WINTER RESOURCE SELECTION BY THE AMERICAN MARTEN (*MARTES AMERICANA*): THE EFFECT OF MODEL RESOLUTION

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ABSTRACT

WINTER RESOURCE SELECTION BY THE AMERICAN MARTEN (*MARTES AMERICANA*): THE EFFECT OF MODEL RESOLUTION

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Successful management requires an understanding of the scale at which species use resources within their environment. Research shows considerable variability in resource preferences of American martens (*Martes americana*) across North America. This variability may be an artefact of the resolution used in analyzing resource selection. To test the effects of resolution, winter resource selection of martens was evaluated using resource-based models at coarse (i.e., forest stands) and fine (i.e., local sites within forest stands) resolutions near Kapuskasing, Ontario. None of the predictor variables reliably explained resource use by martens at the coarse resolution. Fine-resolution models, however, suggested that martens selected sites with a greater abundance of coarse woody debris and a greater proportion of cedar trees in comparison with available sites within marten home ranges. On average, fine-resolution models performed ten times better than coarse-resolution models in classifying resource use by martens.

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INTRODUCTION

Successful management requires an understanding of how species use resources (e.g. food items and habitats) within their environment. Patterns of resource use may indicate associations between animals and important habitat variables (Alldredge and Griswold, 2006). Understanding these relationships is valuable to wildlife and conservation ecologists, and to land managers because this knowledge can facilitate the conservation and management of resources used by a species, thereby increasing the likelihood of population persistence (Theberge and Stevens, 2005).

For any given species, patterns of resource use can vary across temporal scales such as seasons or years, and across spatial scales, from the geographic range of a species, to individual home ranges within a geographic range, to particular habitat types within a home range, to local patches within habitat types, and finally to selection of particular elements within local patches (Manly *et al.*, 2002). Spatial scales can be defined by resolution (the smallest unit measured) and extent (the area over which observations are measured; Turner *et al*., 2001). Scale is an important consideration when investigating patterns of resource use because wildlife may select resources differently at varying scales of analysis, and the resolution of resource use should influence management decisions.

Patterns of resource use can be quantified using resource selection studies, which often compare resources at sites used by animals to available sites (Thomas and Taylor, 1990; Alldredge and Griswold, 2006). A limitation to most resource selection studies is that they do not explain why animals use particular habitats. It is, therefore, assumed that animals select habitats in their environment in direct accordance with the resource benefits that those habitats offer (Johnson *et al*., 2004). Although the relationship between used habitat types and resource benefits are often correlational, they can provide ecologists and land managers with insights into important habitat components required by the study species of interest.

The American marten (*Martes Americana*) has been a species of much controversy in recent years because they display considerable variability in selection preferences across North America. Some studies strongly suggest that ideal marten habitat is composed of mature conifer-dominated forests (Marshall, 1951; Koehler and Hornocker, 1977; Soutiere, 1979; Clark *et* al., 1987; Thompson, 1988; Buskirk and Powell, 1994; Thompson, 1994; Thompson and Colgan, 1994; Hargis *et al*., 1999), which is supported by greater densities (Soutiere, 1979), survival and reproduction (Thompson and Colgan, 1994) of martens living in old uncut forests than in younger cut ones. In comparison to old uncut forests, young regenerating stands are believed to be sub-optimal habitat because they contain reduced structural components (Bowman and Robitaille, 1997) that may be required for predatory escape, cover, prey acquisition, denning and resting. Other studies, however, provide evidence that marten populations may persist in younger forests containing a lower proportion of conifers than previously believed ideal (Thompson *et al*., 1989; Bowman and Robitaille, 1997; Chapin *et al*., 1998; Potvin *et al*., 2000; Payer and Harrison, 2003). In some studies, mixed stands (Soutiere, 1979; Bateman, 1986; Katnik, 1992; Potvin *et al*., 2000) and deciduous stands (Potvin *et al*., 2000) were preferred over coniferous stands. It has been suggested that species composition and age class may be less important than structural components in predicting resource selection by martens (Bowman and Robitaille, 1997; Chapin *et* al., 1997; Payer and Harrison, 2003; Poole *et al*., 2004). Variability in resource preferences by martens may be an artefact of the resolution used in analysing resource selection.

I investigated winter resource selection of the American marten at two spatial resolutions: coarse and fine. Coarse-resolution resource selection models were generated using information available from a forest resource inventory (FRI) database, while fine-resolution models were developed using data collected at local sampling sites along marten travel trajectories within forest stands. Forest resource inventory data were used in developing coarse-resolution models because resource management can be investigated and implemented at this scale using FRI data and geographic information system (GIS) technology (Orrock *et al*., 2000). These tools, however, are limited in resolution, which is of large consequence to animals that select resources at a fine resolution. Consequently, fine-resolution models were developed to investigate this potential problem.

Resource selection by martens was investigated during winter for several reasons. Firstly, martens have an elongate body shape that is convenient for entering subnivean sites and other confined spaces in search of prey, but this body design comes at a high energetic cost (Brown and Lasiewski, 1972). During winter, cold temperatures constrain martens to habitats that offer thermal microenvironments, and sufficient resting and foraging opportunities (Buskirk, 1984; Bateman, 1986; Thompson, 1986; Buskirk and Powell, 1994). Consequently, decisions regarding habitat and resource selection should be of vital importance to martens during winter. Secondly, data collected in a single season can help alleviate temporal effects in addressing spatial questions (Alldredge and

Griswold, 2006). Thirdly, accurate fine-resolution data can be collected by snow-tracking martens during winter.

The purpose of the present study was to evaluate the effects of spatial resolution in modelling resource selection of martens. My objectives were to: (1) test the efficacy of coarse- versus fine-resolution models in predicting resource selection by martens; and (2) identify important resource correlates at sites used by martens.

MATERIALS AND METHODS

Study Area

The present study was conducted during winter (December 1, 2005 to March 31, 2006) in two boreal forest landscapes approximately 60km south of Kapuskasing, Ontario, Canada. The mature forest landscape (centred at 48^{o}48'20" N, 82^{o}33'02" W) was a 180-km^2 area comprised mostly (90%) of uncut stands aged 80-160 years, primarily old conifer (55%) and old mixed (35%) stands (Table 1). The remaining 10% of this landscape was comprised of old deciduous and unclassified stands, wetland sites and water. The managed landscape (centred at 48^{o}50'48" N, 82^{o}31'30" W) was a 320-km^2 area comprised mostly (75%) of recently harvested forest stands aged 0-55 years, primarily young conifer (57%), young mixed (8%), and young deciduous (10%) stands (Table 1). Remnant old-growth stands comprise 10% of the managed landscape, while recently disturbed and unclassifed stands, wetland sites and water comprise the remaining 15% of this landscape. Forest harvest and planning in the study area is currently managed by Tembec Ltd. Dominant tree species in both landscapes included black spruce (*Picea mariana*), trembling aspen (*Populus tremuloides*), white spruce (*Picea glauca*), white birch (*Betula papyrifera*), and balsam fir (*Abies balsamea*). Soils were clay-based and had poor to moderate drainage (Perera *et al*., 2000).

Animal Capture and Telemetry

Nine martens were captured from August to December 2005 in Tomahawk live traps (Tomahawk Live Trap Co., Tomahawk, Wisconsin, USA). Following approved animal care protocol procedures, martens were immobilized using a mixture of xylazine and ketamine, whereby adult males (approximate mass: 1000 g) received doses of 0.05mL and 0.10mL, and adult females (approximate mass: 750 g) received doses of 0.04mL and 0.08mL of xylazine and ketamine, respectively. Sedated martens were fitted with a 30 g very high frequency (VHF) radio collar (model MI2, Holohil Systems Ltd., Carp, Ontario, Canada).

Radio-telemetry was used to identify locations of resource use for martens at the coarse resolution. Locations of resource use were estimated using Locate II (Nams, 1990). Radio-telemetry was also used to estimate marten home ranges using the minimum convex polygon method (Mohr, 1947). This method defines the extent of resource availability to individuals. Habitat availability was different for each marten because they occupied home ranges with little to no overlapping area. Consequently, habitat selection was evaluated separately for each marten. Telemetry data were collected as often as possible after initial marten capture and throughout the study period. To avoid concerns of temporal autocorrelation (i.e., a lack of independence between successive telemetry points) in resource use (Dunn and Gipson, 1977), only telemetry data with at least 24 hours between consecutive fixes were considered.

Coarse-Resolution Resource Selection

Using FRI data provided by the Ontario Ministry of Natural Resources (OMNR), resource variables (stand height, stand classification, and percent composition of conifers, spruce, cedar and balsam fir; Table 2) were used to create 35 candidate coarse-resolution resource selection models. Coarse-resolution models were developed using variables available in the FRI database that were of ecological relevance to martens based on previous resource selection studies.

Stand height is a correlate of stand age and has been shown to be an important predictor of habitat use by martens (Bowman and Robitaille, 1997; Payer and Harrison, 2003). Current management guidelines within Ontario (Watt *et al*., 1996) recommend maintaining forest stands with trees aged 80 years or older (approximately 15m in height or taller). In the present study, stand age and height were highly correlated ($r > 0.9$). Consequently, only one of these predictor variables was used in the analysis. Since model selection procedures require no missing data entries, stand height was used instead of stand age because it contained fewer missing data entries, thereby resulting in the loss of fewer data points.

Stand classification categorized sites as either upland or lowland. Upland stands seem to support greater abundances of small mammals than lowland sites in north-eastern Ontario (Boos and Watt, 1997). In comparison to lowland sites, small mammals were twice as abundant in upland sites within the study area, as assessed by small mammal trapping during 2004 and 2005, prior to the present study. Stand classification was investigated as a predictor variable of resource use by martens because of this pattern in small mammal distribution.

Since martens are often found associated with conifer-dominated forests (Soutiere, 1979; Spencer *et al*., 1983; Buskirk, 1984; Bissonette *et al*., 1989; Thompson, 1994; Thompson and Curran, 1995), the percent composition of conifers was investigated as a predictor variable of habitat use. Conifer, however, combines many tree species into a single metric that may hide selection preferences of martens for specific tree species. Consequently, the percent composition of spruce, cedar and balsam fir were investigated as subset predictor variables. Current management guidelines within Ontario (Watt *et al*., 1996) recommend maintaining forest stands with greater than 40% composition of spruce, cedar and fir trees. Candidate models were dropped from analysis if they included correlated predictor variables ($r > 0.25$). Models containing percent conifer and percent spruce, percent cedar, or percent balsam fir were dropped from the analysis because of multicollinearity.

Locations used by martens were estimated using winter telemetry. Available locations within each marten home range were identified using a random point generator. By overlaying the locations of used and available points on a map of the study area in ArcView GIS (version 3.2, Environmental Systems Research Institute, Redlands, California, USA), resources at these locations was inferred using FRI data. The spatial extent of coarse-resolution sample sites varied with the size of forest stands. Forest stand size varied from 0.001 km^2 to 2.7 km^2 ($\bar{x} = 0.1$ km^2). Resource use was treated as a binary categorical response variable, whereby used habitats were scored a value of one and available habitats were scored a value of zero.

Resource selection models were evaluated in SPSS version 9.0 (SPSS Inc., 1998) using binary logistic regression for each marten separately. Akaike's information criterion (with a correction for small sample sizes, AIC_c; Burnham and Anderson, 2002) was used to evaluate and select the most parsimonious of the proposed models. All models were compared to the model with the lowest AIC_c score using delta AIC (ΔAIC_c) scores:

$$\Delta_i \, AIC_c = AIC_{c\,i} - \min AIC_c$$

where i is the candidate model for comparison and min AIC_c denotes the candidate model with the lowest AIC_c score. All candidate models that had ΔAIC_c scores lower than 2.0 were considered competing candidate models for the "best" model. Akaike weights (w_i) give an estimate for the strength of evidence for a particular candidate model relative to all other candidate models:

$$w_i = \frac{e^{(-\Delta AICci\,/2)}}{\sum_{r=1}^{R} e^{(-\Delta AICci\,/2)}}$$

where R is the number of candidate models being compared. Model performance (i.e., model fit) was evaluated by their ability to correctly classify resource use events by martens.

Fine-Resolution Resource Selection

Radio-collared martens were located by telemetry and backtracked to identify resource use locations. Areas of resource use were sampled every 100m along marten winter travel trajectories. Field observations of the resource variables included in the fine-resolution models appeared to vary at small spatial scales (e.g. 10-20m). Distances of 100m were chosen between successive sample sites in order to increase confidence that sample sites were spatially independent. The spatial extent of fine-resolution sample sites (a circular area approximately 10m in radius) was defined by the basal sweep using a 2M prism. Several fine-resolution resource variables were sampled at these locations: abundance of coarse woody debris (CWD), percent canopy cover, shrub abundance, tree basal area, percent spruce, percent cedar, and percent conifer (Table 3). Fine-resolution models were developed using variables that were of ecological relevance to martens based on previous resource selection studies.

Coarse woody debris (Bowman and Robitaille, 1997; Payer and Harrison, 2003), percent canopy cover (Bateman, 1986; Bowman and Robitaille, 1997; Smith and Schaefer, 2002; Poole *et al*., 2004), shrub abundance (Potvin *et al*., 2000), and tree basal area (Payer and Harrison, 2003) have been identified as useful predictors of habitat use by martens. Furthermore, current management guidelines within Ontario (Watt *et al*., 1996) recommend maintaining forest stands with greater than 50% canopy cover and an abundance of downed CWD. The rational for including the percent composition of spruce, cedar, and conifers was discussed in the previous section.

Available sites were sampled every 100m along transects (1km in length) within a marten home range. The locations of transects were chosen to reflect proportionate forest-stand availabilities within marten home ranges. For example, if a marten home range was comprised of 80% old conifer stands, transect locations were selected to reflect this habitat availability. The exact location of transects within forest-stands, however, was randomly selected within ArcView to better approximate a random sample of habitats within a marten's home range. The same set of resource variables was sampled at available sites as was done for used sites.

The above-mentioned resource variables were used to create 35 candidate fine-resolution resource selection models. Candidate models were dropped from analysis if they included correlated predictor variables ($r > 0.25$). Models containing percent conifer and percent spruce or percent cedar were dropped from the analysis because of multicollinearity. Model selection methods are as outlined in the Materials and Methods section for "Coarse-Resolution Resource Selection" above.

RESULTS

Animal Captures and Home Range Estimates

Population size was exceptionally low during the present study, but five martens provided sufficient telemetry information and snow-tracking accessibility to be included in the analysis of the present study. Two martens (one adult male and one adult female) had established home ranges in the mature forest landscape, while three martens (one adult male, one adult female, and one juvenile female) had established home ranges in the managed landscape. Marten home range estimates in the present study were large ($\bar{x} \pm$ SE $= 18.74 \pm 3.11$ km^2; Table 4).

Coarse-Resolution Resource Selection

At the coarse resolution, resource selection models for each marten can be found in Appendix 1. Models correctly classified habitat use 0.0-26.7% of the time ($\bar{x} \pm$ SE = 5.0 ± 1.7%; Table 5). Parsimonious models among martens tended to be univariate or bivariate, but favoured models differed among martens.

Fine-Resolution Resource Selection

At the fine resolution, resource selection models for each marten can be found in Appendix 2. Models correctly classified habitat use 13.6-85.4% of the time ($\bar{x} \pm$ SE = 48.2 $\pm$ 4.8%; Table 6). Parsimonious models tended to be multivariate, but favoured models differed among martens.

The abundance of CWD was the predictor variable that best explained resource use by martens at the fine resolution (Table 7). Martens that exhibited selection for CWD selected sites that were, on average, five times greater in CWD abundance than available sites (Figure 2). Martens also selected sites with a higher proportion of cedar trees in comparison to available sites within marten home ranges (Table 7). Martens that exhibited selection for cedar composition at the fine resolution selected sites that were two to six times greater in percent composition than in the available sites (Figure 3). Although model selection results provide some evidence that martens selected sites with lower tree basal areas as compared to available sites (Table 7), mean basal areas at used and available sites, however, did not seem to differ for four of the five martens (Figure 4). Percent conifer and spruce composition, percent canopy cover, and shrub abundance were not useful predictors of resource use by martens at the fine resolution (Table 7; Figures 5 through 7).

DISCUSSION

Resource use by martens was not well predicted at the coarse resolution. Most (17 of 26) of the competing "best" models were unable to correctly classify a single habitat use event, strongly suggesting that coarse-resolution models were inadequate at predicting resource use by martens during winter. The poor predictive accuracy of coarse-resolution models can be interpreted in two ways: (1) martens were not selecting resources at the coarse resolution; or (2) martens were selecting resources at the coarse resolution but my proposed models missed this selection. If the latter explanation is true, then either my proposed models lack important variables for predicting resource use at the coarse resolution or observer error incurred during the interpretation of aerial photographs in developing FRI data hinders the ability of coarse-resolution models in detecting differences in resource use by martens. In either case, the FRI database is currently insufficient for successfully modelling resource use by martens.

Fine-resolution models were more reliable than coarse-resolution models in predicting resource use by martens. Overall, fine-resolution models performed moderately well in explaining resource use by martens; mean model fit was nearly 50 percent. This performance was ten times better than the coarse-resolution models.

No particular model at the fine resolution best explained resource use for all martens, as the "best" models differed for each marten. Coarse woody debris (CWD) was the most consistently used variable among four of the five martens, and thus was a reliable predictor of resource use by martens at the fine resolution. Some martens selected sites with greater percent composition of cedar trees, but lower tree basal area in comparison to available sites.

Previous resource selection studies (Buskirk, 1984; Buskirk *et al.*, 1989; Sherburne and Bissonette, 1993; Sherburne and Bissonette, 1994) have also identified CWD as an important predictor of habitat use by martens. During winter, CWD creates access points that allow martens to go beneath the snow surface (Koehler and Hornocker, 1977; Steventon and Major, 1982; Buskirk, 1984; Buskirk *et al*., 1989; Thompson, 1991). Subnivean access is important to martens for two reasons. Firstly, prey species such as deer mice (*Peromyscus maniculatus*), meadow voles (*Microtus pennsylvanicus*) and southern red-backed voles (*Clethrionomys gapperi*) are active within the subnivean zone during the winter. Since small mammals are a staple of marten diets (Buskirk and McDonald, 1984), subnivean access sites provide martens with improved opportunity to capture prey (Thompson, 1986; Andruskiw, 2003). Furthermore, CWD seems to act as a visual cue during hunting episodes (Andruskiw, 2003) that may explain why marten travel trajectories had greater CWD abundance than randomly selected sites within marten home ranges. Secondly, snow- and radio-tracked martens were often found resting within subnivean sites created by CWD. Habitats with an abundance of CWD may provide subnivean rest sites for martens (Buskirk *et al*., 1988).

Martens also tended to select sites with cedars, perhaps because numerous low hanging branches of cedar trees intercept snowfall, thereby creating an abundance of subnivean access sites. Furthermore, cedar trees typically grow in mesic sites, which are used by red-backed voles (Gunderson, 1959), one of martens' preferred prey species (Buskirk and McDonald, 1984). There is some evidence to suggest that martens also preferred sites with lower basal area, but this needs to be further corroborated given the weak evidence for selection. There was little evidence to suggest that either percent conifer or percent canopy cover were reliable predictors of habitat use by martens. Mean availability for these two variables commonly exceeded 40%, well above typical resource guidelines (Watt *et al*., 1996). This may explain why martens did not select for these particular variables and why percent composition of spruce was not the best predictor of winter habitat use by martens as claimed by Bowman *et al*. (1996).

Martens are thought to prefer snowshoe hares to smaller prey species during winter (Raine, 1987; Thompson and Colgan, 1994). The most important habitat component for snowshoe hares is dense understory cover (Wolff, 1980; Litvaitis *et al*., 1985). I accordingly expected shrub abundance to be an important predictor of resource use by martens. This variable, however, did not explain marten resource use, suggesting that martens may not have been exclusively targeting snowshoe hares as prey.

Resource selection infers that an animal actively chooses resources in particular areas over other resource types or locations. This inference requires that animals have sufficient knowledge of the location and quality of resources available to them within their home range. Mean home range size of martens in the current study was much greater than most other studies investigating home range size (Buskirk and McDonald, 1989). It may be argued that martens with large home ranges sample resources rather than actively selecting them because of insufficient knowledge of their entire home range. However, the strong supporting evidence that all five martens were actively selecting resources at the fine resolution suggests that they had sufficient knowledge of resource availability within their home ranges.

Based on small mammal trapping and winter prey-tracking results in the study area, prey resources were low at the time resource selection was investigated. It is possible, and perhaps likely, that resource selection of martens changes with prey abundance. Consequently, selection results from these five martens may not apply at higher prey densities. The effect of prey density on resource selection of martens requires further investigation.

Resource selection results may be limited in making inferences for martens as a species due to low replication ($n = 5$). Furthermore, models were developed to describe resource use within a narrow range of conditions (a single study area over the period of one winter). I therefore suggest that further research be conducted to corroborate the reliability of my research findings for marten populations. Despite these potential limitations, I argue that my findings provide future research direction with regards to investigating coarse woody debris, cedar composition and tree basal area as potentially useful predictors of resource use by martens. My research also provides strong evidence that resource selection by martens can be predicted at fine spatial resolutions. This finding is not only important for modelling marten resource use, but has important implications for resource selection studies as a whole.

Fine-resolution models developed using track-based data were better predictors of resource use by martens relative to coarse-resolution models developed using telemetry and GIS data. I caution, however, that fine-resolution models are not a complete substitute for coarse-resolution models as modelling at a fine scale is costly to researchers, as extensive amounts of time and effort are required to collect fine-resolution data. Appropriate research methodology, therefore, should consider many factors including the ecology of the study species of interest, posed research questions, and funding.

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Table 1. Definitions of forest-stand terms.

Forest-stand Term	Definition
Old	Age ≥ 80 years
Young	20 years ≤ age ≤ 79 years
Recently disturbed	Age < 20 years
Conifer	Composition ≥ 80% conifer tree species (CTS)
Mixed	20 % CTS < composition < 80% CTS
Deciduous	Composition ≤ 20% CTS

Table 2. Definitions of coarse-resolution predictor variables.

Predictor Variable Term	Predictor Variable Defined
Height	Forest-stand height (m).
SC	Stand classification (SC) is a categorical variable that defines upland and lowland forest stands and is derived using site class information from the forest resource inventory database.
Spruce	Percent composition of spruce - black spruce (*Picea mariana*) and white spruce (*Picea glauca*) – within the forest stand.
Cedar	Percent composition of eastern-white cedar (*Thuja occidentalis*) within the forest stand.
BF	Percent composition of balsam fir (*Abies balsamea*) within the forest stand.
Conifer	Percent composition of conifers - black and white spruce, eastern-white cedar, balsam fir, tamarack (*Larix laricina*), jack pine (*Pinus banksiana*) and white pine (*Pinus strobus*) – within the forest stand.

Table 3. Definitions and collection methods of fine-resolution predictor variables.

Predictor Variable Term	**Predictor Variable Defined**	**Data Collection Method**
CWD	Abundance of coarse woody debris	Number of pieces of wood (diameter ≥ 10cm, length ≥ 1m) providing subnivean access within a 2.5m radius of the data collection point.
Canopy	Percent canopy cover	Mean score of four percent canopy cover readings (using a spherical densiometer) taken in each of the cardinal compass directions at the data collection point.
Shrub	Shrub abundance	Number of shrub (diameter < 5cm, height < 3m) stems within a 1m radius of the data collection point.
BA	Tree basal area	Number of trees counted as “in” during a tree density sweep using a 2M wedge prism.
Spruce	Percent spruce	Percent composition of spruce - black spruce (*Picea mariana*) and white spruce (*Picea glauca*) - trees within the tree density sweep area.
Cedar	Percent cedar	Percent composition of eastern-white cedar (*Thuja occidentalis*) trees within the tree density sweep area.
Conifer	Percent conifer	Percent composition of conifer - black and white spruce, eastern-white cedar, balsam fir (*Abies balsamea*), tamarack (*Larix laricina*), jack pine (*Pinus banksiana*) and white pine (*Pinus strobus*) - trees within the tree density sweep area.

Table 4. Home range estimates of martens included in the present study.

Landscape	Marten	Age/Sex	Home-Range Size (km^2)	Number of Winter Telemetry Fixes
Mature	150.247	Adult Male	7.07	21
	151.008	Adult Female	19.02	34
Managed	150.137	Adult Male	22.32	37
	150.719	Juvenile Female	20.05	49
	151.600	Adult Female	25.25	46
Mean $\pm$ SE			18.74 $\pm$ 3.11	37.4 $\pm$ 4.4

Table 5. Model selection results for explaining resource use by martens at the coarse resolution. The competing "best" models (i.e., ΔAICc scores < 2.00) are presented below. See Appendix 1 for more model results.

Landscape	Marten ID	Model Predictor Variables*	AICc	ΔAICc	Akaike Weight (w)	Model Fit % Use
Mature	150.247	Height$^-$	79.136	0.000	0.12	15.0
		Conifer$^+$	80.160	1.024	0.07	0.0
		Cedar$^+$	80.370	1.234	0.07	0.0
		SC$^+$	80.426	1.290	0.06	0.0
		Spruce$^+$	80.508	1.372	0.06	0.0
		Height$^-$, SC$^+$	80.535	1.399	0.06	0.0
		BF^0	80.593	1.457	0.06	0.0
	151.008	SC$^+$	120.653	0.000	0.16	0.0
		Spruce$^-$, SC$^+$	121.456	0.802	0.11	0.0
		Cedar$^+$, SC$^+$	121.817	1.163	0.09	3.2
		Conifer$^-$, SC$^+$	122.256	1.602	0.07	0.0
Managed	150.137	BF$^+$	130.493	0.000	0.09	0.0
		Spruce$^-$	130.584	0.091	0.09	0.0
		Height$^+$	130.829	0.336	0.08	0.0
		Conifer$^-$	130.904	0.411	0.07	0.0
		SC$^+$	130.967	0.474	0.07	0.0
		Cedar$^+$	130.998	0.506	0.07	0.0
		BF$^+$, Height$^+$	131.978	1.486	0.04	0.0
		Spruce$^-$, BF$^+$	132.290	1.797	0.04	0.0
	150.719	Spruce$^-$, BF$^-$	147.229	0.000	0.23	18.9
		Spruce$^-$, BF$^-$, Height$^-$	148.612	1.383	0.11	24.3
		Spruce$^-$, BF$^-$, SC$^+$	148.911	1.682	0.10	18.9
	151.600	Cedar$^+$, Height$^-$	162.245	0.000	0.24	6.7
		Cedar$^+$, Height$^-$, SC$^+$	163.702	1.457	0.12	6.7
		Spruce$^-$, Cedar$^+$, Height$^-$	164.096	1.851	0.09	26.7
		Cedar$^+$, BF$^-$, Height$^-$	164.237	1.992	0.09	8.9

* A positive sign next to a predictor variable denotes that the parameter value of the specified variable is positive, indicating selection for this variable; a negative sign denotes that the parameter value of the specified variable is negative, indicating selection against this variable; a zero value next to a predictor variable denotes that the parameter value could not be estimated due to zero values in all entries.

Table 6. Model selection results for explaining resource use by martens the fine resolution. The competing "best" models (i.e., ΔAICc scores < 2.00) are presented below. See Appendix 2 for more model results.

Landscape	Marten ID	Model Predictor Variables*	AICc	ΔAICc	Akaike Weight (w)	Model Fit % Use
Mature	150.247	Shrub^{+}, Canopy^{+}, Conifer^{+}, BA^{-}	87.470	0.000	0.50	85.4
		CWD^{+}, Shrub^{+}, Canopy^{+}, Conifer^{+}, BA^{-}	88.726	1.256	0.26	82.9
	151.008	Cedar^{+}, BA^{-}	109.066	0.000	0.13	37.5
		CWD^{+}, Canopy^{+}, Cedar^{+}, BA^{-}	109.737	0.582	0.10	43.8
		Canopy^{+}, Cedar^{+}, BA^{-}	110.058	0.953	0.08	31.3
		CWD^{+}, Spruce^{-}	110.447	1.381	0.07	21.9
		CWD^{+}	110.483	1.445	0.06	21.9
Managed	150.137	Canopy-, Spruce^{+}, Cedar^{+}	105.447	0.000	0.38	45.5
		Canopy^{-}, Spruce^{+}, Cedar^{+}, BA^{+}	107.044	1.597	0.17	42.4
	150.719	CWD^{+}, Cedar^{+}	98.512	0.000	0.38	53.1
		CWD^{+}, Spruce^{+}, Cedar^{+}	100.178	1.666	0.17	53.1
		CWD^{+}, Canopy^{-}, Cedar^{+}	100.431	1.919	0.15	53.1
	151.600	CWD^{+}, Canopy^{+}, Cedar^{-}, BA^{-}	118.932	0.000	0.20	54.5
		CWD^{+}, Canopy^{+}, Spruce^{-}, Cedar^{-}, BA^{-}	119.164	0.232	0.18	61.4
		CWD^{+}, Canopy^{+}, Cedar^{-}	120.570	1.638	0.09	59.1
		CWD^{+}, Canopy^{+}, Spruce^{-}, Cedar^{-}	120.613	1.681	0.09	59.1
		CWD^{+}, Cedar^{-}	120.738	1.806	0.08	13.6

* A positive sign next to a predictor variable denotes that the parameter value of the specified variable is positive, indicating selection for this variable; a negative sign denotes that the parameter value of the specified variable is negative, indicating selection against this variable.

Table 7. Predictor variable selection results for explaining resource use by martens at the fine resolution.

Landscape	Marten ID	Predictor Variables*						
		CWD	Shrub	Canopy	Conifer	Spruce	Cedar	BA
Mature	150.247	+	+	+	+	o	o	-
	151.008	+	o	+	o	-	+	-
Managed	150.137	o	o	-	o	+	+	+
	150.719	+	o	-	o	+	+	o
	151.600	+	o	+	o	-	-	-
Overall	Total	+4	+1	+1	+1	0	+2	-2

* A positive sign denotes that the parameter value of the specified variable is positive, indicating selection for this variable; a negative sign denotes that the parameter value of the specified variable is negative, indicating selection against this variable; a zero value denotes that there is no selection for this variable.

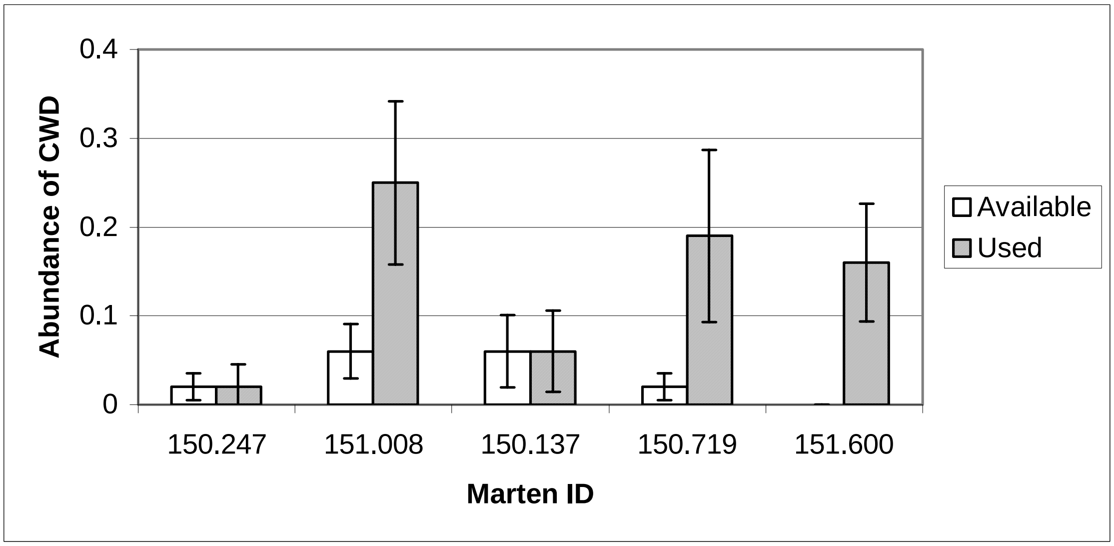

Figure 1. Abundance ($\bar{x} \pm$ SE) of coarse woody debris (CWD) at used and available fine-scale sites within marten home ranges.

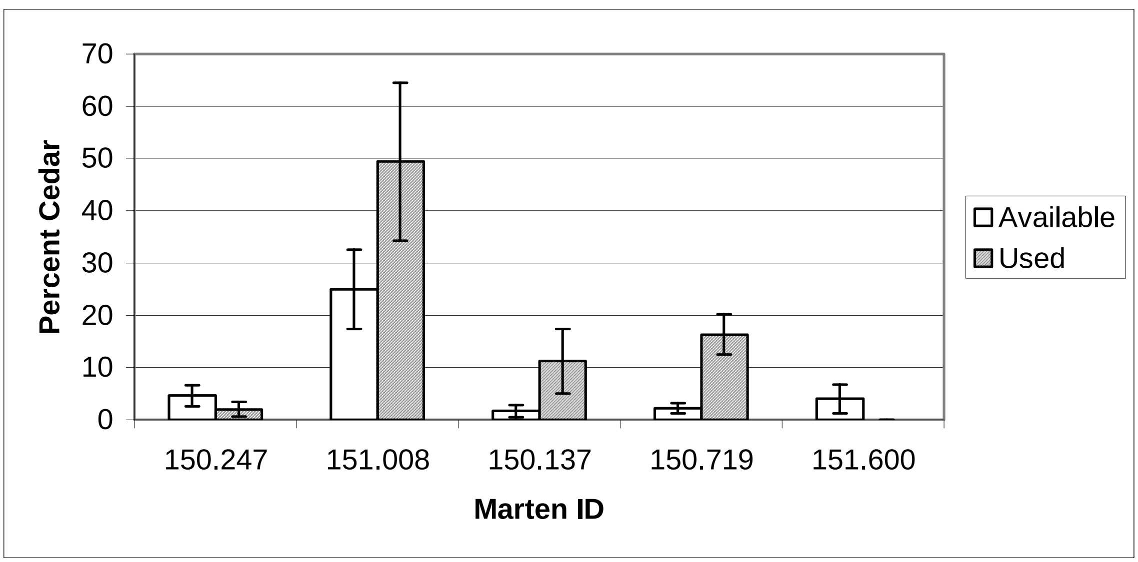

Figure 2. Percent composition ($\bar{x} \pm$ SE) of cedar trees at used and available fine-scale sites within marten home ranges.

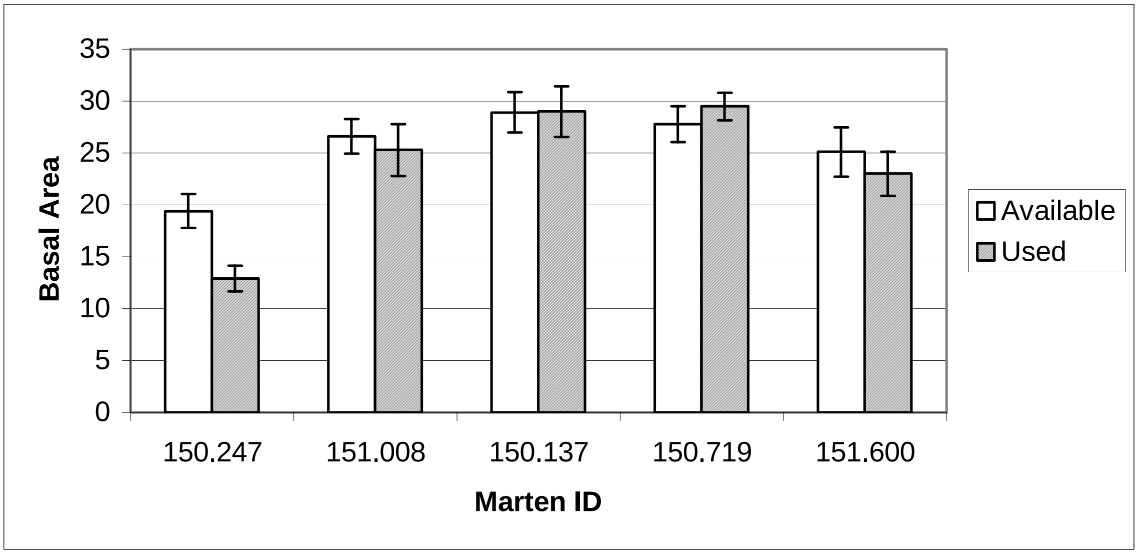

Figure 3. Tree basal area ($\bar{x} \pm$ SE) at used and available fine-scale sites within marten home ranges.

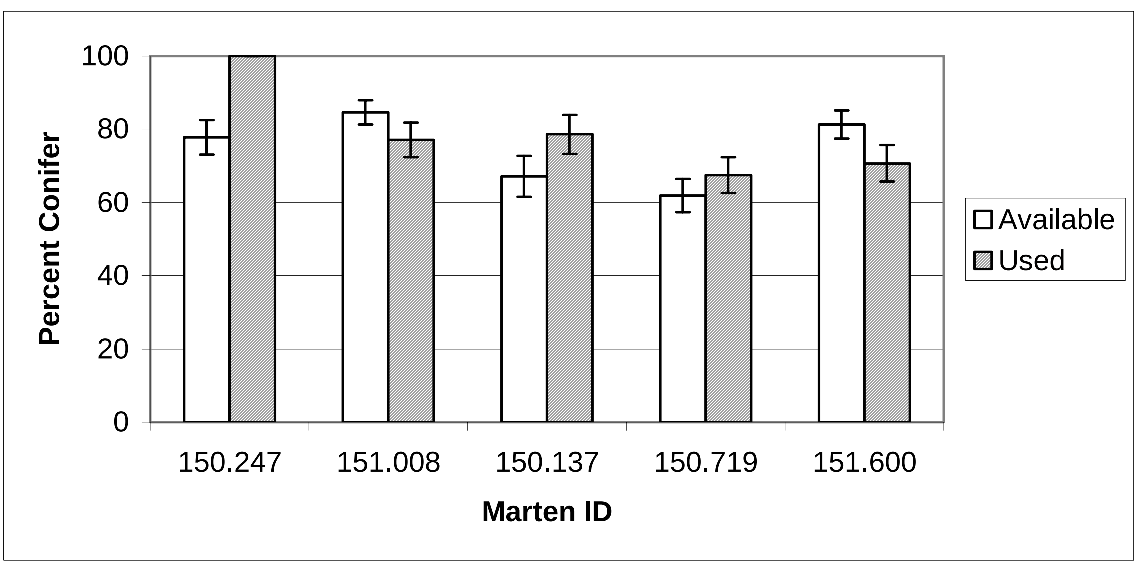

Figure 4. Percent composition ($\bar{x} \pm$ SE) of conifer trees at used and available fine-scale sites within marten home ranges.

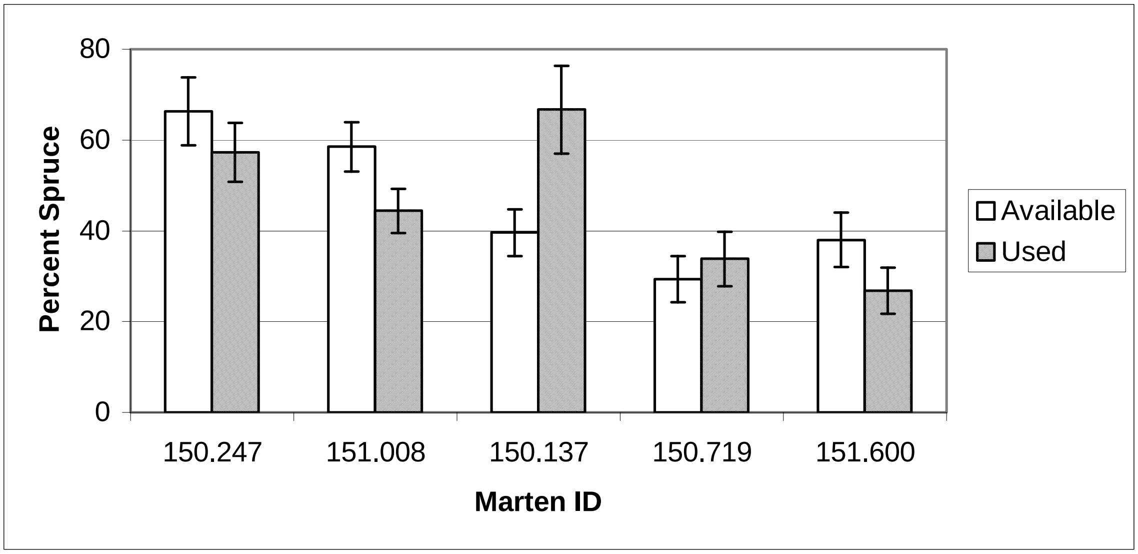

Figure 5. Percent composition ($\bar{x} \pm$ SE) of spruce trees at used and available fine-scale sites within marten home ranges.

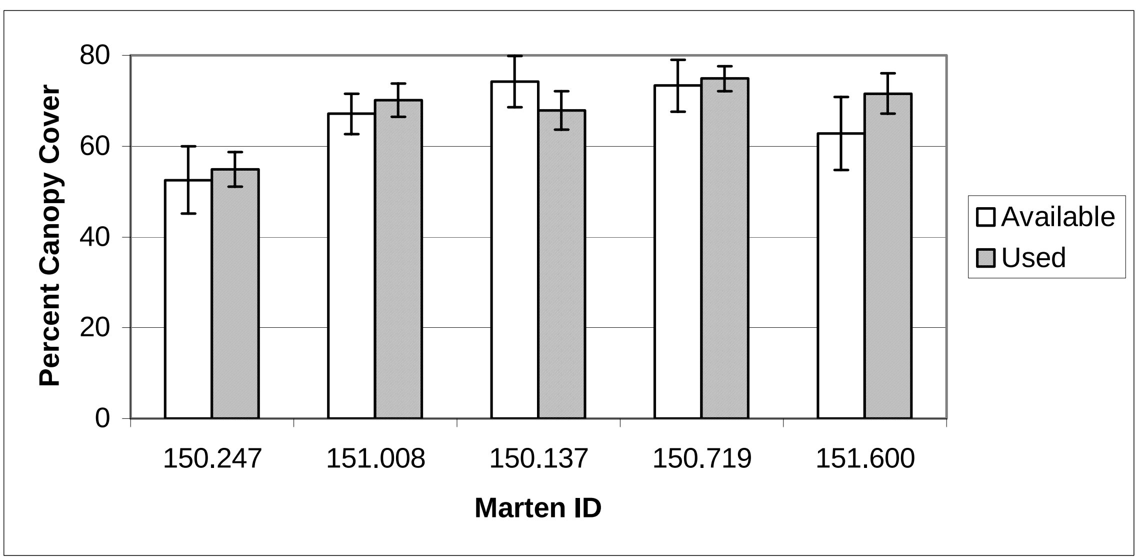

Figure 6. Percent canopy cover ($\bar{x} \pm$ SE) at used and available fine-scale sites within marten home ranges.

Appendix 1. Model selection results for explaining resource use by martens at the coarse resolution. The top twenty of 35 proposed candidate models are shown. Model fit scores are given for models with ΔAICc < 2.0.

a) Marten 150.247: data at 20 used sites are compared to data at 40 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	Height	79.136	0.000	0.12	15.0
2	Conifer	80.160	1.024	0.07	0.0
3	Cedar	80.370	1.234	0.07	0.0
4	SC	80.426	1.290	0.06	0.0
5	Spruce	80.508	1.373	0.06	0.0
6	Height, SC	80.535	1.399	0.06	0.0
7	BF	80.593	1.457	0.06	0.0
8	Cedar, Height	81.279	2.143	0.04	
9	Conifer, Height	81.344	2.208	0.04	
10	Spruce, Height	81.351	2.215	0.04	
11	BF, Height	81.354	2.218	0.04	
12	Cedar, SC	82.161	3.025	0.03	
13	Conifer, SC	82.259	3.123	0.03	
14	Spruce, Cedar	82.379	3.243	0.02	
15	Cedar, BF	82.588	3.452	0.02	
16	Conifer, Height, SC	82.611	3.476	0.02	
17	Spruce, SC	82.623	3.487	0.02	
18	Spruce, Height, SC	82.639	3.504	0.02	
19	BF, SC	82.644	3.508	0.02	
20	Spruce, BF	82.726	3.590	0.02	

Appendix 1. Continued…

b) Marten 151.008: data at 31 used sites are compared to data at 65 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	SC	120.653	0.000	0.16	0.0
2	Spruce, SC	121.456	0.802	0.11	0.0
3	Cedar, SC	121.817	1.163	0.09	3.2
4	Conifer, SC	122.256	1.602	0.07	0.0
5	Height, SC	122.690	2.036	0.06	
6	BF, SC	122.790	2.136	0.05	
7	Cedar, Height, SC	122.945	2.291	0.05	
8	Spruce, Cedar, SC	123.065	2.411	0.05	
9	Spruce, Height, SC	123.640	2.986	0.04	
10	Spruce, BF, SC	123.641	2.987	0.04	
11	Cedar, BF, SC	124.002	3.348	0.03	
12	Conifer, Height, SC	124.435	3.781	0.02	
13	Height	124.803	4.150	0.02	
14	Conifer	124.821	4.168	0.02	
15	Spruce	124.825	4.172	0.02	
16	BF, Height, SC	124.875	4.221	0.02	
17	Cedar	124.910	4.257	0.02	
18	BF	124.910	4.257	0.02	
19	Spruce, Cedar, Height, SC	124.929	4.275	0.02	
20	Cedar, BF, Height, SC	125.180	4.526	0.02	

Appendix 1. Continued…

c) Marten 151.137: data at 32 used sites are compared to data at 70 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	BF	130.493	0.000	0.09	0.0
2	Spruce	130.584	0.091	0.09	0.0
3	Height	130.829	0.336	0.08	0.0
4	Conifer	130.904	0.411	0.07	0.0
5	SC	130.967	0.474	0.07	0.0
6	Cedar	130.998	0.505	0.07	0.0
7	BF, Height	131.978	1.486	0.04	0.0
8	Spruce, BF	132.290	1.797	0.04	0.0
9	Cedar, BF	132.582	2.089	0.03	
10	BF, SC	132.605	2.112	0.03	
11	Spruce, Cedar	132.677	2.184	0.03	
12	Spruce, SC	132.697	2.204	0.03	
13	Spruce, Height	132.708	2.215	0.03	
14	Cedar, Height	132.940	2.447	0.03	
15	Height, SC	132.940	2.447	0.03	
16	Cedar, SC	132.946	2.453	0.03	
17	Conifer, SC	132.995	2.502	0.03	
18	Cedar, SC	133.071	2.578	0.03	
19	BF, Height, SC	134.102	3.609	0.02	
20	Spruce, BF, Height	134.115	3.622	0.01	

Appendix 1. Continued…

d) Marten 150.719: data at 37 used sites are compared to data at 89 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	Spruce, BF	147.229	0.000	0.23	18.9
2	Spruce, BF, Height	148.612	1.383	0.11	24.3
3	Spruce, BF, SC	148.911	1.682	0.10	18.9
4	Spruce, Cedar, BF	149.256	2.027	0.08	
5	BF	149.446	2.217	0.07	
6	Spruce, BF, Height, SC	150.257	3.028	0.05	
7	BF, SC	150.673	3.444	0.04	
8	Spruce, Cedar, BF, Height	150.721	3.492	0.04	
9	Cedar, BF	150.835	3.606	0.04	
10	Spruce, Cedar, BF, SC	151.036	3.807	0.03	
11	BF, Height	151.462	4.233	0.03	
12	Spruce, Cedar, BF, Height, SC	152.243	5.014	0.02	
13	Cedar, BF, SC	152.361	5.132	0.02	
14	Spruce, Height	152.529	5.300	0.02	
15	Cedar	152.548	5.319	0.02	
16	Cedar, BF, Height	152.564	5.335	0.02	
17	BF, Height, SC	152.775	5.546	0.01	
18	Spruce, Cedar	153.194	5.965	0.01	
19	Conifer	153.304	6.075	0.01	
20	Spruce, Cedar, Height	154.217	6.988	0.01	

Appendix 1. Continued…

e) Marten 151.600: data at 45 used sites are compared to data at 87 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	Cedar, Height	162.245	0.000	0.24	6.7
2	Cedar, Height, SC	163.702	1.457	0.12	6.7
3	Spruce, Cedar, Height	164.096	1.851	0.09	26.7
4	Cedar, BF, Height	164.237	1.992	0.09	8.9
5	Cedar, BF, Height, SC	165.073	2.829	0.06	
6	Spruce, Cedar, BF, Height	165.600	3.356	0.04	
7	Spruce, BF, Height	165.601	3.356	0.04	
8	BF, Height, SC	165.702	3.457	0.04	
9	Spruce, Cedar, Height, SC	165.857	3.613	0.04	
10	Height	166.057	3.813	0.04	
11	BF, Height	166.619	4.274	0.03	
12	Spruce, BF, Height, SC	166.805	4.561	0.02	
13	Spruce, Cedar, BF, Height, SC	167.039	4.795	0.02	
14	Spruce, Height	167.060	4.815	0.02	
15	Height, SC	167.203	4.958	0.02	
16	Conifer, Height	167.868	5.623	0.01	
17	Cedar	168.360	6.116	0.01	
18	Conifer, Height, SC	168.761	6.516	0.01	
19	Spruce, Height, SC	168.986	6.741	0.01	
20	Cedar, SC	169.330	7.085	0.01	

Appendix 2. Model selection results for explaining resource use by martens at the fine resolution. Top twenty (or less) of the 35 proposed candidate models (with ΔAICc < 10.0) are shown. Model fit scores are given for models with ΔAICc < 2.0.

a) Marten 150.247: data at 41 used sites are compared to data at 59 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	Shrub, Canopy, Conifer, BA	87.470	0.000	0.50	85.4
2	CWD, Shrub, Canopy, Conifer, BA	88.726	1.256	0.26	82.9
3	Canopy, Conifer, BA	89.705	2.235	0.16	
4	CWD, Canopy, Conifer, BA	91.189	3.719	0.08	

b) Marten 151.008: data at 32 used sites are compared to data at 52 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	Cedar, BA	109.066	0.000	0.13	37.5
2	CWD, Canopy, Cedar, BA	109.737	0.582	0.10	43.8
3	Canopy, Cedar, BA	110.058	0.953	0.08	31.3
4	CWD, Spruce	110.447	1.381	0.07	21.9
5	CWD	110.483	1.445	0.06	21.9
6	CWD, Conifer	111.135	2.069	0.05	
7	Spruce, Cedar, BA	111.249	2.144	0.04	
8	CWD, Spruce, Cedar	111.889	2.784	0.03	
9	CWD, Canopy, Spruce, Cedar, BA	112.052	2.834	0.03	
10	CWD, BA	112.212	3.146	0.03	
11	Spruce	112.304	3.238	0.03	
12	Canopy, Spruce, Cedar, BA	112.317	3.251	0.03	
13	CWD, Canopy, Spruce	112.495	3.390	0.02	
14	CWD, Canopy	112.531	3.465	0.02	
15	Spruce, Cedar	113.071	4.005	0.02	
16	CWD, Canopy, Conifer	113.175	4.070	0.02	
17	Cedar	113.167	4.129	0.02	
18	CWD, Canopy, Cedar	113.273	4.168	0.02	
19	CWD, Canopy, BA	113.403	4.298	0.02	
20	CWD, Canopy, Spruce, BA	113.910	4.755	0.01	

Appendix 2. Continued…

c) Marten 150.137: data at 33 used sites are compared to data at 54 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	Canopy, Spruce, Cedar	105.447	0.000	0.38	45.5
2	Canopy, Spruce, Cedar, BA	107.044	1.597	0.17	42.4
3	CWD, Canopy, Spruce, Cedar	107.508	2.061	0.14	
4	Spruce, Cedar	108.336	2.889	0.09	
5	CWD, Canopy, Spruce, Cedar, BA	109.189	3.742	0.06	
6	Spruce, Cedar, BA	109.955	4.508	0.04	
7	CWD, Spruce, Cedar	110.054	4.607	0.04	
8	Canopy, Spruce	110.695	5.248	0.03	
9	Spruce	112.286	6.839	0.01	
10	Canopy, Spruce, BA	112.359	6.912	0.01	
11	CWD, Canopy, Spruce	112.593	7.146	0.01	
12	CWD, Shrub, Spruce, Cedar	113.350	7.903	0.01	
13	CWD, Shrub, Canopy, Spruce, Cedar, BA	113.710	8.263	0.01	
14	CWD, Spruce	113.951	8.504	0.01	
15	Spruce, BA	114.089	8.642	0.00	
16	CWD, Canopy, Spruce, BA	114.321	8.874	0.00	

Appendix 2. Continued…

d) Marten 150.719: data at 32 used sites are compared to data at 59 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	CWD, Cedar	98.512	0.000	0.38	53.1
2	CWD, Spruce, Cedar	100.178	1.666	0.17	53.1
3	CWD, Canopy, Cedar	100.431	1.919	0.15	53.1
4	CWD, Canopy, Spruce, Cedar	101.993	3.481	0.07	
5	CWD, Canopy, Cedar, BA	102.247	3.735	0.06	
6	Cedar	103.007	4.495	0.04	
7	CWD, Canopy, Spruce, Cedar, BA	103.904	5.392	0.03	
8	CWD, Shrub, Cedar	104.535	6.023	0.02	
9	Cedar, BA	104.590	6.078	0.02	
10	Spruce, Cedar	104.810	6.298	0.02	
11	Canopy, Cedar	105.022	6.510	0.01	
12	Canopy, Cedar, BA	106.353	7.841	0.01	
13	CWD, Shrub, Spruce, Cedar	106.470	7.958	0.01	
14	Spruce, Cedar, BA	106.503	7.991	0.01	
15	CWD, Shrub, Canopy, Cedar	106.531	8.019	0.01	
16	Canopy, Spruce, Cedar	106.796	8.284	0.01	

Appendix 2. Continued…

e) Marten 151.600: data at 44 used sites are compared to data at 50 available sites.

Model #	Model Predictor Variables	AICc	ΔAICc	Akaike weight (w)	Model Fit Use %
1	CWD, Canopy, Cedar, BA	118.932	0.000	0.20	54.5
2	CWD, Canopy, Spruce, Cedar, BA	119.164	0.232	0.18	61.4
3	CWD, Canopy, Cedar	120.570	1.638	0.09	59.1
4	CWD, Canopy, Spruce, Cedar	120.613	1.681	0.09	59.1
5	CWD, Cedar	120.738	1.806	0.08	13.6
6	CWD, Spruce, Cedar	121.321	2.389	0.06	
7	Canopy, Spruce, Cedar, BA	121.763	2.831	0.05	
8	Canopy, Cedar, BA	122.437	3.505	0.03	
9	CWD, Canopy, BA	122.887	3.955	0.03	
10	CWD, Shrub, Canopy, Spruce, Cedar, BA	123.290	4.358	0.02	
11	CWD, Canopy, Conifer, BA	123.422	4.490	0.02	
12	CWD, Canopy, Spruce, BA	123.515	4.583	0.02	
13	CWD, Shrub, Canopy, Cedar, BA	123.717	4.785	0.02	
14	CWD	124.484	5.552	0.01	
15	CWD, Canopy	124.982	6.050	0.01	
16	CWD, Shrub, Spruce, Cedar	125.160	6.228	0.01	
17	CWD, Shrub, Cedar	125.188	6.256	0.01	
18	CWD, Spruce	125.285	6.353	0.01	
19	Canopy, Spruce, Cedar	125.340	6.408	0.01	
20	CWD, Shrub, Canopy, Cedar	125.418	6.486	0.01	