Research Report

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Winter habitat use by mountain goats in the Kingcome River drainage of coastal British Columbia

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Abstract

Using radio telemetry from September 1994 to March 1996, we studied the winter habitat use of 15 mountain goats in the Kingcome River drainage on the south coast of British Columbia, Canada. Our objectives were to identify important attributes of coastal mountain goat winter habitat and, in doing so, to provide resource managers with information that will help them make decisions about conserving and managing goat habitat in coastal British Columbia. We used a digital elevation model, Terrestrial Ecosystem Mapping, and Vegetation Resource Inventory mapping with a Geographic Information System to determine selection by 13 female mountain goats for forested site series and other habitat variables at two different scales. At both scales of selection, mountain goats chose southerly aspects (110–250°) and western hemlock-leading forests greater than 250 years in age, but we observed no evidence for site series preference. Most goat locations were within 150 m distance of rock-outcrop polygons. Depending on the scale of selection analyses, goats selected elevations from 600–1200 m, slopes from 41 to 60°, and the Montane Very Wet Maritime Coastal Western Hemlock (CWHvm2) or Windward Moist Maritime Mountain Hemlock (MHmm1) subzone variants. Goats selected moderate classes of forest volume and crown closure, and sites with shrub cover 1–2 m in height. These attributes are likely associated both with lower snow depths and higher amounts of available forage for goats. Our study shows that it is important for managers to assess whether planned harvests conflict with goat winter habitat. Although the harvestable area on the coast that overlaps with goat winter habitat may not be large, some of these habitats could be very important for goats, particularly during deep snow periods.

KEYWORDS: *coastal western hemlock forests, Geographic Information System (GIS), habitat selection, mountain goats, radio telemetry, site series, Terrestrial Ecosystem Mapping (TEM), winter range.*

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Introduction

British Columbia has the greatest area of mountain goat (*Oreamnos americanus*) habitat in North America and supports over half of the world's population of mountain goats (Krausman 1997). Behaviour of the coastal ecotype varies from that of some Interior populations in British Columbia (Hebert and Turnbull 1977). During winter, goats in dry Interior regions often seek foraging habitat on windswept ridges at relatively high elevations, while goats in coastal environments seek steep escape terrain and old-growth forest at relatively low elevations (Schoen *et al.* 1980; Fox 1983; Smith 1994; Shackleton 1999). Published studies of coastal goat habitat use have predominantly been conducted in Alaska, although observational studies (Hebert and Turnbull 1977; Demarchi *et al.* 2000; Gordon and Reynolds 2000) and a recent Global Positioning System (GPS)-telemetry study (Taylor *et al.* 2006) have been conducted on the coast of British Columbia. By analyzing winter habitat selection using Terrestrial Ecosystem Mapping (TEM) and BC Vegetation Resource Inventory (VRI) data, this study provides new information on coastal mountain goat habitat use.

With forest harvesting comes new roads and, increasingly, helicopter logging, both of which increase the potential for altering goat winter habitat, heightening concerns that important goat habitats could be negatively affected. This research had two objectives: (1) to identify important attributes of coastal mountain goat winter habitat, and (2) to provide resource managers with information that would assist them in making decisions about conserving and managing mountain goat habitat in coastal British Columbia.

We analyzed habitat selection at two spatial scales: the winter range within the study area and the stands within the winter range. We focussed our analyses on the goats' selection of vegetation, terrain, and ecosystem attributes, and we were particularly interested in their selection of ecosystem variants and forested site series. We were also interested in whether goats would select particular forest site series given the species' affinity for escape terrain (Fox 1983; Fox *et al.* 1989; Poole and Mowat 1997), and their need to obtain adequate forage.

By analyzing winter habitat selection using Terrestrial Ecosystem Mapping (TEM) and BC Vegetation Resource Inventory (VRI) data, this study provides new information on coastal mountain goat habitat use.

Study Area

The study area was situated on the south coast of mainland British Columbia, north of Johnstone Strait (Figure 1), and was defined by the height of land surrounding the Lahlah Creek and Satsalla River watersheds. Its total area was approximately 380 km^2, almost half of which consisted of glaciers or alpine tundra. The study area encompassed two drainages: the Satsalla River (290 km^2) and the Lahlah Creek (90 km^2), both of which flow south into the Kingcome River and eventually to the Kingcome Inlet. Elevation ranges from slightly above sea level to approximately 2500 m. In the past, forest harvesting occurred at relatively low elevations, mostly in the Submontane Very Wet Maritime Coastal Western Hemlock (CWHvm1) subzone variant. Although interest in future forest harvesting exists, there is no current forest harvest taking place within the study-area boundaries. Access to the study area is relatively remote and no reports of goat harvesting have been recorded in recent years.

The area's geology includes a mixture of folded sedimentary and igneous rocks with granitic batholith intrusions. Serrated peaks and talus slopes provide evidence of glaciation (Clement 1997). Avalanche chutes are abundant and upper-forested slopes consist of bedrock partly overlain by veneers of sandy colluvium and organics (Clement 1997). Soils that typically characterize mountain goat habitat included Orthic Humo-Ferric Podzols, Orthic Ferro-Humic soils, and Hemic Folisols in thin organic veneers (Clement 1997).

The area is located in the Northern Pacific Ranges (NPR) ecosection. Biogeoclimatic zone units included (arranged low to high elevation): Submontane Very Wet Maritime Coastal Western Hemlock variant (CWHvm1), Montane Very Wet Maritime Coastal Western Hemlock variant (CWHvm2), Windward Moist Maritime Mountain Hemlock variant (MHmm1), and Alpine Tundra (AT) zone. The two CWHvm subzones feature wet, humid climates, with relatively little snow occurring in the vm1 and substantial amounts falling in the vm2. Higher snowfall in the MHmm1 and AT can lead to snowpacks that persist into summer (Green and Klinka 1994). Approximate elevations range from just above sea level to 600 m in the CWHvm1 and to 950 m in the CWHvm2, and from 1400 m in the MHmm1 to 2500 m in the AT (Clement 1997).

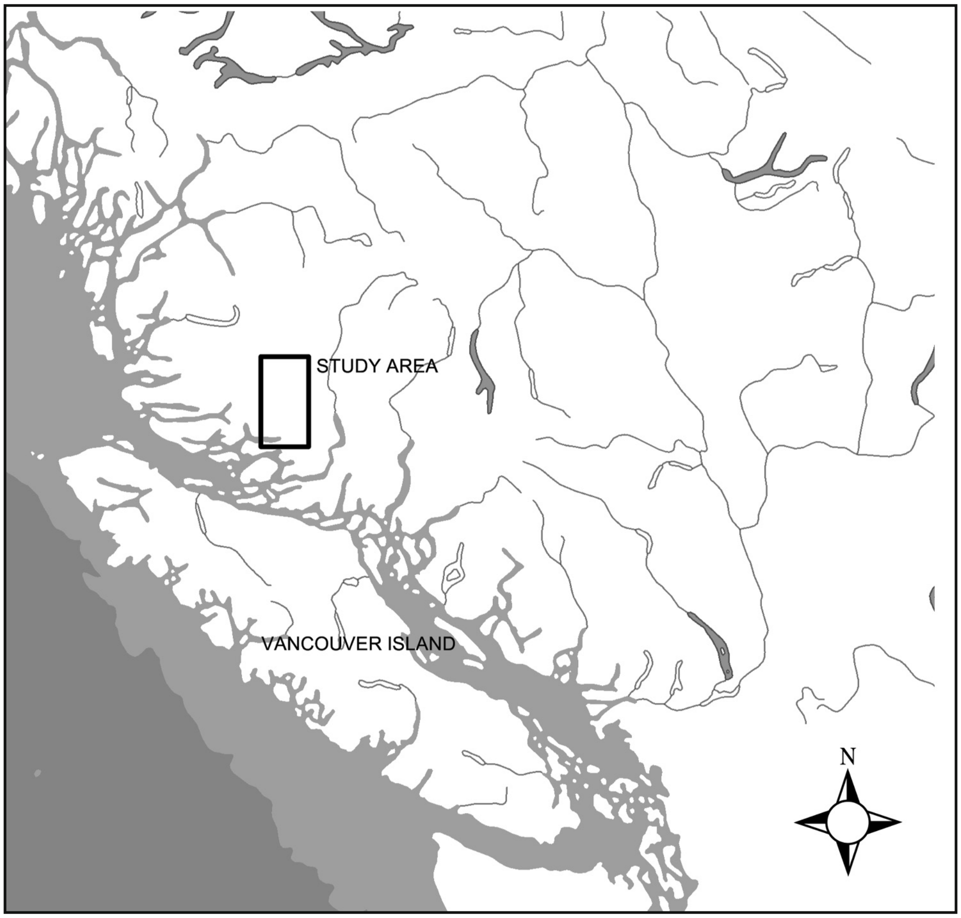

FIGURE 1. Location of the Kingcome River mountain goat study area in southwestern British Columbia.

In the study area, the dominant tree species in the CWHvm1 include western hemlock (*Tsuga heterophylla*) and amabilis fir (*Abies amabalis*). Common shrubs include Alaskan blueberry (*Vaccinium alaskaense*) and regenerating western hemlock, and common herbs included bunchberry (*Cornus canadensis*) and deer fern (*Blechnum spicant*). The same tree species are dominant in the CWHvm2 and we observed the occasional mountain hemlock (*Tsuga mertensia*) and yellow-cedar (*Chamaecyparis nootkatensis*). Similar shrub and herb species are present in the CWHvm2, but the herb layer is sparser than in CWHvm1 and includes rosy twisted stalk (*Streptopus roseus*) and queen's cup (*Clintonia uniflora*). The dominant tree species of the MHmm1 are mountain hemlock and amabilis fir with scattered yellow-cedar. Common shrubs in this variant include Alaskan blueberry, oval-leaved blueberry (*Vaccinium ovalifolium*), copperbush (*Cladothamnus pyroliflorus*), and regenerating conifers. A poorly developed herb layer of five-leaved bramble (*Rubus pedatus*) and rosy twistedstalk characterize this variant. Devil's club (*Oplopanax horridus*) and salmonberry (*Rubus spectabilis*) are found in seepage areas, and Sitka alder (*Alnus sitchensis*), salmonberry, oak fern (*Gymnocarpium dryopteris*), lady fern (*Athyrium filix-femina*), three-leaved foamflower (*Tiarella trifoliata*), and Indian hellebore (*Veratrum viride*) are found in avalanche chutes. All vegetation was described by Shearwater Mapping Ltd. (Clement 1997).

Methods

Capture and Radio-Collaring

We used an aerial netgunning technique to capture 15 mountain goats in the Kingcome River system on August 2, 1994. Individuals were outfitted with VHF radiocollars (frequency range: 150–151 KHz; Telonics Inc., Mesa, Arizona) that were equipped with mortality sensors. We collared 7 females and 1 male in the Satsalla drainage and 6 females and 1 male in the Lahlah drainage. Goats were also eartagged for visual identification. We located collared animals during 15 aerial telemetry flights from September 1994 to March 1996, and recorded incidental observations of other mountain goats. Telemetry was conducted using two perpendicular three-element directional antennae (one forward and one side-pointing) fixed to the skid of an A-Star helicopter, a TR-2 VHF receiver (Telonics Inc., Mesa, Arizona), and a switch box.

In total, 11 telemetry flights were conducted during two winter seasons between December 6 and March 14, which we defined as "winter" (winters identified as "1995" and "1996" include the month of December of the previous year). Due to the possibility of sightability bias associated with using incidental observations, we conducted all analyses with only collared mountain goat data.

Geographic Analysis Tools

GIS analyses were conducted using ArcView™ (version 3.2). BC MELP KID (ArcView extension) was used to convert the projection from geographic to BC Albers Standard Projection (datum NAD 83). All animal range data were analyzed using "Animal Movement," another ArcView™ extension (Hooge and Eichenlaub 2000). A digital elevation model (DEM) was created from 1:20 000 Terrain Resource Information Management (TRIM) mapping coverages.

Winter Range Fidelity

To estimate the fidelity of females for winter range sites between years, we calculated yearly winter ranges (minimum convex polygons) for 12 different females during the winters of 1995 and 1996 (six and four flights, respectively). We then observed the proportion of females whose yearly winter ranges overlapped and we measured the distance between the centroids of their respective winter range pairs.

Habitat Selection

We used univariate chi-square tests ($\alpha = 0.05$) to determine if mountain goats used habitats disproportionately to their availability, demonstrating selection. For significant results, individual classes of habitat were further tested using Bonferroni intervals (Neu *et al.* 1974). Plus and minus symbols in figures indicate which specific categories were used in greater or lesser proportions than availability. Classes of habitat variables were combined where necessary to ensure that expected frequencies were equal to, or greater than, one (Zar 1996). Because adult males are known to use different ranges than female-subadult groups (Stevens 1983), we used only locations of female mountain goats for all selection analyses. Coastal goats have been observed to select habitats at multiple scales (Smith 1986). Therefore, we examined habitat selection at two scales: the study area and the cumulative winter-home range, each equivalent to second- and third-order selection, respectively, of habitat components (Johnson 1979). The cumulative seasonal range was estimated using a 95% adaptive kernel method using locations of collared females from both winters. We used Least Square's Cross Validation (LSCV) as a smoothing parameter for all seasonal range adaptive kernels.

Habitat classes for use and availability analyses were determined using data from three sources: TEM; VRI forest cover mapping (derived by photo interpretation and corrected by ground-sample measurements); and a digital elevation model. We obtained ecosystem variants and site series from the TEM data, and forest measures from the VRI, which included forest presence, leading tree species, net forest volume per hectare (decay, waste, and breakage factors subtracted from gross volumes), forest age, forest height, forest crown closure, and shrub height. We first used chi-square analyses to determine the goats' selection for forested versus non-forested habitat and then tested for selection of leading tree species, net forest volume per hectare, age, and height and crown closure in forested sites only. Similarly, we first tested for selection for shrub presence versus shrub absence and then tested for selection for shrub height. We derived slope, aspect, and elevation data from the DEM. Tables 1 and 2 outline biogeoclimatic classification units (Green and Klinka 1994) and forest-stand attributes used in this study.

Terrestrial ecosystem mapping was conducted in the study area in 1996 at 1:20 000 scale by Shearwater Mapping Ltd. (Clement 1997). A total of 63 full plots and 176 visual records were used to map the area. We attempted to determine winter selection for forested site series by female mountain goats in three separate ecosystem variants: CWHvm1, CWHvm2, and MHmm1. We included only forested site series used by mountain goats in the analyses. We could not test for forested site series selection in CWHvm1 because the number of goat locations (16 out of 115) and concomitant expected frequencies for this variant were too small.

Goat locations could not be directly assigned to a particular site series because each TEM polygon included decile estimates of up to three site series. To account

TABLE 1. Biogeoclimatic and forest-stand attribute classes and abbreviations

Biogeoclimatic units	Code	Subzone variant
	AT	Alpine Tundra
	CWHvm1	Submontane Very Wet Maritime Coastal Western Hemlock
	CWHvm2	Montane Very Wet Maritime Coastal Western Hemlock
	MHmm1	Windward Moist Maritime Mountain Hemlock
Aspect	**Code**	**Aspect (degrees)**
	N	291–70
	E	71–110
	S	111–250
	W	251–290
Leading tree species	**Code**	**Species**
	Ba	True fir (*Abies amabilis*)
	Dr	Red alder (*Alnus rubra*)
	H	Hemlock sp. (*Tsuga* sp.)
	Hm	Mountain hemlock (*Tsuga mertensia*)
	Hw	Western hemlock (*Tsuga heterophylla*)
	Yc	Yellow cedar (*Chamaecyparis nootkatensis*)

TABLE 2. List and descriptions of forested site series used by goats per biogeoclimatic subzone variant

Subzone variant			
CWHvm2		MHmm1	
Site series code	Description	Site series code	Description
AB	HwBa – Blueberry	MB	HmBa – Blueberry
AD	BaSs – Devil's club	MD	HmYc – Deer cabbage
AF	BaCw – Foamflower	MH	Mountain heather meadows
HS	HwCw – Salal	MM	HmBa – Mountain heather
LC	HwPl – Cladina	MO	BaHm – Oak fern
RS	CwHw – Sword fern	MT	BaHm – Twistedstalk
		YH	YcHm – Hellebore

for this, we weighted availability and locations by their respective polygon decile percentages (Jalkotzky 2000; Mowat *et al.* 2002). Therefore, one location represented a fraction of one animal use per particular site series. We then summed these fractions across site series to determine site series use. We similarly determined the availability of each site series in each variant by multiplying the area of every polygon by the polygon deciles for respective site series and summed the totals.

Adjacency to Escape Terrain

To assess the importance of adjacency to escape terrain, we measured distances from goat locations and from random locations (Quantitative Decisions 2000) to an escape terrain surrogate, the TEM feature "rock outcrop." Random locations were generated by GIS to determine whether mountain goats were selecting habitat variables such as "rock outcrop" more frequently than by chance alone. The "rock outcrop" feature is defined as "a gentle to steep bedrock escarpment or outcropping with little soil development and sparse vegetative cover" (Resources Inventory Committee 1998). The majority of these features in the Kingcome River study area are steep enough to be considered escape terrain (C. Clement, Shearwater Mapping Ltd., pers. comm.). We used an ArcView™ script to calculate distances from animal locations to the nearest polygon edge that contained rock outcrop. We then compared these distances with those calculated from rock outcrop to random locations allocated within the overall study area (5000 locations) and within separate variants (1000 locations per variant). Finally, we calculated the percentage of mountain goat locations that were within rock outcrop polygons and we calculated the percentage of each subzone variant that was composed of rock outcrop polygons.

Results

We recorded 337 goat locations, of which 195 were from collar relocations and 142 from incidental observations made during the 15 telemetry flights. We recorded 115 locations from collared females during the winter season, which was the major focus of our analyses. One collared female, estimated to be greater than 10 years of age, died at the end of the first winter of study; no other mortalities were observed. We obtained visual confirmations of collared goats from approximately 32% of all winter telemetry locations ensuring relatively high positional accuracy. The mean distance between an individual goat's winter ranges in 1995 and 1996 was 483.6 m (SE = 80.6), and ranged between 227.7 and 1185 m. Ten of the 12 pairs of winter ranges overlapped between years.

Goats selected CWHvm2 and MHmm1 variants at the study-area scale and only CWHvm2 at the cumulative winter-range scale (Figure 2). Although the CWHvm1 variant was used in proportion to its availability, pooled data showed that it was used rarely overall (Figure 3). However, the CWHvm1 appeared to be used relatively frequently by some individuals and more often during the winter of 1995. In particular, 36% and 45% of the locations of 2 females were in this variant during the winters of 1995 and 1996. Although the availability of older forest classes in the CWHvm1 is affected somewhat by past harvest, the total amount and percentage of forest greater than 250 years old in this variant is actually greater relative to the other forested variants (Table 3).

Of the common site series, only bogs and swamp forests, and floodplain benches were unused. Goats did not select for specific site series in the CWHvm2 or MHmm1 (Figures 4 and 5) and therefore, we did not further analyze nutrient or moisture regimes.

Mountain goats overwhelmingly selected forested sites during winter (Figure 6). They also selected stands dominated by western hemlock at both scales (Figure 7). Mountain goats selected moderate forest volumes of 300–400 m^3/ha and underutilized the lowest and highest volume classes relative to availability (< 100 m^3/ha and > 600 m^3/ha; Figure 8). Goats only selected forests that were greater than 250 years old, and avoided age classes 1 and 2 (> 0–40 years) at both scales (Figure 9). Forest ages between 100–120 years were avoided at the study-area scale and forests between 61 and 80 years old were avoided at the cumulative winter-range scale. Goats selected forest heights between 28.5 and 37.5 m and avoided forests of less than 10.5 m at the study-area scale and greater than 19.5 m at the winter-range scale (Figure 10). It appears that goat use was more closely associated with forest age rather than high crown closure. In fact, 57% of all winter goat observations were in forest sites greater than 250 years old, whereas only 23% of the cumulative winter-range area contained this age class. In the cumulative winter-range area, 75% of the forest greater than 250 years showed less than 55% crown closure. Goats avoided the highest available crown closure class greater than 65%, and selected moderate classes in the cumulative winter range scale between 26 and 35% and between 46 and 55% (Figure 11). Goats selected sites with shrub presence, specifically between 1 and 2 m in height (Figure 12).

At the study-area and winter-range scales, goats selected southerly aspects and avoided northerly ones (Figure 13).

TABLE 3. Percentage of old forests by ecosystem variant

Variant	Total area (ha)	Forested area (ha) > 250 years	% of variant with forest > 250 years
CWHvm1	4715.6	1856.9	39.4
CWHvm2	4863.8	1738.4	35.7
MHmm1	10086.6	1679.5	16.7

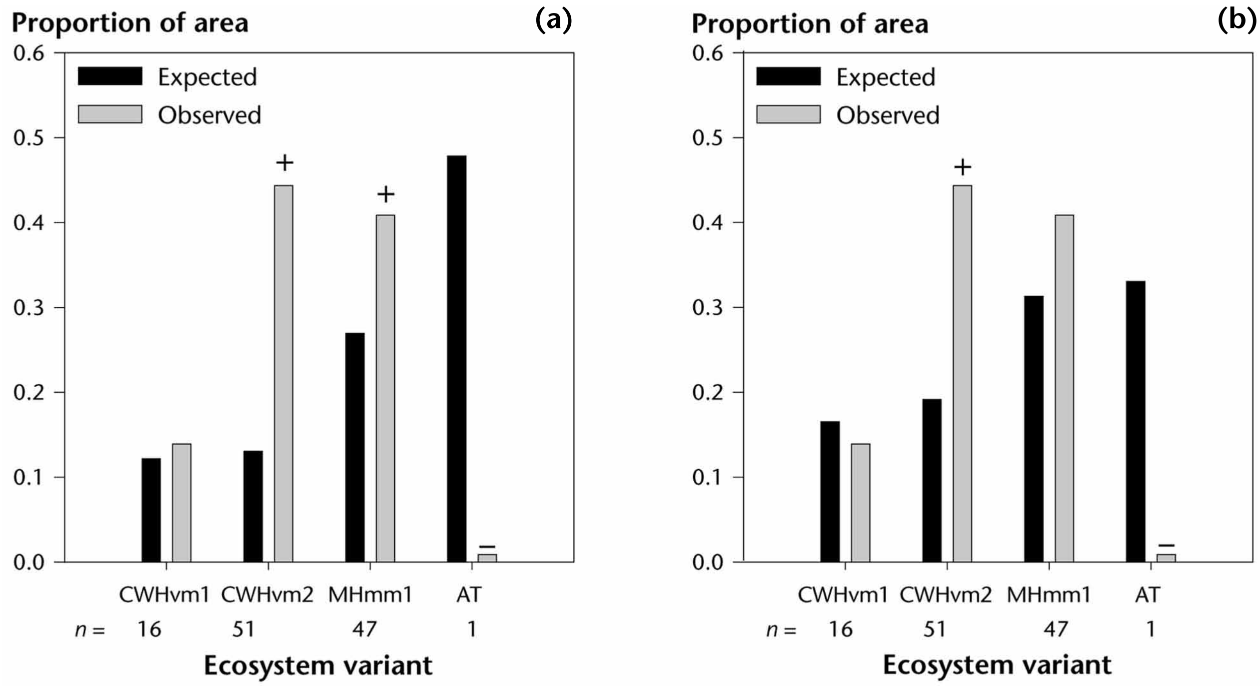

FIGURE 2. Ecosystem variant use by goats relative to availability at: (a) study-area scale and (b) winter-range scale (variants are described in Table 1); *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

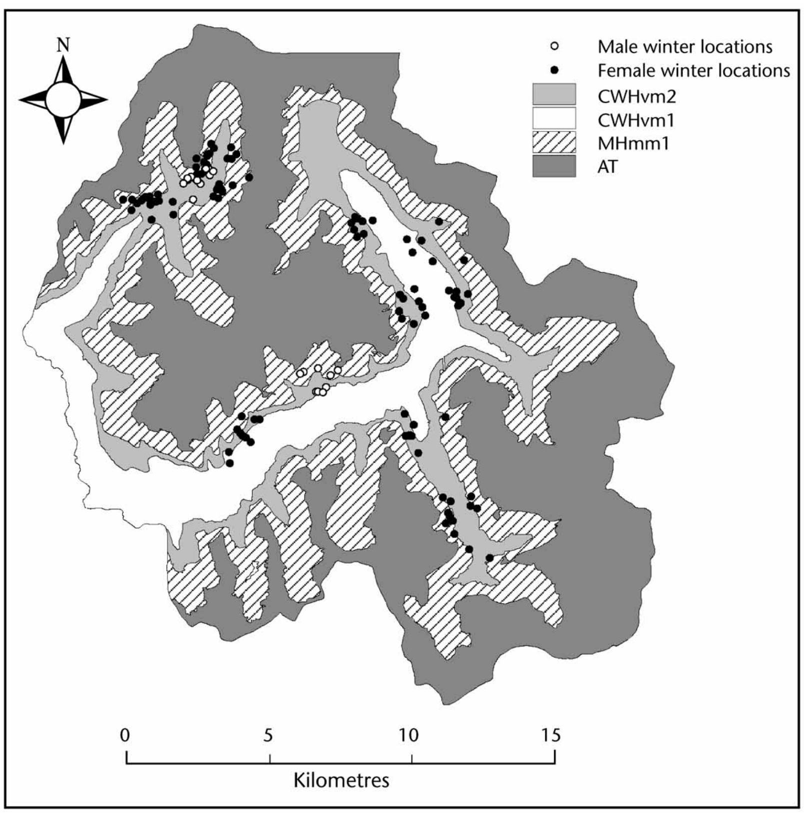

FIGURE 3. All winter collared mountain goat locations in relation to the four ecosystem variants in the study area.

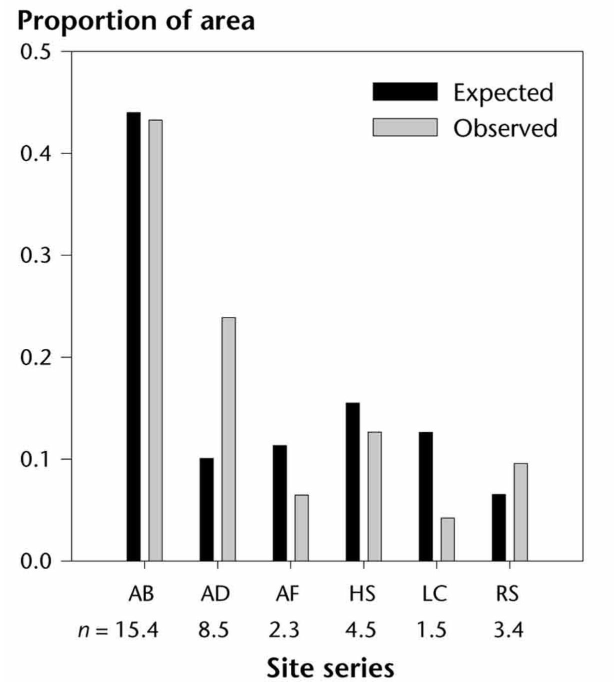

FIGURE 4. Forested site series in CWHvm2 subzone variant used by goats relative to availability (site series are described in Table 2); *n* = number of observations per category.

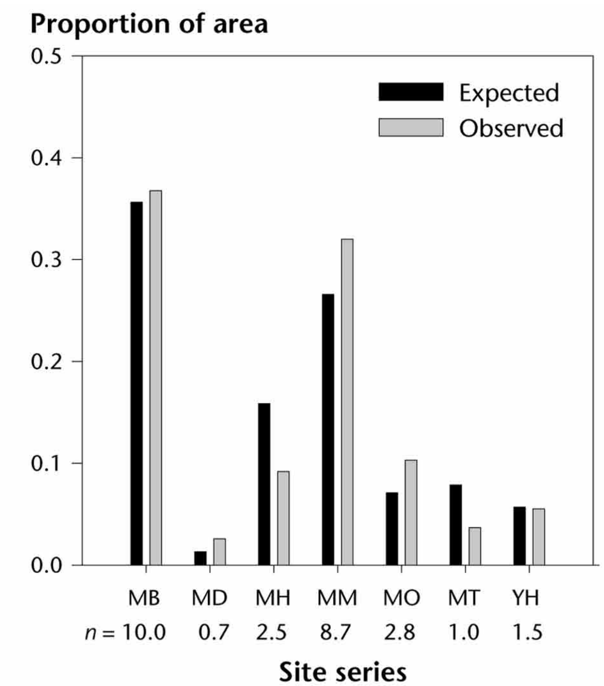

FIGURE 5. Forested site series in MHmm1 subzone variant used by goats relative to availability (site series are described in Table 2); *n* = number of observations per category.

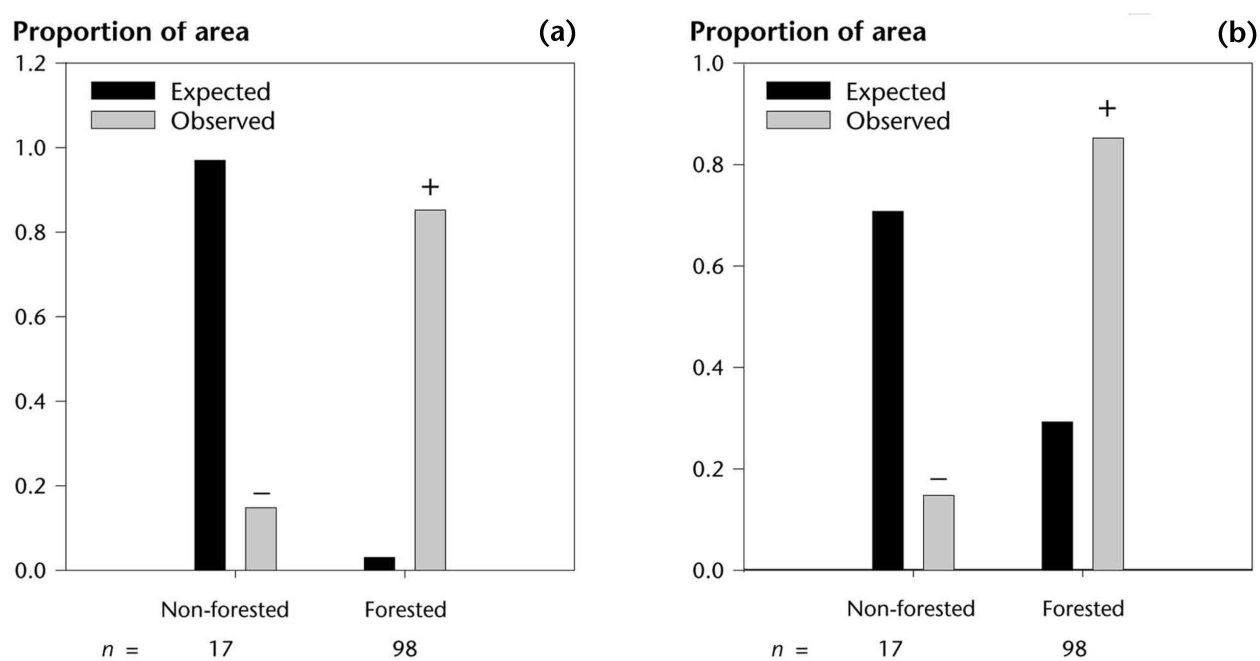

FIGURE 6. Forest use by goats relative to its availability at: (a) study-area scale and (b) winter-range scale; *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

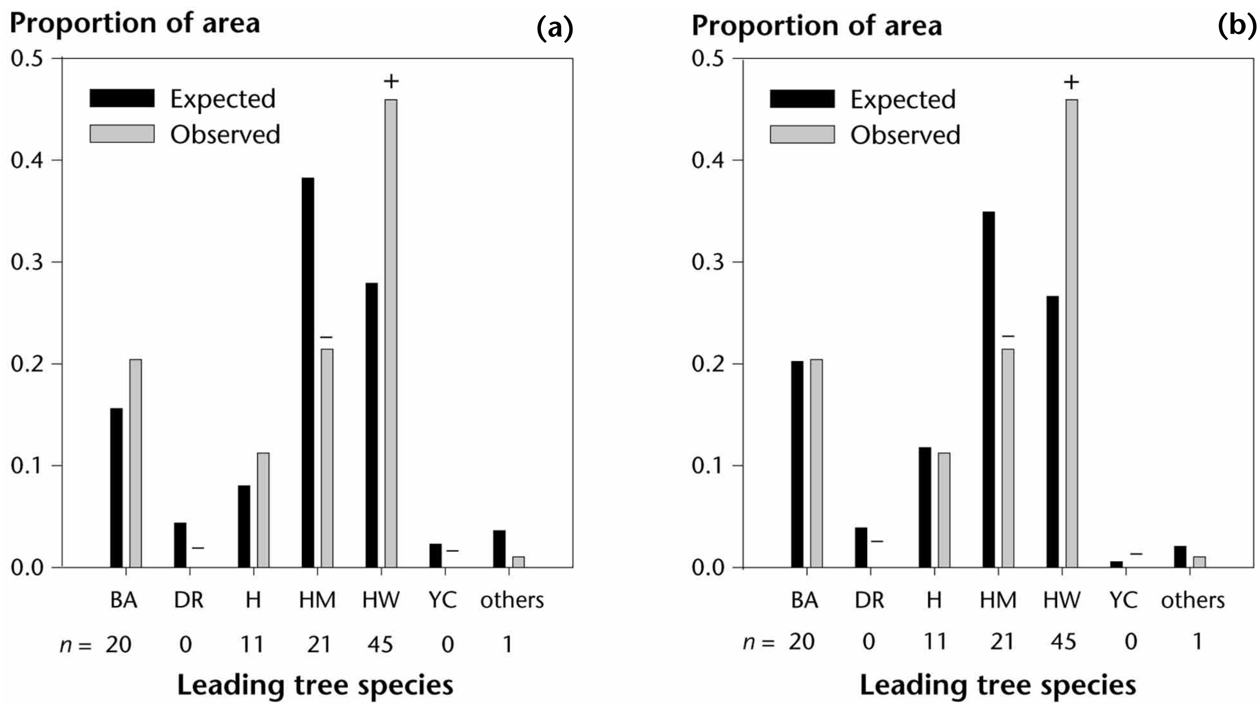

FIGURE 7. Leading tree species used by goats relative to their availability at: (a) study-area scale and (b) winter-range scale (tree species are described in Table 1); *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

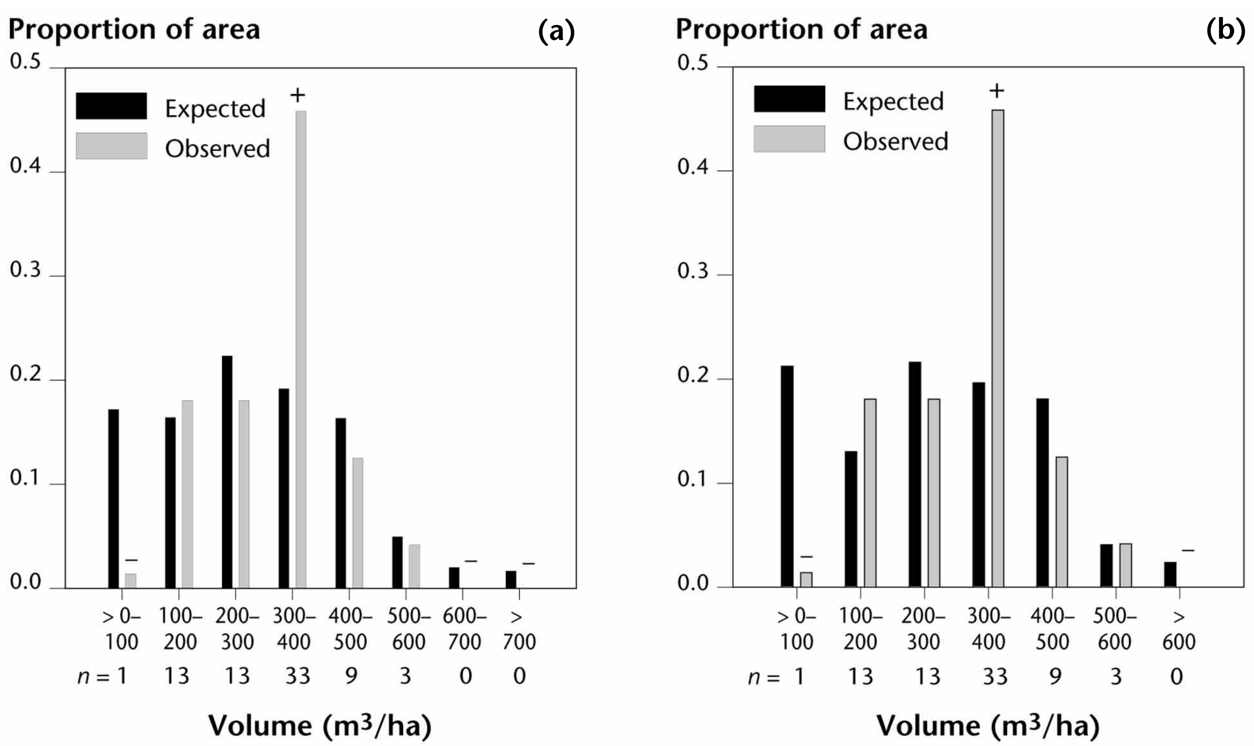

FIGURE 8. Net volume (m^3/ha) used by goats relative to its availability at: (a) study-area scale and (b) winter-range scale; *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

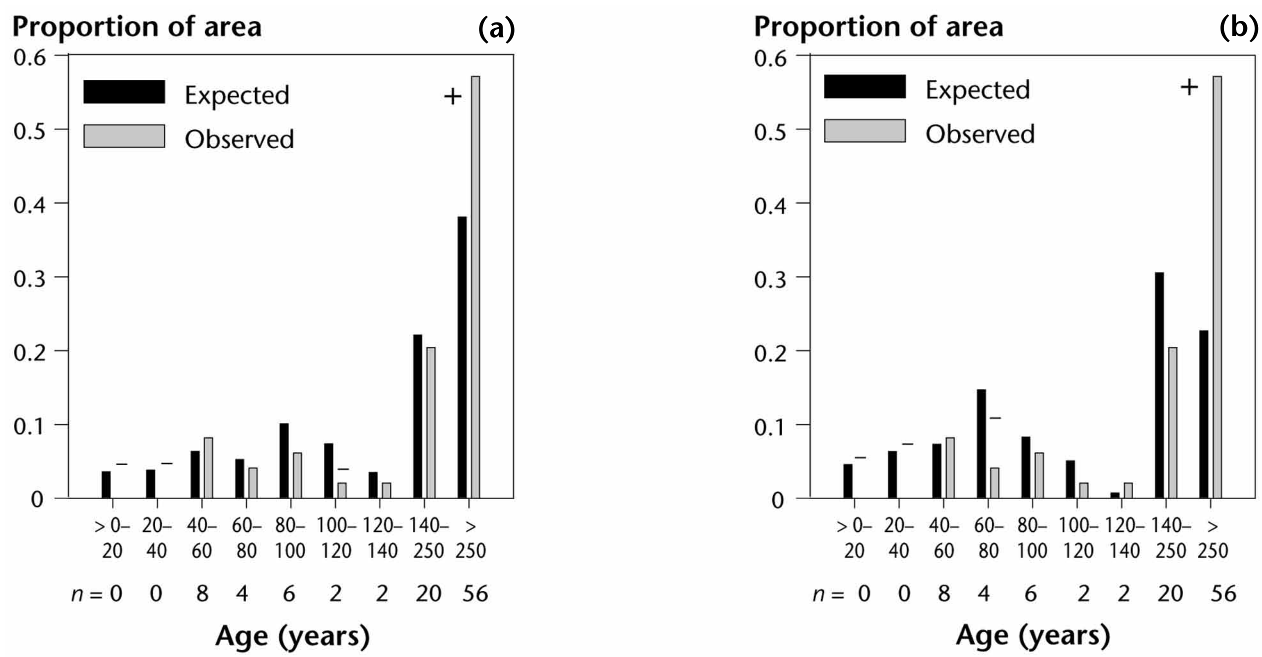

FIGURE 9. Forest age classes used by goats relative to their availability at: (a) study-area scale and (b) winter-range scale; *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

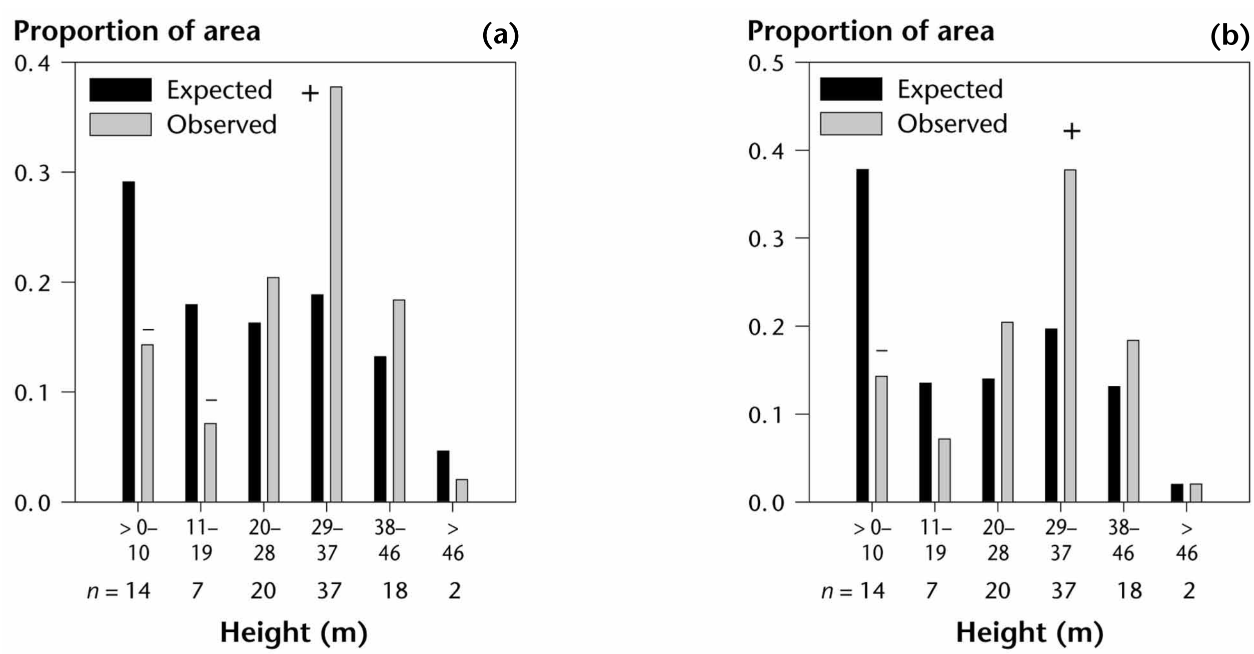

FIGURE 10. Forest height classes used by goats relative to their availability at: (a) study-area scale and (b) winter-range scale; *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

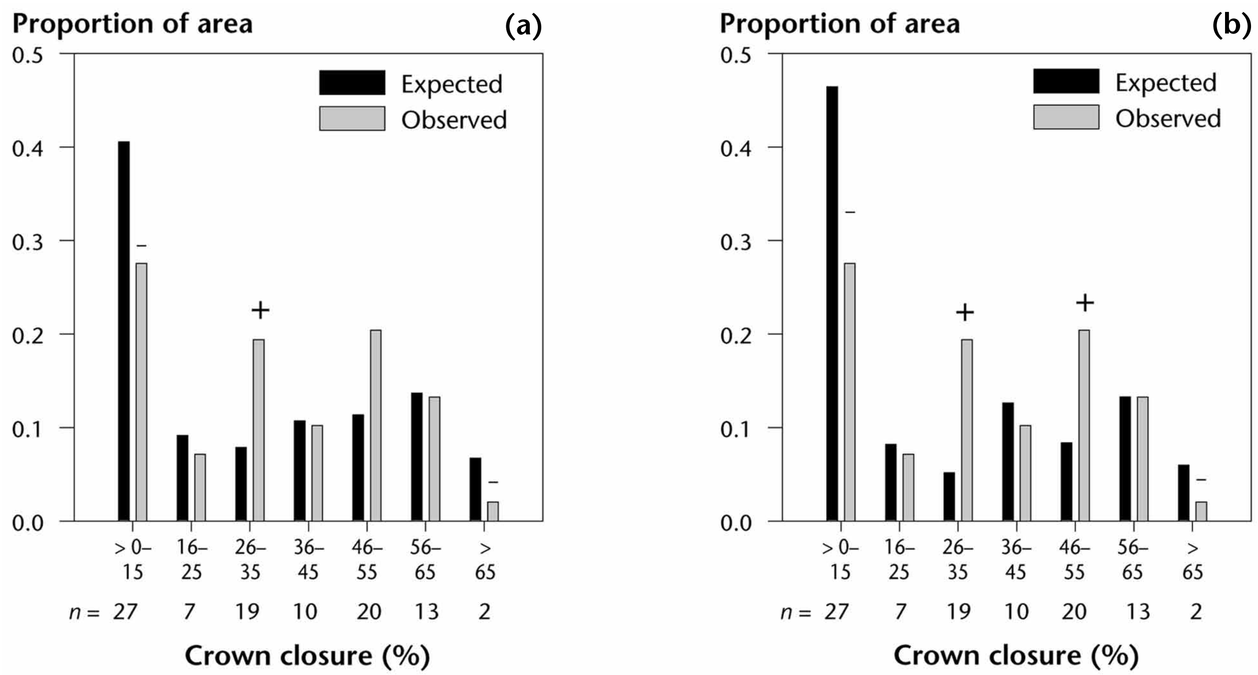

FIGURE 11. Forest crown closure classes used by goats relative to their availability at: (a) study-area scale and (b) winter-range scale; *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

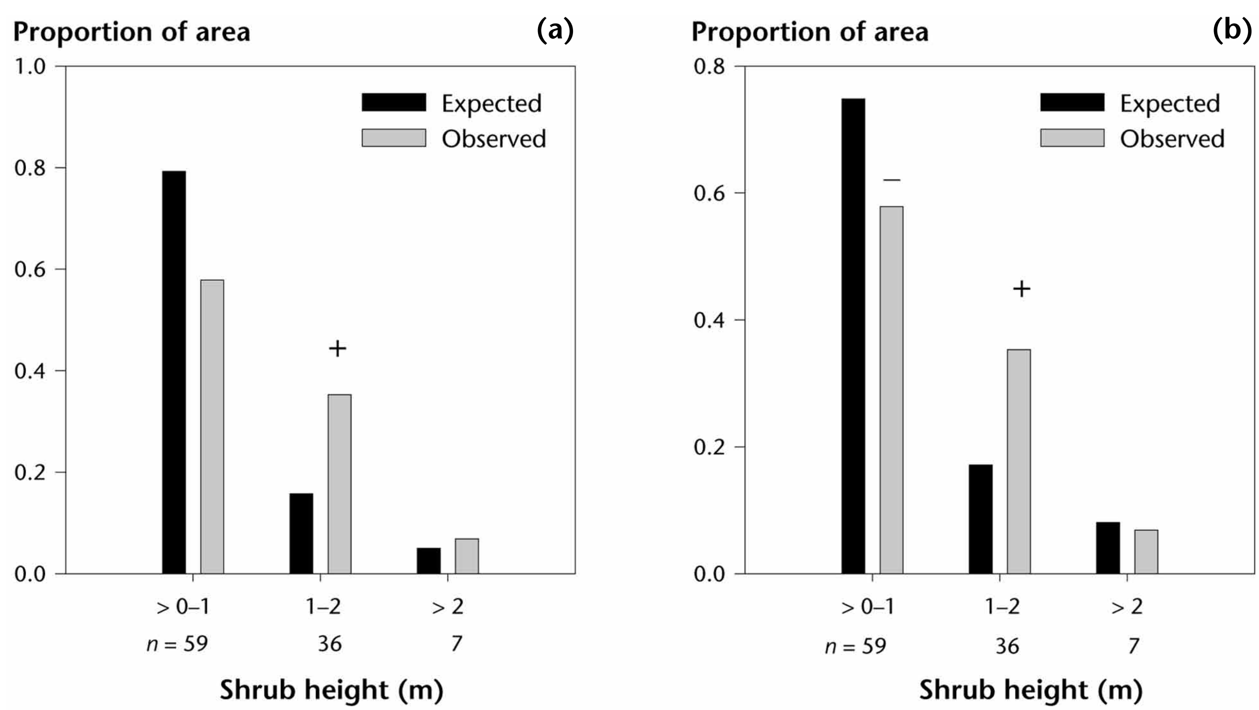

figure 12. Shrub height (m) classes used by goats relative to their availability at: (a) study-area scale and (b) winter-range scale; *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

TABLE 4. Mean distances of goat locations and random points to rock outcrops

	Mean distances (m)	
Variant	**Goat locations to rock outcrops**	**Random points to rock outcrops**
All	98.8	108.4
CWHvm1	168.4	342.8
CWHvm2	118.2	142.0
MHmm1	83.4	69.8

In the study area, goats selected elevation ranges of 600–1200 m (Figure 14) and slopes of 41–60°, and underutilized slopes of less than 30° (Figure 15) relative to availability. In the cumulative winter range, goats selected elevations of 900–1200 m (Figure 14), and slope classes of 41–50° (Figure 15).

Polygons consisting of at least 10% rock outcrop were nearly continuously distributed in the Lahlah and Satsalla watersheds (Figure 16). The percentage of the landscape occupied by these rock outcrops increased with elevation. Rock-outcrop polygons covered 11.8% of the CWHvm1, 25.9% of the CWHvm2, and 40.7% of the MHmm1 subzone variant. Fewer mountain goat locations were in rock-outcrop polygons than we expected. Only 31% of all female locations were in these polygons, although they comprised 46% of the study area. However, many winter locations were located adjacent to, or below, rock-outcrop polygons (Figure 16).

For all subzone variant female goat locations, the overall mean distance of locations to the nearest rock-outcrop polygon was 98.8 m (Table 4, SE = 11.9), while the furthest distance was 571.4 m. Most (75%) pooled locations were within 150 m of rock-outcrop polygons. At 108.4 m, the mean overall distance of random points to the nearest rock outcrop was similar to the mean distance between rock outcrops and goats (98.8 m) (Table 4). However, in the CWHvm1, mean distance from random points to rock outcrops (342.8 m) was more than double that of goat locations (168.4 m).

Discussion

Our failure to detect mountain goat selection for particular forested site series could be related to sampling conditions, or it could be a function of the generalist diet of mountain goats. The high number of site series available in the three forested variants of our study area reduced the number of expected goat locations per site series and increased the sample size necessary to detect selection. Although we reduced the number of potential site series to those used at least once, we were unable to detect selection for this habitat feature. Alternatively, mountain goats may not select for site series. Goats are known to forage on a very broad assortment of plant species (Hjeljord 1973; Fox *et al.* 1989). Fox and Smith (1988) observed that coastal goats appear to select specific forage in the beginning of winter, but rely heavily on remaining available plants, such as conifers, mosses and lichens, in late winter as forage becomes less available. Coastal goat diets contain only small percentages of forbs and shrubs and low amounts of graminoids during winter (Fox and Smith 1988; Fox *et al.* 1989). Terrain and canopy attributes likely play a larger role in guiding goat habitat selection.

In our study, mountain goats selected old forests on warm-aspect, steep slopes at low to mid-elevations, similar to other coastal populations (Hebert and Turnbull 1977; Schoen *et al.* 1980; Fox 1983; Smith 1994). Goats selected western hemlock as a leading stand species and sites with a shrub layer 1 to 2 m in height. Although Smith (1994) observed that higher timber volumes contributed positively to a predictive discriminant function analysis model of winter-habitat selection, we observed that goats selected habitats with only moderate forest volumes and crown closures similar to Taylor *et al.* (2006). During moderate snowpack years, goats use a wide range of forest canopies. For example, in our study area, goats were positively associated with stands from 25 to 55% crown closure.

The selection of moderate forest volumes by goats in the Kingcome River study area may result from the greater use of CWHvm2 and MHmm1 variants relative to that of CWHvm1. The CWHvm1 variant consisted of larger forest volumes and lower availability of rock outcrop than the other variants. A more biologically meaningful interpretation for the selection of moderate crown closures could be related to lichen abundance and winter severity during the study period. Goats frequently feed on old forest litterfall (Fox *et al.* 1989) and lichen can be an important component of goats' diets in late winter (Fox and Smith 1988).

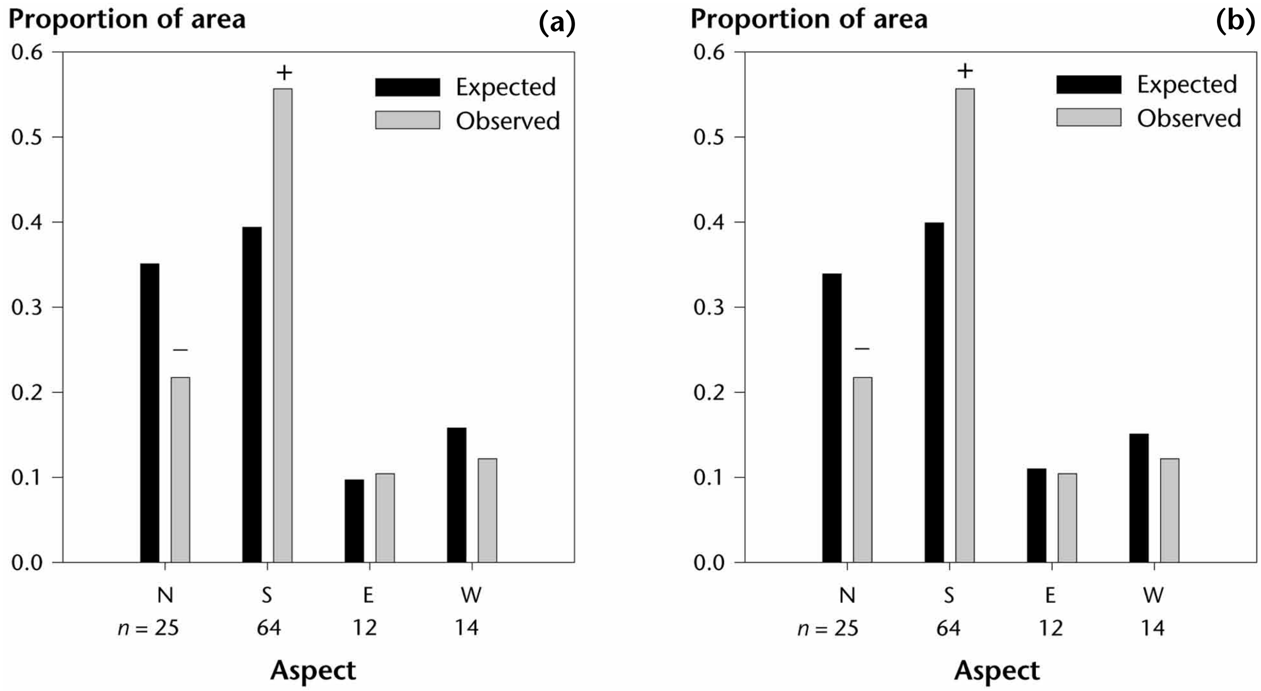

FIGURE 13. Aspects used by goats relative to their availability at: (a) study-area scale and (b) winter-range scale (aspect classes described in Table 1); *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

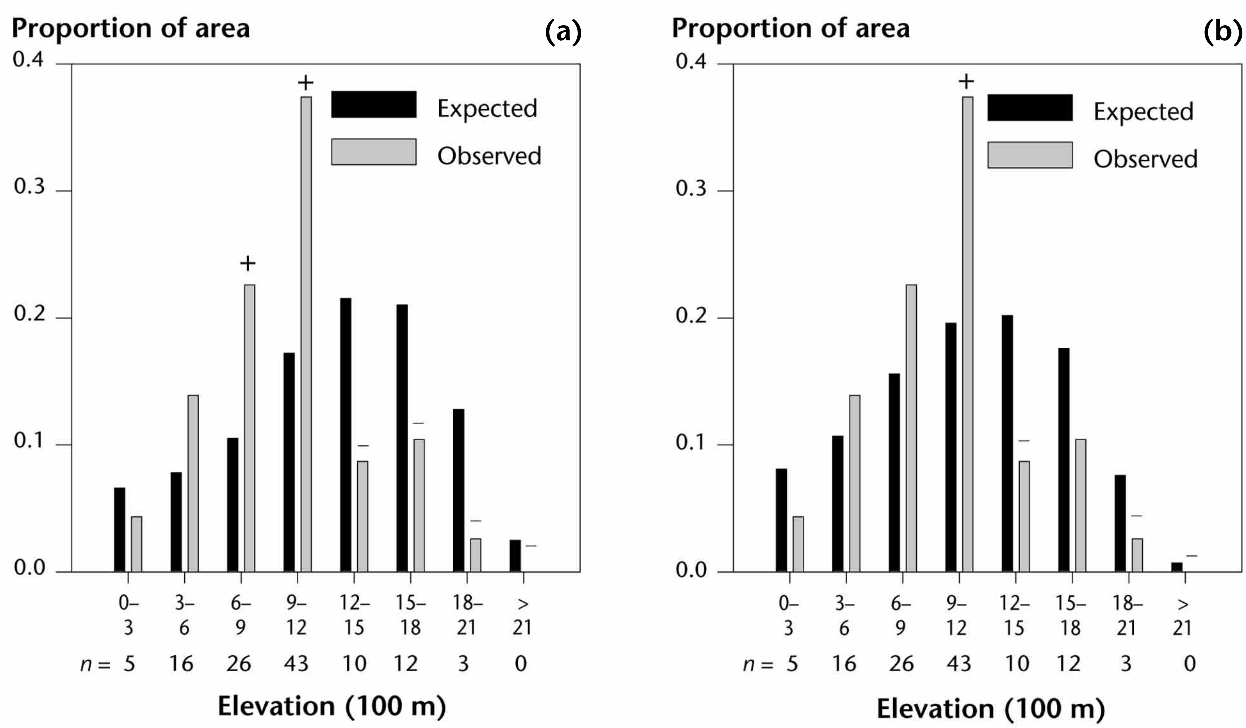

FIGURE 14. Elevations (in 100 m) used by goats relative to their availability at: (a) study-area scale and (b) winter-range scale; *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

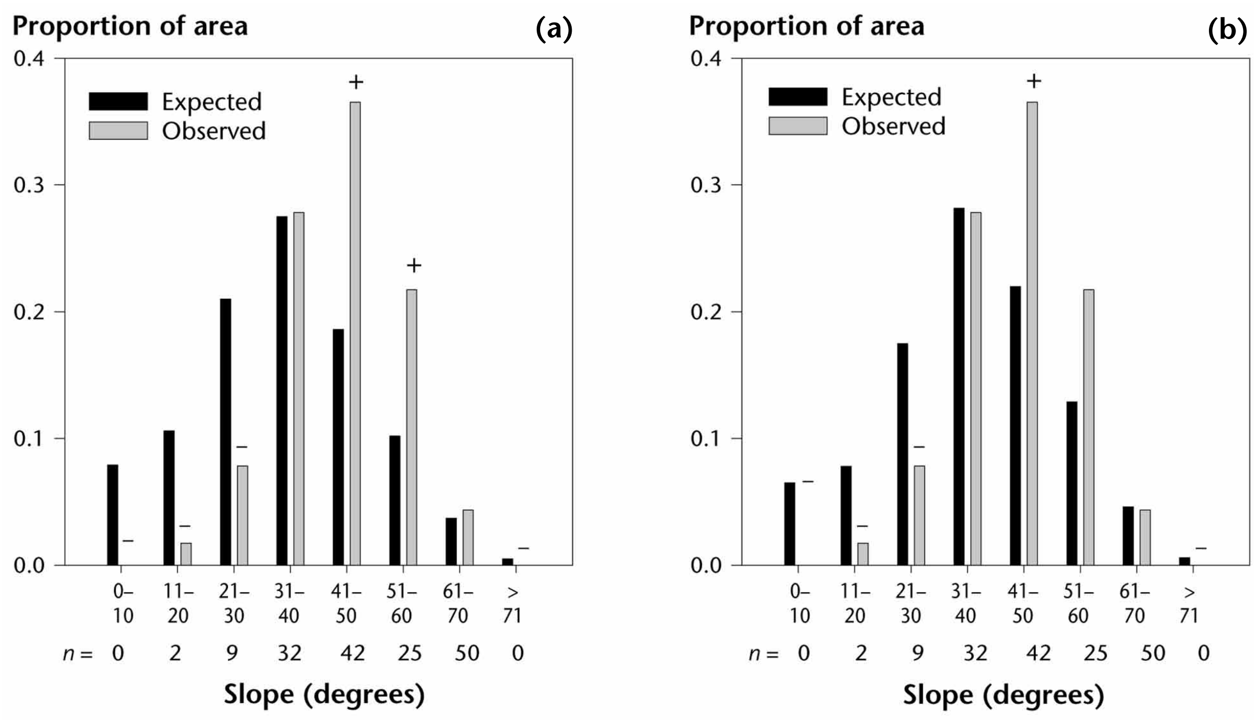

FIGURE 15. Slope (in degrees) used by goats relative to its availability at: (a) study-area scale and (b) winter-range scale; *n* = number of observations per category; + or – indicates which specific categories were used in greater or lesser proportions than availability.

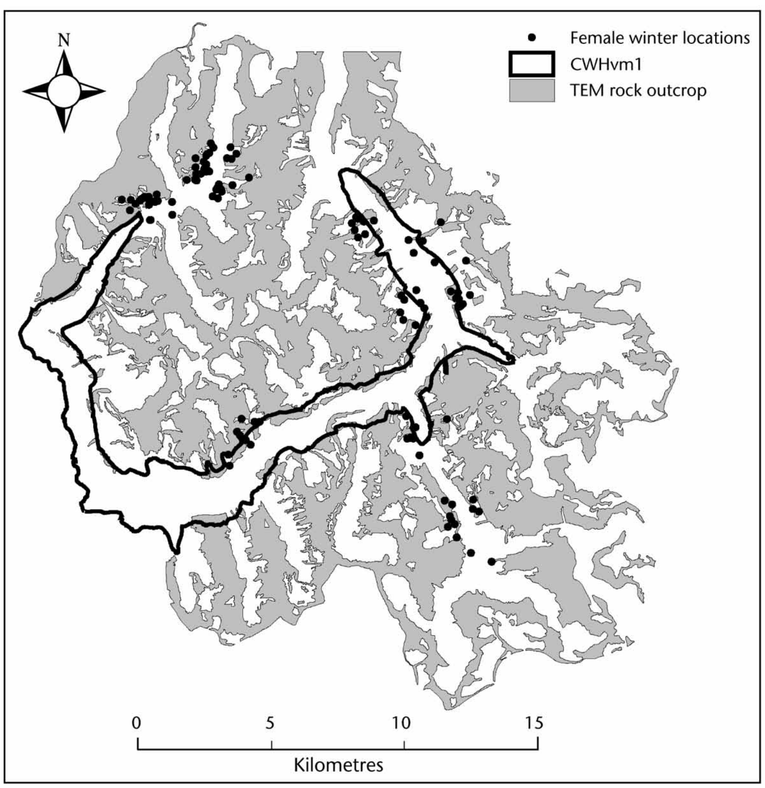

FIGURE 16. Rock-outcrop polygons in relation to female goat locations and the CWHvm1 subzone variant.

Epiphytic lichen abundance and diversity can increase with canopy openness (Pipp *et al.* 2001). Thus, relatively moderate crown closures could potentially be selected during certain weather conditions.

Selection by goats for higher crown closures and volumes may vary with changes in winter severity. Goats likely select habitats with higher crown closure and therefore reduced snowpacks during high snowfall periods to reduce energy expenditure (Daily and Hobbs 1989), which is similar to the habitat selection patterns of other British Columbia coastal ungulates. During severe snowpack winters, goats are more likely to use forest habitats with large, wide crowns of greater than 60% mean crown closure, which are best at providing snow interception cover (Nyberg and Janz 1990).

Our data were primarily derived from two winters that did not appear to have above-average snowpack levels. Supporting weather data was limited because snowpack can vary with elevation and the weather station sites were situated at higher elevations than goat locations. However, in general, snowpack levels in 1994 were below the 30-year average, were average in 1995, and were well-below average in 1996 (River Forecast and Snow Surveys 1994–1996).

We observed female goats to show relatively high site fidelity for winter ranges. Similarly, a 5-year Alaskan study of 43 radio-collared mountain goats showed that 30% of adult males and 90% of females returned to their respective winter ranges (Nichols 1985). We observed a very high proportion of overlapping winter ranges (83%) between years despite our small sample sizes. The average distance we observed between centres of individual annual ranges was 484 m.

Our observation that most goat locations were less than 150 m from rock outcrops supports other research on goat habitat. Suitable habitat has been described as being less than 400 m from escape terrain on the coast in Alaska (Smith 1994). Mean distance of random locations to rock outcrops was similar to the mean distance of goat locations to rock outcrops when subzone variants were pooled. Escape terrain may not be a limiting factor in the Kingcome River study area. However, greater distances to escape terrain in the CWHvm1 could partly explain the goats' higher selection of the CWHvm2. During the relatively mild winters of this study, the CWHvm2 may have offered goats the best compromise between low snowpack foraging areas and proximity to escape terrain.

The use of subzone variants by mountain goats in the Kingcome River study area initially indicated that the amount of goat habitat at risk of harvest by logging might be relatively low. Operability constraints for forest harvest in the CWHvm2 are relatively high in some landscape units (i.e., Upper Kingcome; B.C. Ministry of Sustainable Resource Management and B.C. Ministry of Forests 2002), while goats used the CWHvm1 variant relatively infrequently. Similar use of subzone variants during two average, or low, snowpack years was observed from 18 GPS-collared mountain goats in Bute and Toba Inlets, in south coastal British Columbia (Taylor *et al.* 2006). Pooled data, analyzed at a similar broad scale, showed that males and females were both positively associated with CWHvm2, while male use was in proportion to CWHvm1 availability, and female use was less than CWHvm1 availability.

Habitat use during more severe winters, which are defined by longer lasting and deeper than normal snowpacks at lower elevations, may be more important for goat survival. For example, Rideout (1974) found that juvenile goat mortality varied with winter severity. During such winters, the use and importance of the low-elevation variants such as the CWHvm1 to mountain goats may increase.

Further limitations of this study may have affected our interpretation of mountain goat habitat use. The sample size of goat locations in this data set is limited and represents habitat used during weather conditions appropriate for aerial telemetry flights. Choices of habitat use were constrained to some degree by the lack of old-growth forest available at lower elevations due to prior logging. Although our data might have shown goats selected additional habitat categories with higher sample sizes and power, we have highlighted goat habitat selection or avoidance only where significant; risk management is left to respective managers.

Outside of CWHvm1 habitat, which is likely used more heavily during greater snowpack years, the habitats most often altered by logging activity would be operable forest in the CWHvm2 variant. Most relevant are habitats with slopes from 31 to 40° (60.1–83.9%) where goats use slopes in proportion with availability. In this study, goats were positively associated with steeper slopes of 40–60° (83.9–173.2%), which are typically too steep for current harvest practices. However, helicopter logging that involves the removal of single stems or small patches appears to be increasing in these areas.

Management Implications

Our findings, which indicate goats select winter habitat in old forests on moderately steep slopes with southerly aspects near escape terrain, are consistent with past coastal mountain goat research (Hebert and Turnbull 1977; Schoen *et al.* 1980; Fox 1983; Smith 1994; Taylor *et al.* 2006). These attributes are likely associated with lower snow depths, higher available amounts of forage, and reduced energy expenditures for goats. We also found that indicators of coastal goat winter habitat include western hemlock-leading stands and the presence of shrubs from 1 to 2 m tall.

Similar to another coastal British Columbia study (Taylor *et al.* 2006) conducted during years of low to average snowfall, our study found that goats selected moderate volume forests and most frequently used habitats above the CWHvm1 subzone variant. Consequently, as suggested by other researchers, the area of harvestable coastal forest land base that overlaps with goat winter habitat during years of low to moderate snowpack may be limited (Fox *et al.*1989; Taylor *et al.* 2006).

However, some harvestable forest may become more significant as goat habitat during deep-snow periods. During years of higher snowfall, dense coastal snowpacks force goats to use habitats at lower elevations (Fox and Smith 1988; Fox *et al.* 1989; Smith 1994; Gordon and Reynolds 2000), and during such years, goats have suffered higher rates of mortality (Rideout 1974; Smith 1984 in Smith 1986). Maintaining snow interception cover adjacent to escape terrain at lower elevations could have important population implications during heavy snowpack years. For this reason, we recommend that goat winter ranges include some old forest in the CWHvm1 subzone variant.

Additionally, as others have noted (i.e., Demarchi *et al.* 2000), forestry conflicts with goat habitat will likely increase as timber supplies at low elevations decrease. In recent years, forest harvesting in coastal British Columbia has occurred at higher elevations and in more rugged terrain due to revised operability-line mapping and a rapid expansion in heli-logging operations. Given this trend, it is important for managers to assess whether planned harvest areas conflict with goat winter habitat. Ground surveys should be conducted to determine whether sites at elevations below known winter ranges indicate goat use.

Also, considering the high site fidelity and dispersed nature of goat populations in coastal valleys, protected areas might best be dispersed across the landscape, rather than concentrated in fewer, larger areas that are considered best habitat.

Future research should attempt to observe the effects of relatively new harvest techniques, such as single-tree selection, on goat winter habitat in coastal forests. The influence of larger stem removal and selective harvest techniques in stands should be evaluated to determine whether stand snow-interception function is affected.

Future research should attempt to observe the effects of relatively new harvest techniques, such as single-tree selection, on goat winter habitat in coastal forests. The influence of larger stem removal and selective harvest techniques in stands should be evaluated to determine whether stand snow-interception function is affected. Other important research should be directed towards a better understanding of goat population trends that may be associated with landscape-level forest changes.

Newer technology, such as the use of GPS radio-telemetry collars, allows for better observations of goat-movement patterns, particularly at the landscape level. For example, the study of movements between fragmented forest landscapes could address important issues such as subpopulation linkages and travel corridors. Studies observing goat habitat use before and after logging, particularly in partial-cut systems of variable canopy retention, would be beneficial. Habitat studies using GPS radio-telemetry collars could also be used to better determine the degree of overlap between goat habitats and operable forest areas.

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Test Your Knowledge . . .

Winter habitat use by mountain goats in the Kingcome River drainage of coastal British Columbia

How well can you recall some of the main messages in the preceding Research Report? Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. In our coastal study area, mountain goats made highest use and selection of which following ecosystem variant(s) during winter?
   A) CWHvm1(Submontane Very Wet Maritime Coastal Western Hemlock)
   B) CWHvm2 (Montane Very Wet Maritime Coastal Western Hemlock) and MHmm1 (Windward Moist Maritime Mountain Hemlock)
   C) AT (Alpine tundra)

2. What percentage of mountain goat observations occurred within forested polygons?
   A) 30%
   B) 60%
   C) 85%

3. Habitat occurring in which elevation range was used most frequently by mountain goats?
   A) 300–600 m
   B) 600–1200 m
   C) >1200 m

Answers

1. B 2. C 3. B