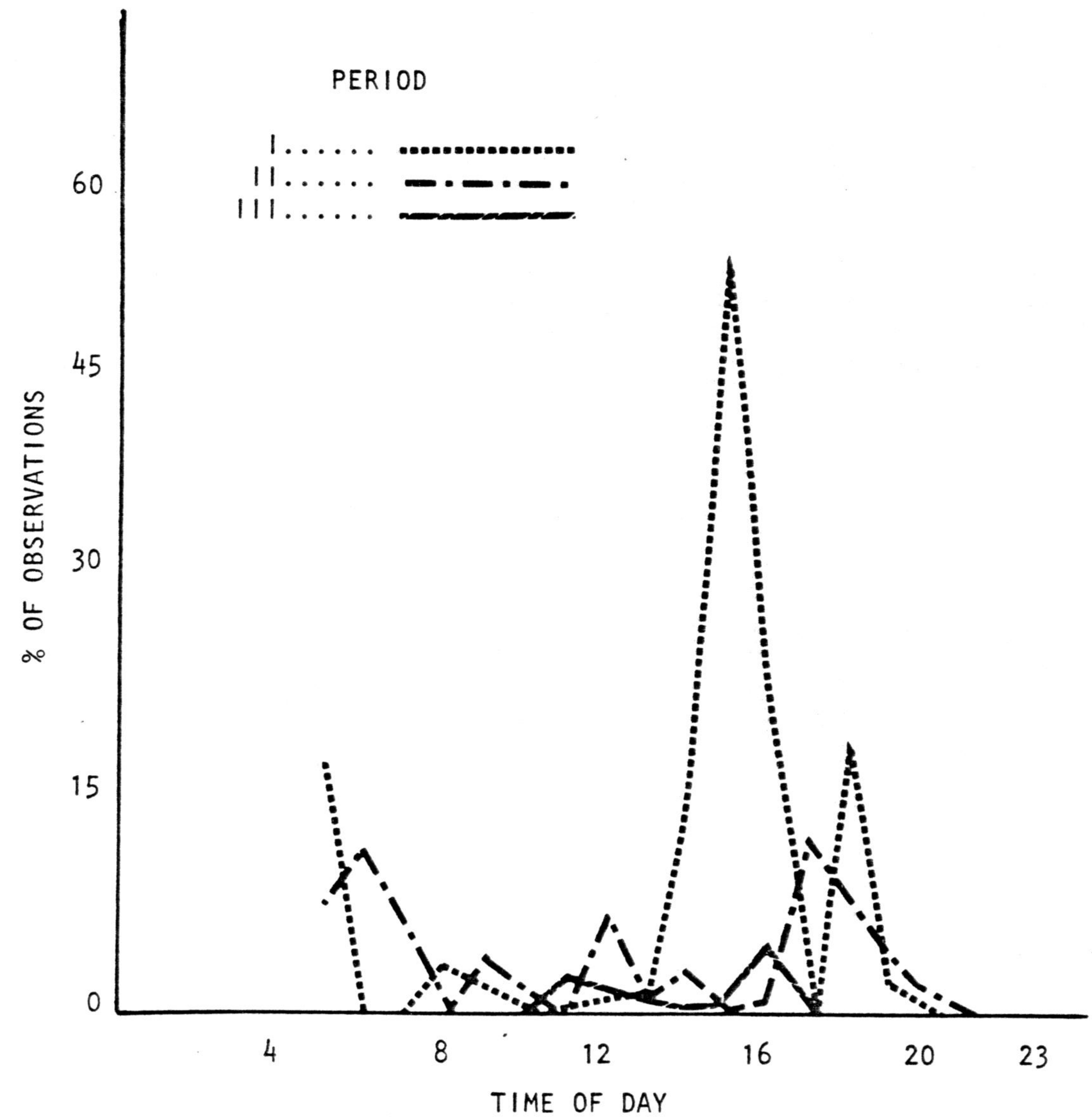


Figure 9. A comparison of the percent of time spent at the salt lick each hour during three periods of the summer.

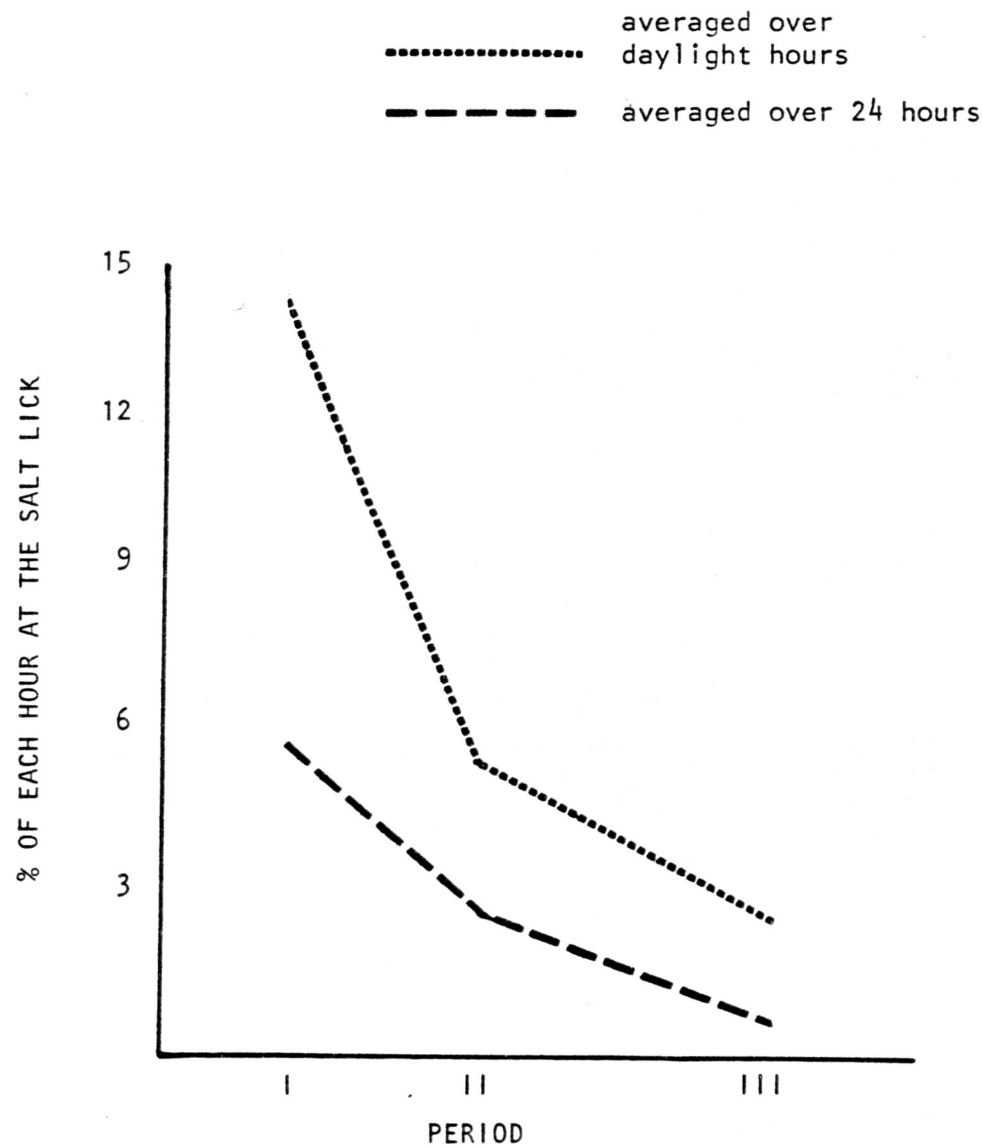


Figure 10. A comparison of the total time spent at the salt lick per day for three periods of the summer.

more prevalent when it was hot. Wallowing as a cooling mechanism has been observed for other large species such as elk and buffalo (Sinclair, 1977), and is particularly effective when the soil is wet. Wallowing goats were often observed to paw through the top soil layers before lying down. As the summer progressed and snowbanks melted, wallows became a much more important cooling source in the hot afternoon. The late summer period, which was wet and relatively cold, had very little wallowing activity (Figure 11).

4.1.2 Activity Pattern by Cohort

Variation in activity pattern during the summer was observed between individuals in different cohorts (Figure 12). For the purposes of this analysis the population was divided into four cohorts: adult females (AF), kids (KI), yearlings (Y), and adult males (AM). Of the four cohorts, kids spent the least time feeding and the most bedding as opposed to yearlings which spent the most feeding and the least bedding. These results can be explained with reference to our knowledge of human behavior. Infants do not require as much food because of their size, but they sleep a good deal more than adults or adolescents. The yearlings, which are still growing, will have a distinct

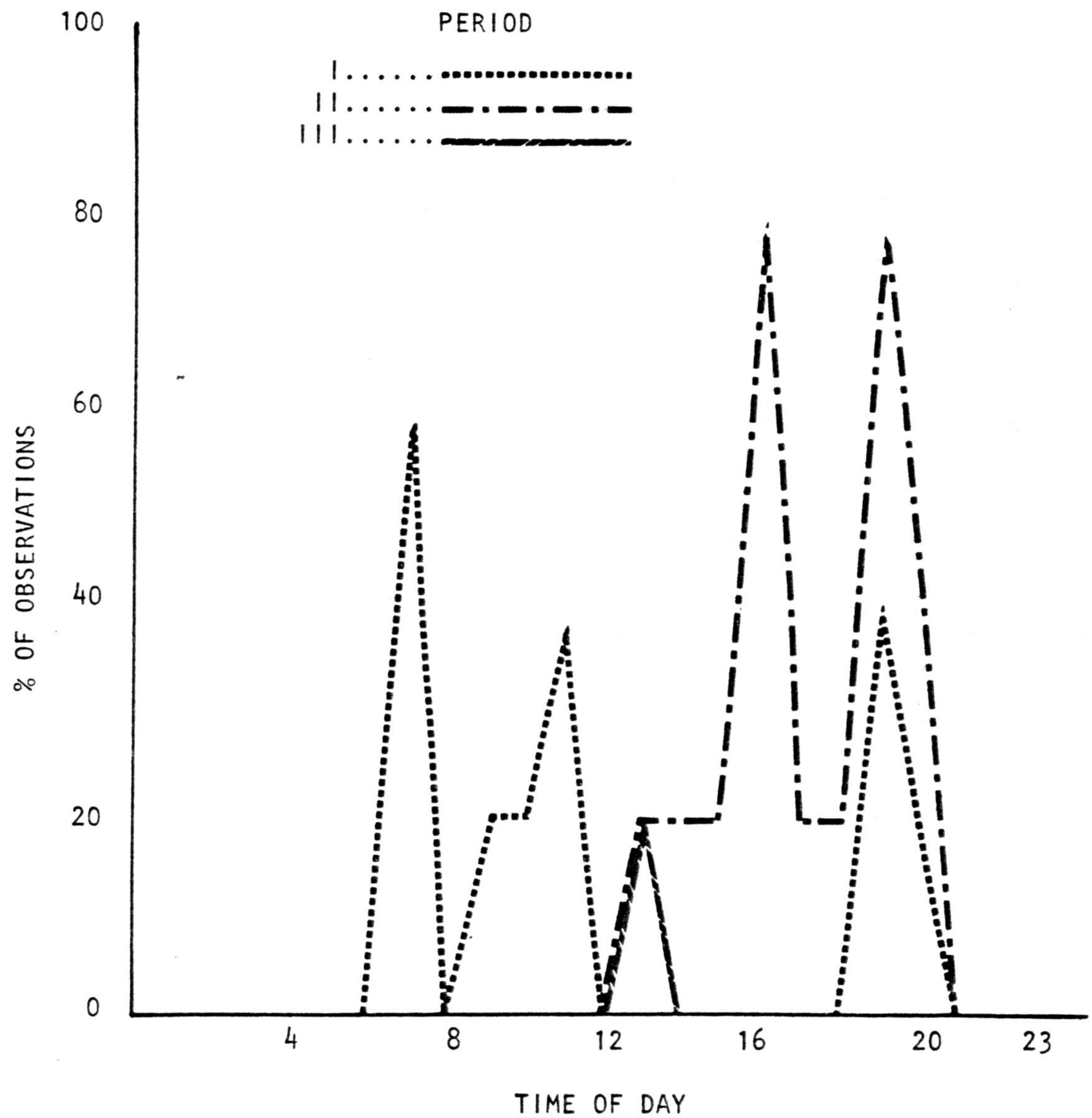
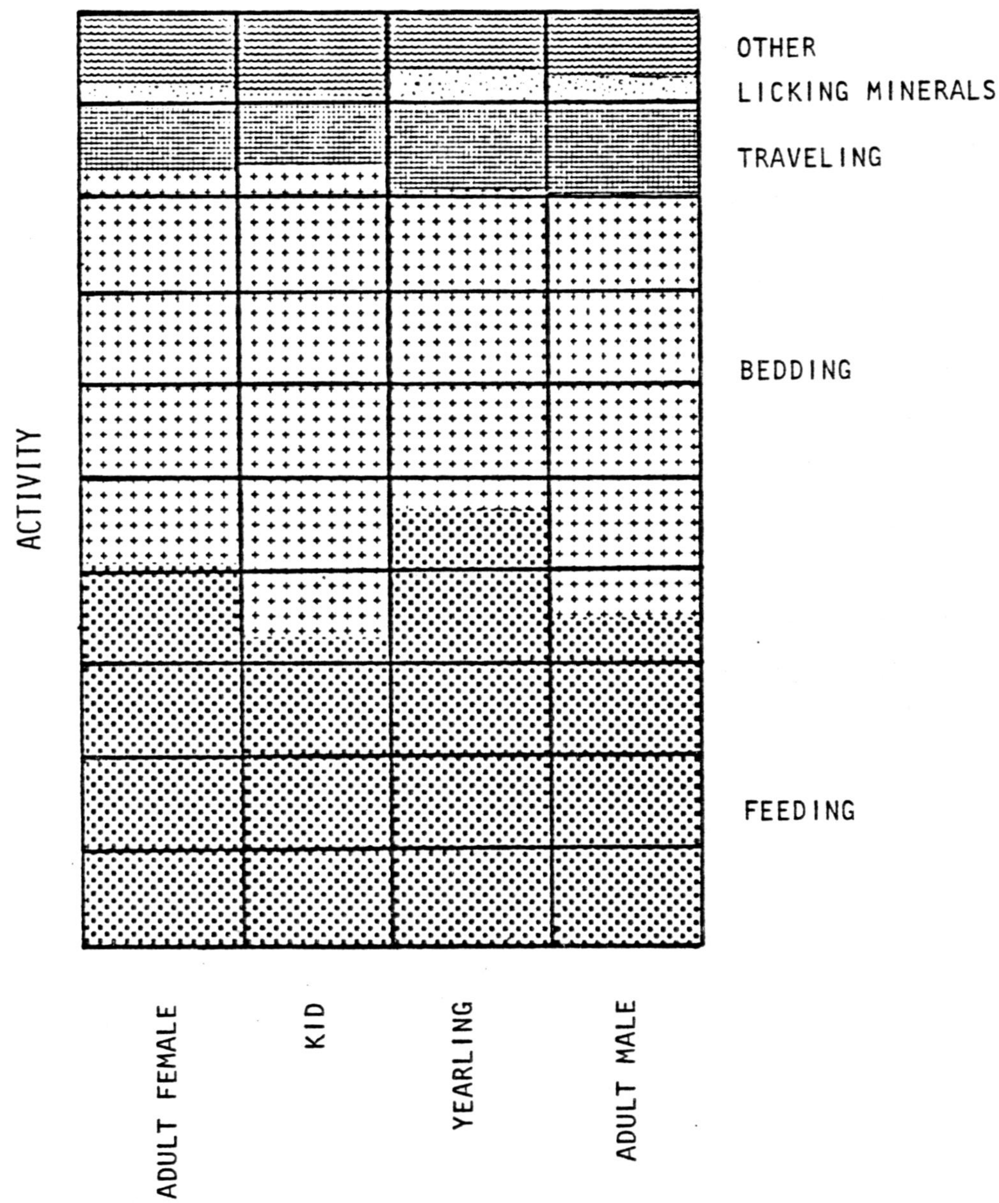


Figure 11. A comparison of the percent of time spent wallowing each hour during three periods of the summer.

Figure 12. A comparison of the percent of total time spent in each activity by four cohorts.



advantage going into their first winter on their own with as favorable a surface/volume ratio as possible; they understandably spend more time foraging than any other group. Adult females spend more time feeding than do adult males, a reflection of the energy costs of care and feeding of offspring.

Hebert (1967) reported that males used the salt licks earlier in the season than females because the females stayed high to have their kids in relative safety. On Klahhane Ridge the percentage of males on the salt early was higher than females as reflected in the ratio of males to females captured between June 12 and June 24 (3:1). After June 24, there was little difference in the use of salt by sex class. Several factors may have contributed to our observations that use of the salt lick did not vary temporally by sex. The lick used by the Klahhane Ridge goat population is on top of the ridge and within one kilometer of many kidding areas,, presenting easy access for females.

Also, although females would be expected to have a greater sodium deficiency due to pregnancy and lactation (Blair-West _et al._ , 1968), the percentage of females affected by those losses would have been small in 1978 because of the low reproductive rate. During the summer the overall use of the salt lick by males and females was approximately equal. However, the females with kids used the lick four times as much as females without kids, as might be expected from the findings of Blair-West _et al._ (1968). However we also found that two year old females frequent the lick four times as much as females with kids. A physiological explanation could not be found, but perhaps the two year olds are subdominant, excluded from the best lick areas, and must spend that much more time in the area to get the sodium they require. This could be tested by observing the ratio of time actually licking to time in the area and comparing adult females of various ages.

4.1.3 Landscape Use By Activity

Landscape use is highly correlated to type of activity. Of the 12 landscape types recorded, three accounted for 87.3 percent of the feeding (open meadow, 55.3 percent; open talus/sliderock, 20.5 percent; open scree with vegetation, 11.5 percent) (Figure 13) and four types accounted for 82.9 percent of the bedding (rocky bluffs, 25.0 percent; snow 23.9 percent; bare ground, 20.5 percent; open meadow 13.5 percent) (Figure 14). Since these two activities account for 82 percent of a goat's

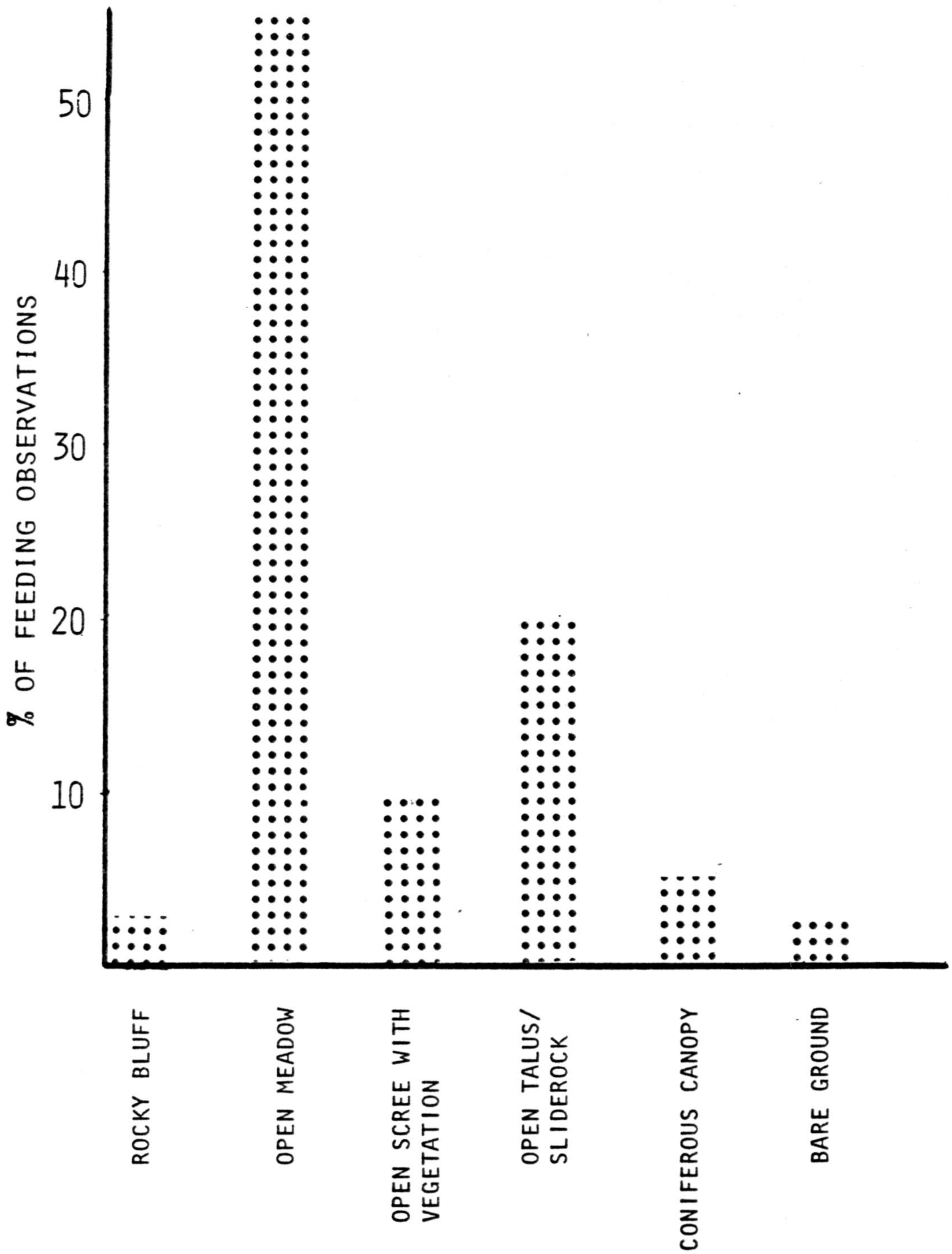


Figure 13. The percent of feeding time in each landscape type.

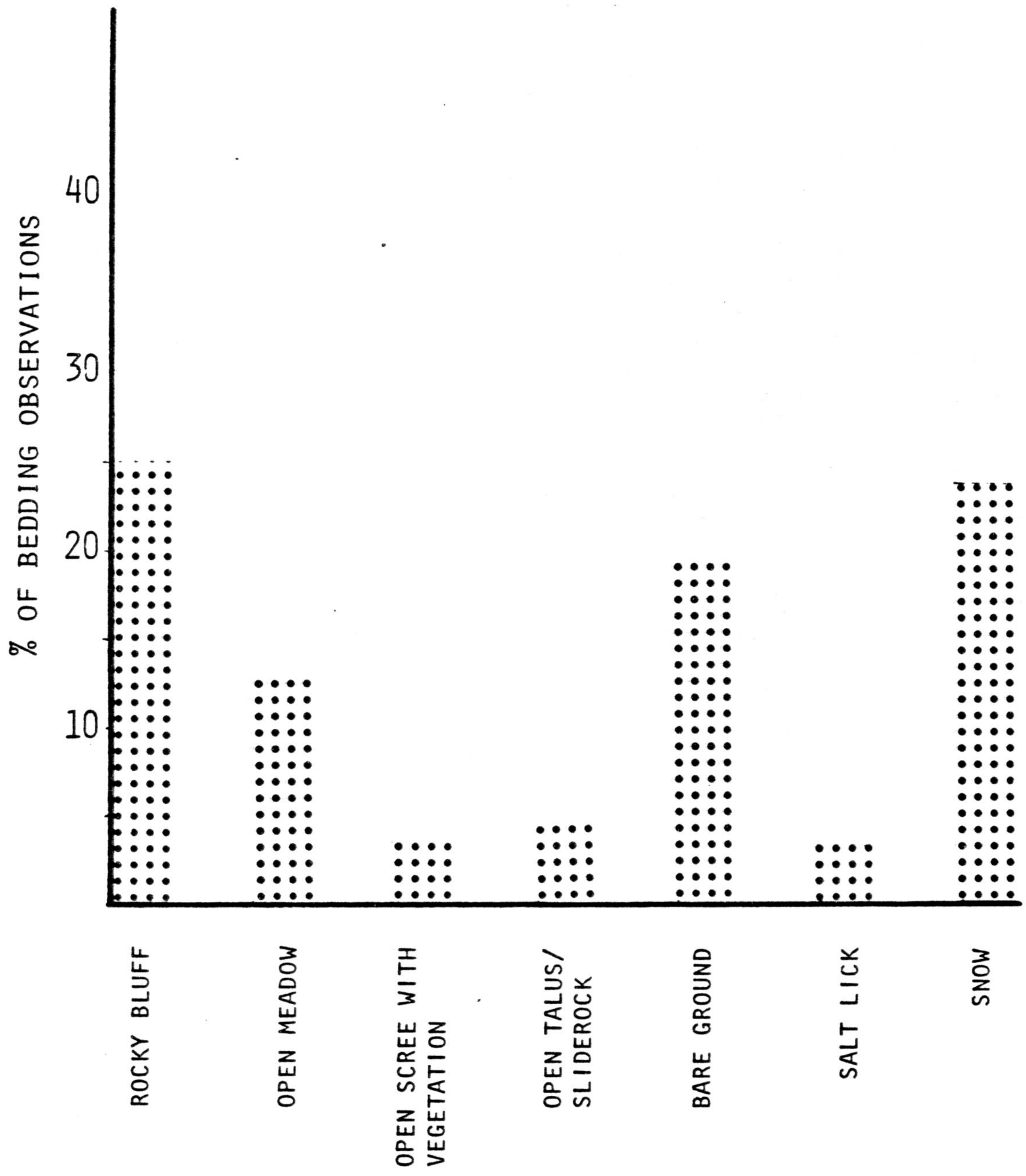


Figure 14. The percent of bedding time in each landscape type.

summer routine, these six landscape types are tentatively considered the most important to summer habitat.

That open meadows are most important as summer feeding areas is not surprising. Of the alpine and subalpine landscape types, the meadows have the highest percent cover of grasses and forbs. According to Pike (pers. comm.) the open meadows have approximately 60 percent cover as compared to 20 percent for the next most important type, open talus/sliderock, or three times as much cover. Available plant production per unit area, then, is greatest in the open meadow type.

A favored bedding type was less obvious. Rocky bluffs are favored for their escape value; snow and bare ground are used primarily during the day for their thermoregulatory value; and the open meadows are used when resting between feeding bouts (Figure 15).

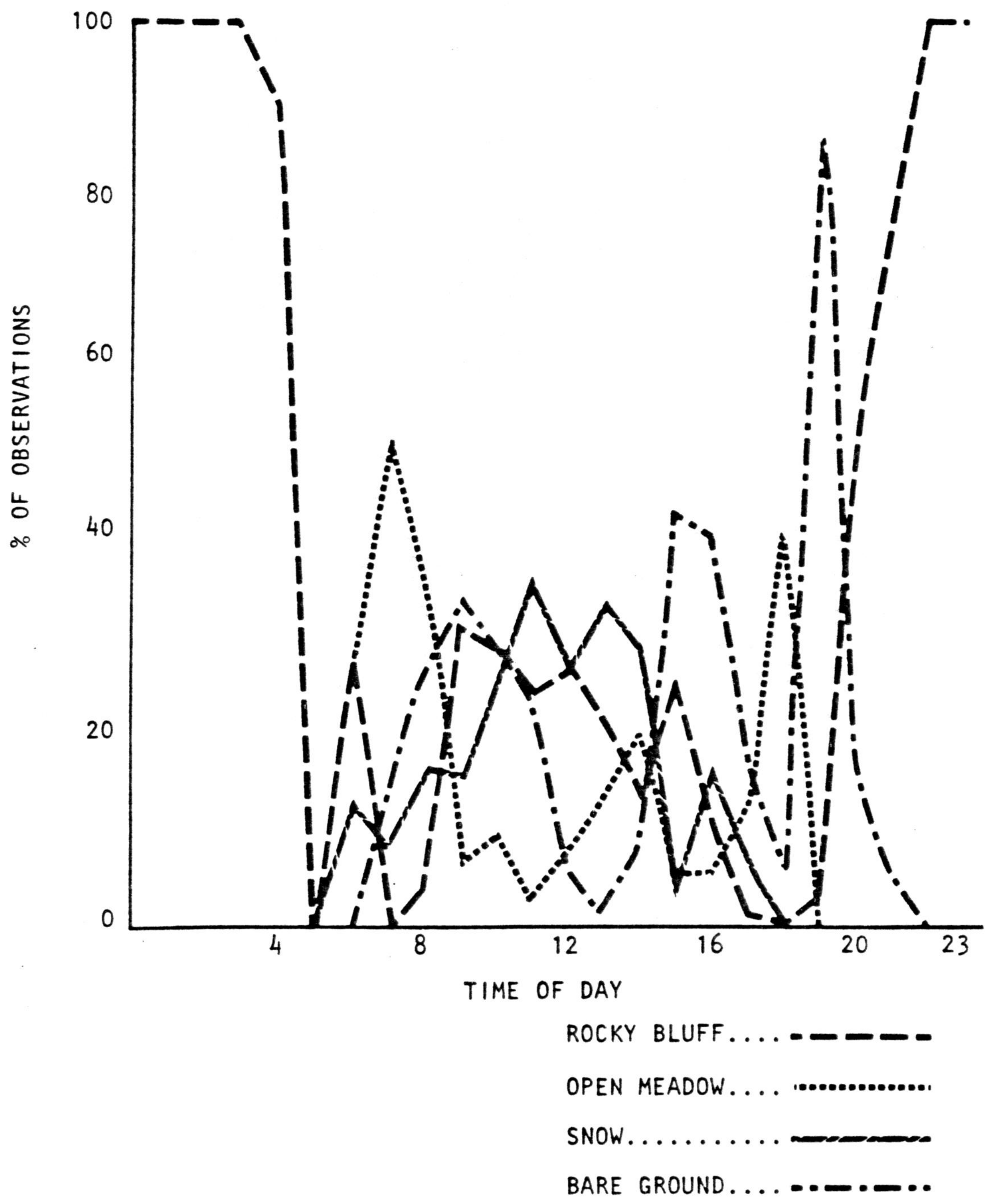


Figure 15. A comparison of the percent of time spent bedding in each landscape type by hour.

4.1.4 Landscape Use By Cohort

Figure 16 shows differential use of the habitat by cohort. The relative importance of each landscape type is about the same for each cohort with some predictable exceptions. The adult females with kids or yearlings spent a significantly greater amount of time on rocky bluff (escape) habitat compared to those without accompanying offspring (Figure 17). The adult males, which have a smaller surface to volume ratio and therefore presumably tend to overheat more readily, spent over 30 percent of their time on snow or bare ground as compared to yearlings, which spent closer to 20 percent of their time on those landscape types.

The importance of each landscape type to the population as a whole can be seen in figure 16.

1. Open meadows are the most heavily used because of their importance to feeding.

2. Rocky bluffs are second with a high escape value.

3. Slide rock is second only to meadows as a feeding type.

Figure 16. Differential use of the landscape types by four cohorts.

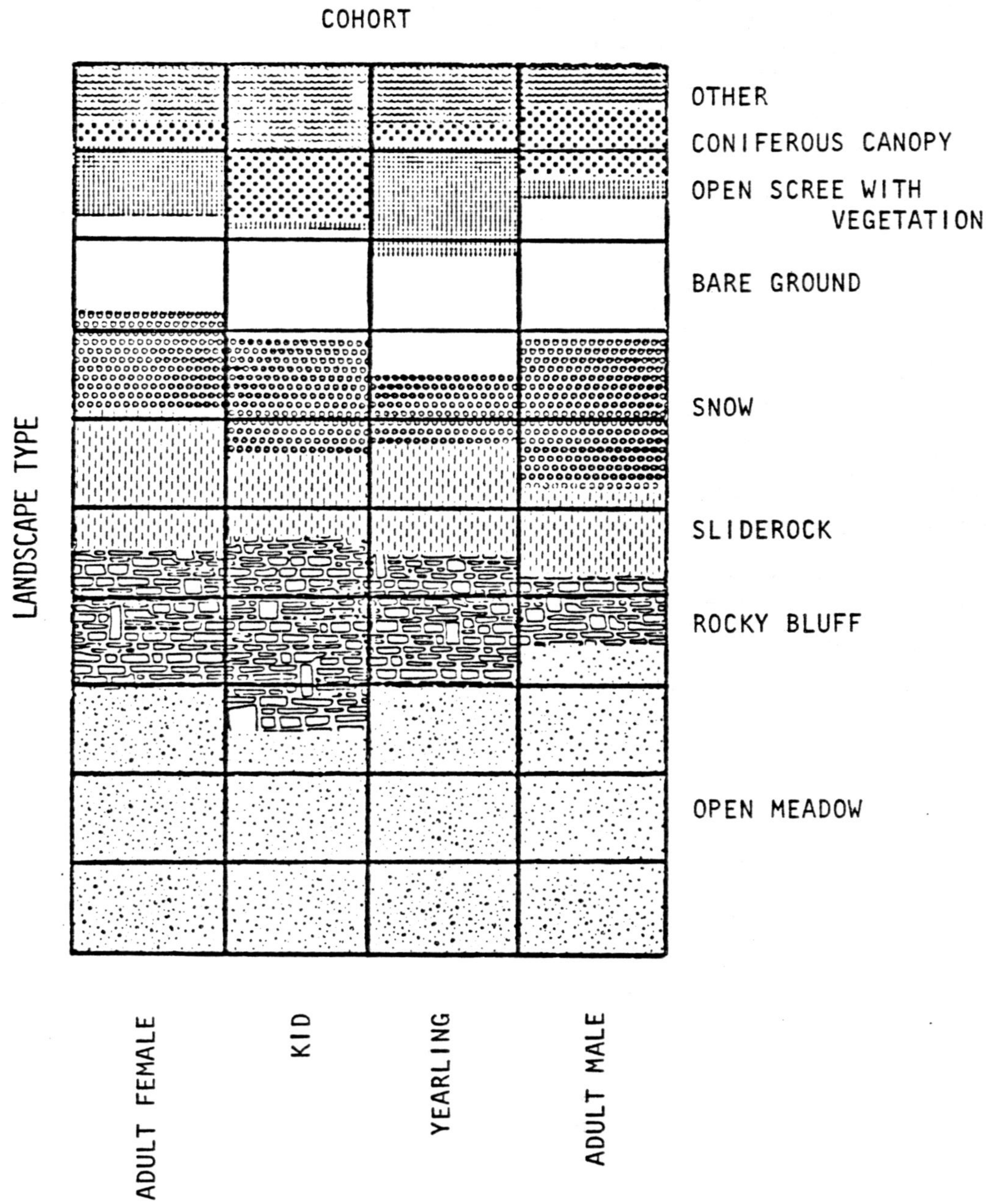
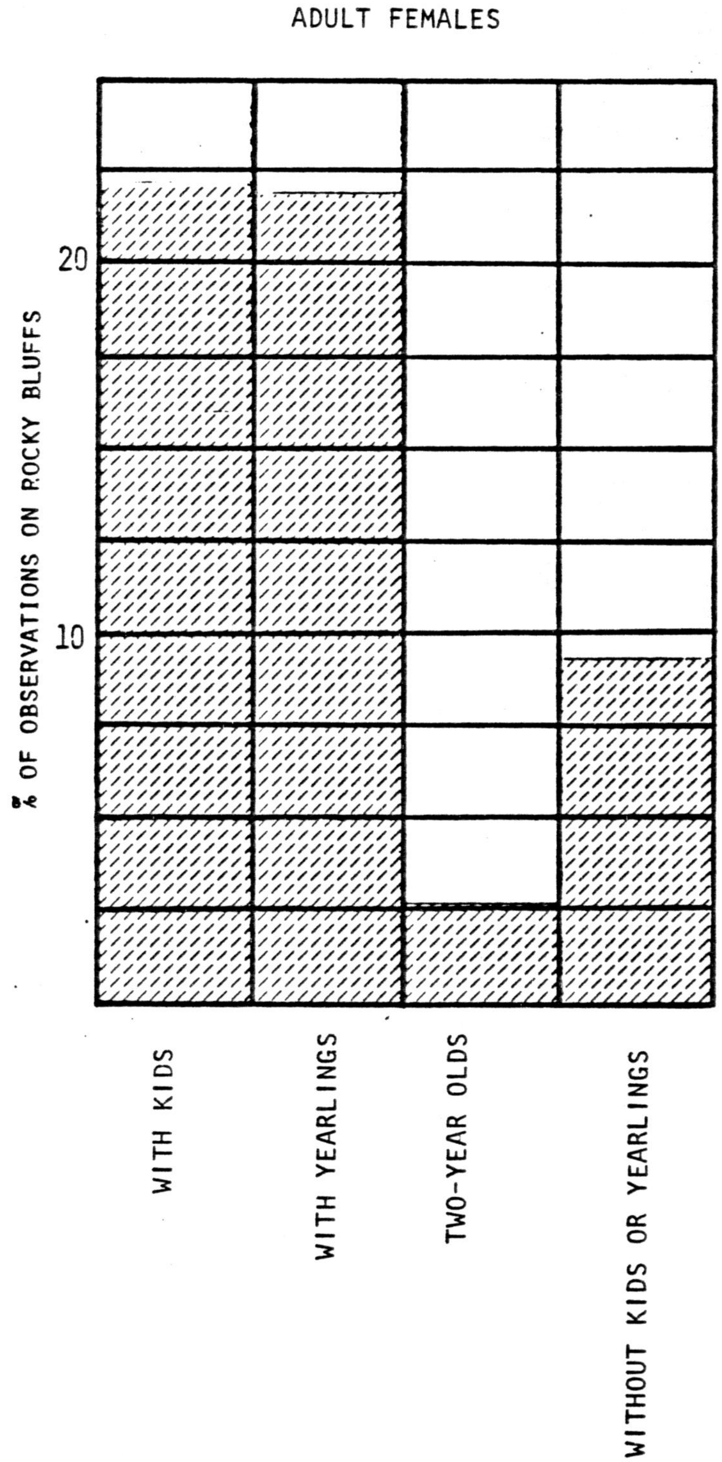


Figure 17. The difference in rocky bluff use by adult females with and without kids or yearlings.



4. Snow is used heavily for thermoregulatory purposes.

5. Bare ground is used for wallowing which during the summer season is primarily for thermoregulation.

6. Open scree with vegetation is third in importance for feeding.

7. Coniferous canopy is used almost exclusively during the hottest part of the summer as an escape from solar radiation. Feeding is the most important activity in this type (56.7 percent) followed by bedding (15.5 percent). The ground cover in this landscape type is heavily used as forage during the hot, dry part of the summer. At this time the grass and forbs here are more lush (succulent) than those in the open meadows on the south side of the ridge since they are later to melt out of the winter's snow.

The other five landscape types were used only 6.4 percent of the time with the salt lick accounting for more than half (3.3 percent).

4.1.5 Landscape Use with Respect to Geomorphology

4.1.5.1 Elevation

The elevation of the alpine and subalpine communities on Klahhane Ridge varies from about 5000 ft. (1524 m) to 6500 ft. (1981 m). Within those constraints, most observations were in the 6000 ft. (1829 m) class (72 percent) followed by the 5500 ft. (1676 m) class (17.5 percent) and then the 6500 ft. (1981 m) class (10.4 percent). The 6000 ft. class was the most important to every activity. The most common activity in the lower elevation class was feeding (54.4%) and in the upper elevation class it was bedding (49.4%). There was no significant correlation between temperature and elevation.

4.1.5.2 Slope

Relative use of slope classes is shown in Figure 18. The predominance of mid - low slopes is partially a result of the large amount of time spent feeding on the meadows and talus/sliderock on the south (more gentle) slope of the ridge and partially an artifact of our data collection. The steep habitat is generally used for traveling and bedding, and both activities are more easily

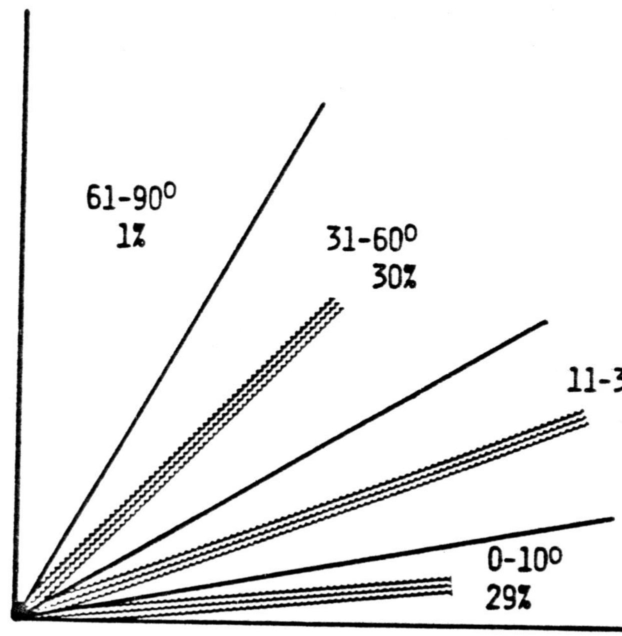


Figure 18. The percent of total time spent in each slope class.

accomplished on ledges. Our slope data reflect the immediate rather than the overall slope of the goat's position. The immediate slope tends to be lower angle than the overall slope when the goats are on cliffs and bluffs. Because of this tendency characteristics of goat habitat would have been better described by using an overall slope.

4.1.5.3 Aspect

Figure 19 is an overview of all the aspects used during the summer without regard to activity or temperature. The most commonly used aspects are north and south. This may be an artifact of the east-west orientation of Klahhane Ridge or it may be that the abundance of north and south aspects on Klahhane Ridge constitutes a factor contributing to its successful goat population. It is important to make this distinction since defining potential habitat is a major goal of this project.

To explore this question and to see which aspects received the greatest impact we examined aspect use by different activities. Figure 20 compares feeding and bedding. The largest percentage of feeding occurs on

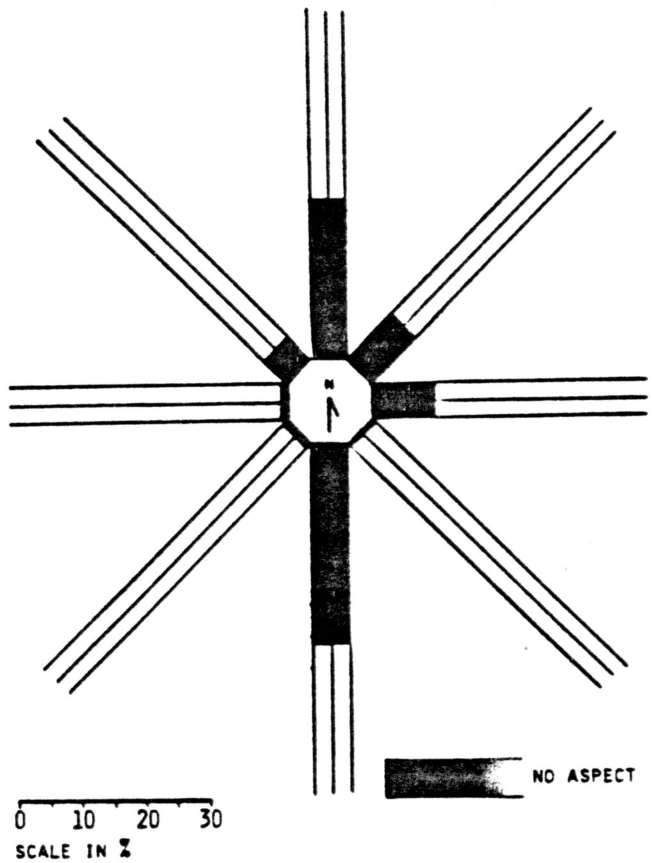
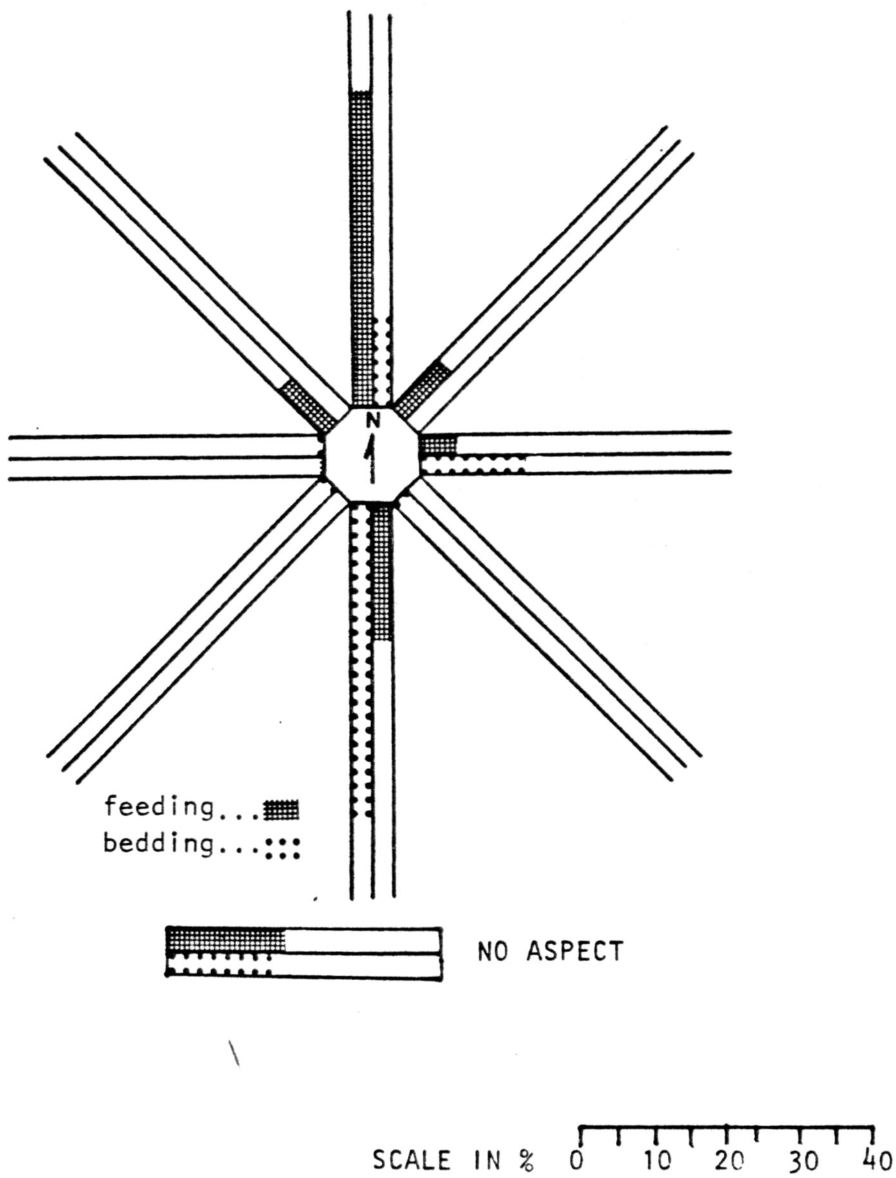


Figure 19. The percent of total time spent in each of eight aspects.

Figure 20. The percent of feeding and bedding observations on each of eight aspects.

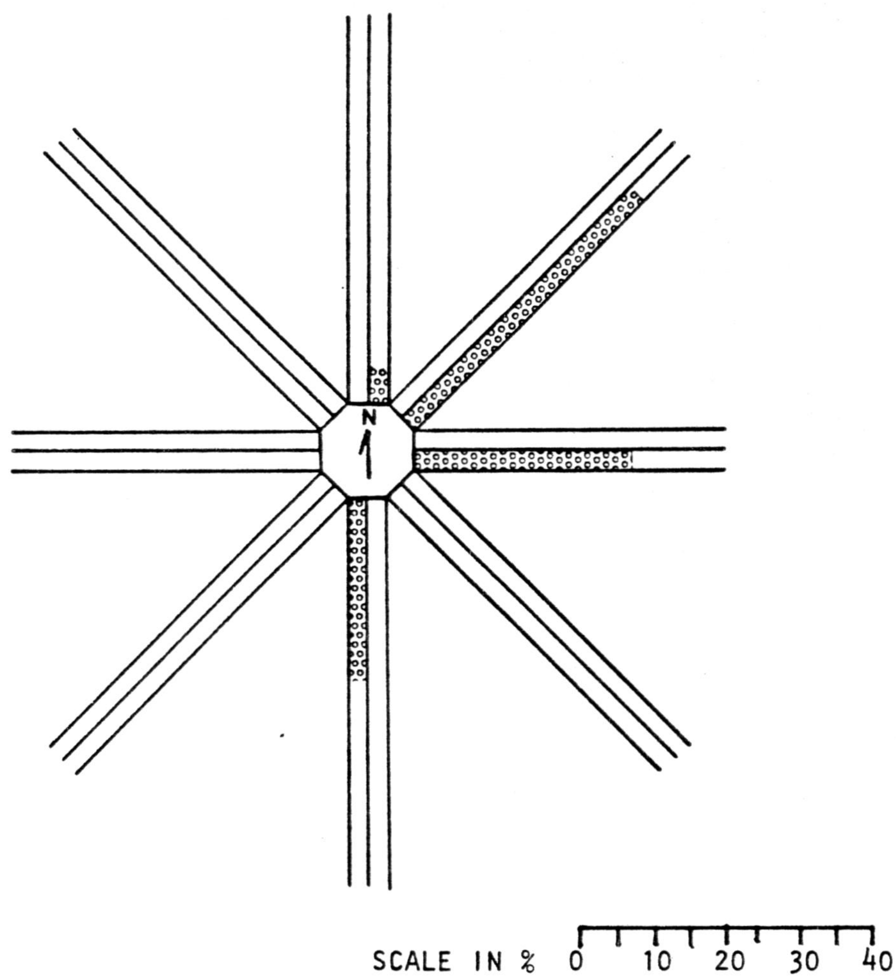


south exposures. This is a direct correlation with the fact that the open meadow and open talus/sliderock which are the most preferred feeding areas are predominately on southern exposures. This in turn may be tied to the tendency for feeding to occur in the early morning and the evening which are times of minimal solar radiation. McFetridge (1977) also found south exposures to be most important to feeding activities, but without a temporal variable he concluded that southern exposures were preferred because of increased solar radiation rather than noting that those times were actually avoided.

The preferred aspect for diurnal bedding was north. All of the late snow fields, coniferous cover and ridge shade occurred on north aspects. These areas are all important to the goats as bedding sites during the day when implementing heat loss appears to be a major consideration. Rocky bluffs which account for most of the remaining bedding sites, are found on a number of aspects.

Wallowing was restricted to areas of bare soil. The aspects preferred for wallowing reflect the distribution of specific wallows (Figure 21). During the late summer when the snow was melted the goats spent much of their time on the north side of the ridge in an open coniferous forest. This was the location of a large and popular

Figure 21. The percent of wallowing observations on each of eight aspects.



wallow with a northwest exposure which accounts for the exceptionally large percentage of observations on that aspect.

Aspect was a major consideration in behavioral temperature control. Figure 22 compares the coldest temperature class (0 - 5 degrees C.) at which observations were recorded to the warmest (18 - 22 degrees C.). At cold temperatures 66 percent of the observations were on southern aspects where solar radiation is greatest. At the highest temperatures 80 percent of the observations were on northerly (NW, N, NE) aspects. At the two intermediate temperature classes there is still a strong preference for southern exposures during colder temperatures and northern exposures during warmer temperatures. The critical temperatures are approximately 11 - 13 degrees C., when 24.62 percent of the observations were on north aspects and 29.83 percent were on south aspects. Above 13 degrees C. the obvious preference is for northern exposures, and below 11 degrees C. the southern exposures are preferred.

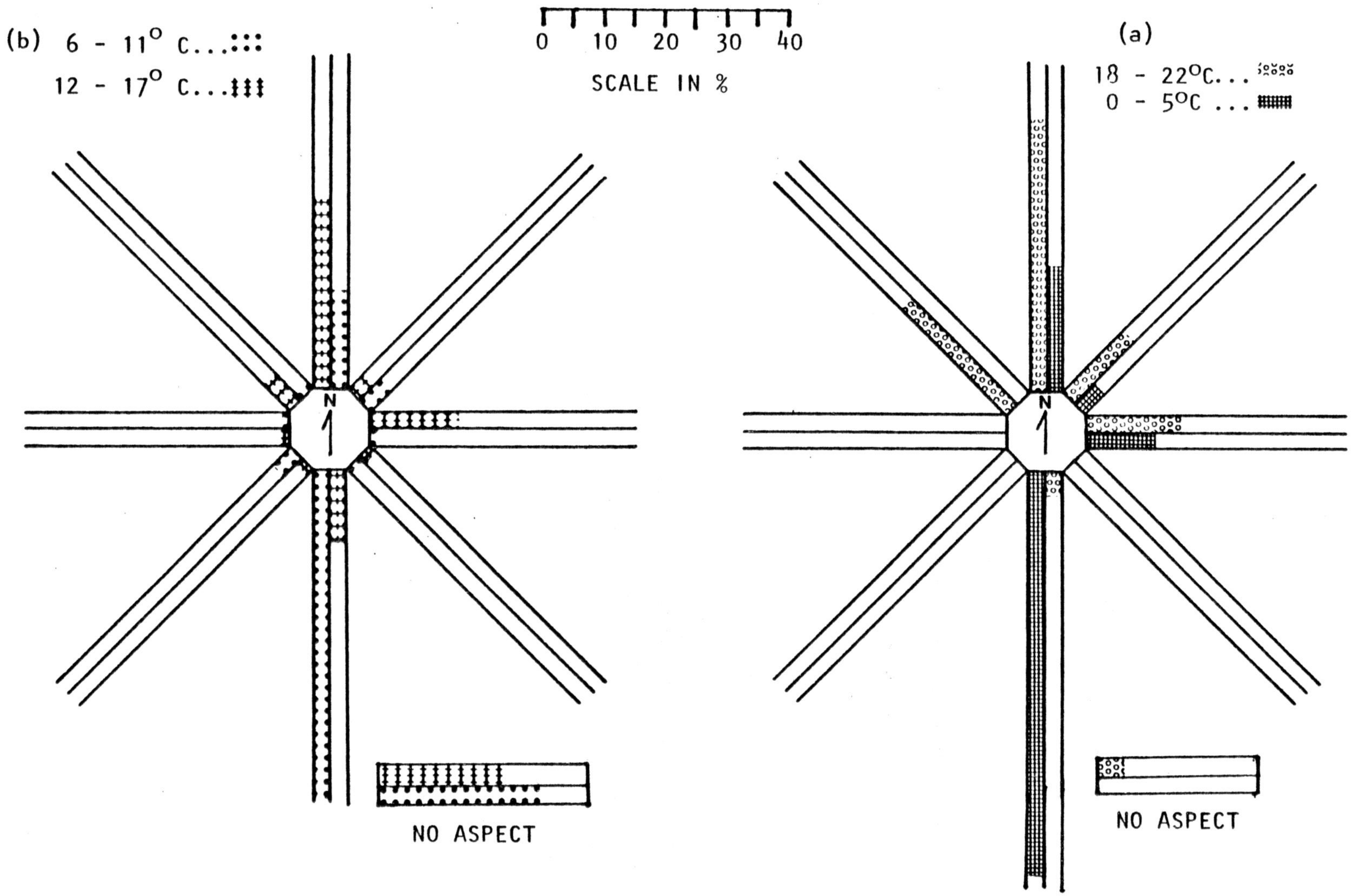


Figure 22. A comparison of aspect use by temperatures: (a) the extremes, and (b) intermediate ranges.

4.1.6 Effects of Climate on Landscape Use

4.1.6.1 Precipitation

Conditions for data collection were most comfortable when there was no precipitation, a fact which is boldly reflected in the data set. Ninety-one percent of the observations were made under those conditions. Three hundred and sixty-seven observations were made in light rain. This level percent of precipitation prompted some selection for cover by the goats. Eighty-one of the observations in light rain were in open landscape types (open meadow rocky bluffs,, open scree with vegetation, open talus/sliderock, bare ground) while 18.8 percent were in landscape types that reflect a possible attempt to seek shelter from the rain (krummholz, coniferous canopy), (Figure 23). With no rain (5112 observations) 95.7 percent are in open areas and 4.3 were in open areas and 65.3 percent were under cover. It seems clear that goats avoid getting wet if they can. The thick pelage of the goat, an excellent insulator when dry, is not as effective when wet.

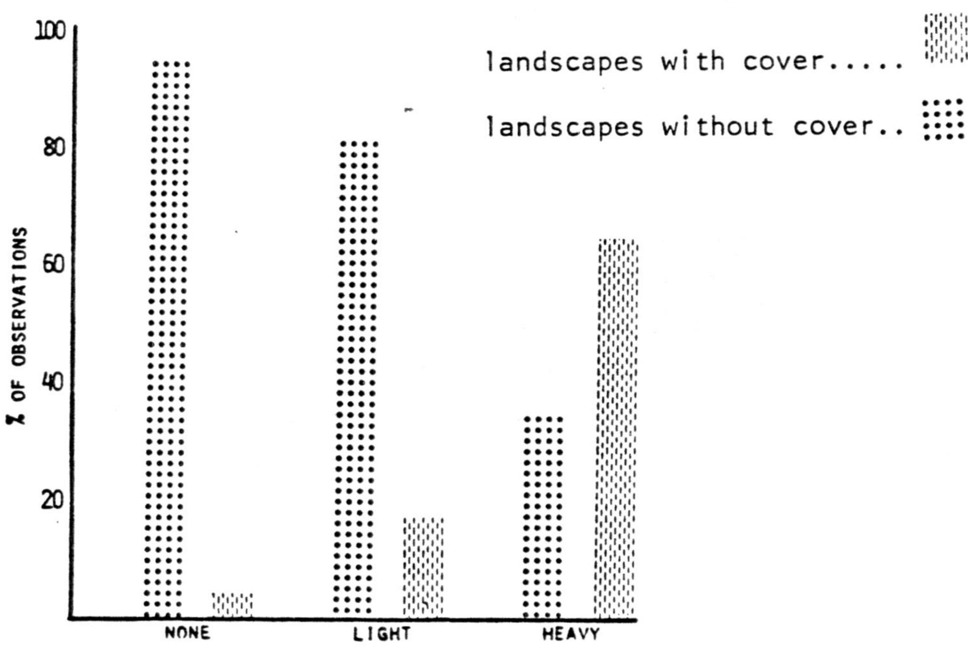


Figure 23. The effects of precipitation on habitat choice.

4.1.6.2 Cloud Cover

The amount of solar radiation incident on an animal has been shown to have a strong influence on the habitat choices it makes throughout a year or a day (Bakken and Gates, 1975; Belovsky, 1977). Cloud cover is effective means in cutting out the shortwave radiation from direct sunlight. This appears to have a significant influence on the amount of time the goats spend feeding, an activity that occurs primarily in open habitat and on southern exposures where solar radiation is potentially more intense.

At noon, when the overall data showed a low in feeding activity, the percent of feeding observations increase with the amount of cloud cover, i.e. with the decrease in direct solar radiation (Figure 24).

4.1.6.3 Wind

Convection is another important factor in thermoregulation, most critical as a consideration in heat loss when there is a large difference between body temperature and air temperature. In the summer season this is rarely a problem. We found no strong correlations

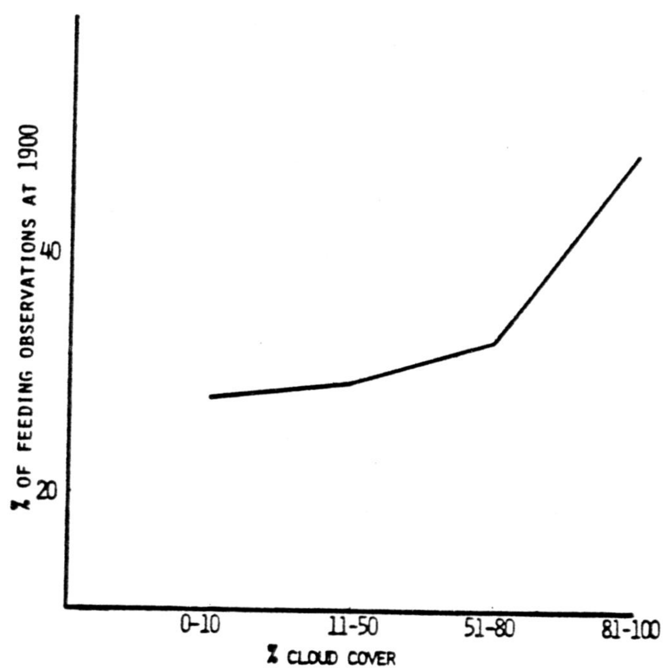


Figure 24. The effects of cloud cover on feeding activity at 1900 hours.

between landscape choices and wind in our summer observations. However,the data were skewed towards mild conditions. Eighty-one percent of the observations were in zero - light wind, 16.5 percent in moderate wind and 0.4 percent in strong wind.

4.2 Goat Density

The relative density of goats estimated for each cell sampled is shown in Figure 25 only area with cells of the densest category was Klahhane Ridge. Both Klahhane Ridge and the Lake Constance area had cells in the moderately dense category. The overall density (d) for each area is shown in Table 5. The areas are listed in order from the

Table 5. Density ratings of six study areas in Olympic National Park.

AREA	TOTAL NO. OF CELLS	NO. OF CELLS RATED: 0	1	2	3	4	TOTAL DENSITY RATING
Klahhane Ridge	27	2	5	9	6	5	2.26
Grand Valley	21	5	9	7	0	0	1.10
Grey Wolf Ridge	19	9	3	7	0	0	0.89
Mt. Constance	27	3	7	13	4	0	1.67
LaCross - Marmot	13	0	7	6	0	0	1.46
Sawtooth Ridge	6	1	0	5	0	0	1.67

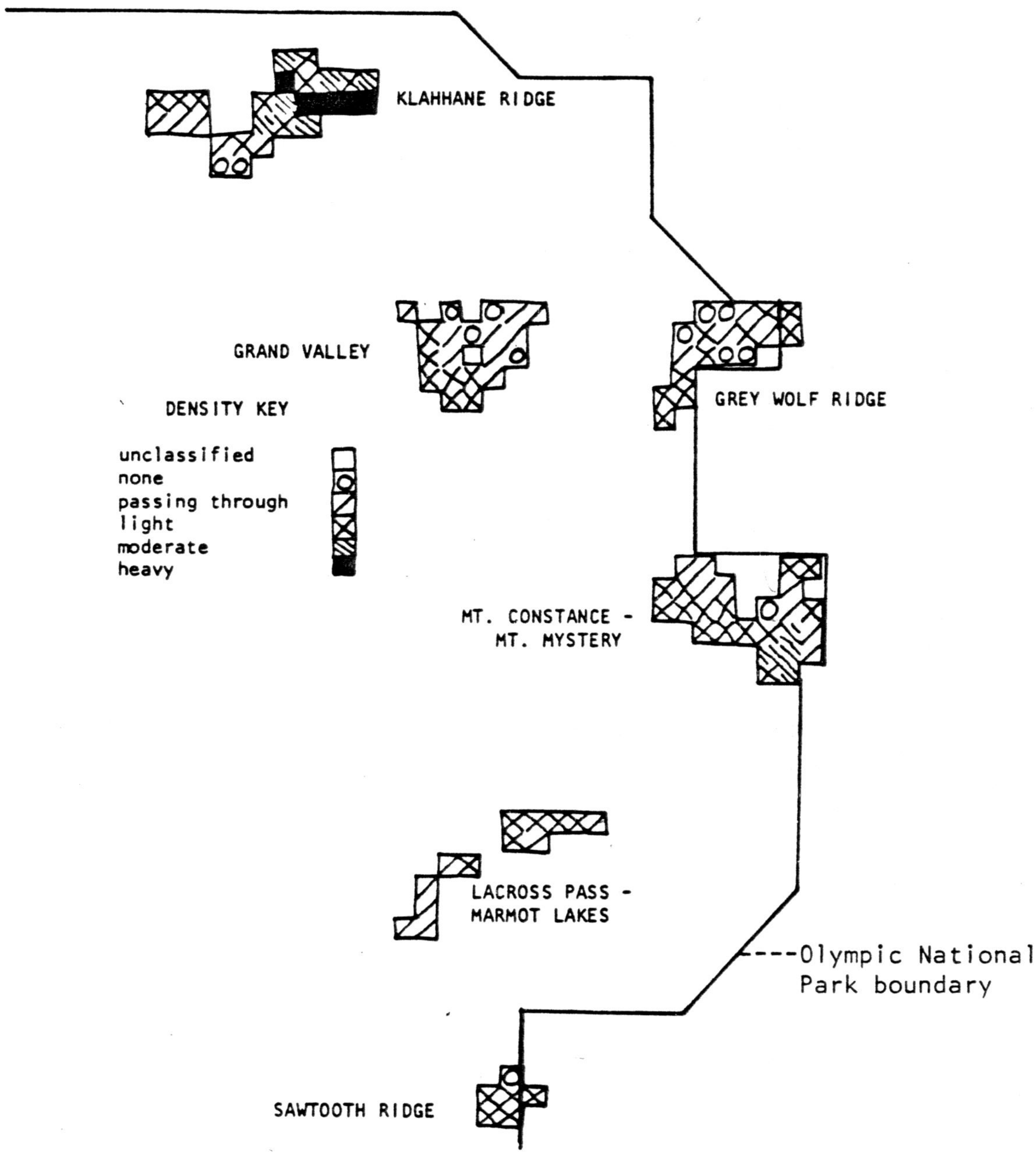


Figure 25. A characterization of goat density by cells throughout the park. The drawing is to scale with each cell representing one square kilometer.

nearest to the farthest from the point of introduction, Lake Crescent.

4.3 Potential Goat Habitat

Employment of remote sensing techniques to locate potential goat habitat produced only fair results. Overall, the satellite was able to distinguish between dense coniferous (north slopes), open coniferous (south slopes), and open areas. Generally open areas in the Olympics are high ridges above tree line, but the satellite imagery also classified roadcuts and parts of residential areas as open. An attempt was made to distinguish between rocky and meadow openings through image interpretation with minor success. Figure 26 is an example of the final classification on Klahhane Ridge . O, K, and T are open classifications. O was trained on meadow, K on the mixed bluff, scree and bare ground common on the south side of Klahhane Ridge, and T was on bare rock. B is a deciduous brush category. It is found in avalanche chutes and riparian areas. 9, 6 and 1 are open coniferous classifications. From comparison with aerial photographs, it appears that 6 is the most open followed by 1 and then 9. The asterisk (*) was trained on snow and the (.) on standing water. Apparently the dense

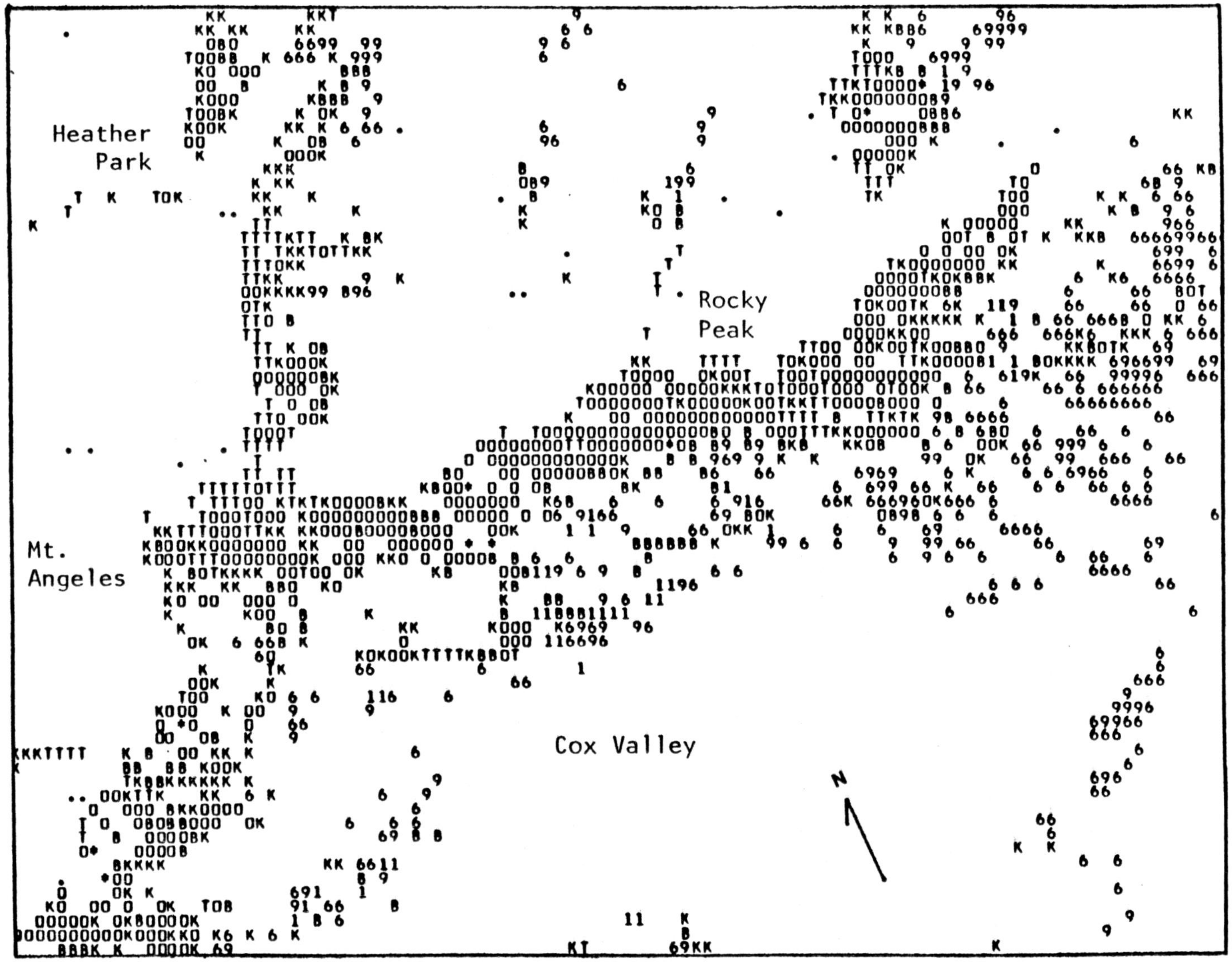


Figure 26. A Landsat classification of Klahhane Ridge.

coniferous and the standing water have a similar reflectance since the satellite imagery shows .'s to be scattered throughout the coniferous areas of the park. Small lakes were not recognizable but lakes the size of Mills, Sutherland or Cushman are quite obvious and good reference points.

It was not immediately apparent from the final classification what combination of letters and numbers pointed to goat habitat or how preference could be perceived. The most obvious distinction between the study areas, all goat inhabited, and uninhabited areas, was a lack of ridge tops (O's, T's and K's) in the uninhabited areas. This could more easily have been detected from simple observation of a topographical map. All six areas contained O's, T's, K's and *'s representing meadows, rock, bluffs and snow. A closer look at the differences between Klahhane Ridge and more sparsely populated areas indicated a possible relationship between preferred habitat, the continuity of the O's, T's and K's, and the east - west orientation of the ridge. Figure 27 shows a portion of the Lake Constance area for comparison with Klahhane Ridge. Our present interpretation of these facts is that the use of satellite imagery does not provide a useful tool in goat habitat analysis under our conditions. The identification of potential goat habitat, into which

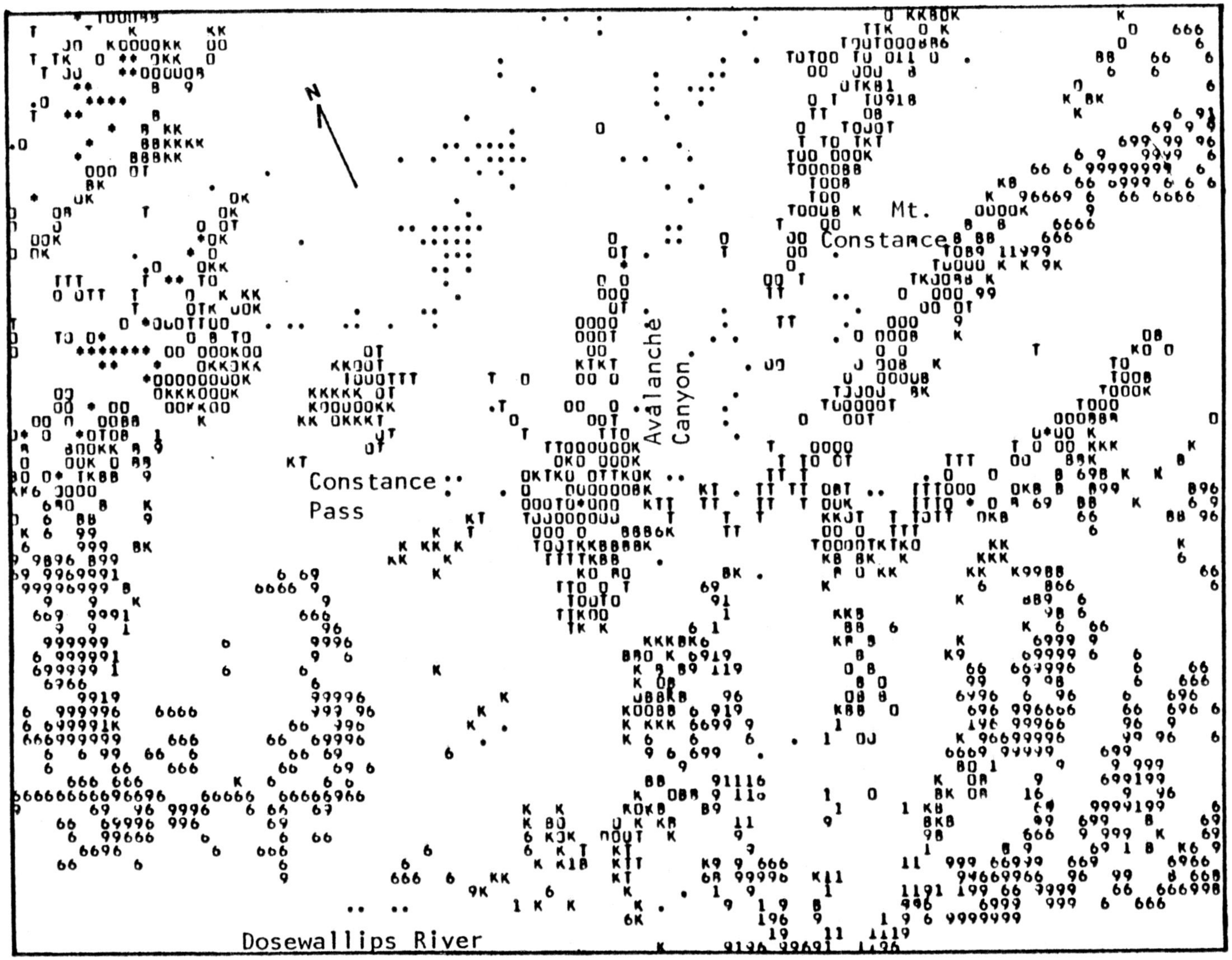


Figure 27. A Landsat classification of the Mt. Constance area.

goats might be expected to disperse in the future, remains only marginally adequate: --no habitat as good as Klahhane Ridge appears to exist in the rest of the park, but the existence of unoccupied habitat of lower quality is as yet undetermined.

CHAPTER 5

Discussion

5.1 Habitat Utilization

The components of good summer goat habitat can be determined from the above information. The most important areas appear to be 1. feeding areas (grasses and forbs preferred), 2. escape cover (rocky bluffs) and 3. an array of options for behavioral temperature control which in a summer setting for a heavily furred animal generally means areas which promote heat loss. Salt is obviously desirable, but it must be possible for populations to flourish without sodium supplements. It was not until 1972 that salt was offered by the Park Service, and urine as a source did not become common until the Hurricane

Ridge Road was built in 1957, 24 years after the first goat was recorded on Klahhane Ridge. At the same time, the direct effects of sodium availability to the population growth on Klahhane Ridge are not known.

The first requirement, forage, is best filled by meadows of predominantly grass and forb cover. Other areas with grasses and forbs can be used for feeding, but probably will not support as dense a population as we observed on Klahhane Ridge. It is not surprising that the habitat most closely associated with goats is steep rocky cliffs and bluffs. This appears to be an important, perhaps essential common denominator wherever goat populations thrive. It is used by all cohorts for bedding and by adult females for kidding. It is generally accepted that goat preference for steep places is a genetic adaptation for predator avoidance. In the Olympics predation is not thought to be an important factor in mortality, partially as a result of the lack of predators, but no doubt also resulting from the goats's affinity for steep rocky habitat. The peninsula does support populations of cougar (*Felis concolor*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), black bear (*Ursus americanus*), and golden eagles (*Aquila chrysaetos*), all of which are capable of taking at least small goats.

Regulating constant body temperatures in an environment that fluctuates between -22 degrees C. and 32 degrees C. (-8 degrees F. and 90 degrees F.) requires physiological and behavioral adaptations. An important physiological change between summer and winter is the loss of the heavy winter coat. But overheating is still a real possibility during summer months. Permanent or semi-permanent snow banks may play an important role in determining potential goat distribution. On ridges, where goats are commonly found because of their preference for rocky areas and alpine meadows, snow is usually the only source of water and an important bedding site. Other habitat considerations for thermoregulation are northern (shady) exposures, sites of good soil development for wallows, and areas with a late water supply. If snow banks are extensive and permanent, they provide a late water source. A canopy is useful for cutting out solar radiation but seems to be adequately compensated for by snowbanks when they are available.

The last consideration is the proximity of each of these attributes to the others. The smallest distance between them is the most desirable from the energy conservation viewpoint. On Klahhane Ridge, which best approximates the ideal if density can be used as an indicator, all of these factors can be found in almost any square kilometer.

5.2 Goat Density

Two factors may contribute to the variations in the densities throughout the park. The first is the quality of the habitat from a goat's perspective and the second is the distance of any area from the point of introduction, i.e. the amount of time elapsed between the first established breeding population and the present. If density were time related, the farthest population would be expected to be the least dense. The data refute this hypothesis by showing that the least dense area is near the northern end of the park and is presumably an older population than that found in the southeast corner of the park .

5.3 Potential Goat Habitat

Although comparisons were possible between Klahhane Ridge, other goat inhabited areas, and areas not now inhabited by goats, the classification system is not yet refined enough to make qualitative distinctions between any two areas. There are two possible reasons why this method of habitat evaluation might fail. The first is that the satellite may be unable to get the resolution necessary to overcome the tremendous effects of topography in a mountainous region. The white tail deer project in Mississippi for example did not have to deal with the shadows of 1900 m. ridges (Joyce <u>et al.</u> , 1977). The second possible reason for failure might be that preferred goat habitat includes some feature which is not detectable by remote systems. An example would be available salt. The goats in the Olympics are dependent on humans for extra-foliar sodium. On Klahhane Ridge there is a still-coveted artificial salt lick which has not been resalted for 3 years. In other areas hikers leave salt in urine and sweat soaked clothing. The drawing power of these sources has not yet been measured although an experiment is in progress. The Washington State Game Department has placed salt blocks in four areas adjacent to the park in an effort to draw goats out of the sanctuary of the park and on to Forest Service land where they can be hunted (Rolf Johnson, Washington Department of Game, pers. comm.).

The possibility of a recurrence of the high population density on Klahhane Ridge and the potential heavy impact of goats on plant communities there, is a matter of managerial concern. From work to date there does not appear to be another area with the same combination of 1) all components (O, T, K, *) present, 2) continuous rather than broken assemblages of O, T, K, and * and 3) an east - west ridge orientation.

CHAPTER 6

Summary

An intensive, quantitative study of the summer habitat use of a population of mountain goats in Olympic National Park showed that the most important components of goat habitat are open meadow, rocky bluffs and a variety of micro habitats for thermoregulatory control. These habitat features were used to train a classification system for use with remote imagery from a Landsat II satellite. The classification was extended to cover the entire east side of the peninsula and the resultant map examined for use in predicting goat densities from habitat quality. Actual goat densities were checked by ground survey and appear to be more related to habitat features than to the age of the population.

The Landsat classification has limited application in its present form but may prove to be of more use when the classifications are refined. On a coarse scale, it does not appear as if there is another area in the park in which the goat population is likely to reach the same density as was recently found on Klahhane Ridge.

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Appendix A

Community Types

1. Cushion plant type. This occurs on moderately steep to steep slopes on windy, exposed south to southwest aspects in the higher elevations. These sites are often clear of snow early and therefore experience frequent freezing and thawing. The vegetation is often semi-woody with (*Phlox diffusa*) and *Douglasia lavigata* typical members of the community.

2. Mesic-grass type. This community occurs in the dryer northeast corner of the park on high altitude 20 - 25 degree slopes with a south to west aspect. The snow is usually gone in early June. Keramoto and Bliss (1970) describe this type as "prairie-like" with the major species being *Festuca idahoensis* .

3. Tall sedge type. This is the most common subalpine meadow community. It occurs where the microclimate is cool and wet, the soils are deep and the growing season relatively short. The most common species is *Carex albonigra* .

4. Moist *Saussaurea* forb type. Another community that occurs in the dry northeast area of the park, this is restricted to shallow gullies below 1500 meters. Mountain

beaver, *Aplondontia rufa*) are common herbivores in the floristically rich community which is the only one with three herb layers -- tall, understory and creeper. Common species in the tall layer are *Saussaurea americana* , *Heracleum lanatum* and *Hydrophyllum occidentale* . In the understory *Viola glabella* is the most importnt species and in the creeper layer the only important representative is *Vicia americana* .

5. Moist *Valeriana* forb type. This community is similar to the *Saussaurea* type but with more species diversity and less cover. It occurs on 20 - 25 degree east to northeast slopes. Boulders are common; creepers are absent. Important species are *Valeriana sitchensis* and *Carex albonigra* .

6. Dry grass-forb type. The most uncommon community, it has been observed only on volcanic soils. Important species are *Festuca idahoensis* and *Delphinium glareosum* .

7. Heath-shrub type. This type is fairly uncommon in the Olympics. It is found in northfacing slope basins. The most common species and one that is diagnostic of this

type is *Phyllodoce empetriformis* . Also important are *Cassiope mertensiana* and *Vaccinium deliciosum* .

8. Dwarf sedge type. This community occurs in concavities where a short growing season results from the late snow melt. The dominant species is *Carex nigricans* , but also evident is *Erythronium montanum* .

Appendix B

Trapping Data Form

DATE: NAMES:

TIME: LOCATION:

NO: AGE: SEX: OFFSPRING:

DRUG: DOSE: TD: ANTI: RT:

RT. HORN - LENGTH: BASE: SPLAY:

RT. FOOT: RT. EAR: TAIL:

GIRTH - CIRCUM: WIDTH:

LENGTH(MINUS TAIL): WEIGHT:

TOOTH CONDITION:

OXYTOCIN - DOSE:

SAMPLES: BLOOD MILK
PELLETS SKIN

PATH: EYES: NOSE:
EARS: HOOVES:
MOUTH:

COMMENTS:

Appendix C

Landscape Use Data Form

DATE: NAME: LOCATION:

SNOW COVER:

#
TI
EL
AS
SL
LS
TE
WI
PR
CC
GS
AF
KI
YF
YM
Y?
AM
A?
?
AB
FE
BR
BC
TM
IM
SW
VI
ES

An explanation of the data sheet follows:

- A number was recorded here corresponding to a number written at the group's location on an enlarged topographic map of Klahhane Ridge. As long as the group remained in the same area, the number stayed the same in subsequent 5 minute periods. When the group moved, the next consecutive number was recorded at the new location on the map and on the data sheet.

TI - The time of the observation was recorded on a 24 hour basis. Observations were always recorded at an even 5 minutes so that during one hour the times went from :00 - :55.

EL - Elevation was recorded to the nearest 500' using an altimeter when available or a topographic map.

AS - Aspect was recorded as one of 9 classes, the eight compass directions and "none" referring to flat locations.

1 SL - Slope was estimated without mechanical aids and recorded as one of 4 classes: 0 - 10 degrees, 11 - 30

degrees, 31 - 60 degrees, 61 - 90 degrees. Slope was recorded as the immediate area of observation rather than an average for a general area. If a goat were bedded on a wide ledge on the side of a bluff the slope class would refer to the angle of the ledge rather than the angle of the bluff.

LS - The ridge was divided into 12 landscape types which were coded 1 - 12 and recorded here. The 12 types are:

1. Rocky cliffs: steep (over 60 degrees), continuous rock.

2. Rocky bluffs: rocky outcroppings broken by conifers, scree or sliderock. These outcroppings tend to have a relatively level area on top with steep sides. There are often several outcroppings in one area.

3. Open meadows alpine and subalpine meadows with a predominately forb-grass community although shrubs are present.

4. Open scree with vegetation: a continuous scree slope with small patches of forbs, grass or low shrubs.

Scree is defined as loose rock particles of fist size or smaller.

5. Open scree no vegetation: same as above but without any vegetation.

6. Open talus little vegetation a continuous talus slope. Talus is defined as loose rock particles larger than fist size. The talus slopes were never completely without vegetation.

7. Slide rock a mixed scree, talus, and vegetation type interspersed with small rocky outcroppings. This type is common on the south side of Klahhane Ridge.

8. Krummholz: patches of subalpine fir, Abies lasiocarpa , mountain hemlock, Tsuga mertensiana , and/or yellow cedar, (Chamaecyparis nootkatensis in subalpine meadows. This landscape type was recorded when the individual was either foraging on the conifers or appeared to be using the trees for cover.

9. Coniferous canopy: a lower elevation type with

an open canopy of conifers. The conifers at that elevation are silver fir, Abies amabilis , subalpine fir and yellow cedar. Ground cover is a mixture of grass and forbs.

10. Bare ground: an area at least 80 percent devoid of vegetation and predominately soil rather than rock. In most cases these areas were bare as a result of goat activities.

11. Salt lick an artificial salt lick where salt blocks were placed several years consecutively and the salt percolated into the soil. Salt has not been provided for two years, but the goats still seek out this area, paw into the ground and eat the soil.

12. Snow: snow fields and snow banks.

TE - The temperature was measured in degrees C. with a Taylor thermometer.

WI - Wind was recorded as one of three classes none-light, moderate, or strong.

PR - Precipitation was recorded as one of six classes light rain, heavy rain, hail, snow, sleet or none.

CC - The amount of cloud cover was recorded as 0 - 10 percent, 11 - 50 percent, 51 - 80 percent, 81 - 100 percent, fog or mist.

GS - The number of goats in the group with which the focus individual was associated. A group was defined after Chadwick (1976) as separated from others by at least 50 meters and engaged in unrelated activities.

The following eight entries were for group composition and referred to the focus individual's group.

AF - Adult female.

KI - Kid.

YF - Yearling female.

YM - Yearling male.

Y? - Yearling of unknown sex.

AM - Adult male.

A? - Adult of unknown sex.

? - Goat of unknown age and sex.

The last ten entries refer to general activity classes. The identification number of each marked goat in the group was put in the space opposite the activity in which it was engaged.

AB - Agonistic behavior.

FE - Feeding.

BR - Bedding, resting.

BC - Bedding, ruminating.

In the analysis, these two activities were considered in one class - bedding (BE).

TM - Traveling.

WA - Wallowing.

LM - Licking minerals. This always occurred either at the salt lick or in a small area where a human had urinated.

SW - Standing/watching.

VI - Visitor interference. This could actually be several different activities, but was used whenever a park visitor appeared to have affected the goat's activity selection.

ES - Eating snow. This was included to determine the importance of snow as a source of water.

Appendix D

Fecal Nitrogen

From October, 1977 through September, 1978, 2 - 6 individual mountain goat fecal samples were collected monthly in the Klahhane Ridge area. Each month's samples were pooled and analyzed using a Kjeldahl procedure with a lithium-sulfate digest (Parkinson and Allen, 1975). The results are charted in Figure 7.

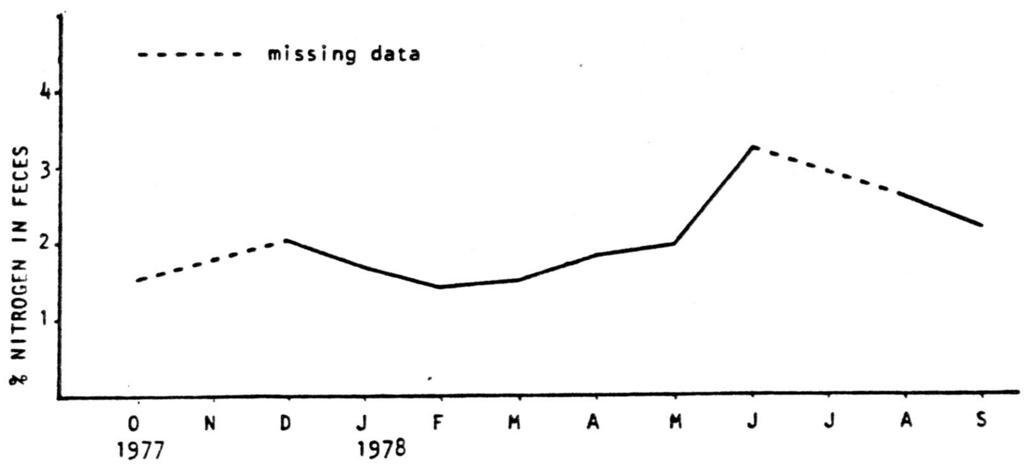

Figure 7. Changes in the percent of nitrogen in fecal samples throughout the year.