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STRATEGY OF RESOURCE USE BY MOUNTAIN GOATS IN ALBERTA

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Strategy of Resource Use by Mountain Goats in Alberta" submitted by Robert John McFetridge in partial fulfilment of the requirements for the degree of Master of Science.

Supervisor

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Date September 26, 1977

ABSTRACT

The use of several habitat types and the population demography of mountain goats were studied during 1974 and 1975 on several ranges along the Smoky River in west central Alberta. Observations of goats were recorded, specifying number of animals, age, sex, location and activity. A series of habitat parameters including vegetative cover type, elevation, slope, aspect and distance to the rock-gravel cover type was subsequently identified at each observation location.

Population estimates obtained during this study indicated that the numbers of goats on Mount Hamell and the Goat Cliffs had decreased from their previous levels. However, in 1975 both populations maintained high productivity and survival, suggesting that they may be increasing their numbers. Kid production varied from 27 to 80 kids per 100 nannies.

A description of plant species composition and standing crop production is presented for major foraging areas. Seasonal changes in fecal crude protein content were used as an index of seasonal changes in forage quality. There were pronounced seasonal differences in fecal crude protein content reflecting the availability of new plant growth at different times of the year. Seasonal changes in forage use were also measured using a method of fecal fragment analysis.

The interaction between mountain goats and their environment was considered by examining the activity of goats with respect to each of the habitat variables and seasonal changes in the proportional use of each habitat. These interactions were considered for the total set of observations and compared with nursery group observations as a

subset of the total observations. Differences in use of habitats between different activities were apparent. The majority of observations were associated with steep rock-gravel habitat; however, these also were associated primarily with bedded or escape activity. Foraging activity was much more prevalent on open level cover types with more abundant vegetation and at greater distances from the rock-gravel cover type. These differences were much more evident when the subset of nursery group observations were considered.

Examination of seasonal patterns suggested that there was an annual cycle of habitat selection related to biological needs associated with events such as parturition, growth and development of kids, the rut and changes in forage quality. There were profound seasonal changes in use with respect to elevation and distance to rock-gravel cover, particularly by nursery groups. There was an apparent separation in the late summer between billies and nursery groups with respect to elevation. In the latter part of the summer, nursery groups ventured further from the rock-gravel and onto higher elevations than at other times of the year. This was not so apparent for adult males unless they accompanied a nursery group.

A strategy of resource use based on the dichotomy between the need for forage and the need for refuge is presented as a possible explanation for the observed patterns of habitat selection. One interesting aspect of the resource strategy of mountain goats is an apparent spatial division of resources between nursery groups and non-nursery individuals. Habitat use by mountain goats is compared with that of other ungulates with emphasis on mountain species and the special problems of resource use in mountainous areas.

Finally the influence of resource development, recreational activities and management practices on mountain goat ranges is considered with respect to the impact on the resource strategy of goats. Recommendations are made for management in Alberta. It is stressed that new priorities should emphasize habitat protection, since problems associated with over-harvesting that were prevalent in the past have been largely overcome.

ACKNOWLEDGEMENT

A project of this nature cannot be completed alone. I am grateful to the members of my examining committee, who gave freely of their time and advice. I wish to thank in particular, my supervisor, Dr. J. O. Murie, who has given invaluable criticism and recommendations for the preparation of this thesis. Dr. R.J. Hudson has provided advice and assistance in using the available computer programs and has inspired much of the "habitat approach" in this report. Dr. W. Samuel has coordinated my communication with T. Cooley in Colorado to investigate the parasite infection in the fecal samples from the areas studied in this investigation. W. Wishart and W. Hall have provided advice on management of mountain goats and have encouraged me to focus towards practical considerations of goat biology. Dr. F. C. Zwickel also made valuable comments on a first draft of this thesis.

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I wish to express my sincere gratitude to Dr. R. M. Hansen of the Department of Range Science at Colorado State University, and the technicians and graduate students at the Composition Analysis Laboratory, who gave freely of their time and facilities to instruct me in the techniques of fecal fragment analysis. Jim Stelfox assisted me in the field and was a cheerful and willing worker. I also thank many residents of Grande Cache, who provided valuable information and assistance.

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INTRODUCTION

The mountain goat *Oreamnos americanus* (Blainville, 1816), is present in the southwestern portion of Alberta along the east slopes of the Rocky Mountains. Within the national parks of Banff and Jasper there are 1000 to 1500 mountain goats (J. Stelfox, pers. comm.) and approximately 1000 exist in the rest of Alberta (survey data of the Alberta Fish and Wildlife Division). In Alberta, mountain goat numbers have declined drastically in several areas since about 1950. This decline has been associated with the development of road access in remote regions, and almost certainly has been the result of over-hunting goats on specific ranges. In the past, hunting regulations were set on the basis of total population estimates for the province without consideration of the fact that only a few areas with easy access were being hunted. These populations were soon reduced, while more remote populations were untouched.

By 1969, wildlife management personnel realized that a number of goat herds were threatened and that in general little was known about other populations. In that year hunting of mountain goats was terminated throughout the province. In 1972 a restricted permit season was established in remote areas of Willmore Wilderness Park, accessible only on horseback or by foot. The annual harvest of mountain goats since 1972 has ranged between 13 and 2[illegible] animals distributed over several zones.

This study has dealt with two of the more accessible populations whose numbers have been depleted very recently in spite of the fact that these have not been hunted since 1969. These study areas are situated about five miles north of the new town of Grande Cache. At the present time resource development along the East Slopes of Alberta is of great concern to wildlife managers since most of the coal resources in this region are associated with productive ungulate ranges.

In recent years more and more studies of ungulate species have concerned habitat selection or resource use (e.g. Hirst 1975, Peek *et al.* 1976, Shannon *et al.* 1975). Saunders (1955) and Hjeljord (1973) have investigated habitat and forage selection by mountain goats. Investigations of habitat use may be of importance in assessing the impact that accrues to wildlife through disturbance of their natural ranges. However, it should be acknowledged that most ungulate studies (including the present one) are not experimental but simply report non-manipulative observation of habitat use. Thus we can only hypothesize about habitat or forage requirements based upon observed preferences.

The intention of this investigation has been to define a strategy of resource use that may provide an explanation of how mountain goats satisfy their biological requirements from the resources available within their environment. It has not been the goal of this study to provide a definitive report of the use of all environmental factors by mountain goats, but rather to examine the use of a few selected factors that may be of importance with respect to the habitat requirements of goats. It must also be remembered that the observations reported here may not necessarily apply to the habitat use by goats in other areas under a different climatic regimé or geographic situation. It is hoped that this study may serve as a guide for future investigations as well as provide baseline data for management of the specific populations studied. The final objective has been to assess the impact of various forms of human activity on mountain goat populations and to discuss management policies that will reduce the impact of human activity on goat populations.

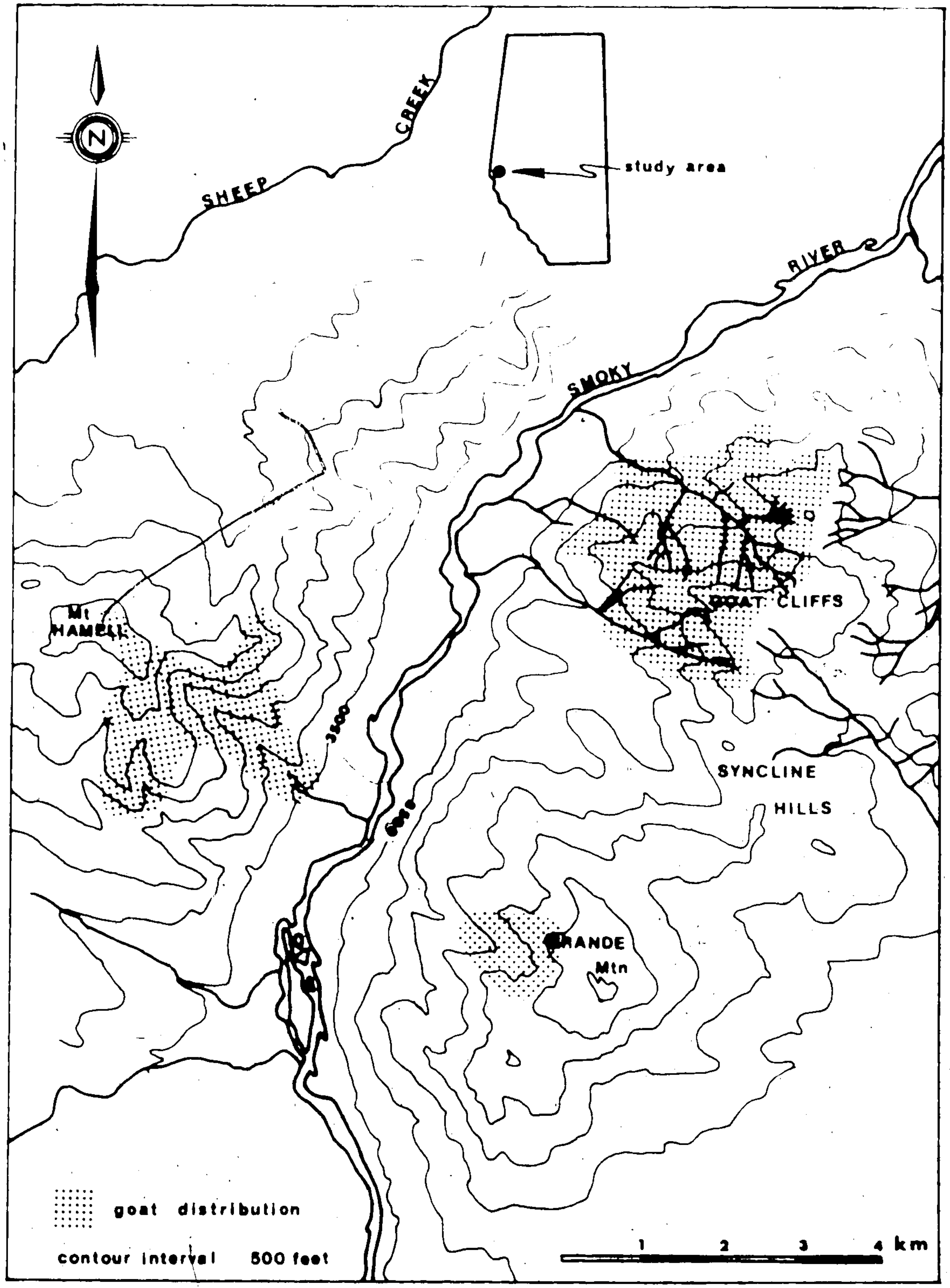
DESCRIPTION OF THE STUDY AREAS

The areas chosen for this project are situated between 53°55' and 54°00' latitude; 119°00' and 119°15' longitude, along the Smoky River in west-central Alberta, encompassing Mount Hamell, the Goat Cliffs and Grande Mountain (figure 1). The elevation ranges from about 3000 feet (914 meters) at the river to 7000 feet (2134 meters) at the top of Mount Hamell. These areas are situated on the eastern edge of the Rocky Mountains. To the north and east is a narrow foothills transition zone, and beyond that lies the boreal forest.

The climate is cool and continental, with cold winters, warm summers, and relatively low precipitation, most of which occurs in the summer and is associated with instability showers rather than frontal activity (C.D. Schultz Ltd. 1976). Frost and even snow may occur at any time of year. Air temperatures are reduced at higher elevations, and south-facing slopes are warmer than others. Chinook winds have a major influence on the winter climate, particularly along the Smoky River, which is lower than the surrounding areas. Thaws may occur during any winter months, keeping many of the subalpine slopes bare of snow and available to foraging herbivores. At ridge-top level the prevailing winds are westerly in the winter and north-westerly in the summer. Wind speeds average 37 km/hr and range up to 92 to 111 km/hr (C.D. Schultz Ltd. 1976).

Vegetative associations are influenced by elevation, slope and aspect. A mosaic of plant communities ranges from riparian at the edge of the river, to tundra in the alpine zone, over a relatively short distance. The mountain communities are moderately complex in terms of species diversity and niche specialization. The faunal community of the alpine and subalpine zones owes much of its diversity to the mixture of montane

Figure 1. Distribution of goats on the study areas.



N
SHEEP CREEK
study area
SMOKY RIVER
Mt HAMELL
GOAT CLIFFS
SYNCLINE HILLS
3500
GRANDE Mtn
goat distribution
contour interval 500 feet
1 2 3 4 km

and taiga species. I discuss vegetative communities in greater detail in a subsequent section.

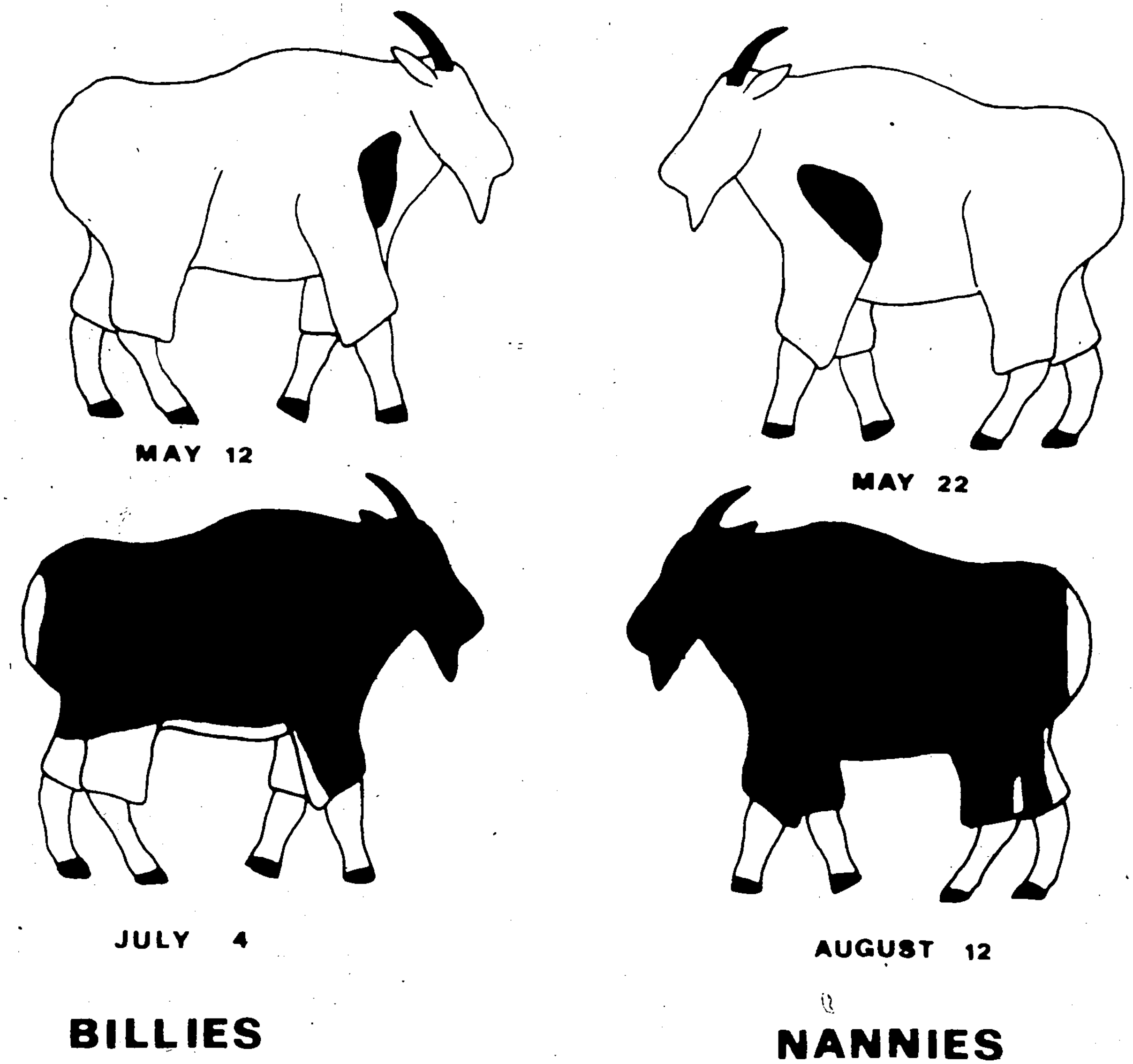
Comparable data for population size and structure and fecal samples were obtained from a goat herd on Caw Ridge in August 1975, situated about 25 km north east of Mount Hamell. This is a long open ridge with extensive alpine communities and widely dispersed cliff areas.

METHODS OF STUDY

Field observations were recorded from May to August and in October and November of 1974, and February and May through August in 1975. Daily observation were conducted between 8:00 AM and 9:00 PM , from base camps situated on each study area, with the aid of binoculars and a 20X spotting scope. The location, age, sex and activity were specified for each observation of single or groups of goats.

The age of a goat was determined on the basis of body size and horn length (see Brandborg 1955). It was often difficult to distinguish yearling goats beyond the age of 16 months from two-year-olds, and two-year-olds beyond the age of 26 months from adults. Determination of sex was usually based upon a combination of characteristics. Sexual dimorphism in horn structure, described by Brandborg (1955), was useful at distances of up to about 800 meters. In the summer, any adult goat that was associated with a kid was assumed to be a female. By the middle of June, adult males could often be distinguished by an advanced state of moult which was not exhibited by other cohorts (figure 2). The scrotum and the udder of adult goats were often visible after moult had been completed on the hind quarters. During summer, certain areas used as bedding sites were occupied exclusively by adult males. Any animal seen in these areas was assumed to be a billy, if its sex was not confirmed by other means. Differences in the urination posture of each sex, discused by DeBock (1970), were occasionally useful for field classification. The sex of indivi[illegible]n a group was determined for as many animals as possible; [illegible]er were listed as unclassified.

Figure 2. Dates of moult progression in billies and nannies during the summer (i.e. earliest commencement and earliest completion of moult in each sex).


MAY 12
MAY 22
JULY 4
AUGUST 12
BILLIES
NANNIES

Most observations of groups were listed according to the prevailing activity of the group at the time of the observation. In addition to recording activities of goats, fecal samples were collected whenever possible. No fecal group was collected unless it was judged to be less than 24 hours old. It was not possible to associate any fecal sample with a particular animal or a particular cohort (with the exception of a few kid samples). Fecal samples were analysed for crude protein content, larval lungworm infection (appendix A) and plant fragment composition.

POPULATION STATUS

Information about the status of the goat populations on Mount Hamell and the Goat Cliffs indicated that both were substantially smaller than they previously were. Kerr (1965) estimated that there were 80 goats residing on Mount Hamell in 1961. At about that time, road access was developed to the top of Mount Hamell. Since then, the population declined to about 55 in 1963 at the end of Kerr's study and 32 in 1974 at the beginning of this study. Fish and Wildlife surveys have indicated that this population may have dropped to as low as 22 goats in the intervening period. In 1972, when 12 goats were removed from the Goat Cliffs for transplant purposes by the Fish and Wildlife Division, there were 60 goats in one group, and probably a number of other goats on that complex (C. Gates pers. comm.). By 1974, there were only 23 goats on the Goat Cliff-Grande Mountain complex. These declines were associated with increased human activity, but in each case there is no evidence to indicate how the population reduction occurred or what was the exact cause.

Census Results

The population numbers reported here are estimates based upon ground observations on each area. The maximum number of individuals of each age and sex class seen at one time was used as the estimate for that cohort. There may have been some error introduced on the east side of the Smoky River by this method due to the discontinuous distribution of goats between the Goat Cliffs and Grande Mountain. However, the extent of movement between these two areas was probably not great enough to distort the estimate of the population in any one year, when the maximum observations from the Goat Cliffs and Grande were summed. This method of population estimate was probably most accurate for the nannies and kids, which were the most conspicuous goats during the summer months. Adult males were often solitary, or in very small groups. Table 1 gives the population estimates for Mount Hamell and the Goat Cliff-Grande complex for 1974 and 1975. The solitary behaviour of adult males accounts for the indefinite estimate of billies in 1975.

Examination of the 1974 and 1975 census data from Hamell and the Goat Cliffs reveals a discrepancy that can only be explained as inaccurate censusing, or as net immigration onto both areas between 1974 and 1975 kidding seasons. On the Goat Cliffs, there were two more two-year-olds in 1975 than yearlings in 1974; therefore, the apparent increase in 1975 is nine goats, which slightly over-estimates the increment by kid production.

Kid Production

In this report I use the term kid production to refer to the maximum number of kids observed in one year. It was not possible to account for pre- or neo-natal mortality of kids in this study. The estimates given in table 1 are probably representative of the kids present prior to winter.

There were two sets of twins born in 1975, one on Mount Hamell and one on Grande Mountain. No twins were recorded in 1974. Figure 3 shows the probability that kid production was equivalent on each area, or in each year. In 1974 kid production on the Goat Cliffs was significantly ($p < 0.05$) lower than that on Mount Hamell. The over all difference in kid production between 1974 and 1975 was great but not significant at the 0.05 level of probability.

Table 1. Summary of population estimates for two study areas in 1974 and 1975.

	Hamell		Goat Cliffs	
	1974	1975	1974	1975
adult male	8	10-13	8	8-10
adult female	12	13	11	10
two-year-old	?	2	?	3
yearling	3	5	1	2
kid	9	9	3	8
total	32	39-42	23	31-33
kids/100 nannies	75	69	27	80

	N	Hamell (8)	Cliffs (11)	1974 (11)	1975 (8)	Hamell 1974(3)	Cliffs 1974(8)	Hamell 1975(5)	Cliffs 1975(3)	Hamell 1974(3)	Hamell 1975(5)	Cliffs 1974(8)	Cliffs 1975(3)
Hamell	(17)												
Cliffs	(10)		0.231										
1974	(12)												
1975	(15)				0.550								
Hamell 1974	(9)												
Cliffs 1974	(3)						0.039						
Hamell 1975	(8)												
Cliffs 1975	(7)								1.000				
Hamell 1974	(9)												
Hamell 1975	(8)										0.673		
Cliffs 1974	(3)												
Cliffs 1975	(7)												0.086

Rows: Nannies with Kids; Columns: Nannies without Kids

Figure 3. Statistical comparison of kid production between areas and between years, using Fisher's exact test, to determine two-tailed probabilit . (Fisher's exact as used by Keeping, 1962, p. 319).

The estimated dates of first born kids and the occurrence of twinning observed by various authors as well as in the present study are listed in table 2. The birth of kids occurred mainly before the end of May; however, some kids were definitely born in the first and possibly second week of June. The occurrence of twins in mountain goats has been reported to be rare by other workers (Brandborg 1955, Kerr 1965, Casebeer *et al.* 1950); however, in this case, two of the 27 nannies with kids had twins. The twinning frequency in this study was 0.07 compared to a mean from table 2 of 0.06 and a range of 0 to 0.14. I was only able to identify twins at an early age when they could easily be associated with a single nanny. By August, it was often difficult to associate any kid with a particular nanny

Mortality and Overwinter Survival

Mortality and survival of goats were not measured directly, but were only inferred by comparison of the numbers in each cohort from one year to the next. Such a comparison of the adult segment of the populations on both areas, suggests that mortality between 1974 and 1975 was very low or nil. On the other hand, if the assessment of yearlings on each area in 1975 is correct, 56% of the kids on Mount Hamell survived to 1975 and 67% survived on the Goat Cliffs. In each case this is probably a normal to high survival rate for mountain goat kids.

The causes of mortality are unknown in these populations. No predation was recorded during this study. Potential predators of adult goats were grizzly bears (*Ursus arctos*) and wolves (*Canis lupus*). Eagles (*Aquila chrysaetos*), coyotes (*Canis latrans*), lynx (*Lynx canadensis*) and wolverine (*Gulo gulo*) are potential predators of kids that were present. Eagles and coyotes were abundant on both study areas. On several occasions eagles

Table 2. Summary of kidding dates and multiple births reported in the literature.

authors	earliest kids	approximate last kid	multiple births
Holroyd 1967	May 24, 1963	June 3, 196[illegible]	2 sets of twins in [illegible] cases
Casebeer et al. 1950	May 26, 1948 (one case on Feb. 27)	June 13	1 set of twins in [illegible]8 cases
Richardson 1971	May 22	middle of June	1 set of twins in many cases
Lentfer 1955	May 30	June 17	2 triplets, [illegible]7 twins 516 cases
Anderson 1940	May 26 (est. May 10)	June 15	3 sets of twins in 21 cases
Kerr 1965	May 16	June 29	0 twins in 3[illegible] cases
Klein (in Kerr)			0 twins in ?
Brandborg 1955	May 15	June 27	6 sets of twins in 185 cases
present st	May 19, 1974	June 1[illegible]	2 sets of twins in 27 cases

were seen stooping at kids, but a serious attack was never observed. An eagle at very close range caused kids to run for the cover of trees. The combined effort of the above predators may influence the survival rate, particularly of the kid cohort and may also influence the distance that goats will venture from the rock-gravel cover type. This last factor will be considered in greater detail in subsequent sections.

Kerr and Holmes (1966) investigated the parasite load of goats on Mount Hamell and found no evidence of mortality that could be directly attributed to any parasite group. Fecal samples collected by myself were analysed by T. Cooley of the Wild Animal Disease Center at Colorado State University for infection by larval lungworms (genus *Protostrongylus*). This information is summarized in appendi [illegible].

Mobility between Areas

The Smoky River acts as a significant barrier to movement of goats between Mount Hamell and areas east of the river. Although the river is not an absolute barrier, the recent development of a road, railway, lumber mill and a coal preparation plant between the two areas probably discourages frequent crossings by goats. The next closest populations of goats are about 20 km distant on Caw Ridge and Stearn Mountain across wide forested valleys. Consequently, movement to and from those areas is also probably an infrequent event. The original colonization of the Goat Cliffs and Grande Mountain must have been from Mount Hamell, since these areas are on the eastern edge of the mountains and are cut off from all other direct contact with goat ranges.

The extent of movement between the Goat Cliffs and Grande Mountain is unknown. The distance between the closest observations on each area was 8 km, encompassing open gentle terrain and spruce-pine forest. No evidence of movement between these areas was observed, although this probably did occur. Dispersal of goats from the main areas onto surrounding marginal areas was difficult to detect by conventional methods. It seems likely that a large portion of the goat population on the Goat Cliffs moved away some time after 1972, onto some of the surrounding areas. Movement back to the Goat Cliffs in 1975 from these marginal areas could account for the appearance of extra two-year-olds in that year.

There were two billies present on the Goat Cliffs in 1974, and at least one in 1975, that were tagged in 1970 in the same location by Fish and Wildlife personnel. This is convincing evidence of the sedentary nature of mountain goats and is particularly noteworthy since that population has been reduced by about 60% since 1970.

Caw Ridge

Observations were recorded for a short period in August 1975 on Caw Ridge, situated about 20 km north west of Mount Hamell. Table 3 summarizes the survey data that was recorded on Caw Ridge. Until very recently Caw Ridge has been relatively undisturbed by human activity. The rate of kid production and the kid-yearling ratio of 2:1, suggest a stable population of goats on Caw Ridge at the present time.

Table 3. Summary of population estimate for Caw Ridge in 1975.

	actual number	ratio*
adult(uncl)	35	100
yearling	6	17
kid	12	34
total	53	

* These are calculated per 100 adults; thus, 34 kids/100 adults may be roughly equivalent to 68 kids/100 nannies.

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RESOURCE CHARACTERISTICS

The study of niche structure in a population of large herbivores requires a consideration of the characteristics of the habitat that are used by the animals. Because of practical limitations I have chosen to consider the habitat preferences of mountain goats only in terms of the following factors: cover type, elevation above sea level, slope of the terrain, aspect and the distance of any point from the rock-gravel cover type. Factors such as precipitation, soil characteristics and microclimatic variation were not investigated. An attempt was made to assess qualitatively and quantitatively the primary production on major feeding areas.

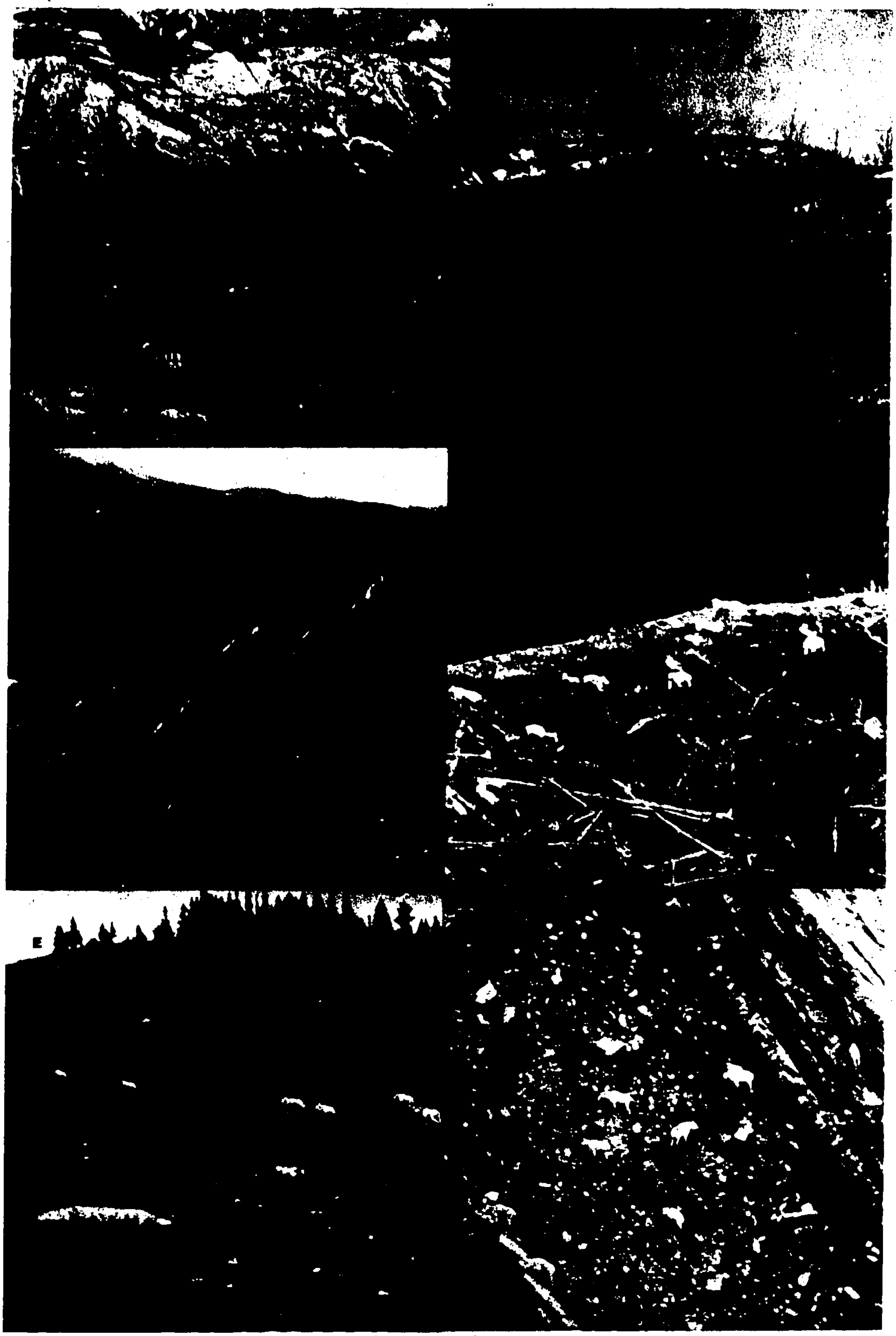
Habitat Parameters

A system of grid coordinates overlying a map of the study area was used to locate observations and to plot environmental variables. Consequently it was possible to identify the habitat parameters associated with each observation of goats. The distance between adjacent grid points represented a distance of 206 meters.

Seven cover types were described on the study areas. These did not represent discrete homogeneous stands, but rather a subjective class that may intergrade more or less gradually with adjacent types. The boundaries of each type have been drawn from field observation and examples of each are shown in figure 4.

Figure 4. Cover types present on the study areas.

A. conifer forest (1) and deciduous forest (2)
B. grassland
C. subalpine ridge
D. burn
E. alpine tundra
F. rock-gravel


E

Deciduous Forest. This is a prevalent cover type below 4500 feet, and is usually dominated by tall dense stands of poplars (*Populus tremuloides* and *P. balsamifera*). In some locations, usually above 3500 feet, a very dense growth of alder (*Alnus crispa*) may replace the poplar. Poplar stands usually support a substantial understory of shrubs, herbs and grasses, but in dense alder thickets at higher elevations the growth of understory species is reduced. Smaller, less dense stands of poplar and willow extend up the valley bottoms and along streams.

Coniferous Forest. This cover type is found predominantly on the moister, cooler, north-facing slopes. Spruce (*Picea englemanni* X *P. glauca*) is the dominant species. The understory may vary from a moss and fungus mat, with species such as *Empetrum nigrum*, *Moneses uniflora* and [illegible] *canadensis*, in the moist, dense stands to alder and birch (*Betula glandulosa*) in the more open stands. The conifer type often intergrades at lower elevations with the deciduous forest, resulting in a mixed forest of varying widths. A characteristic feature of this type is that snow remains much later than on other types at similar elevations. Consequently, the coniferous forest maintained higher moisture and lower temperatures throughout the summer compared to other types.

Grassland. This is not a common habitat on any of the areas. It is situated on south or west-facing aspects below 3500 feet. Trees are absent, but shrubs such as buffalo berry (*Shepherdia canadensis*), wolf willow (*Elaeagnus commutata*) and wild rose (*Rosa acicularis*) are common. Some of the common grasses here include: *Festuca scabrella, Calamogrostis purpurascens, Trisetum spicatum, Agropyron sp.* and *Poa sp.* Numerous herbs such as *Artemisia frigida, Achillea millefolium, Potentilla* sp. and *Ranunculus* sp., are common to this type. This type intergrades with the subalpine ridge type and may be a low elevation equivalent to that type. The aspect and steep slopes of the grassland areas frequently result in higher temperatures and lower soil moisture than is found on other areas at the same elevation.

Subalpine Ridge. This type is normally present above 4000 feet, along the south-facing slopes of high ridges. Conifers, usually spruce, but sometimes lodgepole pine (*Pinus contorta*) are present in sparse stands. Grasses such as *Elymus innovatus, Festuca baffinensis* and *Poa arctica* are prevalent in this zone. Bearberry (*Arctostaphylos uva-ursi*), saxifrage (*Saxifraga tricuspidata*) and several species of Leguminosae are common herbs. This cover type can best be described as a transition zone between grassland and alpine tundra, with intrusion by conifer and deciduous forest. It is characterized by low moisture, moderate temperature and high winds. This zone usually has a very sparse soil with exposed rock and gravel being a common feature. This is a fairly extensive cover type, and is frequently associated with the rock-gravel type.

Burns. This cover type has many vegetative features in common with the subalpine ridge. Grasses and bearberry are the most abundant plant species; wolf willow, bunch berry and legumes are of secondary importance. Alberta Forest Service records indicate that fires have not been a significant influence on either area since fires were first recorded in 1958. Most of the burns were probably much earlier than that date. Burns are characteristically open subalpine meadows on predominantly level ground with very little regeneration of the conifers that formerly were present.

Alpine Tundra. This zone is situated above 6000 feet and is characterized by the complete absence of trees and shrubs. Primary production and species composition may be limited by a very short frost-free period, severe winds, cold temperatures, poor soil conditions and a xeric moisture regime. The substrate usually consists of gravel and shale with a minimum loam content. Major plant species in this area include grasses and sedges (e.g. *Elymus, Bromus, Poa, Festuca, Kobresia* and *Carex*), avens (*Dryas integrifolia*), mountain heather (*Cassiope tetragona*), willows (*Salix nivalis* and *S. arcticus*) and bistort (*Polygonum bistortoides*). The tundra areas are often fairly level or gently sloped. On south-facing slopes and exposed ridges, this type may remain snow-free during most winter months, but on northeast-facing slopes, deep snow drifts may form over the winter, lasting long into the summer.

Rock-gravel. This type consists of surficial rock, gravel, shale or soil and is usually steep and unstable. Because of the texture and structure of the soil in these areas, little moisture remains for plant growth. Only the hardiest grasses, sedges and herbs grow here. During the spring when snow is melting, there are frequent "showers" of rocks and dust from higher cliffs. This type is most frequent at higher, but not the highest elevations.

The elevation of each point on the previously described grid system was determined from topographic maps (National Topographic Series, 1:50,000 scale) and grouped into six categories representing 500 foot contour intervals between 3500 feet and 6500 feet. Aspect was divided into five classes related to exposure: north-facing, south-facing, east-facing, west-facing and level (level areas were exposed in all directions, thus avoiding the need to separate this category into shaded and open categories). Aspect of a point on the grid was recorded as that of the general area rather than the immediate location of that point. Slope was estimated with respect t ategories of 15° intervals from 15 to 75 degrees.

The distance to rock-gravel cover type was expected to be important in terms of habitat requirements of mountain goats. The straight line distance of each point on the grid system to the closest rock-gravel cover type was determined using a computer program called ESCAPE (see appendix B). This was an interval scaled variable with unequal categories. The distance between grid points was equivalent to 206 meters and categories of this variable are a function of that distance.

Primary Production and Vegetative Characteristics

A general analysis of some of the major foraging sites is presented here as background information for comparative purposes and does not specifically relate to habitat selection. Range conditions are compared on different cover types and at different times of the summer. Clip-plots and transects were used to provide information about quantitative and qualitative features of primary production. Variations in plant species composition between transects on the same cover types indicate the range of vegetation that may be found within a cover type on two study areas. On the other hand, data from the clop-plots on the same cover types have been lumped to characterize the differences between cover types rather than express the variation within a cover type. Table 4 lists the mean estimated percent cover and a value for the Braun-Blanquet cover abundance scale (Mueller-Dombois and Ellenberg 1974) as determined from transects on subalpine ridge, burn and alpine tundra cover types. Each transect followed a constant elevation. A sample plot 1 m^2 was located at every tenth meter on each transect and the percent coverage of each plant group was estimated within that plot. The number of plots on each transect varied from 8 to 25.

Table 4. Mean percent cover from 1 meter^2 plots on transects of each cover type in 1975.

	Sub-alpine ridge Goat Cliffs-July 21		Sub-alpine ridge Hamell-July 28		Burn(1) Hamell-July 26		Burn(2) Hamell-July 27		Tundra Goat Cliffs-July 22		Tundra Hamell-July 28	
Cover species	a	b	a	b	a	b	a	b	a	b	a	b
rock - gravel	53.6	4	18.6	2	16.6	2	11.5	2	38.0	3	26.9	3
Arctostaphylos	14.7	2	36.6	3	19.0	2	41.4	3	0.3	+		
grasses and sedges	12.4	2	20.0	2	39.8	3	13.5	2	10.1	2	18.4	2
legumes	1.1	1	5.4	2	4.0	1	9.4	2	11.5	2	4.2	1
Saxifraga	1.3	1	1.6	1			0.4	+			13.0	2
Cornus			3.5	1	9.8	2	4.0	1				
Dryas							trace	r	36.4	3	25.2	3
Salix	4.0	1			trace	r	trace	r			6.0	2
Sh[illegible]herdia	1.7	1	0.5	+	2.4	1	12.3	2				
F[illegible]ria	1.3	1	4.5	1	trace	r	1.7	1	trace	r		
Ro[illegible]	3.6	1	2.3	1								
Achillea	0.8	1	2.1	1	trace	r	0.3	+	trace	r		
Populus	0.2	t										
Juniperus	0.6	1			1.0	1	trace	r				
Erigeron	0.3	t							1.2	1	trace	r
Artemisia	0.9	1										
Ribes	0.6	1										
Potentilla			1.5	1			0.4	+			1.5	1
Myosotis											trace	r
Picea			1.2	1	1.2	1	trace	r	trace	r		
Arnica			trace	r					trace	r		
Galium			0.5	+	trace	r	trace	r				
Epilobium			1.2	1	2.9	1	1.4	1				
Equisetum					trace	r						
Linnea bo.			0.5	+	1.6	1	0.9	1				
Phyllodocae					1.0	1						
Rhododendron					0.8	1						
Castilleja					trace	r						
Zygadenus			trace	r			2.6	1				
Solidago							trace	r				
Aster							0.4	+				
Polygonum											4.2	1
Luzula											0.2	+
Aconitum			trace	r							trace	r
Campanula			trace	r							trace	r
Silene											0.6	1

a percent, b Braun Blanquet cover class.

Grasses and legumes were the only plant groups that were consistantly present on the test plots on the three cover types examined. Bearberry was very abundant on the subalpine ridge and burn cover types but was sparse on the tundra type where the equivalent "mat species" were *Dryas, Saxifraga* or *Salix* (presumably depending upon variations in moisture, exposure or soil conditions). The amount of rock, gravel and organic litter varied extensively from one cover type to another. Exposed rock and gravel were most prevalent on tundra and subalpine ridge cover types (excluding the rock-gravel cover type of course). Organic litter was a prominent component on the burn cover type. A wide variety of dicot herbs were found on all three cover types examined here. Individually, these species constitute a minor component of the vegetation; however, they are a more important component of the vegetative biomass when considered as a group. Shrub species were present on subalpine ridge and burns but totally absent on the alpine tundra.

Quantitative aspects of standing crop on different cover types were determined by clipping all live plant tissue within a 50 cm X 20 cm plot, situated on known feeding locations. Table 5 lists the production of the main plant groups on tundra, burn and subalpine ridge cover types. Table 6 compares the standing crop of grasses and bearberry on the subalpine ridge in May, June and July. The total standing crop on these vegetation types is a reflection of the general productivity of each. Consequently, it is apparent that the burn is the most productive, while the alpine tundra produces the least biomass. Bearberry was a major component in the standing crop on both the subalpine ridge and burn cover types. Grasses and sedges were major components of all three cover types, but on the tundra they accounted for almost 50% of the

Table 5. Standing crop production on three cover types ($grams/1000\ cm^2$). Numbers in parentheses = number of $1000\ cm^2$ plots.

	tundra (1)	burn (3)	subalpine ridge (12)
bearberry		13.3	32.7
monocots	8	28.5	11.6
saxifraga		25	
Phyllodocae		2.0	
Dryas	6	1.6	
Shepherdia		1.0	
lichen	1.5		
miscellaneous	1	3.0	2.6
total	16.5	74.4	46.9

Table 6. Standing crop vegetation on subalpine ridge type ($grams/1000\ cm^2$) for the three summer months.

	grass	bearberry	total	N
May	[illegible].4	28.2	38.2	5
June	16.2	20.6	40.7	3
July	12.7	37.8	55.2	4

standing crop.

The standing crop on the subalpine ridge increased during the summer period. Potentially there may be a greater amount of new forage available in the later part of the summer on all major foraging areas.

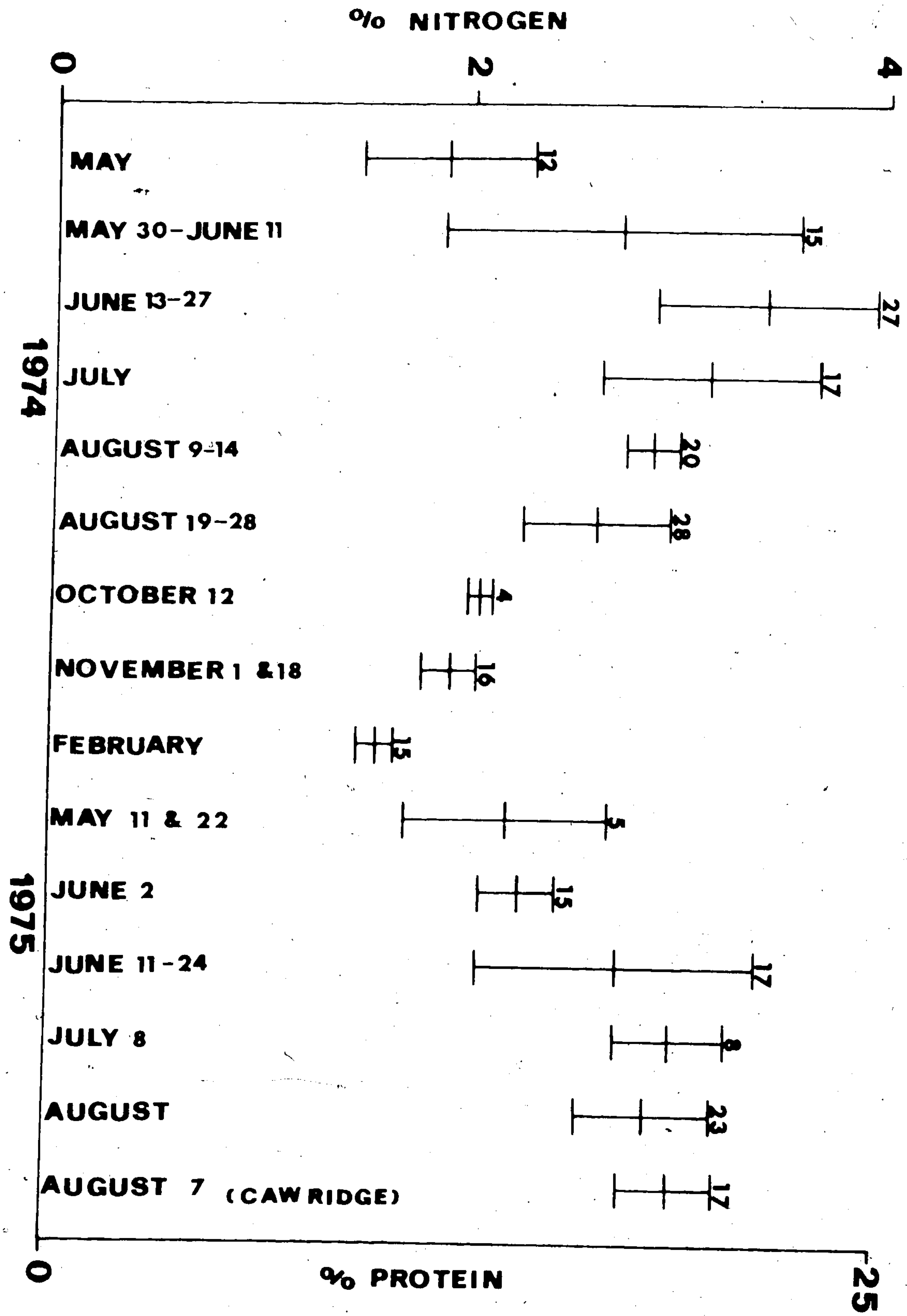
RESOURCE USE AND HABITAT PREFERENCES

Forage Use

The growth of new vegetation in spring begins in early June at low elevations (i.e. below 4000 feet) and progresses to the highest elevations over a period of two to three weeks. Measurement of fecal nitrogen content by the macro-Kjeldahl method (Assoc. Offic. Anal. Chem. 1965) was conducted to indicate seasonal variation in forage quality. Percent nitrogen was used to estimate the percent crude protein as determined by a standard factor of 6.25. Figure 5 demonstrates the seasonal change in fecal nitrogen concentration that was found in 1974 and 1975. Hebert (1973, p.123) showed that there was little variation in the absolute loss of protein via the fecal route between high quality or low quality diets of bighorn sheep; however, sheep did increase their feed intake on a low quality diet. Consequently, Hebert was able to define the relationship between the percent crude protein in the feces of bighorn sheep and the percent crude protein in the forage by the following equation: $Y = .9400 + 1.034\,X \pm 4.58$. The change in percent crude protein in the feces shown in figure 5 may be associated with changes in standing crop biomass on subalpine ridge areas during the summer (table 6) but was almost certainly a reflection of changes in vegetation quality and green-up. As vegetation on goat ranges cured through the summer, fecal crude protein values also declined. Assuming that fecal crude protein reflects vegetation quality, then forage protein content increases rapidly in May and declines gradually from June to the winter months.

Seasonal changes in forage use were measured by fecal fragment identification, using the method of Sparks and Malechek (1968). The forage

Figure 5. Seasonal changes in fecal crude protein content (mean, standard error and number of samples).



% NITROGEN
0
2
4
MAY
12
MAY 30-JUNE 11
15
JUNE 13-27
27
1974
JULY
17
AUGUST 9-14
20
AUGUST 19-28
28
OCTOBER 12
4
NOVEMBER 1 &18
16
FEBRUARY
15
MAY 11 & 22
5
1975
JUNE 2
15
JUNE 11-24
17
JULY 8
8
AUGUST
23
AUGUST 7 (CAW RIDGE)
17
0
% PROTEIN
25

classes used in table 7 were those most easily identified by myself after limited experience with the fragment identification technique. Although there are numerous weaknesses in this method, the most notable are those associated with my own inexperience and the small sample sizes in some of the monthly groups. Anthony and Smith (1974) indicated that it was necessary to use at least 15 fecal samples to obtain a valid representation of a composite sample of fecal groups. Several of the composite samples contained less than this number. The forb category is a broad one that includes predominantly dicot herbs such as *Arnica, Erigeron* and legumes, but also includes browse species such as *Rosa, Populus* and *Betula*.

Trends in seasonal variation in forage use are apparent in table 7. The percent relative density used in this table is an estimation of percent dry weight. Samples from the main study areas were combined since there was very little difference in vegetative composition between these areas and I did not expect major differences in forage selection between these. There was however, a substanial difference between the forage selected in August between the main study areas and Caw Ridge. Grasses and sedges were more abundant in the diet of goats on Caw Ridge than on the other study areas. Conversely, Elaeagnaceae and *Salix* were less abundant. This may reflect the greater use of alpine tundra and subalpine zones by goats on Caw Ridge, although I have no direct evidence to suggest that this is so.

Samples from the main study areas indicate that grasses were used more frequently in the spring and fall and less frequently during the summer. Sedges and conifers showed a slight increase in the November-February samples.

Table 7. Percent relative density of forage groups in fecal fragments.

	1974							1975						
forage class	May	June	late June	July	August	October	November	February	May	June 2*	June	July	August	August (Caw Ridge)
Graminae	42	35	21	12	10	43	26	28	54	54	28	10	13	42
Cyperaceae	1	0	1	1	0	2	3	1	1	1	1	3	0	5
Conifer	0	0	0	1	0	1	3	4	1	0	1	0	0	0
Equisetum	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Elaegnaceae	15	24	39	27	38	18	1	34	17	4	33	10	46	15
Forbs	42	38	34	59	51	35	64	36	26	41	32	73	33	42
Salix	1	3	2	0	2	1	1	1	0	0	6	4	6	1
N	17	23	9	17	20	4	16	15	5	15	17	8	23	17

* samples from Goat Cliffs only.

Habitat Use

Studies of animal preferences frequently require comparison of resource use to resource availability. Petrides (1975), speaking of forage preferences noted that preference indexes could be established for each forage item by dividing the percentage of an item removed by the percent available. This is an appropriate calculation for items that are consumed such as forage; however, when we consider habitat preferences, nothing is being consumed or removed so it is necessary to establish another measure of preference. I feel that it is more important to consider the use of habitat parameters as a proportion of the observations made, rather than in relation to an arbitrary availability factor for each habitat category. All habitat types are constantly available over time (assuming a static environment during an observation period); therefore, relative spatial availability of each habitat type is irrelevant when considering frequency of use where preferences are associated with a habitat type being considered.

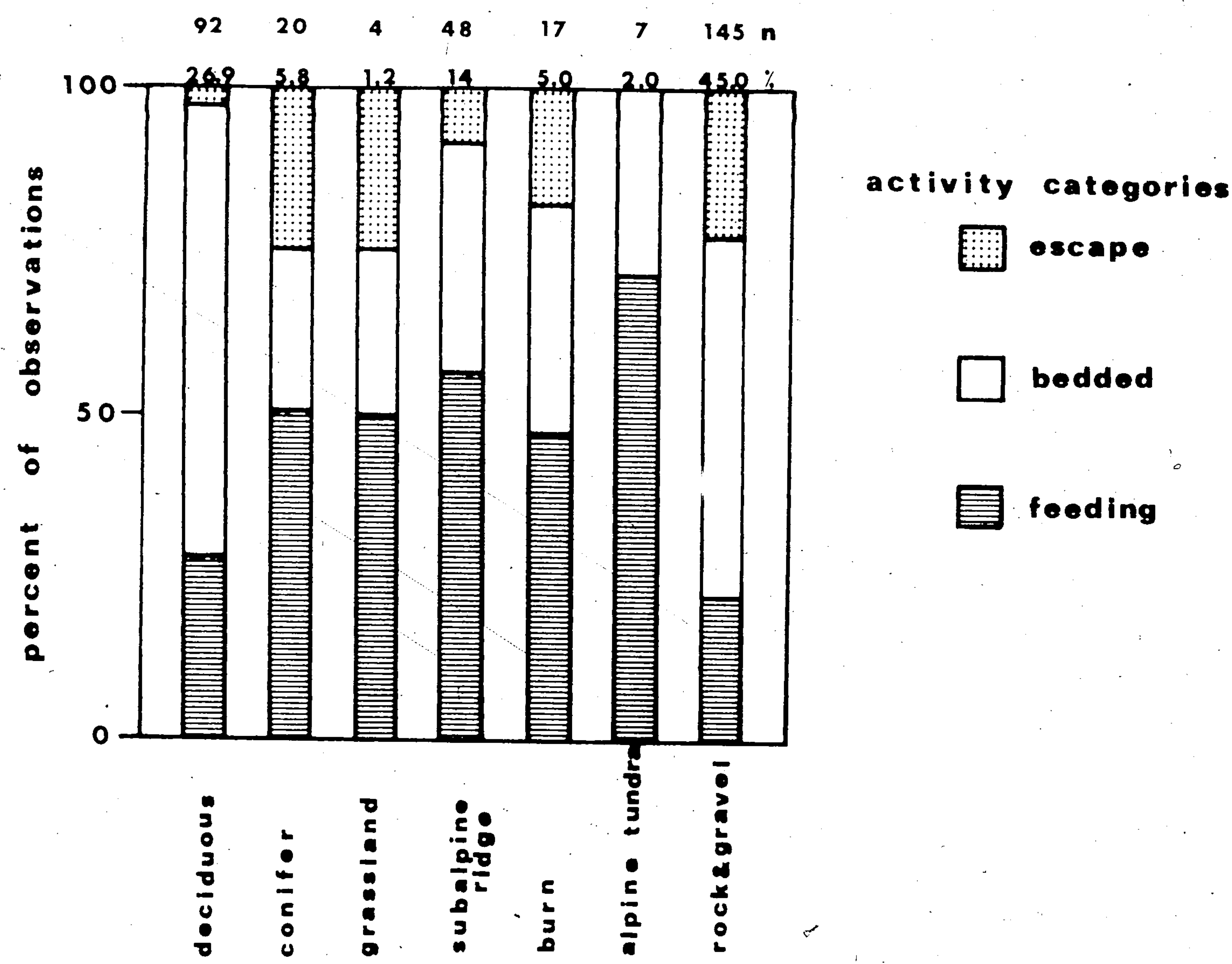
On the other hand, I think that it is possible that some differences in habitat use are associated with the availability of certain types, suggesting that these may be neutral habitat parameters that are used randomly. For example, aspect may not be relevant to habitat selection on cloudy days and the use of different aspects may simply reflect their association with other factors such as cover type or slope. Since the distribution of observations may have been influenced by the relative availability of certain habitats, I will briefly mention some of the differences in spatial availability of habitat types. Grassland and alpine cover types were less abundant than other cover types. The amount of surface area was greater at lower elevations than higher, and greater on intermediate and gentle slopes than steeper ones. West-facing aspects were uncommon on these areas and one could convincingly argue that distance from the rock-gravel cover type is infinitely available. For the most part, it is necessary to assume that these variables are equally available and that differences in numbers of observations on each habitat type reflect differences in preferences for each category with respect to a given activity or a given month.

Major activities considered here were feeding, bedded and escape, which accounted for almost all observations recorded. Observations classified as transit (i.e. goats simply moving from one area to another) were deleted from this analysis. Group observations were listed according to the prevailing activity of the group at the time of the observation. Feeding and bedded activity were easily identified; however, escape activity was complicated by the fact that in most cases, this was an artificially induced activity, occurring in response to the presence of the observer. Therefore, escape activity might be considered a random activity (at least in the initial stages) with respect to habitat parameters. The final stages of escape activity were almost always associated with the rock-gravel cover type, but since the objective of this activity was to obtain refuge from the observer, the final stage was not always observed or recorded.

Appendix III is a multivariate analysis of the relationship between goat activity and habitat use. This includes multivariate and bivariate statistics as well as activity percentages in each category of the habitat variables that are adjusted for interaction between habitat parameters.

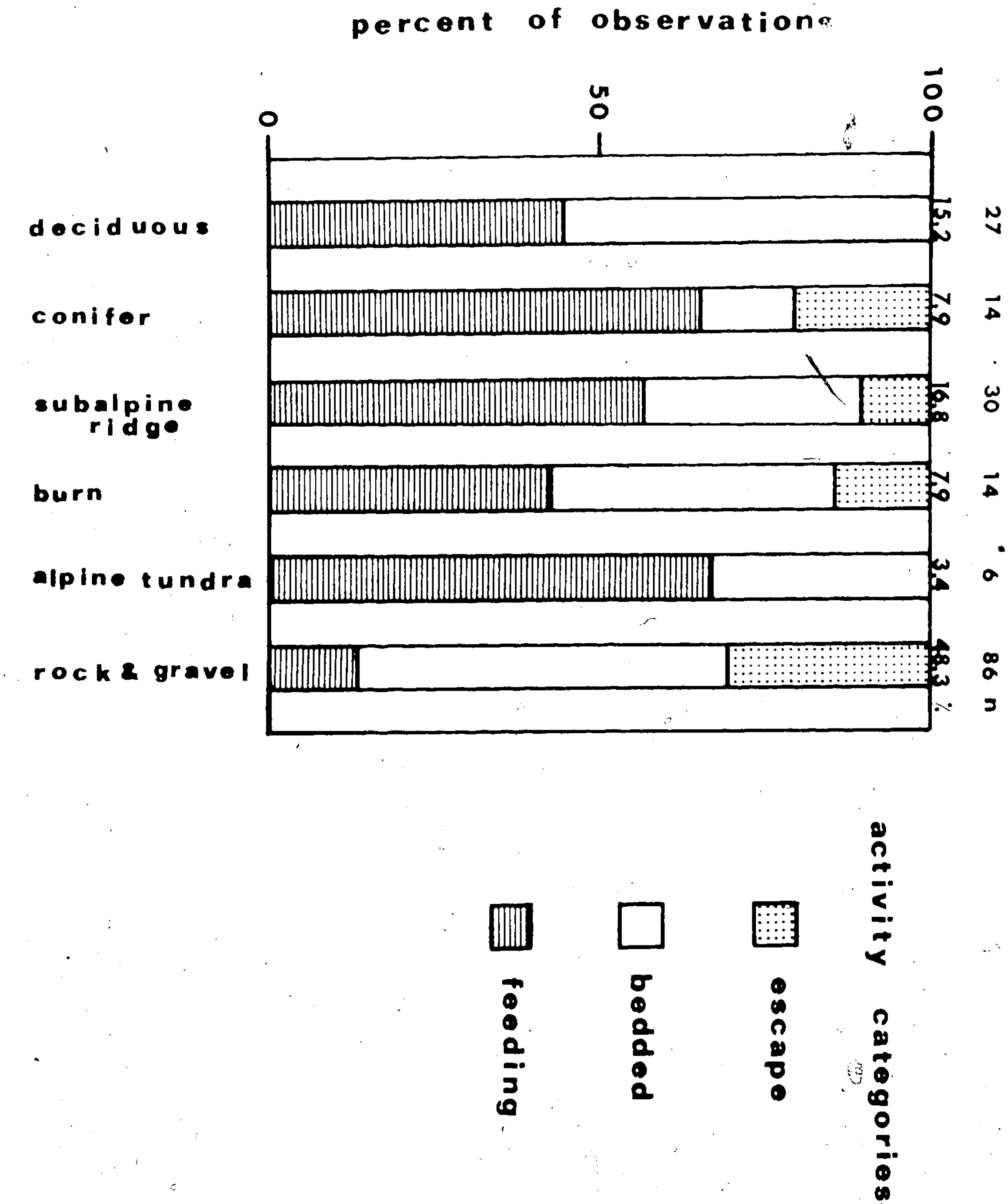
Almost 50% of the total observations (figure 6) and nursery group observations (figure 7) occurred on the rock-gravel cover type. Deciduous forest and subalpine ridge types received moderate use by goats while grassland, burn, tundra and coniferous cover types were used less freq-

Figure 6. Activity on each cover type (total observations).



92
20
4
48
17
7
145 n
26.9
5.8
1.2
14
5.0
2.0
45.0 %
100
50
0
percent of observations
deciduous
conifer
grassland
subalpine ridge
burn
alpine tundra
rock&gravel
activity categories
escape
bedded
feeding

Figure 7. Activity of nursery groups on each cover type.


percent of observations
0
50
100
deciduous
conifer
subalpine ridge
burn
alpine tundra
rock & gravel
15.2
7.9
16.8
7.9
3.4
48.3
%
27
14
30
14
6
86
n
activity categories
escape
bedded
feeding

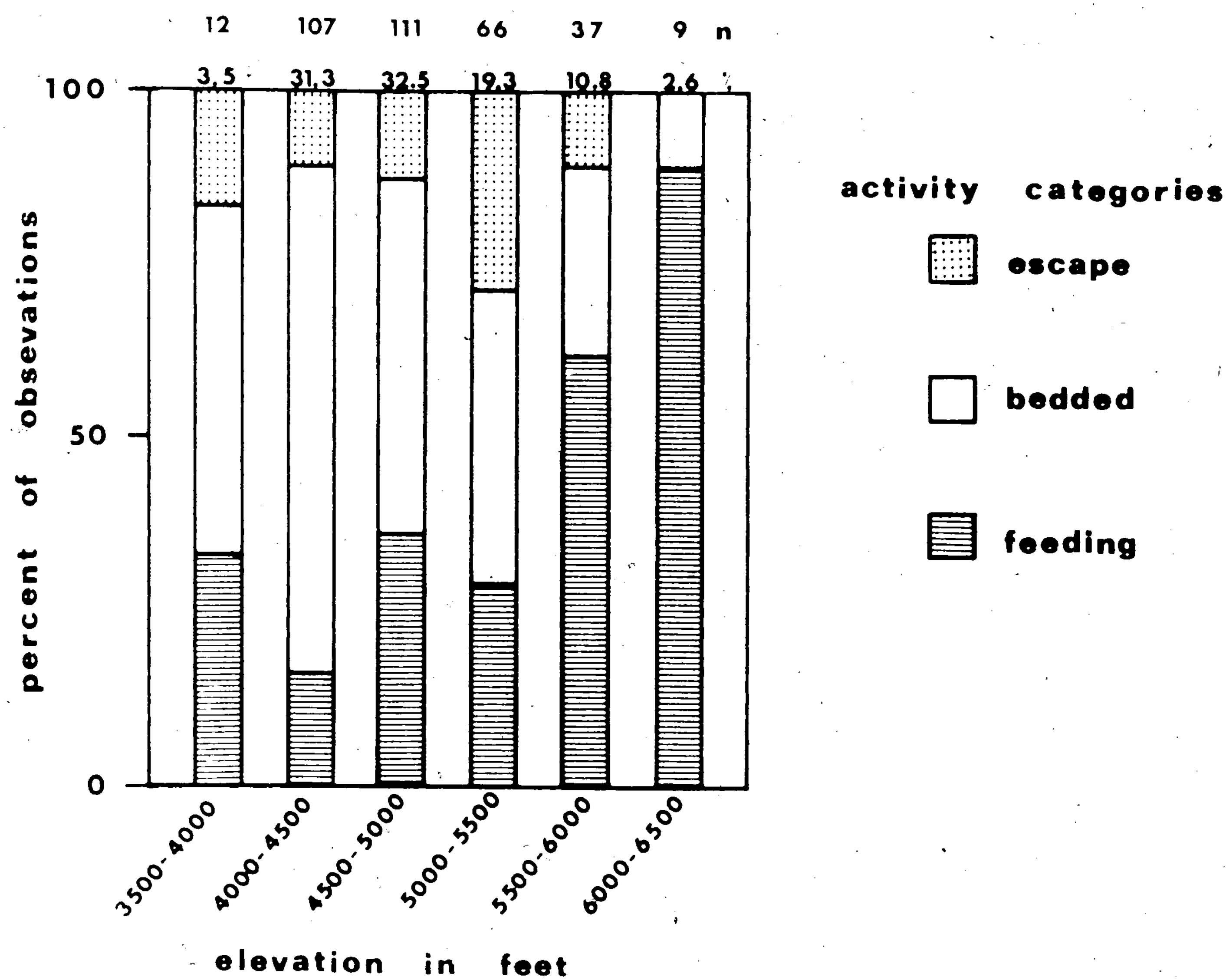
uently. Bedded activity was notably greater on rock-gravel areas and either rare or not recorded on tundra and deciduous forest types. It is logical that foraging activity should be relatively infrequent on the rock-gravel areas but the large number of observations on that type increases the relative foraging time on the rock-gravel type compared to other types. My impression was that most foraging activity on the rock-gravel type was of an incidental nature; however, the dietary contribution of foraging activity on this type is open to speculation.

Nursery groups differed somewhat from the total population in their use of cover types. There was notably less use of the deciduous cover by nursery groups of the rock-gravel type. Use of burn and tundra cover types was almost exclusively by nursery groups: when combined, these areas provide a large foraging domain for nursery groups.

Elevation is an interval scaled variable. Consequently, sequential changes in the activity or numbers of observations in each elevation category must be considered. Differences between total and nursery group observations may also have a sequential significance. Figures 8 and 9 indicate that there was a strong positive correlation between feeding activity and elevation, particularly for nursery groups.

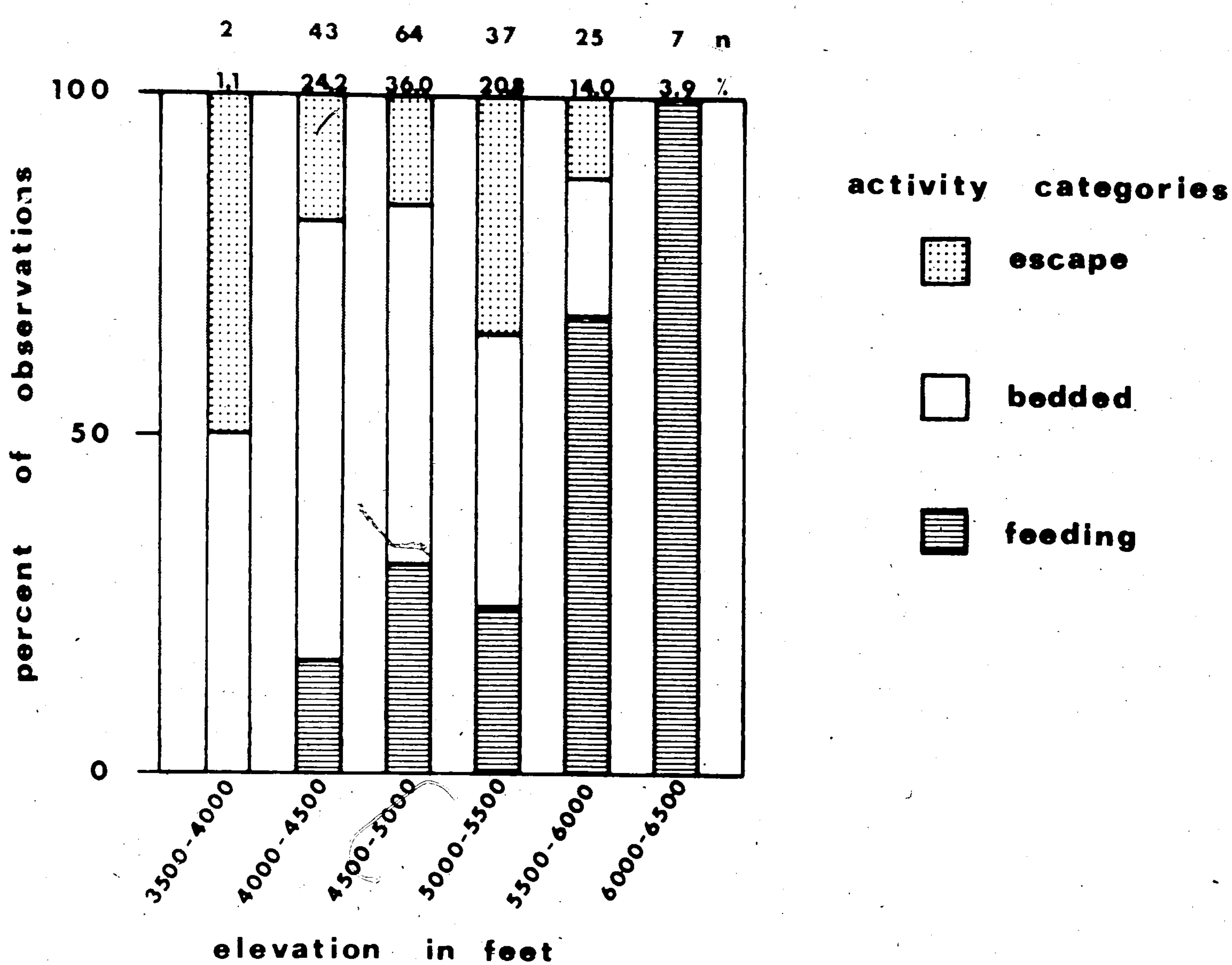
Comparison of the number of observations in each elevation interval in figure 8 (total observations) and figure 9 (nursery groups) reveals that there is a marked divergence between nursery groups and other segments of the mountain goat population. The proportion of total observations in each interval that are nursery groups is shown in the following list:

Figure 8. Activity ~~at~~ each elevation interval (total observations).



12
107
111
66
37
9
n
3,5
31,3
32,5
19,3
10,8
2,6
100
50
0
percent of obsevations
3500-4000
4000-4500
4500-5000
5000-5500
5500-6000
6000-6500
elevation in feet
activity categories
escape
bedded
feeding

Figure 9. Activity of nursery groups at each elevation interval.



2
43
64
37
25
7
n
1.1
24.2
36.0
20.8
14.0
3.9
%
100
50
0
percent of observations
3500-4000
4000-4500
4500-5000
5000-5500
5500-6000
6000-6500
elevation in feet
activity categories
escape
bedded
feeding

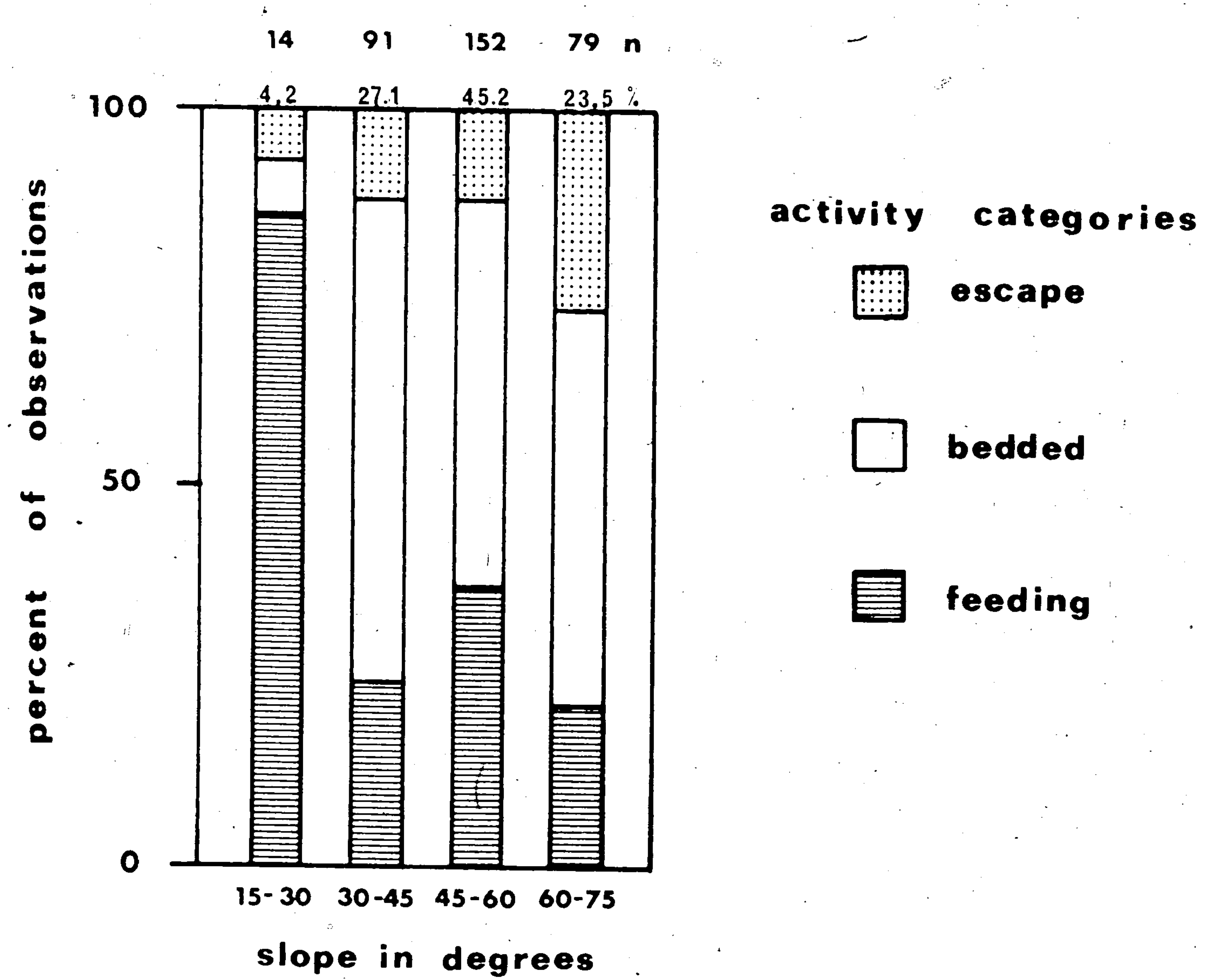
elevation interval (ft.)	nursery groups/total observations
3500-4000	0.17
4000-4500	0.40
4500-5000	0.58
5000-5500	0.56
5500-6000	0.67
6000-6500	0.78

Obviously nursery groups were seen more frequently at higher elevations than were the other segments of the population; however, the 4500-5000 interval was the modal elevation for both total and nursery group observations. There was very little variation in the proportion of escape observations at different elevations. The large value shown for escape activity by nursery groups at the lowest elevation interval, merely indicates that one of two observations were listed as escape. This probably does not represent the true activity of nursery groups at that elevation.

Activities of goats were not entirely random with respect to slope either. Figures 10 (total observations) and 11 (nursery groups) picture the proportional activities in each slope category. In each case foraging activity was much more frequent on the most gentle slopes. Bedded activity prevailed on other areas but there was very little change in the proportion of bedded activity from 30 degrees to 75 degree slopes. Escape activity was greatest on the 60 to 75 degree slopes. This was most notable among the nursery group observations. Almost 50% of the observations occurred on the 45 to 60 degree category. Very little difference was noted between the distribution of total observations and nursery group observations with respect to slope.

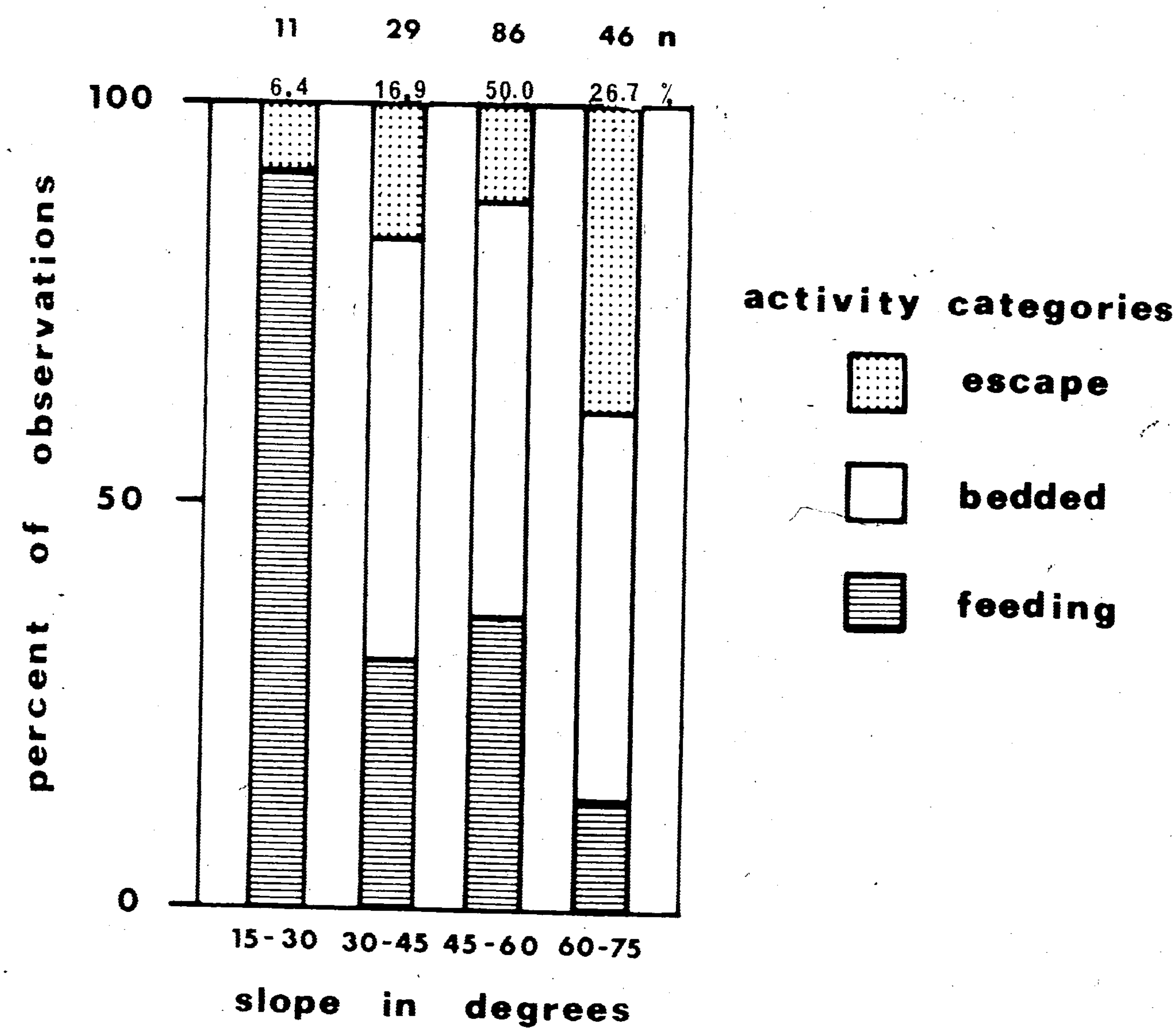
The activities of goats on each aspect should be considered in

Figure 10. Activity on each slope category (total observations).



14
91
152
79
n
4,2
27.1
45.2
23,5 %
100
50
0
percent of observations
15-30
30-45
45-60
60-75
slope in degrees
activity categories
escape
bedded
feeding

Figure 11. Activity of nursery groups on each slope category.


11
29
86
46
n
6.4
16.9
50.0
26.7
%
100
50
0
percent of observations
15-30
30-45
45-60
60-75
slope in degrees
activity categories
escape
bedded
feeding

terms of the effect that aspect has on other factors such as incidence of radiant energy, vegetation type or snow cover. Figures 12 and 13 suggest that radiant energy is an important factor in the selection of foraging sites since foraging activity was greatest on exposed areas and successively less on south, east and north-facing aspects where radiant energy was also reduced. West-facing aspects were uncommon on each area and were not used by nursery groups. There was very little difference between the distribution of total observations and nursery groups with respect to [illegible]bout 48% of the total observations occurred on east-facing aspe[illegible]small proportion of escape and bedded activity that was reco[illegible]exposed aspect may reflect the association of this aspect with high-elevation level areas. Other aspects did not vary substantially with respect to bedded and escape activity.

The relationship that was found to exist between the proportion of foraging activity of goats and the distance to the rock-gravel cover type is one of the most notable features of habitat selection by mountain goats. The relationship shown in figure 14 for total observations is not as pronounced as that shown for nursery groups (figure 15). Associated with the positive relationship with foraging was a negative relationship between bedded activity and the distance to the rock-gravel cover type. About 95% of all observations occurred within 400 meters of the rock-gravel cover type. There was no substantial difference between total observations and nursery group distribution with respect to the distance to the rock-gravel cover type. Escape activity was fairly uniform on all distance categories except that it was slightly greater on the rock-gravel areas.

Figure 12. Activity on each aspect (total observations).

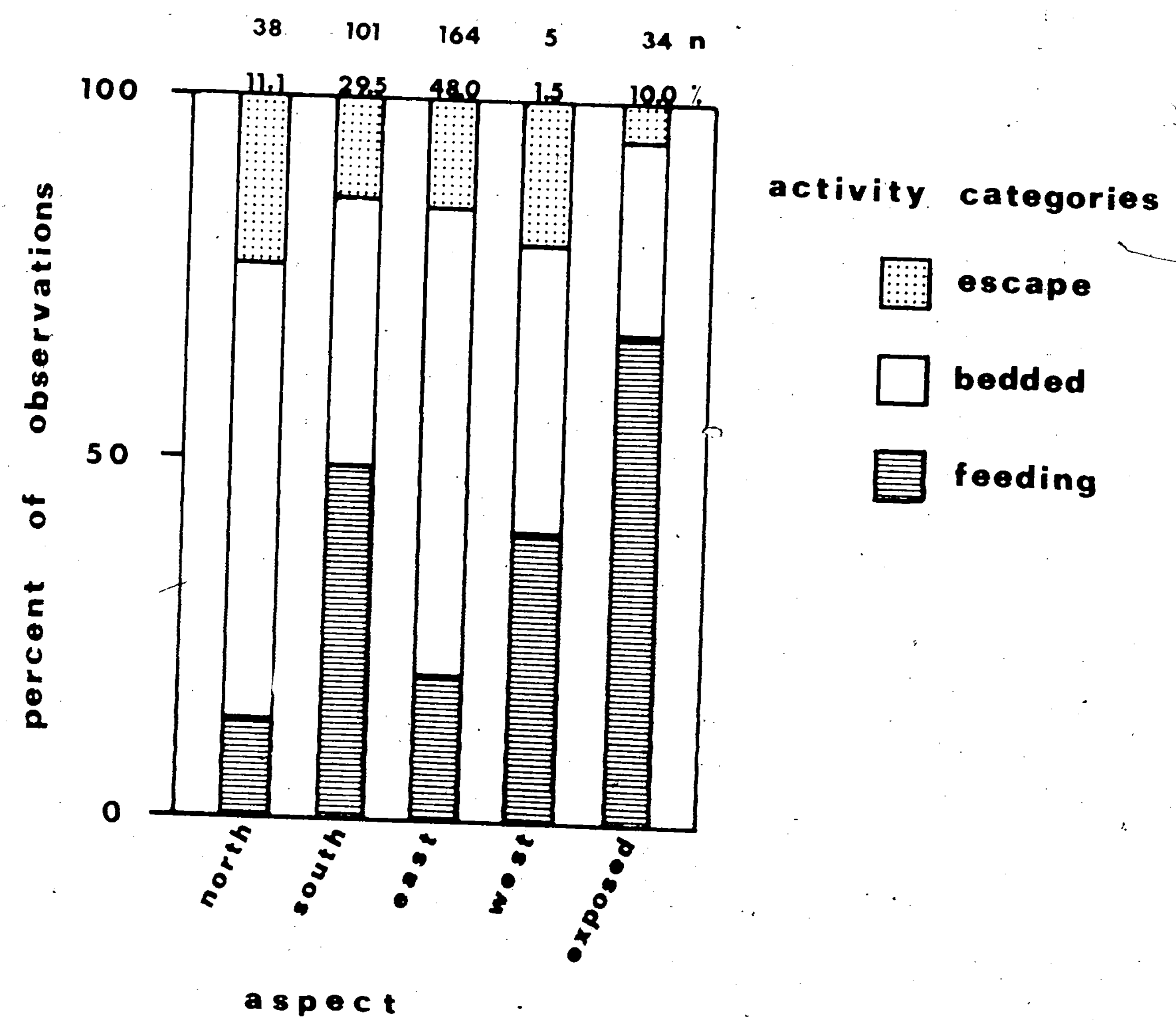
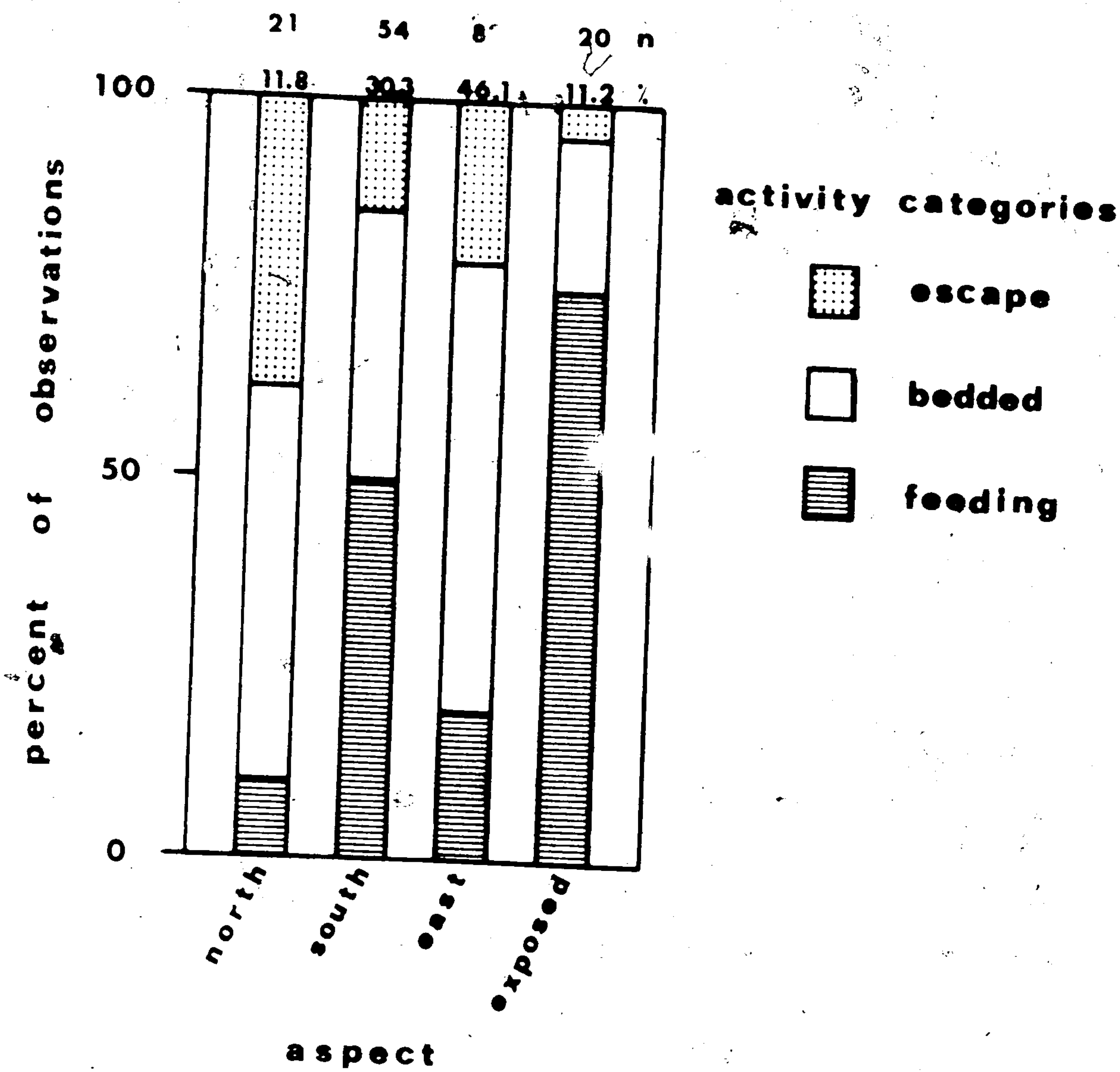

38
101
164
5
34 n
11.1
29.5
48.0
1.5
10.0 %
100
50
0
percent of observations
north
south
east
west
exposed
aspect
activity categories
escape
bedded
feeding

Figure 13. Activity of nursery groups on each aspect.



21
54
8
20
n
11.8
30.3
46.1
11.2
%
100
50
0
percent of observations
north
south
east
exposed
aspect
activity categories
escape
bedded
feeding

Figure 14. Activity at different distances to rock-gravel cover type (total observations).

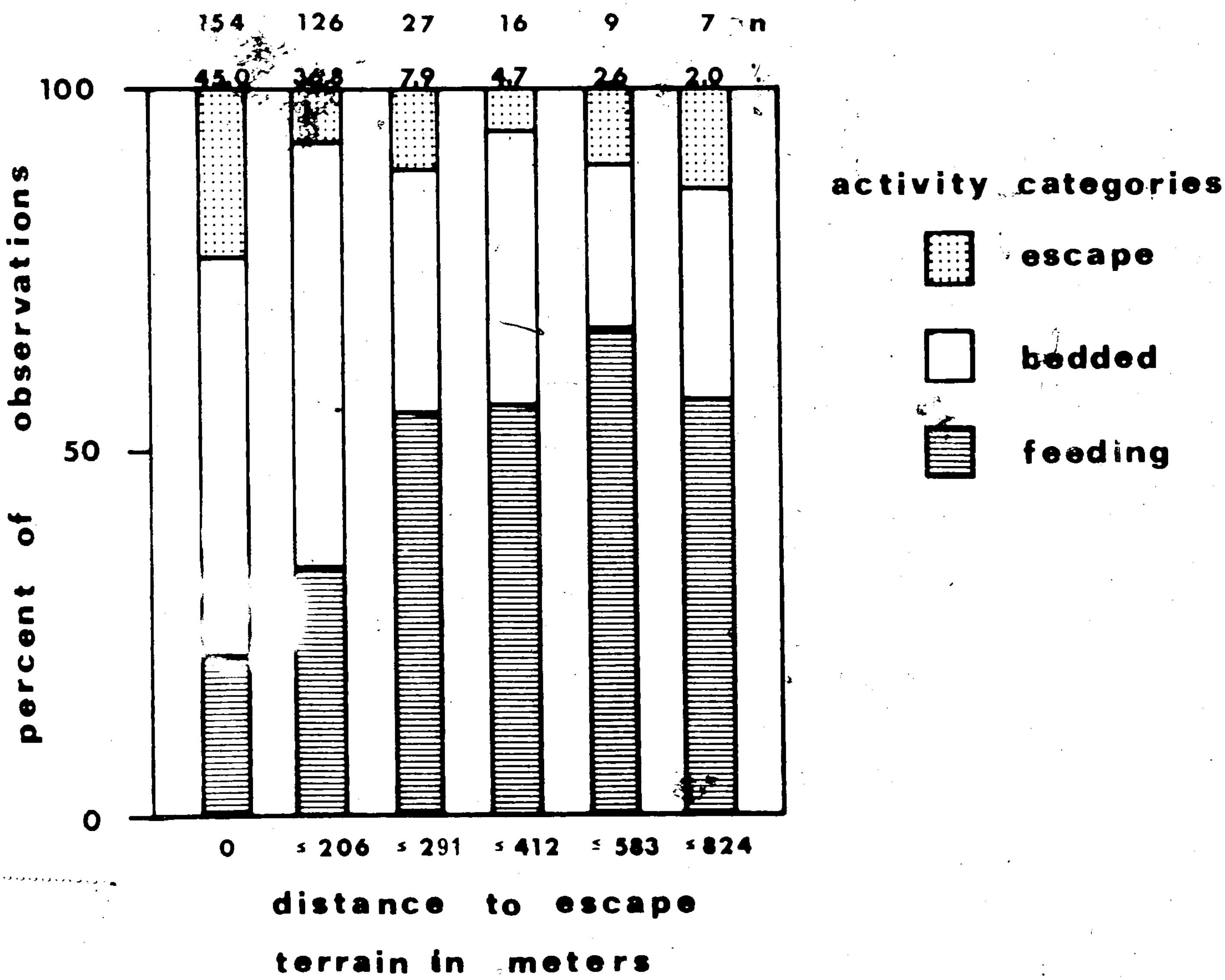
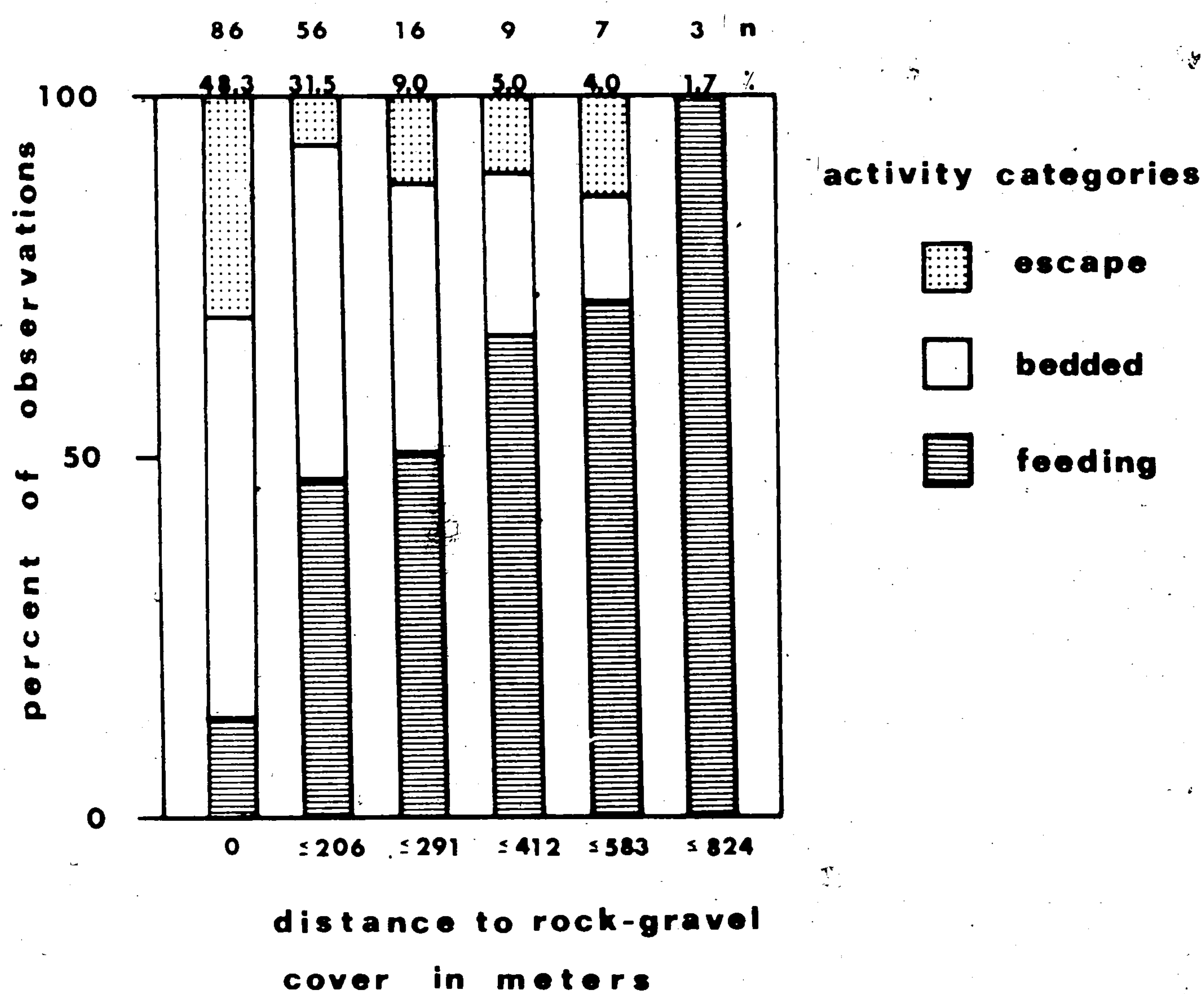

154
126
27
16
9
7
n
45.0
34.8
7.9
4.7
2.6
2.0
%
100
50
0
percent of observations
0
≤ 206
≤ 291
≤ 412
≤ 583
≤ 824
distance to escape terrain in meters
activity categories
escape
bedded
feeding

Figure 15. Activity of nursery groups at different distances from rock-gravel cover type.



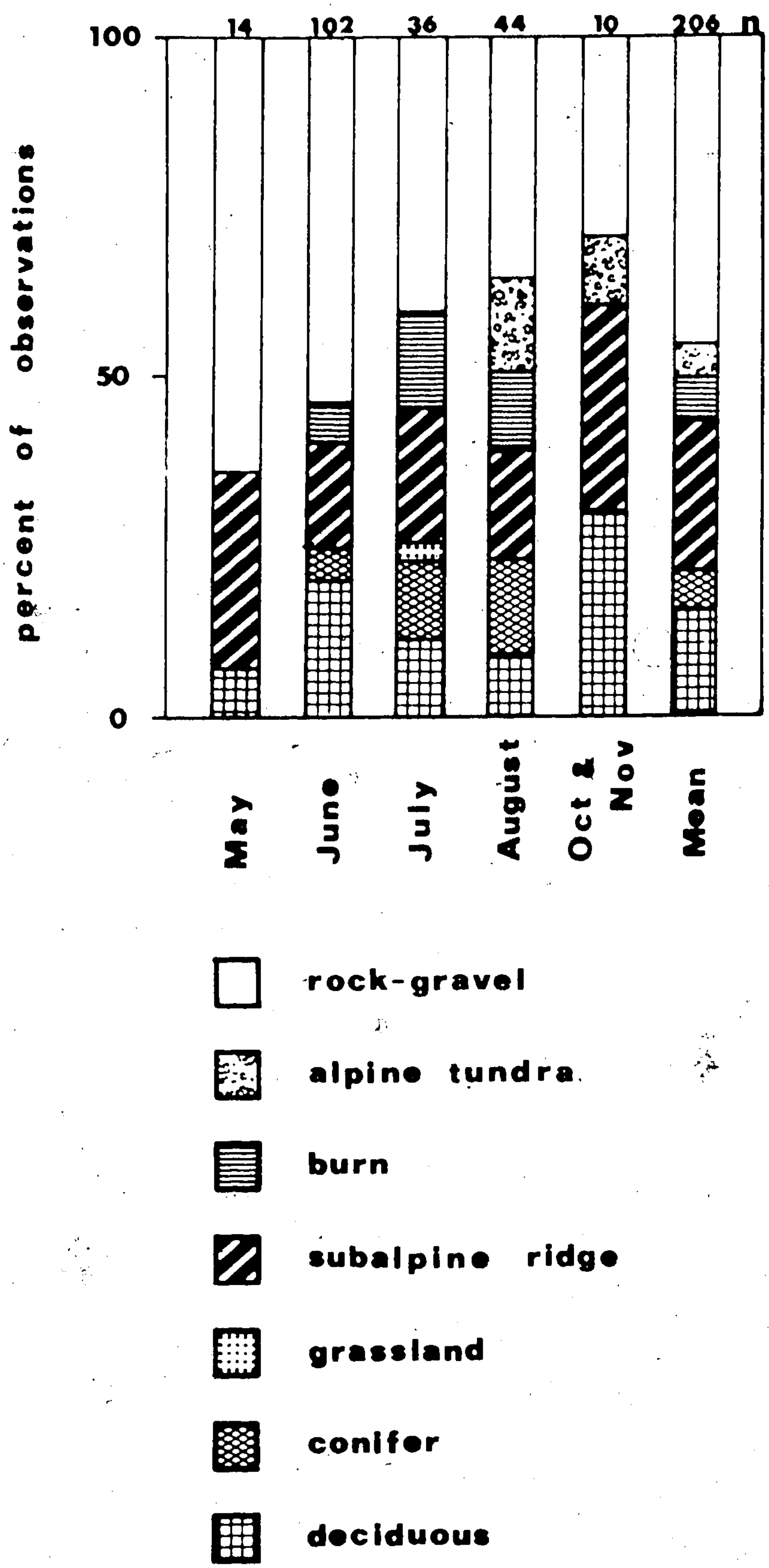
86
56
16
9
7
3
n
48.3
31.5
9.0
5.0
4.0
1.7
%
100
50
0
percent of observations
0
≤206
≤291
≤412
≤583
≤824
distance to rock-gravel cover in meters
activity categories
escape
bedded
feeding

Goat observations were divided into monthly intervals. Observations from all study areas and two years were combined to provide adequate sample sizes. Since observations were only recorded during the summer and fall periods, this examination does not extend to the complete annual cycle of habitat use by goats. Monthly intervals were chosen for convenience although they may not be the most significant intervals to represent seasonal differences in habitat use. The assumption is made in this section that variations in habitat preferences from month to month can be interpreted as reflecting changes in the biological needs of mountain goats that are associated with seasonal events such as parturition, growth and development of kids, the rut and changes in forage quality and availability. Comparison of habitat use by nursery groups and billies in this section provides a greater insight into their respective resource strategies. Variation in numbers of observations from one month to the next, reflects differences in field effort rather than a biologically significant factor.

A multivariate analysis of the seasonal response of goats with respect to habitat use is presented in appendix IV. This includes multivariate statistics, bivariate statistics and coefficients of preference that represent the relative preference for each category of the habitat variables, adjusted for interaction between variables, during each month.

The most significant seasonal changes in habitat use were associated with cover type, elevation and distance to the rock-gravel cover type. Seasonal trends in the use of different cover types of nursery groups were quite apparent (figure 16). Nursery groups

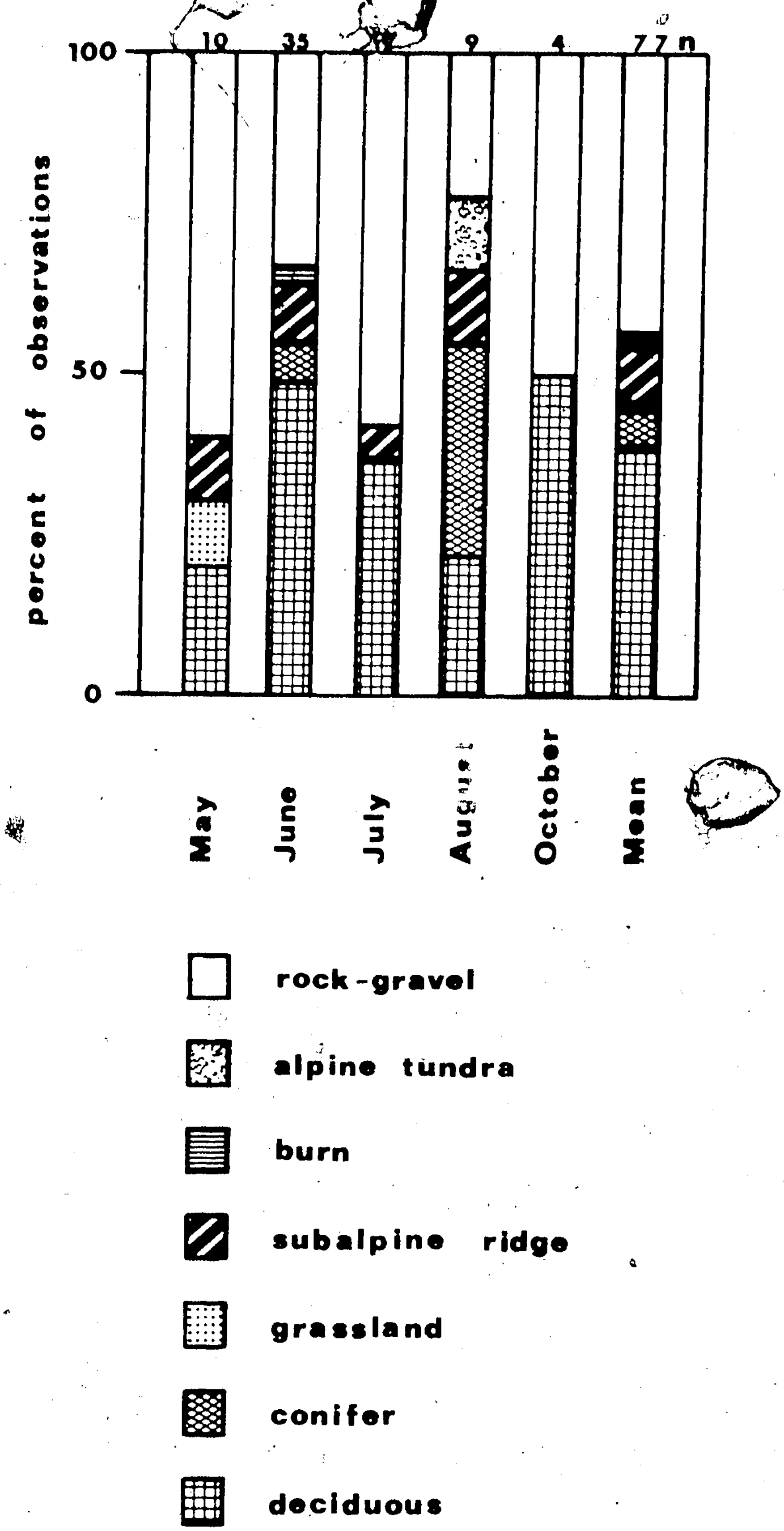
Figure 16. Seasonal distribution of nursery groups on each cover type.


14
102
36
44
10
206
n
100
50
0
percent of observations
May
June
July
August
Oct & Nov
Mean
rock-gravel
alpine tundra
burn
subalpine ridge
grassland
conifer
deciduous

showed a consistent decrease in the proportion of use on rock-gravel areas from spring to fall. Tundra type was used by nursery groups only in August and the fall period, and burn areas were used only in June, July and August. The subalpine ridge areas were used consistently throughout the year. Billies on the other hand (figure 17) showed much less seasonal variation in habitat use. The rock-gravel cover type was also a major habitat used by billies, but variation in the use of this type was used more frequently by billies than by nursery groups while the subalpine ridge was used less frequently. There was a marked shift by nursery groups to areas above 5000 feet from spring to fall (figure 18). The highest elevation category was used only by nursery groups in July and August. As indicated in an earlier section the majority of nursery group observations at higher elevations were associated with foraging activity. Billies showed a similar shift to higher elevations over the summer months (figure 19); however, the habitat used by billies was mostly at lower elevations than that used by nursery groups. The difference in elevations used by nursery groups and non-nursery groups was demonstrated in an earlier section. No use of the highest elevation category by billies was recorded. The lowest elevation category was used much more by billies than by nursery groups.

Nursery groups also showed a marked shift in habitat use during the summer with respect to distance to the rock-gravel cover type. The proportion of observations beyond 206 meters from the rock-gravel cover type increased up to August (figure 20). The most distant category (<583 meters) was used most frequently in August. These areas were not used in May or the October-November period. Changes that occurred

Figure 17. Seasonal distribution of billies on each cover type.



percent of observations
100
50
0
10
35
9
4
77
n
May
June
July
August
October
Mean
rock-gravel
alpine tundra
burn
subalpine ridge
grassland
conifer
deciduous

Figure 18. Seasonal distribution of nursery groups at each elevation interval.

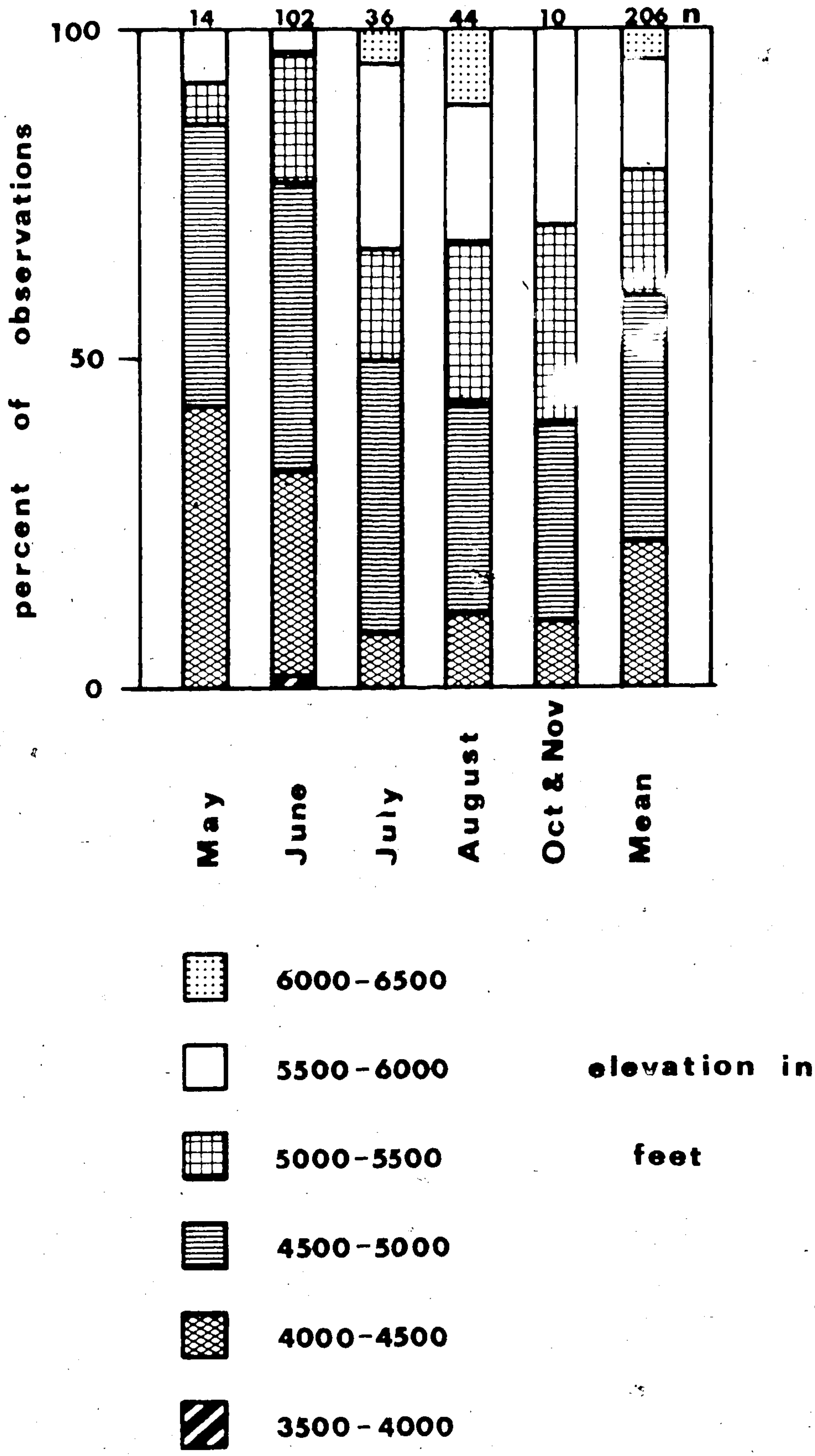
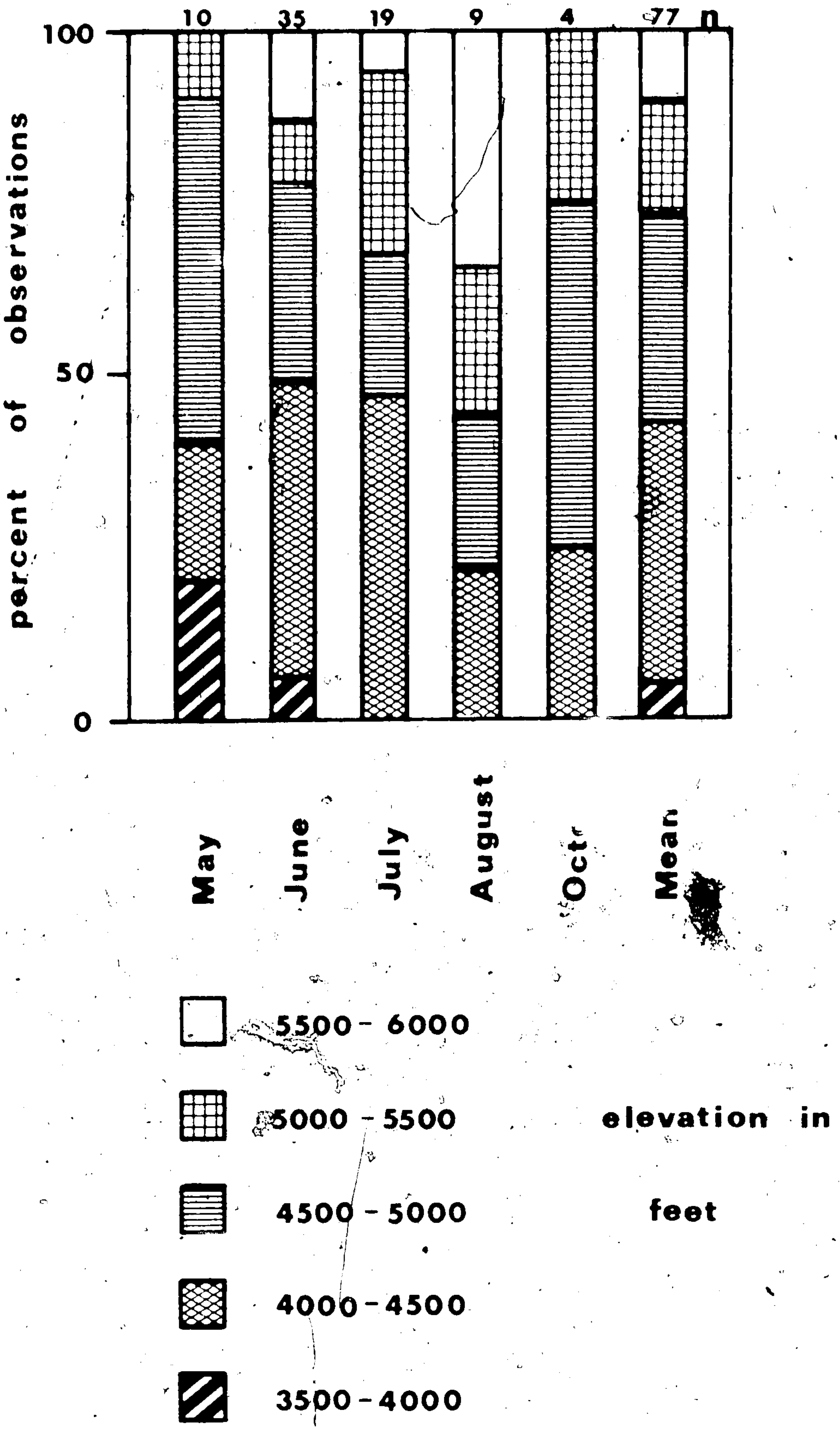
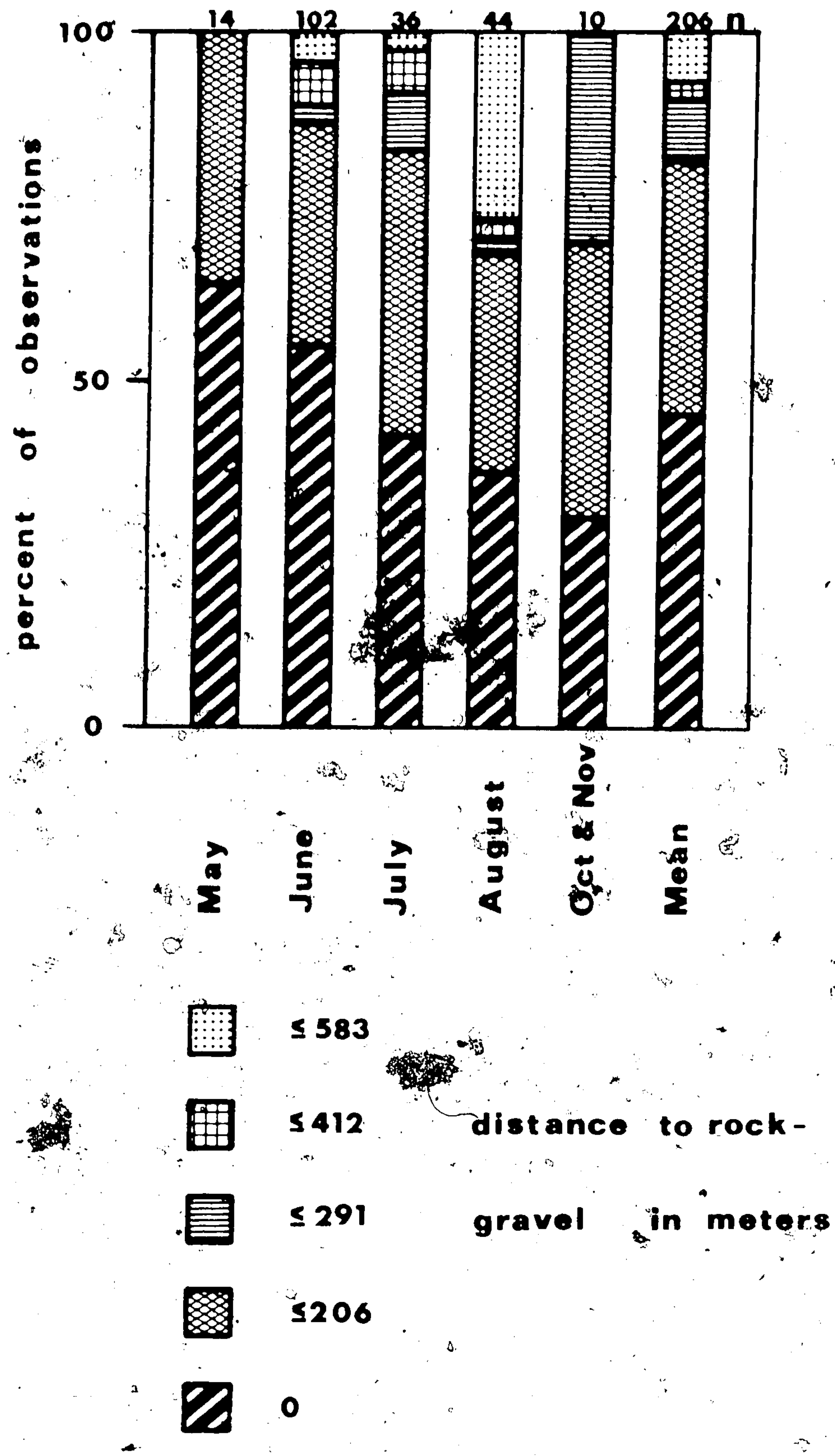

14
102
36
44
10
206
n
100
50
0
percent of observations
May
June
July
August
Oct & Nov
Mean
6000-6500
5500-6000
5000-5500
4500-5000
4000-4500
3500-4000
elevation in feet

Figure 19. Seasonal distribution of billies at each elevation interval.



10
35
19
9
4
77
n
100
50
0
percent of observations
May
June
July
August
Oct
Mean
5500 - 6000
5000 - 5500
4500 - 5000
4000 - 4500
3500 - 4000
elevation in feet

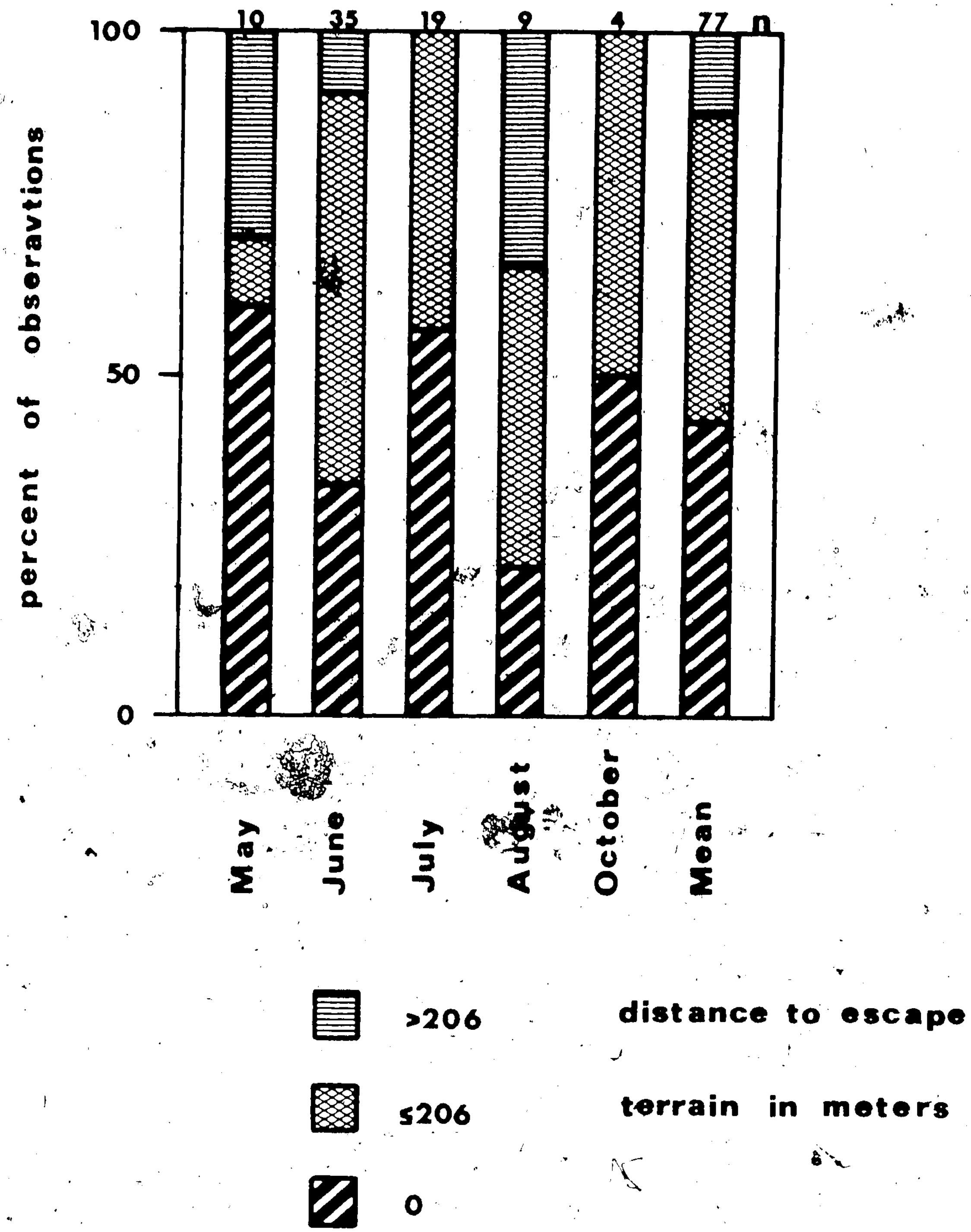
Figure 20. Seasonal distribution of nursery groups at different distances from rock-gravel cover type.



14
102
36
44
10
206
n
100
50
0
percent of observations
May
June
July
August
Oct & Nov
Mean
≤ 583
≤ 412
≤ 291
≤206
0
distance to rock-gravel in meters

in the seasonal habitat use by billies were irregular (figure 21). All observations beyond 206 meters were combined in figure 21 to provide adequate sample sizes. The decline in use of the rock-gravel cover type was not consistent throughout the summer. The greatest use of areas beyond 206 meters by billies occurred in August.

Figure 21. Seasonal distribution of billies at different distances from the rock-gravel cover type.

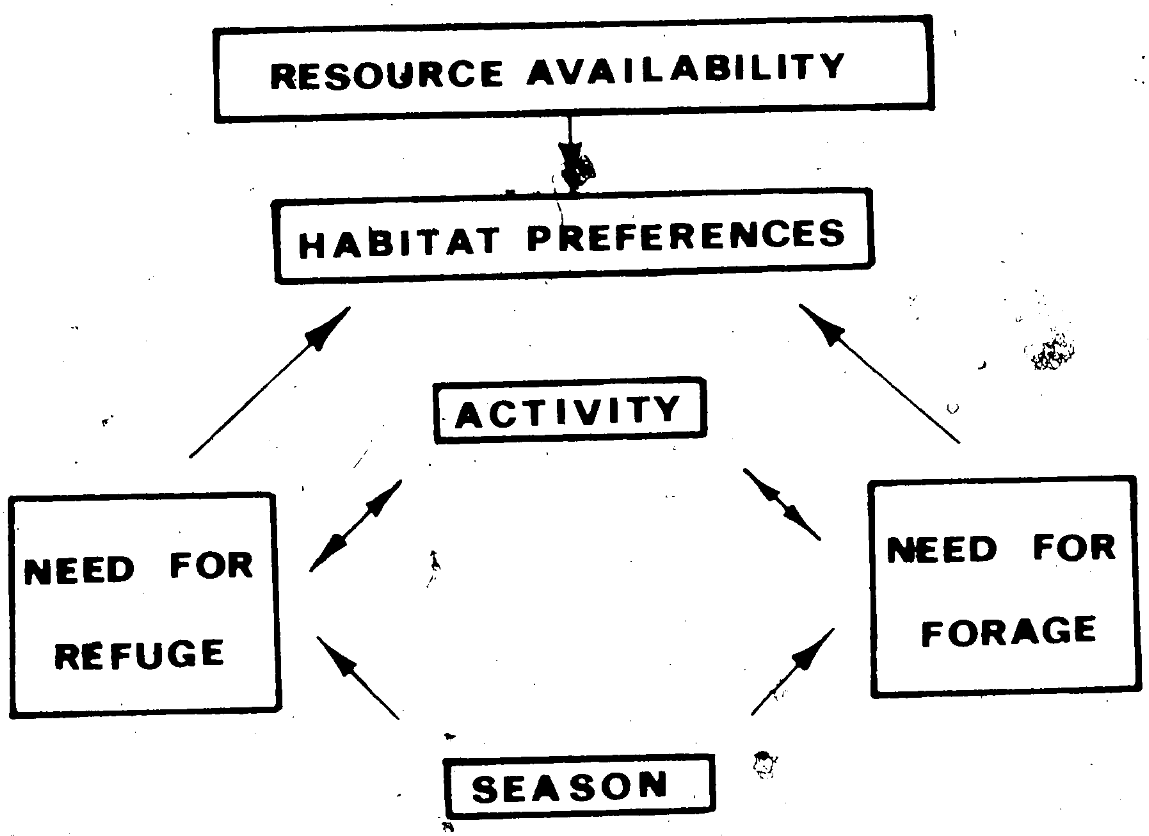


10
35
19
9
4
77
n
100
50
0
percent of obseravtions
May
June
July
August
October
Mean
>206
≤206
0
distance to escape
terrain in meters

The term "strategy of resorce use" is used here as a synonym for ecological niche; however the former is preferred in the present context because it emphasizes the active selection of environmental factors by goats. The idea of a strategy is helpful since it implies a flexible, complex niche in the sense of the multidimensional hypervolume discussed by Hutchinson (1975). This is particularly relevant in a variable and discontinuous habitat such as that occupied by mountain goats. The resource components of the niche have physical, biological and temporal dimensions.

It is apparent from the previous section that the habitat use and resource strategy of mountain goats is divergent between different cohorts of the population. The most consistent picture of resource use was that by nursery groups and it is those groups that I will be concerned with in most of this discussion. In figure 22 a simplified model of the strategy of resource use by mountain goat nursery groups is outlined. This represents my interpretation of the relationships of habitat use that were observed and recorded in this study. This model is based upon the dichotomy between the need for security and that for forage as factors determining habitat use. It might be argued that this dichotomy must be balanced against the existing level of predation. Although several terrestrial predators were present, no interaction with mountain goats were observed. Golden eagles were abundant and occasionally made threatening stoops at nursery groups. I would suggest that the requirement for security is reinforced by low levels of predation by terrestrial carnivores and that the refuge strategy of nursery groups is less effective against avian predators as large as eagles.

Figure 22. Factors influencing habitat preferences of mountain goat nursery groups.


RESOURCE AVAILABILITY
HABITAT PREFERENCES
ACTIVITY
NEED FOR REFUGE
NEED FOR FORAGE
SEASON

Previous investigations of mountain goats have dealt primarily with descriptions of the natural history and social behaviour of this species (e.g. Anderson 1940, Brandborg 1955, Casebeer *et al.* 1950, DeBock 1970, Holroyd 1967 and Kerr 1965). The recent "boom" in studies of habitat preference of various ungulate species has been in response to the recognition of the need for detailed information about the ecological preferences of each species. It is important to consider habitat characteristics that are directly selected by the animals under study, or at least factors that are closely associated with factors that may be selected. Forage composition and forage availability have frequently been considered as the most critical factors in habitat selection but this may not necessarily be true. Several authors (e.g. Chadwick 1973, and Geist 1971) have commented on the wide range of forage species used by mountain goats and thus vegetation types and forage preferences may not be a true reflection of habitat requirements. In the present study I have chosen five environmental variables that may be relevant to the resource strategy of mountain goats in these areas.

Activity

Based on the assumption that different activities of mountain goats satisfy different biological goals such as security and nutrition, it is of interest to consider the extent to which the habitat use associated with each activity overlaps that of other activities. Only in this way can we infer anything about habitat requirements without empirical testing. The obvious goal of feeding activity (although not necessarily the only goal) is a nutritional one. Bedding and escape activity were assumed to demonstrate elements of the need for security. Bedding was a sedentary activity associated with only one location at a time. Escape activity was difficult to classify and consisted of two phases. The first phase is the actual escape or fleeing activity to avoid a threatening stimulus. The second, a refuge phase, was achieved only when the goats reached secure terrain. The fact that the refuge phase is associated with a particular terrain is unique among North American ungulates to mountain sheep and goats. Phase one escape was mainly independent of habitat types since it occurred in response to human presence. Both phases of escape activity have been combined in this analysis since they were not differentiated in the field.

Cover type. Saunders (1955) classified feeding observations of mountain goats by habitat type and found that the sequence of preferences in decreasing order was: grassy slide-rock, ridge tops, alpine meadows, timber and cliffs. It is interesting to compare Saunders' statement that cliffs were seldom used for foraging to the observation in the present study that foraging on cliff areas occurred regularly.

In terms of the habitat selection model used in this section it is possible to apply subjective refuge and forage factors to each of the cover types considered. The rock-gravel cover type received the greatest use. Activities on rock-gravel imply that refuge is the primary goal of goats using this type. Foraging did occur but only as a small proportion of the use. Forage obtained on rock-gravel areas in this investigation may be an important contribution to the nutrient intake, in spite of the observations of Saunders. Subalpine ridge habitats were also preferred areas. Foraging was the prevalent activity, while bedding and escape were intermediate on this type. The close proximity of this type to the rock-gravel areas enhance the refuge factor of most areas classified as subalpine ridge. Consequently, I feel that refuge and foraging are equally attainable goals on this highly preferred cove type. Burn and alpine tundra are foraging areas that were were used infrequently. The large volume of forage on the burn habitats and the high quality of forage on the alpine tundra are major attractions of these types, but I feel that they were less secure due to the open, gentle slope characteristic of these areas. Deciduous forest was used less by nursery groups than by others. The high proportion of bedding activity on this type implied a high refuge value of deciduous cover for non-nursery group goats. Coniferous forest was not a major cover type for goat observations. I cannot explain why foraging activity is so prevalent on this type since most of these areas have very little suitable forage.

Elevation. To the best of my knowledge the relationship between activity of nursery groups and elevation shown in this study (figure 9) has not been previously discussed in the literature; however, it is unlikely that elevation is a factor that is directly related to activities of goats or their habitat selection. It may be that the increase in foraging by goats at higher elevations is an artifact of the topography. This relationship may not occurr on rugged-peaked mountains as opposed to the rounded ones in the Grande Cache area. This is an example of the potential local differences that may exist between the habitat selection of different populations. The presence of tundra and alpine meadows at the highest elevations may cause an inverse relationship between elevation and refuge potential, and a direct relationship with forage quality.

Johnston *et al.* (1968) showed that the palatability of forage was greater at higher elevations, thus the availability of higher quality forage may be a factor that directly encourages foraging (in spite of the lesser standing crop on the tundra cover type, table 5). Except for the lowest elevation category (where there were only 2 observations of nursery groups) the greatest proportion of escape observations were in the 5000-5500 foot interval. This interval is where the most suitable refuge terrain was situated.

Slope. Although only about 6% of nursery group observations occurred on slopes of less than 30°, more than 90% of these were foraging observations. Only on slopes of 30° or less was activity notably different from other slope categories. Foraging activity predominated on the more gentle slopes and escape activity was most prevalent on the steepest slopes. Slope may be an important factor to goats with respect to habitat security. The steepest slopes are frequently used as refuge sites that goats will flee to when disturbed. Nursery groups seem to forsake the security of steeper slopes (more than 30°) only for occasional foraging excursions.

Aspect. This is another habitat variable that is probably not directly selected by goats, but is associated with other factors that are more directly selected, such as local temperature, wind speed, snow cover or vegetation, all of which are probably directly determined by the amount of incident radiation received on each aspect. The exposed habitats at high elevation, possibly receive the greatest amount of radiant energy. South, east and north exposures receive proportionately decreasing foraging activity by nursery groups (figure 13). Bedding activity was low on exposed areas possibly due to the association of these areas with high elevation "low security" habitats. Bedding and escape activity were roughly equal on north, south and east aspects.

Distance to the rock-gravel cover type. Numerous authors have stressed the dependence of mountain sheep and goats on "escape terrain"; however, seldom has it been noted in the literature that the critical foraging areas are adjacent to such habitat and that as the distance to escape terrain increases, the probability that any group of goats is foraging also increases (figure 15). As indicated earlier, 95% of all nursery group observations occurred within approximately 400 meters of the rock-gravel cover type. This fundamental concept of mountain goat habitat selection may be the single, most important factor, limiting both distribution and population size of goat herds. If this concept can be applied to all or most goat populations, then the absolute amount of forage available to any herd is a function of the distance that they will travel from core areas of high security. Murie (1944, p. 142) noted that in the presence of heavy wolf predation, Dall sheep range was restricted to the rugged cliff areas, and that in the absence of wolves, the sheep range expanded onto much less secure habitat. Although predation was not a visible factor on habitat selection by goats in the present study, it is possible that a similar situation is in effect for goats. The total area used by goats, or the frequency of foraging excursions, might be reduced by the presence of heavy predation or regular interference by human activity at some time in the future.

Chadwick (1973) noted that over 95% of the bedded goats that he observed were on cliff areas. This complements my own observations that bedding was the most common activity on rock-gravel areas and that bedding activity decreased proportionately as the distance to rock-gravel cover increased.

Month

One objective of this study has been to determine how habitat selection by goats varies during an annual cycle. Because this investigation was conducted primarily during the summer, the emphasis in this sec-

[illegible] independence and physical [illegible]ification.

[illegible] summer has been widely documented and is supported by observations [illegible] In many cases, including this study, it would be question[illegible] this is a migratory shift since spring and summer range[illegible] [illegible] different [illegible]

[illegible] state that [illegible] the nutritional advantage to bighorn sheep [illegible] areas, described by Hebert (1973), may also apply for mountain [illegible] and that the partial coefficients for [illegible] distribution indicated that factors other than elevation [illegible] for the preference for higher elevation in summer, [illegible] that [illegible] quality forage available in the alpine was the [illegible] described a similar shift to alpine habitat [illegible] study.

[illegible] summer may be interpreted as [illegible] security and for [illegible] (Figure [illegible]). In the spring [illegible] have a high requirement for security because the [illegible] vulnerable, and are able to obtain their forage on or adjacent [illegible] slopes. Later in the summer, security is less [illegible]tial [illegible] activity is observed on less secure terrain to a much [illegible]er [illegible].

Since observations were not recorded during the winter months, [illegible] data on winter patterns of habitat selection by mountain [illegible] during that period I feel that forage availability with respect [illegible] becomes the foremost factor in habitat use, for[illegible] lower elevations when snow conditions are severe. During the winter of 1973-74, snow conditions were very severe, and deep snow drifts persisted at the higher elevations long into the summer. During this period snow conditions at the lower elevations were less restrictive to foraging. The following winter was an example of the other extreme. When I visited the study areas in February, there was very little snow at the highest elevations and the rest of the areas were bare of snow.

At this time goats showed little hesitation to use foraging ranges at higher elevations. Further investigation is necessary to document winter patterns of habitat selection by mountain goats.

RESOURCE DIVISION WITHIN THE POPULATION

Differential use of resources among segments of the same population has been described for a number of species. Morse (1968) discussed spatial partitioning of habitat between sexes of several species of spruce-wood warblers. He maintained that habitat partitioning ". . . offers a potential method by which a species might maximize its numbers in a density dependent situation." This statement may be rephrased as follows: Partitioning of habitat between sexes may allow a more efficient consumption of available resources. On the basis of observations in this study and others, it is possible that resource partitioning between nursery groups and non-nursery animals occurs during at least part of the annual cycle of foraging and habitat use as a method to reduce intraspecific competition. In an earlier section on resource use and habitat preferences, I demonstrated that the frequency of nursery group observations as opposed to non-nursery animals was dependent upon elevation during the summer months. This was by far the most notable separation of habitat use found in the present study.

There was apparently also a separation during the early summer months when pregnant females and nursery groups were using the steepest rock-gravel areas which adult billies and non-pregnant females seldom used. A similar situation was described by Crook (1970) in Gelada baboons (*Theropithecus gelada*) of Ethiopia. He found that these baboons live near canyons and sleep on the gorge cliffs where they are safe from predators (chiefly eagles and other baboons). During the dry season, when food shortages may become critical, all male groups tend to disperse away from canyons to a much greater extent than the harems. Crook suggests that this reduces competition for food between the two groups and results in a differential mortality that was less for members of the harems.

Numerous authors have noted that separate areas are occupied by the adult male cohort of mountain goats during most of the year (e.g. Chadwick 1973, Geist 1971, Hibbs *et al.* 1969 and Kerr 1965); however, Brandborg (1955) noted that this isolation of billies is not absolute. During the summer months, I observed that adult billies were occasionally found with nursery groups, particularly in the late part of August.

I feel that habitat partitioning may be appropriate as a resource strategy in a seasonally variable environment with a diverse array of resources that are abundant and of high quality for only a short period and where interspecific competition is absent or slight. Although physical dimorphism between sexes might be associated with resource partitioning, Morse (1968) suggested that this would be suppressed in order to retain the versatility necessary to respond to fluctuations in resource availability or to conditions on common winter ranges. Sexual dimorphism of mountain goats is apparently limited to body size and horn structure. It is also possible that habitat partitioning in mountain goats is not related to a resource strategy but rather is more closely dependent upon the social biology of this species (i.e. resource partitioning may be more important as a means of reducing social stresses than reducing resource competition).

COMPARISON OF RESOURCE STRATEGY WITH OTHER UNGULATES

The resource strategy of mountain goats is closely related to the habitat and topographic features of the ranges that they occupy. No other North American ungulate relies upon steep mountainous terrain to the extent that mountain goats do. The resource stategy of mountain goats is influenced by their requirement for that terrain in association with foraging ranges. This presents special problems that differentiate goats from other North American ungulate species including mountain sheep. Mountain goats may spend their life span within a small area (perhaps no larger than the present study areas, 25 km^2) seldom moving beyond their home range and seldom violating an annual cycle of habitat selection and resource use described by elevation, distance to rock-gravel terrain and the availability of forage. If the data related to seasonal changes in fecal crude protein content reflect a normal situation in mountain goats, then it must be critical for goats to obtain new growth forage with a high protein content during May in order to restore a depleted nutritional status. I suggest that this is a major factor, as is their critical need for refuge terrain, that enforces a sedentary life-style in this species. Sedentary behaviour enhances reliable foraging patterns on an annual basis and familiarity with refuge areas. Factors such as group instability, range deterioration or harassment may account for examples of extensive movements by goats; however, there are also certain situations in which mountain goats use larger home ranges. In these cases, there are probably much more extensive habitats available than was the case in the present study.

Estes (1974) discussed the change in social structure associated with the radiation of African bovids from forest to savanna habitats. The development of a gregerious social system is argued to be prerequisite to the development of a resource strategy associated with open spaces. In North America, ungulates occupy three generalized ecosystems: forest, plains and mountains. They usually display resource strategies and social systems developed for each of these ecosystems. Comparing North American ungulates Klein (1970) noted that mountain sheep occupy a relatively stable community and appear to have behavioural mechanisms to stabilize population fluctuations, while cervids that are found in more transitory habitat such as ecotone communities and seral stages or second growth communities, are often subject to more severe population fluctuations. Although Klein appears to have over-looked many examples of severe population fluctuations in bighorn sheep in North America, stable populations may be characteristic of mountain goats, which to my knowledge have not experienced major fluctuations in any areas. Chadwick (1973), speaking of mountain goats, felt that "increased aggressive interaction and instability of large groups might act to limit population growth and help to disperse herds onto different ranges."

Table 8 compares some of the contrasing features of mountain bovids in North America. The response of Dall sheep of expanding their home ranges in the absence of predation (noted earlier in reference to Murie 1944) reflects a more opportunistic behaviour than that of goats. The use of several widely dispersed home ranges during different seasons by mountain sheep also demonstrates a greater degree of opportunism than is common to mountain goats. On the other hand mountain goats may be considered to have an obligate resource strategy since they are more dependent on familiarity with refuge areas and maintain a more restricted home range

Table 8. Contrasting features of North American mountain ungulates; *Oreamnos* and *Ovis*.

Oreamnos	*Ovis*
adult billies solitary or in pairs; relatively incompatable with nursery groups; psuedo-subordinate status (Chadwick 1973)	adult rams commonly in bachelor herds; form a dominance hierarchy
sexual dimorphism reduced	sexual dimorphism pronounced
usually sedentary	migratory; at least two seasonal home ranges (Geist 1971)
obligate resource strategy	opportunistic resource strategy

than do most sheep. Chamois *(Rupicapra rupicapra)* and ibex *(Capra ibex)* in the Swiss Alps ha[illegible] een reported (Kramer 1969) to have a very sedentary life style, suggesting sim[illegible]larities with mountain goats in regard to their resource strategies.

It would be of interest in an academic sense to compare the resource use and social systems of North Ameri[illegible]an mountain bovids t[illegible] a wider range of Asian and European mountain bovids, to te[illegible] the principles mentioned in this section. Unfortunately, I have been unable to find references that describe the habitat oriented behaviour of s[illegible] ies such as Himalayan thar *(Hemitragus jemlahicus)*, goral *(Naem[illegible]rhedus sp.)* and serow *([illegible]ricornis sp.)* that are also adapted to mountainous environments. Obs[illegible] vations of these species might limit the generality of observations in this study.

INFLUENCE OF HUMAN ACTIVITIES ON THE RESOURCE STRATEGY OF MOUNTAIN GOATS

In Alberta, mountain goats have maintained a remote existence and consequently have not been subjected to excessive habitat loss or harassment. However, several populations may now be threatened by a variety of human activities that are becoming more and more common in remote areas. Foremost among these are exploration for, and extraction of non-renewable resources. I feel however, that with suitable range management and conservative land use policies, serious harm to goat populations can be avoided. In some situations, it may be appropriate to restore goat populations after reclamation of disturbed areas that previously supported goats. Consequently, it is important to have a detailed concept of goat habitat preferences. In this section, I have speculated on the effect of various human activities on the resource use by mountain goats, particularly with respect to the factors that I have discussed in previous sections.

Development of Non-renewable Resources

Deposits of coal reserves in the East Slopes region of Alberta are closely associated with several goat ranges. The decision about development of these reserves will have a profound impact on Alberta's economic situation and therefore we should anticipate that development will occur in spite of the impact this may have on goat populations. There are three phases of resource development that must be considered with respect to the effect on the resource strategy and ultimate population status of mountain goats. These are exploration, extraction and reclamation. The latter will be discussed under the following section on recommended management policies.

Exploration activities may only have a short term impact by causing temporary abandonment of traditional ranges. As a consequence, a reduction in kid crop or an increase in mortality during a single year or a series of consecutive years may be expected. The total effect of exploration activities would vary with the nature and extent of the activities involved. Road construction and vehicle traffic adjacent to goat ranges would have a substantial impact. Blasting and aircraft activity may also be consequential if prolonged. Extensive activity for three or more consecutive days may have a short term negative impact. During May and June, exploration activities on or adjacent to refuge areas where kids are born would have the most severe impact. After June exploration activities may result in temporary abandonment of optimum foraging ranges but would have little impact on herds that have access to alternate foraging areas.

Since development activities may be expected to endure for much longer periods of time than exploration, they will have a long term impact on environmental conditions and there is very little that can be done to reconcile this impact until extensive reclamation has been completed. When resource development overlaps goat range, the impact on the resident herd may be severe, particularly if a core refuge area is disturbed. Development on peripheral foraging areas may cause a shift to secondary foraging areas if these exist or may result in a more intensive use of the remaining undisturbed areas. Development adjacent to or within visual range of goat habitat may have no direct impact; however, in the long run, subtle factors associated with extraction may be severe. I know of no comprehensive [illegible] mountain goats to [illegible] development [illegible] that [illegible] and [illegible] national parks. [illegible] are quite [illegible] of human presence and highway traffic. On the Goat Cliffs, [illegible] clear view of the preparation plant on the [illegible] River. They were constantly subject to low volume noise from the plant that was [illegible] 1.5 km from the closest part of the goat range and about 6 km from the main ridge of the Goat Cliffs. The goats here apparently have habituated to industrial development that is adjacent to their range but does not actually overlap their range.

It is very difficult to monitor the more subtle [illegible] associated with resource development such as increasing harassment from all-terrain vehicles, aircraft and poaching. In 1976, I found two goats that had been shot by poachers on the Goat Cliffs. Activities such as this are probably not uncommon in areas with developed road access.

In July 1976, the Minister of Energy and Natural Resources issued a coal policy for the province of Alberta. In this statement, the public was assured that no development of coal reserves would proceed unless the government was satisfied that it could be done without irreparable harm to the environment. Coal bearing lands were divided into four categories with respect to potential development. These were: a) wildlife sanctuaries, wilderness areas and provincial parks where no development or exploration would be approved, b) zones where surface mining would not be permitted at the present time, but exploration will be allowed, c) zones where exploration and surface mining would be allowed subject to specific environmental measures and reclamation requirements, d) areas not included in the above categories.

[illegible] Government of Alberta [illegible]

[illegible] in wilderness regions and [illegible]

[illegible] populations in these areas [illegible]

[illegible] trails may provide access [illegible] and [illegible]

[illegible] demand [illegible]

[illegible] used by goats and [illegible] trails [illegible]

[illegible] direct impact [illegible]

[illegible] areas and [illegible]

[illegible] levels. [illegible]

[illegible] previously [illegible]

[illegible] pattern [illegible] resource [illegible]

[illegible] probable that [illegible]

all terrain vehicles [illegible]

could impair the resource use by mountain goats.

There is no indication that the [illegible]

mountain goats has had a detrimental effect [illegible]

Willmore Wilderness Park. A summary [illegible]

in Appendix E. This hunting season has been [illegible]

overkill by maintaining a regular inventory [illegible]

[illegible] the harvest is distributed throughout the [illegible]

[illegible] season lasts for [illegible] days [illegible] September [illegible]

[illegible] causes only a short period [illegible] in the normal pattern [illegible]

[illegible] selection during a [illegible]

and early enough that it does not interfere with the rut in November

and December.

[illegible]

[illegible] research activities of government agencies, environmental [illegible] firms and academic institutions have an impact on the [illegible] mountain goats. This is particularly true of aerial [illegible] with helicopters that are capable of following goats [illegible] surveys of this nature can be one of the most stressful [illegible] goats. It is not unusual for goats to be injured [illegible] attempting to escape from a helicopter hovering above them. [illegible] trapping and drugging procedures cause signif[illegible] Intensive activities of this nature may result [illegible] desertion of preferred ranges. Single incidents of helicopter [illegible] may result in short term changes in patterns of habitat use. These methods are a crucial part of management and research procedures. They should be used under the supervision of experienced personnel in a manner that will cause the least stress.

The effect of non-manipulative ground research would not be much different than that by recreational users, but potentially would be less [illegible], assuming that a regular observer would become familiar enough with his research animals to obtain information with a minimum of interference to the animals that he is working with.

RECOMMENDED GOAT MANAGEMENT POLICIES

In Alberta there are approximately 1000 to 1200 mountain goats outside the national parks spanning a distance of about 480 km from [illegible] in the south to Caw Ridge in the north. Approximately one half of these are located in the Willmore-Grande Cache area. The management of mountain goats by the Fish and Wildlife Division has been successful in recognizing and halting the rapid decline that was occurring on particular ranges due to overharvesting in areas with easy access. The new priority for mountain goat management should be to ensure that adequate habitat is retained and to provide convincing arguments at legislative levels that protection of goat ranges should take priority over development of non-renewable resources. The Environmental Conservation Authority (E.C.A.) has indicated that surface mining for coal is in conflict with every other land use in the East Slopes (1974,p.92). They have also made a number of recommendations regarding land uses in the East Slopes based upon input from public hearings held across the Province. The highest priorities in these recommendations were wildlife, the maintenance of wilderness areas for recreational uses and sustained use of renewable resources in general. The E.C.A. also recommended (p.120) "that the Eastern Slopes be zoned for land use and resource development... and that land use priorities be built into the zoning system."

The management policy of the Alberta Fish and Wildlife Division should include a mechanism to provide reliable information about mountain goat habitat use upon which zoning and development restrictions can be based. This already exists to a large extent since the information required varies only slightly from that required to manage populations for hunting. The difference is that the emphasis should be on habitat use rather than population fluctuations. Based upon findings in this study, it should be possible to define with greater certainty the limitations of mountain goat ranges and to specify how a particular group of goats will respond to disturbance of all or a portion of their preferred range.

A number of specific projects could be conducted to assist in the land zoning process and preparation of a set of reclamation recommendations. The present study is limited by the fact that habitat use was examined in two areas of similar conditions. It could be that extrapolation of conclusions from this study to other areas is not valid. For this reason, there would be value in follow up the present study with a similar one in a different area in order to obtain comparative data on habitat use in a variety of situations.

One major project that would be of great value with respect to ameliorative procedures would be an investigation of reclamation activities in a variety of habitats. I feel that it would be extremely helpful if the Fish and Wildlife Division could prepare a list of recommendations for reclamation of wildlife ranges subject to disturbance by resource development. Topics to consider would include landscaping, revegetation, fertilizing and restocking native wildlife species. With particular reference to reclamation of goat ranges there is much to be determined. It is very possible that proper landscaping after surface mining may greatly improve an area for mountain goats by expanding refuge areas. This may in fact be a very inexpensive form of reclamation since little or no revegetation is necessary. However, it would be necessary to establish the proper conformation of such areas with respect to slope, structure and stability for optimum refuge for goats.

The problem of restocking mountain goats has already been tested by the Alberta Fish and Wildlife Division at Shunda Mountain near Nordegg. Experience gained from this initial project may be of considerable value for the future restocking of reclaimed habitats. Although Shunda Mountain previously supported mountain goats and was still believed to be suitable habitat, (Quaedvlieg *et al.* 1973) the goats transplanted to that site have been slow to reproduce. Future projects might include maintaining a captive or enclosed herd that is artificially maintained specifically for the purpose of restocking depleted areas. Improvement of methods for capture, handling and nutritional information will also be of value in this area.

Reclamation information is only of value in the event that development activities are permitted on goat ranges. The fact that reclamation procedures are largely untested on most habitats occupied by goats leaves much room for experimentation.

Successful management of mountain goats in recent years has been due to regular monitoring of populations and their distribution within the hunted zones and the fact that the hunting season is closely regulated through mandatory registration of all hunters at field check stations. There is no reason why this system should be discontinued as long as populations are maintained at their presently high level within the Willmore Wilderness Area and intensive monitoring is continued.

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Appendix A. Lungworm Infection

The information presented in table A1 was obtained by T. Cooley, (Cooley, T.M. 1976. Lungworms in Mountain Goats. MSc. thesis, Colorado State University, Fort Collins.) from fecal samples collected by myself. Although the incidence of lungworm infection was very high, the larval output was usually low. Cooley found two species of lungworms; these were *Protostrongylus stilesi* and *P. rushi*.

Table A1. Summary of *Protostrongylus* larvae in fecal samples.

	Hamell	Goat Cliffs	Grande	Caw Ridge
numbers of samples	100	76	4	14
mean larvae/gram	2.13	3.60	1.23	14.88*
percent infected	72	78	100	93

* This becomes 0.66 when two kid samples are omitted.

Appendix B. ESCAPE

ESCAPE is a program written for a fortran G compiler to search for the closest point of rock-gravel cover for each location on the study area grid and to calculate the straight line distance between those points. The input for the program is a matrix of cover type codes that includes a code for rock-gravel (in this case it is 7). The output is a matrix (escape) of equal dimensions that reveals the shortest distance of each grid location to rock-gravel cover. Those locations that are classified as rock-gravel are also listed as 0 distance to rock-gravel in the output matrix.

Modification of the program is required to specify matrix size, codes for rock-gravel and the distance between grid points. Matrix dimensions are specified in statements 5 (columns = S) and 6 (rows =K). The rock gravel code is specified in the conditional statement 12 as the value of the logical function. The distance between grid points is used in statements 22 and 23 (in this case it is 206 meters).

The statement function HYPOT is used to compute the straight line distance between two points. The input required for this function are two values A and B that are equal to the short sides of a right angle triangle between these two points.

The matrix of cover type codes is read in and called AREA with dimensions (L,M). SEARCH is another matrix that includes the coordinates of the points in AREA that are coded for rock-gravel. T is a counter used to determine the number of coded locations in search.

The smallest value of HYPOT (A,B) for each of the locations specified in SEARCH ~~is~~ assigned to LEAST, and subsequently to ESCAPE (L,M) for each location in ESCAPE.

```
LST ESCAPE
      IMPLICIT INTEGER (A-Z)
      REAL HYPOT
      INTEGER AREA([illegible]),SEARCH([illegible]),ESCAPE([illegible])
      HYPOT(A,B)=SQRT(A**2+B**2)+[illegible]
      J=12
      K=10
      READ(1,1)((AREA(L,M),L=1,J),M=1,K)
    1 FORMAT(12I1)
      [illegible]
      DO 2 M=1,K
      DO 2 L=1,J
      IF(AREA(L,M).NE.7) GO TO 2
      SEARCH(Q,1)=L
      SEARCH(Q,2)=M
      T=Q
      Q=Q+1
    2 CONTINUE
      DO 4 M=1,K
      DO 4 L=1,J
      LEAST=100000
      DO 3 Q=1,T
      A=(L-SEARCH(Q,1))*2[illegible]6
      B=(M-SEARCH(Q,2))*206
      IF(HYPOT(A,B).GE.LEAST) GO TO 3
      LEAST=HYPOT(A,B)
    3 CONTINUE
    4 ESCAPE(L,M)=LEAST
      WRITE(4,5)((ESCAPE(L,M),L=1,J),M=1,K)
    5 FORMAT(' ',12I5)
      STOP
      END
END OF FILE
```

Appendix C. [illegible] Habitat Selection Analysis

I used a test called Multivariate Nominal Scale Analysis (MNA) which is included in the OSIRIS III package at the University of Alberta Computing Services Center. This test is specifically designed to [illegible] multivariate relationships between nominal scale variables [illegible] type, aspect or activity, by converting coded values for each category into dummy values. MNA provides a variety of information in the printout for each run, not all of which has been used here. Greater detail about the use and interpretation of MNA is available in: Andrews, F.M. and R. C. Messenger 1973. Multivariate Nominal Scale Analysis. University of Michigan, Ann Arbor.

MNA was used to test the relationships between the dependent variable, activity and the series of habitat parameters that were discussed earlier in this text. Although MNA has been designed to account for interaction between independent variables, perfectly overlapping categories such as 0 distance to rock-gravel and the rock-gravel cover type cannot be handled by this test. For this reason it was necessary to make two separate runs: one that included cover type as a dependent variable and one that included distance to rock-gravel. A second alternative was to delete all observations on the rock gravel and include both cover type and distance to the rock-gravel cover as dependent variables. The second alternative reduced the sample size by almost one half and consequently the results are questionable; however, the values obtained from this method [illegible] been included in tables C1 and C2 for comparison. Observations from both study areas and both years have been combined to provide the maximum sample size.

Table C1 lists the R^2 values and multivariate theta [illegible] for each test. These values are indicative of the predictive [illegible] derived from each model used in these tests. The multivariate theta is equal to the proportion of observations that may be correctly [illegible] for activity on the basis of the habitat parameters at that site. This value may be compared to the modal category in order to determine the prediction improvement by each model. The values of R^2 [illegible] theta do not suggest a strongly predictive relationship between [illegible] and habitat parameters; however, this does not [illegible] important trends do exist. The low values of R^2 and multivariate theta may be due in part to the nominal characteristics of [illegible] their subjective determination or even more likely that relationships between habitat and activity are non-linear.

Category specific R^2 values (also in table C1) demonstrate the strength of relationship between each activity and the habitat variables. Invariably, the highest values of R^2 were obtained for nursery group observations suggesting that a stronger relationship exists between habitat types and the activity of nursery groups than for the [illegible] as a whole.

The values of generalized eta-square are shown in table [illegible]. These are analagous in a bivariate sense to R^2 in a multivariate sense and indicate the strength of association between goat activity and each habitat variable. Elevation consistently gave the highest values of eta-square, particularly for nursery groups.

Figures C1 to C10 show the actual and adjusted per cent of each activity category for each category of the habitat variables. [illegible] derives adjusted percents by accounting for interaction between habit[illegible] descriptor variables and assumes that other variables remain constant when calculating adjusted percents for each category of a habitat variable. Since two tests were run for each model, two sets of adjusted percents were obtained: one adjusted for cover type and one adjusted for distance to rock-gravel as well as the other habitat variables. Of course, there was only one set of adjusted percents for cover type and distance to rock-gravel. The actual percents included in these figures were presented earlier in this text and are included again in this appendix for comparison to the adjusted percents. Substantial differences between actual and adjusted percents suggest that there is interaction between habitat descriptors and that the activity observed with respect to a particular category may actually be determined or influenced by other factors.

Table C1   Multivariate relationships between habitat parameters and mountain goat activities.

descriptors#	VALUES OF R^2 generalized	feeding	bedded	escape	mode(%)	multivariate theta	n
C E S A	0.1912	0.2365	0.1872	0.1204	52.63(b)*	0.6082	342
C E S A (N)	0.2790	0.4223	0.2106	0.1838	46.63(b)	0.6517	178
C E S A D	0.2783	0.2640	0.3184	0.1858	50.82(b)	0.6940	183
C E S A D (N)	0.3529	0.3345	0.4020	0.2648	52.75(f)	0.7582	91
E S A D	0.1737	0.2374	0.1585	0.0935	52.63(b)	0.6404	342
E S A D (N)	0.2755	0.4230	0.2037	0.1801	46.63(b)	0.6629	178

C cover, E elevation, S slope, A aspect, D distance to rock-gravel, N tests including nursery groups only; * letter in parenthesis indicates the modal activity (b bedded, f feeding).

Table C2. Bivariate relationship between each habitat parameter and mountain goat activities, using generalized eta-square (MNA).

descriptors*	cover	elevation	slope	aspect	distance
C E S A	0.0837	0.0988	0.0605	0.0948	
C E S A (N)	0.1272	0.1309	0.1030	0.1216	
C E S A D	0.1103	0.1670	0.0884	0.1289	0.0467
C E S A D (N)	0.0535	0.1631	0.0995	0.0915	0.0505
E S A D		0.0988	0.0605	0.0948	0.0544
E S A D (N)		0.1309	0.1030	0.1216	0.1266

* C cover, E elavation, S slope, A aspect, D distance to rock-gravel, N tests including nursery groups only.

Figure C1. Activity on each cover type (total observations).

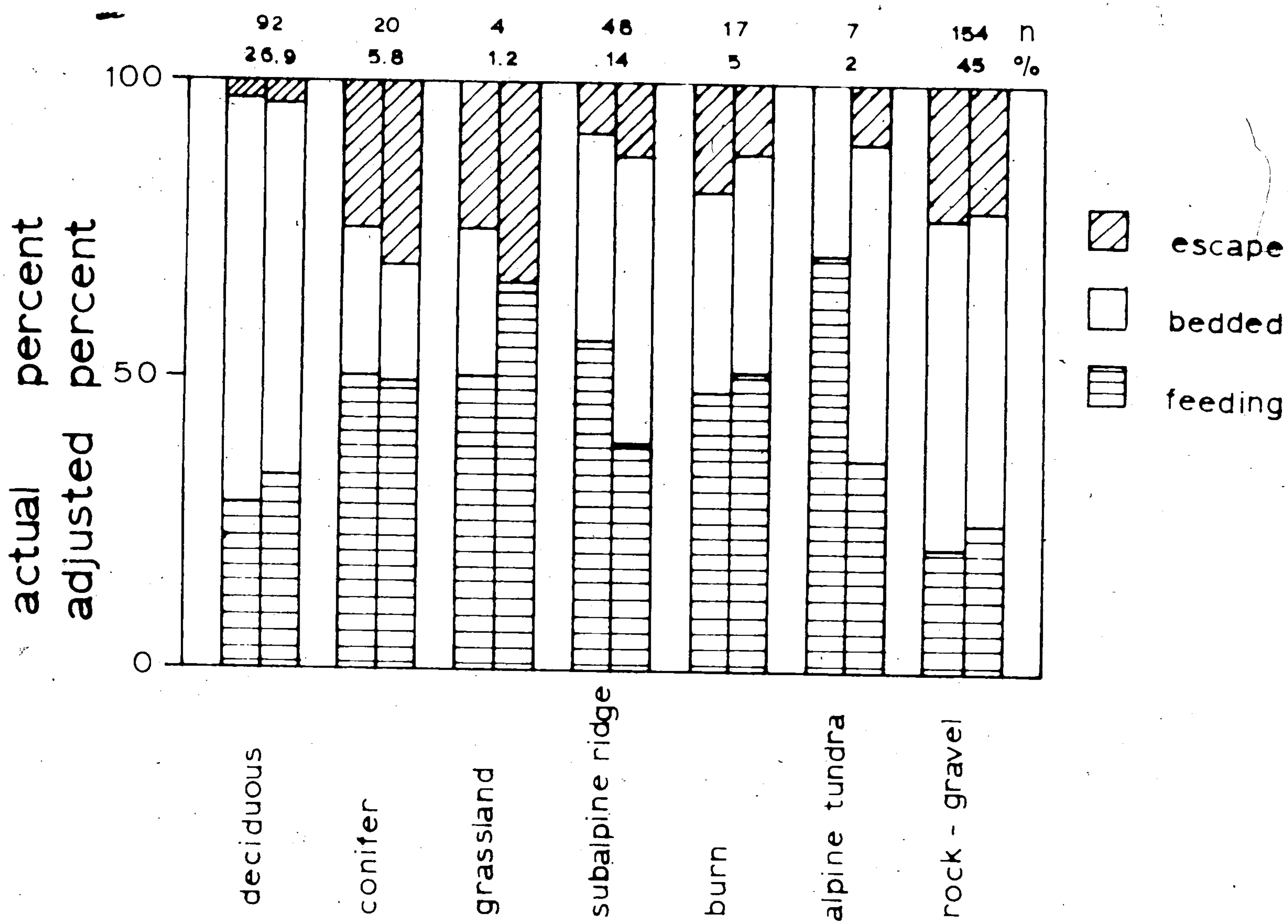

92
26.9
20
5.8
4
1.2
48
14
17
5
7
2
154
45
n
%
100
50
0
actual percent
adjusted percent
escape
bedded
feeding
deciduous
conifer
grassland
subalpine ridge
burn
alpine tundra
rock - gravel

Figure C2. Activity of nursery groups on each cover type.

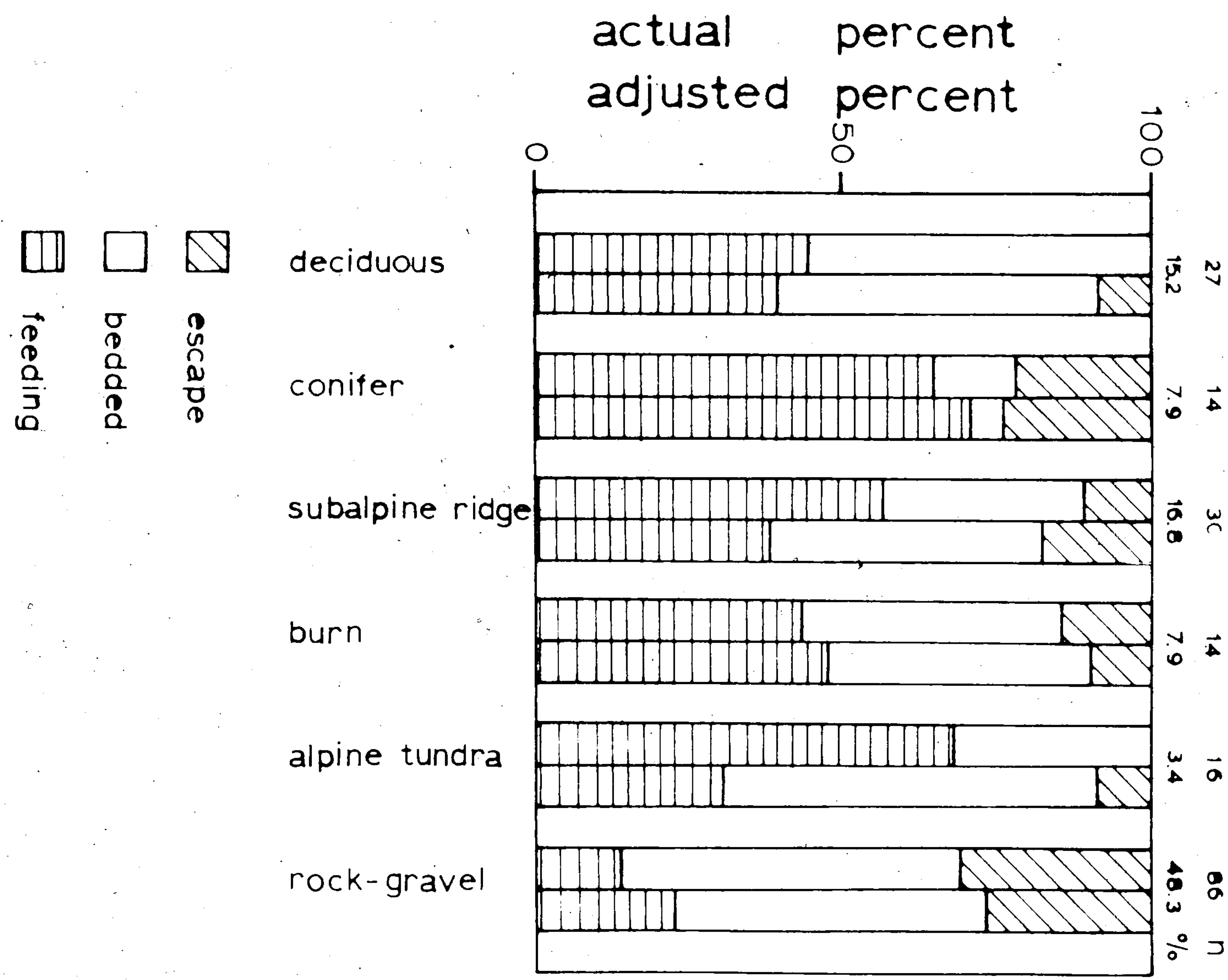

actual percent
adjusted percent
0
50
100
deciduous
conifer
subalpine ridge
burn
alpine tundra
rock-gravel
15.2
7.9
16.8
7.9
3.4
48.3
%
27
14
30
14
16
86
n
escape
bedded
feeding

Figure C3. Activity at each elevation interval (total observations). Adjusted percent (a) derived from all habitat parameters except distance to rock-gravel; ad[illegible]ed percent (b) derived from all habitat parameters [illegible] cover type.

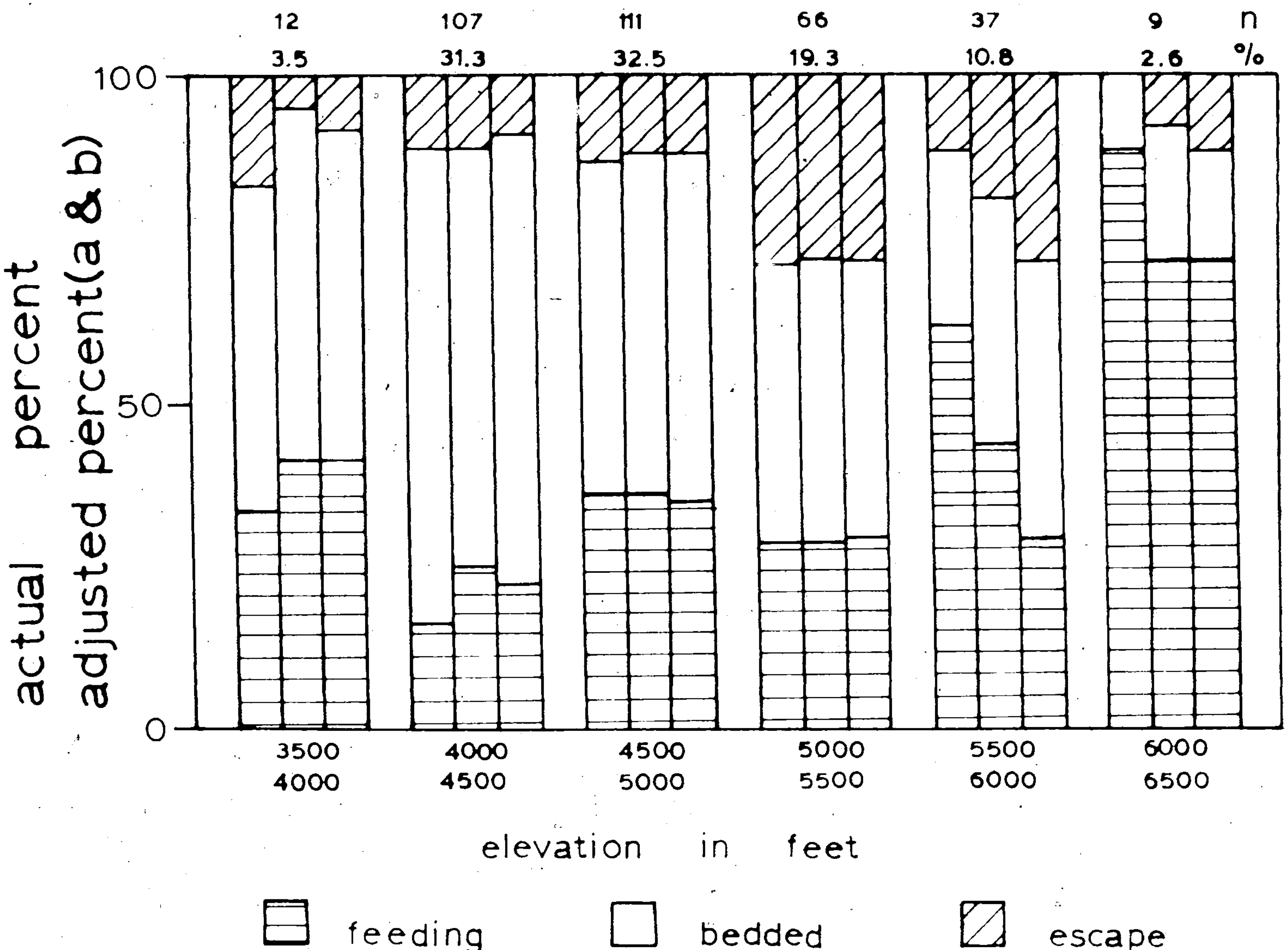
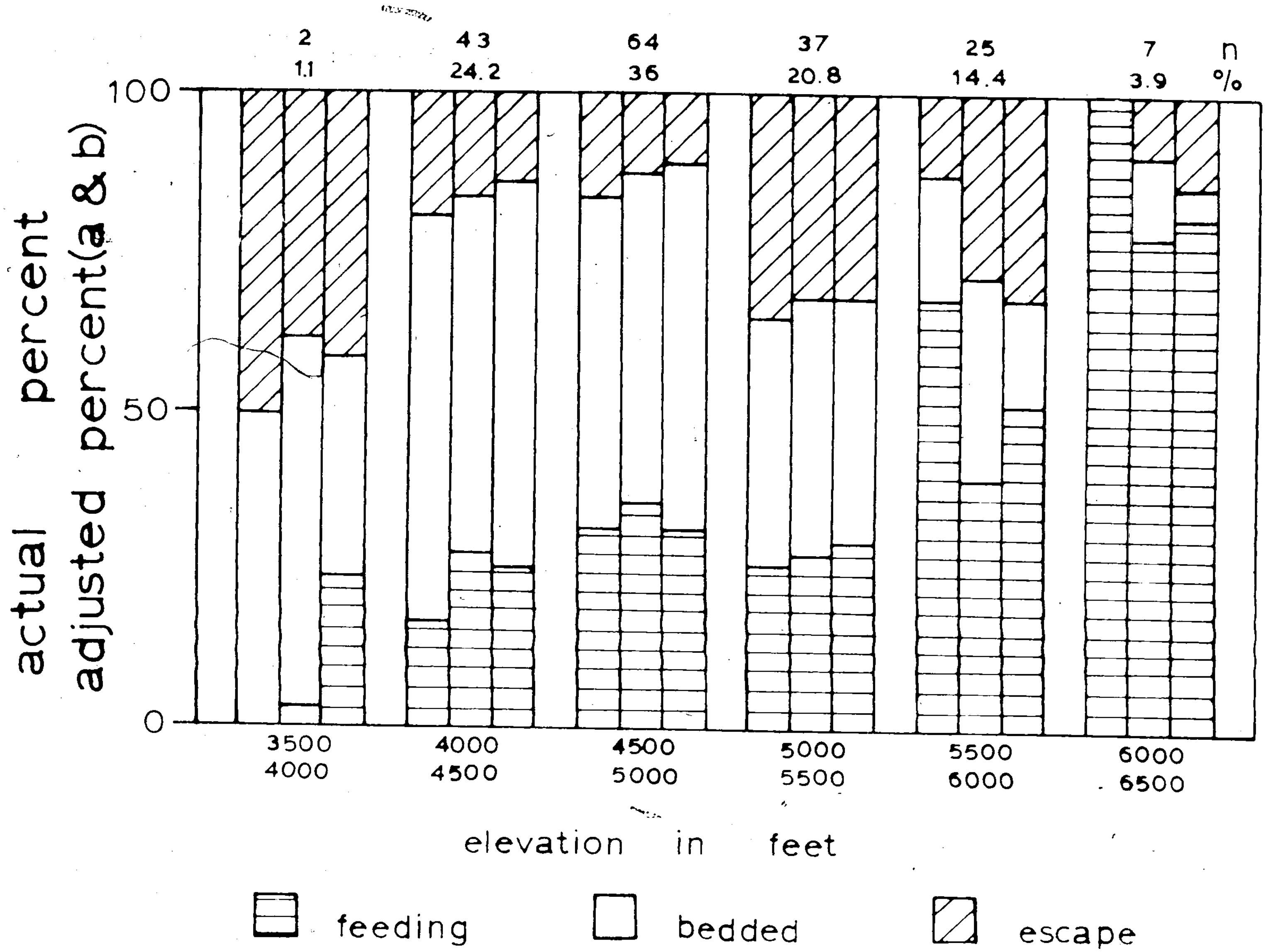
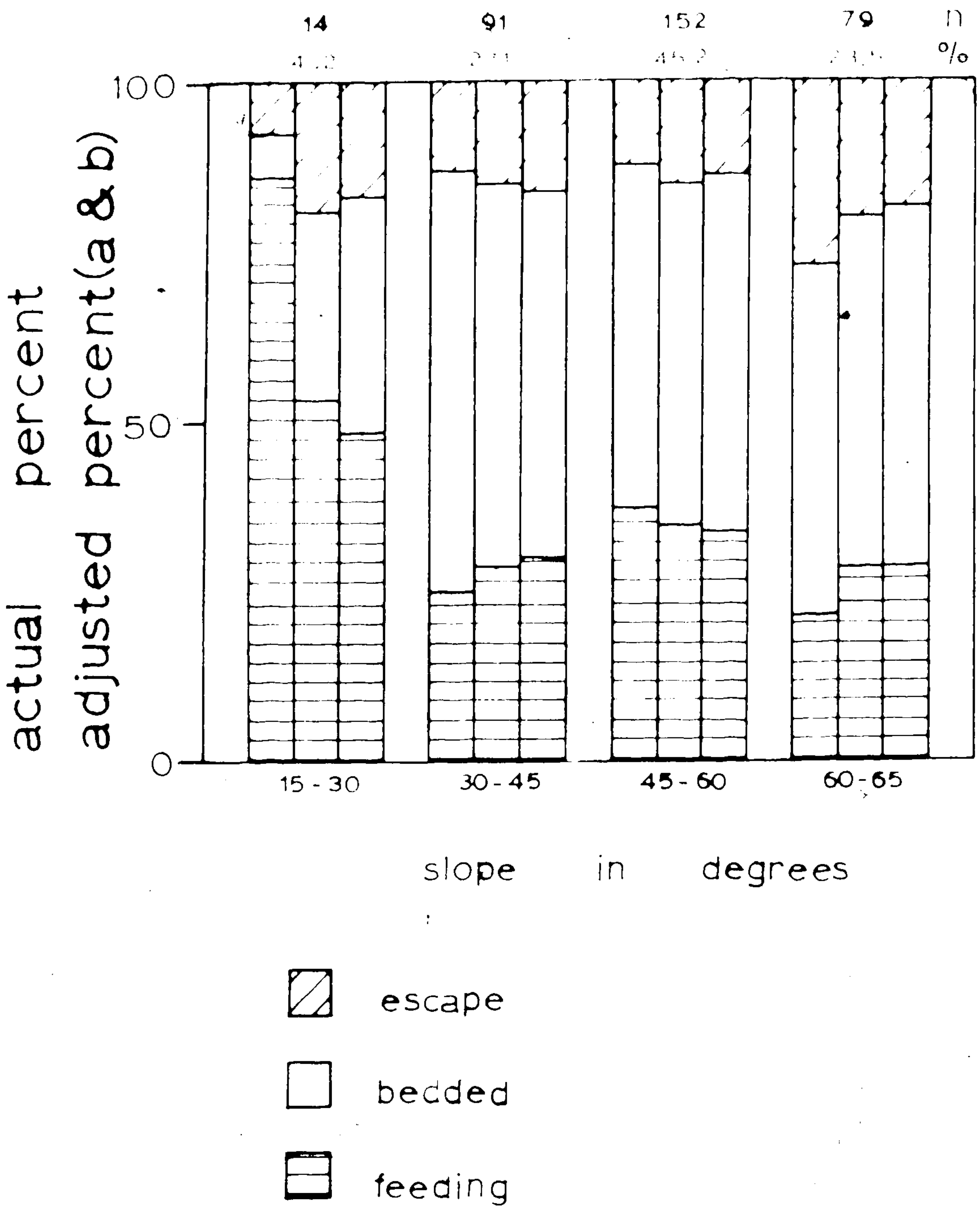

12
107
111
66
37
9
n
3.5
31.3
32.5
19.3
10.8
2.6
%
100
50
0
actual percent
adjusted percent(a & b)
3500 4000
4000 4500
4500 5000
5000 5500
5500 6000
6000 6500
elevation in feet
feeding
bedded
escape

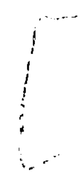
Figure C4. Activity of nursery groups at each elevation interval. Adjusted percent (a) derived from all habitat parameters except distance to rock-gravel; adjusted percent (b) derived from all habitat parameters except cover type.



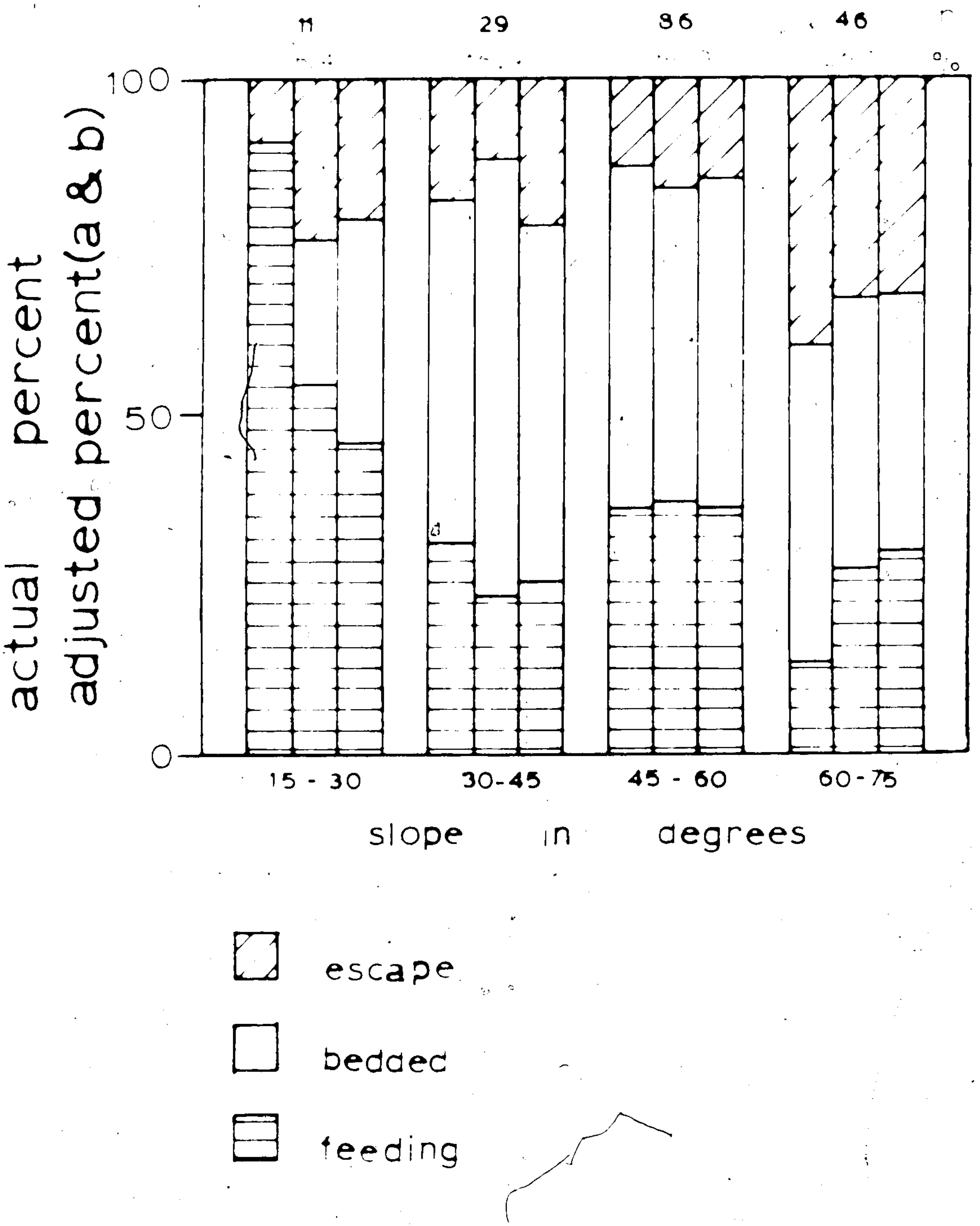
2
1.1
43
24.2
64
36
37
20.8
25
14.4
7
3.9
n
%
100
50
0
actual percent
adjusted percent(a & b)
3500
4000
4000
4500
4500
5000
5000
5500
5500
6000
6000
6500
elevation in feet
feeding
bedded
escape

Figure C5. Activity on each slope interval (total observations). Adjusted percent (a) derived from all habitat parameters except distance to rock-gravel; adjusted percent (b) derived from all habitat parameters except cover type.


14
91
152
79
n
%
100
50
0
actual percent
adjusted percent(a & b)
15 - 30
30 - 45
45 - 60
60 - 65
slope in degrees
escape
bedded
feeding

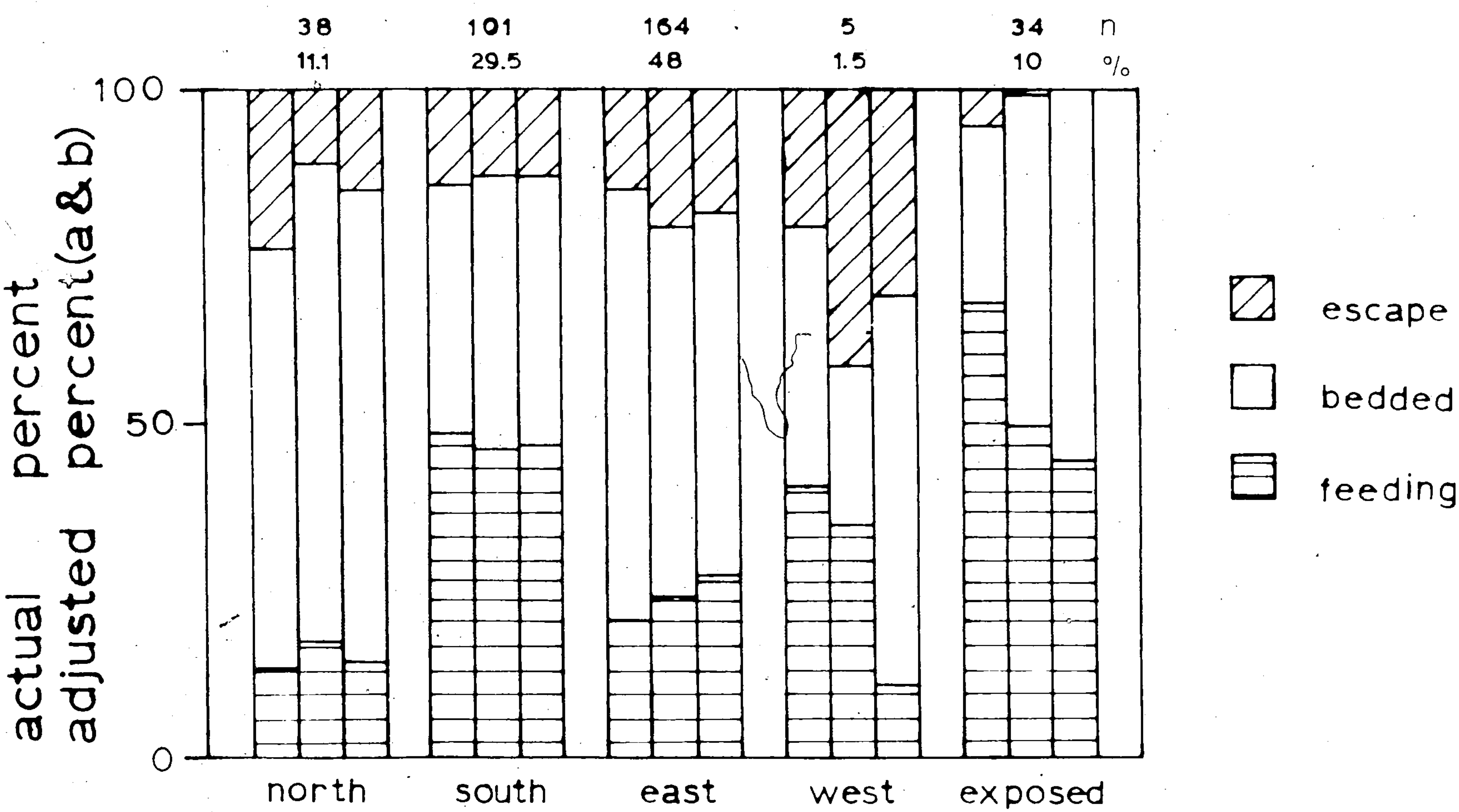


ure C6. Activity of nursery groups on each slope interval. Adjusted percent (a) derived from all habitat parameters except distance to rock-gravel; adjusted percent (b) derived from all habitat parameters except cover type.

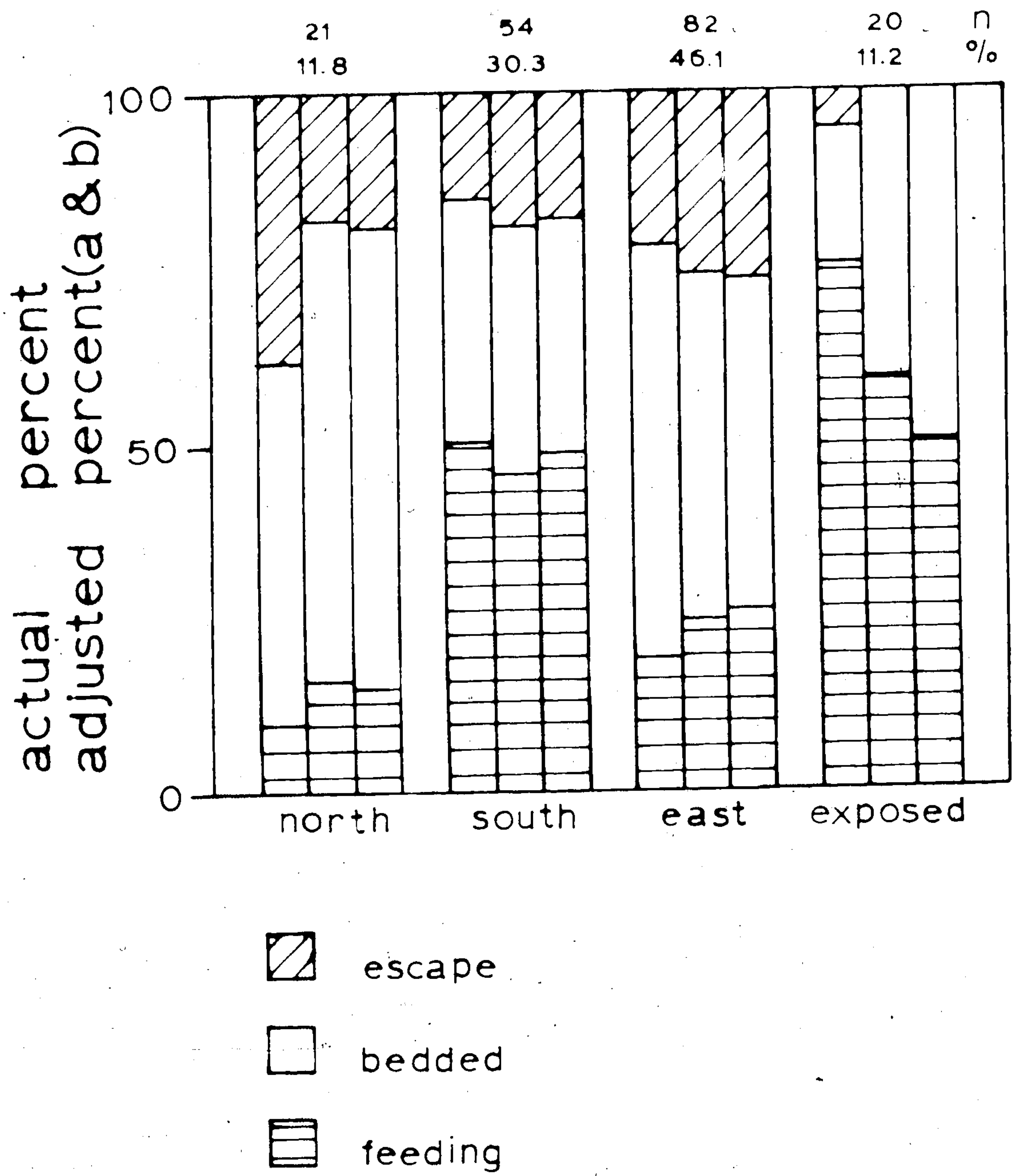


11
29
86
46
100
50
0
actual percent
adjusted percent(a & b)
15 - 30
30-45
45 - 60
60-75
slope in degrees
escape
bedded
feeding

Figure C7. Activity on each aspect (total observations). Adjusted percent (a) derived from all habitat parameters except distance to rock-gravel; adjusted percent (b) derived from all habitat parameters except cover type.


38
11.1
101
29.5
164
48
5
1.5
34
10
n
%
actual percent
adjusted percent (a & b)
100
50
0
north
south
east
west
exposed
escape
bedded
feeding

re C8. Activity of nursery groups on each aspect. Adjusted percent (a) derived from all habitat parameters except distance to rock-gravel; adjusted percent (b) derived from all habitat parameters except cover type.



21
11.8
54
30.3
82
46.1
20
11.2
n
%
100
50
0
actual percent
adjusted percent(a & b)
north
south
east
exposed
escape
bedded
feeding

Figure C9. Activity at different distances to rock-gravel (total observations).

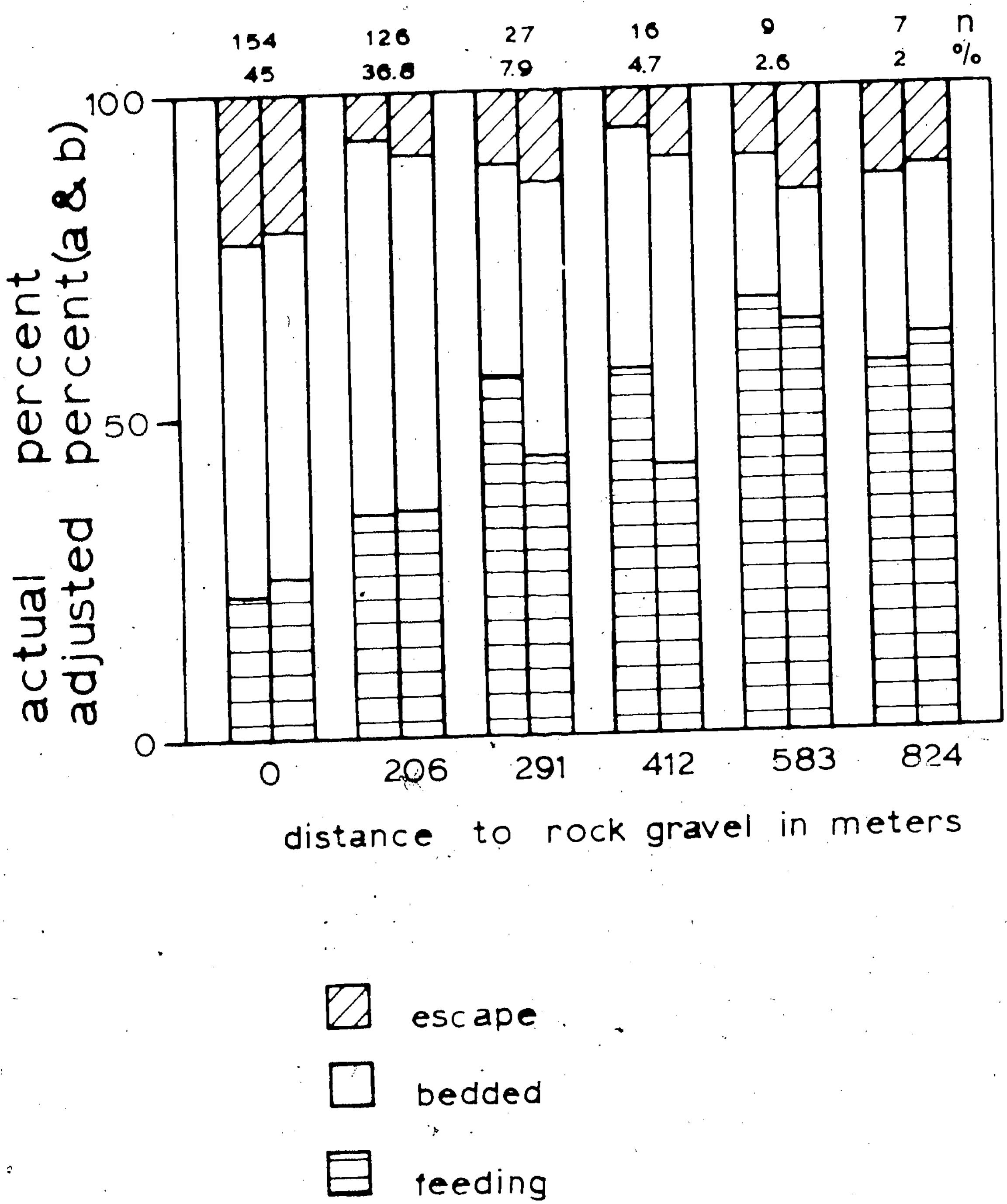
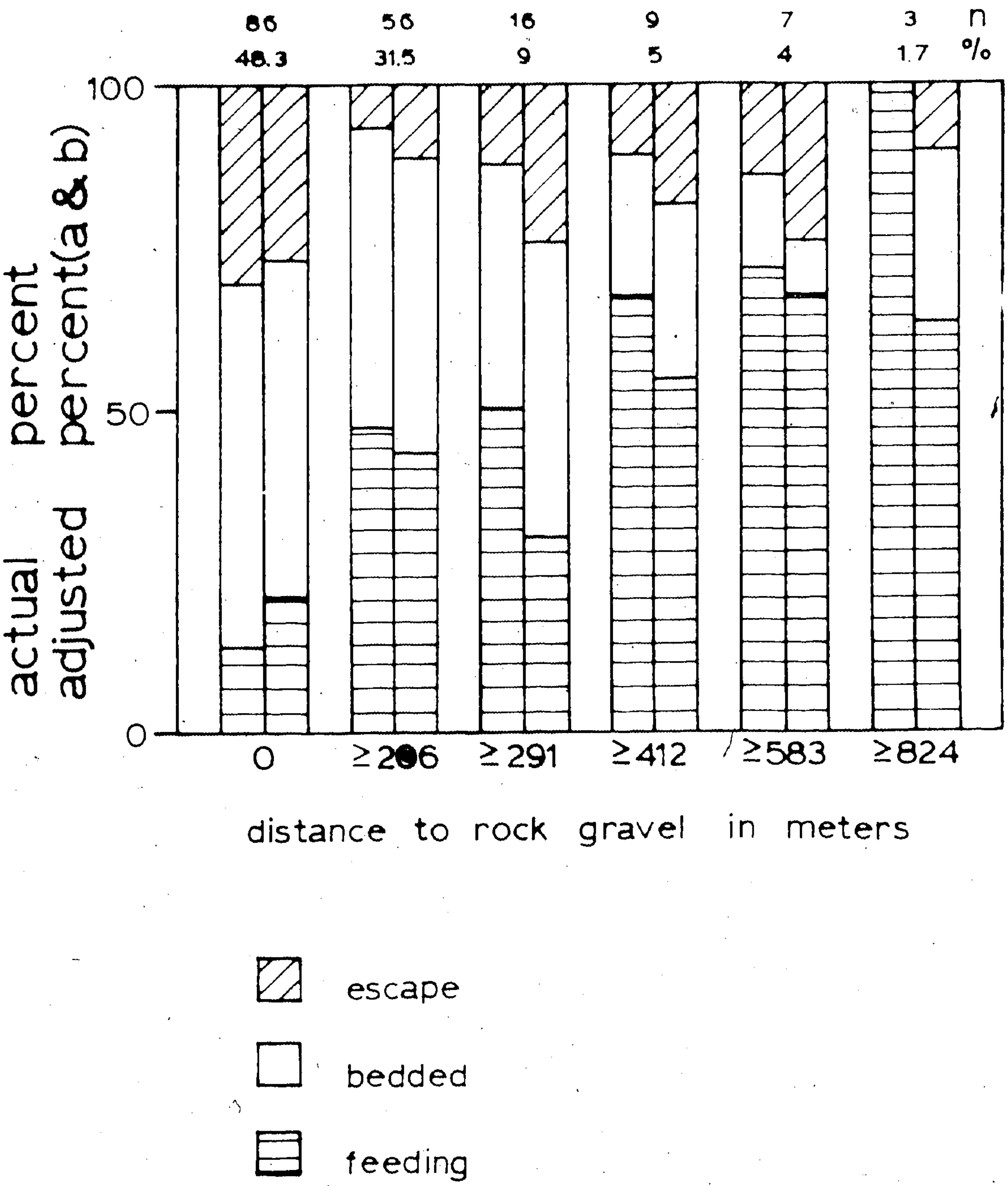

154
45
126
36.8
27
7.9
16
4.7
9
2.6
7
2
n
%
100
50
0
actual percent
adjusted percent(a & b)
0
206
291
412
583
824
distance to rock gravel in meters
escape
bedded
feeding

Figure C10. Activity of nursery groups at different distances to rock-gravel.



86
48.3
56
31.5
16
9
9
5
7
4
3
1.7
n
%
100
50
0
actual percent
adjusted percent(a & b)
0
≥206
≥291
≥412
≥583
≥824
distance to rock gravel in meters
escape
bedded
feeding

Appendix D. Habitat Use versus Month

MNA was also used to compare habitat use during each month of observations. The generalized R^2 and category specific R^2 values (table D1) were low. This may indicate that the monthly intervals do not approximate biologically distinct phases of habitat use. The month of August had the highest values of R^2 reflecting the association of nursery groups at this time with high elevation foraging areas. Generalized eta-square values are listed in table D1. The association between month and habitat use by nursery groups was greatest for elevation.

The adjusted percents used to demonstrate the association between each habitat variable and goat activity did not provide the same information for month. However, MNA also provides a series of coefficients that describe "the effects of membership in the particular category of the dependent variable . . . the coefficients take into account any relationship that may be present between the various independent variables and between each independent variable and the dependent variable." (Andrews and Messenger 1973, see Appendix C for complete reference).

Large coefficients indicate a greater or lesser preference (depending on the sign) in that cell than the mean of total cases. Consequently, an appropriate term for this statistic (at least in the sense that it is used here) is "coefficient of preference." The coefficients derived from MNA are included in tables D3 to D10.

Since elevation was most closely associated with monthly distribution of nursery groups I will briefly discuss the coefficients derived in table D6 for that variable. The positive coefficients in this table clearly support the observation that nursery groups select higher elevations in the late summer. In June the lowest elevations are favoured; while in August, areas between 6000 and 6500 feet are most preferred.

Table D1. Multivariate relationships between use of habitat types by mountain goats and month.

	VALUES OF R^2								
descriptors*	generalized	May	June	July	August	Oct.-Nov.	mode(%)#	multivariate theta	n
C E S A	0.1256	0.1110	0.1223	0.1412	0.1520	0.0950	43.67	0.5012	393
C E S A (N)	0.1788	0.0716	0.1931	0.1970	0.2092	0.0997	49.28	0.5885	206
C E S A D	0.1742	0.2173	0.1760	0.1691	0.1720	0.1355	43.00	0.5459	207
C E S A D (N)	0.2192	0.1263	0.2584	0.1363	0.2686	0.1871	42.99	0.6075	107
E S A D	0.1151	0.0824	0.1247	0.1365	0.1214	0.0825	43.67	0.5062	393
E S A D (N)	0.1745	0.0477	0.1994	0.1558	0.2200	0.1124	49.28	0.5885	206

* C cover, E elevation, S slope, A aspect, D distance to rock-gravel, N tests that include nursery groups only; # modal activity in all cases was bedded.

Table D2. Bivariate relationship between the use of each of the habitat parameters and month, using the generali... -square.

descriptors*	cover	elevation	slope	aspect	distance
C E S A	0.0424	0.0461	0.0196	0.0486	
C E S A (N)	0.0717	0.0941	0.0476	0.0437	
C E S A D	0.0269	0.0720	0.0363	0.0449	0.0289
C E S A D (N)	0.0367	0.1035	0.0598	0.0228	0.0538
E S A D		0.0461	0.0196	0.0486	0.0297
E S A D (N)		0.0941	0.0476	0.0437	0.0492

* C cover, E elevation, S slope, A aspect, D distance to rock-gravel.

Table D3. Coefficient of preference during each month for the different cover types (total observations).

month	deciduous	conifer	grassland	subalpine ridge	burn	tundra	rock
Nov.	2.54	-7.82	-4.90	0.15	-0.12	-4.61	-0.22
Oct.	3.18	-8.45	-8.15	1.88	-4.55	4.72	-0.91
Aug.	-0.49	25.88	-17.06	-3.19	8.32	61.46	[illegible]
July	3.15	2.10	19.87	-7.34	-2.71	-31.32	1.55
June	1.79	-5.14	-47.84	5.21	-10.43	-25.28	1.19
May	-9.26	-11.17	59.25	3.55	5.18	[illegible]	[illegible]
N	104	22	[illegible]	59	[illegible]	8	[illegible]
	25.8	[illegible]	1.0	14.6	[illegible]	2.0	[illegible]

Table D4. Coefficients of preference during each month for [illegible] different cover types ([illegible] nursery groups only[illegible]).

month	deciduous	conifer	grassland	subalpine ridge	burn	tundra	rock
Nov.	2.32	-5.17	-3.92	-0.75	1.83	[illegible].82	0.[illegible]3
Oct.	4.82	-7.48	-2.74	4.26	[illegible].22	[illegible].24	-1.[illegible]
Aug.	-8.63	17.35	-18.20	-4.99	13.16	62.07	4.61
July	3.81	0.89	92.80	-6.19	[illegible].51	[illegible].31	2.19
June	7.54	-7.70	-34.00	0.43	23.22	-14.[illegible]	[illegible]
May	-7.08	-5.50	-13.48	7.92	0.[illegible]	-1.13	[illegible]
N	[illegible]	16	1	37	17	[illegible]	[illegible]
[illegible]	15	8		17	8	3	[illegible]

Table D5. Coefficients of preference during each month for the different elevation categories (total observations).

month	<4000	<4500	<5000	<5500	<6000	<6500
Oct. and Nov.	-1.68	-2.97	-0.79	3.72	6.61	-8.72
Aug.	-15.17	-2.08	-4.78	6.69	7.44	33.13
July	-14.35	-7.71	3.36	1.88	4.60	30.03
June	12.47	6.77	4.61	-8.09	-15.29	-38.28
May	18.73	6.00	-2.40	-4.20	-3.36	-16.16
N	13	115	140	74	42	9
%	3	29	36	19.	11	2

Table D6. Coefficients of preference during each month for the different elevation categories (observations of nursery groups only).

month	<4000	<4500	<5000	<5500	<6000	<6500
Oct. and Nov.	-0.61	-2.30	-1.95	2.27	9.03	-8.12
Aug.	-22.57	-3.85	-6.75	5.48	9.50	44.94
July	-16.45	-10.22	3.94	-4.57	9.87	16.73
June	47.84	7.35	5.86	4.68	-31.39	-43.20
May	-8.21	9.02	-1.10	-7.85	2.99	-10.34
N	2	47	83	41	26	7
%	1	23	40	20	13	3

Table D7. Coefficients of preferences during each month for the slope categories (observations of nursery groups only).

month	0-30°	30-45°	45-60°	60-75°	75-90°
Oct. and Nov.	6.34	1.58	0.51	-3.34	-2.30
Aug.	5.66	-10.01	-2.32	6.77	26.63
July	-11.96	10.19	-3.98	4.38	3.34
June	9.39	4.00	4.36	-11.61	-20.42
May	-9.44	-5.76	1.43	3.80	7.24
N	12	32	106	50	6
%	6	16	51	24	3

Table D8. Coefficients of preferences during each month for the different aspect categories (observations of nursery groups only).

month	north	south	east	level
Oct. and Nov.	11.45	2.65	-3.87	-5.38
Aug.	-8.57	7.68	0.53	-15.87
July	-9.59	-5.54	-0.58	31.86
June	4.12	-7.77	5.78	-6.28
May	2.59	2.99	-1.87	-4.33
N	26	66	93	21
%	13	32	45	10

Table D9. Coefficients of preferences during each month for the different distance to rock-gravel categories (total observations).

	Meters to Escape Terrain				
month	0	<206	<291	<412	>412
Oct. and Nov.	-1.12	0.51	8.38	-9.22	1.87
Aug.	-5.22	2.00	10.00	-6.87	32.52
July	1.74	2.03	-10.30	-0.58	-21.14
June	0.63	2.73	-17.30	5.83	-7.08
May	3.97	-7.27	9.22	10.85	-6.17
N	186	148	29	15	15
%	47	38	7	4	4

Table D10. Coefficients of preferences during each month for the different distance to rock-gravel categories (observations of nursery groups only).

month	Meters to Escape Terrain 0	<206	<291	<412	>412
Oct. and Nov.	-1.55	1.50	12.49	-8.09	-9.30
Aug.	-4.71	-2.69	20.35	-10.91	40.98
July	1.69	3.80	-12.15	-0.02	-23.06
June	3.69	-3.34	-17.80	26.11	-5.99
May	0.89	0.73	-2.88	-7.18	-2.63
N	99	71	17	9	10
%	48	34	8	4	5

Appendix E. Harvest Data (with the permission of Bill Hall, Wildlife Services, Alberta Fish and Wildlife Division)

WILDLIFE SERVICES

Mountain Goat Season

A total of 175 applications were received for the 48 goat hunting permits drawn in 1976; 44 people took part in the hunt which covered six major drainages. As in past years, the utilization of six zones (all or part of WMU's S439, S440, S442 and S444) enhanced hunter distribution and the harvest. The season ran from September 27 - October 9. Total harvest was 29 goats (13 nannies and 16 billies), comparable to previous years' harvests as shown below.

Goat Harvest 1972 - 1976

Year	Harvest		Total
1972	12 nannies	10 billies	22
1973	7 nannies	7 billies	14
1974	6 nannies	7 billies	13
1975	18 nannies	10 billies	28
1976	13 nannies	16 billies	29

The 1976 harvest was distributed as follows:

Area	Permits	Females	Males	Total
A	5	3	2	5
B	14	2	7	9
C	13	3	5	8
D	5	3		3
E	5	1	1	2
F	6	1	1	2
	48	13	16	29