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HABITAT USE BY MOUNTAIN GOATS IN SOUTHEASTERN ALASKA

By

Christian A. Smith

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SUMMARY

For this study 51 mountain goats (Oreamnos americanus) were captured and radio-collared in 3 study areas. A total of 1,702 aerial radio relocations were made between July 1981 and June 1984, with most relocations made in winter (Nov to Mar). Analysis of seasonal habitat use patterns indicated male and female goats often responded differently to habitat variables and environmental conditions. During winter, females used lower elevations than males and were more often found in mid- to high-volume commercial timber. In summer, females used steeper and less-vegetated areas and a wider range of aspects than males. These seasonal differences may be related to females' increased energetic and behavioral costs associated with reproduction. Both sexes were found to use slopes of >30° and to be within 0.4 km of cliffs (i.e., areas of slope >50°) almost exclusively. Forest overstory was a significant factor in winter habitat use in the study area, as over 85% of all winter relocations occurred in forested habitats.

Evaluation of utilization vs. availability data was conducted at 2 levels. At the level of selecting a home range from the ridge and valley complex in the study area, goats avoided lower elevations, gentle slopes, areas over 0.8 km from cliffs, and commercial forest land. Conversely, within their home ranges during winter, goats preferred lower elevations and commercial forest areas. These results demonstrate the value of multi-level analysis of habitat preference and indicate that although goats may include relatively minor portions of commercially valuable timber in their home range, the areas they do utilize may be critical to over-winter survival and productivity of the population.

A mathematical model based on discriminant function analysis of winter habitat selection by goats in the initial study area identified slope as the most important variable in separating goat winter habitat from random points on the study area. Distance to cliffs, timber volume, aspect, and elevation also contributed significantly to the discrimination. The model was used to predict the location of goat winter habitat in 2 other study areas. Approximately 42% of each area was identified as potential winter range. Winter relocations of 13 and 15 goats in these areas were used to test the accuracy of the model. In both cases over 82% of the relocations (n = 280 and n = 60, respectively) occurred within the predicted habitat and in 1 area an additional 17% occurred within 200 m of predicted habitat. Goodness-of-fit tests indicate significant (P < 0.001) selection for the predicted areas. Within certain limits the model can be used with data taken from standard topographic and timber-type maps to identify winter habitat for consideration in land-use planning.

Key Words: habitat use, mountain goat, *Oreamnos americanus*, Southeast Alaska, habitat modeling, forest-wildlife relationships.

CONTENTS

BACKGROUND

Although mountain goats (Oreamnos americanus) are one of the least studied species of large game in North America (Eastman 1977), it is generally recognized that they are more sensitive to habitat destruction and over-hunting than any other ungulate on the continent (Chadwick 1983). Studies in Montana (Chadwick 1973), Alberta (Quaedvlieg et al. 1973), Idaho (Kuck 1977) and British Columbia (Phelps et al. 1983) have documented dramatic declines in goat numbers as a result of human activities.

Concern over the potential adverse effects of timber and mineral development on coastal mountain goat populations has been widely expressed (Hebert and Turnbull 1977, Schoen and Kirchhoff 1982, Smith and Raedeke 1982, Fox et al. 1982, Fox 1983). This concern provided the basis for initiation of this study (Smith 1982). Development of efficient capture and telemetry techniques by Schoen and Kirchhoff (1982) and Nichols (1982a) has provided the means with which to undertake a large-scale analysis of habitat use by goats. The present study has relied heavily on aerial telemetry for data collection.

One of the main objectives of this study was to develop readily applied procedures for identification of critical mountain goat habitat. Accordingly, standard USGS 1:63,360 topographic quadrangle sheets enlarged to 1:31,680 scale, and USDA Forest Service timber-type maps at 1:31,680 scale were used as the basis for evaluating and modeling habitat use by goats in this study. These maps are available for all of the Tongass National Forest and much of the private land in Southeast Alaska and are commonly employed in land use planning by the Forest Service and ADF&G.

OBJECTIVES

To monitor mountain goat movements and determine seasonal habitat use in Southeastern Alaska.

To evaluate physical and biological parameters of seasonal mountain goat habitat.

STUDY AREAS

Three separate study areas were used in this analysis (Fig. 1). The Upper Cleveland Peninsula (UCP), initially chosen in 1981, contains typical coastal mountain goat habitat in the Ketchikan vicinity. The UCP has been described by Smith (1983a). The Quartz Hill Vicinity (QHV) area (referred to in earlier reports as "K-4") was added in 1982 to provide a means of testing habitat modeling and on-site data relevant to the U.S. Borax mine development. Detailed descriptions of the physiography and vegetation of this area were provided by Smith (1984a). The 3rd area, Revillagigedo Island (hereinafter referred to as "Revilla"), was added in 1983 following the transplant of 17 goats to the island (Smith and Nichols 1984) to provide additional evaluation of the goat habitat model. This area has also been described by Smith (1984a).

METHODS

Mountain goats were captured using standard helicopter darting techniques (Schoen and Kirchhoff 1982) with 4 mg of M-99 (etorphine hydrochloride, Lemmon Co., Sellersville, Pa.). On the UCP, goats were randomly selected for marking from groups observed during intensive searches of all ridge complexes in the study area. In the QHV area, systematic attempts were made to collar goats on all major ridge complexes to provide data representative of the entire area.

Details of marking and handling are reported by Smith (1982, 1983a, b). Captured goats were fitted with radio collars (Telonics, Mesa, Az.) and were relocated from the air using twin 2-element Yagi antennae mounted on a Piper PA-18-150 Super Cub as described by Nichols (1982a).

In 1983, 17 goats were captured and transplanted to Revilla Island (Smith and Nichols 1984). All 17 were released at the same location over a 3-week period. Fifteen of these goats were radio-collared and monitored in the same manner as those on the mainland.

Independent grid overlay systems similar to those used by Schoen (1977) were developed for each area with a 10 x 10 matrix, or 100 grid cells per section, on topographic maps. Each cell contained approximately 2.6 ha of land. This size was considered large enough to permit accurate mapping of goat relocations, yet fine enough to permit a single point sample of habitat parameters to describe the cell. Each time a goat was relocated, its position was recorded on a map as being within 1 grid cell identified by the coordinates of the southwest (lower left) corner.

The habitat features for each occupied cell were described by determining (from the topographic maps) the elevation, aspect, slope, and distance to the nearest cliff (i.e., area of measurable slope >50°). Vegetation type and timber volume at the intersection of the grid lines at the southwest corner of the cell were determined from forest cover maps. These parameters have the most influence on goat habitat use in Southeast Alaska (Schoen and Kirchhoff 1982, Fox et al. 1982, Fox 1983). Details of methodology for parameter measurement are provided in Smith (1982, 1983a).

To assess seasonal patterns in habitat use by goats, radio relocations were classified as occurring in winter (1 November through 31 March), spring (1 April through 15 June), summer (16 June through 31 August) and fall (1 September through 31 October). Frequency distributions for habitat parameters for all cells occupied by radio-collared goats during each season were calculated and compared using Chi-square analysis. To test for differences between sexes, distributions for cells occupied by males were compared with those for cells occupied by females on a seasonal basis.

To provide data for availability vs. utilization analysis (Marcum and Loftsgaarden 1980) UCP grid coordinate pairs were randomly selected for measurement. A sample of 10% (n = 1,526) of the grid intersections on the UCP study area was used to estimate frequency distributions for available elevations, aspects, slopes, distance to cliffs, vegetation types, and timber volume classes. These distributions were compared with those for cells utilized by goats using Chi-squared and Bonferroni Z statistics (Neu et al. 1974).

Because the Bonferroni Z multiple confidence interval technique allows for only a limited number of categories, parameter values had to be lumped. For this procedure, elevations were grouped into 800 m categories, and aspects were grouped as flats, N (including NW and NE), E and W, S (including SE and SW), and ridgetop. Slope categories were 0-20°, 21-30°, 31-50°, 51-65°, and 66°+; distance to cliffs was in 0.4 km units. Vegetation types from USDA Forest Service timber-type maps were grouped as commercial forest, muskeg forest, subalpine forest, brush/slide, alpine, and rock/cliff (Appendix A). Standard timber volume classes (0, <8, 8-20, etc., thousand board feet per acre [mbf/a]) were used.

Marcum and Loftsgaarden (1980), Neu et al. (1974), and others have cautioned that typical analyses of utilization vs. availability data rest on the assumption that the investigator accurately measures what is "available" to the animal. Furthermore, Johnson (1980) demonstrated that arbitrary decisions regarding what is considered "availability" can have profound effects on the outcome of analyses of preference; he also suggested that animals may make habitat selection decisions at more than 1 operative level. To address these concerns, utilization vs. availability analyses were performed using 2 levels of selection. The 1st level represents the gross selection of an overall home range from the general study area, while the 2nd level focuses on seasonal use of specific portions of the home range.

For the 1st level of selection, minimum convex polygon (MCP) home ranges for individual goats were plotted on the study area overlay, and habitat features within the home range were compared with those of the overall study area. "Availability" was based on data from the 10% random sample (n = 1,526) of grid intersection points on the UCP. "Utilization" was based on a random sample of at least 75 points within the goat's MCP home range, or all points within the home range for goats with home ranges smaller than 1.9 km^2.

Comparison of MCP home ranges with the overall UCP study area to determine selective utilization of habitats rests on 2 critical assumptions. First, it is assumed that a goat is physically capable of moving over the entire area in selecting its home range and it is implied that each goat is sufficiently aware of the overall area to make conscious choices as to which portion of the area it will include in its MCP home range. Although extensive movements of several goats of both sexes confirmed that these particular animals could indeed traverse the entire study area, there is no way to support the assumption that any goat's failure to utilize a distant portion of the area constitutes a choice, as opposed to a lack of awareness of the area.

The 2nd critical assumption is that sufficient relocations were made of each individual goat to accurately describe the total area used by that goat over the course of the study. This concern has often been raised in mark-recapture and telemetry studies. An approach to resolving this issue is to plot a curve of the area of the MCP against the number of relocations. When this curve approaches an asymptote, it can be assumed that the overall home range has been identified (Bekoff and Mech 1984). However, to identify the overall MCP home range of individuals in seasonally migratory species, such as goats, it is important that relocations not only be sufficiently numerous, but that they occur over enough time to encompass all areas used in an annual cycle.

To ensure that MCP home ranges used for comparison with "availability" on the UCP represent actual "utilization" areas, the home range size was calculated using 1, 2, and 3 years' relocations for the 12 goats monitored from 1981-84. These values were graphed to determine when the curves became asymptotic. Only the home ranges of those individuals monitored for this length of time, or longer, were used in the utilization vs. availability analysis.

The 2nd analysis of availability vs. utilization was made at the MCP home range level. The frequency distribution derived from the random points in the MCP were considered "availability" data, and those from cells occupied by relocated goats were considered "utilization" data. Because the number of relocations during other seasons was limited, and in view of the importance of winter habitat to northern ungulates, only winter relocation cells were used in this analysis.

Evaluation of habitat preference at the MCP home range level also assumes that "availability" is accurately defined. This assumption would appear relatively safe in this case as the area within the MCP was circumnavigated by the collared goat and was, therefore, physically accessible (i.e., within the limits of the goat's greatest movements). It is somewhat less certain that the limited number of winter relocations for the collared goats adequately assesses utilization, and no statistical evaluation of the accuracy or precision of such use was undertaken.

In addition to the descriptive analyses outlined above, a predictive model of goat winter habitat was developed and tested using discriminant function analysis (DFA). For the DFA, the 1,526 random cells sampled on the UCP were divided into 2 groups. The 1st group consisted of those cells used by goats during the winter. Additional cells used by goats not included in the random sample were added to this group, which was considered to be "winter habitat." The remaining random cells unused by the collared goats were considered "other habitat." Stepwise DFA was then used to derive an equation that most accurately separated the 2 cell groups in canonical space. A similar approach was used by Schoen and Kirchhoff (1982), Fox et al. (1982), and Smith (1983b, 1984a).

The discriminant function derived with the UCP data base was then used to predict the location of winter habitat on the QHV and Revilla study areas. To do this, a systematic sample of 25% of the grid cells on the QHV and Revilla study areas, consisting of all pairs with even x and y values, were sampled to determine their elevation, aspect, slope, distance to cliffs, and timber volume as had been done for the UCP cells. Each of the cells was then classified by the DFA as most likely belonging in the "winter habitat" or "other" group. "Winter habitat" cells were mapped on the study area grid overlays. To complete the mapping for nonsampled cells, the 3-corner rule (Smith 1983b) was applied and final winter habitat areas were outlined.

To test the accuracy of the winter range area predictions, all winter relocations for goats collared on the QHV and Revilla study areas were mapped to determine whether they fell within the predicted winter range. Chi-squared goodness-of-fit tests were used to assess the level of significance of the goats' selection for the predicted winter range.

RESULTS AND DISCUSSION

During the course of this study, 1,702 relocations were made of all captured goats (Table 1); of these, 826 were made during winter, 320 were made in spring, 291 were made in summer, and 267 were made in fall.

Seasonal Use Patterns

Seasonal frequency distributions were determined for categories of elevation, aspect, slope, distance to cliffs, vegetation type, and timber volume used by radio-collared goats on the UCP from 1981-84. Chi-squared analyses indicated that significant ($P < 0.001$) seasonal changes occurred in use of elevation, aspect, slope, vegetation type, and timber volume by both sexes, but use of varying distances to cliffs did not change for either sex ($P > 0.06$ for females; $P > 0.59$ for males; $P > 0.10$ for combined sexes) during the year. Analysis of female vs. male distribution for the same habitat parameters on a seasonal basis indicated that the sexes made differential use of elevation in fall and winter; aspect, throughout the year; slope and vegetation type, in winter and summer; distance to cliffs, in winter; and timber volume, in spring (Table 2). At other times, the sexes were similarly distributed with respect to these habitat features. Descriptions of the seasonal patterns follow.

Elevation:

During winter, both sexes were found to be concentrated in the 250-500 m and 500-750 m elevation zones (Fig. 2). Females utilized the lower of these zones to a greater extent than males ($\underline{P}$ = 0.01) and also used the 0-250 m zone 6% of the time. Males used the 500-750 m zone more than the lower elevations and spent more time in the 750-1,000 m zone than females did. Areas above 1,000 m were rarely used by goats of either sex during the winter. The few relocations at these altitudes ($\underline{n}$ = 6) were made following periods of clear, cold weather which enabled goats to climb quickly on frozen snow crust to alpine areas where they could exploit the thermal advantages of direct insulation and temperature inversions. However, unlike areas farther north (Hjeljord 1971, Schoen and Kirchhoff 1982) or intermountain regions (Hebert and Turnbull 1977), there are no windblown ridgetops with exposed forage on the UCP, so goats do not remain on the ridges for extended periods of time.

In spring, the sexes were not differentially distributed (Chi-squared = 4.87, $\underline{P}$ > 0.30) as over 75% of all relocations for both sexes occurred between 250 and 750 m, well below tree line. Males used the lower 250-500 m zone more than they did in winter, while females increased their use of areas above 500 m (Fig. 2). Schoen and Kirchhoff (1982) and others reported similar down-slope movements in spring and attributed this shift to advanced green-up on lower slopes.

Distribution of goats changed dramatically in summer (Fig. 2) as both sexes concentrated in areas above 750 m elevation. No relocations were made below 250 m and fewer than 2% occurred below 500 m. No differences in use of elevation between sexes was detected in summer (Chi-squared = 3.03, $\underline{P}$ > 0.38).

The sexes were distributed differently ($\underline{P}$ = 0.04) during fall (Fig. 2) as females moved to lower elevations sooner than males. While 50% of all female relocations in fall occurred below 750 m, only 30% of all male relocations were below this level. Overall, the 750-1,000 m zone was still the most often selected, but use of areas above 1,000 m was less than one-third of that during summer.

Aspect:

Throughout the year, both sexes were found to use southerly aspects more than any other, though use of south slopes decreased in spring and summer. Both sexes used ridgetops almost exclusively in summer and fall, and were found to use flat areas extremely rarely (Fig. 3). Nevertheless, in every season, males and females were found to be distributed differently ($\underline{P}$ < 0.04) with respect to aspect. These differences resulted from the females' higher use of northerly aspects in all seasons, and east and west slopes in spring. Generally, females were found to be more uniformly distributed than males regarding aspect. Schoen and Kirchhoff (1982) also reported more use of northerly slopes by females. This pattern could be the result of the larger sample of females, the females' need to exploit a wider range of aspects to meet the nutritional needs of pregnancy and lactation, or females' greater sensitivity to some other habitat feature.

Slope:

Throughout the year, both sexes predominantly used slopes in excess of 30° (Fig. 4). Use of gentle-to-moderate (i.e., <30°) slopes was higher for both sexes in summer and fall than in winter or spring. During the winter, the sexes were distributed differently ($\underline{P}$ = 0.002) with males making more use of slopes exceeding 65°, while females made greater use of the 31-50° and 51-65° slopes. In spring, males moderated their use of cliffs and females increased their use of terrain over 65°, resulting in no difference ($\underline{P}$ > 0.15) in overall distribution by slope class (Fig. 6). During summer, the sexes diverged again ($\underline{P}$ < 0.04) as males increased their use of gentle slopes, 0-20°, generally on or near ridgetops, while females tended to remain on slopes exceeding 20°. In fall, use of slopes less than 20° declined for both sexes, and though males tended to use slopes of 51-60° more than slopes of 31-50°, while females used these classes in nearly equal proportions, the sexes were not distributed differently ($\underline{P}$ > 0.74) overall.

Distance to Cliffs:

Males used areas immediately adjacent to cliffs almost exclusively, with over 95% of all relocations in each season within 0.4 km of a cliff and all others within 0.8 km (Fig. 5). While females used some areas farther from cliffs in winter and use of cliff area was significantly different ($\underline{P}$ < 0.001) from males during this season, overall, females were generally as close to cliffs as males. The indicated variation in winter is atypical and most likely due to an artifact associated with the movement of some females to lower elevation sites where cliffs and outcrops used by these goats are too small to be accurately identified as areas of slope exceeding 50° on the scale of maps used in this analysis. All other studies have reported that females generally use more rugged, cliffy terrain than males.

Vegetation Type:

During winter, both males and females used commercial old-growth forest nearly 50% of the time (Fig. 6), but their differential use of other types led to significantly (P < 0.003) different overall use patterns. Females were found more often in noncommercial muskeg forest sites and in brush/slide areas than males, while males made heavier use of subalpine forest.

In spring, males increased their use of commercial old-growth and subalpine forest and reduced use of rock/cliff areas (Fig. 6). Females decreased use of muskeg forest and commercial old-growth and increased use of alpine and rock/cliff types. Nevertheless, no difference ($P > 0.35$) was found in overall use patterns as both sexes continued to use primarily forested habitat.

During summer, neither sex used commercial forest more than 5% of the time (Fig. 6), but both sexes used subalpine forest over 25% of the time. Muskeg forests and brush/slides were little used. Most relocations for both sexes occurred in alpine and rock/cliff types. Use of these 2 categories varied between males and females, resulting in significantly ($P < 0.04$) different distribution of sexes. Males used the alpine type (i.e., krummholz, heath, and forb meadows) more than females. Females used the rock/cliff type (i.e., primarily nonvegetated rock slopes near ridge crests, draws, and permanent snow fields) more than males. These patterns may reflect the females' increased need to remain in habitat more secure from attack by mammalian predators (Smith 1983c, Fox and Streveler, in press) since most are accompanied by kids in summer (Smith, 1984b).

During fall, females' use of commercial old-growth forest increased slightly and both sexes used subalpine forests extensively (Fig. 7). Use of alpine and rock/cliff types by both sexes decreased, and though the same pattern of male preference for the alpine type and female preference for the rock/cliff type prevailed, the sexes were not distributed differently ($P > 0.64$) overall.

Timber Volume:

During winter males and females were not distributed differently ($P > 0.06$) with respect to timber volume (Fig. 7). Both sexes used noncommercial (i.e., less than 8 mbf/acre) forest stands more than any other single class, but nearly 50% of all relocations occurred in commercial stands. Of the commercial classes, the 20-30 mbf/acre stands were most often used (Fig. 7).

The use of commercial stands increased in spring as males moved down from subalpine forests and were found in 20-30 mbf/acre stands over 30% of the time. At the same time, females increased their use of 8-20 mbf/acre stands, resulting in significantly different (P < 0.001) use of timber volumes by the sexes in spring. As in winter, nearly 50% of the goats' time was spent in commercial-volume old-growth timber.

With the goats' shift during summer to primarily alpine habitat, use of nonforested areas was predominant (Fig. 7). Most use of timbered areas was in noncommercial subalpine stands, although both sexes continued to use commercial stands about 5% of the time. The sexes were not distributed differently (P > 0.20) in summer.

Use of commercial-volume timber increased slightly during fall, but the major shift for both sexes was decreased use of nonforest (alpine) areas and increased use of noncommercial (subalpine) timber stands. No significant difference (P > 0.72) between sexes was detected.

Utilization vs. Availability

Although descriptive analyses of frequency distributions are illustrative of general patterns in mountain goat habitat utilization, they do not provide insight into the goats' relative preference for, or avoidance of, specific habitat features. The following comparisons of utilization versus availability of the 6 primary habitat variables for the UCP goats indicate various patterns of habitat use which constitute preference or avoidance. These comparisons were made both at the level of selecting a home range from the UCP and the level of selecting winter locations within the MCP home range for each goat.

The total area of the MCP home range for 6 goats of each sex monitored from 1981-84 on the UCP was determined using all relocations made in 1, 2, and 3 years (Figs. 8 and 9). Results indicated that additional monitoring beyond 2 years added little or no area to the estimated home range size. Accordingly, it was decided that any home range based on at least 2 years of monitoring was adequately identified and was used for further analysis.

Of the 23 goats collared on the UCP, 20 (13 females, 7 males) were monitored for a minimum of 2 years and their home ranges were analyzed. Home ranges of the females averaged 11.7 km^2 (range 1.9 to 22.0 km^2), and those of males averaged 44.9 km^2 (range 5.1 to 90.1 km^2).

Elevation:

Chi-squared analysis revealed that 92% of the females and 80% of the males were selective (P < 0.05) with respect to elevation in establishing their MCP home range on the UCP study area. Sixty-nine percent and 57% of females and males, respectively, were selective ($P < 0.05$) regarding use of elevation within the MCP home range during winter (Table 3). Bonferroni Z analysis indicated that of the 5 elevation classes, all goats (except 1 female) avoided the 0-250 m zone in establishing their home range, but only 40% avoided this zone within their home range in winter (Table 4). In fact, 13% of the females preferred this lowest elevation zone in winter and 63% of the females and 43% of the males used it in proportion to availability. Nearly two-thirds of the females and half of the males also avoided the 250-500 m zone in selecting their home ranges. However, as with the lower zone, in comparing use during winter with availability in the home range, none of the males and only 1 (8%) of the females avoided the 250-500 m zone. All the males and 69% of the females used the 250-500 m zone in proportion to availability and 23% of the females preferred it.

These results indicate that although goats generally avoid lower elevation areas in the course of their annual movements, those areas below 500 m that do fall within a goat's home range may often be used, or even preferred, during winter months. Utilization vs. availability analysis was not performed for spring relocations, but the previously described shift by males, during spring, to areas below 500 m (Fig. 2) suggests that preference for these lower elevations may be even greater during spring.

The mid-elevation zone, 500-750 m, was preferred by 31% of the females when selecting their home range (Table 4). The remaining 69% of the females and all males used this zone in proportion to availability in establishing a home range. Within their home ranges' during winter, only 15% of the females preferred the mid-zone; 77% used it proportionately; and 8% avoided it. Conversely, 29% of the males preferred this zone and 71% used it proportionately. Thus, while more females than males preferred the mid-zone for inclusion in their home range, more males than females preferred to use these elevations during winter. This reflects the general tendency for males to winter at higher elevations than females (Fig. 2).

Males and females were consistent in their use of the 750-1,000 m elevation zone which was preferred by 45% of the goats and used proportionately by the other 55% in selecting their home ranges (Table 4). A comparison of winter relocations with the home range, however, reveals a reverse pattern. The majority (65%) of goats avoided this zone, and only 1 male preferred it.

A similar relationship occurs with respect to the highest elevation zone (1,000+ m), which, though avoided by 46% of the females and 14% of the males, was still preferred or used proportionately by most goats (65% overall) in establishing their home ranges. However, 71% of the females and 57% of the males avoided these areas within their home range during winter (Table 4).

The foregoing analysis of availability vs. utilization of elevation zones demonstrates that goats may be making habitat selection decisions at 2 levels. At the primary level, they elect to utilize areas on a year-round basis, which represents preference for higher elevations than are generally available in the mountain and valley complexes which they occupy. During the critical winter period, however, their selection is reversed and they demonstrate preference for the lower elevation portions of their home range. This dichotomous pattern is also evident with respect to other habitat parameters.

Aspect:

Chi-squared analysis revealed that 85% of the females and 100% of the males were selective ($\underline{P} < 0.05$) with respect to aspect in establishing their home ranges on the UCP, but less than half (46% of the females, 43% of the males) were selective regarding aspect within their home range during winter (Table 3). Bonferroni Z analysis indicated that more females (31%) preferred northerly aspects in their home range, and the remaining 65% used such slopes in proportion to availability (Table 5). Most (77%) of the females included east and west or southerly slopes proportionately, while 8% preferred these aspects and 15% avoided them. Most (77%) of the females avoided flat terrain in establishing a home range and none preferred it. All females included a proportionate amount of ridgetop in their home range.

In contrast to females, no males preferentially incorporated northerly or east and west slopes in their home range and these slopes were avoided by 14% and 29%, respectively, of the males (Table 5). Southerly slopes were preferred by nearly half (43%) and avoided by none of the males for home range area. While a slight majority (57%) of the males avoided flats in circumscribing their home range, nearly a third (29%) preferred flat ground. As with females, all males included a proportionate amount of ridgetop in their home range.

Analysis of winter use of aspect within the home range by females shows a marked contrast to overall home range selection (Table 5). Only 1 (8%) of the females continued to prefer northerly slopes and most (54%) avoided these portions of their home range. East and west slopes were still used proportionately by 77% of the females, but none preferred these aspects. Conversely, no females avoided southerly slopes in winter and more than half (54%) preferred this aspect. Surprisingly, a large percentage of females (55%) used flat terrain in proportion to availability within their home range during winter, though none preferred it. This may reflect the females' tendency to winter low on the slopes, coupled with the decision to use the southwest corner of the grid cells as the descriptive points. For example, if a female were actually located near the base of a steep, south-facing slope, but the corner of the grid cell she occupied fell 100 m away on a valley bottom, her location aspect would be classified as flat.

This apparent anomaly demonstrates 1 potential weakness of the grid scale used. However, this bias should occur rarely, inasmuch as the grid lines are less than 200 m (i.e., 528 ft) apart. A more likely explanation is that females avoid flats in establishing their home range (Table 5) so it would only take a few winter relocations classified as "flat" to indicate proportionate use. In fact, for the 5 females that were found to have made such use, an average of only 1.5 relocations with flat aspects were made for each one. Small sample size may also explain why females were found to make proportionate use of ridgetops during winter (Table 5) even though females spent most of their time at low elevations during winter (Fig. 4).

Winter aspect selection within the home range by males reveals a similar pattern of increased preference for southerly aspects and avoidance of northerly slopes (Table 5). Although no males preferred east and west aspects in winter, fewer males were found to avoid these slopes in winter relative to establishing their overall home range (Table 5). Some males preferred flat terrain in selecting their home range, but none did in winter and over half (57%) avoided it. Twenty-nine percent of the males avoided ridge tops; the remainder used it proportionately.

Slope:

Sixty-nine percent of the females and 87% of the males were selective ($\underline{P}$ < 0.05) with respect to inclusion of various slope angles in their home range and 62% of the females and all males were selective regarding use of slopes within their home range during winter (Table 3). Over half the females (54%) and nearly half the males (43%) avoided slopes of less than 20° and only 1 (14%) male preferred to include this class (Table 6). All 20 goats incorporated a proportionate amount of 21-30° slope in their home range. Several females (31%) preferred the 31-50° slope category; all others included it proportionately, as did all but 1 (14%) male which avoided it (Table 6). All goats, except 1 female which preferred the 31-50° slope, incorporated a proportionate amount of 51-65° slopes in their home ranges, and all but 3 females which avoided the 31-50° category also used the 66°+ slope class proportionately. Thus, overall, goats generally did not prefer slopes less than 31° in their home range and half avoided those slopes of less than 20°. Conversely, none avoided slopes 51-60°, and a few avoided slopes over 66°.

Winter relocations compared with availability in the home range (Table 6) indicated even more pronounced selection in favor of steep (>30°) slopes. For example, even though half of the goats had already avoided slopes of less than 20° in their home range, all but 2 females which used these slopes proportionately were found to have further avoided what small amount of this low slope angle did occur within the home range. Furthermore, 60% of the goats avoided the 21-30° slopes and 70% preferred slopes of 31-50° in winter (Table 6). The tendency by males to select more extreme terrain than females in winter (Fig. 4) is evidenced by the higher percentage of males that avoided slopes less than 30°, and preferred slopes between 30° and 65°. Although selection of the steepest slopes (66°+) by males did not change in winter, females' selection did, as none avoided such slopes and 1 (10%) preferred them (Table 6).

Distance to Cliffs:

All goats except male No. 26 were selective ($P < 0.05$) with respect to distance to cliffs in establishing their home range on the UCP (Table 3). Conversely, only 1 goat of each sex was selective regarding distance to cliffs within their home range during winter. The seemingly counter-intuitive lack of selection in winter is merely an artifact of radical selection at the home range level. Virtually all goats spend their lives within 0.4 km of cliffy terrain (Fig. 5) so their home ranges consist almost completely of cliffs and nearby slopes. Since only 1 distance to cliff dominates the home range, it is impossible for goats to be selective. The exceptions to this pattern in this study, male No. 26 and female No. 29, had the largest home ranges for goats of their sex (90.1 and 22.0 km^2, respectively) thus enabling them to select from an array of categories within their home ranges during the winter.

Bonferroni Z analysis (Table 7) supports the foregoing explanation. In selecting a home range, 80% of the goats preferred areas less than 0.4 km from cliffs and at least 85% avoided areas over 0.8 km from cliffs. Conversely, only 40% were found to prefer areas within 0.4 km of a cliff in the home range during winter, and fewer than 30% avoided areas over 0.8 km from cliffs. It is important to remember that preference and avoidance are relative to availability, so if 100% of a goat's relocations occurred within 0.4 km of a cliff, but 95% of the home range was within 0.4 km of a cliff, this goat would not be thought of as preferring this distance to a cliff. As previously demonstrated with respect to elevation, an animal's selection decisions at the level of establishing its home range can have a profound effect on interpretation of utilization vs. availability at some other level on a seasonal basis. These results reinforce the value of multi-level analysis.

Vegetation Type:

All but 1 female goat were selective (P < 0.05) with respect to inclusion of various vegetation types in their home range on the UCP. However, during winter, less then half were selective regarding vegetation within their home range (Table 3). The fact that a higher percentage of males were selective within their home range again reflects the results of multi-level selection. The females' tendency to utilize a smaller home range with a potentially reduced mix of habitats made it less necessary (or simply less measurable) for them to be selective within the home range during winter. On the other hand, males with larger home ranges, possibly including extensive areas which are rarely used, were more often found to be selective in their use of portions of the home range.

Bonferroni Z analysis revealed that only 1 female preferred commercial old-growth forest in establishing a home range (Table 8). Most goats (55%) used old-growth proportionately, but 38% of the females and 43% of the males avoided commercial forest in establishing their home range. Conversely, no goats avoided the old-growth forest within their home range during winter; 31% of the females and 43% of the males preferred this type.

Low-elevation, non-commercial (muskeg) forest was avoided by most goats in establishing a home range, though 1 (14%) of the males and 3 (31%) of the females used it proportionately and 1 (14%) of the males preferred it. Of those goats with muskeg forest in their home range (n = 16), 1 preferred it, 3 avoided it, and 12 used it proportionately during winter. Preference and proportionate use were higher among females and reflected their tendency to winter at lower elevations.

Selectivity regarding subalpine forest was similar for males and females. Most goats made proportionate use of this type, a few of each sex preferred it, and none avoided it in establishing their home range (Table 8). Within the home range during winter the subalpine type was still used proportionately by most goats. However, some goats avoided the subalpine and none preferred it during winter.

The brush/slide type was used proportionately by most goats in establishing their home range, though a few males preferred it, and a few females and 1 male avoided it (Table 8). During winter, no goats preferred this type and 22% of the goats avoided it.

The sexes were most distinct in their selection regarding alpine areas. Only 31% of the females preferred alpine and 46% avoided it in establishing their home range, while 43% of the males preferred it, and none of them avoided it. Within their home ranges during winter, 71% of the females avoided alpine areas, while only 57% of the males did so. No goats preferred the alpine during winter.

Overall, selection of vegetation type parallels selection for elevation. In establishing their home ranges, goats more often avoided commercial old-growth and muskeg forests (i.e., lower elevations) and used subalpine, alpine, and brush/slide areas (i.e., higher elevations) proportionately. Conversely, in winter the open subalpine, alpine, and brush/slide types were less preferred or even avoided, while preference for commercial old-growth was increased.

Timber Volume:

Over 70% of both sexes were selective ($\underline{P} < 0.05$) with respect to inclusion of various timber volume classes in their home range on the UCP (Table 3). However, although 86% of the males were found to use timber volumes selectively within their home range during winter, only 38% of the females did the same. As previously discussed, the apparently lower selectivity of females, on a seasonal basis within the home range, may reflect their greater selectivity at the home range level.

Bonferroni Z analysis indicated that nonforested areas were used proportionately by 55% of the goats, preferred by 40%, and avoided by only 5% in establishing their home ranges (Table 9). However, within the home range during winter, 62% of the females and 100% of the males avoided nonforested areas, and no goat preferred nonforest during winter.

While noncommercial forest lands were also used proportionately by over half (60%) of the goats, only 10% preferred these stands and 30% avoided them in establishing their home range (Table 9). Within the home range during winter, only 5% of the goats either preferred or avoided noncommercial forest, and 90% used these stands proportionately.

All 3 commercial-volume timber categories were avoided by 50% to 55% of the goats, and preferred by none in establishing their home ranges (Table 9). Conversely, no goats avoided 8-20 or 21-30 mbf/acre timber, and only 1 goat avoided 30+ mbf/acre stands, within their home range during winter. Thirty percent of the goats preferred 21-30 mbf/acre stands at this time.

Thus, as was shown for other habitat parameters, goats appear to be making selection decisions regarding timber volume at more than 1 level. Lower-elevation, commercial-volume forests are generally avoided in establishing the home range, but are highly preferred within the home range during winter.

The criteria an animal uses in determining its lifetime home range may be quite different from those it uses in making decisions regarding seasonal or day-to-day activity areas. The degree of difference between the 2 operative levels should reflect, among other things, the variability of seasonal weather and the degree of heterogeneity of habitat types within the species' range.

Habitat Modeling and Winter Range Predictions

The stepwise discriminant function analysis (DFA) of UCP cells used by radio-collared goats during winter (*n* = 313) vs. a random sample of unused UCP cells (*n* = 1,436) identified slope category as the most powerful discriminating variable for separating the 2 cell groups. The standardized canonical coefficients (Table 10) indicate that slope angle contributed nearly twice as much to the separation of the groups in multivariate space as did distance to cliffs, and more than twice as much as timber volume. The latter 2 variables were relatively close in terms of their discriminating power. Aspect and elevation contributed less to the discrimination, but were, nevertheless, significant in terms of overall separation. From the signs of the coefficients it is evident that slope, aspect, and timber volume make positive contributions to the function (i.e., steeper slopes, more southerly aspects, and higher timber volumes are characteristic of habitat cells) while elevation and distance to cliffs make negative ones (i.e., higher elevations and greater distances from cliffs are more characteristic of random cells).

The derived discriminant function has a relatively large Wilks lambda (0.81) and relatively small separation of group centroids in multivariate space (1.05 for habitat cells vs. 0.23 for random cells), which indicates there is substantial overlap of the groups. This is not surprising, inasmuch as many of the random cells are, in fact, biophysically identical to the cells used by goats during the winter. Nevertheless, the canonical correlation of the equation (0.44) is high enough to suggest that this function can adequately discriminate among the cell groups. This conclusion is also supported by the results of the classification table (Table 11) which indicates that the function correctly classified 84% of the habitat cells and 71% of the random cells when the cells were reprocessed through the function. The most important test of the DFA, however, is how well it predicts areas that will be used by goats during winter.

Of the 1,906 cells systematically sampled on the QHV study area, the DFA classified 808 (42%) as habitat cells. Of the 5,690 cells sampled on Revilla Island, the DFA classified 2,362 (42%) as habitat. These cells were mapped on overlays, and boundaries were drawn around groups of cells following the 3-corner rule as applied by Smith (1983b). The enclosed areas constitute predicted winter goat habitat (Figure 10).

All winter relocations of goats collared on the QHV study area (n = 280) and goats transplanted to Revilla Island (n = 60) were mapped on the habitat overlays. In the QHV area, 82% (n = 227) of the relocations occurred within the borders of the predicted habitat and an additional 17% (n = 49) occurred in cells adjacent to the border (Figure 10). On Revilla Island, 82% (n = 49) of the relocations were within the borders and another 5% were in adjacent cells. Chi-squared analysis of goodness-of-fit indicates that in both the QHV and Revilla Island study areas goats made significant ($P < 0.001$) selection for the predicted habitat cells. Thus it appears that the function does accurately identify areas that will be used by goats during the winter.

The general patterns of habitat selection by mountain goats described in this study are similar to those reported by Schoen and Kirchhoff (1982), Fox et al. (1982) and Fox (1983) for other areas in south-coastal Alaska. In each of these analyses, steepness of slope and proximity of escape terrain (i.e., cliffs) were critical features in identifying year-round goat habitat. Studies in other areas (Idaho--Brandborg 1955; Montana--Rideout 1974, Smith 1976; British Columbia--Hebert and Turnbull 1977, McFetridge 1977, Foster 1982; Colorado--Adams and Bailey 1980) have also stressed the reliance of goats on steep, broken terrain. In a thorough review of habitat selection by goats, Fox (1983) concluded that the need to avoid predation by remaining in rugged terrain was the primary constraint on this species' habitat use. Observations of interactions between goats and mammalian predators (Smith 1983a, Chadwick 1983, Fox and Streveler, in press) have documented the value of escape terrain to this species. Accordingly, it is not surprising that the UCP goats displayed marked selection for steep slopes and minimal distance to cliffs, and that these were the 2 most powerful discriminating variables in the DFA presented here.

The major differences between the results of this study and those from earlier analyses is the goats' extensive use of forested habitat and the relative importance of timber volume in discriminating between winter habitat and random cells. Prior applications of DFA to goat habitat selection in Southeast Alaska either did not consider timber volume (Schoen and Kirchhoff 1982) or were made in "atypical" goat habitat (Fox et al. 1982) where virtually the entire area was forested.

Results of this study confirm the importance of timber as a significant component of winter range for goats in south-coastal Alaska. Winter conditions, (e.g., snowdepth, temperature, forage restrictions) were relatively mild during the period of this study (Smith 1984b). If one recognized the tendency for goats to use lower elevation, more timbered areas during periods of deeper snow, and/or more adverse conditions (Hjeljord 1971, Fox et al. 1982) then we can conclude that the degree of use of timbered areas found in this study is conservative.

In addition to reducing snowdepth, timber on steep broken slopes increases the stability of the snow pack, thus reducing the potential for avalanches, a major source of mortality of goats (Nichols 1982b, Chadwick 1983). Conifers, and the arboreal lichens that grown on them, are also major components of the goats' diet during winter (Fox and Smith, Appendix B). Accordingly, forest overstory must be added to steep, broken terrain and nearby cliffs as an essential element of winter goat habitat in southern Southeast Alaska and coastal British Columbia.

MANAGEMENT IMPLICATIONS

In this study, goats were generally found to avoid or underutilize lower elevations, slopes less than 30°, commercial-volume timber, and any area in excess of 0.8 km from cliffy terrain in establishing their home ranges. Nevertheless, most goats, especially the females, displayed marked preference for the limited portions of lower elevation commercial forest within their home range during winter. Numerous studies have mentioned the importance of these areas of winter habitat to coastal goat populations (Hjeljord 1971, Hebert and Turnbull 1977, Schoen and Kirchhoff 1982, Fox et al. 1982, Fox 1983), and most investigators agree that isolating these habitat areas from human impacts (e.g., logging, road building, mining) and maintaining travel corridors between such habitats are essential to protecting goat populations in this area (Smith and Raedeke 1982, Fox 1983).

Prior to initiating future developments in goat range, planners should identify all potential goat habitat. As Schoen and Kirchhoff (1982) and Fox (1983) suggested, as a 1st approximation, all areas within 0.8 km of any identifiable area with a slope exceeding 50° should be considered potential year-round habitat. For most of southern Southeast Alaska and coastal British Columbia, any such areas with forest overstory should be considered possible winter habitat.

If a more refined approach is needed, results of the discriminant function analysis performed here could be used to predict winter range locations if it can be assumed that the area of concern is biophysically similar to the UCP. This assumption is probably valid as far north as Thomas Bay and as far south as Portland Canal in Alaska. Beyond these limits, this DFA should be applied with caution until further testing can be completed.

To apply the DFA, a sample of points should be selected and at each point the elevation, aspect, slope, distance to the nearest cliff, and timber volume should be determined. All values must be scaled as in Table 12. The raw data values should then be used with the coefficients in Table 13 in the formula:

$$\begin{aligned} SCORE_i = {} & \text{Elevation}*(Ce_i) + \text{Aspect}*(Ca_i) + \text{Slope}*(Cs_i) + \\ & \text{Distance to Cliffs}*(Cd_i + \text{Timber Volume}*(Ct_i) + \\ & (\text{Constant})_i \end{aligned}$$

for both the "Habitat" and "Random" coefficients. Each point will have 2 scores, one a "Habitat" score, the other a "Random" score. Whichever score is larger indicates the group into which that point should be classified. Predicted "Habitat" points can then be mapped for use in land-use planning.

Although the DFA technique proved to be highly accurate in predicting where goats would winter in 2 areas near Ketchikan, the underlying assumptions of DFA were strained in this application. Fortunately, DFA is an extremely robust procedure and violation of some assumptions is not fatal to the results. Nevertheless, it is recommended that managers use the aforementioned predictive model primarily as a guide for concentrating further investigations, such as on-the-ground examination by interdisciplinary teams, on the most likely conflict areas.

Regardless of the method of determination, once identified, goat winter habitat should be avoided to the extent possible by future developments. Most such areas are not suitable for timber harvest, but those that do have potential as special units (e.g., helicopter logging) should be considered in the allocation of retention. Because goats have been found to be sensitive to disturbance associated with road construction and use (Chadwick 1973), any such activity within 1 km of goat winter habitat should be scheduled for the period of 1 June through 31 October.

In addition to direct impact on habitat, resource development may indirectly affect goats through creation of access to previously unhunted populations (Chadwick 1973, Phelps et al.

1983). Hunter harvest will have to be closely monitored to avoid over-exploitation and special road restrictions may be necessary.

Finally, unavoidable habitat losses resulting from timber, mineral, or hydroelectric developments should be mitigated, and the costs of mitigation should be internalized with the development. For example, habitat and resultant goat population losses in the QHV study area, due to development of the U.S. Borax molybdenum mine, should be mitigated through additional transplants of goats into vacant habitat on Revilla Island, with the cost of the operation to be borne by U.S. Borax.

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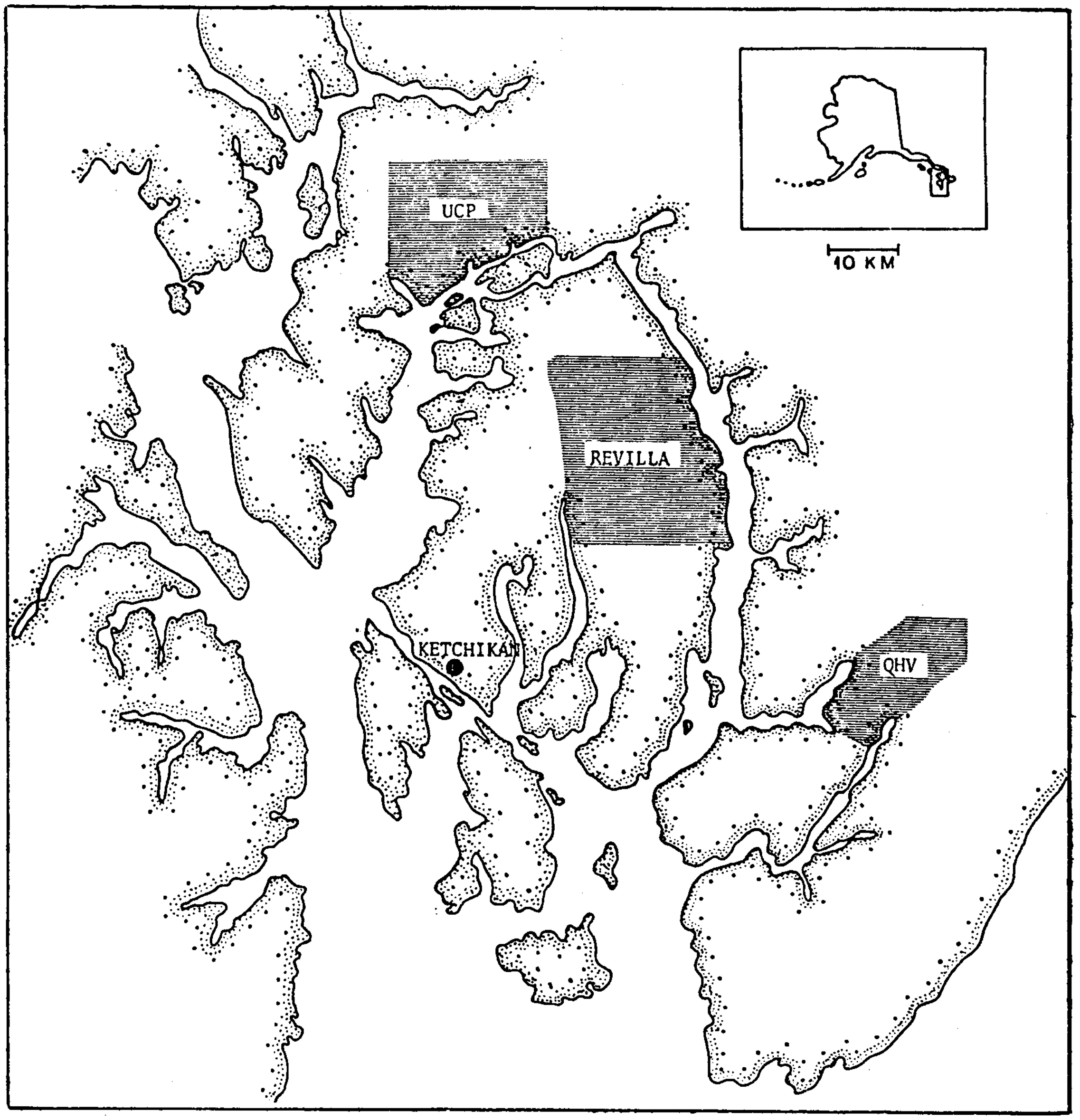

Fig. 1. Location of Upper Cleveland Peninsula (UCP), Quartz Hill vicinity (QHV), and Revillagigedo Island (Revilla) study areas near Ketchikan, Alaska.

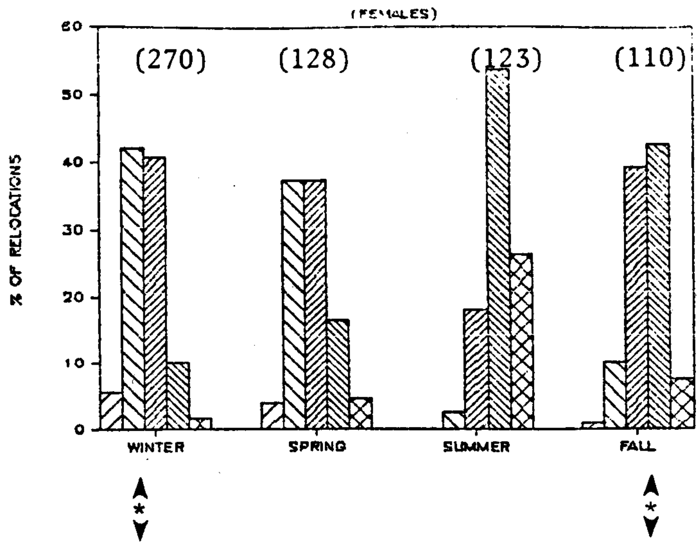

Fig. 2a

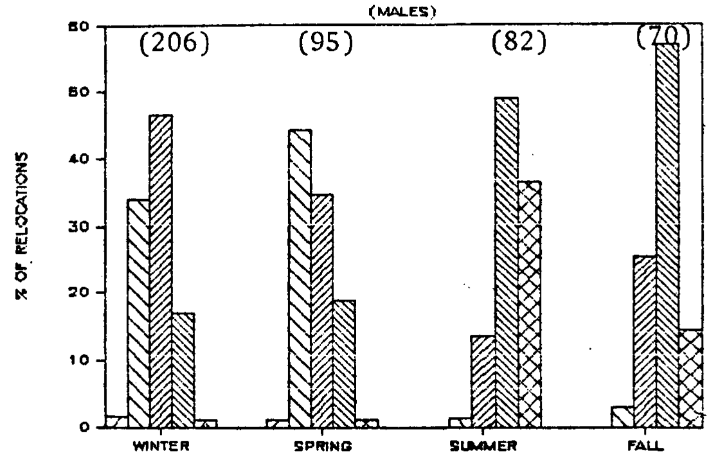

Fig. 2b

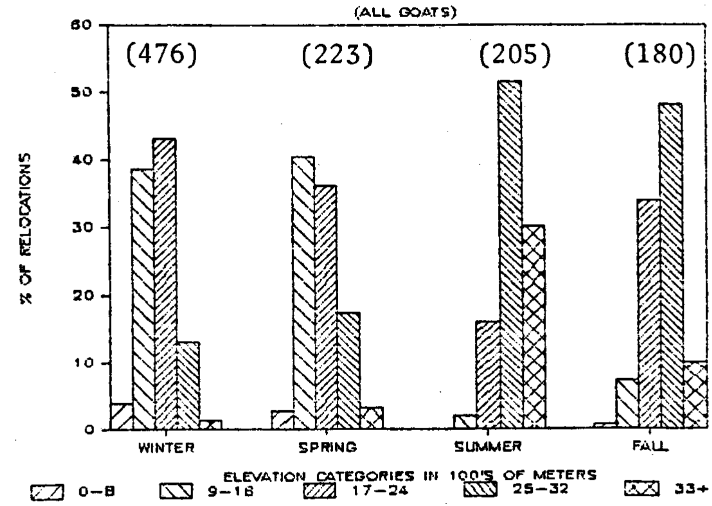

Fig. 2c

Fig. 2. Seasonal frequency distribution of elevations used by radio-collared goats on the Upper Cleveland Peninsula (UCP) study area, 1981-84, based on (n) relocations. Asterisk indicates significantly ($P < 0.05$) different use by males and females.

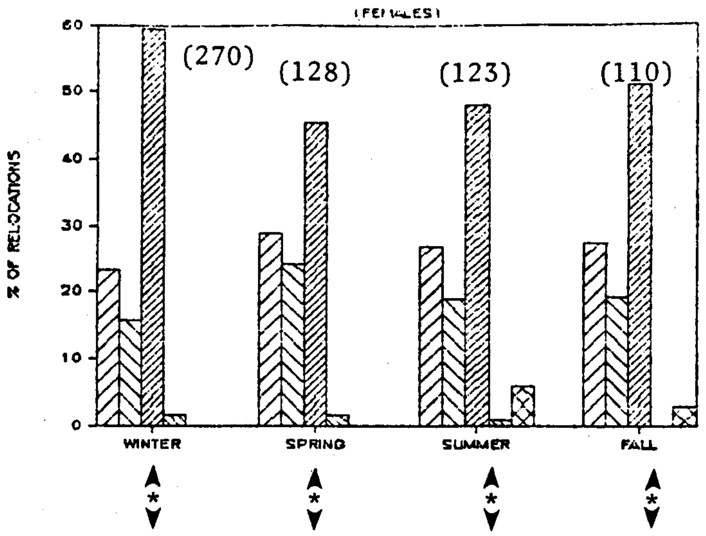

Fig. 3a

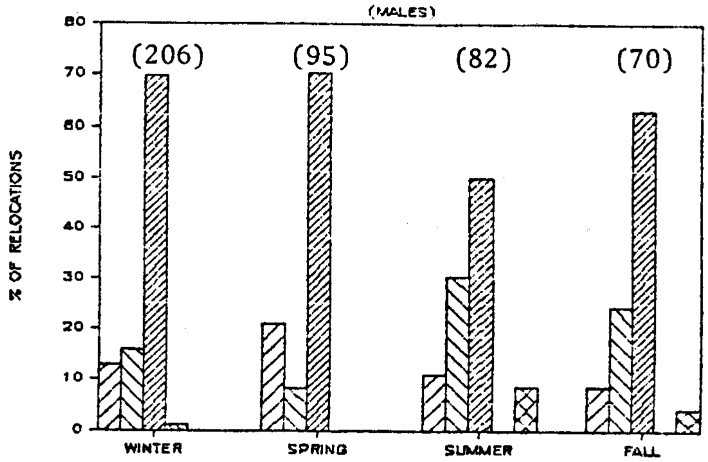

Fig. 3b

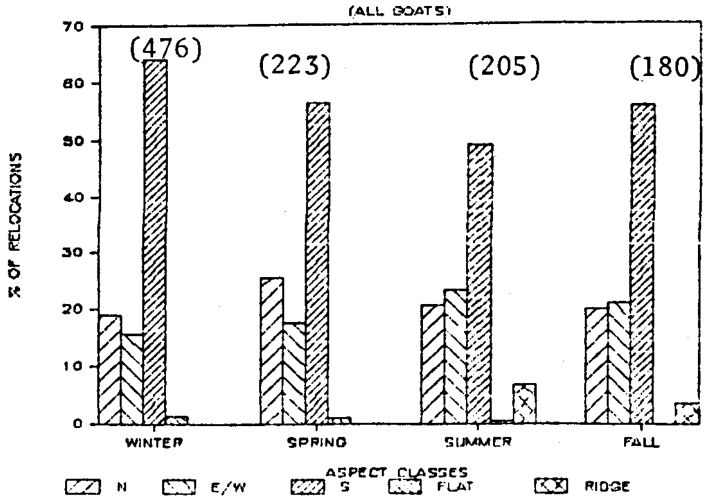

Fig. 3c

Fig. 3. Seasonal Frequency distributions of aspect used by radio-collared goats on the Upper Cleveland Peninsula (UCP) study area, 1981-84, based on (n) relocations. Asterisk indicates significant ($\underline{P} < 0.05$) difference between males and females.

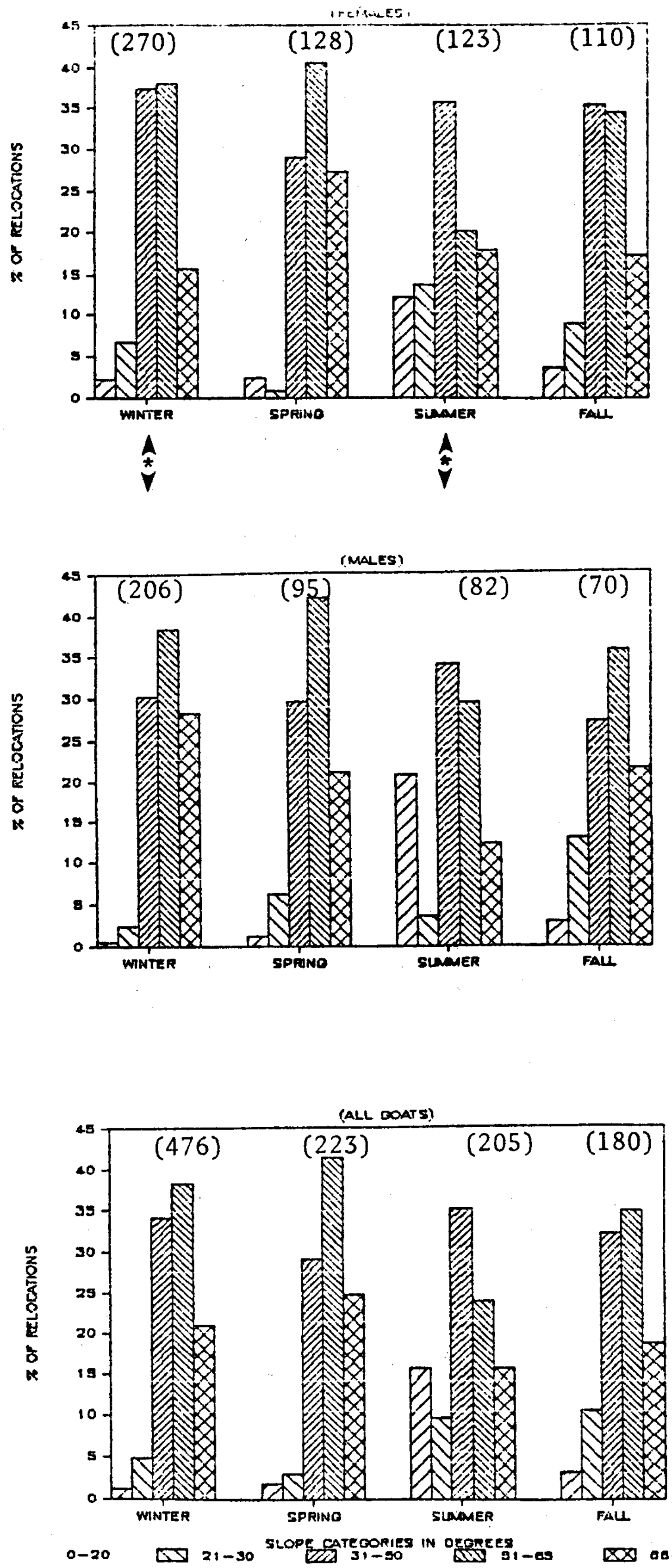

Fig. 4a

Fig. 4b

Fig. 4c

Fig. 4. Seasonal frequency distributions of slope categories used by radio-collared goats on the Upper Cleveland Peninsula (UCP), Alaska, study area, 1981-84, based on (n) relocations. Asterisk indicates significant ($P < 0.05$) difference between males and females.

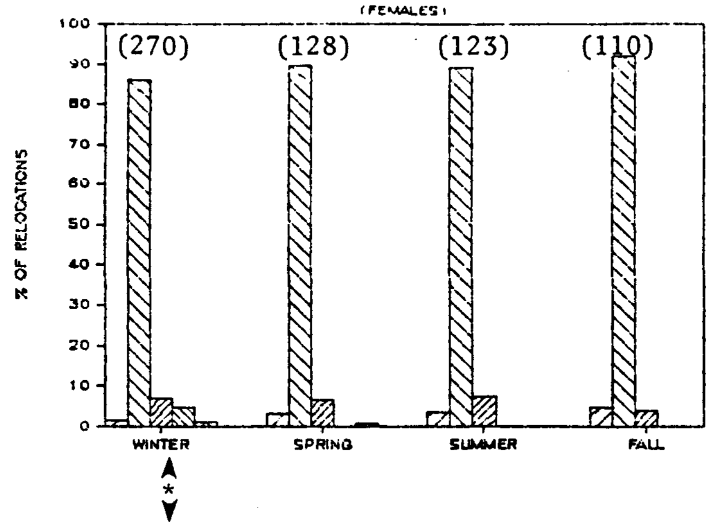

Fig. 5a

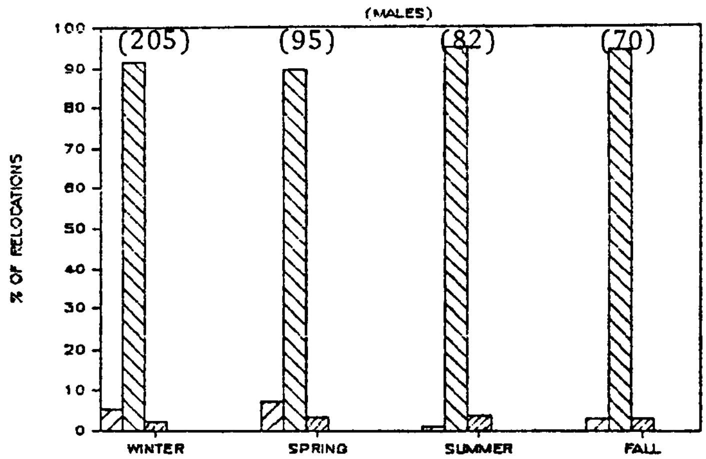

Fig. 5b

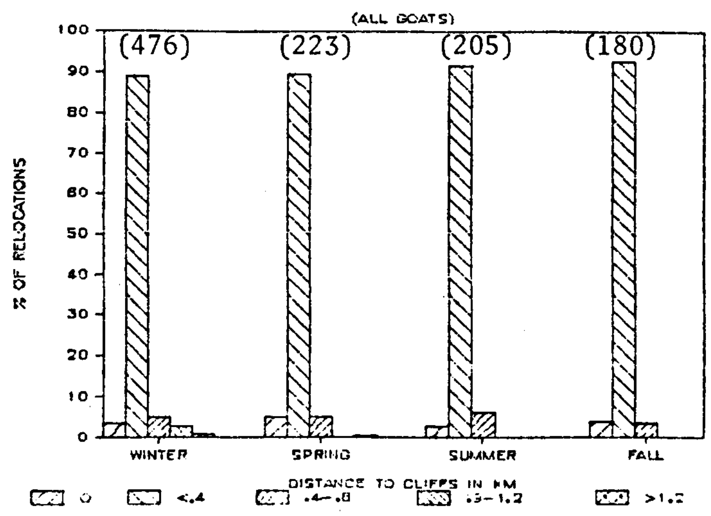

Fig. 5c

Fig. 5. Seasonal frequency distributions of distances to cliffs used by radio-collared goats on the Upper Cleveland Peninsula (UCP), Alaska, study area, 1981-84, based on (n) relocations. Asterisk indicates significant ($\underline{P} < 0.05$) difference between males and females.

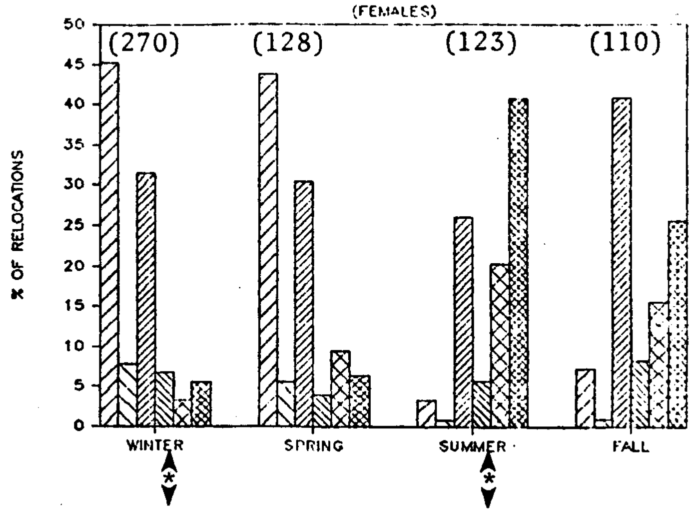

Fig. 6a

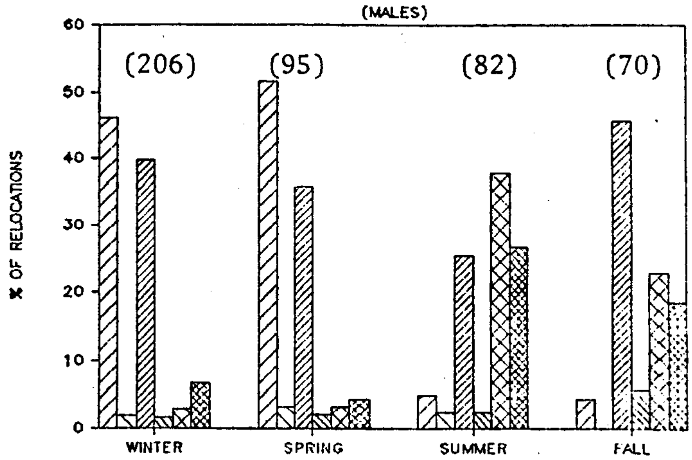

Fig. 6b

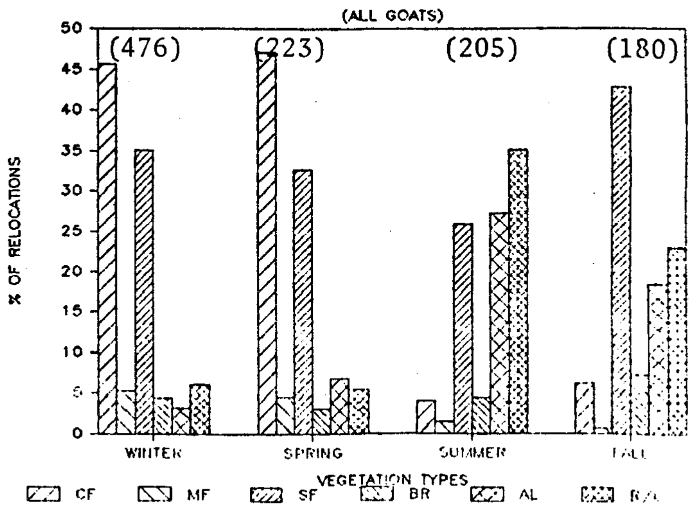

Fig. 6c

Fig. 6. Seasonal frequency distributions of vegetation types used by radio-collared goats on the Upper Cleveland Peninsula (UCP) study area, 1981-84, based on (n) radiolocations. Asterisk indicates significant ($\underline{P}$ < 0.05) difference between males and females. See Appendix A for explanation of vegetation abbreviations.

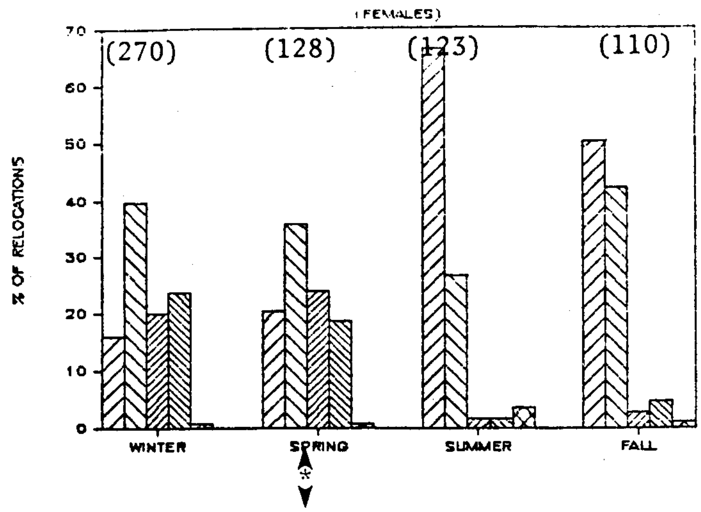

Fig. 7a

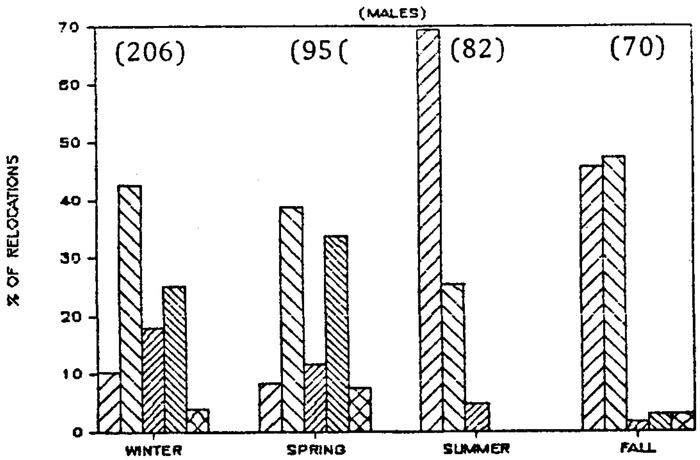

Fig. 7b

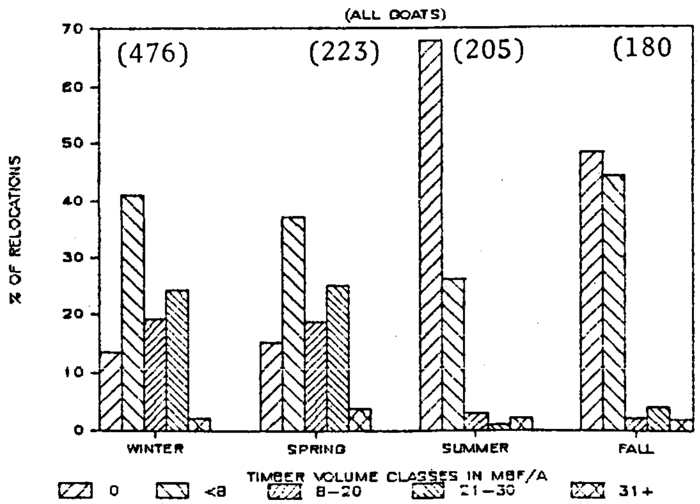

Fig. 7c

Fig. 7. Seasonal frequency distribution of timber volume used by radio-collared goats on the Upper Cleveland Peninsula (UCP) study area, 1981-84, based on ($\underline{n}$) relocations. Asterisk indicates significant ($\underline{P}$ < 0.05) difference between males and females.

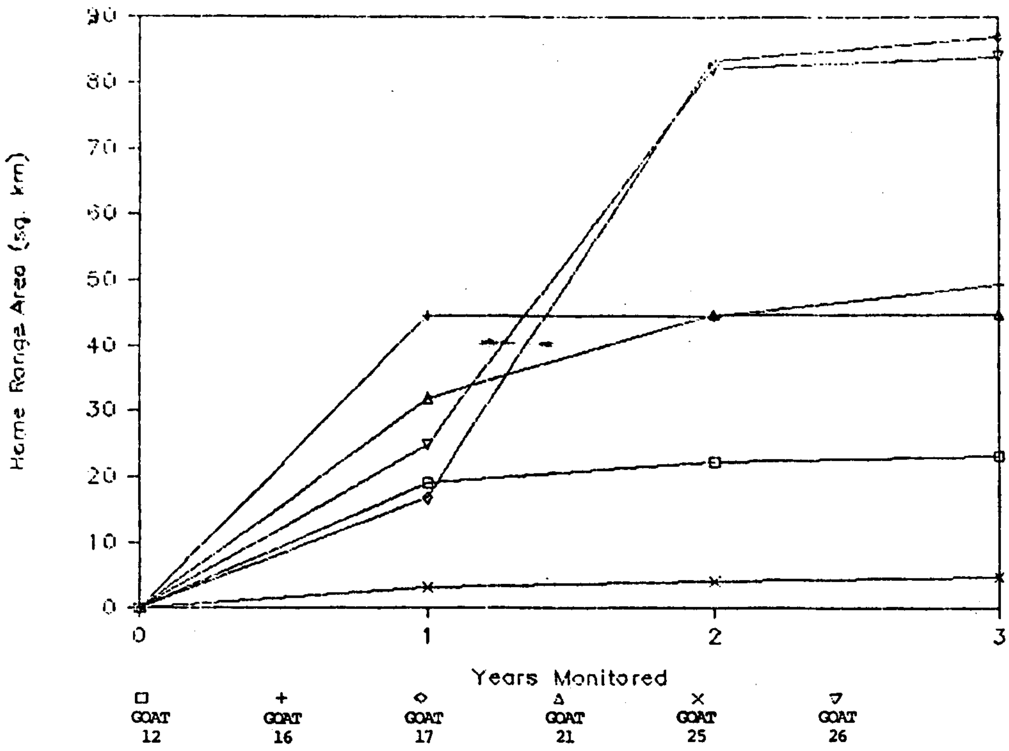

Fig. 8. Home range size as a function of years monitored for male goats on the Upper Cleveland Peninsula (UCP), Alaska, 1981-84.

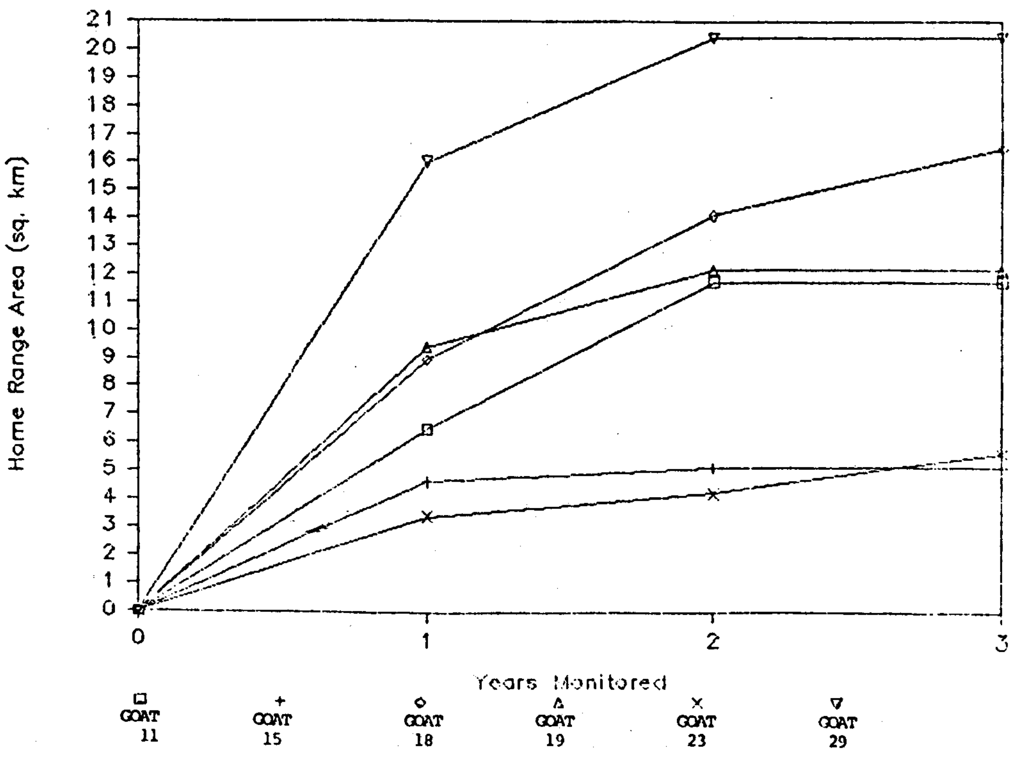

Fig. 9. Home range size as a function of years monitored for female goats on the Upper Cleveland Peninsula (UCP), Alaska, 1981-84.

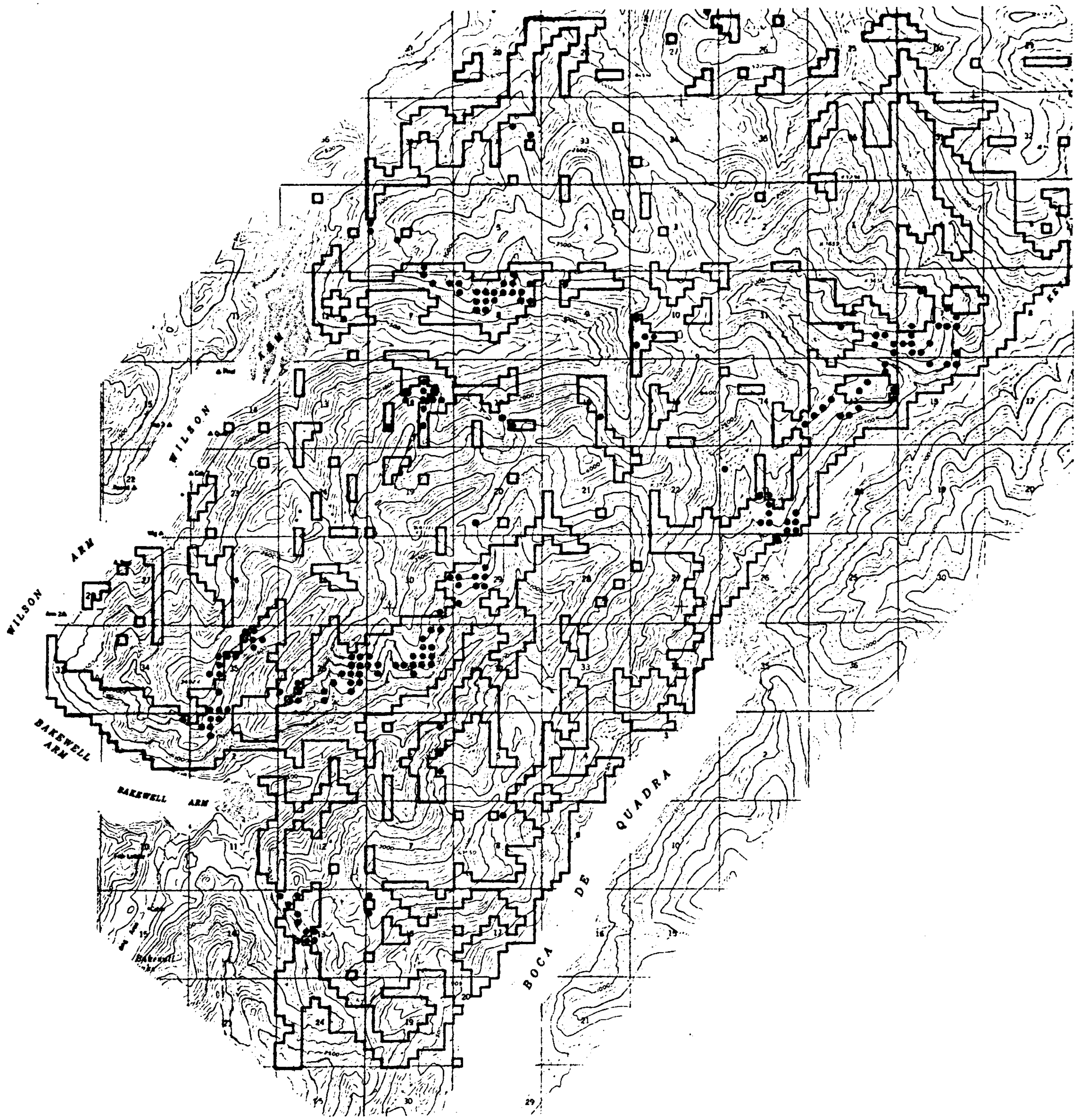

Fig. 10. Location of predicted winter habitat and November through March relocations of 13 radio-collared goats on the Quartz Hill, Alaska, vicinity study area, 1981-84.

Table 1. Relocations of radio-collared mountain goats in the Ketchikan area, Alaska, 1981-84.

Study area	Sex	Season: Winter	Spring	Summer	Fall	Total
UCP[a]	F	270	128	123	110	631
UCP	M	206	95	82	70	453
UCP	All	476	223	205	180	1,084
QHV[b]	F	135	42	19	38	234
QHV	M	155	42	25	45	267
QHV	All	290	84	44	83	501
Revilla[c]	F	44	9	28	2	83
Revilla	M	16	4	14	0	34
Revilla	All	60	13	41	2	117
Total	F	449	179	170	150	948
Total	M	377	141	121	115	754
Total	All	826	320	291	265	1,702

[a] Upper Cleveland Peninsula.

[b] Quartz Hill vicinity.

[c] Revillagigedo Island (transplanted goats).

Table 2. Results of Chi-squared analysis of male vs. female mountain goat utilization of 5 habitat parameters, based on seasonal relocations, Ketchikan area, Alaska 1981-84.

	Elevation	Aspect	Slope	Distance to cliff	Vegetation Type	Timber Volume	(n)
Winter	*[a]	*	*	*	*	N.S.[b]	476
Spring	N.S.	*	N.S.	N.S.	N.S.	*	223
Summer	N.S.	*	*	N.S.	*	N.S.	205
Fall	*	*	N.S.	N.S.	N.S.	N.S.	180

[a] Significant at $P < 0.05$.

[b] $P > 0.05$.

Table 3. Percent of mountain goats demonstrating significant ($\underline{P}$ < 0.05) selection with respect to 5 habitat parameters in establishing minimum convexed polygon (MCP) home ranges (HR) on the Upper Cleveland Peninsula (UCP) study area and in utilization of winter range (WR) within the MCP home range based on Chi-squared analyses of random points and radiolocations 1981-84.

Group	Comparison	Elevation	Aspect	Slope	Distance to cliff	Vegetation type	Timber volume	($\underline{n}$)
Female	HR vs. UCP[a]	92	85	69	100	92	77	13
	WR vs. HR[b]	69	46	62	8	38	38	
Male	HR vs. UCP	86	100	71	86	100	71	7
	WR vs. HR	57	43	100	14	57	86	
All	HR vs. UCP	90	90	70	95	95	75	20
	WR vs. HR	65	45	75	40	45	55	

[a] Analysis based on comparison of frequency distributions of measured parameters at >75 random points within a goat's MCP home range and 1,526 random points on the UCP.

[b] Analysis based on comparison of frequency distributions of measured parameters at November-March relocations for each goat ($\underline{n}$ = 10 to 31) with 75 random points within the goat's MCP home range.

Table 4. Percentage of mountain goats showing preference (+) proportional use (0) and avoidance (-) of elevational zones in selecting year-round home range areas (HR) on the Upper Cleveland Peninsula, Alaska, (UCP) study area and in selecting winter ranges (WR) within their home range, 1981-84.

		Elevation									
		0 - 250 m		250 - 500 m		500 - 750 m		750 - 1,000 m		>1,000 m	
		HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR
Females	+	0	13[a]	0	23	31	15	46	0	23	0[b]
(n = 13)	0	8	63[a]	38	69	69	77	54	31	31	29[b]
	-	92	24[a]	62	8	0	8	0	69	46	71[b]
Males	+	0	0	0	0	0	29	43	14	14	0
(n = 7)	0	0	43	48	100	100	71	57	29	71	57
	-	100	57	43	0	0	0	0	57	14	43
All	+	0	7[c]	0	15	20	20	45	5	20	0[d]
(n = 20)	0	5	53[c]	45	80	80	75	55	60	45	45[d]
	-	95	40[c]	55	5	0	5	0	65	35	57[d]

[a] n = 8 Sample size reduced as this zone did not occur within each goat's home range.

[b] n = 7 Sample size reduced as this zone did not occur within each goat's home range.

[c] n = 15 Sample size reduced as this zone did not occur within each goat's home range.

[d] n = 14 Sample size reduced as this zone did not occur within each goat's home range.

Table 5. Percentage of mountain goats showing preference (+), proportional use (0), and avoidance (-) of aspects in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula, Alaska, (UCP) study area and in selecting winter ranges (WR) within their home range, 1981-84.

		Aspect									
		NW/N/NE		E/W		SE/S/SW		Flat		Ridgetop	
		HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR
Females	+	31	8	8	0	8	54	0	0[a]	0	0
($\underline{n}$ = 13)	0	69	38	77	77	77	46	23	55[a]	100	100
	-	0	54	15	23	15	0	77	45[a]	0	0
Males	+	0	0	0	0	43	57	29	0	0	0
($\underline{n}$ = 7)	0	86	71	71	86	57	43	14	43	100	71
	-	14	29	29	14	0	0	57	57	0	29
All	+	20	5	5	0	20	55	5	0[b]	0	0
($\underline{n}$ = 20)	0	75	50	75	80	70	45	25	50[b]	100	90
	-	5	45	20	20	10	0	70	50[b]	0	10

[a] $\underline{n}$ = 9 Flat terrain did not occur within 4 home ranges.

[b] $\underline{n}$ = 16 Flat terrain did not occur within 4 home ranges.

Table 6. Percentage of mountain goats showing preference (+), proportional use (0) and avoidance (-) of slope categories in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula, Alaska (UCP) study area and in selecting winter ranges within their home ranges, 1981-84.

		Slope categories									
		0 - 20°		21 - 30°		31 - 50°		51 - 65°		>66°	
		HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR
Females	+	0	0	0	0	31	62	8	0	0	10[a]
(n = 13)	0	46	15	100	46	69	38	92	85	77	90[a]
	-	54	85	0	54	0	0	0	15	23	0[a]
Males	+	14	0	0	0	0	86	0	43	0	0
(n = 7)	0	43	0	100	29	86	14	100	57	100	100
	-	43	100	0	61	14	0	0	0	0	0
All	+	5	0	0	0	20	70	5	15	0	6[b]
(n = 20)	0	45	10	100	40	75	30	95	75	85	94[b]
	-	50	90	0	60	5	0	0	10	15	0[b]

[a] n = 10 Slopes over 66° were not available in 3 home ranges.

[b] n = 17 Slopes over 66° were not available in 3 home ranges.

Table 7. Percentage of mountain goats showing preference (+), proportional use (0) and avoidance (-) of areas at various distances to cliffs in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula (UCP) study area, and in selecting winter range (WR) within their home range, 1981-84.

		Distance to cliffs									
		<0.4 km		0.4 - 0.8 km		0.8 - 1.2 km		1.2 - 1.6 km		>1.6 km	
		HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR
Females	+	77	31	7	0	0	13[a]	0	0[b]	0	—[c]
(n = 13)	0	23	69	38	69	15	87[a]	15	100[b]	0	—[c]
	-	0	0	54	31	85	0[a]	85	0[b]	100	—[c]
Males	+	86	57	0	0	0	0[d]	0	0[e]	0	0[f]
(n = 7)	0	14	43	29	43	14	60[d]	14	66[e]	14	0[f]
	-	0	0	61	57	86	40[d]	86	33[e]	86	100[f]
All	+	80	40	5	0	0	8[g]	0	0[h]	0	0[f]
(n = 20)	0	20	60	35	60	15	77[g]	15	75[h]	5	0[f]
	-	0	0	60	40	85	15[g]	85	25[h]	95	100[f]

[a] n = 8 No area over 0.8 km from a cliff occurs within other home ranges.
[b] n = 1 No area over 1.2 km from a cliff occurs within other home ranges.
[c] n = 0 No area over 1.6 km from a cliff occurs within any female home range.
[d] n = 5 No area over 0.8 km from a cliff occurs within other home ranges.
[e] n = 3 No area over 1.2 km from a cliff occurs within other home ranges.
[f] n = 1 No area over 1.6 km from a cliff occurs within other home ranges.
[g] n = 13 No area over 0.8 km from a cliff occurs within other home ranges.
[h] n = 4 No area over 1.2 km from a cliff occurs within other home ranges.

Table 8. Percentage of mountain goats showing preference (+), proportional use (0) and avoidance (-) of vegetation types in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula, Alaska (UCP) study area, and in selecting winter range within their home range, 1981-84.

		Vegetation type									
		Old-growth forest		Muskeg forest		Subalpine forest		Brush/slide		Alpine	
		HR vs. UCP	WR vs. HR	WR vs. HR	WR vs. UCP	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR
Females	+	8	31	0	11[a]	23	0	0	0[b]	31	0[c]
(n = 7)	0	54	69	31	88[a]	77	85	85	73[b]	23	29[c]
	-	38	0	69	11[a]	0	15	15	27[b]	46	71[c]
Males	+	0	43	14	0	14	0	29	0	43	0
(n = 13)	0	57	57	14	71	86	86	57	86	57	43
	-	43	0	71	29	0	14	14	14	1	57
All	+	5	35	5	6[d]	20	0	10	0[e]	35	0[f]
(n = 20)	0	55	65	25	75[d]	80	85	75	78[e]	35	36[f]
	-	40	0	70	19[d]	0	15	15	22[e]	30	64[f]

[a] n = 9 Muskeg forest did not occur in other home ranges.
[b] n = 11 Brush/slide did not occur in other home ranges.
[c] n = 7 Alpine did not occur in other home ranges.
[d] n = 16 Muskeg forest did not occur in other home ranges.
[e] n = 18 Brush/slide did not occur in other home ranges.
[f] n = 14 Alpine did not occur in other home ranges.

Table 9. Percentage of mountain goats showing preference (+), proportional use (0) and avoidance (-) of timber volume classes in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula (UCP) study area, and in selecting winter range within their home range.

		Timber volume class									
		Nonforested		<8 mbf/a[a]		8-20 mbf/a		21-30 mbf/a		30+ mbf/a	
		HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR
Females	+	38	0	15	0	0	0	0	15	0	0[b]
(_n_ = 13)	0	54	38	54	92	38	100	46	85	31	100[b]
	-	8	62	31	8	62	0	54	0	69	0[b]
Males	+	43	0	0	14	0	14	0	57	0	17[b]
(_n_ = 7)	0	57	0	71	86	57	86	43	43	86	66[b]
	-	0	100	29	0	43	0	57	0	14	17[b]
All	+	40	0	10	5	0	5	0	30	0	8[c]
(_n_ = 20)	0	55	25	60	90	45	95	45	70	50	84[c]
	-	5	75	30	5	55	0	55	0	50	8[c]

[a] mbf/a = thousand board feet/acre.
[b] _n_ = 6 30+ mbf/acre did not occur in other home ranges.
[c] _n_ = 12 30+ mbf/acre did not occur in other home ranges.

Table 10. Standardized canonical coefficients of the discriminant function analysis of "Habitat" vs. "Random" cells on the Upper Cleveland Peninsula, Alaska (UCP) study area, 1981-84.

Variable	Constant
Elevation	-.12220
Aspect	.15548
Slope	.70545
Distance to cliff	-.40808
Timber volume	.31803

Table 11. Results of classification of "Habitat" and "Random" cells on the Upper Cleveland Peninsula, Alaska (UCP) study area when reprocessed through the discriminant function analysis, 1981-84.

Actual group	(n)		Predicted group "Habitat"	Predicted group "Random"
"Habitat"	313		264 (84%)	49 (16%)
"Random"	1,436	43	411 (29%)	1,025 (71%)

Table 12. Variable scales and codes for use with classification coefficients for predicting winter goat habitat based on discriminant function analysis of "Habitat" vs. "Random" cells on the Upper Cleveland Peninsula, Alaska (UCP) study area, 1981-84.

Variable	Scale	Code
Elevation	100 Ft contours	100 = 1
		200 = 2
		300 = 3
		etc.
Aspect	N/A	flat = 1
		N, NE & NW = 2
		E & W = 3
		S, SE & SW = 4
Slope	Degrees	0 - 15 = 1
		16 - 20 = 2
		21 - 25 = 3
		26 - 30 = 4
		31 - 37 = 5
		38 - 50 = 6
		51 - 65 = 7
		66+ = 8
Distance to cliff	Miles	0 = 0
		< .25 = 1
		.25 < X < .50 = 2
		.51 < X < .75 = 3
		etc.
Timber volume	mbf/acre	0 = 0
		<8 = 1
		8 - 20 = 2
		21 - 30 = 3
		30+ = 4

Table 13. Classification coefficients for use in predicting goat winter range based on discriminant function analysis of habitat selection patterns of 20 Upper Cleveland Peninsula (UCP) goats from 1981-84.

Variable	Classification coefficient "Habitat"	Classification coefficient "Random"
Elevation (C_e)	0.3792435	0.3967944
Aspect (C_a)	1.2069100	1.0750910
Slope (C_s)	1.2243040	0.7473263
Distance to cliff (C_d)	1.8619730	2.2229880
Timber volume (C_t)	2.1358060	1.7548600
Constant	-12.9007500	-10.4777900

APPENDIX A. Vegetation categories based on groups of standard USDA Forest Service Timber-type classifications.

USDA Forest Service Timber-type Classification		Abbreviation used in this study
H	- Forest stand dominated by hemlock	Commercial forest (CF)
S	- Forest stand dominated by spruce	
C	- Forest stand dominated by cedar	
HS	- Forest stand codominated by hemlock and spruce	
ScM	- Noncommercial forest stand with muskegs	Muskeg forest (MF)
ScL	- Noncommercial forest stand with poor drainage	
NfM	- Nonforested muskeg	
ScR	- Noncommercial forest stand with bare rock	Subalpine forest (SF)
ScH	- Noncommercial forest stand at high elevation	
ScS	- Noncommercial forest stand on steep slopes	
NfA	- Nonforested alder slope	Brush/slide (BR)
NfB	- Nonforested brush slope	
NfS	- Nonforested slide zone	
NfH	- Nonforested high elevation	Alpine (AL)
NfR	- Nonforested rock	Rock/cliff (R/C)

APPENDIX B. Mountain Goat Diet During Winter in Southeast Alaska

JOSEPH L. FOX, College of Forest Resources, University of Washington, Seattle, WA 98195

CHRISTIAN A. SMITH, Alaska Department of Fish and Game, Ketchikan, Alaska

Abstract: Mountain goat (*Oreamnos americanus*) winter diet in southeast Alaska was analyzed from 21 composite samples of fecal material taken from typical forested wintering sites. About 50 plant species were identified in these diet samples. However, only 5 species (2 conifers, a lichen, a moss, and a fern) constituted more than 10% of the material identified in any 1 diet sample. Goat diets were dominated by conifers, lichens, and mosses throughout the winter. As winter snowpack accumulated, forbs and ferns diminished in the diet, while the combined proportion of conifers, lichens, and mosses increased. During deep snow periods, average diet composition was almost completely composed of conifers (43%), mosses (25%), and lichens (25%). Although the trends associated with snow depth were readily apparent, diets were still extremely variable, probably reflecting differences in forage types available at a particular site.

Winter in the coastal mountains of southeast Alaska is typically a period of nutritional deprivation and food scarcity for wild ruminants. Plants dormant during the winter are less digestible and have less protein than during summer (Dietz 1967, Milchanas et al. 1978), resulting in relatively low nutrient availability in winter. Furthermore, freezing temperatures, snow deposition, and wind conditions can greatly alter the physical availability of plants as forage (Gilbert et al. 1970, Fox 1983, Hanley 1984). The availability of forage has been shown to be an important influence on mountain goat habitat use during winter (Fox 1983).

Mountain goats are generalist, or "mixed" feeders (Hofmann 1973, Dailey et al. 1984), and take advantage of a wide variety of plant types for food (Geist 1971, Adams and Bailey 1983). Studies of goat winter food habits tend to indicate an overall preponderance of graminoids in the diet, although forbs, shrubs, ferns, and conifers have been important in some areas (Casebeer et al. 1950, Brandborg 1955, Hibbs 1967, Hjeljord 1971, Chadwick 1973, Smith 1976, Dailey 1984, Johnson 1983, Adams and Bailey 1983). Mountain goats inhabit a wide variety of vegetation types and appear to take advantage of a similarly wide array of available plant types. Most studies of goat winter diets have been carried out in interior mountain ranges, which are more likely to have snowfree wind-blown alpine or subalpine wintering sites (Hebert and Turnbull 1977). The importance of graminoids reported in many of these studies probably reflects the typically graminoid-dominated available forage in these windy sites.

In southeast Alaska, mountain goats commonly use forested areas as wintering sites (Fox 1983; Smith, in press), as do goats in coastal British Columbia (Hebert and Turnbull 1977). The types of forage available in these forest communities are markedly different from alpine ranges, and therefore provide an alternate array of potential food items. Because a substantial portion of the mountain goat's total population occupies heavily forested coastal ranges subject to timber exploitation (Smith and Raedeke 1982, Foster 1982), it is important that we know more about the ecology of goats in this region.

This study was supported by the USDA Forest Service Pacific Northwest Forest Range Experiment Station, Juneau, and the Alaska Department of Fish and Game, Federal Aid Projects W-22-1, W-22-2, and W-22-3, Job 12.4R. Additional logistical support was provided by the Juneau and Ketchikan Ranger Districts, Tongass National Forest.

STUDY AREA

Investigations were conducted in 2 areas of southeast Alaska. One site was located just south of the Herbert Glacier (58°30'N, 134°40'W), 25 km northwest of Juneau. Other sites were on the Cleveland Peninsula (56°15'N, 134°30'W), 40-45 km northwest of Ketchikan. Elevations in the Herbert Glacier area ranged from 50 m to 1,300 m, while in the Ketchikan area they were between sea level and 1,200 m.

In both areas elevations below 700 m were dominated by hemlock (*Tsuga heterophylla*) and spruce (*Picea sitchensis*) forest. Alaska yellow cedar (*Chamaecyparis nootkatensis*) was rare in the Herbert Glacier site and common on the Cleveland Peninsula. Forest understory associations commonly included shrubs such as *Vaccinium ovalifolium*, *V. parvifolium*, *Menziesia ferruginea*, and herbs such as *Cornus canadensis*, *Rubus pedatus*, and *Coptis asplenifolia*. Forest understory is similar in both areas, except that salal *Galtheria shallon*) occurs in the Ketchikan area. Lush subalpine meadows were intermixed with forest from about 600 m to 750 m elevation, and gave way to more sparsely vegetated alpine meadows and rock outcrops at higher elevations. Plant communities present in both areas are described by Fox (1983). Further descriptions of the forest communities are available in Harris and Farr (1974) and Alaback (1980).

Precipitation during winter in southeast Alaska is typically in the range of 200-500 mm at sea level, with greater amounts at higher elevations. Above 500 m elevation the precipitation is generally in the form of snow, while closer to sea level alternating snow and rain is typical. Winter snow depth at sea level may reach 1 m in some years, while other winters may pass without much snow at all below 500 m.

There are some alpine areas with cliffs or wind-blown ridges that support wintering goats in southeast Alaska (Fox 1983). However, most goat wintering sites within the present study areas were below timberline. Wintering goats could be found in heavily forested but relatively steep sites from timberline to near sea level (Smith and Raedeke 1982, Fox 1983).

METHODS

Mountain goat fecal pellets were collected following the winter of 1978-79 and during the winters of 1979-80, 1980-81, and 1981-82. Two initial collections were made at the Herbert Glacier site after snowmelt in May of 1979. Pellets were collected from a wintering site near treeline (800 m) and from another at low elevation (300 m) in hemlock-spruce forest. Two collections were also made following snowmelt in early June 1982 at 2 forested wintering sites (350 m) on the upper Cleveland Peninsula. Composite samples of at least 100 pellets were collected in each site with 2 pellets being gathered from each pellet group encountered. These samples, collected after snowmelt in areas which goats had used all winter, represent goat diet over the entire previous winter period.

The remainder of the fecal pellet collections represent feeding over a portion of the winter period only. For these collections 5 pellets from each of at least 20 pellet groups were collected to form a composite sample for each collection date. Only recent fecal pellets (i.e., pellets found associated with recent snowfalls on top of the snowpack) were collected and thus represent goat pellets dropped usually within about a week of the collection date.

For all samples, except those representing entire winter diets, snow depth was recorded at the time of fecal pellet collection. On the lower Cleveland Peninsula fecal pellet collections were made at 1 site on an approximately monthly schedule during the winters of 1980-81 and 1981-82. By this method changes in goat diet could be related to seasonal progression and snowpack development. Additional late winter samples were collected in February and March of 1982, one from the lower Cleveland

Peninsula and 6 from the upper Peninsula. The highest elevation collection site was at the Herbert Glacier study area in timberline forest at an elevation of 800 m. All other collections were made at elevations between 250 m and 650 m in forested wintering sites.

Botanical composition of diets was based on microhistological analysis (Sparks and Malechek 1968, Vavra and Holechek 1980) providing relative proportions of plant species in the fecal pellet samples. Diet determination of samples from the Herbert Glacier site was performed by the Wildlife Habitat Laboratory at Washington State University in Pullman, Washington. Diet determination of samples from the Cleveland Peninsula site was performed by the Southeast Diet Analysis Lab, Juneau, Alaska.

Potential biases of the microhistological technique have been discussed elsewhere (Todd and Hansen 1973, Anthony and Smith 1974, Vavra et al. 1978, Vavra and Holechek 1980, Holechek et al. 1982, Gill et al. 1983). In this study, the proportions of conifers, lichens, and mosses may be somewhat exaggerated, due probably to their relative indigestibility. However, when looking at trends in the proportion of a species or forage type in the diet, the influence of these biases is minimized.

RESULTS

About 50 species of plants were represented in the winter diet of mountain goats in southeast Alaska (Table 1). Most species, however, occurred only as very minor constituents in the diet. Only 5 species (or indistinguishable pairs of species) occurred as a 10%-or-greater proportion in the diet samples. Twenty-five species (or pairs) appeared, at most, as a 2%-or-less proportion of the diet samples. The conifers _Chamaecyparis nootkatensis_ and _Tsuga heterophylla/T. mertensiana_, the mosses _Hylocomium_ sp./_Rhytidiadelphus_ sp., and the lichen _Lobaria_ sp. were predominant in the goat winter diets (Table 1). Each of these species or pairs constituted greater than 30% of the fecal material analyzed for 1 or more diet samples. Of all species in the diets analyzed, only the above species and the fern _Athyrium filix-femina_ showed up as greater than 10% of all material for a single diet sample. Species of secondary importance in the diets (i.e., appearing as proportions of 5-10% in at least 1 diet sample) included the conifer _Picea sitchensis_, the shrubs _Cassiope_ spp., _Rubus_ spp. and _Vaccinium_ spp., the forbs _Cornus canadensis_ and _Rubus pedatus_, the fern _Blechnum spicant_, and the lichens _Alectoria_ sp./_Usnea_ sp.

Collections of fecal pellets made successively through 2 winters at the same site show general trends toward increased proportions of conifers and decreased proportions of forbs and ferns in goat diets as winter progresses (Table 2). However, the winter of 1980-81 produced very little snowfall in the study area, while that of 1981-82 produced a deep snowpack. Trends in diet during the winter of 1980-81 were not pronounced, whereas during the heavy-snow winter of 1981-82 conifers and mosses increased in the diet as shrubs, forbs, ferns, and graminoids all decreased (Table 2). These trends are probably related to the effects on forage availability of increasing snowpack depth and density. However, they are based on a single dietary analysis for each date, thus precluding any analysis of variance.

When we separate diets from all sites (except those representing entire winters) on the basis of snow depth at the time of fecal pellet collection, only a few of the above trends were significant ($\underline{P} > 0.05$) changes (decreases) associated with increasing snow depth. Although there were numerically decreasing trends for shrubs and graminoids associated with increasing snow depth, they were not significant ($\underline{P} > 0.10$) in the present analysis. The conifer, lichen, and moss components of goat diets did not change as single units, but combined; this group did increase as a proportion of the diet with increasing snow depth ($\underline{P} < 0.05$). Because several different sites, with somewhat different arrays of available forages, were used in this analysis, the high degree of variability is expected and the importance of diet trends enhanced.

Entire winter diet composition was comparable to that averaged from the date-specific samples, and reflected the high variability in composition common among all samples. An average winter diet, based on all 21 samples, and thus somewhat biased toward late winter diet, is presented in Table 4.

DISCUSSION

Graminoids, and occasionally forbs, ferns, or shrubs have appeared predominant in most goat winter diets studied (Table 4). This is most likely a consequence of the majority of studies being conducted in regions where goats winter in wind-blown alpine or subalpine sites, i.e., where these plant types provide the most available forage. The largest graminoid component (16%) in any diet sample here (Herbert Glacier site 2, Table 1) was from the highest elevation site, adjacent to grassy alpine feeding areas. The preponderance of conifers in the mountain goat's winter diet in southeast Alaska is more pronounced than in diets reported from other areas (Table 4). This is undoubtedly due in part to the fact that in southeast Alaska the goat wintering sites were also in the most densely forested areas yet reported (Fox 1983). In only 1 study, in Idaho (Brandborg 1955), have lichens constituted a proportion of the diet comparable to that in the present study; nowhere have mosses been reported as the important dietary component observed in our study.

Brandborg (1955) suggested that there is increased use of conifers as emergency forage during periods of deep snow. Geist (1971) indicated that goats may fill their rumens at first with abundant conifers, then become more selective in the latter part of a feeding period. Such initial heavy use of lichens or mosses in a feeding period may also occur if these types of forage are abundant and conifers are less available.

The analysis of goat fecal material here has indicated that conifers, lichens, and mosses are the predominant constituents of goat winter diet. However, the ability to identify fragments of plants in fecal material varies with species and the digestibility of plant material varies with species (Vavra and Holechek 1980, Rochelle 1980, Gill et al. 1983). Thus, the chances of finding identifiable plant fragments may be either enhanced or diminished for given species of plants. For example, the conifer *Tsuga* sp. is very readily identifiable in the feces (B. Davitt, Wash. State Univ., pers. commun.) and apparently, at least with deer, not very digestible (Schoen and Wallmo 1979). This may in part explain its high representation in the fecal samples. For these same reasons one might also expect other conifers and probably mosses to be somewhat over-represented, while forbs, shrubs, and ferns were under-represented in their proportional contribution to goat diet.

Still, these qualifications do not diminish the conclusion that conifers, mosses, and lichens form a major component of goat diet throughout the winter period, and the bulk of the diet during times of deep snowpack. Apparently, as snowpack increases, forbs and ferns, and then shrubs become relatively unavailable as forage for goats. This would explain their continued presence in goat diet throughout the minimal snowfall winter of 1980-81 and their virtual disappearance in diets as winter (snowpack accumulation) progressed during the season of heavy snowfall in 1981-82 (Table 2). If our sampling had included the period immediately prior to initial winter snowfall, the decline in forbs, ferns, and graminoids would probably have been even more pronounced.

The substantial presence of conifers (erect or in litterfall) and lichens (in litterfall or on tree trunks) in goat diet throughout both winters is likely a function of their abundance and availability even in periods of deep snowpack. The inconsistent rise in percent lichen composition in the diet associated with increasing snow depth (Tables 2 and 3) probably reflects a variability in lichen availability related to the occurrence of windy weather conditions. Much of the lichen available as forage for goats drops from trees in the form of litterfall during windstorms (Fox 1983). Absence of windstorms and consequent lack of available lichen forage may be the cause of the low proportions of lichens for several of the diets analyzed. Because a substantial portion of available conifer forage also drops in the form of litterfall (Fox 1983), the variability in both lichen and conifer constituents of the diet associated with snow depth may be related to their availability as determined by the occurrence of windstorms.

The high occurrence of mosses, especially during the deep snowpack period of the 1981-82 winter, is somewhat more difficult to explain. Mosses may well be the least digestible and most recognizable, and hence the most over-represented component of goat winter diet in the present analysis. However, their relative occurrence tended to increase during the period of deepest snowpack. This is a time when one would expect that mosses, being essentially ground-cover vegetation, would be rendered unavailable by virtue of being covered by snow. The most likely explanation for the substantial occurrence of mosses in the goat winter diets lies in the ubiquitous presence of moss in the moist coastal forests (Alaback 1980), including around the bases of trees, on vertical cliff faces, and sometimes covering boulders. Snow does not accumulate on the steep sides of trees, cliffs, or boulders and these types of microsites may provide the only exposed ground vegetation in periods of deep snow. Furthermore, an advantage may accrue from moss in the diet through the possible cold-resistance protection derived from certain of its characteristic fatty acids (Prins 1982).

Digestibility of forage has been alluded to only in the context of its effect on the chances of finding material in the feces. However, digestibility, along with nutritive quality and toxin concentration of the various plant species eaten is important in determining overall nutritive contribution to the animal (Freeland and Janzen 1974). The relationship of a forage's abundance and nutritive quality to its presence in a herbivore's diet is important in understanding diet selection. While such factors cannot be dealt with here, they must be considered in a full explanation of diet composition.

While accepting a wide variety of plants as forage, mountain goats in southeast Alaska maintained the bulk of their winter diet on a relatively few species of conifers, lichens, and mosses. As winter snow depth increased and rendered more plants unavailable as forage, these species became even more important in the goat's diet. It is likely that forage availability is a predominant factor in determining goat winter diet in this region. Reports of ungulate winter diets dominated by conifers, mosses, and lichens are uncommon. However, such diets are probably the rule for mountain goats in the coastal regions of southeast Alaska and British Columbia. The ability of goats to survive well on such diets is indicated by the unusually low mortality levels and high rates of increase exhibited by coastal goat populations during the period when our collections were made (Smith 1984). In the future, we must take a closer look at goat digestion and the nutritive composition of these forages, as well as goat selectivity in foraging, to better understand the ability of these animals to survive the winter on such a diet.

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Table 1. Percentages of forage species identified in winter fecal samples of mountain goats.

	Study area													
	Cleveland Peninsula											Herbert Glacier		
	Lower								Upper					
	1980-81			1981-82					1981-82			1978-79	1980	
Species	Nov	Dec	Feb	Nov	Dec	Jan	Feb	Mar	Feb	Mar	Entire winter	Entire winter	Dec	Feb
TREES (conifers)														
<u>Chamaecyparis</u> <u>nootkatensis</u>	3.0	17.0	15.0	1.0	7.0	2.0	6.0	14.0	37.0	30.0	32.5	-	-	-
<u>Juniperus</u> <u>communis</u>	1.0	-	-	t[a]	1.0	-	1.0	1.0	1.0	0.2	0.5	-	-	-
<u>Thuja</u> <u>plicata</u>	-	-	-	-	1.0	1.0	-	-	0.5	0.6	1.5	-	-	-
<u>Tsuga</u> spp.[b]	11.0	13.0	26.0	2.0	48.0	23.0	8.0	18.0	10.0	6.0	13.0	52.0	56.0	87.0
<u>Picea</u> <u>sitchensis</u>	-	-	-	-	-	t	t	3.0	0.3	0.1	-	3.0	-	2.0
<u>Pinus</u> <u>contorta</u>	-	-	-	-	-	-	-	1.0	0.4	-	-	-	-	-
SHRUBS														
<u>Alnus</u> <u>sinuata</u>	-	-	-	1.0	-	t	-	-	-	0.4	0.1	2.0	-	3.0
<u>Cassiope</u> spp.[c]	-	-	t	1.0	t	-	-	-	1.0	0.6	0.1	3.0	-	t
<u>Cladothamnus</u> <u>pyrolaeflorus</u>	t	-	-	-	-	-	-	-	-	-	0.1	-	-	-
<u>Empetrum</u> <u>nigrum</u>	-	-	-	t	-	-	-	-	0.1	0.6	-	-	-	-
<u>Leutkea</u> <u>pectinata</u>	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-
<u>Menziesia</u> <u>ferruginea</u>	t	-	t	-	-	t	-	-	-	-	-	-	-	-
<u>Phyllodoce</u> <u>aleutica</u>	-	-	-	-	-	-	-	-	0.4	1.0	-	-	-	-
<u>Ribes</u> <u>Bracteosum</u>	1.0	-	t	t	-	-	-	-	-	0.1	-	-	t	-
<u>Rubus</u> sp.	3.0	2.0	2.0	7.0	2.0	1.0	t	t	-	0.3	0.6	-	1.0	-
<u>Salix</u> sp.	-	-	-	-	-	-	-	-	-	-	-	t	-	-
<u>Sambucus</u> sp.	t	t	1.0	-	-	-	-	-	0.1	0.3	0.8	-	t	-
<u>Vaccinium</u> spp.[d]	1.0	t	6.0	t	6.0	6.0	2.0	1.0	3.0	2.0	4.0	2.5	6.0	5.0
<u>Viburnum</u> edule	-	-	-	-	-	t	-	-	-	-	-	-	-	-

Table 1. Continued.

	Study area													
	Cleveland Peninsula											Herbert Glacier		
	Lower								Upper					
	1980-81			1981-82					1981-82			1978-79	1980	
Species	Nov	Dec	Feb	Nov	Dec	Jan	Feb	Mar	Feb	Mar	Entire winter	Entire winter	Dec	Feb
FORBS														
Coptis asplenifolia	1.0	-	t	2.0	-	-	-	-	-	-	-	0.5	-	t
Cornus canadensis	9.0	6.0	5.0	3.0	4.0	3.0	-	-	0.1	0.2	1.6	5.0	2.0	-
Lysichiton americanus	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-
Maianthemum dilatatum	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-
Moneses uniflora	-	-	t	-	-	-	-	-	-	-	-	-	-	-
Osmorhiza purpurea	1.0	-	t	t	-	-	-	-	-	-	-	-	-	-
Pedicularis verticillata	-	-	-	-	-	-	-	-	-	0.1	0.1	-	-	-
Prenanthes alata	-	-	t	-	-	-	-	-	-	-	-	-	-	-
Rubus pedatus	3.0	4.0	4.0	6.0	1.0	1.0	-	t	0.1	0.1	0.5	1.5	1.0	-
Saxifraga sp.	-	-	-	1.0	t	-	-	-	0.1	-	-	-	3.0	-
Tiarella spp.[e]	2.0	-	t	3.0	t	t	-	-	-	-	0.1	-	t	-
Unidentified forb	5.0	4.0	7.0	4.0	3.0	1.0	-	1.0	1.0	1.2	5.0	-	2.0	-
FERNS														
Athyrium filix-femina	2.0	2.0	2.0	3.0	2.0	2.0	-	-	-	0.4	3.0	11.5	7.0	t
Blechnum spicant	9.0	2.0	3.0	7.0	5.0	1.0	-	-	-	-	6.0	-	t	-
Cryptogramma crispa	1.0	-	-	-	1.0	-	-	-	-	0.1	0.1	-	-	-
Dryopteris dilatatata	t	1.0	1.0	-	t	-	-	-	-	0.1	0.1	-	2.0	-
Gymnocarpium dryopteris	t	1.0	-	-	-	-	-	-	-	-	0.1	-	-	-
Polypodium vulgare	1.0	t	-	1.0	t	t	-	-	-	0.3	0.1	-	-	-
Pteridium aquilinum	5.0	1.0	1.0	t	-	t	-	-	-	0.4	0.5	-	2.0	-
Unidentified fern	4.0	4.0	3.0	4.0	4.0	1.0	t	-	0.2	0.4	2.5	-	1.0	-

Table 1. Continued.

	Study area													
	Cleveland Peninsula											Herbert Glacier		
	Lower								Upper					
	1980-81			1981-82					1981-82			1978-79	1980	
Species	Nov	Dec	Feb	Nov	Dec	Jan	Feb	Mar	Feb	Mar	Entire winter	Entire winter	Dec	Feb
GRAMINOIDS														
Agrostis sp.	-	-	-	2.0	-	t	-	t	-	-	-	-	-	-
Calamagrostis canadensis	1.0	t	-	2.0	1.0	-	-	-	-	0.1	0.1	2.1	-	t
Carex macrochaeta	t	1.0	1.0	1.0	1.0	-	-	-	-	-	0.1	-	-	-
Carex sp.	-	t	t	-	-	-	-	-	-	-	-	1.1	-	-
Luzula sp.	t	-	t	-	-	-	-	-	-	-	-	-	-	-
Unidentified graminoid	2.0	1.0	1.0	3.0	t	-	t	t	0.2	0.1	0.1	5.1	-	t
LICHENS														
Alectoria sp./*Usnea* sp.	t	1.0	t	3.0	t	t	t	2.0	3.0	3.5	1.5	1.0	1.0	t
Lobaria sp.	15.0	19.0	13.0	26.0	1.0	2.0	30.0	16.0	22.0	28.2	9.0	3.5	9.0	1.0
Unidentified lichen	-	-	-	-	-	-	-	-	0.3	0.7	-	-	-	-
MOSSES														
Hylocomium sp./ *Rhytidiadelphus* sp.	14.0	21.0	10.0	11.0	17.0	53.0	52.0	42.0	18.0	17.5	13.0	7.0	6.0	-
Sphagnum cuspidatum	t	-	1.0	2.0	-	-	t	-	-	-	0.1	-	-	-
Unidentified moss	1.0	1.0	1.0	1.0	t	t	t	1.0	3.0	6.0	3.0	-	t	t

Table 1. Continued.

	Study area													
	Cleveland Peninsula											Herbert Glacier		
	Lower								Upper					
	1980-81			1981-82					1981-82			1978-79	1980	
Species	Nov	Dec	Feb	Nov	Dec	Jan	Feb	Mar	Feb	Mar	Entire winter	Entire winter	Dec	Feb
UNIDENTIFIED	1.0	-	1.0	1.0	1.0	1.0	t	t	0.4	0.5	0.6	-	1.0	-

[a] t = <0.5% (assigned an average value of 0.25 for calculation of above means).

[b] T. heterophylla and T. mertensiana.

[c] C. mertensiana and C. stelleriana.

[d] V. parvifolium, V. ovalifolium and V. alaskensis.

[e] T. trifoliata and T. unifoliata.

Table 2. Forage class breakdown (percent) of mountain goat diets on the lower Cleveland Peninsula during the winters of 1980-81 and 1981-82.

	Percent of goat diet							
	1980-81			1981-82				
Forage class	Nov	Dec	Feb	Nov	Dec	Jan	Feb	Mar
Trees (conifers)	14	30	41	3	49	26	15	36
Shrubs	5	2	9	9	8	7	2	1
Forbs	21	14	16	19	8	5	--	1
Ferns	22	11	10	16	12	4	t[a]	--
Graminoids	3	2	2	8	2	t	t	t
Lichens	15	20	13	29	1	2	30	18
Mosses	15	22	12	14	17	53	52	43
Unknown	1		1	1	1	1	t	t

[a] t = <0.5 percent.

Table 3. Mean percentages and standard deviations (in parentheses) for forage classes of goat diets as related to increasing snow depth. Snow depth categories reflect snow measured in non-forested areas in the vicinity of the goat wintering sites.

	Snow depth (cm)			
Forage Class	0-50	50-100	100-200	200+
	4[a]	3	6	4
Trees (conifers)	22(17)	44(16)	47(24)	36(8)
Shrubs	6(3)	7(1)	4(5)	5(1)
Forbs	18(3)A[b]	7(2)B	1(1)C	1(1)C
Ferns	15(6)A	9(5)B	tC	1(1)C
Graminoids	4(3)	1(1)	t[c]	t
Lichens	19(7)	4(5)	21(15)	33(10)
Mosses	16(4)	25(25)	26(20)	24(9)
Unidentified	1(1)	1	t	t

[a] Number of diet samples.

[b] Within a forage class, diet proportion means followed by different capital letters indicate differences (P < 0.05) in composition between snow depths. Where letters are absent, no differences (P > 0.05) exist. Newman-Keuls test (Snedecor and Cochran 1967:273) was used for the multiple comparisons.

[c] t = <0.5 percent. Standard deviations for less than 1 are not shown.

Table 4. Reported food habits of mountain goats during winter.

Investigator	Location	Percent of diet						
		Conifers	Shrubs	Forbs	Ferns	Graminoids	Lichen	Moss
Anderson (1940)	Washington[a]	1	14	10		75		
Casebeer et al. (1950)	Montana[b]		35	2		63		
Klein (1953)	Alaska[b]	2	9	1	55	32	t	
Saunders (1955)	Montana[b]	30	t[d]	10	t	59	t	t
Brandborg (1955)	Idaho[a]		52	1		23	24	
	[b]	t	44	t		54	t	t
Hibbs (1967)	Colorado[a]		12			88		
Hjeljord (1971)	Alaska[a]		5	1	45	49		
	[b]	1	14	1	82	1	t	t
Kuck (1973)	Idaho[b]	6	41	14	t	37	t	t
Chadwick (1973)	Montana[a]	9	12	5	5	61	5	5
Johnson (1983)	Washington[c]	28	37	3		31	1	
Adams and Bailey (1983)	Colorado[c]	33	6	22		39		
Dailey (1984)	Colorado[a]		14	59		27		
This study[e]	Alaska[c]	41	6	6	7	2	18	21

[a] Visual observations.

[b] Rumen samples.

[c] Fecal samples.

[d] t = <0.5 percent.

[e] Average of all 21 diet samples.