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HABITAT USE BY MOUNTAIN GOATS IN SOUTHEASTERN ALASKA

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PROGRESS REPORT (RESEARCH)

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SUMMARY

During this report period, 1 additional study area, designated K-4, was selected near the U.S. Borax mine at Quartz Hill. Thirteen mountain goats (*Oreamnos americanus*) were captured and radio-collared at K-4 using both a net gun and standard helicopter darting with M99 (etorphine). Five additional goats were captured and radio-collared on the previously established Upper Cleveland Peninsula (UCP) study area. Forty-two telemetry flights were made, resulting in a total of 677 relocations of the collared goats. Over 97% of all relocations to date have been accurate to within 2.6 ha.

Preliminary analysis of winter habitat use data indicates that goats are selectively distributed with respect to elevation, slope, aspect, and distance to the nearest cliff-type terrain. Discriminant function analysis (DFA) revealed that slope was most helpful in differentiating between winter goat "habitat" and "nonhabitat," followed in descending order by elevation, aspect, timber volume, and distance to cliffs based on the applied method of dividing habitat from nonhabitat areas. Limitations of the method are discussed.

Despite the preliminary and unrefined nature of the DFA approach used herein, this technique proved highly accurate with respect to predicting the winter locations of goats at K-4. Of 153 relocations between November and March, 126 fell within model winter range areas, and all others were within 650 m of predicted areas.

Key words: habitat use, mountain goat, *Oreamnos americanus*, Southeast Alaska.

CONTENTS

BACKGROUND

Background for this study has been presented previously (Smith 1982, 1983). Additional information on the need for research on coastal mountain goat (*Oreamnos americanus*) biology as well as results to date are available from Smith and Raedeke (In Press), Schoen and Kirchhoff (1982), Hebert and Turnbull (1977), and Fox (1979*a*, *b*).

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.

MATERIALS AND METHODS

During the report period, 1 additional study area was selected in the vicinity of Smeaton Bay and Boca de Quadra (Fig. 1). This site, referred to as the K-4 area, was selected due to the availability of long-term population trend data (Wood 1981) and the ongoing development of a large molybdenum mine by U.S. Borax. Data from this study area can be used both for assessing habitat selection by mountain goats and for on-site planning of mining activities.

Mountain goats were captured at K-4 and on the previously established Upper Cleveland Peninsula (UCP) study areas as described by Nichols (In Press) and with the use of a Coda net gun (Telonics, Mesa, Ariz.) as discussed by Schoen and Kirchhoff (1983). Efforts were made to obtain an equal sex ratio at K-4, while females were selectively captured on the UCP to replace mortalities from the previous study year. Telemetry procedures were described in Smith (1983).

Because the majority of effort during this reporting period was directed at data collection and development of analytic procedures, relatively few analyses were completed. For purposes of this report, only the winter season (Nov-Mar) has received detailed analysis. As the data base expands and statistical techniques are refined, other seasonal periods will be evaluated.

Statistical analysis of mountain goat habitat use during the current year relied heavily on discriminant function analysis (DFA) procedures available through the Boeing Computer Services' Statistical Package for the Social Sciences (SPSS) computer package. Biophysical data for the DFA were obtained by point sampling topographic and timber type maps using a 2.6 ha grid overlay as described by Smith (1983). UCP data were available from random samples taken during the previous report period. Data for the K-4 area were obtained during the current period from a systematic sample of 25% of the grid cells overlaid on the study area.

DFA was used for 2 types of analysis. First, data from the UCP were evaluated using DFA to identify primary factors associated with winter goat habitat selection. Similar applications can be found in Schoen and Kirchhoff (1982) and Fox et al. (1982). (The latter was appended to Smith [1983].)

The 2nd application of DFA was to predict areas where radio-collared goats at K-4 would be relocated during winter based on behavior of UCP goats. Both Schoen and Kirchhoff (1982) and Fox et al. (1982) used DFA for predictive purposes, but neither report provided a rigorous test of the accuracy or general applicability of this procedure as presented here.

For the initial DFA, 1,210 randomly selected cells on the UCP, which were not found to be occupied by radio-collared mountain goats from November 1981 through March 1982, were classified as "nonhabitat." The 271 cells which were occupied at least once by at least 1 goat during that period were classified as "habitat." DFA was then used to identify the particular values for the measured variables which best separated these 2 data sets. These results provide insight into habitat selection.

For the predictive procedure, the DFA was used to examine each of the 1,888 sampled cells at K-4 and classify them as most likely belonging in the "nonhabitat" or "habitat" category based on the analysis of the UCP data. To complete mapping of all points on the K-4 area into "nonhabitat" and "habitat" categories more efficiently than point sampling the remaining 7,500 cells, the following rule was applied. If at least 3 corners of an unsampled cell contacted a sampled cell which was classified by the DFA as "habitat," the unsampled cell was also classified as "habitat" (Fig. 2). This procedure made it possible to draw boundaries around groups of "habitat" cells to facilitate mapping and testing of the accuracy of the DFA procedure for predicting winter goat relocations (i.e., habitat selection).

To validate the "3-corner rule," the cells not included in the original systematic sample were divided into subsets based on their number of corners (0 to 4) abutting previously sampled cells classified as "habitat" by the DFA. Then 50 cells were selected at random from each subset for map sampling and classification by the DFA. This provided estimates of the percent error in applying the "3-corner rule."

RESULTS

Capture and Telemetry

Thirteen mountain goats (7 males, 6 females) were captured in the K-4 area, and 5 additional animals (1 male, 4 females) were captured on the UCP. Table 1 provides a breakdown of the ages and other capture-related data.

Of the 2 capture techniques employed, standard helicopter darting with 4 mg of M99 (etorphine) proved most efficient. Total helicopter flight time averaged 1.2 hours/captured goat. No mortalities occurred; induction times following well-placed shots averaged 6.6 min for males ($\underline{N}$ = 8) and 4.3 min for females ($\underline{N}$ = 7). The only problem encountered with M99 was 1 instance when the initial injection resulted in an underdosage. It was then necessary to administer a massive dose to achieve narcosis.

The net gun did not perform as expected based on accounts by J. Schoen and J. Davis (pers. commun.). Of 6 goats "netted," two escaped beneath the mesh which was draped on adjacent vegetation or rocks and one escaped from entanglement in the net after fleeing over 500 m in precipitous terrain. The remaining 3 goats, all 2-year-old females, were able to run with the net dragging over/behind them until it snagged on vegetation or rocks on a steep slope causing them to lose their footing. The goats continued to struggle in the net until physically restrained by the researchers and blindfolded.

Pursuit and capture flight time using the net gun averaged 2.1 hours/goat, and the procedure led to greater stress and jeopardy to both animals and biologists than helicopter darting. In view of apparent mountain goat susceptibility to capture myopathy (Hebert and Cowan 1971), use of the net gun for capturing these animals is not recommended.

Since initiation of this project, 799 relocations have been made on the UCP; 257 have been made at K-4. Of these, 240 have resulted in visual location of collared mountain goats; 862 have been sufficiently accurate to visually identify habitat parameters associated with the mountain goats' locations; and 1,027 have been accurate enough to permit assignment to a single grid cell.

Discriminant Function Analysis

Winter Habitat Selection:

Table 2 lists the mean and standard errors of the variables for the 2 cell groups used in the DFA. Univariate *t*-tests revealed that radio-collared mountain goats selectively used areas of the UCP that were higher in elevation with more southerly aspect, were steeper and closer to cliffs than in areas they did not use, but did not indicate preferential use of timber volume classes. Multivariate chi-square analysis ($X^2 = 240.0$, df = 5, $P < 0.001$) revealed that the overall selectivity is highly significant.

Although the *t*-tests and chi-squared analyses demonstrated significant differences, the DFA resulted in a relatively large Wilk's lambda of 0.85 and slight separation of group centroids in multivariate space (+0.88 for "habitat" vs. -0.20 for "nonhabitat"). This indicates that the applied method of cell grouping and data collection provided limited discriminating power. Nevertheless, the canonical correlation of the equation, 0.39, is high enough to suggest that this DFA can adequately differentiate between these groups. This conclusion is supported by the accuracy of classification of group cells. Of the 1,481 cells used in the DFA, 71% were accurately classified correctly when reprocessed through the function.

The DFA indicates that of the 5 variables used, slope (which had a standardized canonical coefficient of 0.61) was the strongest discriminating factor between "habitat" and "nonhabitat" cells. Elevation (0.53) was the next best factor, followed in decreasing order by aspect (0.48), timber volume (0.39), and distance to cliffs (-0.26). The magnitude of the coefficients implies that each contributed important information to the final discriminant score.

Winter Range Prediction:

Of the 1,888 cells initially sampled on the K-4 area, 739 (39%) were classified by the UCP-based DFA as belonging in the "habitat" group. These cells and the unsampled cells classified as "habitat" by the 3-corner rule are mapped in Fig. 3.

The test of the 3-corner rule resulted in "incorrectly" including about 20% of the 3-4 corner cells in the "habitat" class, while arbitrarily excluding 54% of the 2 corner cells which should be "habitat" (Table 3). The net effect is probably a conservative estimate of total mountain goat "habitat" on K-4.

Fig. 3 also illustrates the location of cells used by radio-collared goats at K-4 during November 1982 through March 1983. Of

153 relocations, 126 (82%) occurred within the boundaries drawn around cells classified as "habitat" by the DFA and 3-corner rule. A test of goodness of fit reveals that this indicates highly significant selection of the predicted "habitat" area ($\underline{X}^2 = 50.3$, df = 1, $\underline{P} < 0.001$). Of the 27 remaining relocation cells, 20 lie on the perimeter of the mapped "habitat" and the 7 that do not contact "habitat" have a mean distance of 1.6 cells (260 m) to the nearest "habitat" border.

DISCUSSION

Capture and telemetry techniques have been adequately refined to allow relatively safe marking and monitoring of mountain goats. Barring unexpected mortality or radio malfunction, the current sample of 17 mountain goats on the UCP and 13 at K-4 should provide sufficient data over the next year to further develop and test models of seasonal habitat selection.

As used in this report, DFA shows significant potential for evaluation of habitat selection, as well as predicting location of seasonal habitat on new areas. The major limitation of the present analysis is the pair of assumptions inherent in the process by which the UCP cells were grouped for the DFA and the manner in which the total "habitat" and "nonhabitat" areas were selected.

These critical assumptions are the following:

1. That whenever mountain goats are relocated between November and March, they are considered to be in winter "habitat."

2. That all cells not utilized by collared mountain goats are considered to be "nonhabitat."

The initial assumption can be dealt with on an adequate mathematical basis by definition. For example, we can simply state that if a goat is in a cell, that cell is indeed "habitat." On a biological basis, however, such an approach is questionable and some judgment must be used in interpreting telemetry location data. As an extreme example, such an approach would lead to inclusion as "habitat" the surface of a frozen lake if a relocation of a mountain goat occurred as the animal was crossing from 1 ridge to another. Nevertheless, this assumption is less troublesome than the second.

The only way to thoroughly satisfy the 2nd assumption would be to radio-collar every mountain goat in the population and monitor movements continuously throughout the period. Obviously, such an undertaking is impossible. To the extent that the sample of location of collared mountain goats falls short of revealing the location of all cells used by all goats, the 2nd assumption is violated. The degree to which the current analysis violates this assumption is probably relatively large.

By randomly selecting "nonhabitat" points from all over the UCP study area, this analysis doubtless included in this group cells used by mountain goats on ridges where no animals were radio-collared. This approach decreased discriminating power of the DFA because many cells in the "nonhabitat" category were bio-physically similar to cells in the "habitat" category. Future analyses will explore alternative methods of cell group selection, such as doing DFA of cells within a single individual's home range or in a composite of several home ranges, thereby greatly reducing the violation of the 2nd assumption.

Given the foregoing discussion of this analysis' limitations, it is all the more striking that the initial DFA produced significant results which permitted highly successful prediction of winter habitat selection. This implies that mountain goats must be exercising extreme selectivity with regard to the measured habitat variables. Similar results were reported by Fox et al. (1982), Schoen and Kirchhoff (1982), and Smith (1983).

Extreme selectivity, usually directed at steep, broken escape terrain has been reported by numerous authors (Chadwick 1973; Kuck 1977; Fox 1979b; Schoen and Kirchhoff 1982; Fox et al. 1982; and Smith [In Press]). Geist (1971) implied that this species' dependence on such habitat is even greater than that of mountain sheep (*Ovis* sp.). This apparent extreme specificity of habitat selection by mountain goats makes them an ideal choice for further testing and development of DFA and other mathematical models of habitat selection. As the data base is expanded in the future, enhanced analyses and improved predictive capability should be possible.

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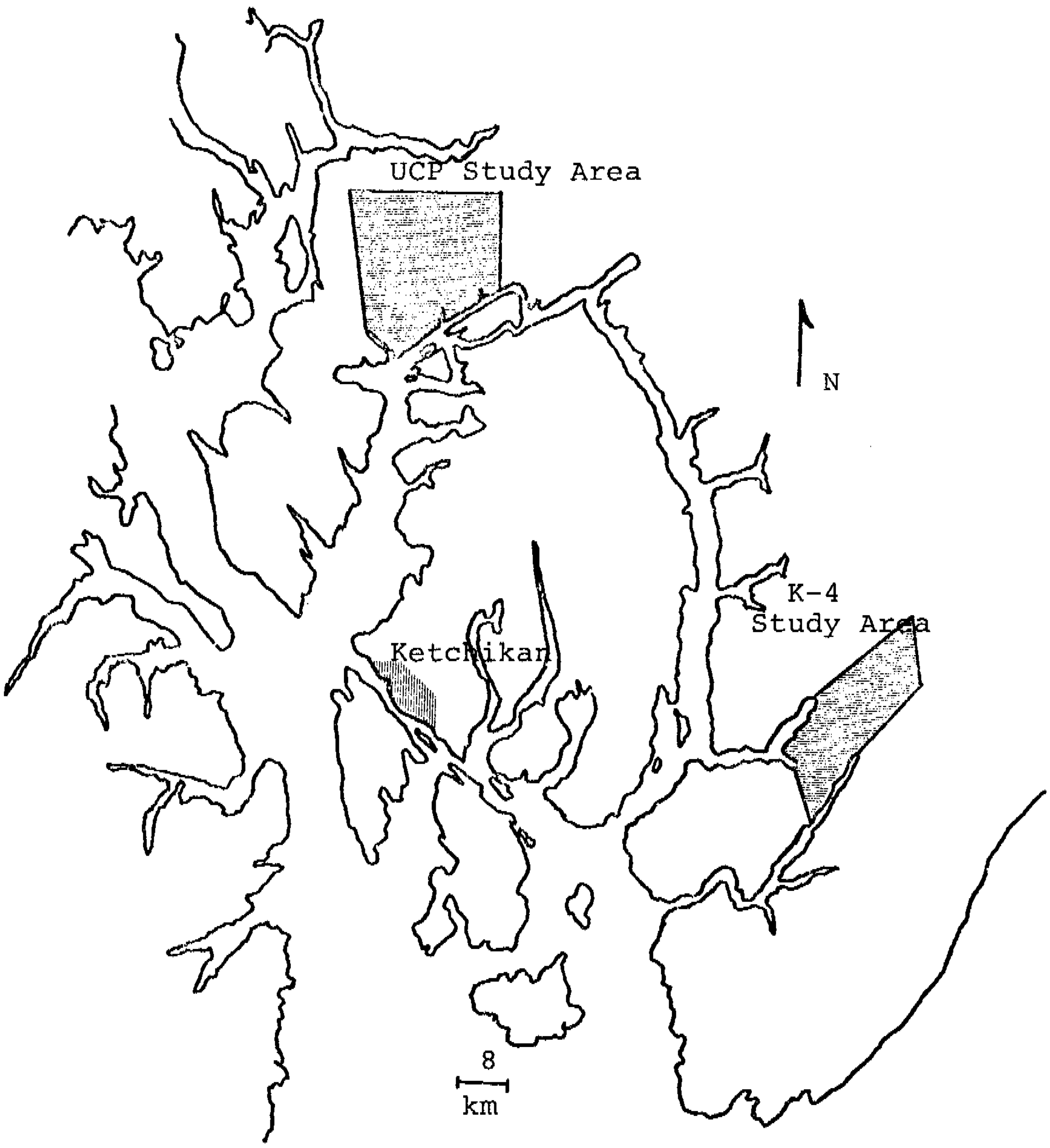

Fig. 1. Location of Upper Cleveland Peninsula and K-4 mountain goat study areas near Ketchikan, Alaska, 1982-83.

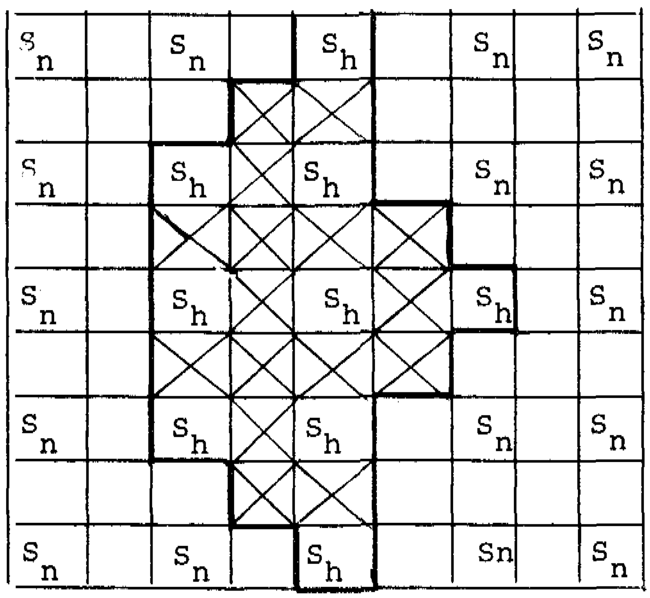

Fig. 2. Application of the "3-corner rule" used for including unsampled cells in mountain goat habitat areas. $\boxed{S_n}$ = systematically sampled cells designated by the DFA as nonhabitat; $\boxed{S_h}$ = systematically sampled cells designated by the DFA as habitat; $\boxtimes$ = unsampled cells with at least three corners contacting $\boxed{S_h}$ cells.

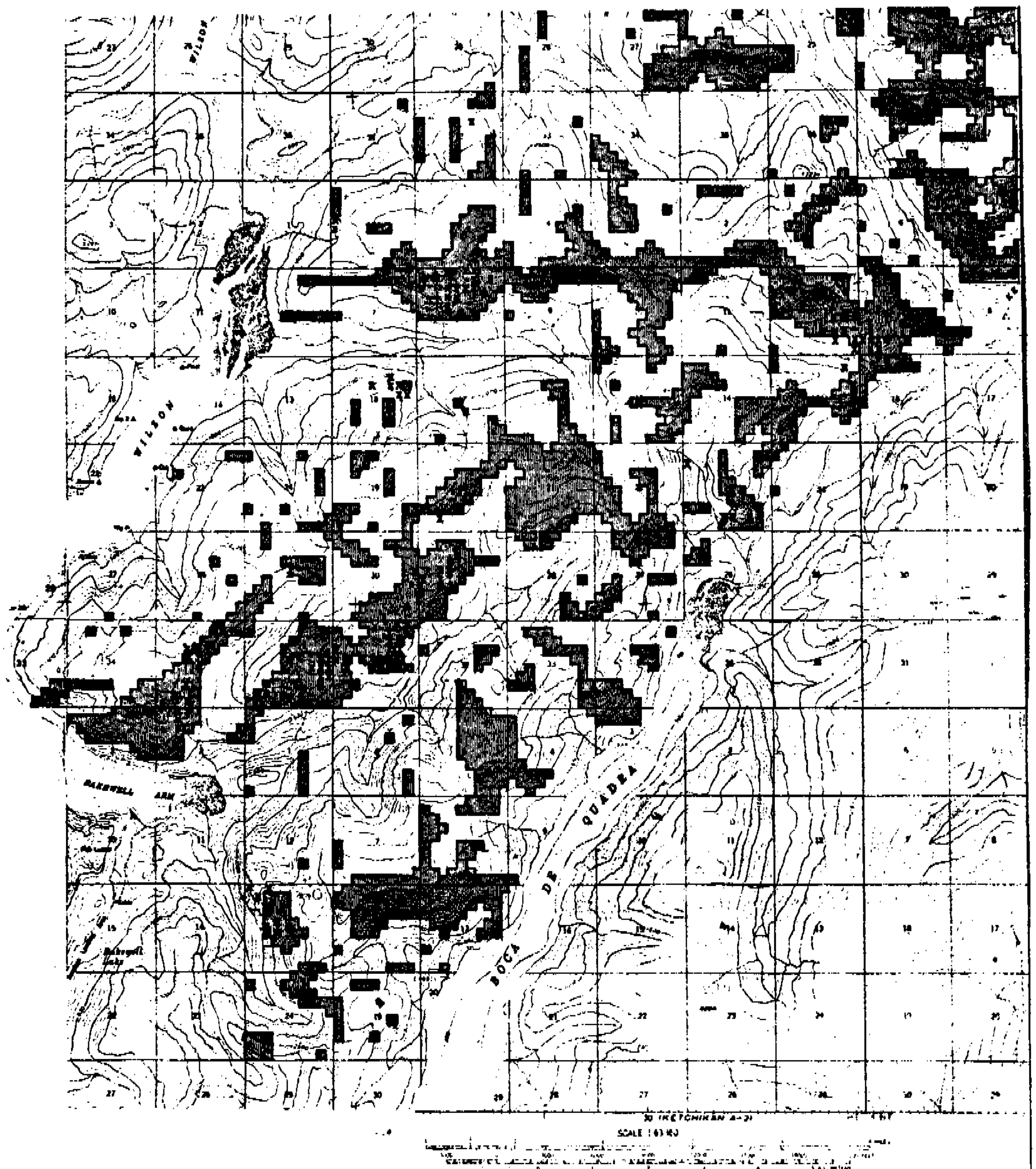

Fig. 3. Predicted winter mountain goat habitat at K-4 study area (shaded portions) and relocations of radio-collared goats (X), November 1982-March 1983.

Table 1. Summary of mountain goat capture results near Ketchikan, Alaska, July 1982.

Animal No.	Study area[a]	Date of capture	Method of capture[b]	Sex	Age (yr)	Status on 30 June 1983
33	K-4	7/21/82	N	F	2	Live; transm.
34	K-4	7/21/82	N	F	2	Live; transm.
35	K-4	7/23/82	D	M	2	Live; transm.
36	K-4	7/23/82	D	M	2	Live; transm.
37	UCP	7/24/82	D	M	4	Live; transm.
38	UCP	7/24/82	D	F	2	Live; transm.
39	UCP	7/24/82	D	F	7+	Live; transm.
40	UCP	7/25/82	D	F	2	Live; transm.
41	UCP	7/25/82	D	F	8+	Dead; recovered
42	K-4	7/26/82	D	F	7	Live; transm.
43	K-4	7/26/82	D/N	F	3	Live; transm.
44	K-4	7/28/82	D	M	6	Live; transm.
45	K-4	7/28/82	D	F	4	Live; transm.
46	K-4	7/28/82	D	M	8	Live; transm.
47	K-4	7/28/82	D	M	4	Live; transm.
48	K-4	7/28/82	D	M	2	Live; transm.
49	K-4	7/29/82	D	M	2	Live; transm.
50	K-4	7/29/82	D	F	3	Live; transm.

[a] K-4 = area between Smeaton Bay-Blossom River and Boca de Quadra-Keta River; UCP = Upper Cleveland Peninsula.

[b] N = Net gun; D = Cap-Chur dart with M99.

Table 2. Mean and standard deviations of Upper Cleveland Peninsula (UCP) point sample values for cells used by radio-collared mountain goats (habitat) and cells not used by radio-collared mountain goats (nonhabitat) during November 1982 through March 1983.

Cell classif.	Mean (SD)				
	Elevation (ft)	Aspect[a]	Slope[b]	Distance to cliff[c]	Timber volume[d]
Habitat (N = 76)	2,170 (24.0)	4.6 (0.03)	5.4 (0.05)	1.1 (0.00)	1.3 (0.03)
Nonhabitat (N = 1,210)	1,770 (55.0)	4.1 (0.07)	4.0 (0.11)	1.8 (0.09)	1.3 (0.07)
Student's t[e]	5.05[f]	5.00[f]	8.75[f]	-7.78[f]	0.00

a Flat and ridgetop = 1; N = 2; NE & NW = 3; E & W = 4; SE & SW = 5; S = 6.

b 1 = 0-15°; 2 = 16-20°; 3 = 21-25°; 4 = 26-30°; 5 = 31-37°; 6 = 38-50°; 7 = 51-65°; 8 = $\geq$66°.

c Units = .4 km.

d 1 = Nonforest; 2 = <8 MFB/acre; 3 = 8-20 MBF/acre; 4 = 20-30 MBF/acre; 5 = 30-50 MBF/acre; 6 = 50+ MBF/acre.

e H_o: Mean of habitat cells = Mean of nonhabitat cells, df = 1,479.

f ($P < 0.05$).

Table 3. Results of discriminant function analysis (DFA) classification of a subsample of grid cells to test the 3-corner rule for classifying other unsampled cells in the K-4 study area near Ketchikan, Alaska.

No. contact corners[a]	% classified "habitat"	% classified "nonhabitat"	_N_[b]
0	4	96	45
1	29	71	49
2	54	46	50
3	79	21	43
4	80	20	45

[a] Number of corners contacting previous systematically sampled cells classified as "habitat" by the DFA.

[b] Fifty random cells were selected in each category, but 0-7 in each category had missing or out-of-range values for at least 1 variable.