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Relation Between Mountain Goats and Their Habitat in Southeastern Alaska

Joseph L. Fox, Christian A. Smith, and John W. Schoen

Abstract

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Mountain goats in southeastern Alaska occupy habitats providing abundant areas of high-quality forage during summer but only limited feeding areas during winter because of deep snow. Winter is a period of severe nutritional deprivation, and goats converge into areas with available forage, often within old-growth forest where relatively low snow depths and litterfall enhance food availability. Goats are further restricted in their habitat use to sites within and near steep and rugged terrain, which provides escape areas from predation by wolves. Because goat winter habitat is limited, even small areas of habitat alteration that impinge on these sites can have a disproportionally large effect on the goat populations concentrated there. Removal of old-growth forest would decrease available forage and thus lower the quality of goat wintering sites when snow-packs are present. Whereas the effects of forest management might be locally important for goats, the total amount of goat habitat subject to this or other habitat alteration is likely to be small and should not greatly affect goat carrying capacity in southeastern Alaska. But, where forest management or other human land use occurs within goat habitat, the limited areas of actual conflict may make avoidance of critical goat habitat practical. Research is needed on digestive physiology of goats, habitat use by goats within the critical areas surrounding escape terrain, and the relations of forest management to goat populations.

Keywords: Wildlife habitat management, wildlife habitat, timber management, habitat selection, mountain goat, Alaska (southeastern).

Contents

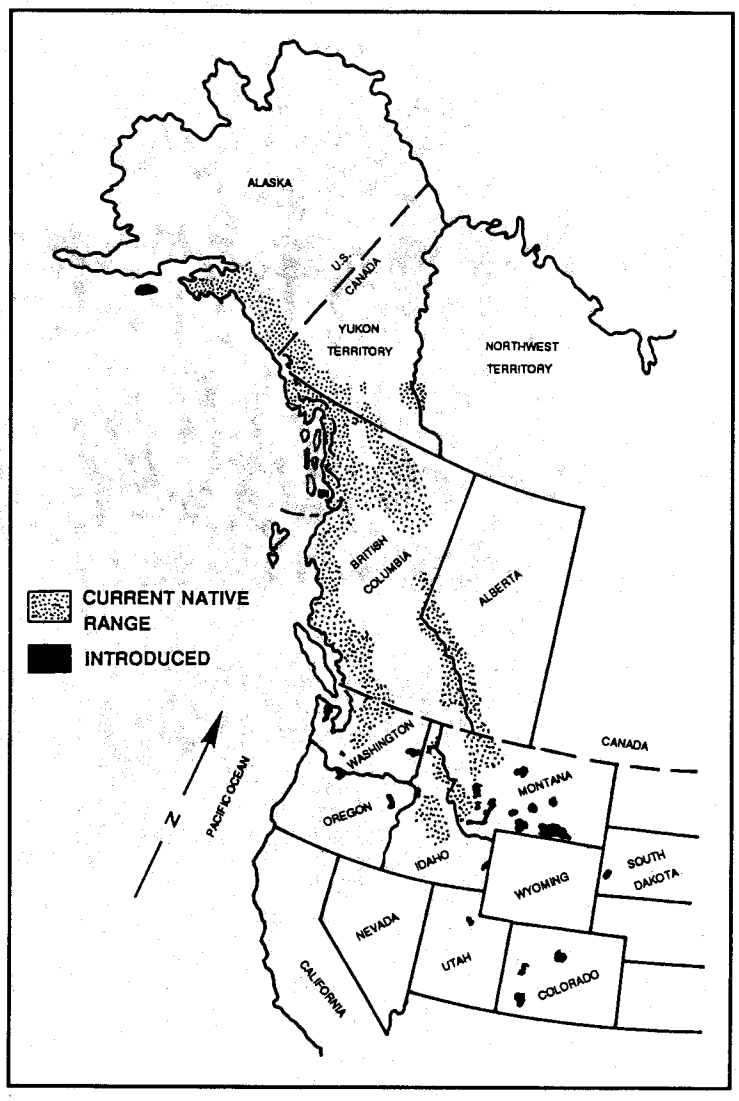

Figure 1—Distribution of mountain goats in North America. (Adapted from Johnson 1977.)

Introduction

The mountain goat (*Oreamnos americanus*) occurs in the Cascade Range and Rocky Mountains of western North America between the latitudes of 43° and 63° N. (fig. 1). In southeastern Alaska (55°-60° N.), goats are endemic to the mainland (Klein 1965b) and common throughout this region (fig. 2). Eighteen mountain goats were introduced to Baranof Island in 1923 (Burris and McKnight 1973); the current population is more than 500.[1] Goats were also introduced to Chichagof Island in the early 1950's but failed to become established (Ballard 1977). In 1983, 17 goats were introduced to Revillagigedo Island (Smith and Nichols 1984); they seem to be establishing a permanent population. The mountain goat population in Alaska has been estimated at 15,000-25,000 (Ballard 1977), of which at least one-third are in southeastern Alaska.

[1] Personal communication, L. Johnson, Alaska Department of Fish and Game, Sitka, AK.

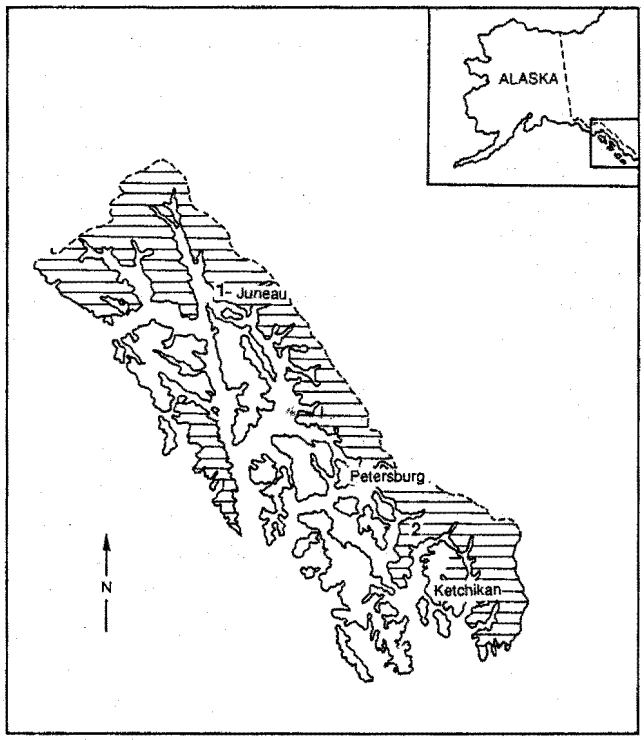

Figure 2—Distribution of mountain goats in southeastern Alaska. The numbers designate study areas: 1—Herbert Glacier near Juneau, and 2—Cleveland Peninsula near Ketchikan.

Goat densities reported in southeastern Alaska average about 1.5 per square kilometer (3.9/mi^2) and range from 0.5 to 4.2 per square kilometer (1.3-10.9/mi^2) (Fox 1984, Smith and Bovee 1984). This is fairly consistent with densities reported elsewhere, although much higher than Hebert and Turnbull's (1977) estimate for coastal British Columbia, which may have been made when the population level for goats in that region was lower than normal. Recent analyses of trends in the number of goats in southeastern Alaska suggest pronounced cycles in population, about twofold to fivefold differences, in association with weather patterns (Smith 1984). Goat populations in southeastern Alaska currently are increasing and are generally at high levels (Smith 1984).

The mountain goat is highly regarded by sport hunters but is not a major Alaska big game species in numbers killed. Mountain goat harvest in Alaska, which averages about 800 annually, is one of the largest for any State or Province but is small relative to the total goat population and to harvest totals for other big game species. At present, travel constraints restrict hunter access to only a small fraction of the overall goat population. Only recently have regulations for hunting by permit been imposed in Alaska, and permits are limited only in regions near large human population centers (Ballard 1977).

The nonconsumptive values of the mountain goat are increasingly recognized (Ballard 1977). At both Misty Fjords and Glacier Bay National Monuments, opportunities are promoted for viewing mountain goats. Several areas in the Tongass National Forest have been closed to hunting to increase public viewing opportunities.

Goat habitat in southeastern Alaska lies in a mountainous region with a strong maritime influence that moderates temperatures but brings high levels of precipitation throughout the year. Mountain ranges in the region generally rise to about 2000 meters (6,550 ft), although in the north some peaks are much more than 3000 meters (9,850 ft). High

annual precipitation (200-500 centimeters [80-200 in] at sea level and more at higher elevations) and no pronounced summer drought result in abundant plant growth throughout the growing season, which allows dense tree growth to develop even on steep and rocky slopes. Elevations as high as 700 meters (2,300 ft) are generally covered with coniferous rain forest dominated by Sitka spruce (*Picea sitchensis*)[2] and western hemlock (*Tsuga heterophylla*), intermixed with ericaceous shrub- and subshrub-dominated muskeg. Subalpine forests and meadows occur from about 700 to 900 meters (2,300-2,950 ft), and alpine vegetation grows to about 1500 meters (4,900 ft). Rock, permanent snowfields, and glaciers constitute most of the area above 1500 meters (4,900 ft); numerous glaciers descend to or near sea level.

Although temperatures are mild compared with continental climates, winter snowfall within mountain goat range is usually deep, dense, and long lasting. Above 500 meters (1,650 ft), winter precipitation is mostly snow; below this elevation, rain and snow commonly alternate throughout the winter. Some winters may produce virtually no snow accumulation at sea level; in other years, accumulations may exceed 1 meter (3.3 ft). Deep snowpack covers most of the summer foraging areas, which makes food availability an important factor in goat survival during winter.

The ability of goats to survive inclement winters is influenced by their nutritional condition and by the amount and quality of forage available throughout the winter. Whereas the summer range is mainly alpine and subalpine habitats, much of the winter range in southeastern Alaska is restricted to forested habitats. Some climatic differences also seem to affect acceptable wintering sites for mountain goats. In relatively cold and windy sites, usually associated with more interior locations and those near the deep river gorges emanating from British Columbia, windblown alpine slopes often provide suitable goat winter range. In contrast, the warmer coastal areas typically receive deep, dense snow in alpine regions, which results in increased use of forested areas as winter habitat. This relation has also been described for goat habitat in British Columbia (Hebert and Turnbull 1977). Whereas forested goat wintering sites are more prevalent in the warmer southern portions, and alpine sites are more prevalent in the colder northern portions, topographic variety in southeastern Alaska produces both conditions in specific locations throughout the region.

As snow accumulates, goats concentrate on patches of winter range. Management practices altering the quality or quantity of winter range for goats have greater consequences than can be inferred from the amount of area affected. The greatest impacts occur when high-quality patches of winter range or sites used only in severe winters are affected. Although most goat winter habitat in southeastern Alaska is in such steep and isolated terrain that resource development and human activity are essentially precluded, important exceptions exist. The major sources for potential alteration of mountain goat habitat are development activities associated with logging, mining, and hydroelectric power.

Because logging in southeastern Alaska has expanded during the past 30 years into less productive upland sites and to mainland areas, the chances of affecting goat habitat have increased. Intensive mining and its associated development requirements can affect goat habitat, although the bedrock mining conducted in southeastern Alaska is generally more site specific and restricted in scope than is logging. Recent interest in developing new hydroelectric dams has increased concern for key winter habitat for goats.

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[2] Nomenclature for vascular plant names follows Hulten (1968) and Hitchcock and Cronquist (1973).

From 1975 to 1985, a cooperative effort among the Alaska Department of Fish and Game, the USDA Pacific Northwest Research Station, and the Universities of Alaska and Washington has been directed at research on habitat use by mountain goats in southeastern Alaska. Radio-telemetry-based studies in both northern (Juneau) and southern (Ketchikan) portions of the region and ground-based observational and habitat quality studies, predominantly around Juneau, have provided substantial new data on mountain goat habitat use in the area. These studies form the basis for much of the information presented on mountain goat ecology in this paper.

Home Range and Movements

Studies of 28 radio-collared mountain goats in southeastern Alaska show that year-round home ranges are usually from 10 to 20 square kilometers (4-8 mi^2); the range of a few individuals approached 90 square kilometers (35 mi^2) (Smith 1985).[3] Seasonal-use areas within home ranges were often distinct, although in most cases overlap did occur (Schoen and Kirchhoff 1982). Winter-use areas were generally much smaller than summer areas and, in some cases, were less than 0.2 square kilometers (0.08 mi^2) (Smith 1982). Whereas seasonal range fidelity was relatively high during 2 years of study, some differential use of preferred sites occurred from one year to the next (Schoen and Kirchhoff 1982).[4] One-third of the monitored goats used different sites from one winter to the next, with males showing a much greater tendency than females for such behavior, a result of the extensive movements by males during the early winter rutting period (Schoen and Kirchhoff 1982, Smith 1985) (see footnote 4).

Adult males had larger home ranges and more distinct seasonal ranges than did females. Males and females are most often found together during the October-December rutting period and generally remain separate the rest of the year. Mean distance between the centers of summer and winter ranges for males and females, respectively, were 2.9 and 2.2 kilometers (1.8 and 1.4 mi) (Schoen and Kirchhoff 1982). These distances are less than reported elsewhere (Chadwick 1973, Rideout 1974) and may be a function of either the high quality of goat habitat or the barriers to movement caused by glaciers in southeastern Alaska. Part of the seasonal separation of ranges is due to a vertical migration; the lowest elevations are used in winter and spring, the highest in late summer (Fox 1978, Schoen and Kirchhoff 1982, Smith 1985).

Although the overall home range sometimes exceeded 30 square kilometers (12 mi^2), the area usually used within the home range was generally much smaller and was closely associated with patches of steep, rugged terrain (Schoen 1979, Schoen and Kirchhoff 1982, Smith 1985). Movement patterns reflected travel among these patches of preferred habitat. Data from the ground-based observational studies indicated that average daily movements were small, about 15-30 meters (50-100 ft) but usually increased in clear weather (Fox 1978). During clear weather, goats tended to move to higher elevations—locations averaged about 200 meters (650 ft) higher than those used in rainy conditions (Fox 1978).

During the rutting period from October to December, male goats made their longest moves in search of females. These movements can encompass the winter ranges of several females or groups of females and involve extensive travel across forested valley bottoms (Smith and Raedeke 1982).

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[3] Schoen, J.W. Unpublished data on file at Alaska Department of Fish and Game, Juneau, AK 99824.

[4] Smith, C.A. Unpublished data on file at Alaska Department of Fish and Game, Fairbanks, AK 99701.

In clear weather during summer, goats were especially active in the hours around sunrise and sunset (Fox 1978). In cloudy or rainy weather, activity began after sunrise and remained relatively constant throughout the day (Fox 1978). In winter, goats were most active in the middle of the day, regardless of weather.[5]

Habitat

In a study area near Juneau, about 90 percent of year-round habitat use by goats was within 400 meters (1,300 ft) in elevation of the approximately 850-meter (2,800-ft) timberline (Schoen and Kirchhoff 1982). On the Cleveland Peninsula near Ketchikan, the mean elevation used was less than 600 meters (1,950 ft) (Smith 1985), and goats made substantial use of habitats below timberline. Some use occurred as low as sea level, whereas the highest elevations used in southeastern Alaska approach 2000 meters (6,550 ft) (Fox 1978, Fox and Taber 1981).

Southerly aspects were preferred in winter and early spring, whereas a more even goat distribution across aspects was apparent during summer (Fox 1978, Schoen and Kirchhoff 1982, Smith 1985). The goats used terrain year-round that had a mean slope angle of about 35°, with relatively steeper slopes used in winter and spring. Ninety percent of goat use occurred on slopes greater than 25° (Fox 1978, Schoen and Kirchhoff 1982, Smith 1985).

The preference of mountain goats for steep and rugged terrain is well known (Brandborg 1955, Rideout and Hoffmann 1975) and is generally explained as predator avoidance, which is implied by the term "escape terrain" (Fox and Streveler 1986, Rideout and Hoffmann 1975). To determine the degree of affinity mountain goats have for escape terrain, we measured the distribution of goat use associated with distance from steep and rugged terrain. Escape terrain was defined as slopes of 50° or greater with the terrain surface being broken up, usually by rock outcroppings.

In two studies in southeastern Alaska, more than 90 percent of locations (n = 810 and 1,702 locations) of radio-collared goats were within 400 meters (1,300 ft) of steep and rugged terrain throughout the year (Schoen and Kirchhoff 1982, Smith 1985). In a forested wintering site near Juneau, 95 percent of goat use (measured by presence of goat droppings) was within 250 meters (800 ft) of steep and rugged terrain (Fox 1983). Evidence from the Canadian Rocky Mountains corroborates this important restriction in goat habitat use: during summer in Alberta, 95 percent of all goat nursery group activity took place within 400 meters (1,300 ft) of steep and rocky terrain (McFetridge 1977). In early winter, these goat nursery groups stayed even closer to steep and rocky terrain; 95 percent of activity was within 300 meters (975 ft).

Goats in southeastern Alaska use alpine, subalpine, and some heavily forested habitats (Fox 1983, Schoen and Kirchhoff 1982, Smith 1985). Goats near Juneau use rock outcrops, alpine tundra, subalpine forest, and shrubland habitat types predominantly during summer; they use rock outcrops, alpine tundra, and old-growth forest habitats in winter (Schoen and Kirchhoff 1982). In an area near Ketchikan, goats also use predominantly alpine tundra, subalpine forest, and rock outcrop habitats during summer, but during winter make use of subalpine and low-elevation old-growth forest habitats almost exclusively (Smith 1985).

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[5] Fox, J.L. Unpublished data on file at Department of Ecology, University of Tromsø, N-9001 Tromsø, Norway.

In measuring forage production and availability in winter, Fox (1983) recognized 13 vegetation types in mountain goat range in a study near Juneau. These types and several others described by Alaback (1980), Jacques (1973), Smith (1984), and Streveler and others (1973) can be placed within the classification of Alaska vegetation developed by Viereck and Dyrness (1980) (table 1).

Table 1—Classification of vegetation types common within goat range in southeastern Alaska[a]

Level II	Level III	Level IV[b]	Key species
Conifer forest	Closed conifer forest	a-f	*Picea sitchensis* *Tsuga heterophylla*
	Open conifer forest	a-c	*Tsuga mertensiana* *Chamaecyparis nootkatensis*
	Conifer woodland	a	*Pinus contorta*
Sedge-grass tundra	Wet sedge-grass	c	*Carex nigricans* *Fauria crista-galli*
	Mesic sedge-grass	b	*Carex macrochaeta*
Herbaceous tundra	Alpine herbaceous tundra	a,b	*Saxifraga* spp. *Artemisia arctica*
Shrub tundra	Ericaceous shrubs	d,e	*Empetrum nigrum* *Vaccinium* spp.
Mat and cushion tundra	Open mat and cushion	a,e,f	*Salix* spp. *Leutkea pectinata*
Tall shrub	Closed tall shrub	b	*Alnus sinuata* *Athyrium filix-femina*
Tall grass	Bluejoint-herb	b	*Calamagrostis canadensis*
	Herbs	b,c,d	*Heracleum lanatum* *Veratrum viride*
Sedge-grass	Wet sedge-grass	a,b	*Carex* spp. *Sphagnum* spp.

[a] Classification according to Viereck and Dyrness (1980).

[b] Letters in this column refer to vegetation type descriptions given in Viereck and Dyrness (1980).

Sources: Alaback 1980, Fox 1983, Jacques 1973, Streveler and others 1973.

In summer, mountain goats made the most use of habitats that included tall grass-herbs, mesic sedge-grass tundra, and alpine herbaceous tundra, with substantial use also of closed tall shrub, open conifer forest, and wet sedge-grass tundra (Fox 1978, Hjeljord 1971, Schoen and Kirchhoff 1982, Smith 1985). During winter, predominant use shifted to closed conifer forest, alpine herbaceous tundra, tall grass-bluejoint-herb, and a special case of open conifer forest (that is, the stunted timberline trees known as krummholz), with lesser use of closed tall shrub and some types of shrub tundra (Fox 1983, Schoen and Kirchhoff 1982, Smith 1985; see footnote 5).

In British Columbia and Washington, where more logging has been done within goat range than in Alaska, evidence of goat use exists in logged areas (Hebert and Turnbull 1977, Reed 1983). The use by goats of closed conifer forest in winter (and parts of spring and fall) is important in considering the effects of timber harvest on goat habitat quality in these areas.

Ecological Bases of Goat-Habitat Relations

Predation

Large predators in southeastern Alaska commonly include the wolf (*Canis lupus*), wolverine (*Gulo gulo*), brown bear (*Ursus arctos*), and black bear (*Ursus americanus*), with coyotes (*Canis latrans*) present in a few areas. Although all these species are known to hunt mountain goats (Carbyn 1974, Chadwick 1983, Guiguet 1951, Seton 1929), only the wolf has been suggested as an important predator of goats (Ballard 1977, Fox and Streveler 1986).

Wolves visited alpine goat habitat in study areas near Juneau and Glacier Bay an average of every 2 weeks throughout the year (Fox and Streveler 1986). At these sites, 62 percent of 124 wolf scats collected in or near goat range included remains of mountain goats (Fox and Streveler 1986). Where goats constitute a substantial portion of available prey, they may form a significant proportion of the diet of wolves. The effect of wolf predation on goat populations is unknown, although some speculate that under certain conditions it may be an important influence (Ballard 1977).

Observed interactions between wolves and mountain goats indicate that goats use a strategy to avoid predation that is typical of many mountain ungulates (Fox and Streveler 1986, Smith 1983). Goats generally move into steep and broken terrain when approached by large mammalian predators. Mountain goats are better adapted than are large predators for travel in such rugged terrain and are hence safer there. The need to remain close to escape terrain is thus an important constraint on goat habitat use. Even where predation is not an important mortality factor, goats stay close to escape terrain (Brandborg 1955, Stevens 1979); this suggests a behavior strongly selected for throughout their evolution.

Both bald eagles (*Haliaeetus leucocephalus*) and golden eagles (*Aquila chrysaetos*) prey on young goats (Brandborg 1955, Seton 1929, Smith 1976); the primary means of defense against such attacks is for the young to remain under or very near their defending nannies. This predator-avoidance behavior is exhibited on all terrain types (see footnote 5).

Nutrition and Diet

The relation between goats and their habitat includes seasonal changes in the availability and quality of food and the physiological requirements of the goats. Little research has been done on the physiological and nutritional ecology of mountain goats; they are probably similar, though, to deer and other ungulates of northern latitudes in their seasonal cycle of weight gain in summer and weight loss in winter (Fowler and others 1967). Weights of goats captured in Alaska fall within this pattern of summer weight gain and winter weight loss (Nichols 1982).

Table 2—Estimated daily intake of digestible energy and energy required for maintenance of an adult mountain goat in summer and winter

Season	Body weight[a]	AMR[b]	Dry matter intake[c]	Dry matter digestibility[d]	Energy intake[e]	Net energy gain or loss
	Kilograms	*Kilo-calories*	*Grams*	*Percent*	*Kilocalories*	
Summer	60	3020	31	70	4980	+1960
Winter	70	3390	17	35	1590	-1800

[a] Body weight for female goat 2 years old or older (Sources: Lentfer 1955, Nichols 1982).

[b] AMR is the activity metabolic rate measured in kilocalories per day. AMR is a constant (here assumed to be 2) times the basal metabolic rate (BMR), which is equal to 70 times body weight to the 0.75 power. Both rates vary somewhat seasonally. (Sources are from studies on deer: Moen 1973, Wallmo and others 1977.)

[c] Dry matter intake per kilogram of body weight per day. (Sources are from studies on deer: Alldredge and others 1974, Bandy and others 1970.)

[d] Sources: Hanley and McKendrick 1983, Johnston and others 1968, Smith 1969.

[e] Energy intake in kilocalories per day = (BW)(DMI)(GE)(DMD)(ME), where BW = body weight, DMI = dry matter intake, GE = gross energy content (4.5 kilocalories/gram), DMD = dry matter digestibility, and ME = metabolizable energy coefficient (0.85). See Wallmo and others (1977) for an explanation of the equation.

During summer, both the abundance and quality of forage are relatively high. The growing parts of plants are high in cellular content and low in cell wall constituents, thus providing the best food source for rapid animal growth (Van Soest 1982). Plants also generally increase in forage quality, as measured by nitrogen content, with increasing elevation (Hebert 1973; Johnston and others 1968; Klein 1965a, 1970). In addition, the summer-long emergence of new growth from snowbanks and continuous plant growth in the moist coastal climate of southeastern Alaska provide highly nutritous forage all summer (see footnote 5). Energy intake by mountain goats should exceed physiological demands during summer, resulting in weight gain (table 2). In the coastal goat ranges of southeastern Alaska, the consistently abundant nutritous forage in summer probably allows goats to achieve high growth rates and prime physical condition by the time winter arrives each year. The quality of summer forage influences the physiological condition in which an animal approaches the winter period of nutritional deprivation and thus affects its chances for survival or successful reproduction.

Winter is a period of severe nutritional deprivation and food scarcity for mountain goats. Winter-dormant plant parts that remain after senesence, leaf fall, and translocation of nutrients to root storage are relatively low in nitrogen and high in structural material (cell walls) (Hanley and McKendrick 1983). In winter, forage quantity and quality are low, energy needs of goats exceed intake, and goats lose weight (table 2). The quality and quantity of forage available in winter influences how quickly summer reserves are depleted, again affecting chances for survival and reproduction.

Ruminants such as the mountain goat require forage with adequate energy and nitrogen for maintenance and growth. The cellular contents of the forage contain most of the nitrogen, mineral nutrients, and some easily digestible carbohydrates, whereas the cell walls provide mainly an energy source (Van Soest 1967). The mountain goat uses both plant components but is probably similar to deer in emphasizing the cell-soluable fraction by selectively browsing (Dailey and others 1984, Hanley 1980). Browse diets high in digestible energy are usually also high in nitrogen and essential minerals. But because of large seasonal changes in forage availability and quality, goats must make differential use of plants and plant parts through the year. Geist (1971) suggests that the generalist dietary habits of the goat may compensate for its specialization in physical habitat; that is, its preference for being near cliffs.

Plants also contain certain compounds, either toxins or digestibility reducers, that provide a kind of antiherbivore defense function (Feeny 1976, Rhoades and Cates 1976). The concentration of these compounds is highly variable in both species specificity and phenology and therefore requires assessment of specific diets to determine their effect. Because chemical composition differs greatly among species, forage variety producing a mixed diet is very important to goats (Freeland and Janzen 1974, Westoby 1974).

Mineral deficiencies in the diet can result in use of mineral licks by goats, and this sometimes results in use of otherwise poor goat habitat (Hebert and Cowan 1971, Singer 1978). The use of mineral licks is generally greatest in spring and early summer and is thought to correspond primarily to high sodium needs at that time of year (Hebert and Cowan 1971, Stevens 1983). No reports have been made of goats using natural mineral licks in coastal areas of Alaska. Relatively high sodium content found in a common summer forage species (*Carex macrochaeta*; see footnote 5) of goats in coastal Alaska suggests that goats might fulfill their sodium requirements from forage alone and could explain why they do not use salt licks in this region.

Diet composition—Food selection by goats in coastal Alaska is discussed by Fox and Smith (1988) and Hjeljord (1971, 1973). A list of plant species known to be eaten by goats in southeastern Alaska can be obtained from the literature (table 3). The list is long, demonstrating the generalist nature of goat feeding habits and suggesting the high value of a mixed-species diet. The dietary importance of a plant species to goats is ultimately determined by the species' quality and abundance, however.

In spring, one of the first areas of plant growth is the herbaceous understory of low-elevation alder (*Alnus sinuata*) shrublands. This is reflected in the preference by mountain goats for such vegetation in south-facing avalanche slopes at this time of year (Schoen and Kirchhoff 1982). Highly nutritious rhizomes and new shoots of the fern *Athyrium filix-femina* may be important dietary constituents in spring and in the winters without snow accumulation at low elevation (Hjeljord 1971, Klein 1953).

During summer, several abundant sedges and forbs including *Carex macrochaeta*, *C. microchaeta*, *Artemisia arctica*, *Lupinus nootkatensis*, *Luetkea pectinata*, *Fauris cristagalli*, and *Arnica latifolia* are common in goat diets (Hjeljord 1971; see footnote 5). Mountain goats tend to move to higher elevations as the snow melts and feed throughout the summer on the highly nutritous new growth of plants emerging from melting snowbanks (Fox 1978, Klein 1970).

Table 3—Plant species in southeastern Alaska reported to have been eaten by mountain goats

Species	Source	Species	Source
Trees:		Forbs:	
Alnus rubra	b	*Achilla borealis*	b
Chamaecyparis nootkatensis	e	*Actea rubra*	c
Taxus brevifolia	c	*Aconitum delphinifolium*	b
Thuja plicata	e	*Anemone narcissiflora*	b,f
Tsuga heterophylla	e	*Angelica lucida*	b
Tsuga mertensiana	a,b,e,f	*Aquilegia formosa*	b
Picea sitchensis	a,e	*Arnica cordifolia*	c
Pinus contorta	e	*Arnica latifolia*	b,c
Populus tricocarpa	a	*Arnica lessingii*	b
		Artemisia arctica	a,b,f
Shrubs:		*Aster subspicatus*	c
Acer glabrum	c,d	*Astragalus alpinus*	b
Alnus crispa	c,f	*Caltha leptosepala*	f
Alnus sp.	e	*Campanula lasiocarpa*	b
Amelanchier alnifolia	a,c,d	*Campanula rotundifolia*	c
Cladothamnus pyrolaeflorus	e,f	*Castilleja unalaschcensis*	b
Juniperus communis	c,e	*Circaea alpina*	c
Ledum palustre	d	*Claytonia sibirica*	f
Menziesia ferruginea	c,e	*Coptis asplenifolia*	e
Oplopanax horridus	f	*Coptis trifolia*	b
Potentilla fruticosa	c	*Cornus canadensis*	a,e
Ribes bracteosum	e	*Epilobium angustifolium*	b,c,d
Ribes lacustre	c	*Epilobium glandulosum*	c
Ribes laxiflorum	b	*Epilobium latifolium*	b
Ribes triste	a	*Epilobium hornemannii*	f
Rosa nutkana	d	*Erigeron compositus*	c
Rubus idaeus	c	*Erigeron peregrinus*	b
Rubus parviflorus	c	*Euphrasia mollis*	b
Rubus spectabilis	b,f	*Gentiana glauca*	b
Salix spp.	e,f	*Geranium erianthum*	b
Sambucus racemosa	a,b,c	*Heracleum lanatum*	b,c,f
Sambucus spp.	e,f	*Heuchera glabra*	b
Shepherdia canadensis	d	*Hieracium triste*	b
Sorbus scopulina	a,c	*Lloydia serotina*	b
Spiraea beauverdiana	c,d	*Lupinus nootkatensis*	b,f
Symphoricarpus albus	c,d	*Lysichiton americanum*	e
Vaccinium ovalifolium	b,e	*Maianthemum dilatatum*	e
Vaccinium parvifolium	e	*Mimulus lewisii*	c
Vaccinium sp.	e,f	*Mitella pentandra*	f
Viburnum edule	a,e	*Moneses uniflora*	e
		Myosotis alpestris	b
Subshrubs:		*Osmorhiza chilensis*	c
Antennaria monocephala	b	*Osmorhiza purpurea*	e
Arctostaphylos uva-ursi	a,b	*Parnassia fimbriata*	c
Cassiope mertensiana	e	*Pedicularis verticillata*	e
Cassiope stelleriana	b,e	*Pedicularis oederi*	f
Cassiope tetragona	d	*Petasites frigidus*	f
Dryas drummondii	b	*Petasites hyperboreas*	b
Empetrum nigrum	a,b,e	*Polemonium acutiflorum*	b
Luetkea pectinata	b,e	*Polygonum viviparum*	b
Loiseleuria procumbens	a	*Potentilla villosa*	b
Lycopodium alpinum	b	*Prenanthes alata*	b,e
Lycopodium selago	b	*Primula cuneifolia*	b
Phyllodoce aleutica	b,e	*Prunella vulgaris*	c
Rubus chamaemorus	a	*Ranunculus cooleyae*	f
Salix arctica	a	*Ranunculus pacificus*	f
Salix rotundifolia	b	*Rubus pedatus*	b,e
Sibbaldia procumbens	b	*Rumex fenestratus*	a

Sources are listed at end of table.

Table 3—Plant species in southeastern Alaska reported to have been eaten by mountain goats (continued)

Species	Source	Species	Source
Sanguisorba stipulata	b	*Carex lachenalii*	a,b
Saxifraga bronchialis	c	*Carex macrochaeta*	a,b,e,f
Saxifraga punctata	f	*Carex microchaeta*	b
Saxifraga tricuspidata	a,b	*Carex podocarpa*	a
Saxifraga spp.	e,f	*Carex pyrenaica*	b
Schizachne purpurascens	a	*Carex scirpoidea*	b
Sedum rosea	b	*Carex* spp.	a,e
Senecio triangularis	c	*Elymus glacus*	c
Smilacina racemosa	c	*Festuca altaica*	b
Solidago multiradiata	b	*Festuca ovina*	b
Stelleria sitchana	b	*Hierochloe alpina*	a,b
Stelleria spp.	f	*Luzula multiflora*	b
Streptopus amplexifolius	b,c	*Luzula parviflora*	b,c,e,f
Tiarella spp.	e	*Luzula wahlenbergii*	b
Valeriana sitchensis	c,f	*Luzula spicata*	b
Veratrum viride	b,c	*Phleum commutatum*	d
Veronica wormskjoldii	b	*Poa alpigena*	b
Viola langsdorfii	b	*Poa leptocoma*	a,b
		Poa stenantha	b
Ferns:		*Trisetum spicatum*	a,b
Athyrium filix-femina	a,b,c,e,f		
Blechnum spicant	b,e	Lichens:	
Botrychium lunaria	b	*Alectoria* sp.	e
Cryptogramma crispa	e	*Cetraria* sp.	b
Cystopteris fragilis	c	*Cladonia* sp.	b
Dryopteris dilatata	e	*Lobaria* sp.	e
Dryopteris sp.	a	*Peltigera* sp.	b,f
Gymnocarpium dryopteris	e	*Thamnolia vermicularis*	b
Polypodium vulgare	e	*Usnea* spp.	e
Pteridium aquilinum	e	Unspecified spp.	c
Graminoids:		Mosses:	
Agrostis spp.	e	*Hylocomium* sp.	e
Calamagrostis canadensis	b,e	*Rhytidiadelphus* spp.	e
Calamagrostis purpurascens	c	*Sphagnum cuspidatum*	e
Carex circinnata	b	Unspecified spp.	a,b,c,e

Sources:

a Klein 1953

b Hjeljord 1971

c Chadwick 1973

d Campbell and Johnson 1983, Johnson 1983

e Fox and Smith 1988

f J.L. Fox, Unpublished data on file at Department of Ecology, University of Tromsø, N-9001 Tromsø, Norway.

Food selection in winter is much more restricted than in summer (Fox and Smith 1988). Species making up the bulk of the winter diet are conifers (*Tsuga heterophylla, T. mertensiana, Chamaecyparis nootkatensis*), lichens (*Usnea* spp., *Alectoria* spp., *Lobaria* spp.), mosses (*Rhytidiadelphus* sp.), and some *Vaccinium* spp. shrubs (table 4). These species constituted over 90 percent of goat fecal material collected from forested wintering sites (Fox and Smith 1988). Some 50 other species were eaten in small amounts. Above timberline, alpine herbs and graminoids are probably more important in the winter diet than is suggested by the diets of goats in forested habitat (shown in table 4).

Table 4—Plant species composition of goat fecal material collected near Juneau and Ketchikan, winters, 1979-82[a]

Species	Fecal content					
	November (n=2)	December (n=3)	January (n=1)	February (n=6)	March (n=5)	Mean (n=17)
	Percent					
Trees:						
Chamaecyparis nootkatensis	2	8	2	22	27	17
Tsuga spp.	7	36	23	25	8	20
Shrubs:						
Rubus spp.	5	1	1	t[b]	t	1
Vaccinium spp.	1	4	6	4	2	3
Forbs:						
Cornus canadensis	6	4	3	1	t	2
Rubus pedatus	5	2	1	1	t	1
Tiarella spp.	3	t	t	t	t	t
Ferns:						
Athyrium filix-femina	3	4	2	t	t	1
Blechnum spicant	8	2	1	1	t	2
Pteridium aquilinum	3	1	t	t	t	1
Lichens:						
Alectoria spp./ *Usnea* spp.	2	1	t	2	3	2
Lobaria spp.	21	10	2	18	26	18
Moss:						
Hylocomium spp./ *Rhytidiadelphus* spp.	13	15	53	19	22	21

[a]Only those species averaging ≥1 percent of the fecal material in any month are included.

[b] t = less than 0.5 percent.

Sources: Fox and Smith 1988; J.L. Fox, unpublished data on file at Department of Ecology, University of Tromsø, N-9001 Tromsø, Norway.

During winter, evergreen forbs (for example, *Cornus canadensis*, *Rubus pedatus*) are probably the most nutritous forage species (table 5) (Hanley and McKendrick 1983, Schoen and Wallmo 1979). Goats eat these forest herb-layer forages only when snow depths are shallow enough to permit feeding near ground level (Fox and Smith 1988). Graminoids are common winter foods in some regions (Chadwick 1973, Hibbs 1967, Hjeljord 1971) and probably in some of the timberline wintering sites in southeastern Alaska. The low nitrogen content of graminoid forages (Johnston and others 1968) (table 5) probably requires additional feeding on more nitrogen-rich shrubs or conifers at these sites, if sufficient ground herbs are not available. Arboreal lichens (for example, *Usnea* spp., *Lobaria* spp.) are eaten from tree trunks and litterfall. Lichens can provide valuable energy and nitrogen as well as possible benefits in digestion of other species (Rochelle 1980). The high presence in goat feces of such a low-quality forage as moss probably reflects its consistent availability on tree trunks and cliffs or boulders, even in periods of deep snow, and its low digestibility and highly recognizable appearence in fecal analysis.

Forage availability—Annual forage production can be as high as 4000 kilograms/hectare (21,700 lb/acre) in lush herbaceous alpine or subalpine meadows (Kuramoto and Bliss 1970). More typically, alpine plant communities produce between 200 and 2000 kilograms/hectare (1,100-10,900 lb/acre) annually (Bliss 1966, Pfitsch and Bliss 1985, Scott and Billings 1964), and these figures are probably also representative of southeastern Alaska. Understory forage production in old-growth forest averages about 800 kilograms/hectare (4,350 lb/acre) (Alaback 1980). When old-growth forest is removed in southeastern Alaska, shrubs dominate on the site for the first 15-25 years. Young conifers overtop shrubs to form a closed canopy, below which the vascular understory species disappear for about 100 years before the canopy begins to open and they reestablish themselves (Alaback 1980, 1982, 1984; Harris and Farr 1974). The production of vascular understory species (goat forage) changes greatly during this successional sequence; it is as high as 5500 kilograms/hectare (29,900 lb/acre) at about 20 years to near zero at 50 years, and then rises slowly to the 800 kilograms/hectare (4,350 lb/acre) typical of old-growth forest by about 300 years (Alaback 1982, 1984). Differences in old-growth forest structure and forest management practices can to some extent lessen the magnitude of this sequence (Hanley 1984).

After plant senesence and leaf fall and before snow accumulation, the remaining annual forage production of vegetation types in goat habitat near Juneau ranged from 30 to 400 kilograms/hectare (150-2,150 lb/acre) (Fox 1983). Typical late winter snowpack decreased available forage to zero in many vegetation types. Types with the greatest amounts of available forage were the tall grass-bluejoint-herb (240 kilograms/hectare; 1,300 lb/acre), open conifer forest-krummholz (145 kilograms/hectare; 800 lb/acre), closed conifer forest (20-100 kilograms/hectare; 100-550 lb/acre), and alpine herbaceous tundra (50 kilograms/hectare; 250 lb/acre) (Fox 1983). Goat winter range contained relatively little area of the tall grass-bluejoint-herb and krummholz types compared with alpine herbaceous tundra and closed coniferous forest (fox 1983).

In coastal portions of the region, where warmer temperatures result in high-density snowpacks and windblown open areas do not occur above timberline, the most forage is generally available in closed canopy coniferous forest. Open conifer forests and open tall shrub on very steep sites can also provide significant amounts of forage, depending on snow depth.

Table 5—Chemical composition of important winter forage species[a]

Species	NDF[b]	ADF[c]	Cellulose	Lignin/ cutin	IVDMD[d]	Nitrogen
			Percent			
Trees:						
Chamaecyparis nootkatensis	39.7	31.1	22.6	8.6	47.3	1.00
Tsuga heterophylla	64.3	51.0	32.7	12.2	26.2	.84
Shrubs:						
Rubus spectabilis[e]	64.0	47.2	27.5	39.6		1.79
Vaccinium alaskensis	66.6	50.3	29.8	20.5	36.1	1.50
Forbs:						
Cornus canadensis	35.6	21.7	19.0	1.6	75.6	1.70
Rubus pedatus	35.9	19.1	16.0	3.0	54.3	1.65
Tiarella trifoliata	37.0	27.8	18.1	9.4	61.3	1.54
Fern:						
Dryopteris dilatata[f]	52.0	37.5	19.6	17.8	48.2	1.92
Graminoid:						
Deschampsia caespitosa[g]	70.7	37.3	22.1	4.4	29.7	1.14
Lichens:						
Lobaria spp.	61.0	29.3	15.8	9.8	29.2	3.57
Usnea spp.	33.0	5.8	2.5	2.1	20.7	.42
Moss:						
Rhytidiadelphus loreus	86.3	58.6	35.3	21.0	12.4	.60

[a] Data from Hanley and McKendrick (1983) (collected January 9, 1981), except where otherwise indicated.

[b] NDF = neutral detergent fiber.

[c] ADF = acid detergent fiber.

[d] IVDMD = in vitro dry matter digestibility (48 hour).

[e] From Schoen and Wallmo (1979).

[f] Data from other ferns not available.

[g] Data from other graminoids not available.

Energy expenditures—Besides lowering the amount and quality of forage available to goats, winter snowfalls increase the energy costs of routine activities; for example, goats must expend energy to paw through the snow for food. Snow generally makes travel more difficult, although if snow has a hard crust, travel costs may be reduced. Studies of deer have found that a sinking depth in snow of about 30 centimeters (12 in) more than doubled the energy expenditure for travel compared to bare ground, and energy costs increased exponentially at greater sinking depths (Mattfeld 1974, Parker and others 1984). During two winters of field study near Juneau, typical snow conditions near and below timberline resulted in goats sinking to depths of 20 to 30 centimeters (8-12 in) (see footnote 5).

The air temperature must be about -20 °C (-5 °F), depending on wind and solar radiation, to cause an elevation in metabolism in goats (the lower critical temperature for maintaining homeothermy) (Krog and Monson 1954). In southeastern Alaska, temperatures below this value are generally uncommon, thereby suggesting that cold stress is not an important factor for goats in this region. There is evidence, though, that low temperatures and high winds may cause goats to seek sheltered sites (Fox 1983). Other data suggest that thermal stress from sunlight on warm summer days cause goats to use breezy ridgetops, snowbanks, or the shade of rocks and trees (Fox 1978, Stevens 1979).

Patterns of Habitat Selection

The most important factors influencing habitat selection by goats in southeastern Alaska seem to be security from predators and acquisition of food. The steep and broken topography characteristic of escape terrain often has substantial surface rock and does not support productive plant communities, so the survival advantages of selecting escape terrain may be offset by the quality and quantity of available forage at those sites.

In summer, the moist alpine and subalpine meadows typically occurring outside of escape terrain generally support the most productive vegetation. These plant communities are attractive to goats because the forage is abundant and high in nutritional value. The benefits of increased nutrients gained by leaving escape terrain to feed in these lush alpine meadows during summer probably offset to some degree the costs of insecurity and increased vulnerability to predation.

In winter, the sites providing escape terrain are generally those with the least snow. Snow thickness (measured perpendicular to the slope) decreases in proportion to the cosine of slope angle; for example, a slope of 60° has a snow thickness half that of flat ground. Steep slopes on southerly aspects receive the most sunlight, so more snow is removed there through sublimation and melt than on northerly aspects. Because potential energy of the snowpack increases with slope angle, snowslides are more common on steep slopes. The shallow snow depths in steep terrain with southerly exposure result in increased availability of forage at these sites.

Because of the snow-shedding characteristics of steep slopes, the amount of forage available in escape terrain—compared to that in other sites—is probably relatively higher in winter than in summer. The relative nutritional benefits to goats using areas away from escape terrain are thus generally lower in winter; goats should tend to remain closer to cliffs in winter. Still, vegetation exists outside escape terrain that usually provides more forage in winter (Fox 1983). In areas outside and equidistant from escape terrain, goats preferred the sites with more forage (Fox 1983).

Goats spend between 60 and 75 percent of daylight hours within or at the edge of escape terrain in both summer and winter (Fox 1983, Schoen and Kirchhoff 1982, Smith 1985). Assuming nighttime bedding in escape terrain, the longer period of daylight in summer means that goats spend substantially more time outside escape terrain then than in winter. The percentage of time spent feeding does not seem to be different inside or outside escape terrain (Fox 1983); however, the forage intake rate is probably much greater in the dense vegetation outside escape terrain. The percentage of time goats spend feeding or searching for food increases with distance from escape terrain (McFetridge 1977), probably because feeding is the only incentive for being away from escape terrain. But the relative amount of feeding time may decrease slightly with distance because of an increase in time devoted to keeping alert to the presence of predators (Risenhoover 1981).

Management Implications

The heavy year-round precipitation and abundant alpine habitat results in highly productive goat summer range in southeastern Alaska. With the presence of permanent snowfields and no pronounced summer drought, plant growth (including new growth) continues all summer. These characteristics of summer habitat should contribute to high growth rates and consistent late summer attainment of prime body condition in goats from southeastern Alaska.

During winter, mountain goats must contend with substantial snowfall on a regular basis. In southeastern Alaska, goat populations are probably constrained in large part by the availability and quality of winter forage. Winters with deep snow are associated with major declines in goat populations (Smith 1984). Once goat populations are low, wolf predation may retard recovery (Ballard 1977, Fox and Streveler 1986).

The amount and distribution of escape terrain may put an upper limit on summer carrying capacity. This carrying capacity seldom will be reached, however, because of the more significant limitations on food abundance and quality imposed during winter. The amount and distribution of escape terrain within suitable winter habitat is a primary determinant of goat winter range, and the winter snow regime is a limiting factor on nutrition within that potential range. Any management activity reducing the quality or quantity of those winter ranges is likely to have a significant impact on goat populations in the affected areas.

Direct habitat alteration in mountain goat range has not yet become a major concern for wildlife managers. Most goat habitat does not encompass economically valuable natural resources (other than aesthetically valuable ones). A major concern for goat management is increased human access resulting in increased legal harvest, illegal harvest, and disturbance (Phelps and others 1983, Quaedvlieg and others 1973). In British Columbia, for example, large declines in goat populations are attributed to increased hunter access after new road systems were created in formerly undeveloped areas (Foster 1977).

The effects of hunting and increased animal disturbance resulting from development of human access are important management concerns, but many of these problems can be addressed through special restrictions, road closures, and timing of human use. Road building and logging activity near goat winter habitat can, for example, be scheduled for June through October to avoid harassment of animals during the winter. Mineral development near cliff areas used by female goats for birthing and early neonatal periods can be restricted to August through April.

Most active timber management takes place in areas not impinging on goat habitat. Where such management occurs within goat habitat, it is likely to be either in areas used by goats for feeding during winter or in "travel corridors" between patches of goat winter habitat. In these goat wintering areas, old-growth forest canopy intercepts snow, thus reducing snow depths on the forest floor (Fox and Taber 1981, Kirchhoff and Schoen 1987, Schoen and Wallmo 1979) and increasing the availability of understory forage. Old-growth forest also provides forage from fallen trees and a litterfall of branch tips and arboreal lichen (Fox 1983, Rochelle 1980). Clearcutting of old-growth forest in goat wintering sites might produce reductions in available forage during winter and lower the quality of those sites for goats, even during times of abundant forage (5-25 years after clearcutting), because the typically deep winter snowpack tends to bury forage as well as impede movement in the clearcut areas. The harvested sites generally do not provide nearly as much forage as does old-growth forest when snowpacks are present in winter. Even so, the amount of goat winter range within commercially exploitable forest appears to be relatively small, suggesting that, on a large scale, logging will not greatly affect habitat carrying capacity for mountain goats.

Within the limited areas of goat habitat affected by logging, measures should be taken to avoid conflicts. Results of recent studies in coastal goat range confirm that important goat wintering sites may occur within commercial forest lands (Fox 1983, Fox and others 1982, Hebert and Turnbull 1977, Reed 1983, Schoen and Kirchhoff 1982, Smith 1985, Smith and Raedeke 1982). As timber harvests proceed on the mainland in southeastern Alaska, extending into higher elevations and using advanced technology such as helicopter logging, direct alteration of more goat winter habitat is inevitable. Clearcutting has already removed timber from known goat wintering sites in Alaska near Icy Bay (see footnote 4), Haines (Hundertmark and others 1983), and Baranof Island (see footnote 1). In the future, timber harvests and mining should, where possible, be directed away from goat wintering sites. Inasmuch as such sites are usually limited in extent and expensive to develop, the tradeoffs for avoiding goat habitat are likely to be acceptable.

Wintering sites for mountain goats can be identified by escape terrain, essentially steep and broken topography. Because most goat use occurs only within a limited distance from escape terrain, avoiding habitat alteration within this distance should minimize disturbance to goat populations. For goat range where resource development is planned, we recommend identifying on maps all areas of primary escape terrain. For this identification, escape terrain can be defined as any area of broken or uneven surfaces and having a slope equal to or greater than 50°. Such sites are relatively easy to identify from topographic maps and aerial photos, although some sites in heavy forest can be difficult to discern. After these sites are identified, an area within 400 meters (1,300 ft) of the border of the escape terrain should be circumscribed. If a more elaborate method of identifying goat habitat is desired, a multivariate model developed by Fox and others (1982) and Smith (1985) can be applied, but digitized topography and vegetation characteristics are required within the area of mapping. Once goat habitat is identified, development activities should be avoided within areas 400 meters (1,300 ft) wide that border escape terrain. Special consideration should be given to those areas occurring at low elevation or on southerly exposures because they often include critical wintering sites.

Goat wintering sites are dictated by the presence of escape terrain, but small patches of escape terrain within the winter range of a single goat may be separated by areas of commercial timber. Large clearcuttings in areas outside of goat wintering sites, but located in travel routes between such sites, will tend to increase the energy expended in travel if deep snow is present. Additionally, goat travel corridors between important wintering sites should be identified and preserved where they occur in forested areas.

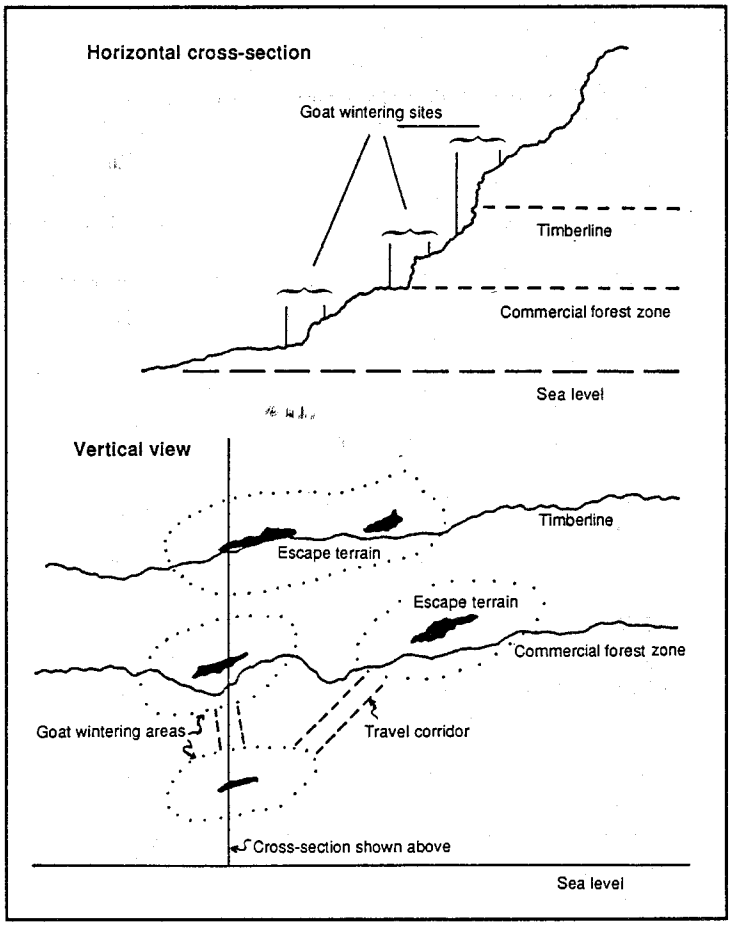

Figure 3—An example of goat wintering sites in conjunction with commercial forest.

Decisions on management of goat wintering sites should not be based on the population at the time of management action. Fluctuations in goat population size (Smith 1984) and shifts in use of wintering areas from one year to another (Schoen and Kirchhoff 1982, Smith 1982) preclude meaningful short-term assessment of habitat importance based on numbers of animals present.

A typical juxtaposition of goat wintering sites in conjunction with commercial forest is presented in figure 3. The location of a goat wintering site within commercial forest illustrates a situation where timber operations, or other commercial development, must deal with questions of conflict with goat habitat needs. If facilities for any developments are within mountain goat habitat, they must be as far as possible from prime winter habitat or escape terrain in general. It is most important to avoid any habitat degredation within 400 meters (1,300 ft) of the escape terrain. If no alternative to timber harvest exists within this zone, sequential clearcuttings emanating away from the escape terrain that ensure continual access to some old-growth forest may be the best approach to management. The scheme could be similar to that proposed by Harris (1984) for old-growth forest retention; however, the rotation of cuts would have to be long enough to allow reestablishment of the relation between canopy cover and understory typical of old-growth forest (Alaback 1982, Wallmo and Schoen 1980). In any case, forested travel corridors between wintering sites should be kept intact to prevent movement of goats from being blocked by deep snow in clearcuttings.

Regardless of the effect a particular resource development activity may have on habitat, increased road access into previously undeveloped goat range greatly increases mountain goat vunerability to exploitation. Currently goat hunting is regulated through a permit system. Where increased access to small discrete populations occurs, consideration could be given to the need for further restricting hunting by reducing the number of permits. Small goat herds are particularly vulnerable to overhunting and may take many years to become reestablished because of low emigration from other areas.

Because of the sensitivity of the mountain goat to increased human access, we recommend that an interagency group of wildlife specialists be involved early in the transportation planning process associated with resource development in mountain goat range. Additionally, it is recommended that development activities involving helicopter traffic be reviewed by wildlife specialists, because mountain goats are particularly sensitive to disturbance by these aircraft.

Significant site-specific differences occur amoung goat ranges in southeastern Alaska. Habitat relations for goats in interior (colder) areas are somewhat different from those on coastal sites, such as Baranof Island or the Cleveland Peninsula. The importance of forested wintering sites for goats seems to be greater in the warmer, coastal sites, and such sites seem to be more prevalent in the southern portions of the region. It will be important, nevertheless, to conduct site-specific field work during any environmental assessment of major land use activities affecting mountain goat habitat in southeastern Alaska.

Relatively few areas that include goat winter range occur in or next to prime commercial timber. But where such sites occur, they are generally at low elevation and represent critical goat wintering grounds in times of very deep snowpack. Forest management can have a pronounced effect on mountain goats in these areas.

Research Needs

Research on habitat use by mountain goats in southeastern Alaska has been done since 1975. We have made some advances in identifying home range characteristics and habitat preferences of goats. The critical importance of escape terrain and food availability have been suggested as paramount in the goat's selection of its range and daily movements (Fox 1983). We postulate that areas within 400 meters (1,300 ft) of escape terrain encompass all areas used by goats except for travel lanes between areas of escape terrain. This hypothesis needs verification with detailed information, especially for forested wintering sites.

Data on habitat use from radio-collared goats has identified patterns in goat use of wintering sites under various snow conditions (Schoen and Kirchhoff 1982). Radio-telemetry data based on aerial relocations are relatively imprecise, however, and provide limited information on habitat selection within the short distances from escape terrain, where most goat use occurs. Alternative measurements of habitat use, such as direct observation and pellet-group distribution, may provide better information on microhabitat selection.

Much of the research effort on deer-logging relations in southeastern Alaska (Hanley 1984, Schoen and others 1985, Wallmo and Schoen 1980) may also apply to the occasional small areas of goat habitat similarily affected. Where logging will occur within known goat wintering sites, however, an experimental approach using different patterns of clearcuttings should prove productive in quantifying the effects of logging on goat use of an area.

Aspects of goat ecology requiring further study include their use of areas within the critical zone surrounding escape terrain, their digestive physiology related to the ability to survive winters on large amounts of apparently unnutritious forages, and the relations of forest management to goat populations. The last item requires information on population dynamics, so techniques for monitoring populations need to be further developed.

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Mountain goats in southeastern Alaska occupy habitats providing abundant areas of high-quality forage during summer but only limited feeding areas during winter because of deep snow. Winter is a period of severe nutritional deprivation, and goats converge into areas with available forage, often within old-growth forest where relatively low snow depths and litterfall enhance food availability. Goats are further restricted in their habitat use to sites within and near steep and rugged terrain, which provides escape areas from predation by wolves. Because goat winter habitat is limited, even small areas of habitat alteration that impinge on these sites can have a disproportionally large effect on the goat populations concentrated there. Removal of old-growth forest would decrease available forage and thus lower the quality of goat wintering sites when snowpacks are present. Whereas the effects of forest management might be locally important for goats, the total amount of goat habitat subject to this or other habitat alteration is likely to be small and should not greatly affect goat carrying capacity in southeastern Alaska. But, where forest management or other human land use occurs within goat habitat, the limited areas of actual conflict may make avoidance of critical goat habitat practical. Research is needed on digestive physiology of goats, habitat use by goats within the critical areas surrounding escape terrain, and the relations of forest management to goat populations.

Keywords: Wildlife habitat management, wildlife habitat, timber management, habitat selection, mountain goat, Alaska (southeastern).

Pacific Northwest Research Station
319 S.W. Pine St.
P.O. Box 3890
Portland, Oregon 97208-3890