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WINTER HABITAT SELECTION OF MOUNTAIN GOATS IN THE NORTH TOLT AND MINE CREEK DRAINAGES OF THE NORTH CENTRAL CASCADES

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Abstract: Aerial surveys were conducted during the winters of 1990, 1991, and 1992 to determine habitat use by mountain goats (Oreamnos americanus) in 2 drainages of the north-central Cascades. Mountain goat locations were evaluated for aspect, topography, stand age and structure, elevation, and snow accumulation levels. Forage production was estimated for clear-cut, partial-cut, and forested stands. Winter diet composition was determined through fecal pellet analysis. Snow accumulation data were used to detect elevational shifts in response to major snow events. Mountain goats in these drainages of the north-central Cascades have habitat selection characteristics that are intermediate between coastal and interior mountain goat ecotypes. The present Washington mountain goat habitat model is discussed, with specific regards to forest management activities.

Considerable research has been conducted on mountain goat habitat selection in coastal (Hebert and Turnbull 1977, Schoen 1978, 1979, Schoen et al. 1981, Fox and Taber 1981, Fox and Raedeke 1982, Schoen and Kirchoff 1982, Fox 1983, Smith 1986, Fox et al. 1989) and interior (Saunders 1955, Hjeljord 1973, Kuck 1977, Hebert and Turnbull 1977, Adams and Bailey 1980) regions. However, the habitat selection by mountain goats in the Cascade Mountains, where climatic characteristics are intermediate between these extremes, is poorly understood. With increasing logging activity occurring in mountain goat winter range, it is essential that we better understand the relationships between timber harvest and mountain goat habitat usage.

The 4 objectives of this study were: (1) to determine mountain goat winter habitat use with emphasis on areas of potential timber harvests; (2) to understand the role of goat diets, forage production, and snow accumulations in winter habitat selection; (3) to assess herd productivity and population status; and (4) to reevaluate the Washington Department of Wildlife's mountain goat habitat classification model.

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STUDY AREAS

North Tolt River Drainage

The North Tolt study site covers 41 km^2 on the Weyerhaeuser Company's Snoqualmie Tree Farm in west-central Washington state (47°45' N, 121°36' W), approximately 50 km northeast of Seattle. The North Tolt River drains in a southwesterly direction to the Puget Sound lowlands. The Cascade range in this area varies in elevation from 488 to 1829 m.

The climate in this area of the Cascade mountains has both maritime and continental influences. Average annual precipitation in this area ranges from 120 cm to 300 cm. The average winter temperature (Dec - Mar) for the western Cascade mountains (213 to 1524 m) is 31.9 F, and ranges from 28.9 F (Jan) to 34.7 F (Mar).

This area is dominated by coniferous forest, with western hemlock (Tsuga heterophylla) and Douglas-fir (Pseudotsuga menziesii) at lower elevations, and mountain hemlock (Tsuga mertensiana) and true firs (Abies spp.) at mid to upper elevations. Extensive cliff systems, which are dispersed throughout the basin, are a composite of distinct cliffs and steep, rocky terrain, intermingled within forested and clear-cut habitats. The area is managed for timber production, and has undergone considerable recent harvest activity. Harvesting has progressed upslope from the valley floor and is currently occurring at elevations where mountain goats are found in the winter.

Mine Creek Drainage

The Mine Creek study site encompasses 3 km^2 35 km south of the North Tolt drainage (47°24' N, 121°38' W). Mine Creek drains in a northerly direction into the Snoqualmie River. Elevation varies from 366 to 1500 m and vegetational associations, as well as climatic characteristics, are similar to the North Tolt site. This area has been intensively harvested, and the habitat consists primarily of recent clear cuts and residual patches of old-growth timber.

METHODS

Habitat Selection

Systematic helicopter surveys were conducted in the North Tolt drainage during the winter of 1989-90, and in both study areas during the winters of 1990-91 and 1991-92, to determine winter habitat use patterns by mountain goats. Preliminary surveys in the North Tolt drainage were conducted from 18 January to 19 March 1990 for a total of 4 surveys. Techniques and procedures were tested and areas of goat concentration were identified. Information from these surveys was not used in the analysis of habitat relationships.

Aerial surveys were conducted bimonthly from 6 December 1990 to 28 March 1991, for a total of 8 complete surveys (only 1 survey was completed in December and 3 surveys were completed in March). Monthly surveys were conducted in the North Tolt and Mine Creek drainages from 13 January to 12 March 1992 for a total of 3 surveys.

The geographic location of each goat observation was recorded by latitude, longitude and elevation, using a LORAN-C navigational system. Locations were also plotted on aerial photographs and/or topographic maps at the time of observation. A goat location was defined as any number of mountain goats observed in close proximity and appearing to interact. A track location was defined as any number of tracks in the snow observed in areas when no goats were visually observed.

Goat observations were recorded by habitat type and presence or absence of cliffs. Habitat type categories were clear cuts (including regeneration less than 15 years old), partial-cut old growth forests, open old growth forest (less than 50% canopy closure), and closed old-growth forest (greater than 50% canopy closure). Canopy closure was determined by visual estimation. "Forests" in the North Tolt drainage are predominantly remnant old growth stands. Cliffs were found in most classifications, so cliff designation was used only if no other habitat type was noted.

A cover type map for the entire North Fork Tolt basin was compiled using satellite imagery. The reflected electromagnetic wavelength signatures from the satellite image were grouped into cover types as follows: rocks, old forest (conifer >70 yrs old), mature (conifer 35-70 yrs old), young conifer (conifer 15-34 yrs old), old regen (conifer-hardwood 15-34 yrs old), new regen (replanted cuts <15 yrs old), and non-stocked (unplanted cuts). The conifer >70 yrs class represents the remaining uncut old growth of the area. The results of the satellite classifications were verified by cross checking with existing timber stand data. The resulting cover type map was incorporated into a GIS data base that could then determine percent coverage by plant cover types for different elevational bands or geographic areas within the basin.

Satellite imagery data and GIS procedures were used to compare habitat within goat concentration areas and the habitat within the North Tolt basin in general between 762 and 1524 m in elevation. These elevation limits coincide with the range of elevations where goats were observed during aerial surveys. Goat concentrations were defined by a minimum convex polygon from plotted goat locations. Relationships between the percentage of available forest and elevation were determined by separating the North Tolt drainage into 151 m elevational bands from 762 to 1524 m and then analyzing the available habitat within each band.

Forage Production

Percent plant cover was used as a measure of forage production in representative areas of recent clear cut, partial-cut old-growth, and closed forest old-growth stands. In each stand type, 20 5-m^2 circular plots were located 10 paces apart on transects running parallel to the slope from a randomly located starting point. For each plot, percent plant cover was recorded for 3 general vegetation categories (herbaceous plants, shrubs, and trees). Plant cover was recorded only for potential forage 0.15 to 1.83 m above ground. We did not quantify lichen and litterfall availability, which could be another source of forage in forested stands.

Food Habits

Winter mountain goat diet composition was determined through micro-histological examination of fecal pellets. Pellets were collected in the early Spring of 1991 and 1992 in winter goat concentration areas. Five pellets from 20 different pellet groups were collected from 3 areas in North Tolt drainage. Pellets were taken from groups of varying depositional ages (fresh to old), to capture the variation in the diet over a greater portion of the winter.

For each sample, pellets were ground, mixed, and sub-sampled to determine diet composition. Analysis was conducted by the Wildlife Habitat Management Laboratory at Washington State University using analytical methodologies described by Davitt and Nelson (1980) and Nelson and Davitt (n.d.). Results are reported as percent diet composition, by forage classes and major plant species, using epidermal fragment cover as the sampling criterion. Correction factors for the differential digestibility of forage plants were not calculated.

Goat Distribution and Snow Patterns

General snow conditions were noted on each aerial survey, and recordings of snow conditions were made for each individual goat observation. Snowfall and snow accumulation records from nearby weather stations were used to analyze relationships between goat elevational patterns, snow patterns, and habitat use.

Herd Composition and Productivity

Goats observed during the helicopter surveys were classified by sex and age on the basis of body size (for kids and yearlings) and horn configuration. Most goats were observed from relatively close quarters (50-100 m) to more confidently classify goats into sex and age categories. In some cases goats were located in cover that did not allow classification, and were recorded as unknowns. No attempt was made to distinguish 2.5 year-old goats from adult goats.

RESULTS

Mountain Goat Observations

A total of 92 goat observations in 54 locations (42 in the North Tolt, 12 in Mine Creek) and 24 track locations (16 in the North Tolt, 8 in Mine Creek) were recorded during surveys conducted in the winter of 1990-91. A total of 38 goat observations in 19 locations (15 in the North Tolt and 4 in the Mine Creek drainage) were recorded during surveys in the winter of 1991-92. Only 1 track location was recorded in 1991-92, and this was in the Mine Creek Drainage. The low number of track locations may have been a result of the low snow levels throughout this winter.

Habitat Selection

Mountain goat habitat selection was closely tied to the presence of cliffs. Cliffs were noted in 77% and 65% of all goat locations in the North Tolt and Mine Creek drainages respectively.

With regards to habitat types selection, mountain goats were most often observed in open habitats (Fig. 1). Over the 2 year period, open forest and clear-cut habitats accounted for 53% and 26% respectively of the goat locations in the North Tolt drainage. In the Mine Creek drainage, goats showed a greater use of clear-cut habitats (67%) and less use of open forest habitats (28%).

Remnant old growth forests in the North Tolt area had relatively open canopies, with 57% of all stands older than 70 years of age classified as open forest (less than 50% canopy closure). Open and closed remnant forest where highly intermingled throughout the North Tolt drainage.

We found no significant differences (Chi-square, $P = 0.253$) between the composition of cover types in the goat concentration areas and in the basin in general (Fig. 2). A comparison of the goat locations with available cover types in the basins indicates a selection against closed forest stands.

Forage Production

Forage production was inversely related to forest canopy cover. Percent plant cover was consistently greatest in clear-cut habitats, lowest in forested habitats, and intermediate in partial-cut habitats (Fig. 3). An exception to this was the increase in tree browse production in partial cut units. The Mine Creek site lacked partial cuts. However, the same pattern of increased forage production in clear-cuts was found (Fig. 3).

Food Habits

Conifers were the dominant forage of mountain goats in the North Tolt drainage, making up an average of 45.1% of the winter diet (Table 1). Shrubs, forbs, and graminoids made up a considerable proportion of the remaining winter diet, with lichens and mosses accounting for only a small

Table 1. Diet composition of mountain goats in the North Tolt drainage based on fecal pellet analysis.

Forage Component	Percent of Composite diet		
	1990-91	1991-92	Average
Conifers	41.9	48.2	45.1
Shrubs	20.9	22.3	21.6
Forbs	11.5	0.8	6.2
Grasses	9.0	3.2	6.1
Sedge/rush	2.6	20.6	11.6
Ferns	8.4	4.3	6.4
Mosses	2.5	0.0	1.3
Lichens	1.3	0.7	1.0
Seed/nut	1.9	0.0	1.0
Insect	0.1	0.0	0.1

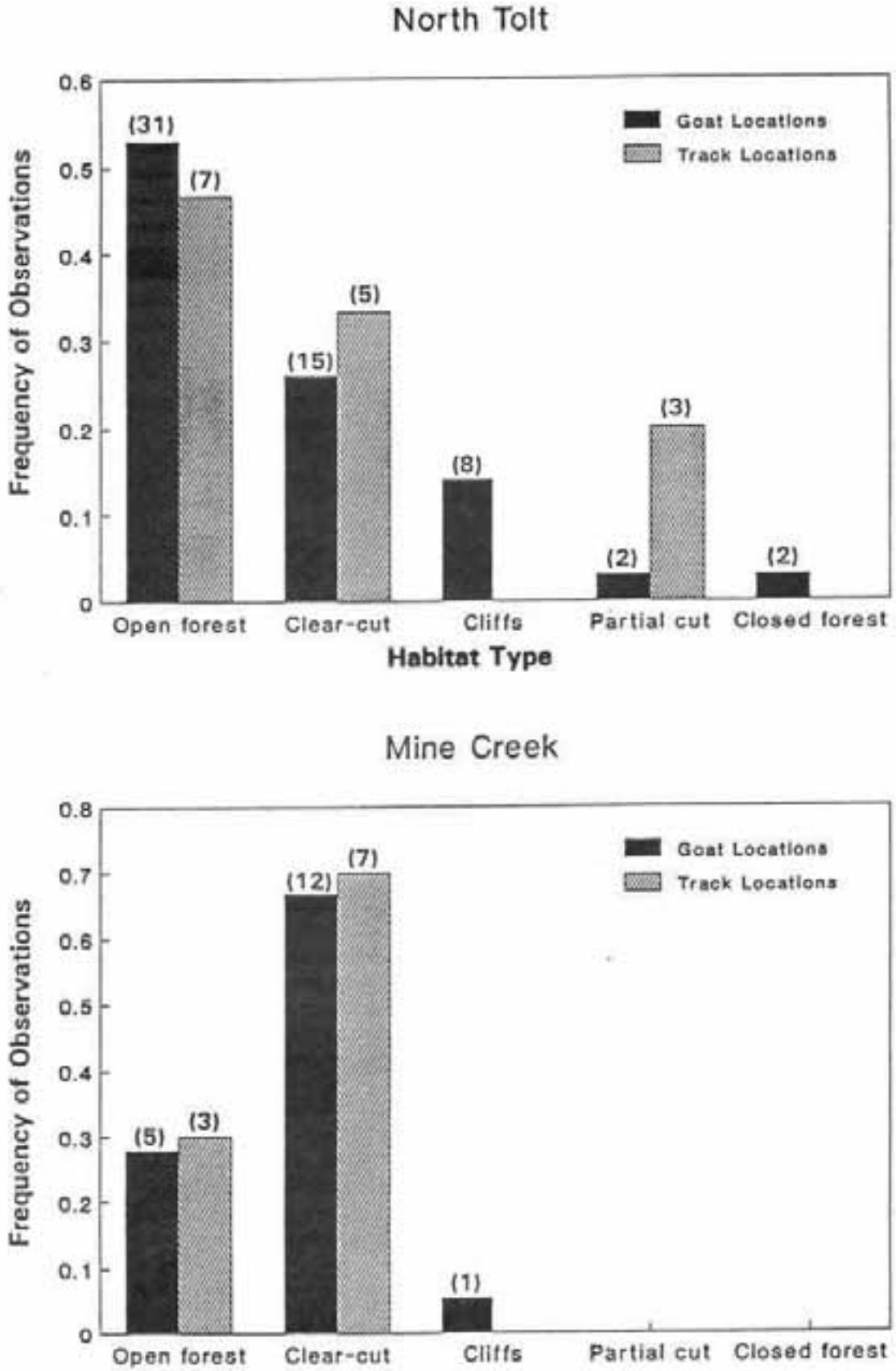


Fig. 1. Frequency of goat and track locations in specific habitat types recorded from aerial surveys conducted in the North Tolt and Mine Creek drainages, winters of 1990-91 and 1991-92. Number in parenthesis equals sample size.

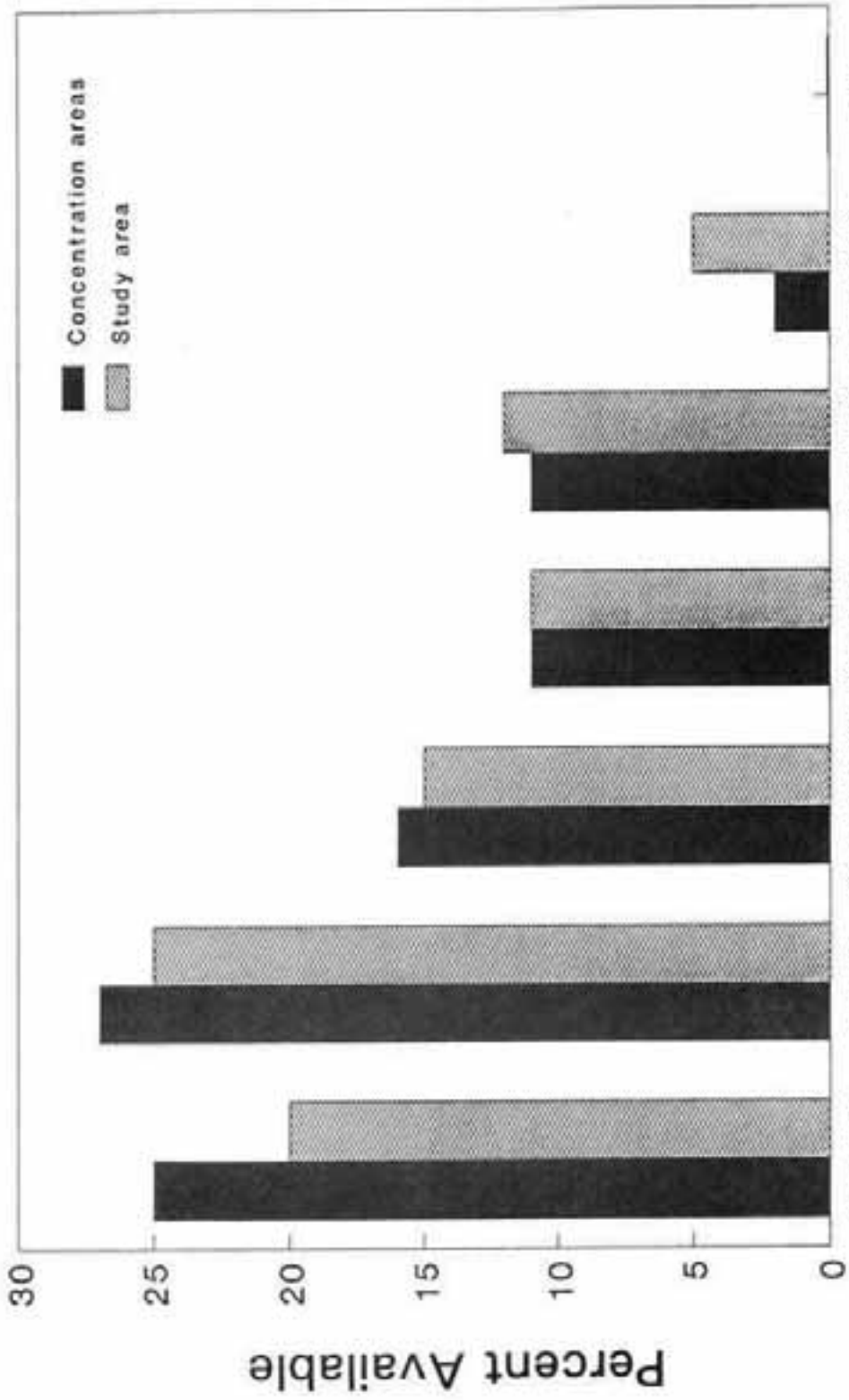


Fig. 2. Habitat available within goat concentration areas and the North Tolt study area between 762 and 1524 m. Categories are old forest (conifer > 70 yrs old), mature (conifer 35-69 yrs old), young conifer (conifer 15-34 yrs old), old regen (conifer-hardwood 15-34 yrs old), new regen (conifer <15 yrs old), non-stocked (unplanted clear-cut), and rock.

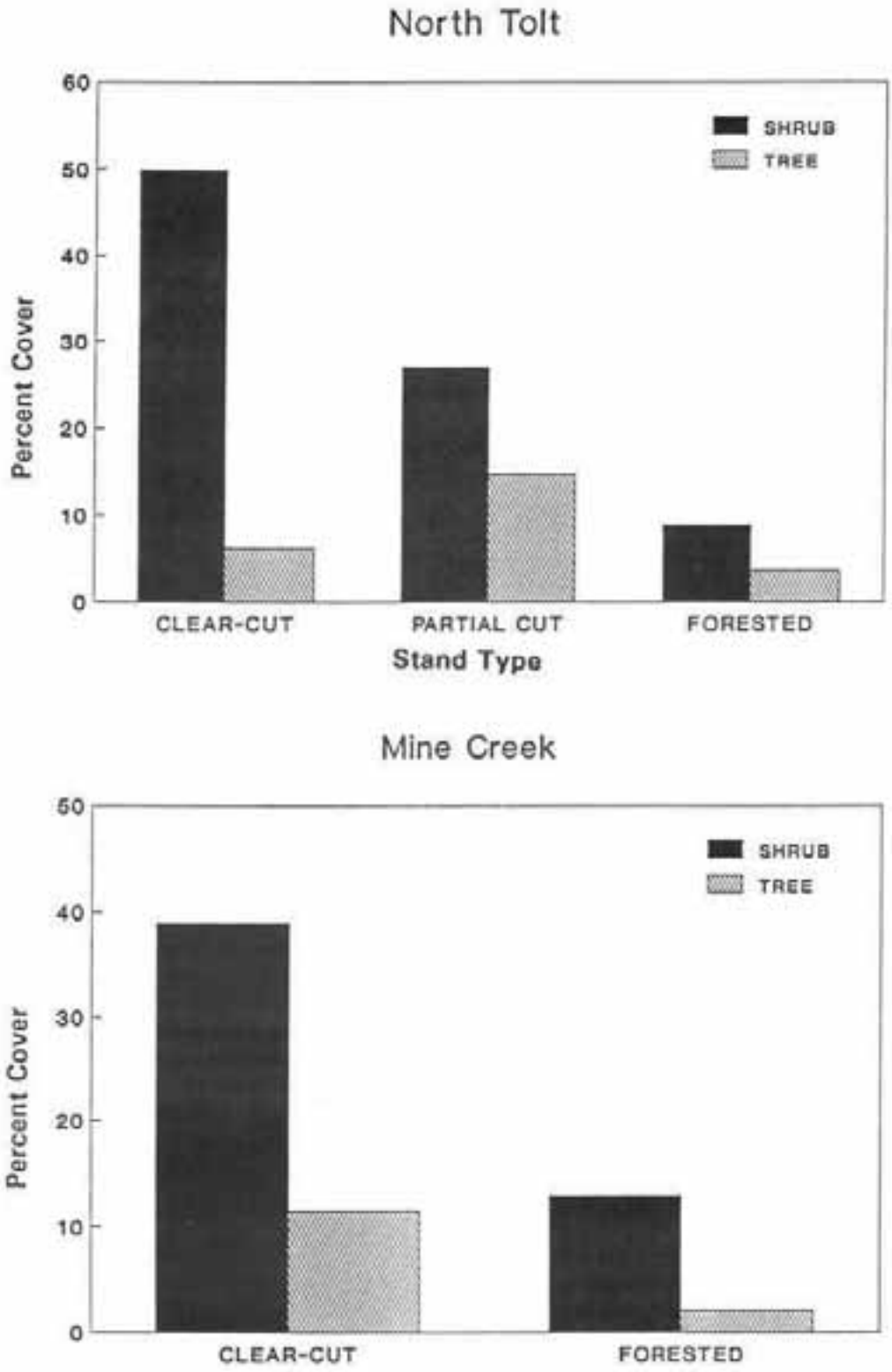


Fig. 3. Percent plant cover in 3 forest stand types in the North Tolt and Mine Creek drainagees, summer and fall of 1991.

percentage. Diet varied little between the 1990-91 and 1991-92 winters, with the exception of a decrease in forbs and an increase in the sedge-rush class.

Goat Distribution and Snow Patterns

Winter snow conditions, expressed as snowfall and snow accumulation levels, were considerably different in the winters of 1990-91 and 1991-92 (Fig. 4). The winter of 1991-92 had considerably less snowfall, and snow accumulations were well below annual averages.

Mountain goats were widely distributed in elevation over both winters (Fig. 5). The average elevation of goat locations for both winters combined was 1126 m in the North Tolt and 1055 m for the Mine Creek drainage. There was little difference in elevational distribution of goats between years (Table 2), even though snow patterns varied greatly. During the 1990-91 season, aerial surveys were conducted immediately following or within a week of 5 major snow events. The goat observations recorded during these flights showed no elevational shift.

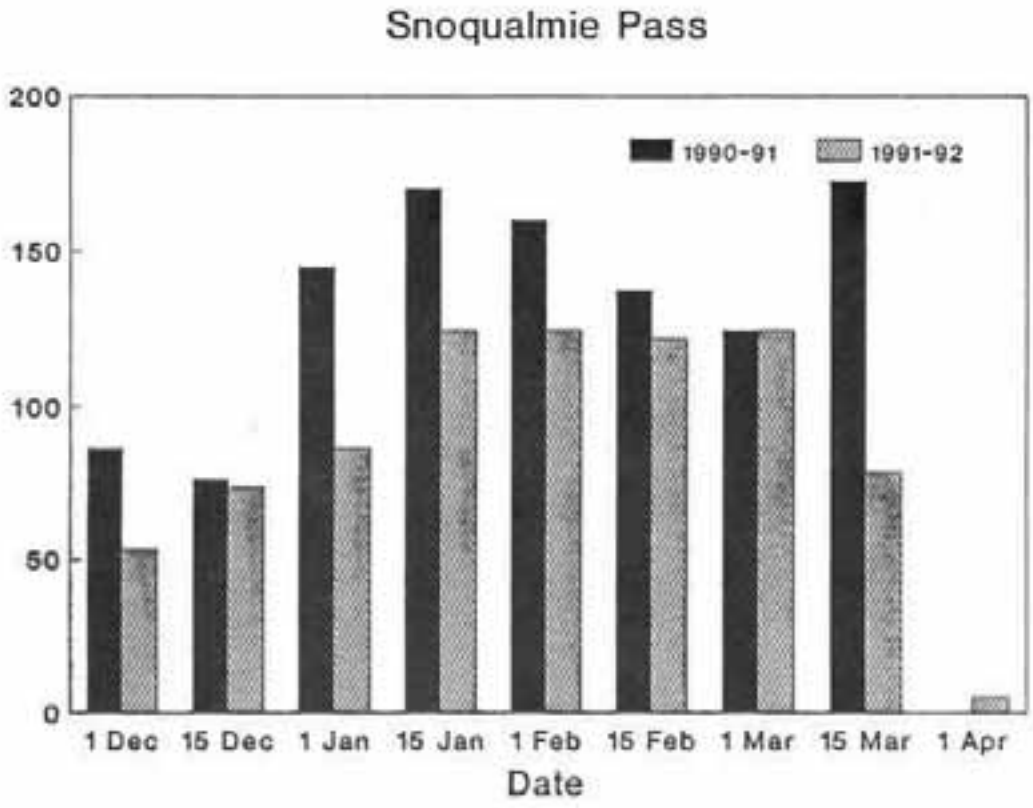
Table 2. Average elevation (in meters) of mountain goats observations in the winters of 1990-91 and 1991-92.

	1990-91		1991-92	
Area	Avg. Elev	Std Error	Avg. Elev	Std Error
North Tolt	1116	140	1182	177
Mine Creek	1058	147	1164	144

When the elevation of goat observations in the North Tolt drainage was broken down by month, a pattern did appear (Fig. 6). We noted a significant change in average elevation from February to March during the winter of 1990-91 ($F = 3.519$, $P = 0.004$). However, multiple comparisons indicated that the difference in elevation of goat observations between flights was only significant for the last flight, when weather conditions restricted the survey to the lower elevations. In the winter of 1991-92, no decline in average elevation was noted, however lower snow levels during this winter may have confounded any comparisons between winters.

Herd Composition and Productivity

In 1990-91, 74 goats (with 20 unknowns) were classified in North Tolt, and 18 (with 6 unknowns) in Mine Creek. In 1991-92, 30 goats (with 8 unknowns) were classified in North Tolt and 8 goats (with 3 unknowns) in Mine Creek. Average group size varied from 1.8 for the North Tolt site and 1.5 for the Mine Creek site over the winter of 1990-91, to 2.0 in both the North Tolt and Mine Creek sites in 1991-92.



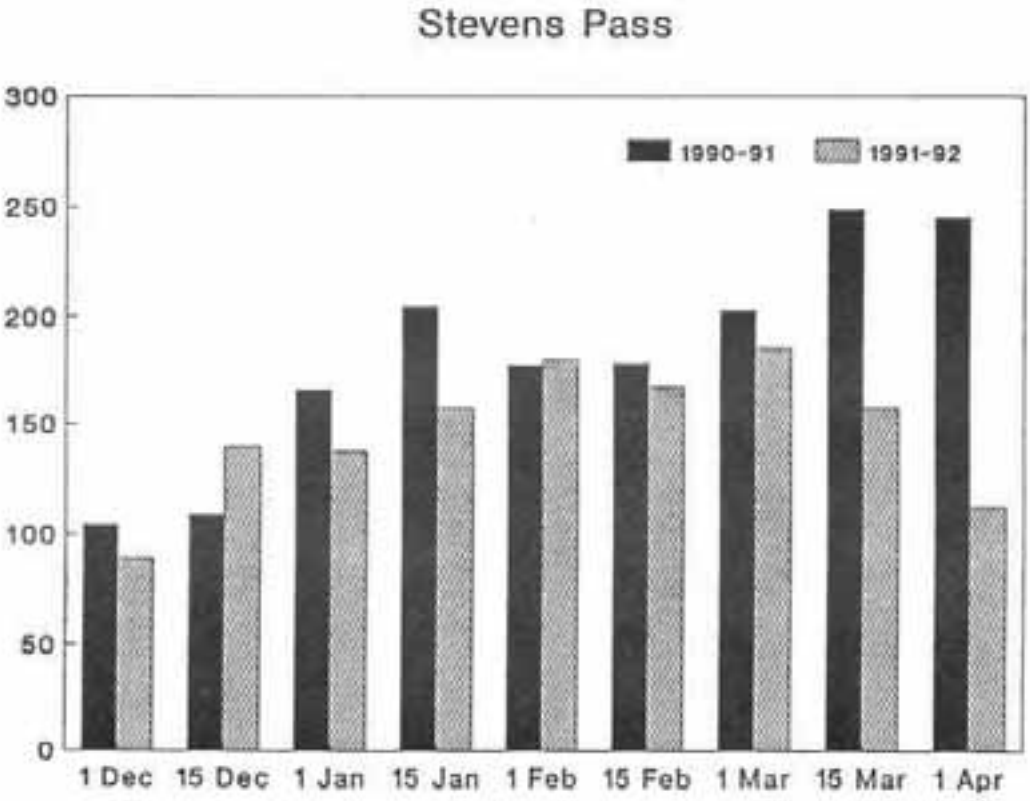


Fig. 4. Snow accumulation levels at Snoqualmie and Stevens Pass, winters of 1990-91 and 1991-92.

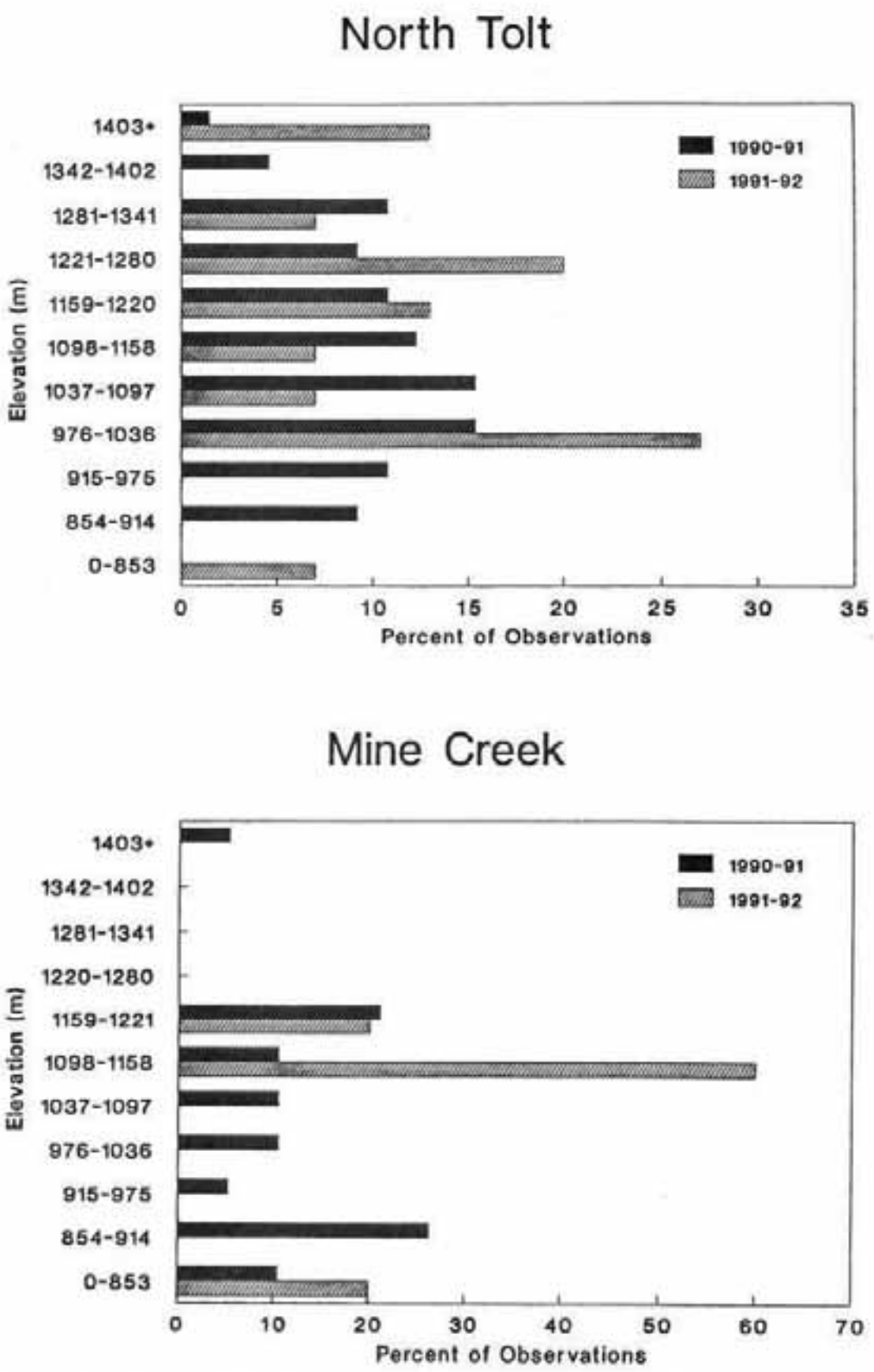


Fig. 5. Elevational distribution of mountain goat observations from aerial surveys in the North Tolt and Mine Creek drainages, winters of 1990-91 and 1991-92.

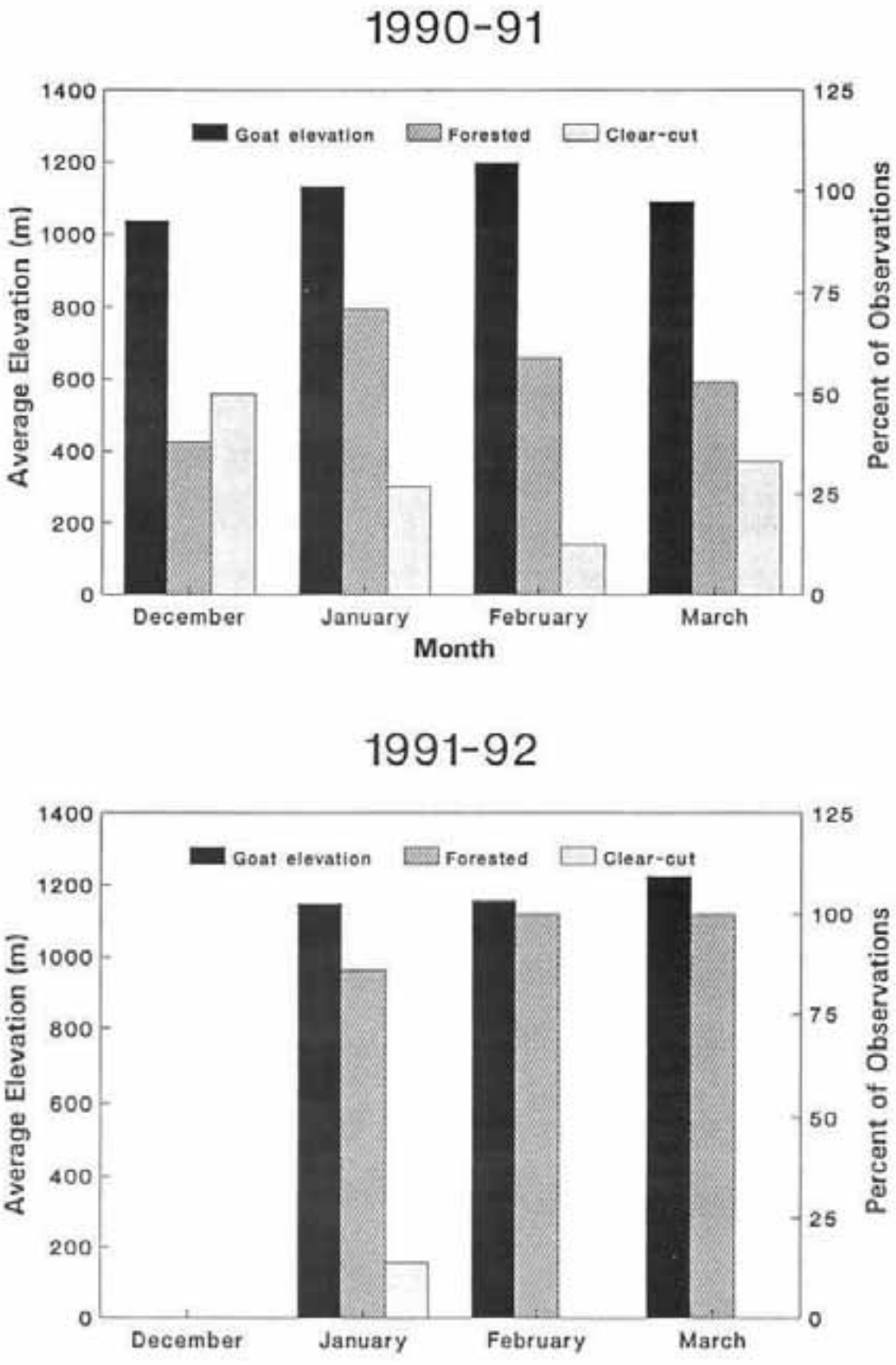


Fig. 6. Average elevation of goat locations and percentage of goat locations in forested and clear-cut habitats in the North Tolt drainage, winters of 1990-91 and 1991-92.

The average kid to nanny ratios for both winters combined were relatively high in the North Tolt (100:100), and slightly lower in Mine Creek (60:100) (Table 3). The proportion of billies in the classifications is relatively low (0.3 billies per nanny), approximating ratios from introduced herds in the Olympic mountains (Moorhead 1976).

In order to minimize the bias associated with our failure to identify some goats in the 1990-91 surveys, we classified unknown goats into sex and age categories based on herd composition records of billy to nanny ratios from Cascade mountain goat herds (Anderson 1940, Wright 1977, and Johnson 1983). We used average ratio of 0.81 billies per nanny to adjusted herd composition data for 1990-91.

Table 3. Herd composition from aerial surveys conducted in the North Tolt and Mine Creek drainages during the winters of 1990-91 and 1991-92. Composition is based on 100 nannies. Sample size (n) does not include unknowns.

		Goats per 100 Nannies			
Area	Year	Kids	Yearlings	Billies	n
North Tolt	90-91[a]	83	17	30	54
	90-91[a]	70	15	85	74
	91-92	200	100	150	22
	90-92	100	33	52	76
Mine Creek	90-91	67	33	167	12
	91-92	50	100	0	5
	90-92	60	60	100	17

[a] Herd composition was adjusted to account for the unknowns

No billies were positively identified in the Mine Creek site during the winter of 1991-92. Unknowns accounted for 38% of the observations. Unlike the 1990-91 surveys, 75% of the unknown observations were in groups of 3 or more. This would indicate that a larger proportion of the unknowns were nanny groups and not single billies. The failure to classify these suspected nanny groups may explain the very high kid:nanny ratios and the elevated billy:nanny ratios.

DISCUSSION

Habitat Selection

Mountain goats wintering in this area of the north-central Cascades were closely associated with cliffs and rock outcroppings. The cliff systems were dominated by predominantly open canopied, old-growth forest stands, partial-cut,

and clear cuts habitats. Open cliffs without trees were uncommon on goat winter range in this area.

Based on our mountain goat observations, closed forest stands were not heavily utilized by goats throughout the study period in both drainages. However, a comparison of the composition of the cover types in the goat concentration areas showed no selection for or against any cover type. In addition, an observational bias against detection of goats in closed forest must be considered. However, most cliff systems do not have extensive closed forest components. Unless goats are less dependent on cliffs than we have noted, or as has been reported elsewhere (Johnson 1983), closed forest detection bias would not have a significant effect on determining overall habitat selection.

There was a noted increase in goat observations in forest stands in mid-winter, coincident with the upward shift in elevational distribution (Fig. 6). This increase in use of forest stands may be an artifact of landscape patterns in this area. The percentage of available forest increased as elevation increased. Elevations at 762-1067 m were 56% forested while upper elevations at 1220-1372 m were 73% forested. Clear-cuts declined from 33% to 14.5% from the lower to the higher elevation band. This landscape pattern is a result of the historical logging activity, which proceeded sequentially upslope from the valley floor and is currently occurring in mountain goat winter range.

Forage Production

Although clear cuts produced the most forage, snow accumulations and logging slash must be considered when evaluating the availability of this forage to wintering mountain goats. It is energetically costly for goats to move in deep snow, or to maneuver through extensive slash accumulations. Heavy snow accumulations can bury forage. However, unlike southeast Alaska, where heavy snow accumulations restrict goat use to canopied habitats (Fox et al. 1989), the snow accumulations of the western Cascades are sporadic, lighter, and affected by rain on snow dynamics, especially at elevations from 915 to 1220 m. Use of open forest and partial-cut units may have been a response by the goats to increased forage availability and decreased snow accumulations under open canopies.

Food Habits

Analysis of diet composition over the two winters indicated that mountain goats in this area of the north-central Cascades have diet characteristics that are intermediate between coastal and interior ecotypes (Fig. 7). The high proportion of shrubs, forbs, and grasses indicates foraging activity in clear-cut or open forested stands. Lichens and mosses account for only 3.8% of the winter diet, which indicates very limited reliance on a canopied overstory for forage production. However, portions of the conifer component may have come from litterfall.

Coastal diets are characterized by forest related forage components such as conifers, lichens, and mosses, with small percentages of forbs, shrubs, and virtually no graminoids (Fox and Taber 1981, Fox and Smith 1988, Fox et al. 1989). Rocky mountain goat diets are characterized by high percentages of open space forage plants such as graminoids, shrubs, and forbs (Saunders 1955,

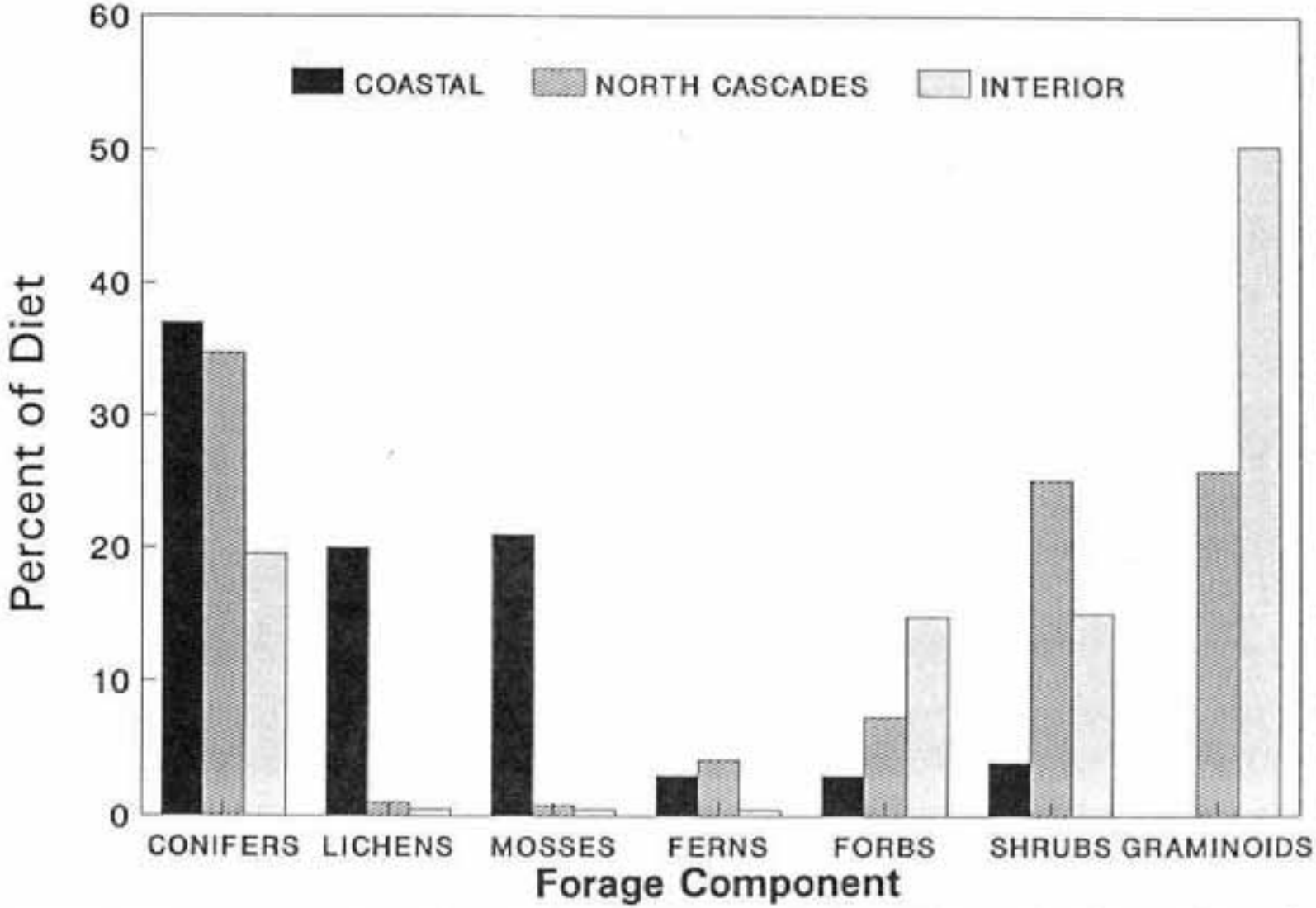


Fig. 7. Diet composition of mountain goats from coastal (Fox and Taber 1981, Fox and Smith 1988, Fox et al. 1989), Cascade (Johnson 1983, authors), and interior (Brandborg 1955, Saunders 1955, Adams and Bailey 1983) regions.

Brandborg 1955, Adams and Bailey 1983). There is a substantial component of conifer use in interior diets, however lichens and mosses are relatively unused.

Other studies have indicated great variance in diet composition over several winters (Johnson 1983). The diet of North Tolt mountain goats did not vary greatly between the winters of 1990-91 and 1991-92.

Goat Distribution and Snow Patterns

Major snow events did not cause noticeable shifts in mountain goat elevational distribution or habitat selection. The elevational distribution of goats was unchanged between two winters with great differences in snow accumulation levels. There was no increase in forest use during periods of higher snowfall or accumulations. In Mine Creek, goats used the forest stands only in 1992 when there was little or no snow on the winter range. Snowfall and goat habitat use patterns did not appear to be related in the North Tolt drainage.

Herd Productivity and Composition

Few studies have reported on the sex and age composition of mountain goats on winter range. The average fall kid:nanny ratio in an introduced and expanding herd on the Olympic peninsula of Washington state was 55:100 over a 6 year period from 1976 to 1981 (Stevens 1983). Brandborg (1955) reported an average ratio of 34:100 in the winter and early spring from 1949 to 1952 in the Salmon River range of Idaho. A kid to nanny ratio of 60:100 was reported for winter range in the Cascades of Washington from 1977 to 1980 (Johnson 1983).

The productivity of the mountain goats wintering in the North Tolt and Mine Creek drainages, interpreted from kid:nanny ratios and possible incidence of twinning, indicates high reproductive success. In the winter of 1992 in the North Tolt drainage, 29% of observed nannies had 2 kids at heel, which may indicate twinning. In addition, possible bias from classification of 2 yr-old females as adults would only increase kid:nanny ratios.

Possible bias due to classification of goats into an "unknown" category must be considered. During the winter of 1990-91, 60% of unknown goat classifications were singles. Due to the solitary nature of billies in winter (Johnson 1983), we feel that a majority of these unknown goats were males. Anderson (1940) found billy:nanny ratios of 77:100, 98:100, and 83:100 for various areas of the Cascades, and Johnson (1983) reported a ratio of 1:1 in the north Cascades. Our observed low proportion of adult males in this winter (0.3 billies per nanny) supports our conclusion that adult males are under-represented in our classifications.

During the winter of 1991-92, more of the unknown observations (75%) were in larger groups that included nannies. The bias from failing to classify all the nannies is reflected in the very high kid:nanny and nanny:billy ratios for this season.

MANAGEMENT IMPLICATIONS

As in other studies, cliffs were the primary factor determining mountain goat habitat selection in this area of the north-central Cascades. Creation or maintenance of a diversity of habitats, centered around commonly used cliff

systems, would have beneficial effects on mountain goat productivity and conservation.

Timber harvesting in mountain goat habitat may have both beneficial and detrimental impacts. Primary among the negative effects is increased disturbance and vulnerability of mountain goats caused by road access to winter ranges (Johnson 1983). In our study sites, road access was strictly controlled by the Weyerhaeuser Company. The high productivity found in our study sites may indicate the positive results from increased forage production resulting from timber harvesting, coupled with effective control of road access.

The Washington Department of Wildlife describes mountain goat habitat by map cover types. This habitat mapping focuses on "thermal" and "transitional" cover types. The use of winter thermal cover by mountain goats has not been documented by previous studies. Fox and Taber (1981) indicated that thermoregulatory behavior was not an overriding determinate of goat habitat selection in Alaska goat populations. In the Department of Wildlife's description of mountain goat habitat types, both "winter thermal" cover and "transitional optimal" cover is associated with mature, old growth, and young forests with closed canopies.

In our study areas, non-forested habitats were selected by mountain goats. Although storm events are relatively short lived in the Cascades, goats may use closed forests more intensively during these periods. Future assessment is needed to determine if the increased use of forested habitats in mid-winter is an artifact of the distribution of the forest as a result of past logging activity, or if these upper elevation old growth forests are an important element of winter mountain goat habitat.

Mountain goats in our study areas exhibited habitat use patterns intermediate between coastal and interior ecotypes (Table 4). The study area goats occupied a wide range of elevations from 762 to 1524 m, while coastal goats generally range lower, and interior goats range higher.

Habitat selection by these mountain goats appeared to be a compromise between the dependence on forests by coastal ecotypes and the avoidance of forested areas by interior ecotypes. Unlike coastal ecotypes, the diet composition of Cascade goats indicates no dependence on forage from the forest canopy, although a portion of the conifer component may have come from litterfall under a canopy. The dominance of goat diets in the Cascades by conifers, graminoids, and shrubs indicates foraging in open habitats. However, graminoids do not dominate the diet as they do in interior regions.

Snow characteristics have been reported to play a dominant role in the winter site selection of mountain goats (Fox et al. 1989). Coastal regions receive wet, heavy snows that limit forage availability and goat mobility. Interior regions receive relatively light, dry snows that can be swept off by the wind. The North Cascades snow charac- teristics are influenced by both coastal and interior climes. Snow conditions change over the winter and heavy snowfall events are sporadic and short lived.

Whether mountain goat habitat selection in this area of the Cascades is representative of the Cascades in general is arguable. At this time there is very limited information available on habitat selection, population dynamics, and food

habits of mountain goats in the Cascades Mountains. Although the North Tolt and Mine Creek information may not be applicable to undisturbed areas, it may be applicable to areas where intensive forest management has and is occurring. Our study areas are fairly representative of commercial forests in upper elevation river drainages of the north central Cascades. Issues of access and timber harvesting impacts in other areas of the north-central Cascades could be assisted by the information in this study.

Table 4. Summary of selected winter characteristics of coastal, interior and Cascade mountain goat ecotypes

Characteristic	Coastal	Cascades	Interior
Elevation	0-1494[a]	762-1524[b]	1524+[c]
Habitat types	Cliffs in dense forest[d]	Cliffs in clear-cut & open forest[e]	Cliffs,non -forested ridges[f]
Diet composition	1)Conifer 2)Moss 3)Lichen	1)Conifer 2)Graminoid 3)Shrub	1)Graminoid 2)Conifer 3)Shrub
Snow Characteristics	wet, heavy	intermittent, variable	dry, light windblown

[a] Fox et al. 1982, Schoen and Kirchoff 1982, Smith 1986, Fox et al. 1989
[b] Wright 1977, Authors
[c] Hebert and Turnbull 1977, Adams and Bailey 1980
[d] Hebert and Turnbull 1977, Fox and Taber 1981, Fox 1983, Fox et al. 1989
[e] Johnson 1983, Authors
[f] Hjeljord 1973, Hebert and Turnbull 1977, Adams and Bailey 1980

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