

*Mountain Goat
Winter Habitat Suitability Mapping
In the Kispiox Forest District*

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FRBC Wildlife Habitat Inventory Project

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INTRODUCTION

The mapping project documented in this report was conceived in order to provide information necessary for achievement of stated objectives in the Kispiox Land and Resource Management Plan (British Columbia Government 1996):

- “To maintain natural ecosystems and habitat to sustain viable populations of all native wildlife within their natural ranges.”
- “To protect or enhance populations and habitat of rare or endangered and regionally significant species.” (British Columbia Government 1996:44)

The mountain goat (*Oreamnos americanus*) is one of the native and regionally significant species within the Kispiox LRMP area. Because of the significance of this species to the local public, the Kispiox LRMP also includes specific strategies for considering mountain goats in the context of broader LRMP Objectives:

- “Mountain goat winter range will be identified at the landscape planning level.”
- “Effects of access on mountain goats will be addressed at the landscape planning level.”
- “Connectivity, between alpine and lower elevation winter ranges for annual movements, and between landscapes for population dispersal, will be maintained through landscape planning.” (British Columbia Government 1996:46)

At the time the LRMP was prepared, available mapping of goat habitat in the Kispiox forest district was very limited. Although the LRMP itself included a small-scale map of mountain goat habitat suitability, generalised across all seasons and based on 1:250,000 biophysical map units (Turney 1996; British Columbia Government 1996:42), this map was insufficiently detailed for the landscape level planning envisioned by the LRMP.

The goal of this mapping project was therefore to produce 1:20,000 scale maps of habitat suitability for goats in the LRMP planning area, maps which the project team hopes will suffice for the landscape level planning contemplated in the LRMP.

The project team narrowed the focus of mapping efforts to the winter season because winter is generally recognized as the most limiting time for mountain goats, particularly through limited access to escape terrain and food in close proximity (Hebert and Turnbull 1977, Smith 1977, Fox *et al.* 1989). We mapped suitability (the quality of the habitat under current conditions), rather than capability (the optimum habitat condition under any possible seral condition), because we felt that suitability is easier to estimate from existing databases, is relatively stable over time for this species (which uses primarily un-forested habitats or adjacent mature forest stands), and is the most useful information layer for landscape planning with a relatively short time horizon.

PROJECT AREA

The area covered by this project includes all of the Kispiox Forest District in west-central British Columbia (Figure 1). The area is ecologically diverse, and includes portions of the ecological subdivisions listed in Table 1. The District covers portions of the Skeena River drainage, and a series of mountain ranges comprising the eastern side of the coastal ranges.

Table 1. Ecological subdivisions included in Planning Area

<u>Ecological subdivision</u>	<u>Units included in Planning Area</u>
Ecoprovinces	Sub-Boreal Interior, Coast and Mountains
Ecoregions	Skeena Mountains, Nass Basin (NAB), Nass Ranges (NAR)
Ecosections	Southern Skeena Mountains (SSM), Northern Skeena Mountains (NSM)
Biogeoclimatic Zones	SBSmc2, ESSFwv, ESSFmc, ICH mc1, ICHmc2, CWHws2, MHmm2, AT

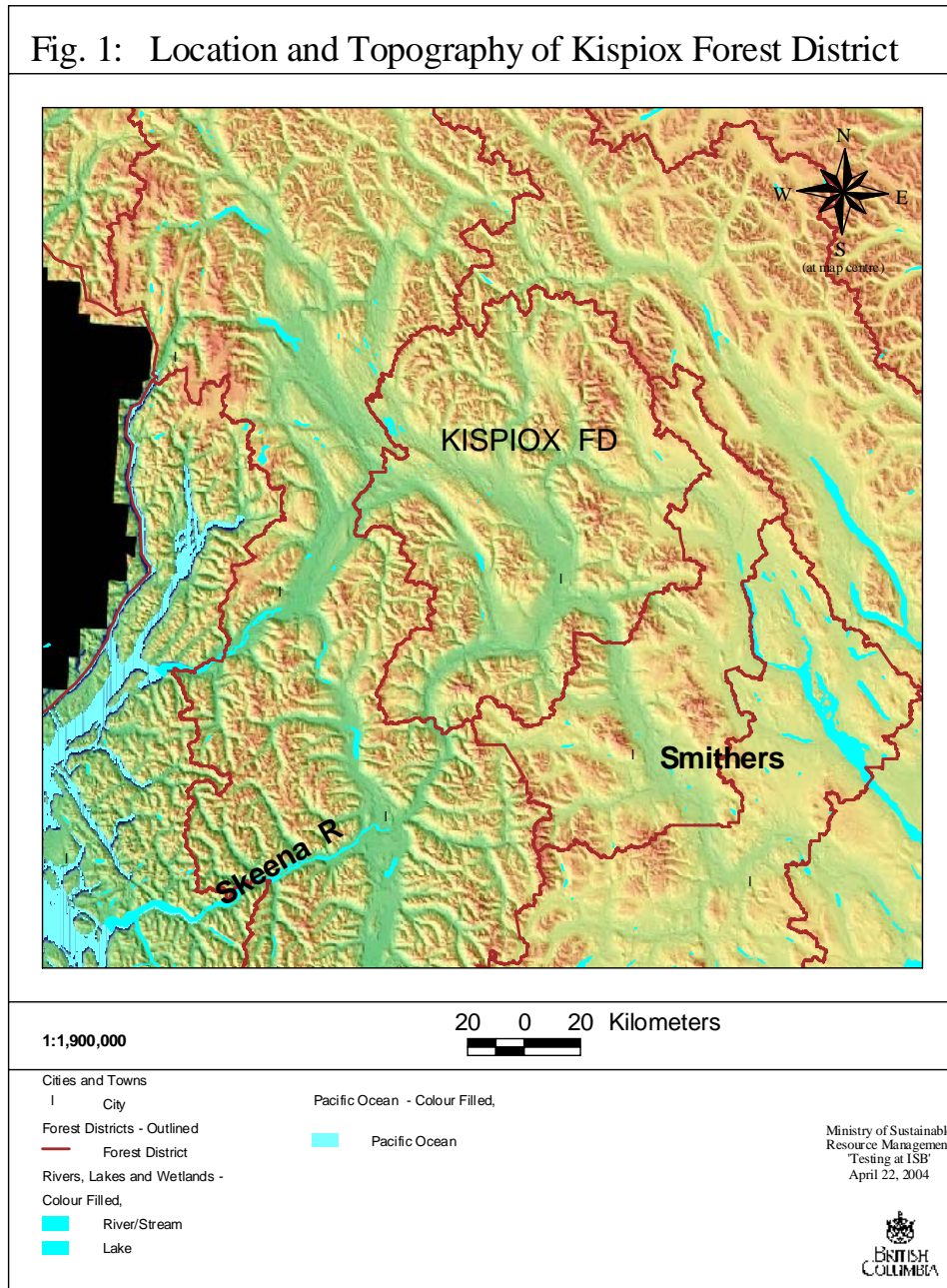
METHODS and RESULTS

Overall Approach

This mapping project was undertaken by a team of government and private sector biologists, working as partners, representing Skeena Cellulose Incorporated (Todd Mahon), the Ministry of Forests (Maggie Marsland, and Don Morgan), the Ministry of Environment (Darren Fillier, James Warren, George Schultze, Tom Smith and Don Reid), and the private sector (Allan Edie). We divided up the key tasks in the production process as follows: project coordination (MM, DR); expert opinion and field knowledge for map development (TM, AE, GS, DF); translation of verbal model to a working GIS model (JW, DM, AE); field testing (DR, DF, GS, JW, TS).

Development and testing of the mapping model progressed through phases described by Brooks (1997) as Development, Calibration, Verification, and Validation. Although Brooks' (1997) discussion refers specifically to Habitat Suitability Index (HSI) models, it applied quite well to the less quantitative modelling approach used here (Resources Inventory Committee 1999). The development phase included assembling all existing information (e.g., literature, expert experience and opinion) regarding factors limiting distribution and habitat choice by mountain goats in the project area, and converting that information into a set of algorithms for predicting habitat quality from data describing habitat characteristics. Calibration included reviewing initial maps to check that identified habitats included all obviously important ones, and excluded areas that were apparently not habitat. Verification consisted of ranking a set of habitats for their quality independently of the mapping exercise, and comparing the resulting independent ranks with those suggested by draft maps. (Discrepancies here could arise from errors in the habitat inventory layers from which the maps are derived, and/or inappropriate threshold values for key parameters in the model). Validation involved

Fig. 1: Location and Topography of Kispiox Forest District



testing the performance of the model against inventory data on mountain goat populations in the project area.

This report describes development and calibration of the mapping model up to a version that was considered good enough to verify and validate. It then describes the subsequent, verification and validation, and outlines a revised model.

Initial Assumptions for Model Development

The project team made several key assumptions in order to initiate model construction. First, in a general sense, we assumed that recorded habitat preferences reflect habitat requirements, that habitat preferences are reflected in changes in individual fitness, and that preferred habitats are an appropriate focus for management and protection efforts intended to benefit mountain goats.

Second, we assumed that the most important habitats in the study area are similar to those described in the literature on mountain goats. Specifically, we assumed that mountain goats rarely occupy habitat far from suitable escape terrain, and that preference among habitats near escape terrain are determined primarily by forage availability and secondarily by thermal conditions (Fox *et al.* 1989; Smith 1986). We assumed that high quality winter habitat, providing escape terrain with relatively low snow accumulation, combined with nearby foraging habitat, is the most limiting habitat type annually, especially in years with above average snowfall. Further background on assumptions regarding winter security habitat, winter feeding habitat, and winter thermal habitat is provided below:

Winter Security Habitat (Escape Terrain): Mountain goats use cliffs, rocky outcrops and talus slopes, where they can climb out of the reach of predators, as their escape terrain (Hebert 1967, Chadwick 1973, Foster 1982, Schoen and Kirchoff 1982, Stevens 1983, Fox *et al.* 1989). Goats are rarely found more than three to five hundred metres from these essential security habitats (Schoen and Kirchoff 1982, Foster 1982, Smith 1986, Fox *et al.* 1989). These security habitats are most frequently found at relatively high elevation, in the subalpine and alpine. However, goats do use lower elevation canyons and terrain with cliffs, often within the forested landscape, quite extensively in some portions of their range (Foster and Rahe 1985, Smith and Raedeke 1982, Harrison 1999, Turney *et al.* 2000).

Winter Feeding Habitat: Winter foods depend on availability, but the diet is primarily comprised of grasses and sedges, shrubs, lichens and conifers (Chadwick 1973, Thompson 1980, Stevens 1983). These foods can be found on alpine tundra, with or without escape terrain, and also in mature forest or early seral meadow and shrub, with or without escape terrain. In choosing winter range, goats are constrained by finding foraging areas close to or within escape terrain, and by avoiding areas with deep snow. Goats avoid areas with snow depths >50 cm (British Columbia Government 1997). On alpine winter range, goats prefer windblown alpine tundra ridge-tops and cliffs and outcrops where prevailing winds can provide snow-free areas (Hebert 1967, Smith 1977,

Adams and Bailey 1980). In the interior, or on rain-shadow ranges, goats tend to use alpine areas most frequently as winter range. In the Coast Ranges goats tend to use lower elevation, timbered, habitats more frequently in winter, probably because they can avoid the deeper snows by coming to lower elevations and by moving under a closed canopy (Foster 1982, Fox and Smith 1988, Fox *et al.* 1989).

Winter Thermal Habitat: Mountain goats often select south-facing habitats in winter, both in the interior and near the coast, presumably because these slopes are warmer on average and snowmelt is faster when it occurs (Smith 1977, Fox 1978, Schoen and Kirchoff 1982). Mature timber may also provide substantial thermal cover, and protection from wind and precipitation (Smith 1986). Goats will use caves for cover from storms (Smith 1977).

Development and Calibration of the Model

We developed the model in a series of team workshops and meetings during which we discussed the ecology of mountain goats in the study area, the ecological factors limiting population size and distribution, and the habitat conditions goats select or avoid in winter. We decided that we only had enough understanding of goat ecology in this area to rank the land base into four categories of winter habitat suitability: 1 (High), 2 (Moderate), 3 (Low), 4 (Nil). Development of the model was gradual and iterative, and included repetitive calibration and testing to ensure that draft maps included all four suitability classes in meaningful amounts. The model available by the time verification and validation phases began was version 6, and is included in Appendix 1.

One of the challenges in the development process was the limited inventory data available for describing habitats. Neither Terrestrial Ecosystem Mapping nor Predictive Ecosystem Mapping was available for the Kispiox FD. However, we agreed that mountain goats use habitats primarily in response to available escape terrain which serves as refuge from predators, and secondarily in response to available food in areas close to escape terrain. In the absence of ecosystem mapping, we felt that escape terrain could be adequately derived from detailed topographic information contained in Terrain Resource Information Mapping (TRIM), and that available food could be derived from Forest Cover mapping.

Escape Terrain:

We assumed that the core, highest quality winter habitats will be escape terrain where goats can obtain refuge from predators, but still have nearby access to food. We assumed that winter escape terrain could be defined in terms of three variables: slope steepness (with escape terrain consisting of slopes steep enough to produce rock outcroppings or cliffs), an upper elevation constraint (above which food resources adjacent to escape terrain are likely very limited), and aspect (which reflects the observed preference of goats for warmer southerly aspects).

The first analytical step was to convert TRIM data to slope steepness, a task completed by using a digital elevation model (DEM). We were unsure of the spatial extent of slopes of various steepness in the KFD, so we went through a series of trials with the DEM during which we varied the break points in slope steepness between the

habitat classes. We could not test the lower limit of escape terrain steepness (slopes below which there is no rocky outcropping) without field verification, so we chose this to be 40 degrees. We then divided all slopes steeper than 40 degrees into the three classes, assuming that goats would prefer the intermediate of these three classes. We found that slopes greater than 70 degrees were rare (0.19% of the land base) and that a fairly substantial portion of the land base was steeper than 60 degrees, so we used 60 degrees as one class break. We chose 50 degrees, midpoint between 40 and 60 degrees, as the other class break.

We chose 1800 m as the elevation threshold above which goat habitat use is likely to decline due to the limiting effects of winter climate on growth of alpine forage plants. This limit was based on known winter locations of goats from previous surveys.

We assumed that the warmer of two aspect classes spanned 135 to 270 degrees, and the colder class the remaining range.

The DEM had a pixel size of 25 x 25 metres, so the application of the above rules produced a wide range of polygon sizes for escape terrain. We recognized that many of the smaller polygons were probably not large enough to be meaningful goat range, and that, when these small polygons were buffered with food habitat, they would exaggerate the spatial extent of goat range. To correct this problem, we chose a minimum polygon size of 1 hectare, or more explicitly, 16 contiguous pixels, of the same escape rating class (1, 2 or 3), where contiguity is defined as any pixel sharing a common side or a corner (i.e. 8 potential pixels). Polygons containing less than 1 ha of steep terrain were rated as class 4 for escape suitability.

Sequential application of the above rules regarding steepness, elevation and aspect produced 19 potential combinations for rating of escape terrain. Details of these are best understood by referring to Appendix 1.

Feeding habitats:

After it had defined all the escape terrain polygons, our model then circumscribed buffers around these polygons to account for the movements of goats away from escape terrain to find both food and sometimes shelter during inclement weather. We used two classes of buffer, the first and generally higher suitability one being within 200 m of escape terrain, and the second more than 200 but within 500 metres. Each of these buffers was given the same or a reduced suitability rating as adjacent escape terrain, the rating depending on Forest Cover data. Detailed rating rules are tabulated in Appendix 1, but deserve brief elaboration here.

First we differentiated forested polygons by age class into two groups. The first group included age classes 1 (1-20 yrs, or early seral) and age classes 7, 8 and 9 (>120 yrs, or old growth). These age classes were considered valuable because of their ability to produce substantial forage in the shrub and herb layers, in the form of regenerating understorey conifers (primarily *Abies lasiocarpa*) or arboreal lichens. The second group included age classes 2 through 6 (21-120 yrs, or mid to mature seral), which were considered to produce less forage if crown closure was high (26 to 100%). Areas within 200 meters of escape terrain received the same rating as adjacent escape terrain unless they were closed canopy forests in age classes 2 through 6, in which case they were rated as class 3. Areas between 200 and 500 m from escape terrain received the same rating as escape terrain unless they were closed canopy forests in age classes 2 through 6, in which

case they received a rating of 3, or unless they were in age classes 1 and 7 through 9, in which case they received a rating one level lower than the adjacent escape terrain, but never lower than class 3.

When polygons in the buffers were alpine tundra (A), alpine forest or krummholz (AF), non-productive brush (NPBR), non-productive burn (NPBU), non-productive forest (NP), swamp (SWAMP), clay bank (CL), non-commercial brush (NCBR), or insufficiently stocked (NSR), we gave those in the 0-200 m buffer the same rating as the escape terrain, and reduced the rating by one class, but never below class 3, for those in the 200-500 m buffer. Polygons classified as Rock (R), in either buffer, received the same rating as the escape terrain. Areas greater than 500 m from escape terrain, and Glaciers and icefields in TRIM were given class 4 (Nil), .

Verification of the Model.

Verification included testing the reliability of three parameters used in the mapping model, - aspect, elevation, and slope steepness, - based on the locations of goats in previous winter inventories, and on the comparison of mapped to observed escape terrain. As part of verification, we also scrutinized the map product for ratings that didn't make sense based on the expected behaviour of the algorithm. This allowed us to uncover some Non Forest Land Use classes that we had overlooked in the calibration. These were: Urban (U), Lakes (L), Rivers (RIV), Gravel Bar (G), Gravel Pit (GR), Clearing (C), Meadow (M), Open Range (OR) and No Typing Available (NTA). We did not gather sufficient site specific information to verify separation of the three suitability classes of habitat.

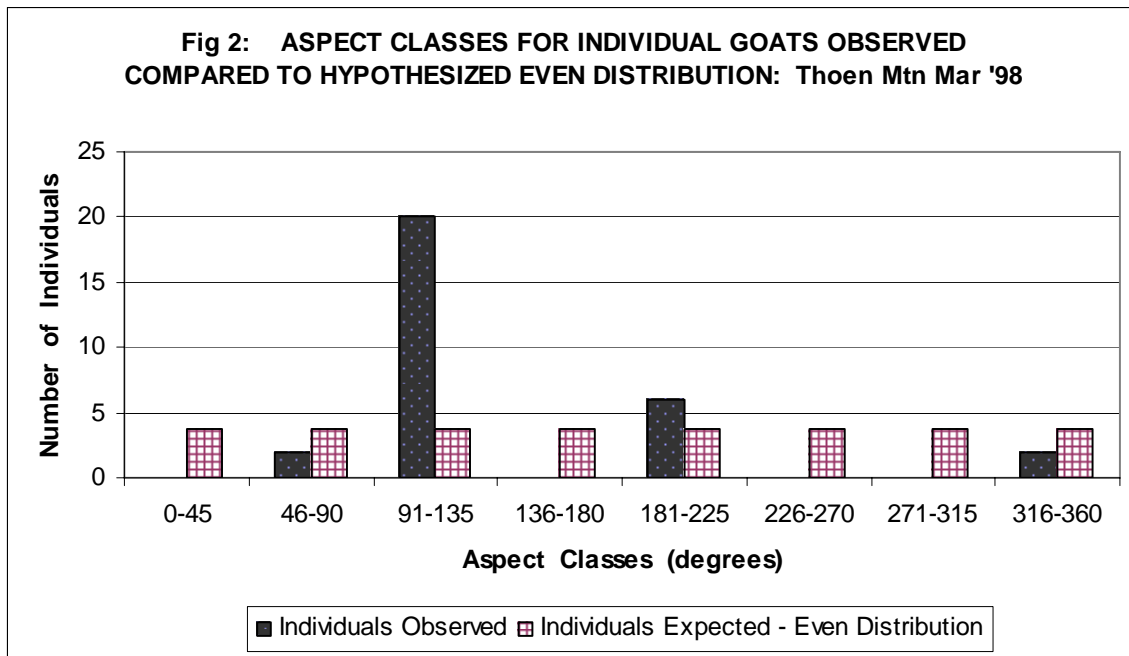
Aspect:

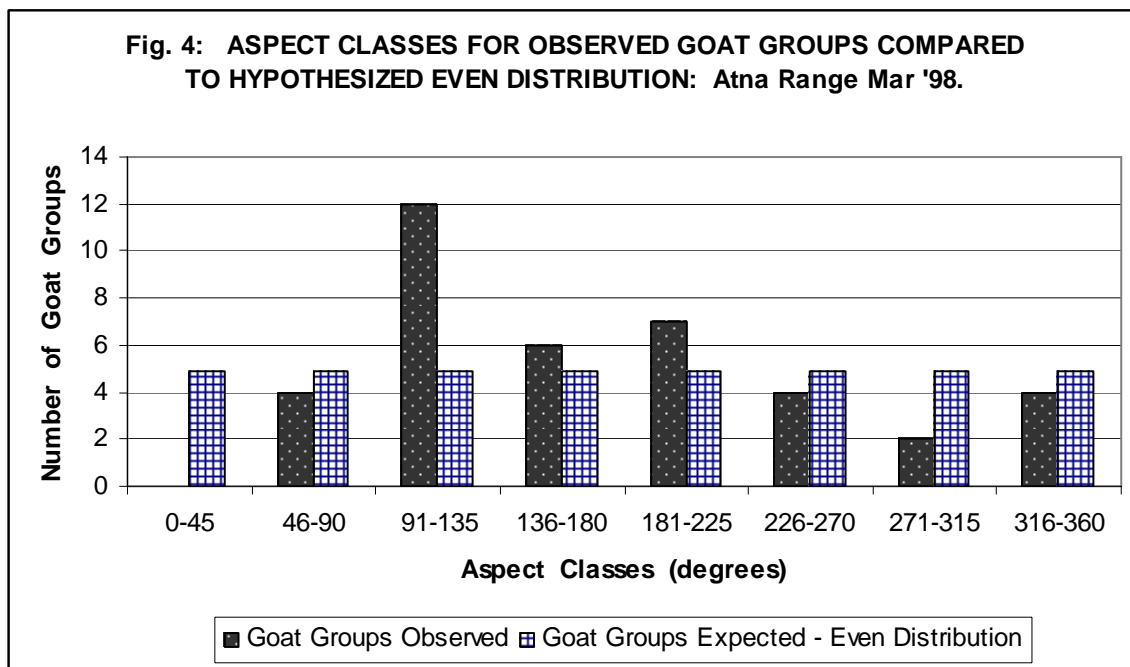
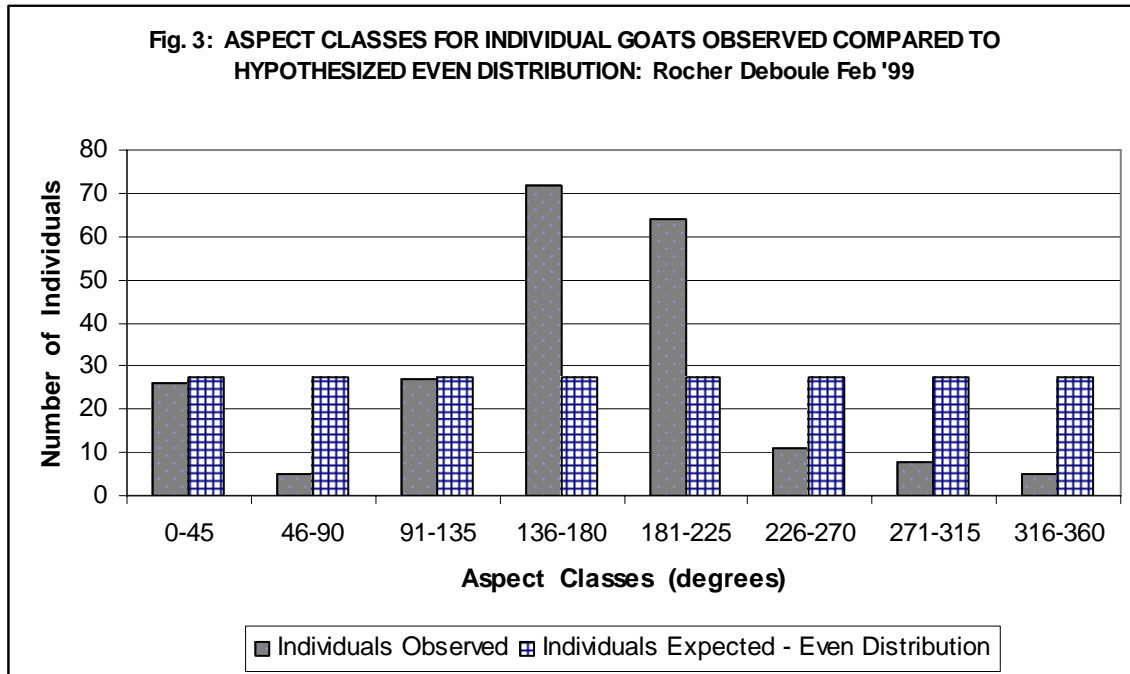
Null Hypothesis: Goats distribute themselves on different aspects in proportion to the availability of the aspect class.

Alternative Hypothesis: Goats choose certain aspect classes in preference to others.

Test. We examined the frequency distributions of aspects of point locations of goats obtained through helicopter based GPS during (a) previous late-winter surveys of goats in the study area, and (b) wide-ranging helicopter surveys of the extent of escape terrain in March 2001. For these analyses, the GPS locations of goat groups were mapped at scales between 1:20,000 or 1:40,000 on a TRIM layer with 20 m contour interval. The aspect of each group's location was determined as the direction perpendicular to the general trend in the contours at the location. These data may suffer from the inherent inaccuracy in the ability of the helicopter GPS to pinpoint the goats, and because of the need to estimate the general trend in the contours at the point. However, there is no reason for these inaccuracies to be biased systematically in any one direction. Nevertheless, data were lumped into eight aspect classes (each with a range of 45 degrees) to smooth out some of the potential inaccuracies.

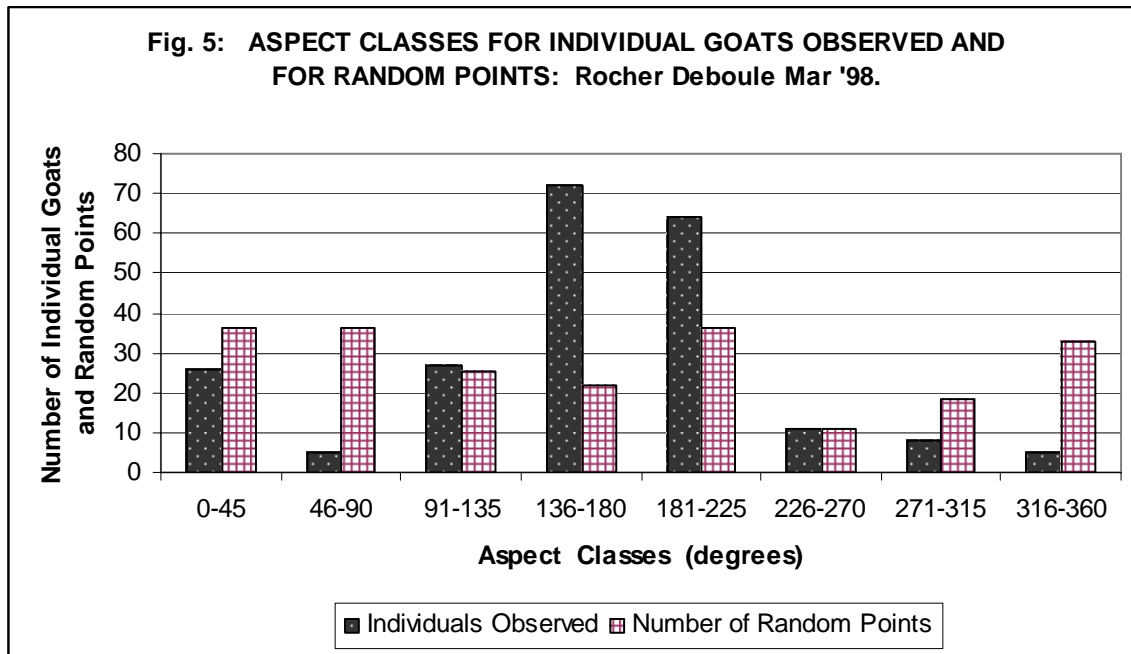
Result: Historical survey data from Thoen Mtn (n=30 individual goats), the Rocher Debole Range (n=218 individual goats), and the Atna Range (n=39 goat groups) indicate that goats do not distribute themselves on all aspects in proportion to their availability, if one assumes that all aspect classes are equally available (Figs. 2, 3 & 4). In the first two figures, each goat is considered an individual data point, even when a member of a group. In the third figure, the aspect class for each goat group, rather than each individual goat, is depicted. In all three cases the results were statistically significant in a Log-likelihood ratio goodness of fit test. G-statistic values for Thoen, Rocher Debole and Atna were, respectively, 67.57, 105.75 and 20.86, with the threshold value for significance being 14.07 with 95% probability and 7 degrees of freedom.





On these three surveys, observers attempted to count all goats on the range. Consequently the survey likely covered all aspect classes in proportion to their availability in the mountain block. However, it is possible that certain aspects are more common than others in certain mountain blocks (though this possibility is reduced by classifying data in broad aspect classes). Consequently we compared the data on aspect classes of individual goats on the Rocher Deboule survey to the aspect classes of a set of

random points (n=60) in the same mountain block (Fig. 5). Once again the null hypothesis was rejected (G-statistic = 178.83, P <0.05, d.f.=7).



The data in Figs 2 through 5 indicate that goats use the northerly aspects (270-360 and 0-90 degrees) less than expected, and most of the southerly aspects (90-225 degrees) more than expected. The exceptions were relatively heavy use of the north-northeast aspects (0-45) on Rocher Deboule range, and only a moderate use of the west-southwest aspects (225-270) in many surveys. These results may reflect the effects of winds on local distributions, with animals using the more easterly exposures for shelter. It is also possible that wind patterns or solar influence may have resulted in relatively unfavourable snow conditions in areas apparently avoided.

Conclusion: In the draft model we assumed goats prefer aspects from 135 to 270 degrees. The verification data suggest the better threshold aspects would be 90 and 270 degrees.

Elevation:

Null Hypothesis: Goats distribute themselves throughout the range of elevations on the mountain range.

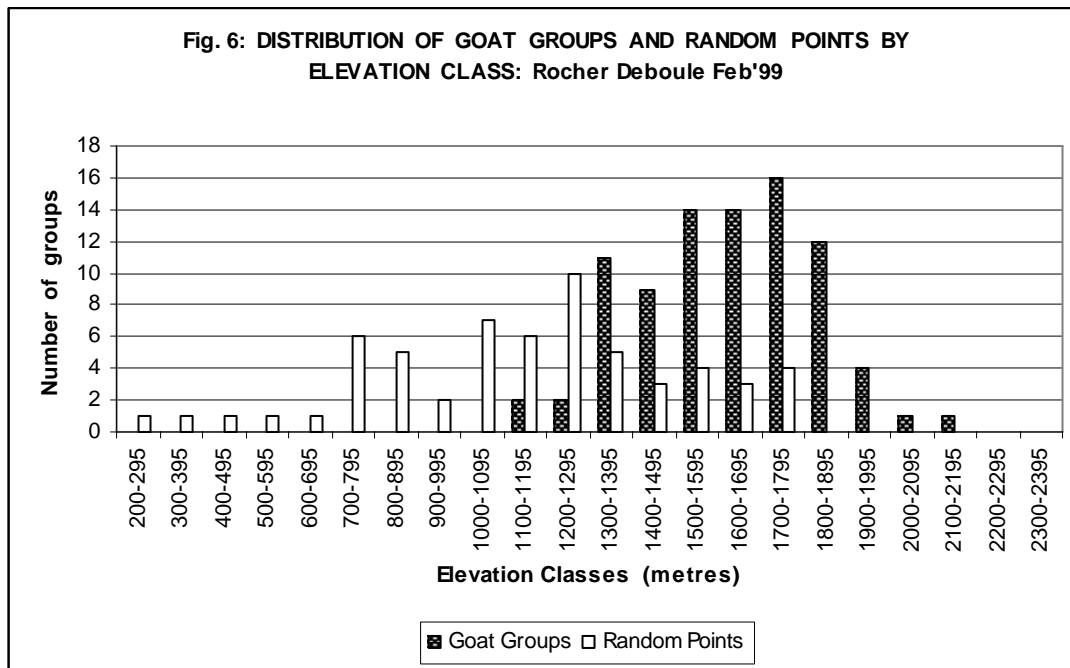
Alternate Hypothesis: Goats occupy a select range of elevations, and rarely go above 1800 m in winter.

Test. We examined the frequency distributions of elevations of point locations of goats obtained through helicopter based GPS during previous, late-winter, surveys of goats in the study area. For these analyses, the GPS locations of goat groups were mapped at scales between 1:20,000 or 1:40,000 on a TRIM layer with 20 m contour interval. The

elevation of each group's location was determined to the nearest 10 m. These data may be somewhat biased in a negative direction (i.e. lower elevation) because the helicopter flies at some horizontal distance from the mountain side

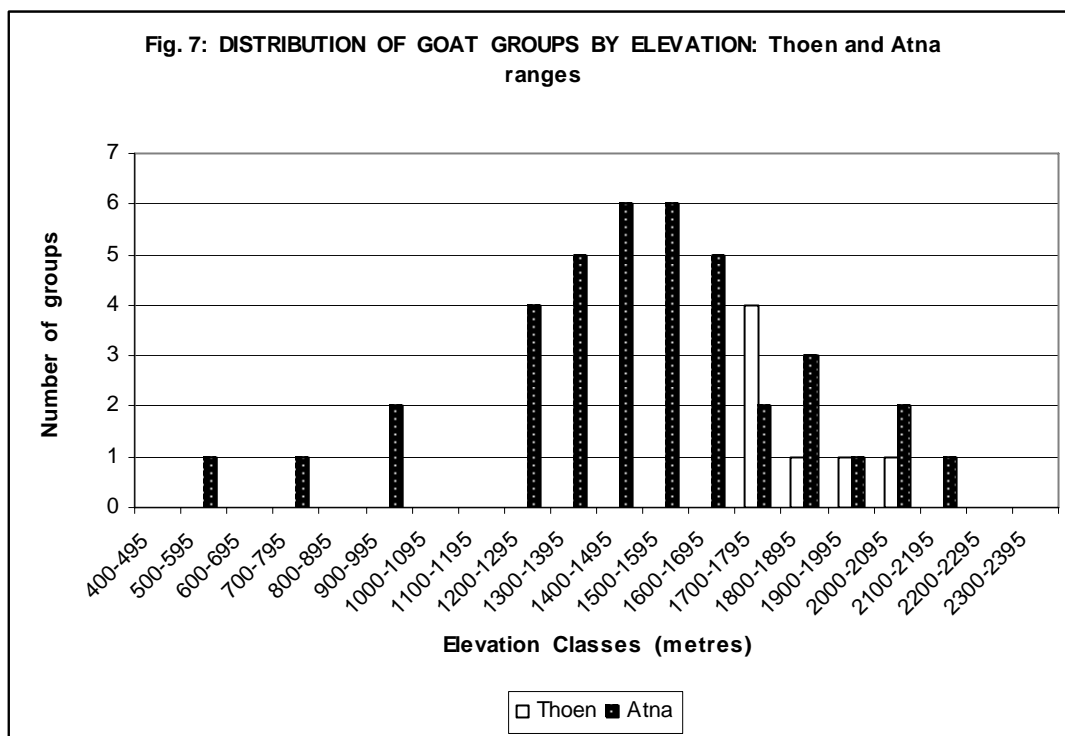
Result: The percentage of individual goat groups below 1800 m on population estimation surveys was 79% for Rocher Deboule range, 57% for Thoen Mtn, and 82% for Atna range (Figs. 6 & 7).

The distribution of elevations used by goats on Rocher Deboule was substantially different from a random distribution of elevations on the same map sheet (Fig. 6) (Log-likelihood ratio = 170.65 > Chi-square with P<0.05 and 19 d.f. of 30.14). This demonstrates the somewhat obvious fact that most winter goat habitat is on the steeper, high elevation slopes with escape terrain. It also demonstrates that the very highest elevations (> 2000 m) were used by a substantially smaller segment of the goat population.



Conclusion: 1800 m is a reasonable higher elevation threshold for differentiating the highest quality winter range from range of lower quality. Given a likely negative bias in the measurement of elevation, this threshold may be somewhat low, with a slight reduction in the spatial extent of the highest quality escape terrain. The resulting error is likely to be small, given the relatively small proportion of the land base falling above this elevation.

Despite the fact these surveys rarely found goats below 1000 m., we do not recommend a lower elevation threshold, below which escape terrain would be considered of lower value. This is because the low elevation escape terrain used by goats in winter, though limited to a number of canyons in the forested land base, is likely of substantial value to wintering goats because these areas provide safety and proximity to food when higher elevation sites are snowbound.



Slope Steepness:

Null Hypothesis: Forty degrees represents a mean lower threshold for predicting the occurrence of goat escape terrain (rocky outcrops with cliffs), with 1 hectare of contiguous habitat > 40 degrees being a reasonable minimum patch size for escape terrain.

Alternate Hypothesis: There are other thresholds that better approximate a sufficient description of the lower limits of size and steepness of escape terrain.

Test: We examined the sufficiency of 40 degrees and 1 ha as thresholds by taking maps of locations of escape terrain (defined by these thresholds) on three helicopter flights in March 2001 over eight Landscape Units in the Kispiox Forest District (McCully, Moonlit, Lower Cranberry, Cutoff Mountain, Kuldo, Shegunia, Kitsuns, Skeena West). These areas were chosen because they included substantial numbers of small polygons whose value as escape terrain was questionable in the opinions of persons familiar with the areas. Many of the questionable polygons were along river courses in the forested land base. The choice of landscape units, and sometimes the poor weather on the mountain tops, resulted in our surveys focusing on the validity of many lower elevation polygons, and spending relatively little effort at high elevations.

Result: We examined 223 mapped escape terrain polygons in the eight LUs. 135 of these (61%) did not include any cliffed, rocky outcrops that could be classed as escape terrain. These polygons fell into two principal categories. Many were relatively steep

slopes on valley sides, not close to drainage channels, and with forest cover but no extensive sections of exposed bedrock. The second class was associated with drainage channels, being relatively steep forested or cutbank slopes falling into the water course. The Cutoff Mtn, Kuldo and Kitsuns areas had the most inaccurately classified polygons.

These results confirmed that 40 degrees was not steep enough as a lower threshold, and too many areas were being classed as escape terrain. To rectify this problem, we first changed the lower threshold to 45 degrees, and re-examined the map to see how many of the inaccurately classified polygons were no longer classed as escape terrain. Of the 135 polygons, 121 (90%) were no longer classified as escape terrain when 45 degrees was used as the threshold. The remaining 14 polygons known not to be escape terrain, but still classified as such, were in the Kuldo and Cutoff Mtn areas, and were not associated with drainage channels. It appeared that these steep slopes were on bedrock or surficial deposits that could support forest growth, and that eroded fairly evenly across the slope such that harder rock outcrops did not occur.

Increasing the lower threshold to 45 degrees re-classified most of the inaccurate polygons, but also resulted in losing 41 (47%) of the 88 polygons that had previously been correctly classed as escape terrain. All but 6 of these lost polygons of escape terrain were associated with drainage channels, being relatively small areas of rocky outcrops along incised canyons. The mapping routine apparently dropped them as escape terrain because they no longer included sufficient contiguous pixels with at least 45 degrees slope to make up the 1 hectare area threshold. However, we knew that a number of these were used by goats in winter judging by our observations on the flights (Upper McCully trib; lower Tsigwinselda; Kuldo headwaters), and historical observations.

We experimented with changing the lower limit of contiguous pixels to 0.5 ha, while maintaining the lower slope steepness threshold of 45 degrees. This resulted in re-establishment of 22 (54%) of the 41 lost polygons of known escape terrain, including the three areas we knew goats were using. The polygons that were not re-established were small areas of escape terrain, some in canyons and a few on open valley sides.

Conclusion: The data indicate that 45 degrees is better than 40 degrees as a lower threshold of slope steepness, and 0.5 ha is better than 1 ha as a lower limit of polygon size, in order to define escape terrain.

These thresholds are not perfect. The geology in some portions of the District does not produce rocky outcrops on some slopes steeper than 45 degrees. The 45 degree rule still results in overestimation of escape terrain on some mountain blocks (notably Cutoff Mtn and Kuldo drainage). It is not possible to change the limit for different portions of the District, so we recommend sticking with 45 degrees as an overall compromise. This is probably suitable for landscape level planning, but operational planning will need to evaluate specific polygons, at least with air photo interpretation.

The 0.5 hectare limit, when combined with the 45 degree limit, still did not allow all of the small, disjunct areas of potential escape terrain to be correctly classified, though it improved the classification appreciably. This resulting map is probably suitable for landscape level planning. However, forest development planning near incised drainages will need to include site searches for evidence of historical goat use as a validation of this suitability map.

Validation of the Model

We validated the model by flying an independent inventory of goats on three days in March 2001, covering eight Landscape Units (McCully, Moonlit, Lower Cranberry, Cutoff Mountain, Kuldo, Shegunia, Kitsuns, Skeena West) within the Forest District. On these same flights we also verified the locations of escape terrain (as outlined above for slope steepness and polygon size). However, goat locations did not influence the verification exercise and were subsequently mapped on the final verified map (Fig. 8), so the validation was independent of the verification. For the validation we attempted to cover the entire landscape unit, recording locations of observed goats and goat groups. The data consist of 5 locations with tracks (each of which is rated as one goat), plus 25 locations with goat groups (totalling 101 goats), or a grand total of 106 goat records.

Null Hypothesis: Goats do not strongly select the higher quality mapped habitats, but distribute themselves in proportion to the relative availability of habitats (i.e. randomly).

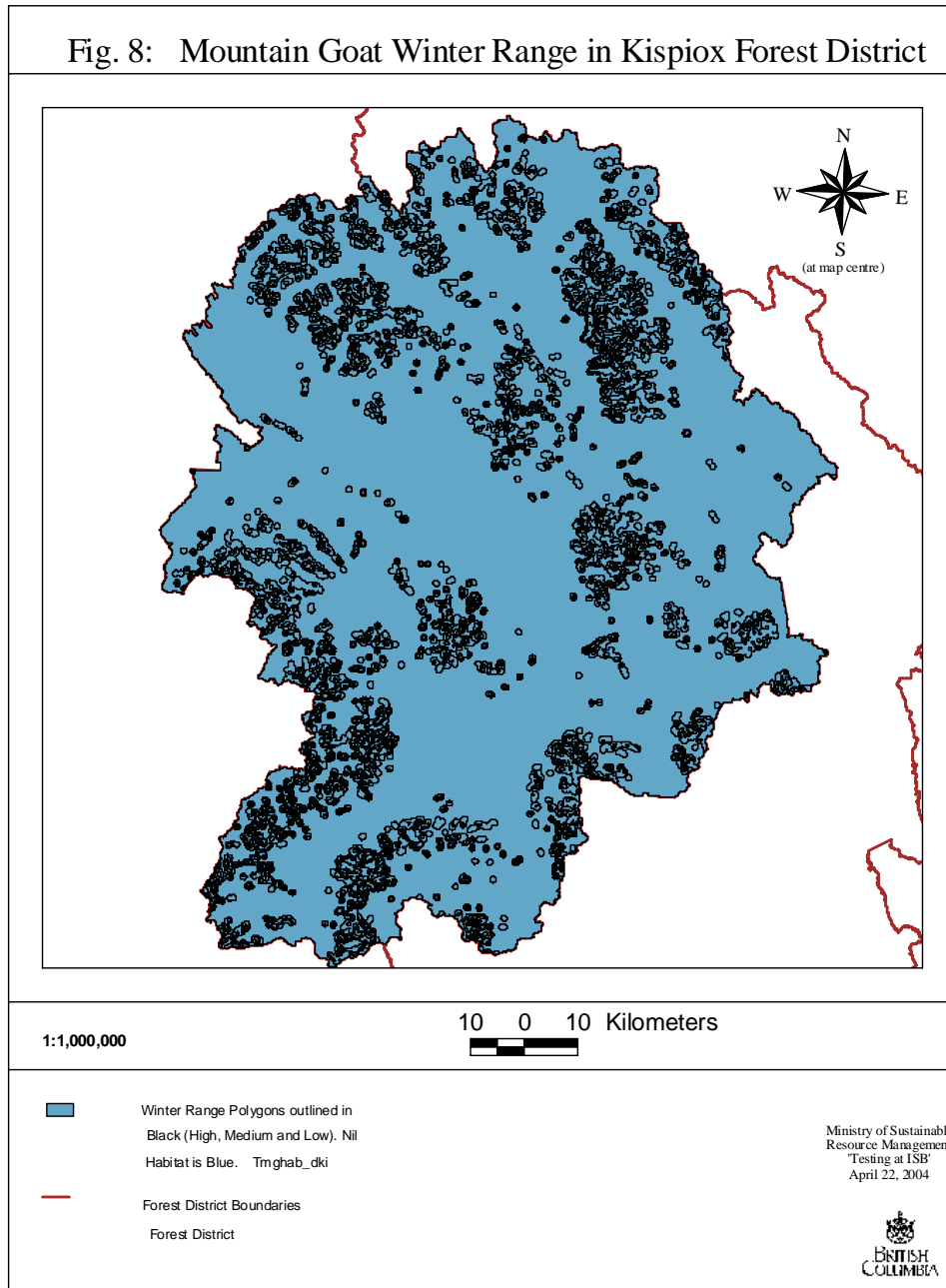
Alternative Hypothesis: Goats select the higher quality habitats, and avoid the habitat class with the lowest rating (Nil).

Test: We assumed that the frequency distribution of habitat classes from a sample of random points throughout the District represented the relative areal extent of those classes. We compared this distribution (the expected random distribution under the null hypothesis) with the observed distribution of goats in March 2001 in different habitat classes as per the revised model after the verification (Appendix 2). The data were summarized in terms of selection indices for each of the four habitat classes following Krebs (1999:478) and Manly *et. al.* (1993). Krebs (1999) provides formulae for calculating the log-likelihood G test (recommended when one of the expected values is less than 5) for a summary test of deviation from random, and tests for significant differences between the class-specific selection indices.

Result: The data for expected and observed numbers of goats, and the resulting selection indices are summarized in Table 2. The distribution of observed goats was significantly different from the expected, random distribution (Log-likelihood ratio = 137.622 which is much greater than the Chi-square = 7.815 at $P < 0.05$ and d.f.=3). Goats showed significant selection for each of habitat classes 1, 2 and 3. In these cases the proportion of that habitat type available (p) in the District fell outside the confidence intervals around the proportion of that habitat type used by goats (o), and goats used the habitat types more than they were available (Table 2). Goats avoided habitat class 4, as the proportion available (p) fell outside and far above the confidence interval on the proportion used (o) (Table 2).

Another test of model validity is whether or not the strength of selection is highest in habitat class 1 (high), and progressively less in the classes 2, 3 and 4. The standardized selection indices indicate that the goats do scale habitats in this general sequence, being most selective of class 1 (0.649) and progressively less selective through classes 2 (0.231), 3 (0.116) and 4 (0.004). In addition, the confidence intervals for

Fig. 8: Mountain Goat Winter Range in Kispiox Forest District



selection indices (w) for each habitat class show no overlap, strongly suggesting that these selection indices are significantly different from one another. Krebs (1999:481) provides a statistical test for this possibility. For our data: w for class 1 is significantly different from w for class 2 (Chi-square = 9.178, $p < 0.005$); w for class 2 is significantly different from w for class 3 (Chi-square = 19.423, $p < 0.001$); and w for class 3 is significantly different from w for class 4 (Chi-square = 79.153, $p < 0.001$).

Conclusion: The data provide solid support for the model; the null hypothesis is rejected in favour of the alternative. Goats selected winter habitats (escape and buffer combined) classed High, Moderate or Low, and avoided the habitat class ranked Nil. In addition, the strength of that selection was in rank order, with the High class being selected more heavily than the Moderate class, which was in turn selected more heavily than the Low class. This is strong support for the relative ranking of useable habitats, and a strong validation of the model.

Table 2. Proportion of each habitat class available to goats in the Kispiox Forest District and used by goats as observed on validation flights, with derived statistics for selection indices for each habitat class..

Habitat Class	Proportion Available (p)	Number Goats Observed	Proportion Used (o)	Confidence Interval on o	Selection Index (w)	Standardized Index (B)	Standard Error of w	Confidence Interval on w
1	0.010	17	0.160	0.079 - 0.241	16.000	0.649	3.561	9.020 - 22.980
2	0.058	35	0.330	0.226 – 0.434	5.690	0.231	0.787	4.147 - 7.233
3	0.152	46	0.434	0.325 – 0.543	2.855	0.116	0.621	2.234 – 3.476
4	0.780	8	0.076	0.018 – 0.134	0.097	0.004	0.033	0.032 - 0.162
Totals	1.000	106	1.000		24.642	1.000		

CONCLUSIONS and RECOMMENDATIONS

State of the Model and Possible Improvements

Verification suggested some improvements to the winter habitat suitability model (Appendix 1) which resulted from the development and calibration phases. Overall, escape terrain became less extensive in the District because the minimum slope steepness was 45 degrees instead of 40 degrees. This was despite the wider range of aspects (90 through 270 degrees, instead of 135 through 270 degrees), and the smaller minimum contiguous polygon size (0.5 ha instead of 1.0 ha), both of which tended to increase the contribution to escape terrain. These improvements resulted in the final model (Appendix 2), which we validated.

Despite the improvements, the model is not perfectly accurate. It is still a little liberal in what it includes as escape terrain. The principal reason for this is that, with the lower limit of escape terrain steepness set at 45 degrees, the modeled escape terrain still includes some forested slopes without the rocky outcrops necessary to truly define escape terrain. The second reason is that we use 0.5 ha, instead of 1.0 ha, of contiguous pixels as the lower limit of contiguous habitat necessary to define escape terrain. This results in the inclusion of some riparian canyon habitats that are steep but not truly cliffed. We feel that leaving the model somewhat liberal in its definition of escape terrain, is better than making it more conservative and running the substantial risk of losing known goat winter range. For example, with the 1.0 ha rule, much of the Tsigwinselda canyon is lost from the mapped winter range.

This opens the question of potential further improvements to the model. The following issues regarding definition of escape terrain may be worth further work, but have not been addressed so far because of lack of resources:

- Making the lower slope steepness rule more conservative, by increasing it in increments of one degree. This may remove some of the inaccurately defined escape terrain polygons, but at the risk of losing some that are now accurately defined. It is unlikely that any one rule will accurately define all situations because of the variability in bedrock geology, and its tendency in some areas to produce less erodible layers (cliffs) at moderate slope steepness.
- Changing the algorithm for minimum area of contiguous pixels in escape terrain (now set at 0.5 ha of pixels, all within one suitability rating) to allow pixels with differing suitability ratings to be amalgamated in one polygon to which the minimum area rule is applied. Changing this rule may allow a reinstatement of the 1.0 ha minimum area rule, thereby removing some of the incorrectly labelled escape terrain polygons in canyons, while maintaining the canyon escape terrain which was correctly identified under the 0.5 ha rule.

Similarly, further fine-tuning of rules controlling assignment of suitability ratings to different forest types may be worthwhile:

- In the two versions of the model presented here, open canopy forests in age groups 2 through 6, and from 200 to 500 meters from escape terrain, receive the

same suitability rating as adjacent escape terrain. However, forests in age groups 1, 7, 8 and 9, which are valuable for the same reasons as open canopy forests in other age groups, receive a lowered suitability if they are between 200 and 500 m from escape terrain. The reasons for this inconsistency were not clear at the time this report was prepared, but treating these two forest types similarly may make more sense, because both provide good foraging opportunities as well as potential benefits related to thermal and snow conditions. Whether open canopy forests of ages 2 to 6 should receive the same reduction as ages 1, 7, 8 and 9 forests, or alternately the reduction now applied to ages 1, 7, 8, and 9 forests is moot. The two alternatives may be testable by determining which one results in the clearer selection by goats of high value habitats in repeats of the validation tests reported earlier.

Our verification and validation did not adequately address the issue of changes to suitability depending on forest age class, crown closure and non-forested land class. This would require a more intensive assessment of goat habitat selection, particularly of the habitats in the buffer zones. The Kispiox Forest District sits astride the transition from coastal, precipitation-rich ecosystems to interior, rain-shadow ecosystems. Consequently there may be substantial variability in the choices goats make of the same non-forested habitat class or same combination of stand age and crown closure as they move from the more coastal areas (e.g., Nass Ranges) to the more interior mountains (e.g., Mt. Thoen). However, given the fact that we use only a coarse, four-class rating scheme, we feel that much of the detail of goat behaviour, and its variability, is not of great consequence in assigning reasonably accurate ratings to various Forest Cover polygons within the buffers.

Using the Map and Model

This winter suitability map is a product that can be used, by itself, as a tool for strategic and tactical land use planning. At a District wide level, it provides an immediate insight into the areas of highest quality winter range for mountain goats. These are: the Nass Ranges, the Seven Sisters mountain complex, the Rocher Deboule Range, the Kispiox Mountain complex, the Mt. Thomlinson complex, Mt Thoen, and the Atna Range. As a result, land managers can see immediately where access control measures should gain priority attention in order to reduce the primary impact of forest harvesting activities on goat populations, which is increased hunting mortality. Managers can also immediately see where additional inventory to identify critical goat habitats (e.g., mineral licks and associated trails, and kidding areas) is needed.

Notably, the model and map also identify a number of lower elevation canyon habitats that sit within the forest harvest land base. A few examples are: Tsigwinselda canyon on the north side of Kispiox Mtn; Shegunia mainstem canyon; Shenismike Creek, tributary to the Babine River; and Gail Creek, tributary to the Babine River. These are often well used in winter, perhaps when goats need to get out of deeper snow at higher elevations. They may also be used in other seasons, for example as licks. However, it is very unlikely that they support isolated populations of goats year-round. Many of the

goats very likely move from these canyons to the more extensive higher elevation habitats periodically. What is often lacking is knowledge of where and how goats move through forested habitats to and from the higher elevation ranges. This map provides clear direction on where to focus the necessary inventory of goat trails and movement corridors.

This map should also be used at an operational forest development scale (e.g., cutblock and road layout; silvicultural prescription), in conjunction with on the ground survey work, to deal with some of the potential overestimation of range in some landscapes and the fact that the map does not deal with movement corridors. The forest should be examined closely on the ground by a biological consultant when potential roads or cutblocks overlap or come within 100 m of mapped winter range, or come within 100 m of a drainage along which the map identifies goat winter range. The forest should be examined on the ground for evidence of use by goats (trails, droppings, beds). The most likely scenario is that the proposed road or cutblock would be close to an incised creek or river. Goats may be travelling from the edge of the steep slopes by the drainage, back into the forest to find shelter and/or forage. They may have trails through the forest near the drainage which they use to move between discrete pieces of escape or foraging terrain along the same drainage, or even between drainages. These trails may be aligned generally parallel to a drainage, but could cross forest at quite some distance from the incised drainage when the drainage meanders and the shortest line of travel does not follow the meander.

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**Appendix 1: A synopsis of the model used in the verification exercise (This is goat model 6 from the development and calibration phases).
There are two principal phases: delineation of escape terrain, followed by buffering of the escape terrain.**

Kispiox mountain goat winter habitat suitability

A) ESCAPE TERRAIN

Overall Rating	Escape Rating	Upper Slope (degrees)	Lower Slope (degrees)	Upper Elevation (metres)	Upper Aspect (degrees)	Lower Aspect (degrees)	Forest Age Class	Crown Closure	Non-Forest Land	Forest Land - Non Forested	Upper Escape Proximity	Lower Escape Proximity
	1	1	<= 60	> 50 .	<=1800	<= 270						>135
	2	2	<= 60	> 50 .	<=1800	> 270						
	2	2	<= 60	> 50 .	<=1800							<= 135
	2	2	<= 60	> 50 .	>1800	<= 270						>135
	3	3	<= 60	> 50 .	>1800	> 270						
	3	3	<= 60	> 50 .	>1800							<= 135
	2	2	<= 50	> 40	<=1800	<= 270						>135
	3	3	<= 50	> 40	<=1800	> 270						
	3	3	<= 50	> 40	<=1800							<= 135
	3	3	<= 50	> 40	>1800	<= 270						>135
	4	4	<= 50	> 40	>1800	> 270						
	4	4	<= 50	> 40	>1800							<= 135
	2	2		> 60	<=1800	<= 270						>135
	3	3		> 60	<=1800	> 270						
	3	3		> 60	<=1800							<= 135
	3	3		> 60	>1800	<= 270						>135
	4	4		> 60	>1800	> 270						
	4	4		> 60	>1800							<= 135
	4	4	<= 40 .									

Note: The above escape ratings should be run first. They incorporate mobility modifiers of aspect and elevation. The resulting polygons should then be tested for size, and small ones made class 4 before applying the buffering process below. Four runs to determine escape ratings are needed, one pair with only class two and three polygons being tested for size, and the other pair with all classes tested. One run of each pair should throw out polygons smaller than 1 ha, the other less than 4 ha.

B) BUFFERING ESCAPE TERRAIN

Overall Rating	Escape Rating	Upper Slope (degrees)	Lower Slope (degrees)	Upper Elevation (metres)	Upper Aspect (degrees)	Lower Aspect (degrees)	Forest Age Class	Crown Closure	Non-Forest Land	Forest Land - Non Forested	Upper Escape Proximity	Lower Escape Proximity
							1,7,8,9				<= 200m	>= 0m
							1,7,8,9				<= 500m	> 200m
	3						2,3,4,5,6	3,4,5,6,7,8,9,10			<= 200m	>= 0m
	3						2,3,4,5,6	3,4,5,6,7,8,9,10			<= 500m	> 200m
									A, AF, NPBR, NPBU, NP		<= 200m	>= 0m
									A, AF, NPBR, NPBU, NP		<= 500m	> 200m
										NCBR, NSR	<= 200m	>= 0m
										NCBR, NSR	<= 500m	> 200m
							2,3,4,5,6	0,1,2			<= 200m	>= 0m
							2,3,4,5,6	0,1,2			<= 500m	> 200m
									Rock		<= 200m	>= 0m
									Rock		<= 500m	> 200m
	4										> 500m	

Note: Rating of 1 is highest; "reducing" this by 1 produces a rating of 2. Ratings below 4 according to the above arithmetic, (ie. 5 or higher numerically) are mapped as 4.

After determining all escape polygons and adjacent buffers, icefields (in TRIM data) should be made class 4, excluding them from both escape habitat and adjacent habitat.

Appendix 2: A synopsis of the revised model derived from the verification exercises and used for the validation.
There are two principal phases: delineation of escape terrain, followed by buffering of the escape terrain.

Kispiox mountain goat winter habitat suitability

A) ESCAPE TERRAIN

Overall Rating	Escape Rating	Upper Slope (degrees)	Lower Slope (degrees)	Upper Elevation (metres)	Upper Aspect (degrees)	Lower Aspect (degrees)	Forest Age Class	Crown Closure	Non-Forest Land	Forest Land - Non Forested	Upper Escape Proximity	Lower Escape Proximity
	1	1	<= 60	> 50	<=1800	<= 270						>90 .
	2	2	<= 60	> 50	<=1800	> 270 .						
	2	2	<= 60	> 50	<=1800							<= 90
	2	2	<= 60	> 50	>1800	<= 270						>90 .
	3	3	<= 60	> 50	>1800	> 270 .						
	3	3	<= 60	> 50	>1800							<= 90
	2	2	<= 50	> 45	<=1800	<= 270						>90 .
	3	3	<= 50	> 45	<=1800	> 270 .						
	3	3	<= 50	> 45	<=1800							<= 90
	3	3	<= 50	> 45	>1800	<= 270						>90 .
	4	4	<= 50	> 45	>1800	> 270 .						
	4	4	<= 50	> 45	>1800							<= 90
	2	2		> 60	<=1800	<= 270						>90 .
	3	3		> 60	<=1800	> 270 .						
	3	3		> 60	<=1800							<= 90
	3	3		> 60	>1800	<= 270						>90 .
	4	4		> 60	>1800	> 270 .						
	4	4		> 60	>1800							<= 90
	4	4	<= 45									

Note: The above escape ratings should be run first. They incorporate mobility modifiers of aspect and elevation. The algorithm assigns an escape rating class (1 through 4) to each pixel (25 x 25 m). It then looks, pixel by pixel, for groups of pixels with the same rating (1 through 4) that can be considered contiguous (sharing at least one side or a corner). If such groups consist of greater than 8 pixels (0.5 ha), they are then considered escape terrain. If 8 or less pixels, they are then dropped from the escape terrain, and become class 4.

B) BUFFERING ESCAPE TERRAIN

Overall Rating	Escape Rating	Upper Slope (degrees)	Lower Slope (degrees)	Upper Elevation (metres)	Upper Aspect (degrees)	Lower Aspect (degrees)	Forest Age Class	Crown Closure	Non-Forest Land	Forest Land - Non Forested	Upper Escape Proximity (metres)	Lower Escape Proximity (metres)
The buffering sequence below should be done in sequential iterations according to polygon class. All class three polygons should be buffered first, class 2 next, and class 1 last. This is to ensure that higher class polygons take precedence by overwriting earlier buffers applied to lower class polygons.												
Class three escape polygons must be prevented from applying buffers over Class 1 or 2 escape polygons, and Class 2 prevented from applying them over Class 1.												
However, Class 2 polygons should be permitted to apply class 2 buffers over Class 3 escape or buffer areas, and Class 1 should be permitted to apply higher suitability buffers over any lower rated escape or buffer area.												
Same as adjacent escape							1,7,8,9				<= 200	>= 0
Reduce rating by 1, but to no less than 3							1,7,8,9				<= 500	> 200
	3						2,3,4,5,6	3,4,5,6,7,8,9,10			<= 200	>= 0
	3						2,3,4,5,6	3,4,5,6,7,8,9,10			<= 500	> 200
Same as adjacent escape									A, AF, NPBR, NPBU, NP, SWAMP, CL		<= 200	>= 0
Reduce rating by 1, but to no less than 3									A, AF, NPBR, NPBU, NP, SWAMP, CL		<= 500	> 200
Same as adjacent escape										NCBR, NSR	<= 200	>= 0
Reduce rating by 1, but to no less than 3										NCBR, NSR	<= 500	> 200
Same as adjacent escape							2,3,4,5,6	0,1,2			<= 200	>= 0
Same as adjacent escape							2,3,4,5,6	0,1,2			<= 500	> 200
Same as adjacent escape									R		<= 200	>= 0
Same as adjacent escape									R		<= 500	> 200
	4										> 500	
	4								U, L, RIV, G, GR, C, M, NTA, OR		<= 500	>= 0

Note: Rating of 1 is highest; "reducing" this by 1 produces a rating of 2. Ratings below 4 according to the above arithmetic, (ie. 5 or higher numerically) are mapped as 4.

After determining all escape polygons and adjacent buffers, icefields (in TRIM data) should be made class 4, excluding them from both escape habitat and adjacent habitat.