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Bi-Level Analysis of Habitat Selection by Mountain Goats in Coastal Alaska

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ABSTRACT

Habitat selection by mountain goats (Oreamnos americanus) was studied on a 400 km^2 area in south coastal Alaska from 1981- 84 using radiotelemetry. Twenty marked goats were relocated a total of 1,052 times from fixed wing aircraft. Each relocation was assigned to a 2.6 ha grid cell on the study area for which elevation, aspect, slope, distance to cliff, vegetation type, and timber volume were measured. The same attributes were measured for a random sample of 1,526 grid cells. Analysis of availability vs. utilization were made at the level of selecting a home range from the overall ridge-and-valley complex and at the level of selecting winter habitat within the home range. At the level of selecting a home range, goats avoided lower elevations, slopes < 30° and commercial volume forest; generally included aspects in proportion to availability; and showed strong preference for areas within 0.4 km of cliffy terrain. Conversely, within the home range in winter, goats preferred lower elevations and commercial forest habitat, favored south aspects, and showed no preference for proximity of cliffs. Reasons for these seemingly contradictory results are discussed and the importance of bi-level analysis of selection is demonstrated. Implications for habitat selection studies and forest habitat management are identified.

INTRODUCTION

Numerous authors have published descriptive accounts of habitat types used by mountain goats throughout their native and introduced range (Klein 1953, Brandborg 1955, Hjeljord 1971, Chadwick 1973, Rideout 1974, Smith 1976, Kuck 1977, Hebert and Turnbull 1977, McFetridge 1977, Chadwick 1983). These reports provide information on the general character of terrain and vegetation used by goats. In more recent studies, most authors have attempted to assess availability of habitat features, as well as their use, to provide insight into the species' pattern of habitat selection (Thompson 1980, Adams and Bailey 1980, Foster 1982, Fox et al. 1982, Schoen and Kirchhoff 1982, Smith 1986). Fox (1983) conducted a thorough analysis of several hypotheses

to explain the observed patterns. However, most previously reported studies have employed direct observational techniques, so results contain undetermined biases toward open habitat types where observability is high (Foster 1982).

In addition to observability bias, previous studies of mountain goat habitat selection may contain bias associated with arbitrary decisions as to habitat availability. Johnson (1980) demonstrated that researchers' decisions regarding what is considered "available" can have profound effects on the outcome of commonly-used analyses of preference. He also suggested that animals may make habitat selection decisions at more than one operative level.

In an attempt to avoid these biases, habitat selection by mountain goats in southcoastal Alaska was studied using radiotelemetry and a bi-level analysis of availability vs. use. Habitat preference was evaluated at the level of selecting a home range from the overall ridge-and-valley complex of the study area and at the level of selecting winter range within the overall home range.

STUDY AREA

The Upper Cleveland Peninsula (UCP), approximately 80 km north of Ketchikan, Alaska, was chosen as being typical of areas occupied by coastal mountain goats (Hebert and Turnbull 1977). Elevations range from sea level to over 1,500 m; topography is complex; steep, broken terrain predominates. Vegetation below 700 m is primarily old-growth forest of Western hemlock (Tsuga heterophylla), Sitka spruce (Picea sitchensis), and cedar (Thuja plicata and Chamaecyparis nootkensis) with sedge (Carex spp.) muskegs in poorly drained areas and alder (Alnus rubra) on steep slide zones. Above 700 m alpine heath/tundra areas are interspersed with rock, scree and limited permanent snow fields.

METHODS

Mountain goats were captured during July 1981 and 1982 using standard helicopter darting techniques (Schoen and Kirchhoff 1982) with 4 mg. of M-99 etorphine hydrochloride (Lemmon Co., Sellersville, Pa.). Captured goats were fitted with radio collars (Telonics, Mesa, Az.) and were relocated at approximately 7 day intervals from the air using twin 2-element Yagi antennae mounted on a Piper PA-18-150 Super Cub as described by Nichols (1982).

An independent grid overlay system was developed for the study area with a 10 x 10 matrix providing 100 grid

cells per section on USGS topographic and USDA Forest Service timber type maps at the scale of 1:31,680. Each cell contained approximately 2.6 ha of land. This cell size was considered large enough to permit accurate mapping of goat radio-locations, yet fine enough to permit a single point sample of habitat attributes to describe the cell. Each time a goat was located, its position was recorded on a map as being within 1 grid cell identified by the coordinates of the southwest (lower left) corner.

Habitat features were determined for each occupied cell and for a 10% random sample (N = 1,526) of cells on the study area. Elevation, aspect, slope, and distance to the nearest cliff (i.e. area of measurable slope > 50°) were taken at the grid line intercepts on topographic maps. Vegetation type and timber volume were determined at the same point from standard USDA Forest Service forest cover maps. Details of methodology for habitat measurements are provided in Fox et al. (1982).

The procedure described by Marcum and Loftsgaarden (1980) using chi-squared and Bonferroni Z statistics (Neu et al. 1974) was used for statistical analyses. Individual confidence intervals were determined at the 98% level; the confidence level for the combined "family" of intervals was 90% for all features except vegetation type where the use of 6 categories resulted in an 88% overall confidence level.

For this study, elevations were grouped into 250 m categories. Aspects were grouped at Flats (i.e. no slope), North (including NW and NE), East and West combined, South (including SE and SW), and Ridgetop. Slope categories were 0-20°, 31 - 50°, 51 - 65°, and 66°+. Distance to cliffs was measured in 0.4 km units. Vegetation types were grouped as commercial forest, muskeg forest, subalpine forest, brush/slide, alpine, and rock/cliff. Standard Forest Service timber volume classes (0, <8, 8-20, etc. thousand board feet per acre (mbf/a)) were used.

For the 1st level of selection, minimum convex polygon home ranges for individual goats were plotted on the study area overlay, and habitat features within the home range were compared to those of the overall study area. Only those goats for which use-area curves had reached an asymtote, indicating complete mapping of the home range (Bekoff and Mech 1984), were included in analyses. "Availability" was based on data from the 10% random sample of grid intersection points on the study area. "Utilization" was based on a random sample of at least 75 points within goat's home range, or all points within the home range for goats with home ranges smaller than 1.9 km^2.

The 2nd analysis of availability vs. utilization was made at the home range level. The frequency distribution

derived from the random points in the home range 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.

RESULTS

Twenty mountain goats (13 females, 7 males) were included in analyses for this study. 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). Due to the limited sample size, results for the sexes were combined. Their selection of the habitat parameters was as follows.

ELEVATION

Chi-squared analyses revealed that 90% of the goats were selective ($P < 0.05$) with respect to elevation in establishing their home range on the study area (Table 1). Sixty-five percent of the goats were selective ($P < 0.05$) regarding use of elevation within the home range during winter (Table 1).

Bonferroni Z analysis indicated that of the 5 elevation classes, all goats avoided the 0-250 m zone in establishing their home ranges, but only 40% avoided this zone within their home range in winter (Table 2). In fact, 7% of the goats preferred this lowest elevation zone in winter.

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. The opposite is true of the highest 2 elevation categories.

The 750-1,000 m elevation zone was preferred by 45% of the goats and used proportionately by the other 55% in selecting their home ranges, but the majority (65%) of goats avoided this zone in winter (Table 2). The 1000 m elevation zone was also preferred or used proportionately by most goats (65% overall) in establishing their home ranges, but 57% of the goats avoided these areas within their home range during winter (Table 2).

This analysis of use 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

Table 1. Percent of mountain goats (N = 20) demonstrating significant ($P < 0.05$) selection with respect to 5 habitat features in establishing home ranges (HR) on the Upper Cleveland Peninsula (UCP) study area and in utilization of winter range (WR) within the home range based on Chi-squared analyses of random points and radiolocations, 1981-84.

Comparison	Elevation	Aspect	Slope	Distance to Cliff	Vegetation Type	Timber Volume
HR vs. UCP[a]	90	90	70	95	95	75
WR vs. HR[b]	65	45	75	10	45	55

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

[b] Analyses based on comparison of frequency distributions of measured values at November-March relocations for each goat (N = 10 to 31) with 75 random points within the goat's home range.

Table 2. Percentage of mountain goats (N = 20) 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 - 1000 m		1000 m	
	HR vs. UCP	WR vs. HR[a]	HR vs. UCP	HR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR[b]
+	0	7	0	15	20	20	45	5	20	0
0	5	53	45	80	80	75	55	30	45	43
-	95	40	55	5	0	5	0	65	35	57

[a] N = 15 Sample size reduced as this zone did not occur within each goat's home range.
[b] N = 14 Sample size reduced as this zone did not occur within each goat's home range.

Table 3. Percentage of mountain goats (N = 20) 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[a]	HR vs. UCP	WR vs. HR
+	20	5	5	0	20	55	5	0	0	0
0	75	50	75	80	70	45	25	50	100	90
-	5	45	20	20	10	0	70	50	0	10

[a] N = 16; Flat terrain did not occur within 4 home ranges.

elevations than are generally available in the ridge-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 respects to other habitat features.

ASPECT

Chi-squared analyses revealed that 90% of the goats were selective ($P < 0.05$) with respect to aspect in establishing their home ranges on the study area, but less than half were selective regarding use of aspect within their home range during winter (Table 1).

Bonferroni Z analysis indicated that at the level of selecting a home range from the UCP study area most ($\geq$ 70%) of the goats included proportional amounts of all slope aspects and ridgetops, but strongly avoided flats (Table 3). Within their home ranges during winter, however, there was a distinct preference for south-facing slopes and 45% of the goats avoided northerly aspects (Table 3).

SLOPE

Seventy percent of the goats were selective ($P < 0.05$) with respect to inclusion of various slope angles in their home ranges and 75% were selective regarding use of slopes within their home ranges during winter (Table 1). Bonferroni Z analyses revealed that 50% of the goats avoided slopes of less than 20° (Table 4). Most ($\geq$ 75%) of the goats included proportionate amounts of steeper slopes in their home range (Table 4).

Winter relocations compared to availability within the home range indicated even more pronounced selection in favor of steep (>30°) slopes (Table 4). For example, even though half of the goats had already avoided slopes of less than 20° in establishing their home range, all goats except 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 during winter. In addition, 60% of the goats avoided the 21-30° slopes and 70% preferred slopes of 31-50° in winter (Table 4). Use of the steepest category was also more pronounced in winter (Table 4).

DISTANCE TO CLIFFS

All goats except 1 male were selective ($P < 0.05$) with respect to distance to cliffs in establishing their home range on the study area (Table 1). Conversely, only 1 goat of each sex was selective regarding distance to cliffs within their home range during winter. This seemingly

Table 4. Percentage of mountain goats (N = 20) 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 Category									
	0 - 20°		21 - 30°		31 - 50°		51 - 65°		66°	
	HR vs. UCP	WR vs. UCP	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR[a]
+	5	0	0	0	20	70	5	15	0	6
0	45	10	100	40	75	30	95	75	85	94
-	50	90	0	60	5	0	0	10	15	0

[a] N = 17; Slopes over 66° were not available in 3 home ranges.

Table 5. Percentage of mountain goats (N = 20) 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, Alaska (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	WR vs. UCP	WR vs. HR[a]	WR vs. UCP	WR vs. HR[b]	HR vs. UCP	WR vs. HR[c]
+	80	40	5	0	0	8	0	0	0	0
0	20	60	35	60	15	77	15	75	5	0
-	0	0	60	40	85	15	85	25	95	100

[a] N = 13 No area over 0.8 km from a cliff occurs within other home ranges.
[b] N = 4 No area over 1.2 km from a cliff occurs within other home ranges.
[c] N = 1 No area over 1.6 km from a cliff occurs within other home ranges.

counter-intuitive lack of selection in winter is merely an artifact of radical selection at the home range level. Virtually all goats spend their entire lives within 0.4 km of cliffy terrain 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 5) 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 hone range during winter, and fewer than 30% avoided areas over 0.8 km from cliffs.

VEGETATION TYPES

All goats except 1 female were selective ($P < 0.05$) with respect to inclusion of various vegetation types in their home range on the study area (Table 1). However, less than half were selective regarding use of vegetation types within their home range during winter (Table 1).

Selection of vegetation type parallels selection for elevation. In establishing their home ranges, goats more often avoided commercial old-growth and muskeg forest (i.e., lower elevations) and used subalpine, alpine, and brush/slide areas (i.e., higher elevations) proportionately (Table 6). Conversely, in winter the open subalpine, alpine, and brush/slide types were less preferred or even avoided, while preference for commercial old-growth forest was increased (Table 6).

TIMBER VOLUME

Seventy-five percent of the goats were selective ($P < 0.05$) with respect to inclusion of various timber volume classes in their home range on the study area (Table 1). However, only 55% were found to use timber volumes selectively within their home range during winter.

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 7). However, within the home range during winter, 75% of the goats avoided nonforested areas, and none preferred nonforested habitat during winter.

Table 6. Percentage of mountain goats (N = 20) 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 ranges, 1981-84.

	Vegetation Type									
	Old-growth forest		Muskeg forest		Subalpine forest		Brush/slide		Alpine	
	HR vs. UCP	WR vs. HR	Hr. vs. UCP	WR vs. UCP[a]	HR vs. UCP	WR vs. HR	HR. vs. UCP	WR vs. HR[b]	HR vs.UCP	WR vs. HR[c]
+	5	35	5	6	20	0	10	0	35	0
0	55	65	25	75	80	85	75	78	35	36
-	40	0	70	19	0	15	15	22	30	64

[a] N = 16; Muskeg forest did not occur in other home ranges.
[b] N = 18; Brush/slide did not occur in other home ranges.
[c] N = 14; Alpine did not occur in other home ranges.

Table 7. Percentage of mountain goats (N = 20) showing preference (+), proportional use (0) and avoidance (-) of timber volume classes in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula, Alaska (UCP) study area, and in selecting winter range (WR) within their home ranges, 1981-84.

	Timber Volume Class									
	Nonforested		<8 mbf/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. ER	HR vs. UCP	WR vs HR[a]
+	40	0	10	5	0	5	0	30	0	8
0	55	25	60	90	45	95	45	70	50	84
-	5	75	30	5	55	0	55	0	50	8

[a] N = 12; 30+mbf/acre did not occur in other home ranges.

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 7). 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 were preferred by none in establishing their home ranges (Table 7). 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 features, 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 those stands of commercial volume timber that do occur within the home range are highly preferred during winter.

DISCUSSION

The criteria an animal uses in determining its overall 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.

By examining habitat selection at two different levels it may be possible to reduce bias associated with arbitrary decisions regarding availability. This approach should produce results which are more realistic in biological terms and provide insights into habitat selection that otherwise might not be revealed.

In this study, at the level of selecting a home range, mountain goats were found to prefer areas at high elevations with generally steep slopes, spent most of their time in close proximity to cliffs and avoided commercial forest stands. This would be expected based on the general model of goat habitat selection (Schaller 1977, Chadwick 1983, Fox 1983). However, analyses at the level of selecting winter habitat within the home range revealed that during the critical winter months, goats made preferential use of the lower elevation portions of their home ranges including commercial forest cover.

Without the partitioning applied here, it is likely that evaluation of availability vs. use of timber volume by goats in winter would have indicated that goats avoid commercial timber stands. This might lead resource managers to conclude that timber harvesting will not adversely affect goat habitat. However, results presented here and elsewhere (Schoen and Kirchhoff 1982, Fox et al. 1982, Fox 1983, Smith 1986) clearly indicate that certain commercial forest stands are highly preferred by coastal mountain goats in winter. Given the nature of winter weather in this region with abundant, high density snowfall, and the effect of weather on goat population dynamics (Smith 1984), it is not surprising that old-growth forest is a critical component of winter range for coastal mountain goats. Thus, land use planning decisions must reflect the need to protect these areas to maintain goat populations.

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QUESTIONS AND ANSWERS

Questions not recorded regarding old growth forest and mountain goat winter survival.

Scott Brainard presented this paper for Christian Smith

Scott Brainard: Well, when I worked for Chris we did some helicopter surveys, so we had the chance to get down on the ground and collected pellets and looked at goat feed. We found they were eating the branches off of cedar hemlock, its been five years now. I don't think goats forage on these trees to the extent that its damaging the timber, but they do utilize those commercially important species to subsist. We had a goat that was wintering almost 3,000 feet elevation in southeast Alaska. He stuck out the whole winter in a place that was so desolate you couldn't believe it, and he was subsisting in an area where there was no understory, nothing but cedar. He was eating cedar. I don't know if Chris has presented this in the other papers or not. I don't want to get a little ahead of his game, but, yes, we did find that goats ate cedar but as far as damage to old growth forest, I don't think there's a problem.