STAND LEVEL HABITAT USE
BY FURBEARER SPECIES
IN THE ANAHIM LAKE AREA
OF BRTISH COLUMBIA

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EXECUTIVE SUMMARY

The results of this study indicate that track transects can be used to examine stand level attributes for importance to furbearing species. The recommendations from this report should be used to direct forest development and identify important habitat attributes that can be managed for at the stand level.

Spruce is a habitat element that was positively linked to all seven animals examined here. Analyses indicate that mature and old spruce habitats are preferred by marten, lynx, ermine, snowshoe hare and red squirrel. For coyote, this was the only habitat used more than expected. Lynx also showed strong selection for habitats with greater numbers of both B1 and B2 spruce. Due to its importance for furbearing species, spruce leading habitats should be targeted when creating reserves in the West Chilcotin.

Increases in the amount of woody debris was associated with increased use for six out of the seven species examined here. Only coyote had a negative association with CWD variables. Woody debris provides both thermal and protection cover as well as escape terrain for both predators and prey. However, both the size and distribution of CWD are important. The arrangement of woody debris in this study was clumped with many segments having little or no debris while others had large numbers of pieces that were piled over 1m high. Adjusting harvesting methods to retain the vertical and spatial heterogeneity may provide managed stands with CWD characteristics that are important to furbearers.

Increased basal area in large dead trees was important for marten in this study for both univariate and multivariate analyses. This attribute was not significantly related to fisher habitat use; however, this study did not examine the maternal denning period, and fisher here may still require large diameter snags for maternal den sites during spring. Management should ensure that wildlife tree patches contain trees representative of the largest stem diameters in the area to be developed.

Prey species such as snowshoe hare, red squirrel, and grouse had strong positive relationships with marten, fisher, and lynx. Ensuring that managed habitats provide adequate resources for prey species is essential since predators will not persist without them. One area of concern may be the effects of thinning on this habitat. Pre-commercial thinning can reduce stem densities to 1200-1500 stems/ha whereas natural stands range between 5000-10,000 (or greater) stems/ha. Ensuring that areas of denser stems are retained may be important in maintaining this species.

Finally, this study examined stand level attributes that may affect furbearing species. However, landscape level attributes such as minimum viable patch size and connectivity are also likely to impact furbearing species. Future studies should examine the effects at this level of habitat organization and the impacts of the current mountain pine beetle epidemic.

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1.0 INTRODUCTION

This study documents and compares furbearer use of different habitat types in the Anahim Lake area. There is concern in this area about the effects of timber harvesting on furbearer populations, and managing for furbearers is a legal requirement of the Cariboo Chilcotin Land Use Plan. Information on furbearer habitat requirements has not been documented in the Anahim Lake area and is required to aid in forest management. Most of the information available on furbearer requirements is from the United States and eastern Canada. The collection of local information that reflects the habitat types found in the Anahim Lake area is essential in managing for these species.

This study is one of two projects that is examining furbearer use of the ecosystem and habitat types in the Yun Ka Whu'ten Holdings Ltd operating area around Anahim Lake. This project focuses on stand level habitat attributes that may affect furbearer use. The second study will examine landscape level patterns of habitat use and field work for this project has now been completed[1]. Together, these two projects are designed to provide information that will assist in developing overall resource management guidelines for these species. The purpose of this study is to examine the relationship between forest age, dominant vegetation, structural characteristics and the relative use of these habitats by furbearers in the study area.

Specifically the study objectives are as follows:

1) Determine if habitat types characterized by the leading tree species and structural stage can be used to model specific furbearer habitat use patterns.
2) Determine other stand level habitat attributes that may affect furbearer habitat use patterns.
3) Make recommendations on stand level resource management for furbearers in the Yun Ka Whu'ten Holdings Ltd Operating Area.

2.0 ACNOWLEDGEMENTS

Project funding was provided by Yun Ka Whu'ten Holdings Ltd., and the Forest Investment Account. This project would also not have been possible without the work of Anahim Lake community members and others from outside the area. Track data collection was completed by Steve Richburg, Paul Lowrie, and Ronald Cahoose. Habitat data collection and other support was provided by Ronald Cahoose, Stanley Cahoose, Clarence Cahoose, Larry King, Becky Holt, Arnold Sill, Steve Richburg, and Satnam Manhas. Rick Dawson and Ray Coupe from MOF Cariboo Region provided valuable insights and review of the sampling plan. Rick Dawson reviewed the final report. Finally, Becky Bravi provided the impetus and support to keep this project moving forward.

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[1] Davis, R.L. 2003. Yun Ka Whu'ten DNA Pilot Project 2002/2003 Summary Report. Unpublished report submitted to Yun Ka Whu'ten Holdings Ltd.

3.0 STUDY AREA

The study area is located on the Interior Plateau near Anahim Lake, B.C. in the Sub-boreal Pine-Spruce (SBPS) and Montane Spruce (MS) Biogeoclimatic Zones (BEC) (Meindinger and Pojar, 1991)(Figure 1). The area is bounded by Highway 20 on the south, Tweedsmuir Park to the west, Anahim Peak to the north, and includes the Corkscrew Creek basin to the east. Elevations in the study area range from 1100-1500m.

Vegetation surveys were conducted in the MSxv (very dry, very cold) subzone, the SBPSxc (very dry, cold), and the SBPSmc (moist, cold) subzones. Lodgepole pine (*Pinus contorta*) was the leading species in the tree layer on most transects with white spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*) leading on a small number of transect segments. The B1 shrub layer (>2m tall) was dominated by lodgepole pine and white spruce with lesser amounts of trembling aspen and *Salix spp*. Soopolallie (*Sheperdia canadensis*) and *Salix spp* dominated the B2 layer (<2m tall) with minor amounts of lodgepole pine, common juniper (*Juniperus communis*), and white spruce. In wetlands, willow (*Salix spp*.), bog birch (*Betula glandulosa*), and sedge (*Carex spp*.) were the dominant species.

4.0 METHODS

Track Transects

Furbearer track sampling follows the methodology outlined by Ashcroft *et al* (2002)[2]. Starting points for transects were located in 1998 along the following main roads in the study area: Beeftrail Main, Blackwater trail, Corkscrew Main, Christensen Creek Trail, Dean River Road, and Highway 20. A total of 216 sample sites were chosen to cover a wide range of habitat types and represent the three BEC subzones. The sites were required to have little or no human caused habitat disturbance and had to be accessible by truck or snowmobile. Out of the 216 sites, 105 were chosen for conducting track transects with 35 in each subzone.

At each site, a compass bearing perpendicular to the road was used to set the transect orientation and the starting point was established at 100m from the road edge. Transects were established at each site by blazing, tying ribbon, and tagging a point of commencement (POC) tree with orange paint, two wraps of pink/black striped ribbon, and metal tags. The transects were divided into 50m segments using two wraps of pink/black striped ribbons and two wraps of yellow ribbons at the start of each 50 m segment. The distance from the POC was marked on the yellow ribbon and painted in orange on the nearest tree. Each transect was composed of two parallel 500m long legs placed 250m apart. Data was collected on the 500m long leg "A" on the way in and on the 500m long leg "B" on the way out.

[2] Ashcroft, G., L. Davis, and S. Richburg. 2002. Furbearer use of forested stands in the Anahim Lake area, British Columbia – Third year project report. Unpublished report for Yun Ka Whu'ten Holdings Ltd.

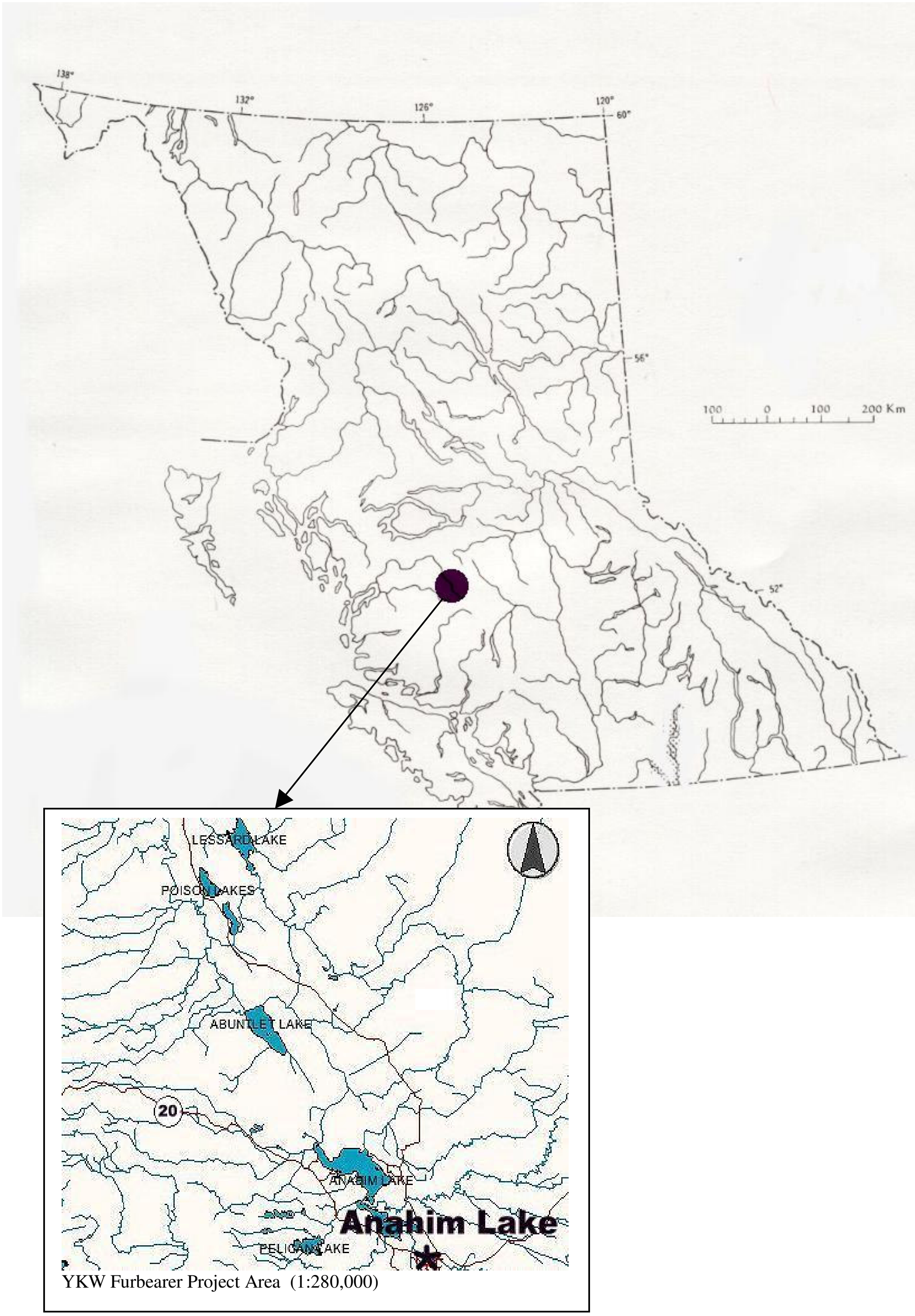


Figure 1. Map of project study area near Anahim Lake, British Columbia.

The sampling of transects was conducted randomly by the use of a random number list. Once all 105 transects had been sampled once, a new list was used to continue sampling. Sampling commenced 0.5-37 days after a significant snowfall. During the sample period, atmospheric conditions that maintained snow quality for accurate track identification were required. Track transects were not conducted if weather conditions resulted in tracks becoming obscured, or if it was not clear that the tracks had been made since the last identified snowfall.

At the start of each transect, the observers recorded the starting time, temperature, and estimated the snow type for each transect. Snow depths were taken at a point 5m along the line of travel from the start of each segment. Tracks that crossed the transect line were tallied by segment for each species. Tracks that crossed the transect had to deviate by more than 1m perpendicular to the transect before they could be tallied again. After a significant snowfall (>5cm), sampling continued at the discretion of the observers. As long as the observers were able to determine species and time since the last snowfall, sampling proceeded.

4.1 Habitat Sampling

Due to budget and time constraints, only 53 transects could be used for this analysis. All transects were plotted on forest cover maps and the amount of transect in each habitat type was determined. Habitat types are defined as a combination of structural stage and leading species. At this stage, stand age acted as a surrogate for structural stage and mature pine leading forest types were found to cover approximately 90% of transect segments. Transect numbers were randomly drawn and habitat representation was recorded. The resulting sampling plan obtained approximately proportional representation from all available habitat types. All transects that had not been harvested were eligible for sampling. The habitat sampling plan was divided into two levels that allowed comparison both within and between stands.

Level 1 - Broad stand level classification
The transects were walked by an experienced surveyor who completed a map for each transect showing the structural status, leading species, and presence of wetlands for each segment of the transect. The classification of structural status follows categories described in *Describing Ecosystems in the Field* (DEIF, 1998). Due to low amounts of structural stages 4 and 5, they were combined as one category. Wetlands were classified using definitions in the *Riparian Management Area Guidebook* (FPC, 1995) and by structural stage (DEIF, 1998). With the exception of riparian habitats, three co-dominant trees were aged in every fifth segment of a habitat type.

Level 2 - Measurement of individual stand attributes
The following habitat attributes were collected in each segment of the transect: basal area; density and decay class of trees; density of small saplings and saplings; coarse woody debris (CWD) volume, number of pieces, and decay class; percent cover of all woody debris, the percent cover of the shrubs by layer; and the size/cover of rock.

A variable radius plot was used to obtain a count of number of trees by decay class, species, diameter class (small pole, 12.6-27.5cm; pole, 27.6-42.5cm; and large tree, >42.5cm dbh), and basal area. The plot was centered at the 25m mark of each segment, and a 4 BAF prism was used on all plots. Where there was greater than 10 trees in the plot, a half plot was conducted. Half plots were also conducted where the habitat type changed within the plot. The half plot was then conducted on the side of the segment containing the habitat type that represented the majority of the segment.

A 5.64m fixed radius plot was used to tally the number of conifer/aspen stems in the small sapling (>1.3m tall and <7.49cm dbh) and sapling size classes (7.5-12.49cm dbh). A half plot was conducted where the habitat type changed within the 5.64m radius plot. The half plot was then conducted on the side of the segment containing the habitat type that represented the majority of the segment.

The percent cover of shrubs was estimated by layer (B1, 2-10m and B2< 2m tall) in a 11.28m radius plot centered at the 25m mark of each segment. The three shrub species making up the majority of the cover were listed for each layer. CWD was also recorded by percent cover in the 11.28m radius. The observer estimated the percent cover of effective CWD and placed it into one of four categories: 0-5%, 5-15%, 15-25%, and >25%. Effective CWD cover is a subjective estimate of CWD that is usable by furbearers during winter to access subnivean spaces. This estimate includes the cover provided by root wads and piles of branches.

Coarse woody debris (CWD) was also measured using the line intersect method. A 25m transect was conducted in the first 25m of each segment where all CWD encountered that was >10cm in diameter and <45º incline to the horizontal was recorded by diameter, decay class, height off the ground, and presence of cavities. Root wads are not included as CWD due to problems in calculating volumes. Calculations of volume followed Lofroth (1991).

The percent cover and size class of rock may influence the availability of subnivean spaces during winter. Percent cover was estimated for visible rock and placed into one of four categories (0%, 1-7%, 7-15%, 15-25%, and >25%). Three size categories were used to further characterize rock (small <30cm, medium 30-100cm, and large >100cm).

A site description was also completed for each segment. The description includes the average slope and aspect of the segment. Aspects were recorded by cardinal bearing (N, NE, E, SE, etc.) For segments with a slope of less than 10%, the slope was listed as gentle and the aspect variable.

4.2 Data Analysis

The number of tracks per 50m segment was standardized to tracks/50m segment/week for each species to account for differences in the time between the last snowfall and the snow track observations. Although each transect was sampled in each year of the three years that tracking was conducted, some transects had 2 sample days in a given year. To account for this, the number of tracks for each segment was averaged for each species over all three years. This yielded a mean number of tracks for each species in each segment.

Chi-square analysis was used to make univariate comparisons of used versus available habitat for all species with greater than 60 observations. This comparison used the sum of the mean number of tracks per segment for each habitat category. Species were seen to select for a habitat type when the proportion of habitat used was much greater than available. To help gauge this comparison, Ivlev electivity Indices were calculated (Krebs 1989). This index is calculated by subtracting proportional use minus proportional availability and dividing by the sum of proportional use and proportional availability. The index ranges from +1 to -1 with positive values indicating preference and negative values indicating avoidance. However, this index is sensitive to low sample sizes and this must be taken into account when sample sizes are close to zero. To aid in determining which habitat categories were significantly different, Bonferroni confidence intervals were calculated for univariate comparisons with significant results.

Multivariate analyses were conducted using logistic regression for key species with adequate abundance for analysis (marten, fisher, and lynx). Species occurrence was converted to presence/absence and modeled for probability of use for each set of habitat variables (models). A-priori models were refined using an examination of univariate analyses to produce a set of first order candidate models. An information-theoretic approach was used to differentiate among competing models (Burnham and Anderson 2002). This approach weights the models to account for bias (under-parameterization) and variance (over-parameterization) (Burnham and Anderson 2002). Models were tested for over-dispersion and Akaike Information Criteria (AIC) was calculated for all candidate models in the set. Over-dispersion occurs when sampling variance exceeds the theoretical variance. This is often a problem with count data where there may be small violations of assumptions such as independence or homogeneity of individuals (Burnham and Anderson 2002).

Evidence ratios were calculated to show the relative ‘distance’ of candidate models from the ‘best’ model. All models within 0-4 AIC units of the best model are considered to be the top models. The variables contained within these models are likely to have the greatest influence on furbearer habitat use (Burnham and Anderson 2002).

5.0 RESULTS

A total of 1042 segments on 53 transects are include in this analysis. SBPSxc contains 397 segments, the MSxv contains 416 segments, and the SBPSmc contains 229 segments. Mature and mid structural stage lodgepole pine comprised the greatest amount of habitat by segment with other habitat types covering between 1-7% of the transects (Table 1). Of these, mature spruce (6%) and shrub carr (5%) were the most abundant. The shrub carr category is a combination of both short shrub (3b) and tall shrub (3c) structural stages.

When structural stage was compared to tree age data, several discrepancies were found. Occasionally, stands were actually younger than the range given in DEIF (1998); however, survey notes indicated that these stands had increased complexity and/or were richer sites with larger diameter trees. Much more prevalent was stands being older than the range given in DEIF (1998). Twenty-seven segments out of 183 (15%) were more than 20 years older than the DEIF (1988) range for the structural stage that was given to the segment. For some sites, field notes indicate that the segment was borderline and structural features of the stand resulted in the younger classification. For other sites, the small tree diameters and lack of a more complex stand structure clearly put these stands into a 'younger' structural stage. Tree ages in this study ranged from 13 to 330 years. Table 2 lists the age range found for each structural stage. Despite the differences between actual stand ages and structural classifications, it is assumed that structural differences are most important to wildlife, and all analyses in this report are based on the DEIF classifications made in the field.

The most abundant furbearing species found during track transects were snowshoe hare and red squirrel (Table 3). Marten, coyote, lynx, fisher, and ermine were found in intermediate amounts. Low density species (wolf, otter, fox, wolverine, mink, and long-tailed weasel) had less than 60 sets of tracks over the three years and no statistical tests were performed on these species due to the low numbers.

Table 1. Habitat representation by segments in the YKW furbearer project area. Habitat is a combination of leading species and structural stage.

Habitat	# segments	Proportion
Aspen 5+6 (At 5-6)	18	0.02
Lodgepole pine 5 (Pl5)	344	0.33
Lodgepole pine 6 (Pl6)	446	0.43
Lodgepole pine 7 (Pl7)	27	0.03
Shrub carr 3 (SC3)	49	0.05
Sedge 2 (SE2)	35	0.03
Spruce 5 (Sx5)	14	0.01
Spruce 6 (Sx6)	75	0.07
Spruce 7 (Sx7)	24	0.02
Spruce-Pine 6 (SxPl6)	10	0.01
Grand Total	1042	1

Table 2. Age range of structural stages in Anahim Operating Area based on mean value for each segment.

Structural stage	DEIF range	Actual range
Pole – young forest (4-5)	10-80 years	14-273 years
Mature (6)	80-140 years	55-330 years
Old (7)	>140 years	68-292 years

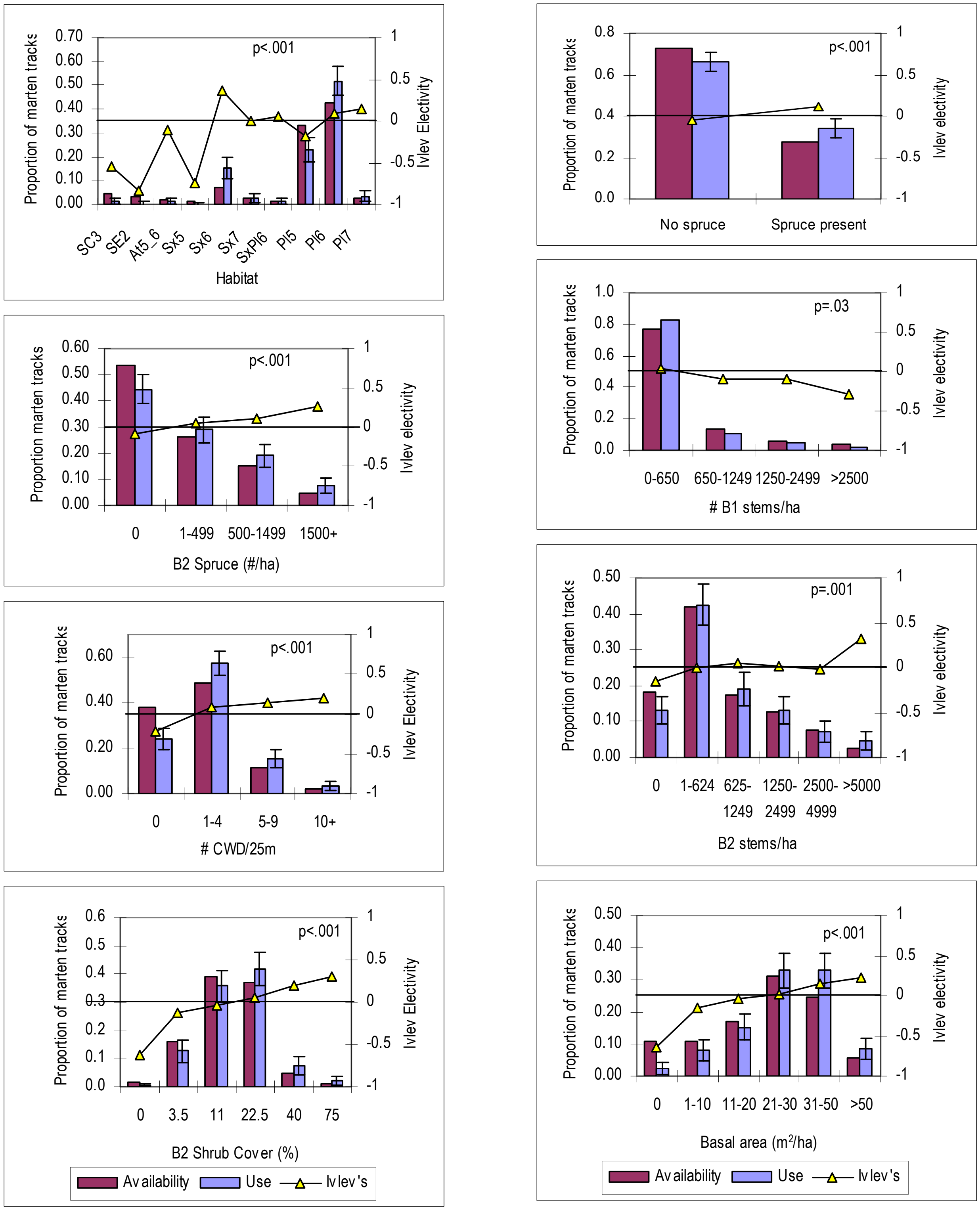
Table 3. Number of tracks by species in YKW furbearer project. Number of tracks is the sum of the mean number of tracks/50m/week.

Species	Number of tracks
Coyote	306
Gray wolf	58
Grouse	115
Wolverine	18
Snowshoe hare	4181
River otter	5
Lynx	237
marten	529
Fisher	198
Ermine	168
Long tailed weasel	6
Mink	9
Red squirrel	2817
Red fox	21

Marten

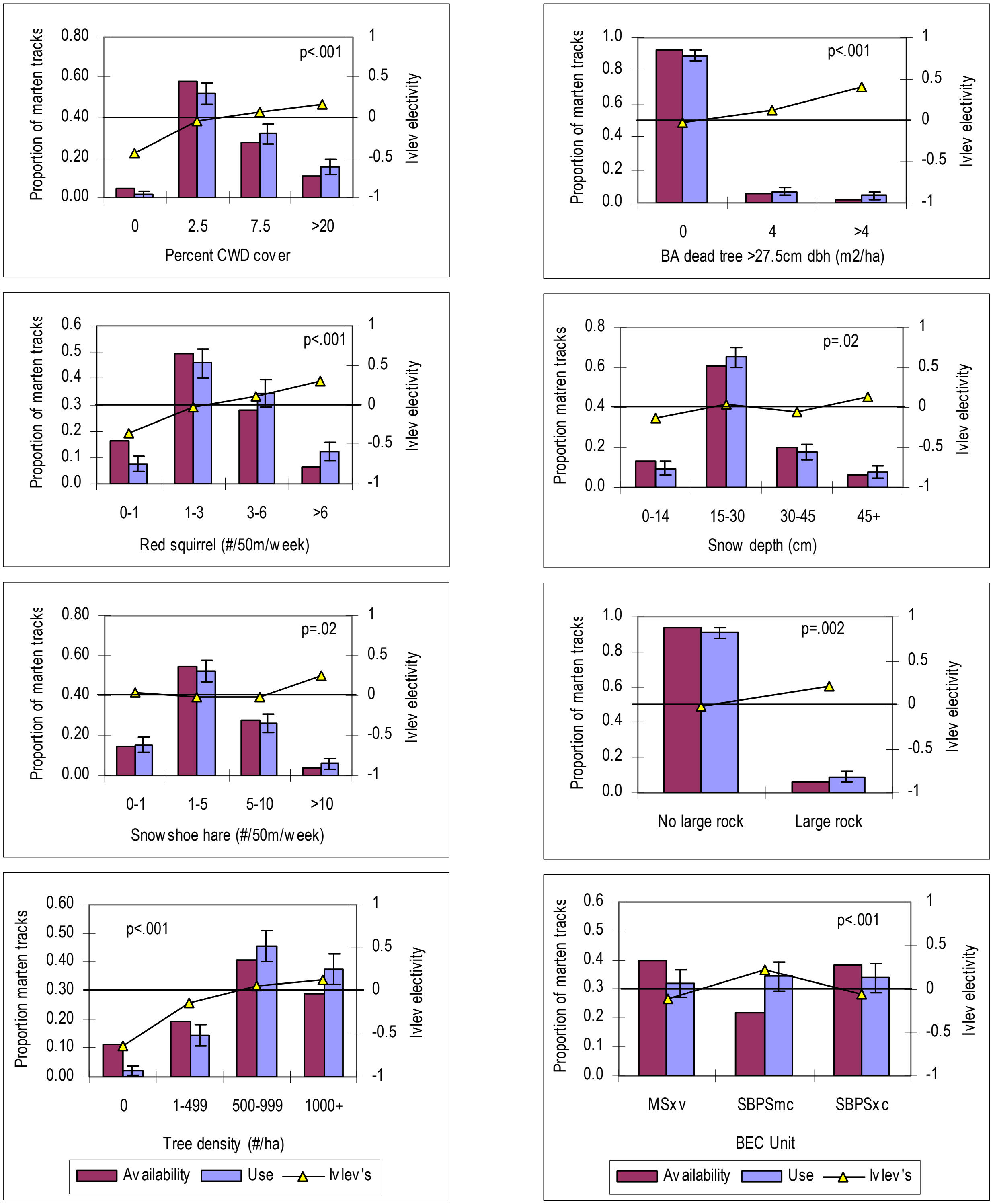
Chi-square analysis on marten found significant relationships with 18 variables (α=.05). Graphs of the 16 variables exhibiting the greatest potential for influencing marten habitat selection are shown in Figures 2 and 3. Graphs of the remaining variables are shown in Appendix 1. Marten showed strong selection for mature pine and spruce habitat types (Pl6 and Sx6). Old pine (Pl7) was used slightly more than expected while old spruce (Sx7) was used in proportion to availability. Marten avoided shrub carrs (SC3), sedge wetlands (SE2), and mid-aged pine (Pl5).

Stands with greater numbers of B1 stems were avoided by marten while stands with high densities (>5000) of B2 stems were selected for. Marten showed a trend of increasing use with increasing B2 spruce densities and generally selected for spruce types. Increases in the number of pieces of CWD resulted in increasing selection by marten and a similar trend was seen with increases in the % CWD cover. The presence of large rock in a segment was also selected for. Increases in basal area, the basal area of large dead trees, and the number of trees all resulted in greater selection by marten. Increases in the abundance of red squirrel tracks coincided with greater selection by marten, while increased marten use was only seen for snowshoe hare on segments with >10 hare tracks. The SBPSmc subzone had the greatest proportion of tracks and was strongly selected for.



MARTEN UNIVARIATE ANALYSES

Figure 2. Significant (α=.05) univariate analyses on marten with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.



MARTEN
UNIVARIATE ANALYSES

Figure 3. Significant (α=.05) univariate analyses on marten with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.

Multivariate modeling for marten focused on those variables showing significant trends or significant use relative to other categories (categorical variables). The global model for marten had evidence of moderate-high dispersion with the ratio of deviance to degrees of freedom much greater than 1 ($\hat{c}$ =5.9). Therefore, quasi-likelihood methods (QAIC) will be used where Log (L)/ $\hat{c}$ is the calculated likelihood for each model. Table 4 lists the models that were used in this procedure.

Table 4. Models used to predict the probability of detecting a marten in the YKW Operating Area. QAIC values are a relative index of model parsimony (accounting for dispersion) with ΔAIC values giving the distance between any model and the most parsimonious model. AICώ is the relative influence of each model, and the Ratio AICώ give the ratio of evidence relative to the best model.

	Model structure	QAIC	K	Log L /$\hat{c}$	ΔAIC	AICώ	Ratio AICώ
1	Constant + Sx6 +Pl6 + SBPSmc + CWDcover	184.5	6	86.23	0.00	0.363	1.0
2	Constant + Sx6 +Pl6 - wetland	185.3	5	87.63	0.79	0.244	1.5
3	Constant - largerock - Sx5 - wetland	185.9	5	87.97	1.48	0.173	2.1
4	Constant - largerock - Sx5 – wetland + Sx6 + Pl6 + #CWD + SBPSmc + CWDcover + BA_dead + Leam	187.6	12	81.79	3.11	0.077	4.8
5	Constant - Sx5 - wetland + Sx6 + Pl6 + BA_all + SBPSmc + CWDcover + Tahu	188.1	10	84.07	3.68	0.058	6.3
6	Constant + Sx6 +Pl6 + SBPSmc + CWDcover + BA_dead + Tahu	188.3	8	86.14	3.82	0.054	6.7
7	Constant - largerock - Sx5- wetland + Sx6 + Pl6 + #B2_S + BA_all + #trees + SBPSmc + CWDcover + BA_dead	190.0	13	81.99	5.52	0.023	15.8
8	Constant - Sx5 - wetland + Sx6 + Pl6 + B2_S + #trees + SBPSmc + CWDcover + BA_dead + Tahu - Leam	192.7	13	83.36	8.25	0.006	62.0
9	Constant + Sx6 + Pl6 + CoverB2 + #CWD + BA_all + SBPSmc + CWDcover + BA_dead + Tahu	194.7	11	86.37	10.29	0.002	171.2
10	Constant+ CoverB2 - largerock - Pl5 + Pl7 - Sx5 - wetland + Sx6 + Pl6 + #CWD+ BA_all - B1_all - spruce	200.4	16	84.21	15.97	0.000	2929.7
full	Constant+ CoverB2 - largerock - Pl5 + Pl7 - Sx5 - wetland + Sx6 + Pl6 + #CWD + #B2_S - B1_all + BA_all - spruce + #trees + SBPSmc + CWDcover + BA_dead - Leam + Tahu	203.2	21	80.59	18.73	0.000	11676.5

Habitat parameters: CoverB2 - % cover B2 layer; largerock - rock > 1m; Pl5 - pole-young forest pine stands; Pl7 – old pine stands; Sx5 - pole-young forest spruce stands; wetland – sedge, shrub carr, and high brush; Sx6 – mature spruce; Pl6 mature pine, #CWD – number/25m; #B2_S - # B2 spruce stems/ha; B1_all - # B1 stems/ha; BA_all – basal area/ha; spruce – presence of spruce; #trees - # trees/ha; SBPSmc – presence vs other subzones; CWDcover - % cover of all woody debris; BA_dead – basal area/ha of dead trees > 27.5cm dbh; Leam – # snowshoe hare; Tahu - # red squirrel.

Models with a ΔAIC of less than 2 have high empirical support and 3-4 have reasonable empirical support (Burnham and Anderson 2002). The results indicate marten have a high probability of being found in mature spruce and pine (Sx6 and Pl6) habitats and not being found in mid aged spruce (Sx5) and wetland habitats. Greater CWD cover, greater numbers of CWD, and greater basal area in large dead trees are habitat attributes that indicate a higher probability of marten habitat use. The models also indicate that the SBPSmc subzone and areas containing greater numbers of red squirrel also have a higher probability of containing marten.

Fisher

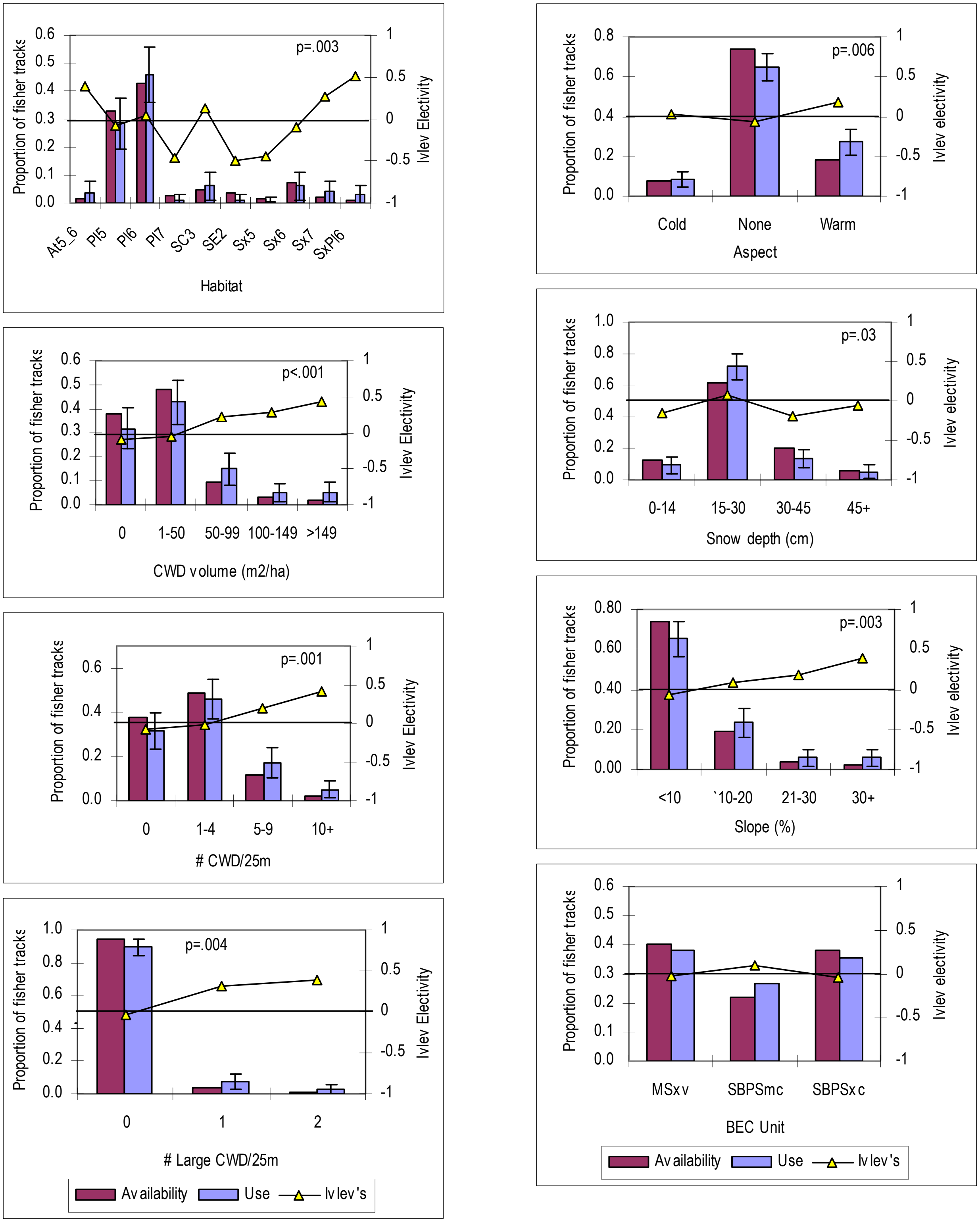
Chi-square analysis on fisher found significant relationships with 10 variables (α=.05). Graphs of the 16 variables exhibiting the greatest potential for influencing fisher habitat selection are shown in Figures 4 and 5. The only habitat used less than expected by fisher was sedge wetland. Increases in the value of CWD variables were associated with increasing use except for CWD cover which showed no selection. More fisher were found on warm aspects and steeper slopes than expected. Strong increases in use were seen with greater numbers of both snowshoe hares and red squirrel. Increased fisher use was also seen for segments with the highest grouse use. Table 5 lists the models used in the multivariate analysis on fisher. Overdispersion was relatively low for this species ($\hat{c}$ =1.9) and AIC was corrected to account for this (QAIC).

Table 5. Models used to predict the probability of detecting a fisher in the YKW Operating Area. QAIC values are a relative index of model parsimony (accounting for dispersion) with ΔAIC values giving the distance between any model and the most parsimonious model. AIC$\acute{\omega}$ is the relative strength of each model, and the Ratio AIC$\acute{\omega}$ give the ratio of evidence relative to the best model. K is the number of parameters (including $\hat{c}$ and constant). The total number of observations is 1042.

	Model structure	QAIC	K	Log L /$\hat{c}$	ΔAIC	AIC$\acute{\omega}$	Ratio AIC$\acute{\omega}$
1	Constant + SxPl6 +Sx7+ #LarCWD + SBPSmc	517.8	6	252.9	0.00	0.347	1.0
2	Constant + SxPl6 +Sx7+ #LarCWD + SBPSmc + At	519.4	7	252.7	1.58	0.158	2.2
3	Constant + Sx7+ #LarCWD	519.8	4	255.9	2.00	0.128	2.7
4	Constant + Sx7	519.8	3	256.9	2.04	0.125	2.8
5	Constant + SxPl6 +Sx7+ #LarCWD + Grouse	519.9	6	253.9	2.11	0.121	2.9
6	Constant + SxPl6 +Sx7+ #LarCWD + At	521.6	6	254.8	3.79	0.052	6.7
7	Constant + SxPl6 +Sx7+ At	521.7	5	255.8	3.89	0.049	7.0
8	Constant + SxPl6 +Sx7+ At + #LarCWD + Grouse + Leam + Tahu	524.0	9	253.0	6.20	0.016	22.2
9	Constant + Pl5 + Sx5 + Sx6 + Pl6 + Shrubcarr + SxPl6 +Sx7+ At + #LarCWD + SBPSmc + Aspect + Grouse	526.6	14	249.3	8.84	0.004	83.2
10	Constant + Pl5 + Sx5 + Sx6 + Pl6 + Shrubcarr + SxPl6 +Sx7+ At + #LarCWD + SBPSmc + Aspect + Slope + Leam + Tahu + Grouse	531.4	17	248.7	13.58	0.000	888.4
full	Constant + Pl5 + Pl7 + Sx5 + sedge + Sx6 + Pl6 + Shrubcarr + SxPl6 +Sx7+ At + #LarCWD + SBPSmc + Aspect + Slope + Leam + Tahu + Grouse - CWDvol + #CWD - snow	541.3	22	248.7	23.52	0.000	127758.2

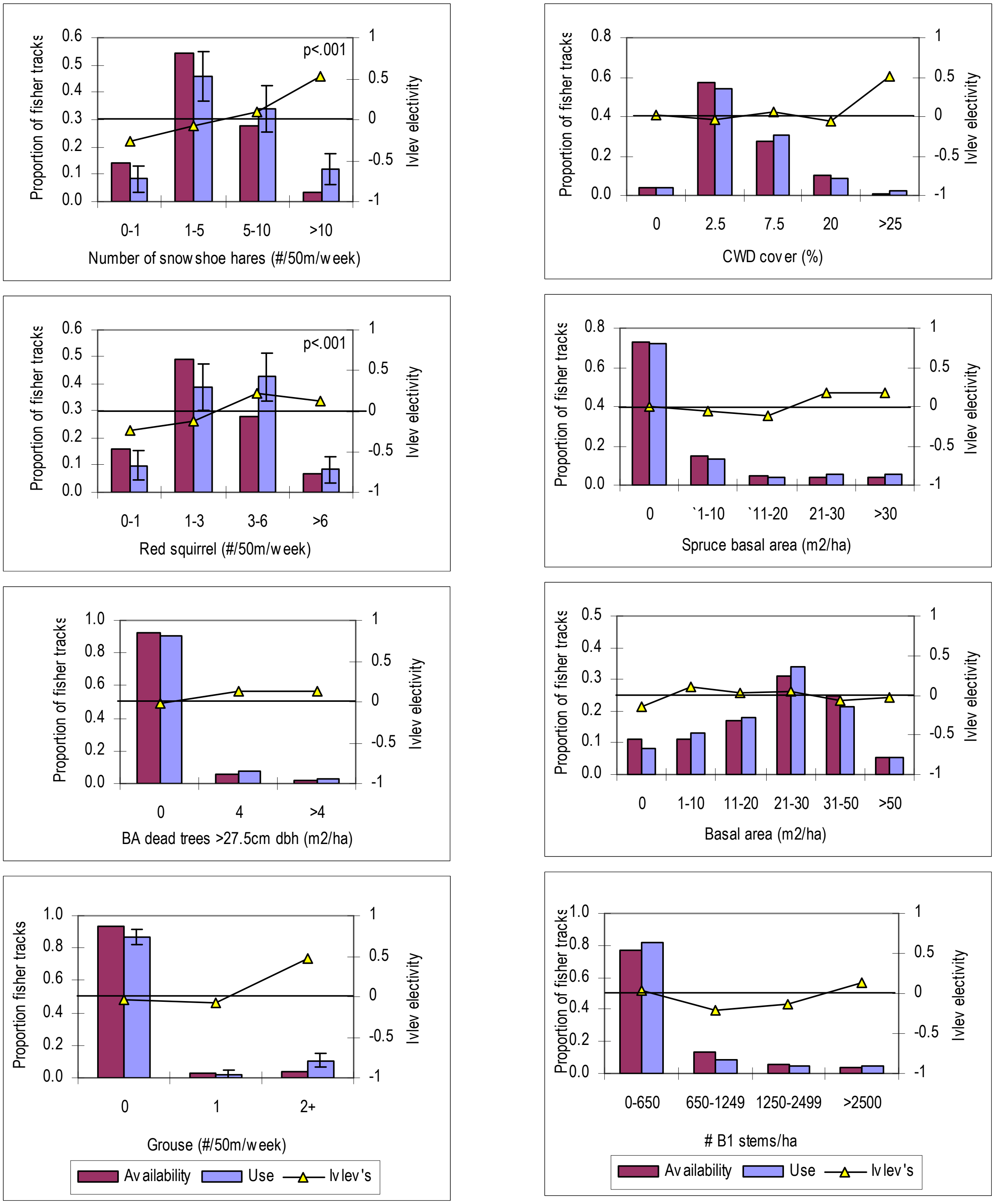
Habitat parameters: Pl5 - pole-young forest pine stands; Pl7 – old pine stands; Sx5 - pole-young forest spruce stands; sedge - sedge wetlands; shrubcarr – all shrub dominated sites; Sx6 – mature spruce; Pl6 mature pine,SxPl6 - mature mixed stands; Sx7 - old spruce stands; #LarCWD - # CWD >27.5cm dbh; CWDvol - m^2 of CWD/ha; #CWD - number/25m; SBPSmc - SBPSmc vs other subzones; Leam – # snowshoe hare; Tahu - # red squirrel; Grouse - # grouse (all species); Aspect – warm (W to SE) vs cold (E to NW); Snow – snowdepth (cm).

Aspen stands were pooled for the multivariate analysis (Pole to mature) due to low numbers of segments. Three models had a ΔAIC of less than 2 and four models had ΔAIC less than 4. The results indicate that old spruce, mixed mature spruce/pine and aspen types have a greater probability of containing fisher. The number of large CWD was present in 5 of the seven top models. Greater numbers of grouse also increased the probability of fisher being present.



FISHER UNIVARIATE ANALYSES

Figure 4. Significant (α=.05) univariate analyses on fisher with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.



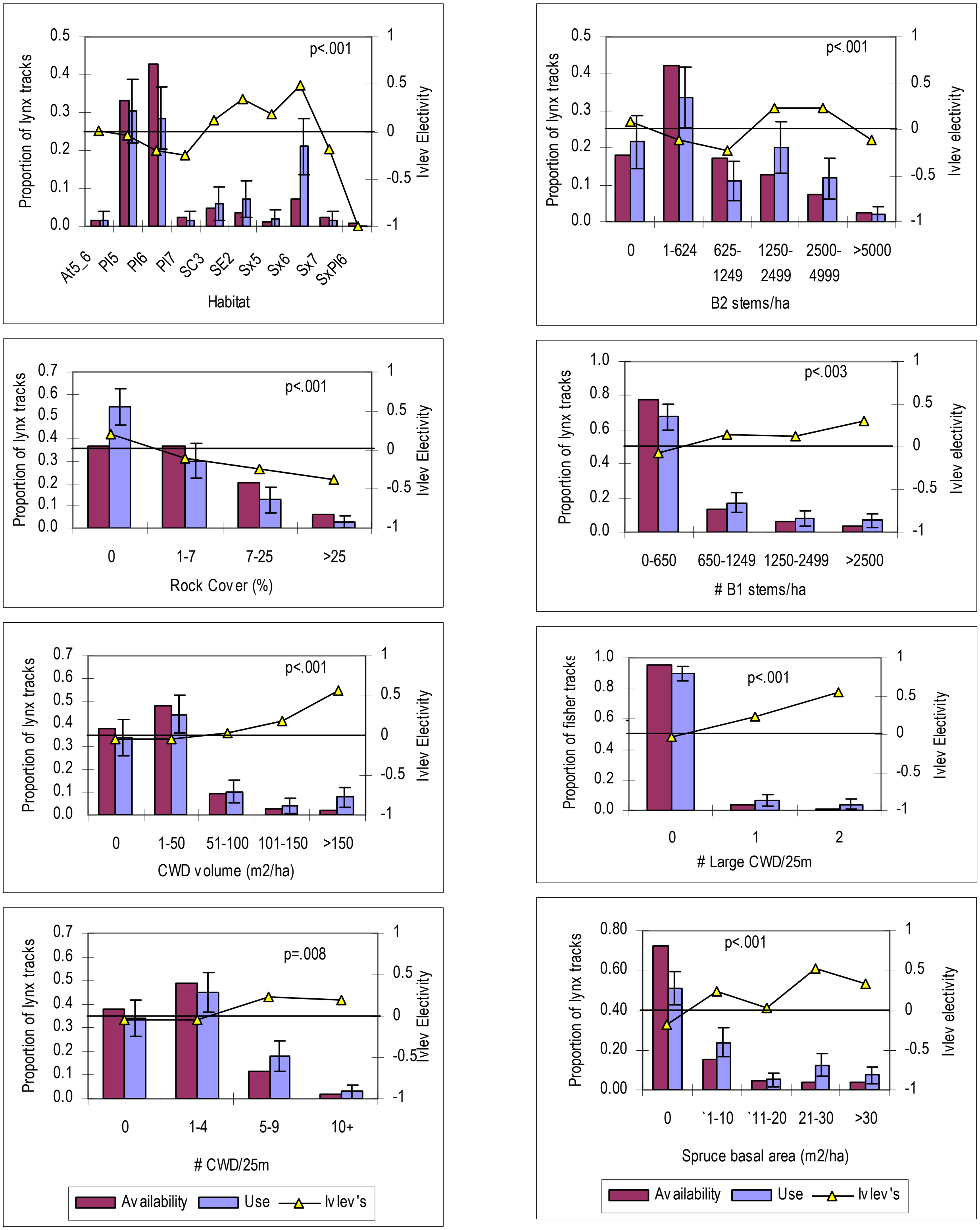
FISHER UNIVARIATE ANALYSES

Figure 5. Significant (α=.05) univariate analyses on fisher with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.

Lynx
Chi-square analysis on lynx found significant relationships with 20 variables (α=.05). Graphs of the 16 variables exhibiting the greatest potential for influencing lynx habitat selection are shown in Figures 6 and 7. Graphs of the remaining variables are shown in Appendix 1. Lynx selected for mature spruce habitats, but avoided mature pine (Pl6) and mature spruce-pine. Sedge wetlands also had high use. Lynx avoided sites with increasing rock cover, but were found in greater numbers than expected in segments where CWD variables increased. Increasing amounts of spruce was also associated with increased lynx selection. Generally, lynx use decreased with increasing structural stage. Increasing snow depth had variable impact on lynx use with increasing use except in the deepest category (>45cm). The MSxv was used significantly more and other subzones significantly less than expected. Use of segments containing snowshoe hare increased dramatically with increasing hare track density. Lynx also showed selection for segments with the greatest grouse densities.

Table 6 gives the results of the multivariate analysis on lynx. Overdispersion was evident with $\hat{c}$=3.3. Two models had a ΔAIC of less than 2 and three models had less than 4. The top two models have presence of spruce as a key indicator in predicting lynx presence and one other model also has spruce as a positive predictor variable. Other important positive predictors included MSxv, shrub carr/high shrub habitat, sedge wetland, large CWD, B1 stem density, snowshoe hare use, and grouse use. The only negative indicator was mature pine habitat.

Coyote
Chi-square analysis on coyote found significant relationships with 19 variables (α=.05). Graphs of the 16 variables exhibiting the greatest potential for influencing coyote habitat selection are shown in Figures 8 and 9. Graphs of the remaining variables are shown in Appendix 1. Coyote showed variable response to a number of attributes. B1 shrub cover, B2 stems/ha, Rock cover, and B1 stems/ha had no clear trend in electivity indices. CWD variables showed decreasing use by coyote at greater levels of the attributes. Likewise, the number of trees/ha shows decreasing selection with increasing tree density. Structural stage 4-5 spruce stands were selected for whereas mature pine habitat was avoided. Generally, more open, younger habitats received greater use by coyotes, and this may be best illustrated by the structural stage graph. Coyotes also made increased use of segments containing shallower snow and gentle slopes. The SBPSxc and SBPSmc subzones were selected for, while the MSxv was avoided. Coyote exhibited variable response to snowshoe hare track density by selecting for the lowest and second highest hare track densities. Segments containing greater track densities of grouse and squirrel were both avoided.



LYNX
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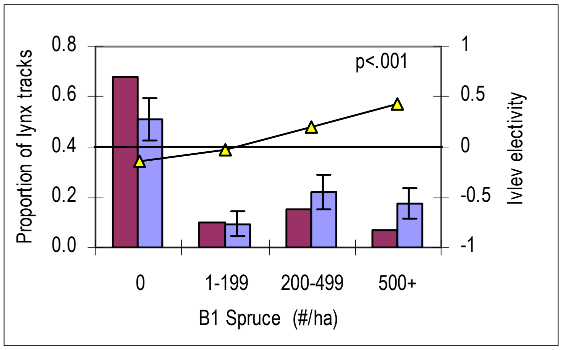
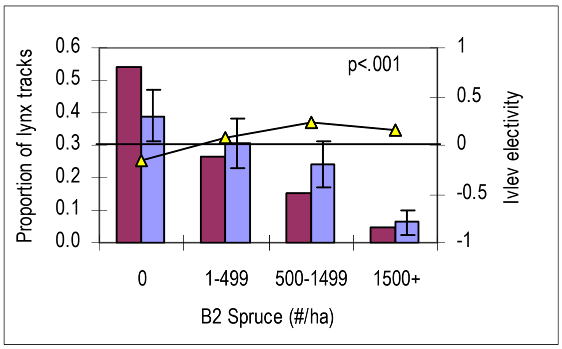
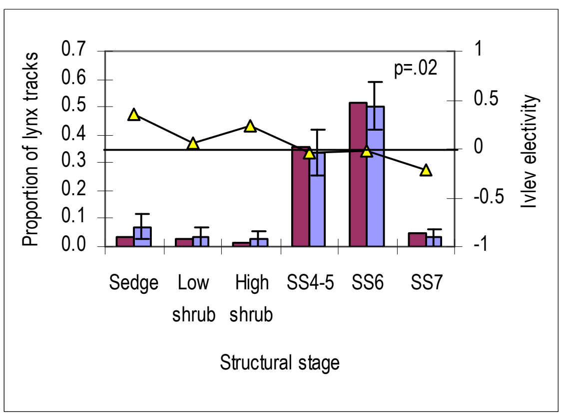
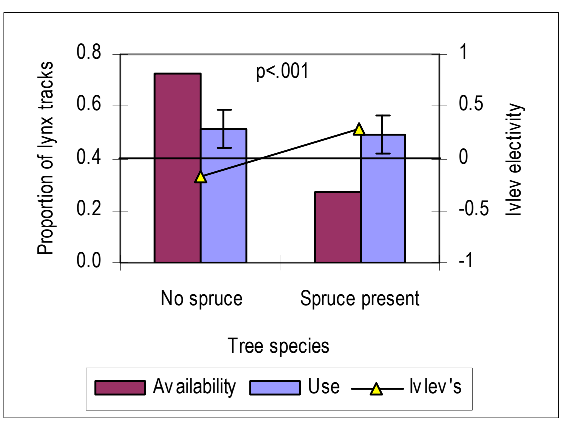
Figure 6. Significant (α=.05) univariate analyses on lynx with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.

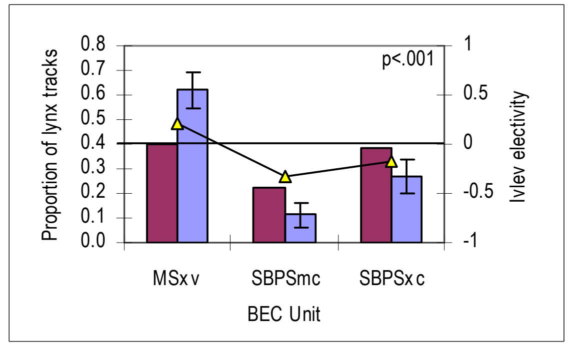


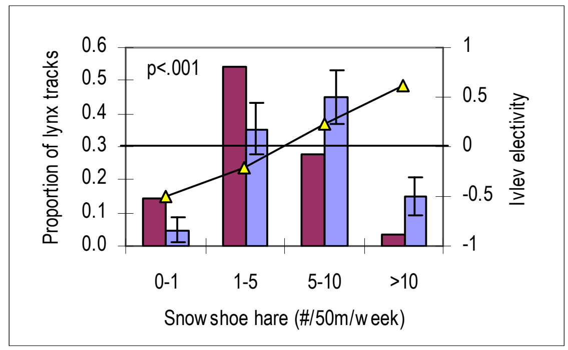


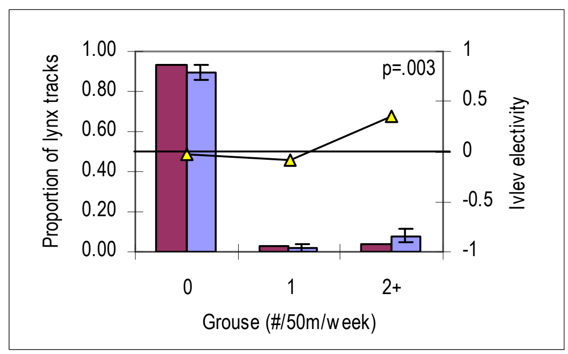




LYNX
UNIVARIATE ANALYSES







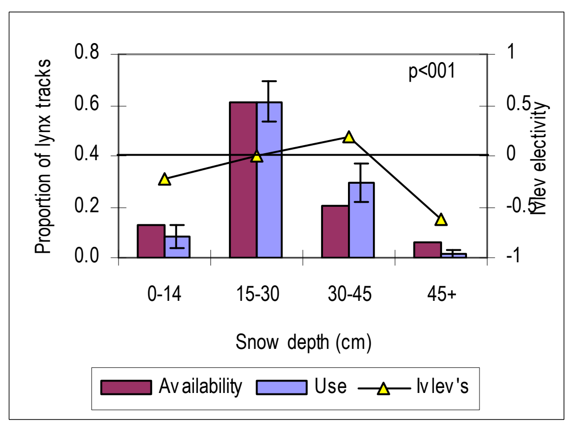
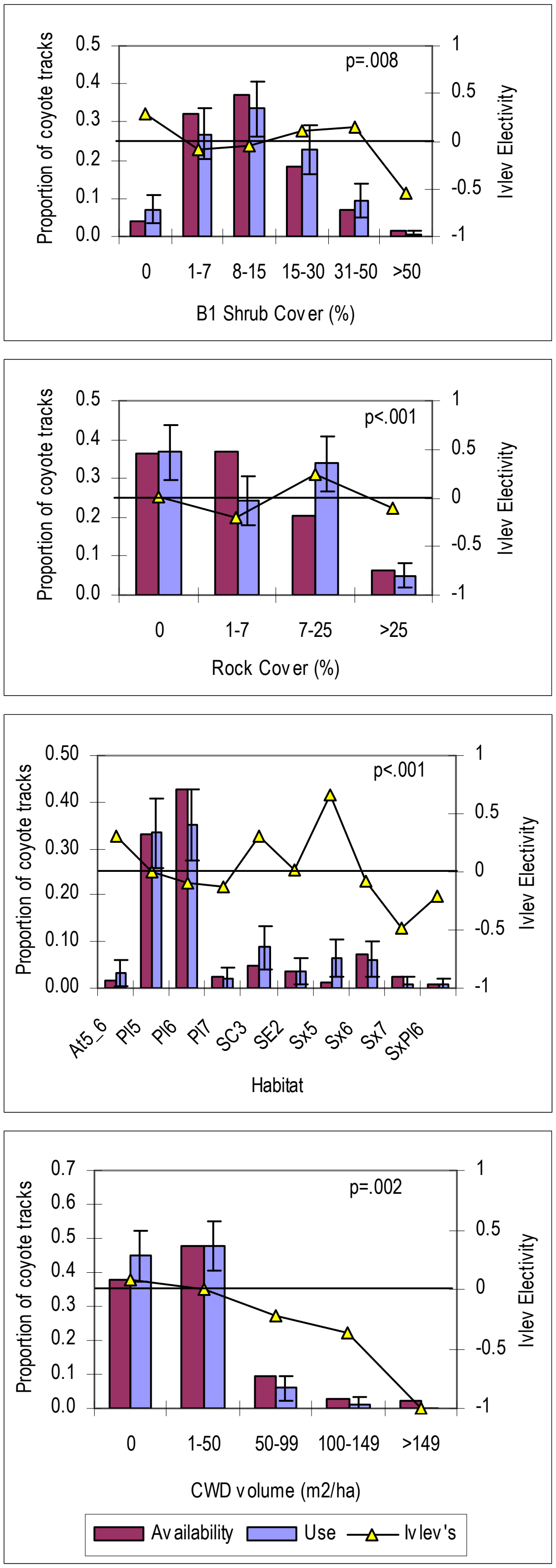


Figure 7. Significant (α=.05) univariate analyses on lynx with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.

Table 6. Models used to predict the probability of detecting a lynx in the YKW Operating Area. QAIC values are a relative index of model parsimony (accounting for dispersion) with ΔAIC values giving the distance between any model and the most parsimonious model. AICώ is the relative strength of each model, and the Ratio AICώ give the ratio of evidence relative to the best model. K is the number of parameters (including ĉ and constant). The total number of observations is 1042.

	Model structure	QAIC	K	Log L /ĉ	ΔAIC	AICώ	Ratio AICώ
1	Constant + MSxv + spruce	300.0	4	146.0	0.00	0.291	1.0
2	Constant + spruce	301.1	3	147.5	1.02	0.174	1.7
3	Constant + Shrubcarr + B1_all + spruce + Grouse + MSxv	301.4	7	143.7	1.36	0.147	2.0
4	Constant + Sx6 - Pl6 + Shrubcarr + Grouse + MSxv	301.6	7	143.8	1.56	0.134	2.2
5	Constant + sedge + Sx6 - Pl6 + Shrubcarr + Grouse + Leam	302.0	8	143.0	1.93	0.111	2.6
6	Constant + Sx6 - Pl6 + Shrubcarr + B1_all + Spruce	304.1	7	145.0	4.02	0.039	7.5
7	Constant + Sx6 - Pl6 + Shrubcarr + B1_all	304.7	6	146.3	4.63	0.029	10.1
8	Constant + Sx6 + Shrubcarr + CWDvol + B1_S	304.8	6	146.4	4.78	0.027	10.9
9	Constant + Sx6 - Pl6 + Shrubcarr + Grouse + B2_S	305.2	7	145.6	5.15	0.022	13.1
10	Constant + Sx6 - Pl6 + Shrubcarr + Grouse + #LarCWD	305.8	7	145.9	5.71	0.017	17.4
11	Constant - Sx5 + sedge + Sx6 + Shrubcarr + Grouse	308.0	7	147.0	7.90	0.006	52.0
12	Constant - Pl5 - Pl7 - Sx5 - Sx6 - Pl6 + Shrubcarr - SxPl6 - Sx7 + CWDvol - B1_all + Spruce + MSxv + Leam + Grouse	309.7	16	138.8	9.61	0.002	122.2
13	Constant - Pl5 - Pl7 - Sx5 - Sx6 - Pl6 + Shrubcarr - SxPl6 - Sx7 + #CWD + #LarCWD + Spruce + MSxv + Leam + Grouse	310.6	16	139.3	10.52	0.002	192.0
full	Constant – rockcov - Pl5 - Pl7 - Sx5 + sedge - Sx6 - Pl6 + Shrubcarr - SxPl6 - Sx7+ At + CWDvol - #CWD - #LarCWD + B2_S + B2_all – B1_S + B1_all + Spruce + MSxv -snow + Leam + Grouse	314.9	26	131.4	14.83	0.000	1661.0

Habitat parameters: rockcov - % rock cover; Pl5 - pole-young forest pine stands; Pl7 – old pine stands; Sx5 - pole-young forest spruce stands; sedge - sedge wetlands; shrubcarr – all shrub dominated sites; Sx6 – mature spruce; Pl6 mature pine,SxPl6 - mature mixed stands; Sx7 - old spruce stands; #LarCWD - # CWD >27.5cm dbh; CWDvol - m^2 of CWD/ha; #CWD - number/25m; B2_S - # B2 spruce stems/ha; B2_all - # B2 stems/ha; B1_S - # B1 spruce stems/ha; B1_all - # B1 stems/ha; MSxv - MSxv vs other subzones; Leam – # snowshoe hare; Grouse - # grouse (all species); Snow – snowdepth (cm).



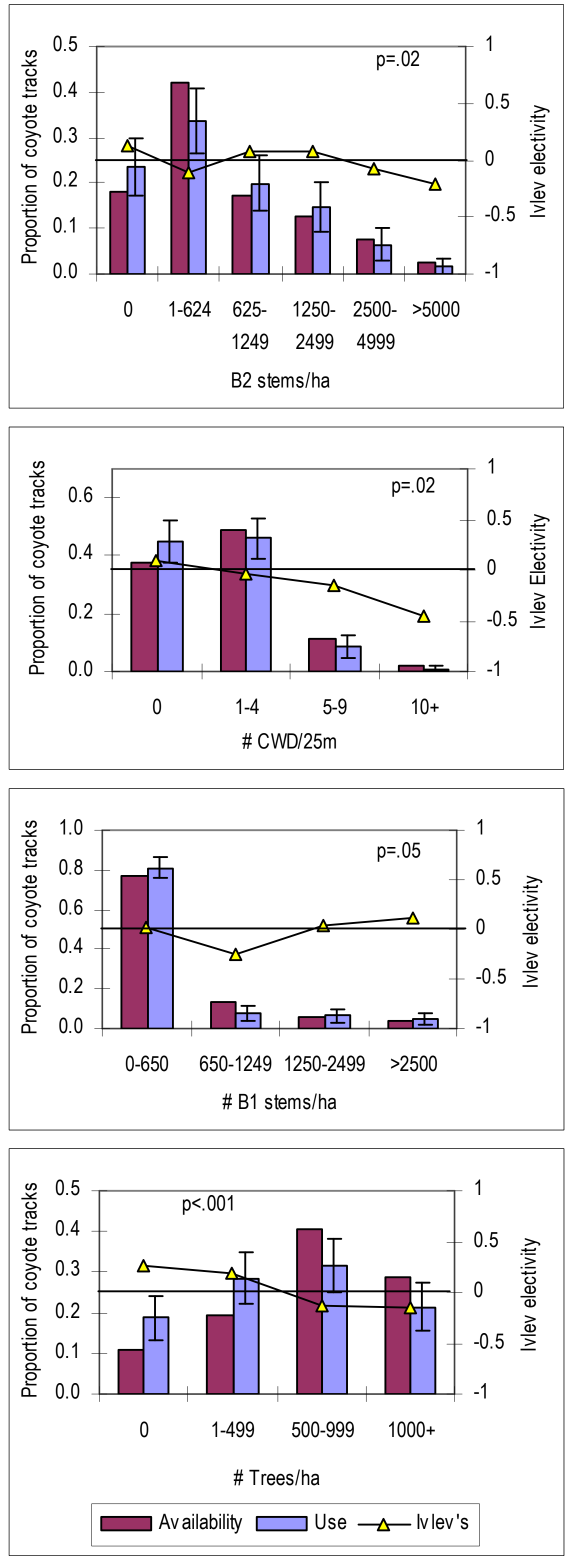
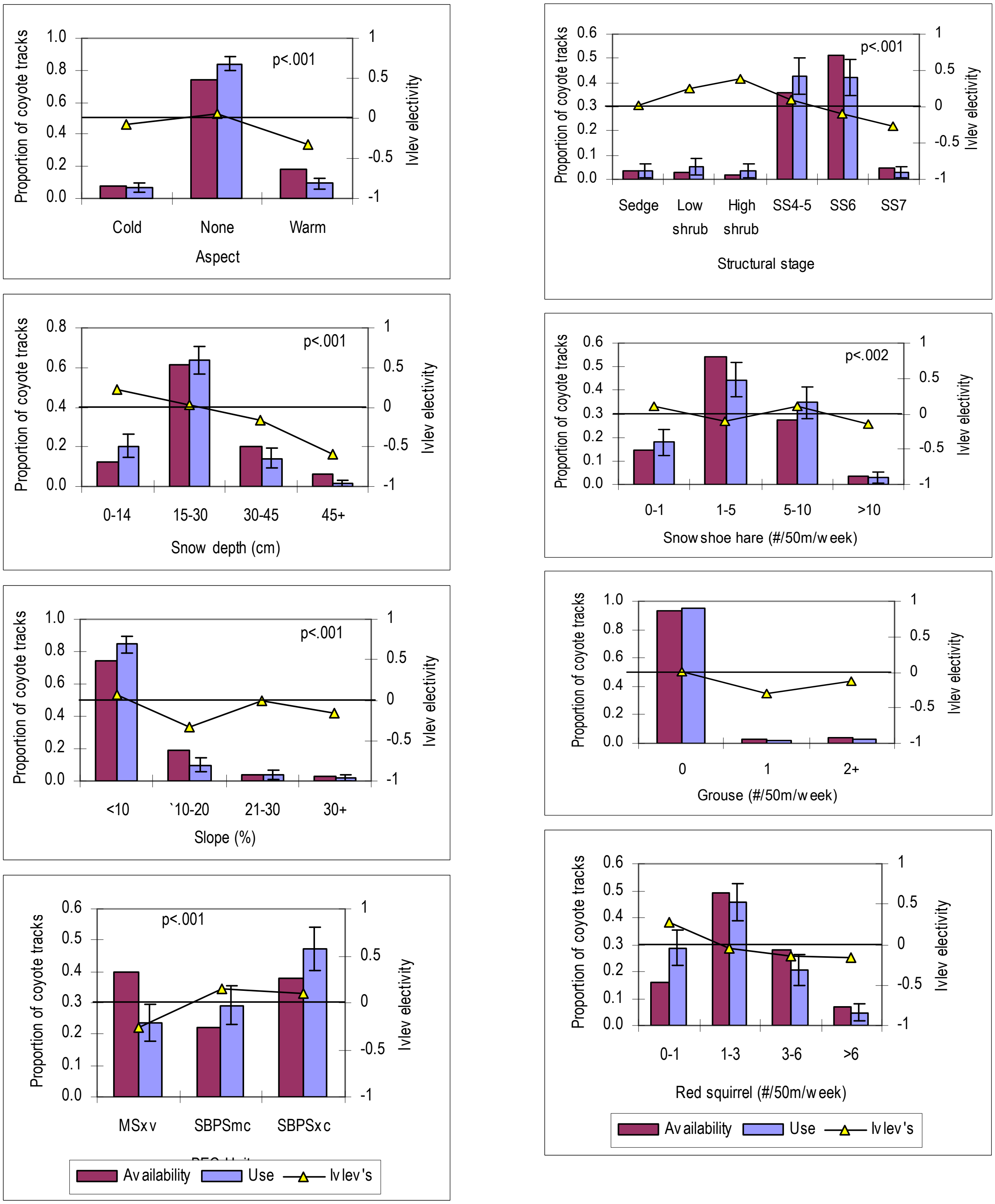


Figure 8. Significant (α=.05) univariate analyses on coyote with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.

COYOTE
UNIVARIATE ANALYSES



COYOTE
UNIVARIATE ANALYSES

Figure 9. Significant (α=.05) univariate analyses on coyote with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.

Ermine

Chi-square analysis on ermine found significant relationships with 21 variables (α=.05). Graphs of the 16 variables exhibiting the greatest potential for influencing ermine habitat selection are shown in Figures 10 and 11. Graphs of the remaining variables are shown in Appendix 1. Generally, ermine avoided habitats containing pine and used spruce dominated habitats more than expected. Shrubby wetlands were also a favored habitat. CWD variables all indicate increased use with greater amounts of these attributes. B1 and B2 shrubs categories had variable use with no clear trends. Likewise, no clear trend is evident for basal area, except when only spruce are considered. Ermine showed strong selection for both increased spruce basal area and presence of spruce. Structural stage showed increasing selection for forested stages (4-7) and differential selection for non-forested stages. The strongest selection was seen for high shrub and old structural stages. Ermine showed a preference for the SBPSmc and the SBPSxc was used less than expected.

Snowshoe hare

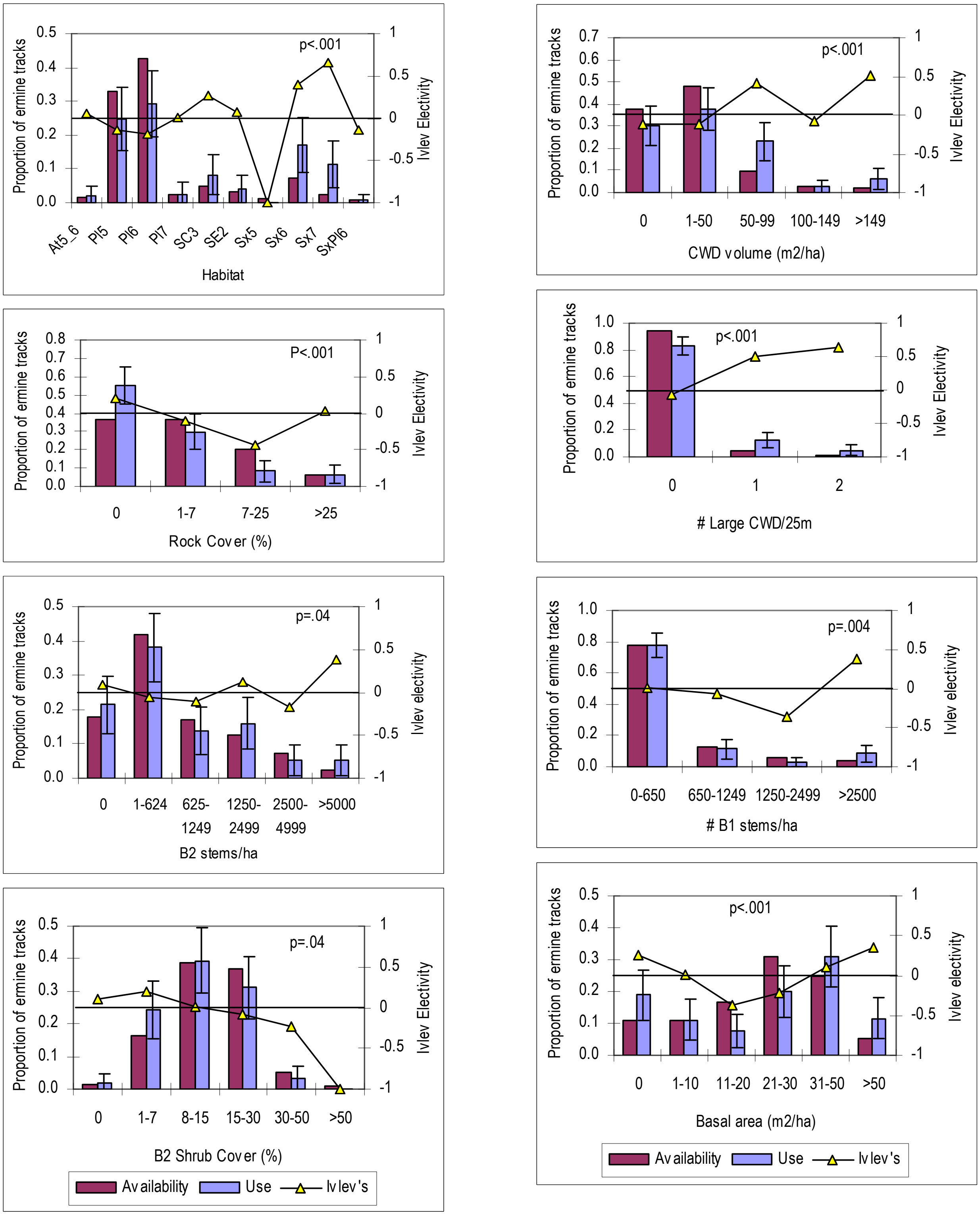
Chi-square analysis on snowshoe hare found significant relationships with 13 variables (α=.05). Graphs of the 8 variables exhibiting the greatest potential for influencing snowshoe hare habitat selection are shown in Figure 12. Graphs of the remaining variables are shown in Appendix 1. Hares selected for mature spruce and shrub habitats while mature pine had less tracks than expected. When structural stage is examined, high shrub was the only stage used more than expected. Hares selected for increasing B1 and B2 stem densities, and more tracks were found when spruce was present. Hares showed some selection for greater CWD volumes and the greatest numbers of tracks were found in the MSxv.

Red squirrel

Chi-square analysis on red squirrel found significant relationships with 15 variables (α=.05). Graphs of the 8 variables exhibiting the greatest potential for influencing squirrel habitat selection are shown in Figure 13. Graphs of the remaining variables are shown in Appendix 1. Squirrels selected for mature spruce and were found in greater numbers in mature pine, mid structural stage pine, and old spruce habitats. Increases in basal area and spruce basal area were also associated with greater proportions of squirrel tracks. Likewise, greater B1 and B2 stem densities were associated with significantly greater use. Squirrels also used segments containing greater numbers of large trees and large CWD more than expected. The highest densities of red squirrel occurred in the MSxv and SBPSmc, with the SBPSxc being used less than expected.

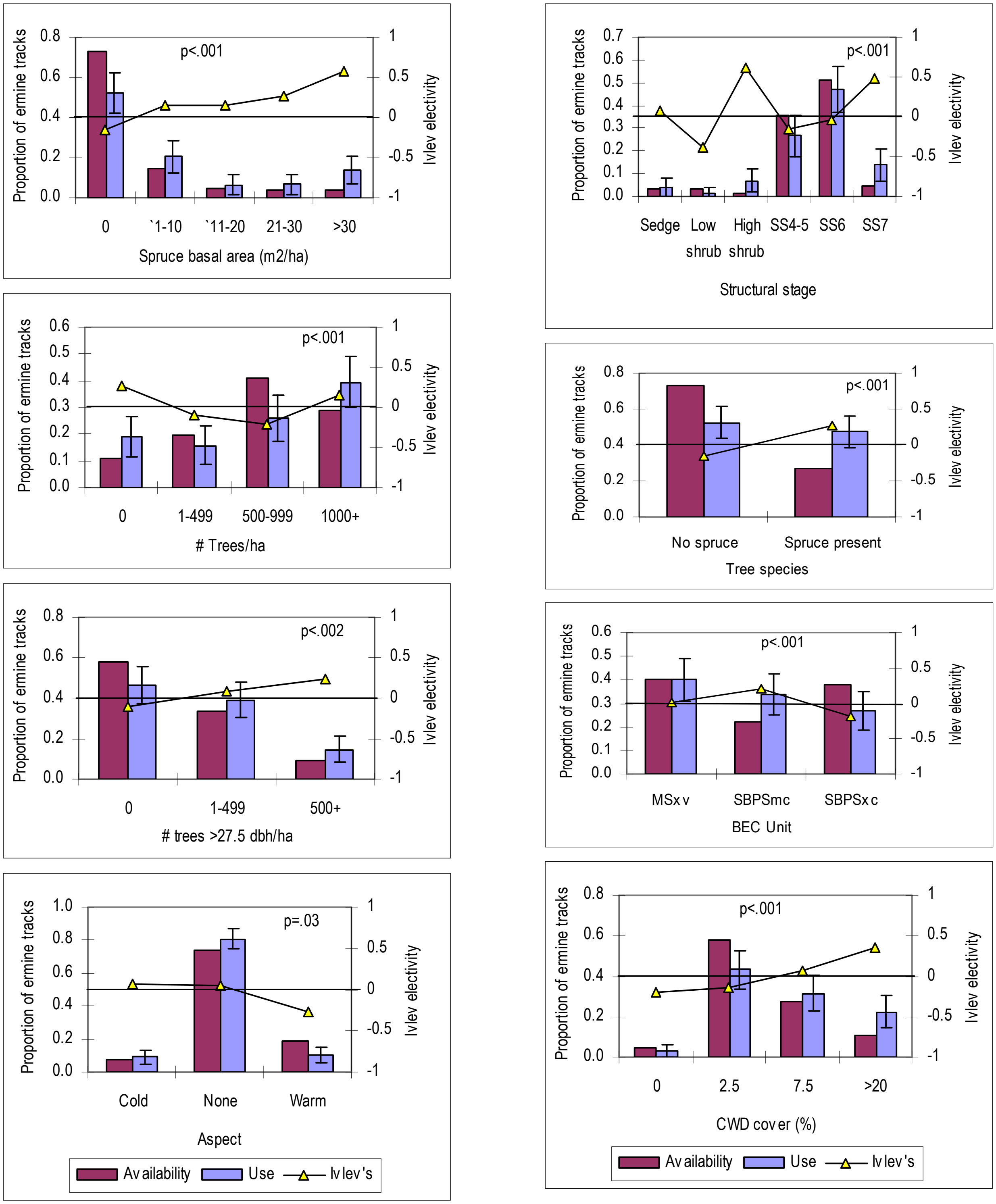
Low density furbearing species

The number of tracks for low density species is shown in Figure 14 by habitat type. Wolves were the most abundant of these species with >45 tracks found in pine types. Approximately 20 wolverine tracks were found, with the majority in pine habitats. The majority of red fox and mink tracks were found in mid-aged pine. Otter and long-tailed weasel were the lowest density species.



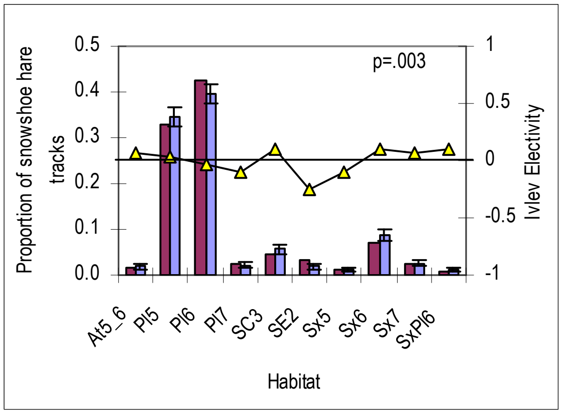
ERMINE UNIVARIATE ANALYSES

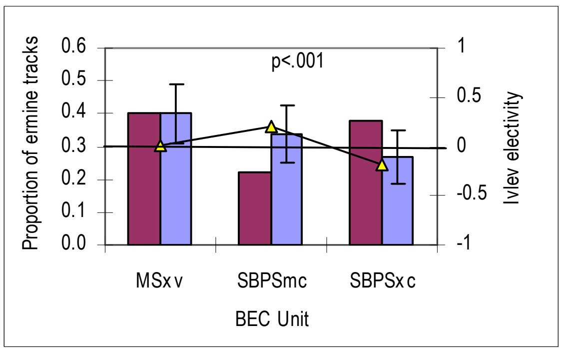
Figure 10. Significant (α=.05) univariate analyses on ermine with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.

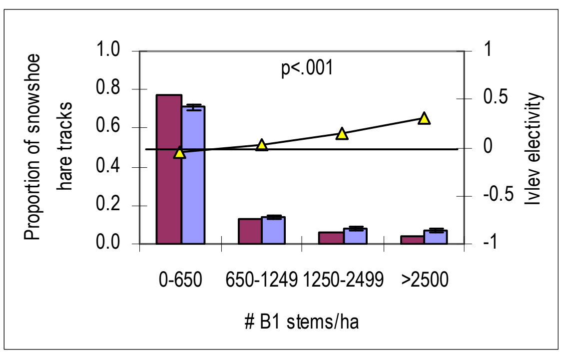


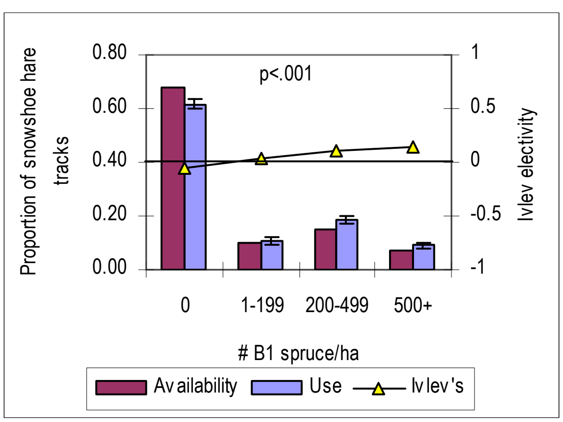
ERMINE UNIVARIATE ANALYSES

Figure 11. Significant (α=.05) univariate analyses on ermine with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.

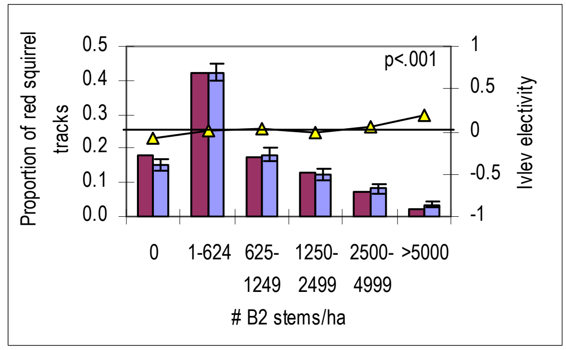


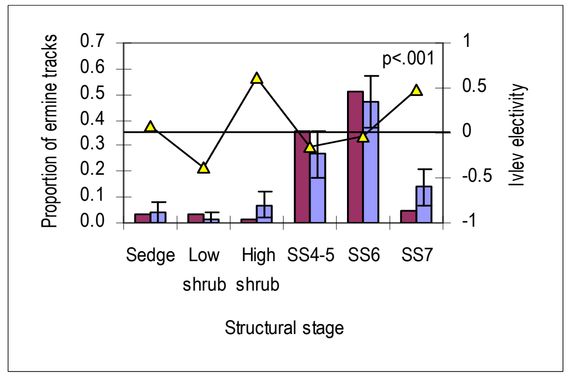


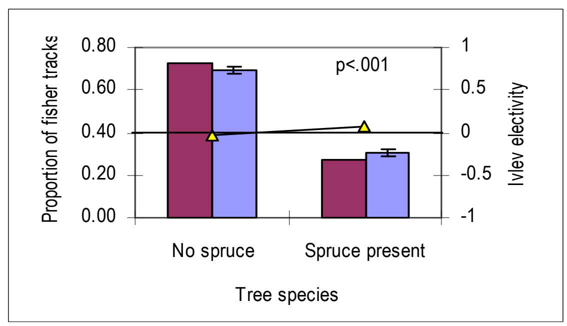




SNOWSHOE HARE UNIVARIATE ANALYSES







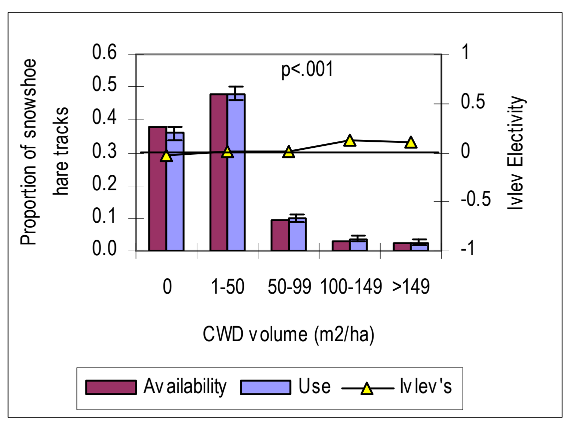
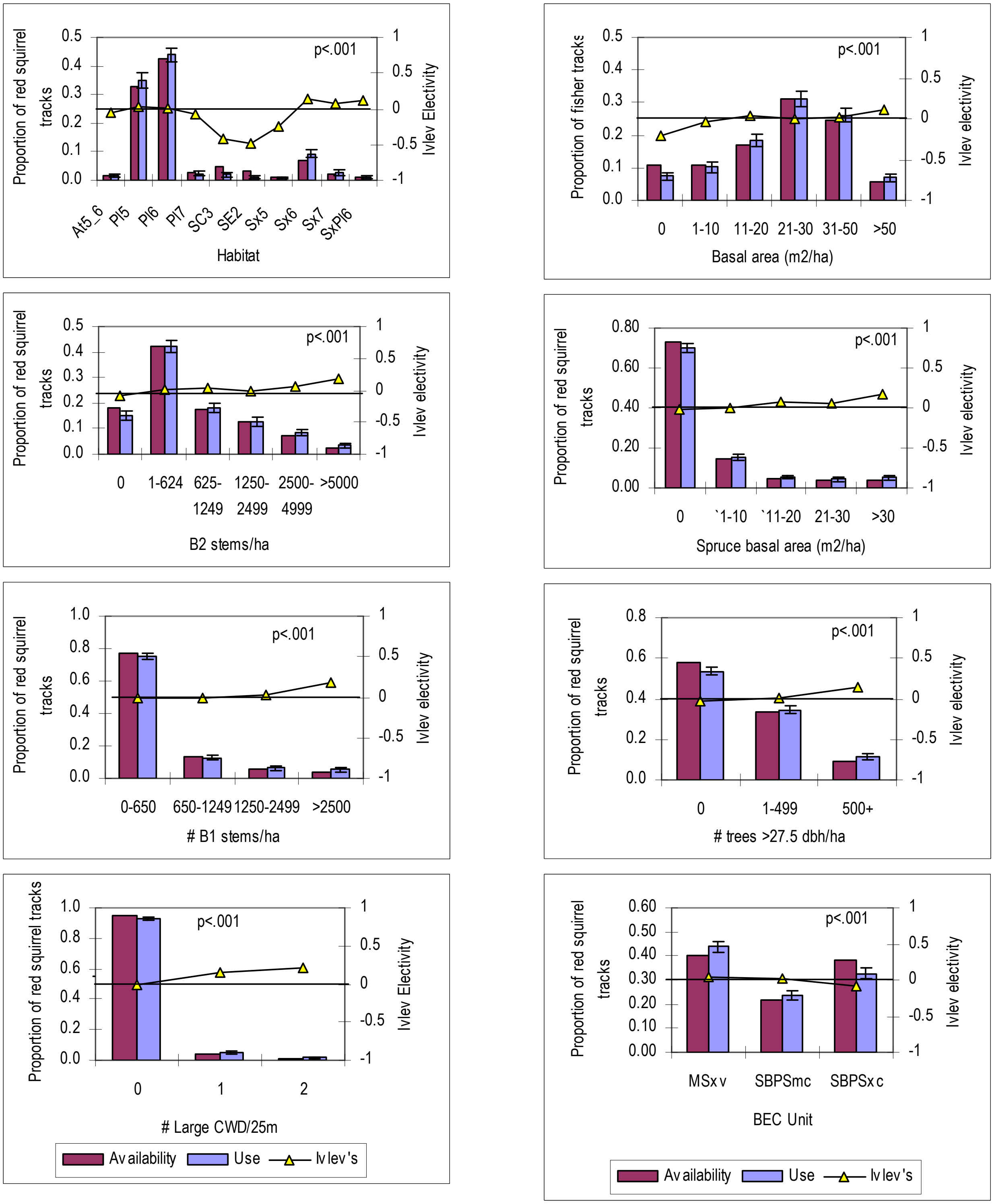


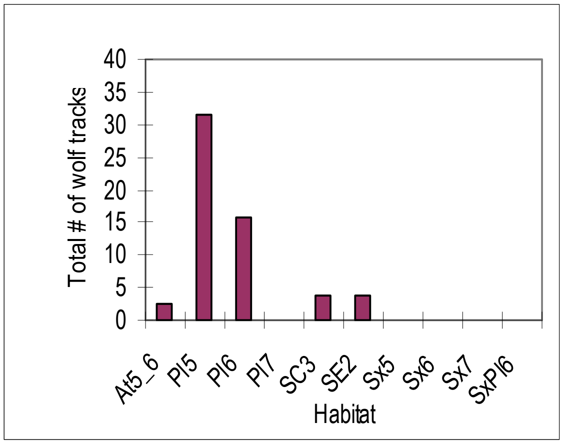
Figure 12. Significant (α=.05) univariate analyses on snowshoe hare with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.



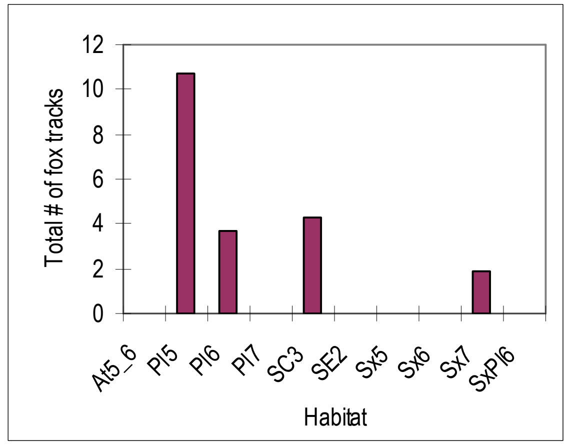
RED SQUIRREL UNIVARIATE ANALYSES

Figure 13. Significant (α=.05) univariate analyses on red squirrel with Bonferroni confidence intervals and Ivlev electivity indices. Positive indices indicate preference and negative indices indicate avoidance.

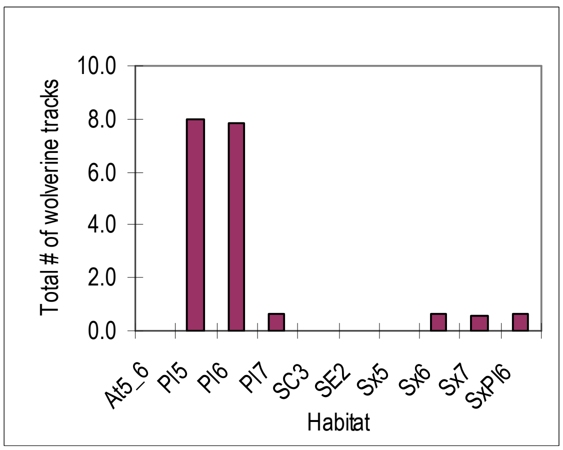
a) Gray wolf



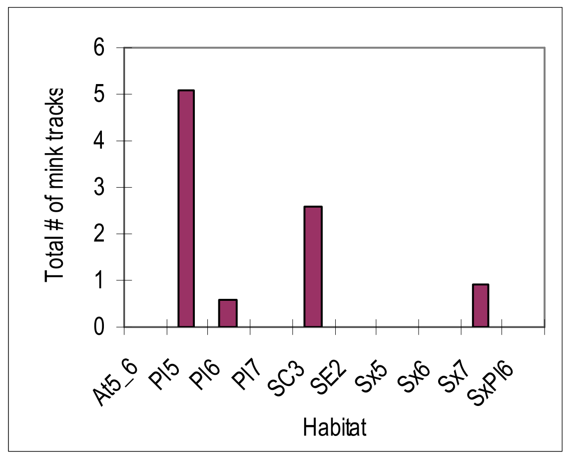
b) Red fox



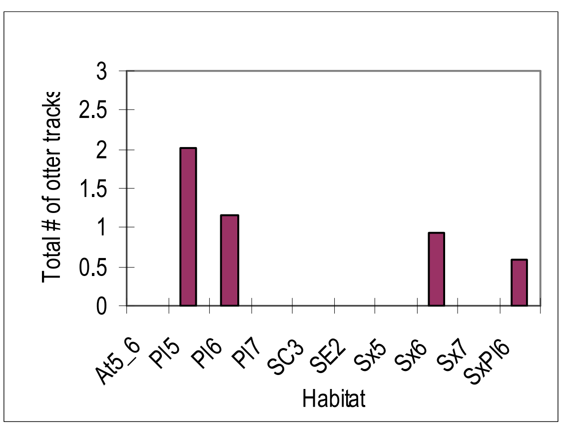
c) Wolverine



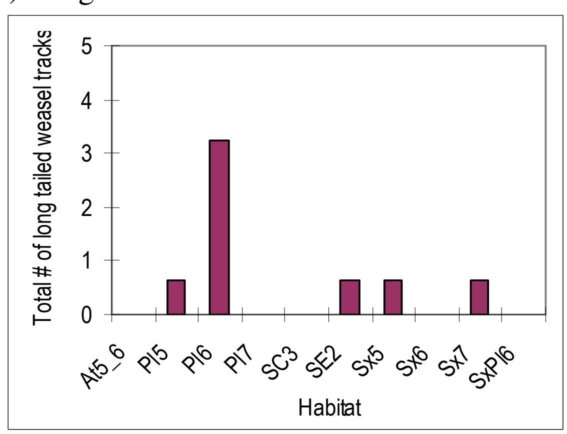
d) Mink



e) Otter



f) Long-tailed weasel



LOW DENSITY SPECIES

Figure 14. Low density furbearing species in the Yun Ka Whu'ten Holdings Ltd operating area. Values are the total number of tracks found over the three year project on the 53 transects used in this study.

6.0 DISCUSSION

Winter is a critical season for many species due to increased energetic costs associated with scarce food and cold temperatures. Winter temperatures in the West Chilcotin are among the coldest in the southern half of BC, and animals surviving here would be expected to select habitats that minimize energetic losses and maximize benefits. Other seasons may also carry challenges (e.g. breeding) that may have to be taken into account; however, ensuring that adequate winter habitat is present is likely to be important for most furbearing species.

The vegetation sampling process use in this study involved assigning a structural stage to each segment of the transects using structural features and age criteria. However, this process is somewhat subjective and has overlapping age ranges (DEIF 1988). Often stands are transitional and must be placed into only one structural stage. When tree ages derived from increment cores were compared to structural stage ranges most significant (>20 years) deviances were due to younger structural stages being assigned to older stands. This problem may be inherent in classifying the types of stands found in the Chilcotin. Stands that developed on poor, dry growing sites are often single storey and have small diameters (e.g. 20cm or less) even though the stand may be quite old (trees >200 years). CWD volumes are typically low on these sites and there is often little shrub development except small pine and soopolallie. These stands do not fit the structural definition of old forest (i.e. structurally complex with shade tolerant tree species present in all vegetation layers and abundant snags/CWD in all stages of decomposition). Often these stands were placed in the mid-structural stage (4-5) due to their characteristics, although survey notes usually indicated that the stands were borderline mature. The opposite problem also occurred in stands that have been affected by low level disturbance. Many stands in the Chilcotin were affected by mountain pine beetle and/or low intensity fires. The resulting stands can resemble either old forest (multi-layered with abundant CWD) or pole aged stands (only the occasional vet) depending on the level of disturbance. Despite the large age range for the structural types found in this analysis, the results found here indicate that structural features have an important impact on wildlife use and were appropriate for this analysis.

Marten

In this study, marten showed a preference for mature coniferous forest during winter which supports the findings of others (Buskirk et al. 1989, Wilbert 1992, Buskirk and Powell 1994). However, marten did not seek out the more structurally and floristically complex old forest habitat that they are frequently reported to require (Buskirk and Powel 1994, Thompson and Harestad 1994). Marten did show a strong association with CWD and this attribute has been associated with access to subnivean prey (Corn and Rapheal 1992, Thompson and Curran 1995), escape from predation (Thompson 1994, Hodgman et al. 1997), and the provision of thermoregulatory resting/denning sites (Chapin et al. 1997). Chi-square results in this study indicated that more tracks were found in habitats containing large rock. This feature also provides increased habitat complexity and subnivean access that marten have been observed to use[3]. Ruggiero et al. (1998) found that rock crevices were the most selected denning site for marten in Wyoming. This feature may also provide access to food resources during winter.

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[3] Furbearer trailing occurred during the winter of 2002/2003 and individual marten tracks were often observed accessing subnivean spaces associated with large rock (YKW unpublished data).

Numerically, microtines have been found to form the majority of marten diets with snowshoe hare, squirrel, and grouse also comprising a significant portion in some studies (Martin 1994, Poole and Graf 1996, Cumberland et al. 2001). Microtines use subnivean spaces in vegetation and beneath other structures to move about in winter. This study classified all microtine tracks as unidentified rodents, and no significant relationship with marten use was found. This may be due to these rodents occupying subnivean spaces and making few tracks on the surface of the snow. There was a strong relationship with the number of red squirrel tracks, and marten also selected segments with the highest snowshoe hare track densities. Cumberland et al. (2001) suggest that although these larger species are found in lower frequencies than small rodents in marten diets, their caloric value can dominate the total calories consumed. Marten showed some selection for habitats with greater B2 stem densities, and this may occur when taking advantage of greater hare densities in those habitats.

Multivariate modeling for marten had a relatively high overdispersion. High variance is often found in count data where there is some dependency between observations (Burnham and Anderson 2002). Transects in this study were 500m long and composed of consecutive segments. In this design, an animal crossing one segment has a greater probability of crossing the segments on either side than segments on another transect. This lack of independence is a potential pseudoreplication problem inherent in this type of study design. However, it was not feasible to randomly intersperse all sample plots within the study area to completely eliminate dependency between samples. Hulbert (1984) recognizes this and advises that there are situations where adequate interdispersion can only be achieved by dispensing with strict randomization. D'Eon (2001) used a similar study design to that employed here to examine deer habitat use. In that study, he suggests that the use of 50m segments provided an optimal balance between sample independence and changing differences in habitat conditions. Burnham and Anderson (2002) suggest that substantially large values (6-10) are usually caused by a model structure that does not account for an acceptable amount of the variation in the data. The value for marten lies just below this range and it is likely that there are missing variables that would explain more of the variation in the data. Landscape level attributes were not examined in this study and others have found that marten are affected at this level of habitat organization (Hargis et al. 1999, Chapin et al. 1997b)

Despite the high variance, the multivariate results support the findings of others (Buskirk et al. 1989, Wilbert 1992, Buskirk and Powell 1994) by indicating that mature spruce and pine habitats have a greater probability of containing marten. Increased CWD was also strongly associated with marten habitat as has been found by others (Corn and Rapheal 1992, Thompson and Curran 1995, Thompson 1994, Hodgman et al. 1997). Interestingly, large rock was found to be negatively associated with the probability of finding marten despite the univariate results. This may be due to multivariate modeling only taking presence/absence into account and not total track densities. Hares and squirrels were positive indicators of marten presence; however, neither species showed selection for this attribute. Large rock may be associated with increased access to both microtines and potential den sites. When hunting in this habitat, marten may exploit it fully and leave increased numbers of tracks in isolated areas. Likewise, segments in the vicinity of den sites would have greater track densities, but only be recorded as a single presence. Greater basal area in large dead trees was present in two of the top 5 models. Large dead trees provide opportunities for denning and these structures have been found to be important marten den sites in Oregon, Washington (Martin et al. 1997), and Wyoming states (Ruggiero et al. 1998).

Fisher

In this study, fisher showed a preference for old spruce, mature mixed stands, and mid-aged to mature aspen types. Other researchers have documented the use of deciduous habitats during winter (Weir and Harestad 1997, Badry et al. 1997). Increased selection was also seen for shrub habitats and this may be associated with increased numbers of snowshoe hare. This study found that hares made significantly greater use of high shrub habitat. Powell (1979) found that hares were one of the most important prey items in fisher's diets; however, it has been suggested that fishers are opportunistic foragers that will diversify their diet when preferred prey are scarce (Powell et al. 1997). There was strong selection for increasing density of snowshoe hare tracks by fisher, and these results suggest that fisher may target prey species based on their density. This is supported by fisher selection for segments containing squirrel and grouse only where there was greater use by these species. Fisher may pursue hare as a primary prey, but switch when hares are scarce or alternate prey densities are high. Fisher showed selection for CWD attributes and this structure may be important in providing denning sites or subnivean access. Fisher prey also includes microtines, and subnivean access via large CWD would be important in accessing this food item.

Warm aspects and steeper slopes were also selected for in this study. Krohn et al (1997) found that fishers were restricted to areas with shallow snowpack; however, no clear trend was evident in this study. Hare and squirrel abundance was greatest in deeper snowfall subzones (SBPSmc and MSxv) and fisher may use topographic features to access this prey base. Warm aspects and steeper gradients are associated with shallower snow conditions. Using these habitats would lower energetic costs when traveling between forage sites in deeper snow zones.

Multivariate analysis on fisher had relatively low overdispersion. The top models indicate that old spruce, mature spruce-pine stands, and aspen stands had greater probability of containing fisher. Fisher have been seen to occupy a range of habitat types to access different prey sources (Powell 1994). Large CWD was also in 5 of the top 7 models indicating strong association with this attribute. These results are supported by fisher trailing data from the winter of 2002/2003 which found that animals used a variety of habitats and often traveled along edges of meadows. In that study, CWD and rock crevices that were passed by fisher were usually investigated extensively[4]. Fisher foraging strategy appears to be to access a variety of habitats, utilize edge effect, and investigate any structure that will provide habitat for prey species.

Lynx

In this study, lynx showed a preference for mature spruce habitat and avoided mature pine habitat. This is supported by Banfield (1974) who suggests that lynx are closely associated with dense climax forest. Pool et al. (1996) also found that dense coniferous and deciduous forests along with dense shrublands had the greatest lynx use; however, unlike this study, most of the forested stands were aged 20-80 years post fire. The Pool et al. (1996) study also found that wetland complexes were least selected. In contrast, sedge wetlands had greater numbers of lynx

[4] Furbearer trailing occurred during the winter of 2002/2003 and high use fisher behavior was often observed associated with any CWD and large rock encountered (YKW unpublished data).

tracks than shrub habitat in this study. Stands with greater numbers of B1 and B2 spruce were selected for by lynx. Hares, their main prey item, also showed some selection for high densities of B1 spruce in this study. Murray et al. (1994) found that open spruce forests were favored by lynx over dense spruce forest. In that study, lynx showed increased use of closed spruce habitat in a year when hare densities were greatest there, but this was not significant (Murray et al. 1994). In this study, lynx showed a strong trend of increasing use of segments containing spruce and segments with greater hare track densities. Habitats with the greatest numbers of grouse tracks also were selected for significantly. Lynx may search out habitats with high grouse numbers or just exploit this habitat when greater numbers of grouse are found.

CWD variables showed strong selection in this study. Lynx are known to preferentially use CWD for denning sites (Koehler 1990, Koehler and Aubry 1994, Slough 1999). CWD provides cover from elements and predators as well as providing escape terrain (Koehler 1990). Koehler and Aubry (1994) suggest that the availability of suitable den sites may be an important determinant of habitat quality for lynx. Lynx may also relocate dens within years in response to disturbance and the proximity of alternative den sites could be important (Slough 1999). This study also found that lynx made significantly more use of the MSxv than either the SBPSmc or SBPSxc subzones.

Multivariate analysis on lynx had relatively low overdispersion. The top models indicate that mature spruce and shrub carr habitats have the greatest probability of containing lynx. Lynx use of shrub carr is likely to be associated with higher hare densities in the high shrub structural stage. These stands have high stem densities that provide overhead cover for hare. The presence of spruce and high B1 stem densities also raise the probability of a habitat containing lynx. CWD variables were not in the top models; however, this may be due to the conversion of track density to presence/absence. Lynx denning sites would have greater numbers of tracks, but this information would be lost in the multivariate analysis. The strength of the univariate analyses and references in the literature suggest that CWD should be viewed as an important component of lynx habitat.

Coyote

In this study, the only significant habitat preference shown by coyote was for structural stage 4-5 spruce. Murray et al. (1994) found that coyote hunting success and number of hare kills was greatest in dense spruce. Even when hares were relatively scarce, coyotes still made greater use of dense spruce types (Murray et al. 1994). In that study, snow depth was shallower and harder in the spruce types that coyotes used. Coyotes have a relatively high foot load ratio (ratio of body mass to foot area) and this may influence their habitat choice (Murray et al. 1994). In this study, coyotes showed a strong avoidance of segments with deeper snow. Among habitats, structural stage 4-5 spruce was the habitat with the third shallowest snow conditions after structural stage 5-6 aspen, and 4-5 pine with shrub carr containing the fourth deepest snow depth. All of these habitats received coyote use in proportion to or slightly greater than availability. Interestingly, snowshoe hare used structural stage 4-5 spruce slightly less than it was available and coyote habitat use did not rise consistently with hare use. For coyote, increased hunting success in a habitat type may make it more desirable than high prey densities.

Coyotes are considered generalists with respect to habitats, climates, and foods across north America (O'Donoghue et al. 1998). During winter in the Yukon, coyotes were found to switch from hares to small mammals during cyclic highs for rodents (O'Donoghue et al. 1998). Success was greater for meadow dwelling *Microtis* species than forest dwelling small mammals such as voles (O'Donoghue et al. 1998). We were not able to quantify small mammal densities effectively in this study due to their subnivean habits in winter. However, in this study coyote made more use of habitats with less structure, such as both low and high shrub, than more complex older forest which may be associated with searching for *Microtis* species. Scavenging is also likely to be important during winter. High and low shrub habitats are associated with moose forage and coyotes may patrol these areas due to a greater likelihood of finding wolf killed moose carcasses.

Ermine

In this study, ermine used old and mature spruce significantly more than expected while mature pine was avoided. Ermine are reported to prefer early successional habitats (Simms 1979, King 1989) whereas forests are usually avoided due to lower small mammal densities and a lack of cover (King 1989). In contrast, Thompson et al. (1989) found no selection between different stand ages in Ontario forests. No early successional forest communities were included in this study; however, the high shrub structural stage received more use than availability. The greater use of old and mature spruce habitats in this study may be related to increased cover and prey availability. The old structural stage has greater vertical and spatial heterogeneity as well as increased CWD cover which would provide increased protection for ermine. Samson and Raymond (1998) found greater use of woody debris piles and edge habitat by ermine in plantations during the summer. This study also found greater ermine use associated with increasing values of all CWD indices. In addition, habitats containing spruce generally have greater moisture and are more productive, which may lead to greater prey abundance. This combination of attributes may make old and mature spruce stands in the west Chilcotin more attractive for ermine. However, at this time we do not know how this use compares to that in early successional forest habitats.

Snowshoe hare

In this study, snowshoe hare used mature spruce significantly more than expected while mature pine and sedge habitats were avoided. Snowshoe hare use a wide variety of habitats including conifer dominated, deciduous riparian forest, and shrub habitats, but prefer young successional forest especially those 10-20 years post disturbance (Stevens and Lofts 1988). This reported preference is supported by the significantly greater use of segments containing more B1/B2 stems and the high shrub structural stage in this study. Hares also made greater use of segments containing spruce, and this may be due to increased productivity of preferred browse species such as willow in this type of habitat. Areas with greater CWD volumes were used significantly more than areas with no CWD. This material provides good thermal and escape cover for hares (Stevens and Lofts 1988)

Red squirrel

In this study, red squirrel used mature spruce significantly more than expected while treeless habitats were avoided. Mature pine, mid structural pine and old spruce received use in excess of availability. It is likely that the greatest influence on squirrel use is the availability of conifer seeds, especially spruce and pine which are its most important diet item (Stevens and Lofts 1988). This preference would explain the increased use of stands with greater basal area and greater spruce basal area in this study. Stevens and Lofts (1988) reported that larger diameter trees are chosen preferentially over small diameter trees for nesting, and this is supported by squirrels greater use of segments with larger diameter trees in this study. Squirrels also made greater use of habitats containing large CWD. This material would provide increased escape terrain, middens for cone storage, and substrate for hypogeous fungi (Maser et al. 1979). Hollow logs are often used as midden sites (personal observations of author) and large diameter pieces would provide greater volume for storage. Squirrels will forage on fungi and will often dry them for later use (Stevens and Lofts 1988).

7.0 CONCLUSIONS

The analysis of this data has revealed a number of areas where species habitat requirements overlap. Recognizing and making use of overlapping requirements may allow resource managers to manage for species at risk or regionally important species in a way that minimizes the impact on other resources. Further, producing important habitat attributes in managed stands is likely to make them more productive for all wildlife species.

Spruce is a habitat element that was positively linked to all seven animals examined here. Univariate analyses suggested that mature and old spruce habitats are preferred by marten, lynx, ermine, snowshoe hare and red squirrel. Multivariate analyses indicated that these habitats were among the most important in determining the presence of marten, fisher, and lynx. This overlap also extends to species other than furbearers. These stand types also provide good winter habitat for moose when present near riparian areas. Baker (1986) found that moose selected spruce forest within 200m of wetlands during winter in the West Chilcotin. Riparian spruce forest in the Chilcotin was found to have greater diversity, richness, and abundance of bird species than pure pine stands[5]. The presence of young spruce is also important to some species. For coyote, this was the only habitat used more than expected. Lynx also showed strong selection for habitats with greater numbers of both B1 and B2 spruce.

Spruce may be of value to these species due to increased canopy volume. Typically, spruce has more branches, less space between branches, and a greater tendency to form brooms than pine. This structural difference provides increased cover and denning opportunities for species such as red squirrel, marten, and fisher. Young dense spruce types were found to have shallower, more compact snow conditions in one study that may increase the efficiency of predators (Murray et al. 1994). The dense overhead cover may also decrease the effectiveness of avian predators such as goshawks and owls making this habitat attractive to hares. Lastly, spruce generally grows on moister, more productive sites in the Chilcotin. This productivity results in greater biomass and may translate into more prey species regardless of structural stage.

Increases in the amount of woody debris was associated with increased use for six out of the seven species examined here. Only coyote had a negative association with CWD variables.

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[5] Waterhouse, M.J. 1995. Breeding bird communities in riparian habitats of the MSxv and SBPSxc in the Cariboo Forest Region. Unpublished report on file with the Kamloops Forest Region.

Woody debris provides both thermal and protection cover as well as escape terrain for both predators and prey. However, both the size and distribution of CWD are important. The arrangement of woody debris in this study was clumped with many segments having little or no debris while others had large numbers of pieces that were piled over 1m high. A study on lynx den site characteristics in the Yukon found that 'jackstrawed' woody debris piles (irregular piles with high vertical diversity) were preferred den sites (Slough 1999). Chapin's (1997) results in Maine suggest that structural complexity produced by woody debris may be more important for marten than the age or species composition of the forest overstorey.

Multivariate modeling indicated that greater numbers of large woody debris was important for fisher while increasing CWD cover was important for marten. These two measures encompassed the opposite ends of the spectrum for woody debris. CWD cover included brush piles and root wads that provided significant cover. The greater importance of this parameter for marten may relate to the smaller size of marten and its use of small mammals as prey. Marten would be able to use smaller openings to access subnivean spaces and small mammals would also benefit from this type of cover. In contrast, the fisher is larger and may require large CWD to access subnivean prey species.

Chapin (1997) found that industrial landscapes were generally characterized by low amounts of CWD in Maine. In contrast, Proulx and Kariz (2002) found greater numbers of CWD in cutblocks than forest and less distance between CWD pieces in a study in the SBSwk3 near Fort St. James, BC. However, CWD in cutblocks was generally shorter, had less vertical diversity, and was present in a lower range of decay classes (Proulx and Kariz 2002, Loyd 2002). Generally, the SBPS and MS in the Chilcotin have greater *average* volume of CWD after logging (personal observations); however, as seen in other studies the piece size and distribution appears to be different from natural stands. Due to being run over while skidding, much of the CWD is broken into shorter lengths and often oriented in the direction of skid trails. This also results in decreased spatial and vertical heterogeneity in the distribution of CWD. Adjusting harvesting methods to retain the vertical and spatial heterogeneity may provide managed stands with CWD characteristics that are important to furbearers.

Increased basal area in large dead trees was important for marten in this study for both univariate and multivariate analyses. Ruggiero et al (1998) found that marten selected for areas with greater abundance of snags >20cm in diameter when choosing den sites in Wyoming. Two separate studies in Oregon also found that large diameter (>50cm) was the critical feature of snags used by marten (Bull et al. 1996, Rapheal and Jones 1997). Fisher also showed a trend of greater use of segments containing large snags in this study, but the trend was not significant. Powell et al. (1997) found that fisher maternal den sites were located in larger, dead trees during March through July in New England. This study examined winter use that typically covered the period from mid November to mid March. Therefore, fisher here may still require large diameter snags, but for maternal den sites in during spring. Increasing basal area in large wildlife trees also benefits larger bird species since larger birds have a tendency to seek nest trees with greater diameters (Bunnell et al. 1999).

Prey species such as snowshoe hare, red squirrel, and grouse had strong positive univariate relationships with marten, fisher, and lynx. Prey species were also among the most important habitat features in multivariate analyses. Ensuring that managed habitats provide adequate resources for prey species is essential since predators will not persist without them. Red squirrel are likely to be maintained in residual forest following harvesting, although midden abundance may decrease with residual patch size (Cote and Ferron 2001). Spruce grouse tend to use dense coniferous forests during winter and more open forests during the breeding season (Campbell et al 1990). Spruce grouse are likely to be maintained in moderate numbers as long as sufficient areas of mature to old forest are retained. Ruffed grouse occupies a wider variety of habitats including aspen stands, brushy areas of cutblocks, and riparian thickets (Campbell et al 1990). Habitats such as these will be maintained in a managed landscape. Snowshoe hare use dense cover and are associated with pole aged stands. One area of concern may be the effects of thinning on this habitat. Pre-commercial thinning can reduce stem densities to 1200-1500 stems/ha whereas natural stands range between 5000-10,000 (or greater) stems/ha. Ensuring that areas of denser stems are retained may be important in maintaining this species.

8.0 LIMITATIONS

Winter track transect data can provide relative estimates of density as long as the assumption of a positive correlation between track density and population density is true (Harestad 1992). Thompson et al. (1989) found that the number of tracks was significantly correlated with live captures of marten, hare, and red squirrels. This suggests that track counts can be used as an index of habitat preference (Thompson et al. 1989). However, areas with high abundance can sometimes be ‘sink’ habitats. A study in Alaska found that the greatest density of martens occurred in a young burn, but that the majority of animals were juveniles with a near absence of adult females (Paragi et al. 1996). They hypothesized that, although prey were plentiful, the burn lacked necessary breeding resources. If breeding females avoid this habitat, adult males would also be absent and more likely to be defending territories that overlapped with the breeding females (Paragi et al. 1996). Thus, sink habitats act as overflows for preferred habitat and may have greater, but misleading densities. Track transects cannot differentiate between sex or age and there is a possibility that some higher density habitats are ‘sinks’ for surplus population. However, given that the preferred habitats identified in this study are generally well supported in the literature and densities were relatively low, this problem is not likely to be present here.

The multivariate analyses used on marten, fisher, and lynx provide a method of examining all habitat attributes together. The use of AIC techniques allows the fit of the different models to be compared while considering the principal of parsimony. Accounting for model parsimony decreases the probability of including parameters in the model that describe the data set, but not the population of interest (Burnham and Anderson 2002). Overdispersion was evident for all three species that were analyzed using this technique; however, it was within acceptable limits for fisher and lynx. The relatively high overdispersion for marten is likely to be due to two sources. The first involves significant amounts of unexplained variation in the data (Burnham and Anderson 2002). Although the chosen models clearly have an effect on furbearer habitat use, there are likely to be other variables that also have significant effects. A likely source of this variation would be landscape level attributes that were not examined in this study. Future studies should incorporate this level of examination.

The second source of overdispersion is due to problems with count data in studies such as this. Individual segments within transects are not independent due to segments having a greater probability of containing a track of a given species if the animal crossed an adjacent segment. An examination of the marten data revealed that the data was very clumpy. That is, there were few examples of solitary segments containing marten tracks. Usually, 2-5 consecutive segments would contain tracks and this may support a lack of independence. However, habitat types and attributes also often have a clumped distribution. Thus, an animal entering preferred habitat would be expected to exploit all segments within it. Lack of independence may also result where low representation leads to poor interspersion of habitats. For instance, habitats with very low representation in the Anahim area are only likely to be present in a low number of transects. The mature spruce-pine habitat is a good example of this where 10 segments are present on 7 different transects. If several of the segments had some feature unrelated to the habitat type that increased the probability of finding an animal track (such as being located on main game trails), a spurious result may be obtained. In contrast, results for habitats present on many transects (e.g. greater than 20) would be impacted much less by this type of effect. Eliminating these problems would involve a study design that randomly interspersed and sampled more than 1000 separate segments each year. This would not have been possible given time and budget constraints. We are left with accepting the limitations of this design and viewing the results from habitats with low representation (Table 7) with some caution. Hulbert (1984) recognizes the problems associated with obtaining good interspersion in some studies and advices that dispensing with strict randomization may sometimes be the only way to conduct studies such as this.

Table 7. Habitat types in the Anahim Area with low representation.

Habitat type	Number of segments	Number of transects
Mature spruce-pine (SxPl6)	10	7
Mid-structural spruce (Sx4_5)	14	8
Old spruce (Sx7)	24	9
Mid-mature aspen (At5_6)	18	11
Old pine (Pl7)	27	14
Sedge (SE2)	35	15

This study has only examined furbearer habitat requirements during winter, whereas impacts during other seasons may also be important. Breeding females often have specific requirements for den sites and require increased access to prey items while raising young. Others have found that marten (Raphael and Jones 1997), fisher (Powell et al. 1997), and lynx (Slough 1999) have specific habitat requirements around maternal den sites that signal good quality habitat. However, in the case of Mustelids, effects during winter are likely to have a strong influence on reproductive output due to delayed implantation of the blastocyte. Implantation may not occur in females that do poorly over-winter.

Young forested structural stages were not sampled in this study and this habitat may be important for some species. This habitat type is becoming more prevalent as harvesting proceeds in the Anahim Lake area. An understanding of habitat elements that increase wildlife use of young forests would be valuable as the area of this habitat increases in the landscape. Some of the furbearer transects have been harvested and this would provide an opportunity to examine the effects on wildlife use. However, older cutblocks are also required to adequately examine the long term effects on wildlife use.

Finally, there are likely to be other important variables that have not been examined here that affect furbearer populations. Landscape level effects such as minimum patch size, fragmentation, connectivity and spatial distribution of resources may affect furbearing species. These effects are likely to become more pronounced as the mountain pine beetle epidemic proceeds in the Anahim Lake area. American marten (*Martes americana*) have been shown to require core areas of 150ha or more of residual forest to be successful (Chapin et al. 1998; Hargis et al 1999). A study in spruce – pine stands of Utah found that landscapes with >25% non-forested habitat had no marten captures and that natural non-forested habitat should be included when assessing fragmentation (Hargis et al 1999). Based on this study, Hargis et al (1999) reported that the landscape pattern in which a forest stand occurs is just as important as the structural aspects of the stand. Other territorial species such as fisher (*Martes pennanti*) are also likely to be affected as harvesting proceeds (Steventon, 2002). Furthermore, furbearing species in dry ecosystems, such as the SBPS, may require larger residual patches than those in more productive ecosystems.

9.0 RECOMMENDATIONS

Knowledge of the stand level habitat requirements of furbearing species in the Anahim Lake area will furnish resource managers with avenues for addressing both species of concern and all furbearing species. This study has identified a number of habitats and habitat attributes that affect furbearers and their prey. This information can be used to tailor management prescriptions in resource plans. Specifically, the following recommendations are made concerning forest development in the West Chilcotin:

1. Spruce leading habitats are important to most furbearing species, and mature + old spruce leading habitat should be maintained in sufficient quantity and quality to preserve healthy populations of furbearers. This study did not examine population effects since this is a landscape level issue; however, results from the DNA pilot project for this area may provide some insights into patch size requirements for marten and fisher. The results from this study indicate that there is an overlap between furbearer habitat and moose wintering habitat where spruce stands are located next to wetlands. This overlap may aid in achieving some of the Anahim Round Table Draft Resource Management Objectives (ART 2002). The objectives concerning moose and furbearers are to: *protect and maintain sufficient quantity and quality of habitat for [furbearers and moose] to maintain healthy populations in perpetuity across [their] historic ranges*. For moose the strategy includes establishing buffers up to 200m wide adjacent to key wetlands and riparian habitats. It appears that this strategy would also benefit furbearers, but it has the potential to make a significant impact on the local timber supply given the extensive wetland areas present in the Anahim area. There is also evidence that riparian forests burned at the same rate as upland forest, which implies that disturbance may be a natural feature of

these stands (Steventon, 2001, Andison 2002). Therefore, instead of creating permanent reserves, rotating reserves of increased rotation length could provide a balance that addresses furbearer needs, historical patterns of disturbance, and timber supply concerns.

2. Coarse woody debris (CWD) benefits most furbearing species, and the maintenance of natural CWD characteristics should be promoted during forest development. The natural characteristics of CWD include heterogeneous spatial and vertical distribution. Thus, CWD in natural stands ranges from areas with very sparse distributions to areas with abundant CWD characterized by high vertical diversity. This arrangement could be promoted in a number of ways. Identifying areas with high concentrations of CWD during development and delineating them with stub trees would limit damage caused by skidding. These CWD management patches would not have to be large and could be oriented in the direction of skidding to minimize the impact. Furthermore, it would be more valuable to have several smaller patches instead of one large patch. Vertical heterogeneity could also be promoted within patches by adding any adjacent non merchantable snags. Instituting these patches ensures that longer pieces of CWD will be present post harvest. Other measures to promote natural CWD characteristics include not moving marginal wood that exhibits decay to the roadside, not burning all roadside debris piles, and leaving all dead and down trees in the riparian management zone.

3. Reserve spruce regeneration/advanced regeneration wherever possible, since this structure is valuable to snowshoe hare and furbearing species such as lynx. Habitats containing greater densities of young spruce had higher abundances of snowshoe hare and some furbearers. This habitat may act as a dispersal source for snowshoe hare which is prey for many forest carnivores. The spruce will also provide increased vertical heterogeneity and denning opportunities in the new stand. An opportunity also exists to combine CWD management areas with patches of young spruce and stub trees, since grouped resources are often of greater value to wildlife.

4. Large diameter dead trees are important to many species of wildlife and should be retained wherever possible. Protecting snags in wildlife tree patches, reserve zones, or no work zones should be pursued wherever possible. The Biodiversity Guidebook (1995) recommends that wildlife tree patches should encompass trees in the upper 10% of the diameter distribution of the stand. As well, some wildlife tree patches should be placed in upland positions to provide representation of this habitat type and live deciduous trees should be left whenever possible.

5. Ensure that habitat types important to prey species are maintained through time and space. Thinning is likely to affect the quality of this habitat for snowshoe hare, and trials should be conducted to determine the effects of this silviculture treatment. Snowshoe hare are associated with dense sapling to pole sized forest and high shrub habitats. Forest managers have control over the availability and characteristics of young forested habitats. Although young forest habitat is not likely to be limited in the short term due to the mountain pine beetle epidemic, plans should be made to ensure that some of this habitat is available in most areas through time and that silviculture treatments do not adversely affect hare densities.

6. Landscape level analysis is required to examine minimum effective patch size, effects of fragmentation, connectivity requirements, spatial arrangement of habitats, and furbearer population parameters. Maintaining healthy populations of furbearers is dependant on determining landscape level requirements for habitat, viable population size, mortality rates, and dispersal capabilities. The current DNA pilot project may shed light on some of the landscape level habitat requirements; however, a larger project is required to determine population attributes and data from other seasons may be required. Data from the current project should be analyzed in the 2003-2004 fiscal year. Information from the project can then be evaluated to determine the effectiveness of this technique and the direction of future research. Until further research results are available, forest managers should manage conservatively to maintain the important stand types for furbearers in relatively large and well connected pieces.

7. Mountain pine beetle impacts will affect the availability of future habitat, and a number of furbearer transects should be reserved from harvesting to assess the changes due to the current beetle epidemic. Currently, there are approximately 25 transects that had habitat information collected in the summer of 2002 and have no timber development. At least half these transects should be reserved from development for a period of 10+ years. The selection of transects should be random, but representation of each of the three subzones would be desirable. The existing habitat information from the transects would form a baseline for tracking the changes that accompany the mountain pine beetle epidemic. As well, continued winter track transect sampling of the 53 transects would allow an examination of the effects of salvage harvesting on furbearer populations.

8. The data from this project also includes information on moose track densities, and this information should be used to assess Bakers (1991) study on moose in the Anahim Lake area. The existing data could be coupled with the information from the local wetland study completed in 2001. The wetland project involved classifying all wetlands in the YKW operating area and only needs field verification at this time to complete it. Once this is done, an examination of moose needs at the stand and landscape can be completed. This information would identify the types of wetlands/riparian habitats that should be looked at when applying management objectives for moose and furbearers during winter.

9. Involve the local community in resource management at both the research and planning level. Involving community members in research projects benefits the community by increasing local knowledge on the factors that are contributing to management decisions. This passing of information is a two way street since local knowledge can benefit the development of both research and management plans. An example of the benefit of this is based on an interview with local resident Henry Jack where information was provided on the local denning habits of marten and fisher. Henry indicated that rock was important denning habitat and results from this study appear to support this for marten.

11.0 REFERENCES

Badry, M.J., Proulx G., and Woodward, P.M. 1997. Home-range and habitat use by fishers translocated to the aspen parkland of Alberta. . *In* Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton. pp 233-251.

Banfield, A.W. 1974. The mammals of Canada. Univ. of Toronto Press, Toronto, Ontario.

B.C. Ministry of Environment, Lands, and Parks, and B.C. Ministry of Forests. 1998. Field Manual for Describing Ecosystems in the Field. Land Management Handbook No. 25.

Bull, E.L., Akenson J., Betts, B., and Torgensen, T. 1996. The interdependence of wildlife and oldgrowth forests. In Proceedings of the workshop on wildlife tree/stand level biodiversity. Edited by P. Bradford, T. Manning, and B. I'Anson. Min. of Environment, Victoria, BC. Pp 71-75.

Bunnell, F.L., Kremsater, L.L., and Wind, E. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships within stands. Environ. Rev. 7: 97-145.

Burnham K.P. and Anderson, D.R. 2002. Model selection and multimodel inference. A practical information-theoretic approach. 2nd edition. Springer-Verlag, New York, Inc. 488pp.

Buskirk, S.W. and R.A. Powel. 1994. Habitat ecology of fishers and American marten. *In* Martens, sables, and fishers: biology and conservation. Cornell Univ. Press, Ithaca, N.Y. pp 283-296.

Buskirk, S.W., S.C. Forest, M.G. Rapheal, H.J. Harlow. 1989. Winter resting sites o marten in the central Rocky Mountains. J. of Wildl. Manage. 53:191-196.

Campbell, W., Dawe, N., McTaggart-Cowan, I., Cooper, G. and McNall, M. 1990. The birds of British Columbia. Volume two, nonpasserines: diurnal birds of prey through woodpeckers. UBC Press, Vancouver, BC.

Corn, J.G. and Raphael, M.G. 1992. Habitat characteristics at marten subnivean access sites. J. of Wildl. Manage. 56:442-448.

Chapin, T.C. Phillips, D.M. Harrison, D.J. and York, E.C. 1997. Seasonal selection of habitat by resting marten in Maine. *In* Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton. Pp 166-181.

Chapin, T.C., Harrison, D.J., and Katnik, D.D. 1997b. Influence of landscape pattern on habitat use by American marten in an industrial forest. Conser. Biol. 12(6): 1327-1337.

Cumberland, R.E., Dempsey, J.A., and Forbes, G.J. 2001. Should diet be based on biomass? Importance of larger prey to the American marten. Wildl. Soc. Bull. 29(4):1125-1130.

D'Eon R.G. 2001. Using snow-track surveys to determine deer winter distribution and habitat. Wildl. Soc. Bull. 29(3):879-887.

Harestad, A. 1992. Monitoring bats and furbearers for biodiversity studies. *In* Methodology for monitoring wildlife diversity in B.C. forests. Workshop proceedings edited by L. Ramsay. Pages 61-63.

Hargis, C.D., Bissonette, J.A. and Turner, D.L. 1999. The influence of forest fragmentation and landscape pattern on American marten. J. of Appl. Ecol. 36: 157-172.

Hargis, C.D. and Bissonette, J.A. 1997. Effects of forest fragmentation on populations of American marten in the intermountain west. *In* Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton. Pp 437-451.

Hodgeman, T.P., Harrison, D.J., Katnik, D.D., and Elowe, K.D. 1994. Survival in an intensively trapped marten population in Maine. J. Wildl. Manage. 58:593-600.

Hulbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54:187-211.

King, C.M. 1989. The natural history of weasels and stoats. Christopher Helm, London, England, 253 pp.

Koehler, G.M. 1990. Population and habitat characteristics of lynx and snowshoe hares in north central Washington. Can. J. of Zool. 65:565-567,

Koehler, G.M. and Aubry, K.B. 1994. Lynx. *In* The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. USDA Forest Service, Rocky Mtn. Forest. pp 74-98

Krohn, W.B., Zelinski, W.J. and Boone, R.B. 1997. Relations among fishers, snow, and martens in California: results from small scale spatial comparisons. *In* Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton. pp 211-232.

Loyd, R. 2002. Post-harvest CWD – the long and short of it. *In* Optimizing wildlife trees and coarse woody debris retention at the stand and landscape level. Northern Interior Vegetation Management Association and Northern Silviculture Committee Winter Workshop, January 22-24, 2002, Prince George, BC. Pages 9-15

Martin, S.K. 1994. Feeding ecology of American marten and fishers. *In* Martens, sables, and fishers: biology and conservation. Cornell Univ. Press, Ithaca, N.Y. pp 297-315.

Maser, C., Anderson, R., Cormack, K., Williams, J., and Martin, R. 1979. Dead and down woody material. Chapter 6 In Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Edited by J.W. Thomas, USDA Agricultural Handbook 553. 512pp.

Meidinger, M.L. and J. Pojar. 1991. Ecosystems of British Columbia. B.C. Min. For., Res. Br., Victoria, B.C. Special Report Series No. 6.

Morrison, M.L. 2001. A proposed research emphasis to overcome the limits of wildlife-habitat relationship studies. J. of Wildl. Man. 65(4):613-623.

Murray, D.L., Boutin, S. and O'Donoghue, M. 1994. Winter habitat selection by lynx and coyotes in relation to snowshoe hare abundance. Can. J. of Zool. 72: 1444-1451.

O'Donoghue, M., Boutin, S., Krebs, C. J., Zuleta, G., Murray, D., and Hofer, E. 1998. Functional responses of coyotes and lynx to the snowshoe hare cycle. Ecology, 79(4): 1193-1208.

Poole, K.G. and Graf, R.P. 1996. Winter diet of marten during a snowshoe hare decline. Can. J. Zool. 74:456-466.

Poole, K.G., Wakelyn, L.A. and Nicklen, P.N. 1996. Habitat selection by lynx in the northwest territories. Can. J. of Zool. 74: 845-850.

Powell, R.A. 1979. Ecological energetics and foraging strategies of the fisher (Martes pennanti). J. of Animal Ecol. 48(2): 195-212.

Powell, R.A. 1994. Effects of scale on habitat selection and foraging behavior of fishers in winter. J. of Mamm. 75(2): 349-356.

Powell, R.A., York, E.C. and Fuller, T.K. 1997. Seasonal food habits of fishers in central New England. *In* Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton. pp 279-308.

Powell, R.A., York, E.C., Scanlon, J.J., and Fuller, T.K. 1997. Fisher maternal den sites in central New England. *In* Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton. pp 265-278.

Proulx G., and Kariz, R. 2002. Coarse woody debris and small mammal populations in the sub-boreal spruce biogeoclimatic zone of the Fort St James District, British Columbia. *In* Optimizing wildlife trees and coarse woody debris retention at the stand and landscape level. Northern Interior Vegetation Management Association and Northern Silviculture Committee Winter Workshop, January 22-24, 2002, Prince George, BC. Pages 5-7.

Raphael, M.G., and Jones, L.L. 1997. Characteristics of resting and denning sites of American martens in central Oregon and Western Washington. *In* Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton. pp 146-165.

Ruggiero, L.F., Pearson, D.E. and Henry, S.E. 1998. Characteristics of marten den sites in Wyoming. J. Wildl. Manage. 62(2): 663-673.

Samson, C., and Raymond, M. 1998. Movement and habitat preference of radio tracked stoats, Mustela ermine, during summer in southern Quebec. Mammalia, 62(2): 165-174.

Simms, D.A. 1979. North American weasels: resource utilization and distribution. Can. J. of Zool., 57: 504-520.

Slough, B.G. 1999. Characteristics of Canadian Lynx, Lynx Canadensis, maternal dens and denning habitat. Can. Field Nat. 113(4): 605-608.

Stevens, V. and Lofts, S. 1988. Wildlife habitat handbooks for the southern ecoprovince. Volume 1: species notes for mammals. A. Harcombe, technical editor. Wildlife Branch, Ministry of Environment, Wildlife Habitat Report No. R-15.

Steventon, J.D. 2001. Harvesting patterns, fragmentation, and historic landscape pattern in sub-boreal forests of the Prince Rupert Forest Region. Draft report with Prince Rupert Forest Region.

Thompson I.D. 1994. Marten populations in uncut an logged boreal forests in Ontario. J. Wildl. Manage. 58:272-280.

Thompson I.D. and Curran, W.J. 1995. Habitat suitability for marten of second growth balsam fir forests in Newfoundland. Can. J. of Zool. 73:2059-2064.

Thompson, I.D. and A.S. Harestad. 1994. Effects of logging on American martens, and models for habitat management. *In* Martens, sables, and fishers: biology and conservation. Cornell Univ. Press, Ithaca, N.Y. pp 355-367.

Thompson I.D. Davidson, I.J., O'Donnell, S. and Brazeau, F. 1989. Use of track transects to measure the relative occurrence of some boreal mammals in uncut and regeneration stands. Can. J. of Zool. 67: 1816-1823.

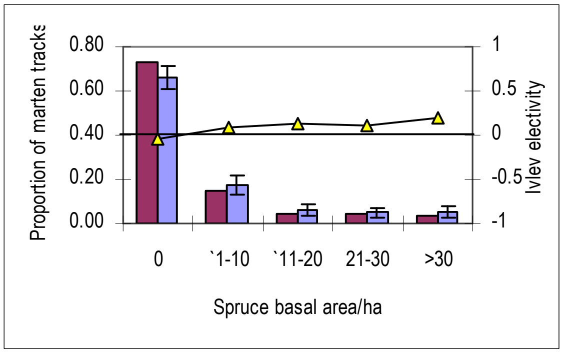
Weir, R.D. and Harestad, A.S. 1997. Landscape level selectivity by fishers in south-central British Columbia. *In* Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton. pp 252-264.

Wilbert, C.S. 1992. Spatial scale and seasonality of habitat selection by martens in southeastern Wyoming. M.S. Thesis, Univ. Wyoming, Laramie. 91pp.

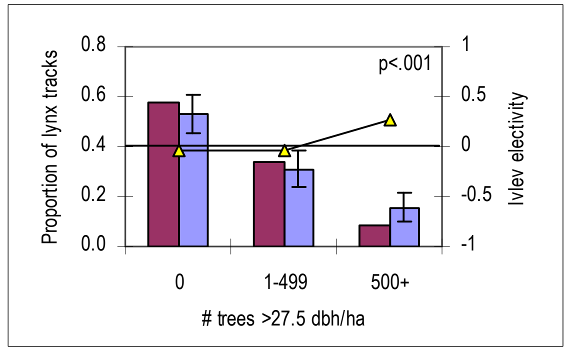
APPENDIX 1

ADDITIONAL GRAPHS ON SPECIES USE

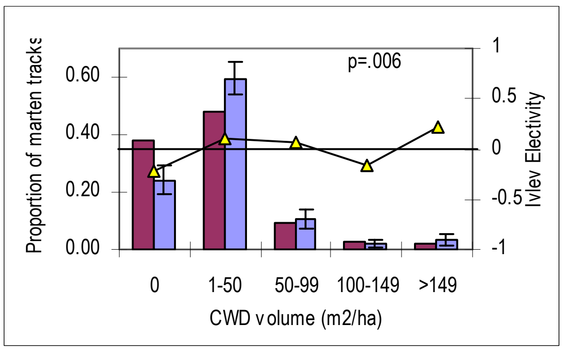
OF HABITAT ATTRIBUTES



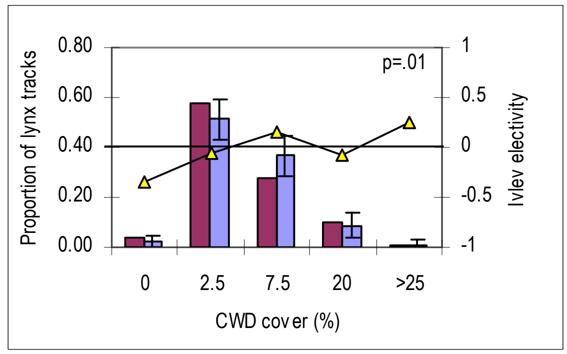
Marten and spruce basal area



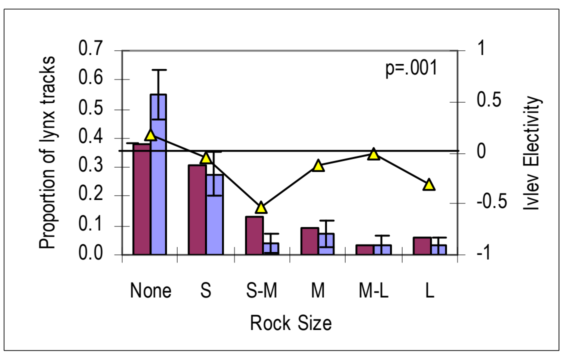
Lynx and density of large trees



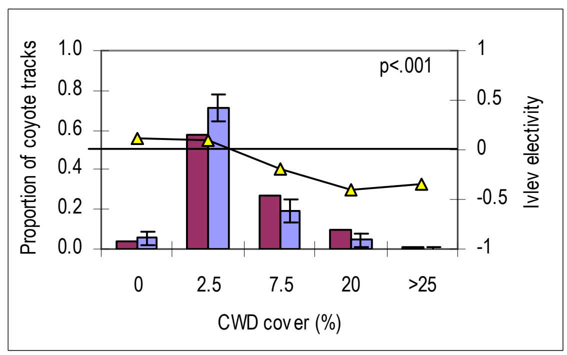
Marten and CWD volume



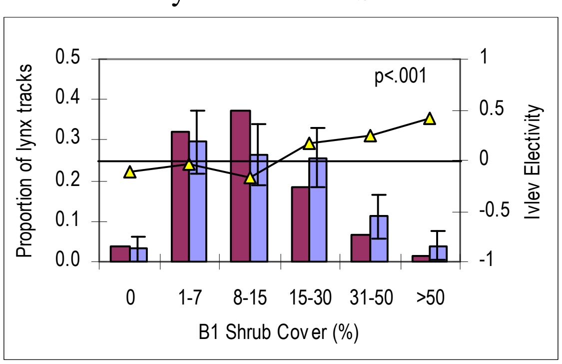
Lynx and CWD Cover



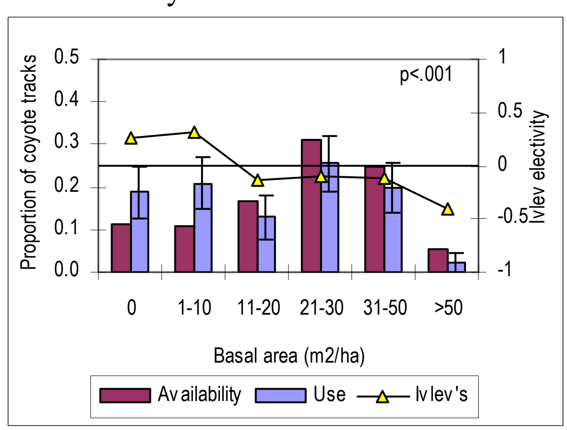
Lynx and Rock Size



Coyote and CWD Cover

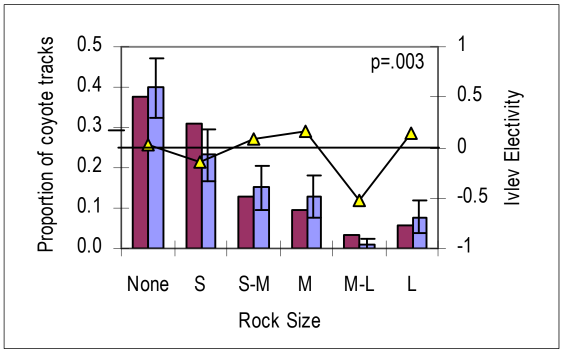


Lynx and Percent Shrub Cover

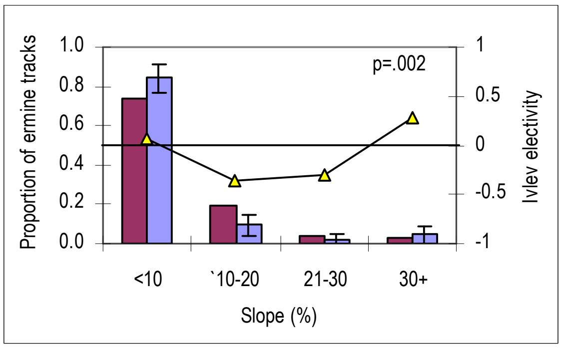


Coyote and Basal area/ha

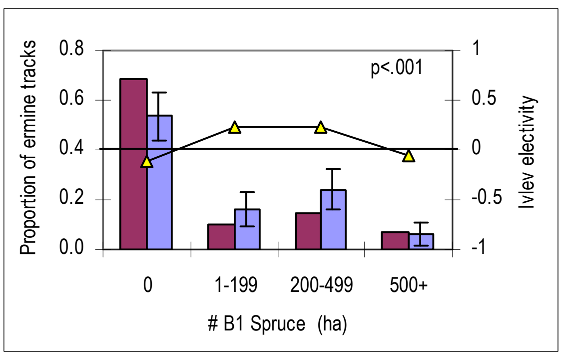
APPENDIX 1. ADDITIONAL GRAPHS



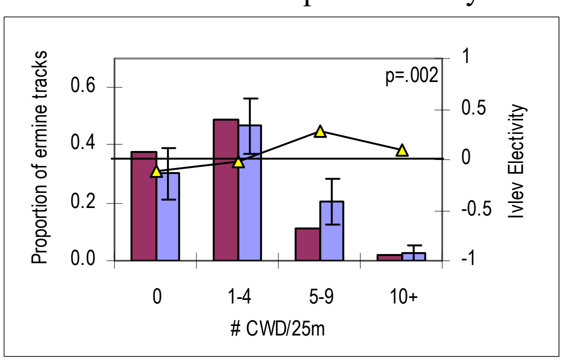
Coyote and Rock Size



Ermine and Slope Class



Ermine and B1 Spruce Density



Ermine and # CWD/25m

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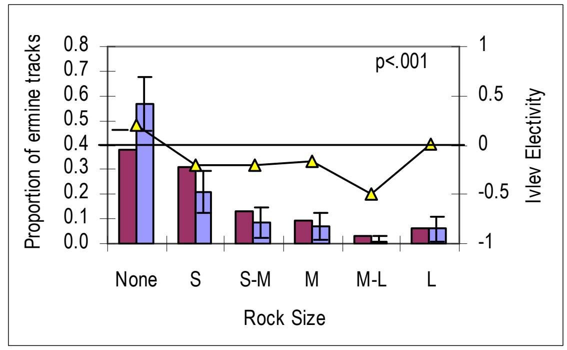
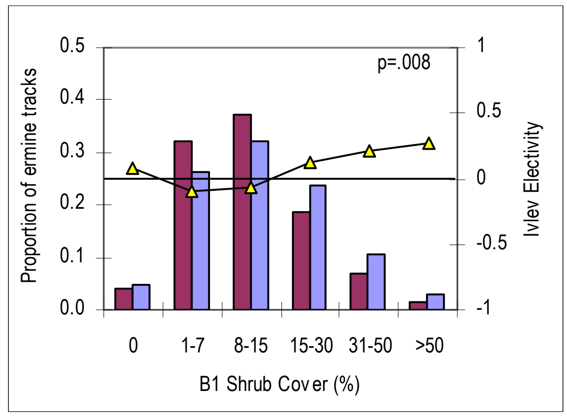
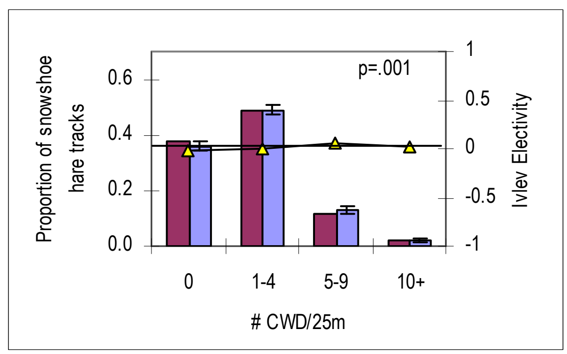


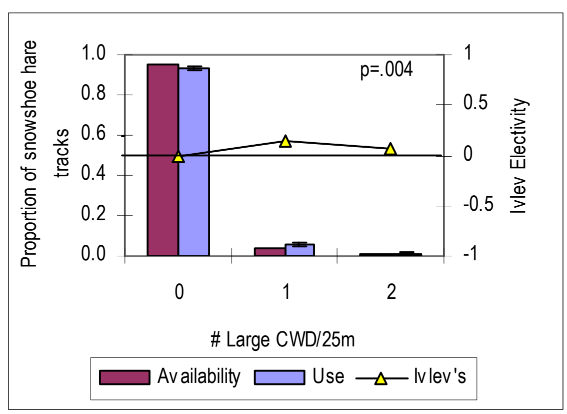
Ermine and Rock Size



Ermine and B1 Shrub Cover



Snowshoe hare and # CWD/25m



Snowshoe hare and # Large CWD/25m

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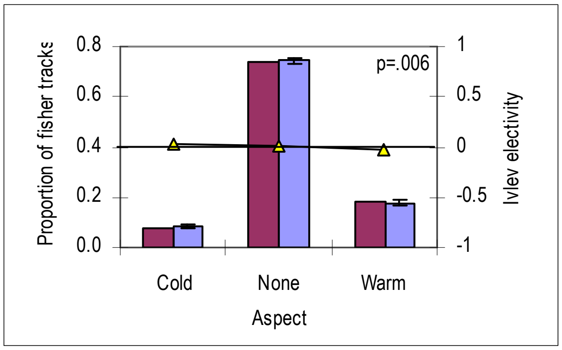
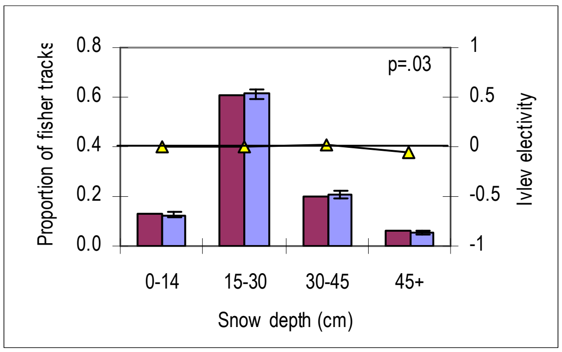
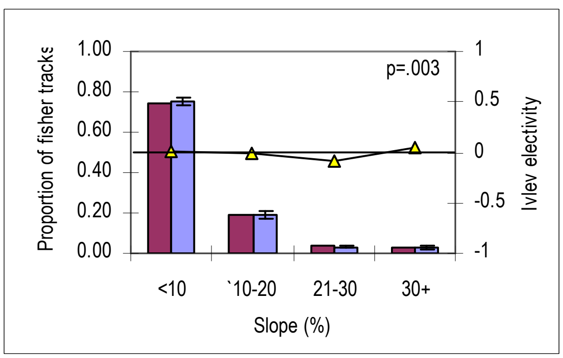


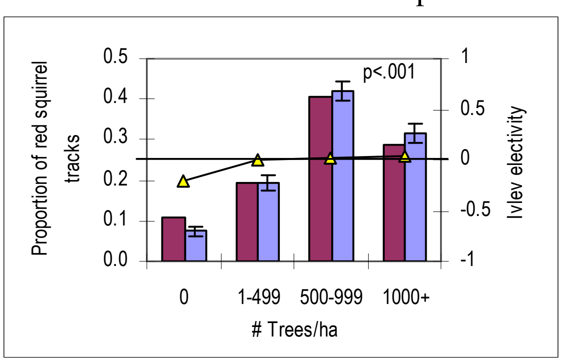
Snowshoe hare and Aspect



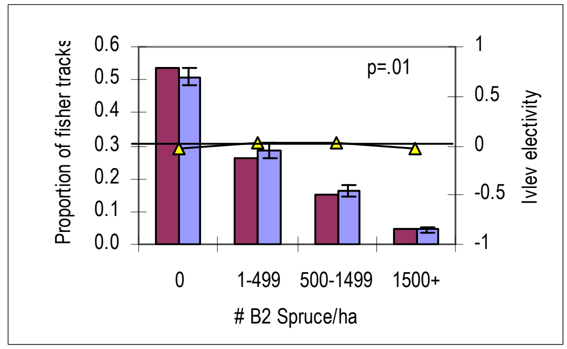
Snowshoe hare and Snow Depth



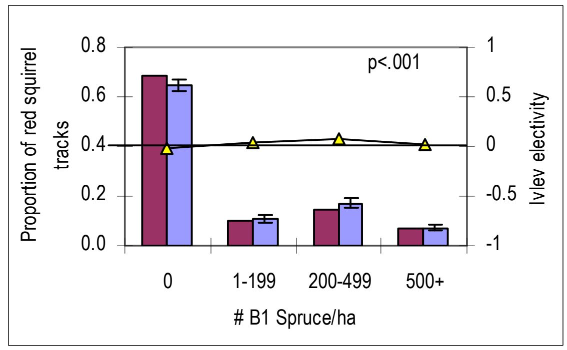
Snowshoe hare and Slope



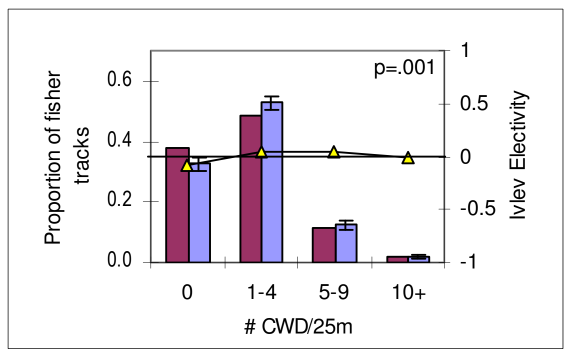
Red Squirrel and # Trees/ha



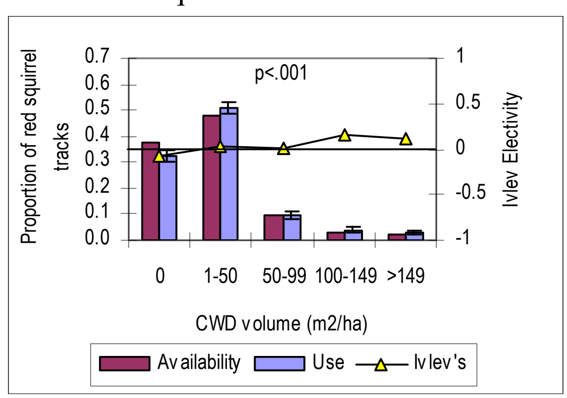
Red Squirrel and # B2 Spruce/ha



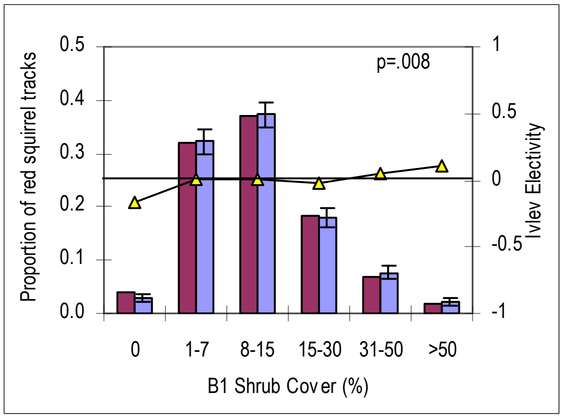
Red Squirrel and # B1 Spruce/ha



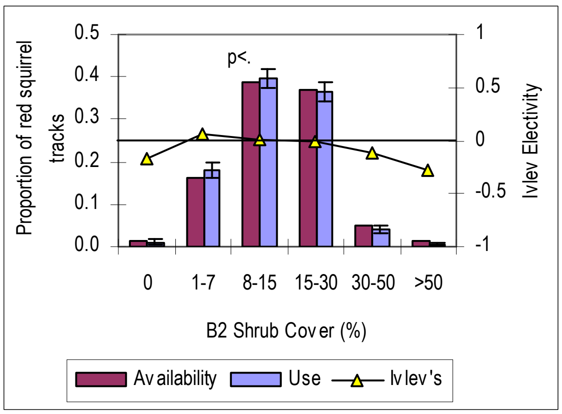
Red Squirrel and # CWD/25m



Red Squirrel and CWD Volume



Red Squirrel and B1 Shrub Cover



Red Squirrel and B2 Shrub Cover

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