DENNING ECOLOGY AND HABITAT USE BY FISHER (*Martes pennanti*) IN PINE DOMINATED ECOSYSTEMS OF THE CHILCOTIN PLATEAU

by

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Abstract

I used radio-telemetry to monitor 24 fisher (*Martes pennanti*) in the Chilcotin area of British Columbia. Fisher used heart rot cavities in old lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii var. glauca*), and trembling aspen (*Populus tremuloides*) trees located primarily on south aspects for reproductive dens. Den trees in the Chilcotin were smaller in diameter than those documented elsewhere in western North America, but were locally large. Fisher used both arboreal and terrestrial rest sites in the Chilcotin, but terrestrial sites were preferred during periods of deep snow. Arboreal rest sites were usually on rust brooms in white spruce (*Picea glauca*) and terrestrial rest sites were typically associated with large diameter coarse woody debris. Mean home range size for 10 females in my study was 30 km^2 and the male fisher I monitored had a home range of 166 km^2. Within home ranges, fisher preferred areas close to streams.

Keywords: fisher, *Martes pennanti*, British Columbia, radio telemetry, reproductive dens, rest sites, home range

This thesis is dedicated to:

The Ulkatcho First Nation who understood the importance of this work

and cared enough about their territory to invest in research;

The trappers of the West Chilcotin who foresaw the changes in the forest

and pushed for local studies on furbearers;

And Chunihcho who led me down a Chilcotin path

and showed me some of her secrets.

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1.1 Fisher (*Martes pennanti*)

1.1.1 Description

Fisher (*Martes pennanti*) are medium-sized carnivores with the long thin body that is characteristic of the weasel family (Powell 1993). Their ears are large and set close to the head. Their fur is deep brown to black with lighter tri-coloured guard hairs around the face, neck, and shoulders. The species exhibits sexual dimorphism with females weighing 2-3 kg and measuring 75-95 cm in length while males weigh 4-6 kg and measure 90-120 cm in length. Fisher have 5 toes with retractable claws and relatively large feet, presumably for traveling on snow. Most often, they travel using a typical loping gait of the weasel family where one foot lands slightly in front of the other and the hind feet land in the same location as the front. However when snow is deep and soft or there is a thin crust, fisher will walk (Powell 1993).

1.1.2 Life history

Parturition and breeding occur in late winter to early spring with gestation lasting nearly a full year (Powell 1993). Fisher mate approximately 7 days following parturition and are polygamous breeders. Both male and female fisher are capable of breeding at 12 months, but generally do not breed until their second year (Douglas and Strickland 1987). The fisher's long gestation is due to delayed implantation which delays normal development with a period of embryonic dormancy during the blastocyst stage. The blastocysts lie dormant for approximately 10 months until February when they implant (Douglas and Strickland 1987). Final development of the foetus lasts about 40 days (Frost *et al.* 1997) and parturition occurs between February and early April across the species' range (Douglas and Strickland 1987). In British Columbia (BC), fisher parturition has been reported between March 23rd and April 10th (Hall 1942; Weir 2000). Typically, fisher give birth to 1-3 kits (Powell 1993) with an average of 2.3 estimated from counts of corpora lutea in harvested fisher (Weir 2003).

Kits weigh 40-50 g and depend completely upon their mother (Powell and Zielinski 1994). The young nurse for 8-10 weeks (Powell 1993), and are reported to disperse the following fall in Maine (Arthur *et al*. 1993). Weir (2003) reported that dispersal may occur later in the Williston Lake area of BC with young fisher taking up to 2 years to successfully establish a home range.

Fisher home ranges are intra-sexually exclusive and substantially larger in BC than reported elsewhere (Weir 2003). In western conifer dominated forests, fisher habitat is generally associated with habitat features that are usually found in late successional stands (Jones and Garton 1994, Weir 1995). This is especially true of structures used for resting, whelping, and rearing. Resting sites are typically found on spruce brooms, on large limbs, in tree cavities, or beneath coarse woody debris (Weir 1995).

Fisher forage for a wide range of prey species across their range, but focus primarily on snowshoe hare (*Lepus americanus*), red squirrels (*Tamiasciurus hudsonicus*), and other small mammals in BC (Weir 2003). Foraging habitat is usually in patches of high density prey that are searched intensively using frequent changes in direction (Powell 1993). When foraging in areas of low density prey, fisher travel in relatively straight lines and deviate opportunistically to capture prey (Powell 1993). The greatest source of mortality for fisher is from humans, primarily due to trapping in most studied populations (Powell 1993). However, canids, large raptors, lynx (*Lynx canadensis*), wolverine (*Gulo gulo*), and conspecifics also occasionally kill fishers (Douglas and Strickland 1987; Roy 1991; Weir 2000).

1.1.3 Fisher in British Columbia

Fisher is a Provincially blue-listed species in BC that is found at relatively low densities and has a population estimate of less than 3800 individuals. The species is vulnerable to over trapping and habitat loss is a major threat (B.C. Conservation Data Centre 2006). Throughout their range, fishers are reported to require forests with overhead cover (de Vos 1952; Coulter 1966; Kelly 1977; Powell 1977; Arthur *et al.* 1989; Weir 1995), and in western coniferous forests have an affinity for habitat attributes that are usually associated with late successional stands (Jones and Garton 1994; Weir 1995). The permanent loss of forested habitats due to land conversion and hydroelectric development, especially in productive lower elevation forests, is a threat in some areas of the Province (Weir 2003). However, forest harvesting has the greatest potential to affect fisher habitat negatively, due to the prevalence of clear-cut harvesting (Weir 2003). Clear-cut harvesting affects the temporal availability of forested cover and, generally, decreases the abundance of late successional forest attributes over time. The current mountain pine beetle (*Dendroctonus ponderosae*) (MPB) infestation affecting BC is exacerbating habitat loss over a large portion of the fisher's range due to the loss of MPB impacted forest and accelerated salvage harvesting. Currently, there is little information on fisher habitat requirements in pine dominated habitats and hence there is little guidance that biologists can contribute to management guidelines.

Fisher are found throughout most of BC in forested habitats with the greatest occurrence in the central and northeastern areas of the Province (Weir 2003). Within the Central Interior of BC, a large portion of fisher range occurs on the Chilcotin Plateau (Weir 2003). Forests on the Chilcotin Plateau are dominated by lodgepole pine (*Pinus contorta*) stands of which approximately 80% are susceptible to the mountain pine beetle attack. Previous research in the Chilcotin includes a track transect based study on fisher habitat use[1] and two pilot DNA-based inventories for fisher[2,3]. The track transect based study used logistic regression to model habitat characteristics of fisher use sites and found that stands composed of old spruce, mature spruce-pine, and trembling aspen (*Populus tremuloides*) had greater probability of containing fisher. Stands containing greater amounts of large diameter coarse woody debris were also more likely to be used by fisher.

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[1] Davis, L.R. 2003. Stand level habitat use by furbearing species in the Anahim Lake Area of BC. Unpublished report prepared for Yun Ka Whu'ten Holdings Ltd.

[2] Davis, L.R. (2003). DNA Pilot Inventory for Fisher in the Anahim Supply Block. Unpublished Report for Yun Ka Whu'ten Holdings Ltd.

[3] Davis, L.R. (2003). DNA Pilot Inventory for Fisher in the Redbrush. Unpublished Report for Tsi Del Del Enterprises Ltd.

Several studies of fisher habitat indicate that older stands with continuous canopy cover are required to provide security (Coulter 1966; Arthur *et al.* 1989; Weir 1995; Weir and Harestad 1997) and snow interception (Leonard 1980; Raine 1983). The mature spruce and mixed tree species stands used by fisher in the Chilcotin[1] generally have greater canopy cover than pure pine stands and so may provide the increased security and snow interception that fisher are thought to require. Canopy cover may be important during winter to minimize costs of locomotion. Fisher sink deeper into soft snow than marten (*Martes americana*) and avoid areas with deep soft snow (Leonard 1980; Raine 1983). Vegetation in foraging areas also influences the catchability of prey (Powell 1993) and the presence of structural elements, such as coarse woody debris (CWD), can provide fisher with access to subnivean (*i.e.*, below snow) prey in winter. I have followed fisher tracks and observed individuals zig-zaging from element to element during winter and on 2 occasions observed prey remains beneath CWD.

Fisher are selective in their choice of resting structures (Weir 2003). Weir (2003) identified 4 distinct types of rest structures: branch, cavity, coarse woody debris, and ground. In the Chilcotin, I have observed fisher using several types of structures as rest sites: large branches, brooms in white spruce (*Picea glauca*) caused by spruce broom rust (C*hrysomyxa arctostaphyli)*; red squirrel (*Tamiasciurus hudsonicus*) nests in the canopy of lodgepole pine and Douglas-fir (*Pseudotsuga menziesii var. glauca*); heart rot cavities in large diameter lodgepole pine, Douglas-fir, and trembling aspen; beneath complexes of large woody debris; and below ground in red squirrel middens and bushy-tailed woodrat (*Neotoma cinerea*) nests (personal observations). Weir (2003) has linked ambient temperature to the choice of rest structure with CWD and ground-based structures used more frequently than more exposed types when temperatures are very cold and windy.

Fishers have low reproductive output relative to their lifespan (Weir 2003) and low rates of juvenile survival (Krohn *et al.* 1994; Strickland 1994; Weir 2003). Therefore, understanding fisher reproductive requirements is important in maintaining this species. Whelping and rearing structures are usually in cavities of larger diameter trees with deciduous trees used typically across the species range (Powell 1993; Weir 2000). In BC, fisher have only been reported using cavities in large declining black cottonwood (*Populus balsamifera* spp. *trichocarpa*) or balsam poplar (P*opulus balsamifera* spp. *balsamifera*) for whelping and rearing (Weir 2003). However, there are many areas of the Province, such as the Chilcotin, where these trees species are rare or absent.

My project examines denning, resting, and home range level habitat selection by fisher at different spatial scales. Habitat selection by animals has been hypothesized to occur at several different spatial scales or orders, and the explicit definition of the spatial scale of inquiry is important in the interpretation of study results. Weir and Harestad (2003) pointed out that failure to identify the spatial scale of inquiry can lead to inappropriate application of management strategies when findings are applied to different regions. Johnson (1980) identified first order selection as the geographical range of a species and second order as the home range of an individual or social group within the geographical range. Third order selection occurs when animals choose habitat components (*e.g.*, forest stands) within home ranges, and fourth order selection pertains to the choice of individual food items at a site (Johnson 1980). Lofroth (1993) asserted that the fourth order could be extended to any habitat component a species uses and identified the forest patch and element (*e.g.*, tree, broom, log) as additional levels of selection between the third and fourth orders. Forest patches are small areas of habitat (*e.g.*,100 m^2) within forest stands that can differ from the stand in tree species composition, age, or other habitat characteristics. The latter three orders can then be related to the scales used to describe forest ecosystem dynamics: stand, patch, and element (Weir and Harestad 2003). These scales are nested with elements located within patches, patches within stands, stands within home ranges, and home ranges within landscapes (Figure 1.1).

1.2 Project Rationale

Most of the information on fisher ecology in BC has come from studies near Williston Lake and east of Williams Lake. Information on habitat use from other areas is required to guide management and conservation options for fishers at the Provincial level. Key knowledge gaps identified for fisher in BC are habitat use and reproductive denning ecology in pine dominated habitats of BC's central interior (BC Conservation Data Centre 2006). As well, the long-term effects of mountain pine beetle kill and associated forest management on fisher habitat is of management concern.

My study examines habitat use and selection by fisher in drier ecosystems of the Central Interior of BC to address current knowledge gaps for this species. The Chilcotin Plateau lies west of Williams Lake in the Central Interior of BC and in the rain shadow of the Coast Mountains. The area is rated as medium to high fisher habitat capability (Weir 2003) and local trappers consistently capture fisher (Eric Lofroth, BC Ministry of Environment, pers. comm.). My project will also provide forest managers with information to guide retention strategies for stand features and structural elements that are important for fisher habitat.

1.3 Study Area

My study areas are on the Interior Plateau of British Columbia near Anahim Lake and Puntzi Lake. They are in primarily the Sub-boreal Pine-Spruce (SBPS) Biogeoclimatic (BEC) Zone but small portions are in the Interior Douglas-fir (IDF) BEC zone near Puntzi Lake and the Montane Spruce (MS) BEC zone at higher elevations of both study areas (Meindinger and Pojar, 1991; Figure 1.2).

The Anahim study area is approximately 2000 km^2 and bounded by Kappan Lake to the south, Tweedsmuir Park on the west, Gatcho Lake to the north, and Itcha Ilgatchuz Park to the north east. The Puntzi study area is approximately 3000 km^2 and bounded by Itcha Ilgatchuz Park to the northwest, the headwaters of the Chilcotin River to the north, Alexis Lakes to the east, and Highway 20 on the south. Elevations range from 1100-1500 m and are similar in both study areas.

Several biogeoclimatic subzones are present within the study areas: MSxv (very dry, very cold) subzone, the SBPSxc (very dry, cold), the SBPSmc (moist, cold), and the IDFdk4 (dry cool 4) subzones. In the SBPS and MS, lodgepole pine is the leading species in the tree layer of most stands with white spruce and trembling aspen leading occasionally. The tall shrub layer (B1 layer; >2 m tall) is dominated by lodgepole pine and white spruce with lesser amounts of trembling aspen and willow (*Salix* sp.). Soopolallie

(*Sheperdia canadensis*) and willow dominate the B2 layer (<2 m tall) with minor amounts of lodgepole pine, common juniper (*Juniperus communis*), and white spruce. In wetlands, willow, bog birch (*Betula glandulosa*), and sedge (*Carex* sp.) are the dominant plants (Meidinger and Pojar 1991).

In the portions of the study area containing IDFdk4, pure Douglas-fir stands are patchily distributed at lower elevations with mixed stands of lodgepole pine and Douglas-fir forming the most common forest cover. Small stands of trembling aspen are locally abundant with black cottonwood found in low elevation riparian areas. The tall shrub (B1) layer is dominated by Douglas-fir and lodgepole pine, with soopolallie and common juniper leading in the B2 layer (Meidinger and Pojar 1991).

Historically, the major disturbance agent over most of the Chilcotin Plateau was stand-initiating fires which occurred primarily in the SBPS and MS BEC zones. These fires were often very large and resulted in dense stands of lodgepole pine. In the IDF, low severity stand maintaining fires and mixed severity fires were more common. Since the 1950s in the West Chilcotin, additional disturbance has occurred through clear cut and diameter limit harvesting, but most of the logging activity has occurred in the last 20 years. However, the area that has been harvested is still relatively small compared to the area burned by fires. The majority of harvesting is concentrated near sawmills that are centred in William's Lake with smaller operations in Anahim Lake and Hanceville. Historically, MPB has existed at endemic levels in the areas forests with larger outbreaks occurring periodically such as in 1985 and the current epidemic. Over the past 10 years

MPB has infested large areas of the Chilcotin with most salvage logging operations concentrated on areas within 200 km of sawmills located in Williams lake.

1.4 General Methods

I obtained an animal care certificate from the Provincial Wildlife Veterinarian prior to beginning the project in the 2005. Procedures for the capturing and handling of fisher followed guidelines in Resource Inventory Committee (RIC) Live Animal Capture and Handling Guidelines for Wild Mammals, Birds, Amphibians and Reptiles No. 3, V2 (BC Ministry of Environment Lands and Parks. 1998a). I contracted local trappers to capture fisher in the area of their traplines. All trappers received training on the ethical treatment of animals prior to beginning the project. Fisher were live-trapped using Tomahawk Live Traps that were covered and lined with hay. Feeding stations were baited and monitored until fisher sign was found at the station. At that time, traps were set and visited daily until the animal was caught. I then transported the animals to veterinary facilities in Williams Lake using insulated travel boxes containing food to minimize stress due to cold and noise.

The implantation of radio transmitters and monitoring followed guidelines in standards for RIC Wildlife Radio Telemetry (BC Ministry of Environment Lands and Parks. 1998b). The fisher were implanted with Telonics IMP140L radio transmitters by licensed veterinarians. A small sample of hair with roots (approximately 8-10 hairs) was also plucked for DNA analysis while the animal was under anaesthesia. Captured animals had a patch of hair on their shoulders dyed blond so that trappers could immediately recognize and release those individuals that had already been implanted.

Once the animals had recovered from the anaesthesia, they were fed and returned to the field at the same location that they were captured.

1.5 Objectives and Approach of Thesis

The focus of my study is to address knowledge gaps identified for fisher in BC concerning habitat use and reproductive denning ecology in pine dominated habitats of BC's central interior. The long-term effects of mountain pine beetle kill is of management concern and forest managers require strategies to help preserve fisher habitat (BC Conservation Data Centre 2006).

My specific objectives are to:

1. Identify and describe natal and maternal fisher denning habitat in the Chilcotin area of BC. This includes ecological site characteristics, physical characteristics of habitat elements within adult female fisher home ranges, and factors associated with the origin of important characteristics of the habitat elements (*e.g.*, diseases, physical damage, fire, etc.).

2. Identify and describe rest structures used by fisher in the Chilcotin area of BC, including ecological site characteristics, physical characteristics of habitat elements used for resting, and factors associated with the origin of important characteristics of these habitat elements.

3. Examine habitat use by fishers at the home range and landscape scales. This includes describing the composition of important habitat types and relating the composition to availability in the landscape.

4. Provide recommendations to guide management of forests and maintain fisher habitat in pine-dominated areas of the central interior.

Chapter 1 of my thesis examines the selection of reproductive denning structures by fisher at the element, patch, and stand levels. Chapter 2 describes the selection of resting structures at the element, patch, and stand levels. Habitat selection and composition of home ranges by fisher are examined in Chapter 3. In Chapter 4, I summarize the results of my research, discuss its management implications, recommend strategies to maintain fisher habitat, and consider the limitations of my research.

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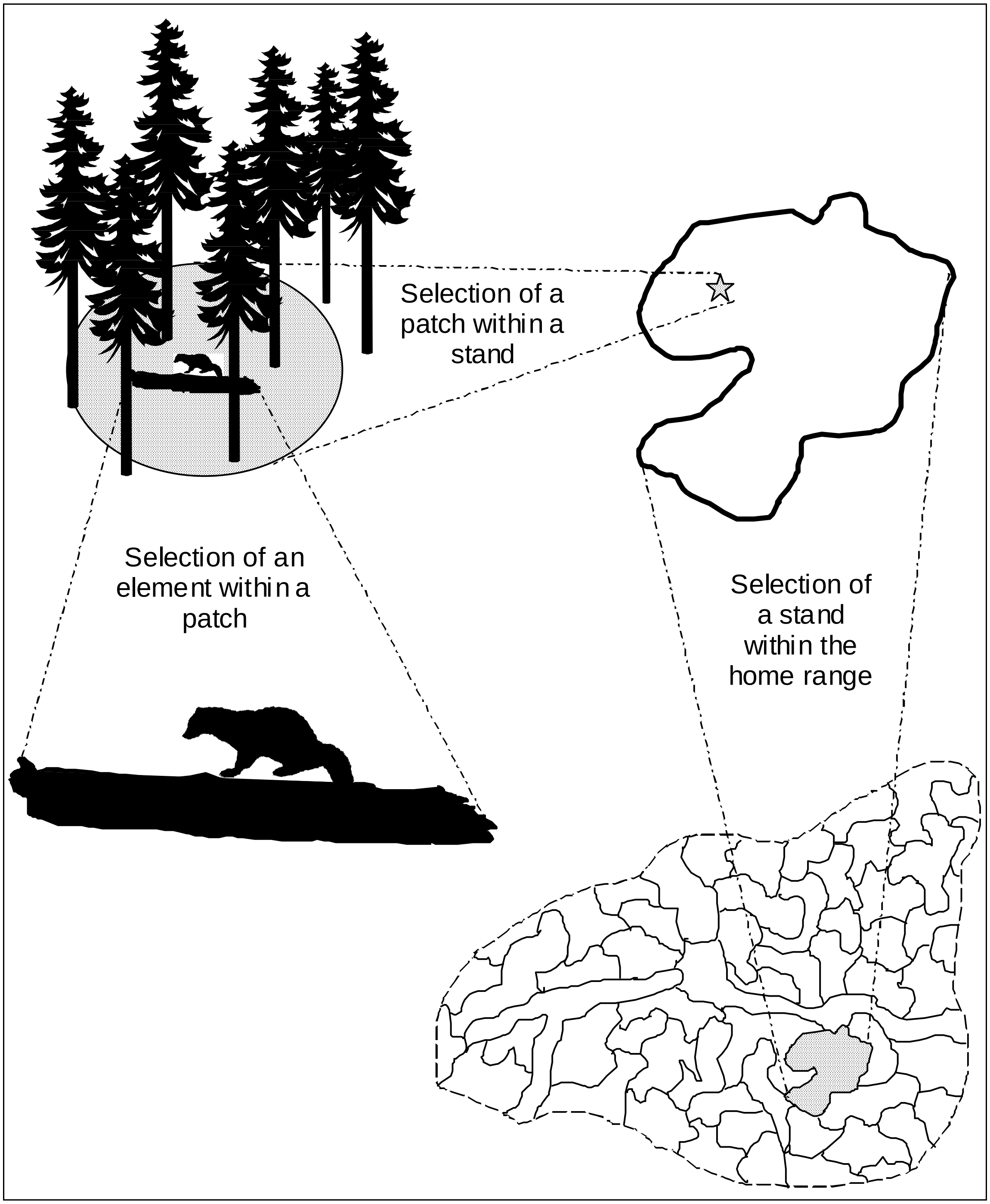

Figure 1. Scales of selection within forested landscapes are hierarchical and selection by animals can occur at each level. Reprinted with permission from R.D. Weir.

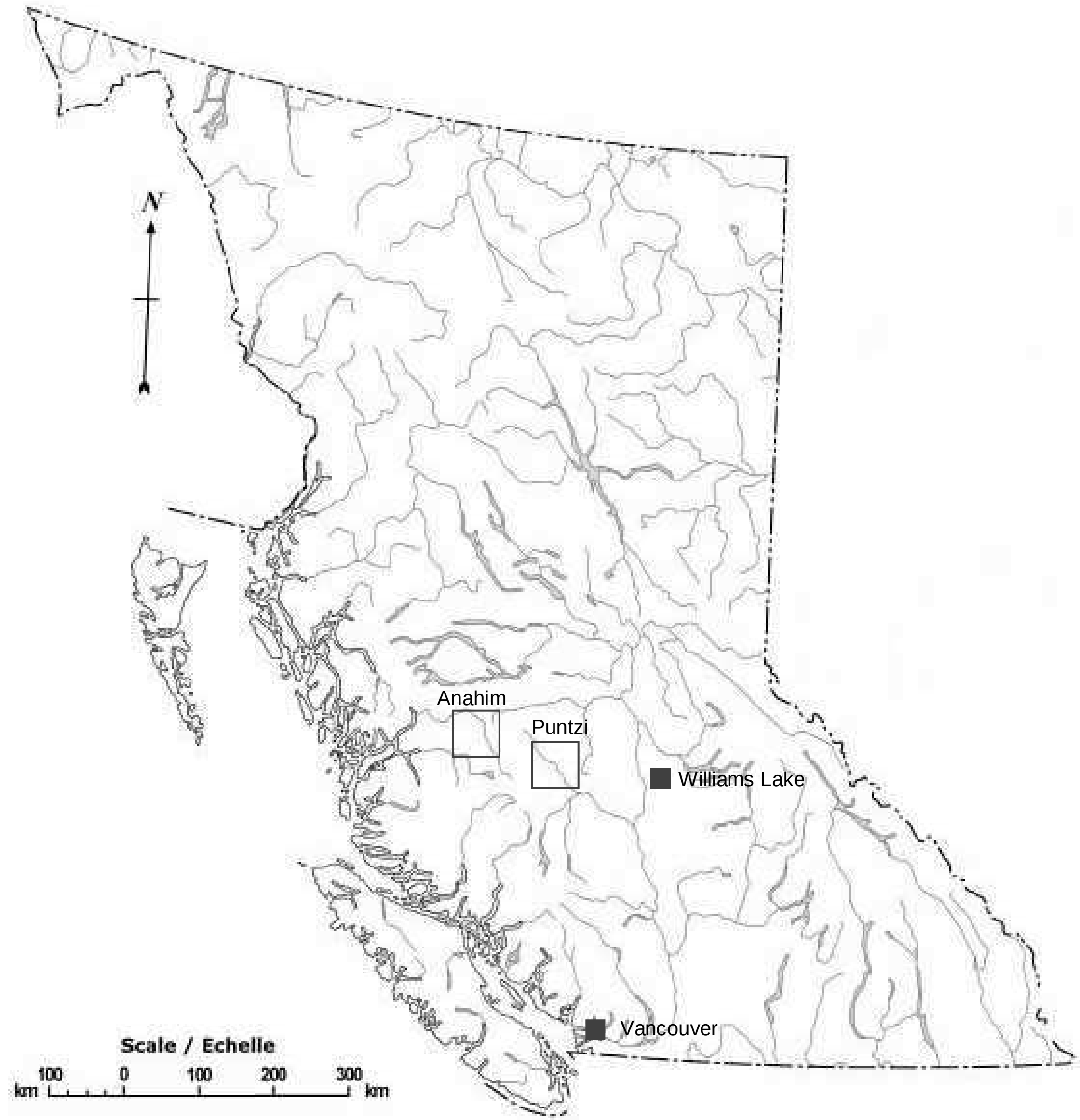

Figure 2. Map of the Anahim and Puntzi study areas on the Chilcotin Plateau of British Columbia, Canada.

2: Reproductive Denning Ecology of Fisher (*Martes pennanti*) in the Chilcotin Area of British Columbia

2.1 Abstract

I used radio-telemetry to identify 20 reproductive den sites of 14 female fisher in the Chilcotin area of British Columbia between 2005 - 2008. These reproductive dens were in cavities of large diameter trees similar to other studies from across the fisher's range. Trees used as reproductive dens by fisher in the Chilcotin were smaller in diameter than reported elsewhere in western North America, but were generally large compared to other trees within the same forest patch. As well, den plots had greater numbers of large trees (>27.5 cm dbh) compared to random plots in a fisher's home range. Fisher used cavities in trembling aspen (*Populus tremuloides*) (n = 7, $\bar{x}$ = 45.8 cm dbh, SE = 1.4), lodgepole pine (*Pinus contorta*) (n = 9, $\bar{x}$ = 39.0 cm dbh, SE = 1.7), and Douglas-fir (*Pseudotsuga menziesii var. glauca*) (n = 4, $\bar{x}$ = 68.4 cm dbh, SE = 5.1) for natal and maternal dens. Fisher used live declining trees (wildlife tree class 2) preferentially for den trees, but trees in more advanced stages of decay were also used. Aspect influenced the location of den trees with most of the reproductive dens found on a south aspect. This finding may be related to the very cold temperatures that occur in the Chilcotin during late winter and early spring. Fisher dens located on southern aspects would benefit from the heat provided by solar radiation during these periods. Age class was another important predictor of for den trees with older stands more likely to be used than younger stands. Mesoslope position was not a predictor of fisher den presence; however, this may be

confounded by the different tree species used for dens and the site conditions associated with those species. All natal dens in aspen were located in the toe position next to riparian features. Increased moisture available in riparian zones likely increases site index and thus produces the larger trembling aspen that are preferred as den trees. Female fisher using dens in riparian areas may also benefit from increased prey abundance and prey diversity. Most conifer den trees were in the mid and upper mesoslope positions, generally in open stand types that may have resulted in lower incidence of crown fire and allowed tree survival to older ages. The incidence of heart rot is greater in older stands and older age is also associated with larger tree diameter. The mean age of the 3 largest diameter trees in den patches were 177 years, for lodgepole pine, 372 years for Douglas-fir, and 96 years for trembling aspen. The ages of den trees could not be used in this calculation due to the presence of heart rot. The average age of coniferous den trees in the Chilcotin was much older than trees of these species in random plots.

2.2 Introduction

Forest dwelling wildlife are affected by habitat changes induced by fire, forest pests, and forest harvesting, as well as subsequent silvicultural practices (Hunter 1999). These disturbances can result in loss of decaying old trees at the stand level and, if extensive, at the landscape level. Such changes to the availability of large decaying trees can reduce the abundance and diversity of primary and secondary cavity nesters (Thomas 1979). Given this, the loss of mature forest stands due to mountain pine beetle and associated salvage harvesting has the potential to reduce fisher natal and maternal denning habitat in pine dominated landscapes. Fisher have low reproductive output relative to their lifespan (Weir 2003) and low rates of juvenile survival (Krohn *et al*. 1994; Strickland 1994; Weir 2003). Further impacts on reproductive habitat may result in the extirpation of local populations. Therefore, understanding fisher reproductive requirements is important in maintaining this species. Structures used for whelping and rearing are usually cavities in larger diameter trees with deciduous species typically used across the fisher's range (Powell 1993; Weir 2000). Often, more than one structure are used by fisher for raising young in a season. The structures can be defined as a natal den to identify the structure used for whelping and maternal dens for subsequent structures used for rearing fisher kits. I refer to these structures collectively as reproductive dens or if they are in trees, then den trees. In BC, fisher have been reported only using cavities in large declining cottonwood (*Populus balsamifera spp trichocarpa*) or balsam poplar (*Populus balsamifera spp balsamifera*) for natal and maternal dens (Weir 2003); however, there are many areas of the Province, such as the Chilcotin, where these trees species are rare or absent.

Within the Central Interior of BC, a large portion of fisher range occurs on the Chilcotin Plateau (Weir 2003). Forests on the Chilcotin Plateau are dominated by lodgepole pine stands, of which approximately 80% are susceptible to the mountain pine beetle attack. Most of the information on fisher ecology in BC has come from studies located near Williston Lake and in the Cariboo that are generally characterized by wetter, more productive forest habitat than is found in the Chilcotin area of BC. Information on habitat use from other areas is required to guide management and conservation options for fisher especially areas where the forest cover is dominated by lodgepole pine (B.C.

Conservation Data Centre 2006). My study helps address one of the key knowledge gaps identified for fisher in BC, *i.e.*, denning ecology in pine dominated habitats of BC's Central Interior (BC Conservation Data Centre 2006).

In this chapter, habitats used by fisher for denning will be compared to those available at 3 spatial scales: stand, patch, and element. My specific objectives are to:

1. Identify and describe natal and maternal fisher denning habitat in the SBPS Biogeoclimatic Zone.

2. Describe the abundance and distribution of maternal denning habitat elements within adult female fisher home ranges.

3. Provide recommendations for forest management in pine-dominated forests of the Central Interior.

My project will provide forest managers with information to guide retention strategies for stand features and structural elements that are important for fisher habitat in areas dominated by lodgepole pine. As well, other wildlife species use the same structures and old trees that are used by fisher. Hence forest management prescriptions directed at fisher will benefit other wildlife dependent on old forest and structures characteristic of old trees.

2.3 Methods

In BC, fisher natal denning occurs in late March through early April (Hall 1942, Weir 2000). I used radio-telemetry to collected data on the location and site characteristics of fisher den sites between April and June over three years (2005/2006, 2006/2007 and 2007/2008). I located natal dens by radio-tracking adult females on a daily basis once they begin to exhibit activity around a central location. Den sites were marked and described during the period of use. I re-visited each den for a full vegetation description after the snow had melted. At den locations (determined by visual detection or signal isolation to one structure), I collected information about slope, topography, aspect, broad ecosystem unit, structural stage, biogeoclimatic unit, percentage cover vegetation, tree characteristics, presence of prey, and temperature (Table 1) as recommended by BC Ministry Environment, Lands, and Parks and BC Ministry of Forests (1998). Site information and variable radius plot data were collected at a random distance (1-10 m) and direction from the den tree. Fisher often rest in large trees (Seglund 1995; Weir and Harestad 2003; Zielinski et al. 2004; Yaeger 2005) which has the potential to bias some habitat parameters (*e.g.*, crown closure). Offsetting the plot allowed me to compare site information with random plots that were also not centred on a large tree. I also conducted an 11.28-m fixed radius plot centred on the den tree where detailed wildlife tree information was collected (BC Ministry Environment, Lands, and Parks and BC Ministry of Forests 1998). Within each fisher's home range, I collected the same data at random plots so I could conduct analyses for habitat selectivity. However, the random fixed radius plots were not tree centred and wildlife tree data were collected only on trees >27.5 cm diameter at breast height (DBH, *i.e.*, 1.3 m above the ground) for 9 out of 10 plots with a full plot conducted on every 10th plot. This procedure was used because fisher never used trees smaller than 27.5 cm DBH for reproductive dens.

I measured the height and width of openings to den tree cavities to characterize access points to reproductive dens. I also measured the depth of cavity using a weighted string that was lowered into the cavity and plumbed until the bottom of the cavity was located. The internal diameter of the cavity was determined by boring (0.64 cm hole) the tree at points located at 10 cm, 20 cm, and 30 cm above the bottom of the den and measuring the length of a rod inserted into the tree. Boring and measuring occurred at 4 points (cardinal directions) at each elevation above the bottom of the den. These measurements were averaged and then subtracted from the trees external diameter at each elevation to provide the average thickness of the trees shell (or holding wood). This measurement was doubled and then subtracted from the external diameter to yield the average internal diameter of the den cavity. All holes created by boring were plugged with a wooden dowel. These measurements were possible only on a subset of trees due to safety concerns.

I collected information on site characteristics in the home ranges of fisher with > 25 relocations for comparisons with fisher use sites. Some habitat types are relatively rare in the study areas, but were considered important for fisher resting. To ensure that I obtained sufficient data on rare habitat types, I used map-based stratification to obtain at least 5 plots in each stratum in a fisher's home range. Habitat was stratified based on stand age and tree species composition data on forest cover maps (Table 2).

2.3.1 Data Analyses

I compared characteristics of den trees, the den patch, and the forest stand between used and unused locations using conditional exact logistic regression (Proc Phreg, SAS 9.1) in a case – control design. I compared the den trees of individual fisher to other trees within the fisher den patch and compared characteristics of den patches to random plots within the fisher's home range. To develop and test models predicting fisher den use, I first conducted univariate analyses on individual habitat variables thought to affect the choice of fisher dens. I conducted multivariate comparisons using variables that appeared to influence fisher den selection in univariate analyses ($P < 0.25$) after removing highly correlated variables. I used the remaining variables to developed models that were compared using an information-theoretic approach (Burnham and Anderson 2002). Models that are ranked within 2-4 units of the "best" model contain attributes likely to have a significant effect on selection of denning structures by fisher.

2.4 Results

Fourteen female fisher were live trapped and implanted with radio transmitters between 2005 and 2008. Twelve of the fisher had a total of 20 reproductive dens during this period. Two of the 12 fisher were later discovered dead and did not have enough locations to delineate their home range, while 1 of the 12 fisher was captured late in the project and only information on the den site was collected. All reproductive dens were found in cavities of trees that were, generally, the largest in the patch. For a subset of den trees, measurements of the den opening and internal dimensions were taken. The den openings averaged 8.9 cm (SE = 0.62 cm) wide by 10.7 cm (SE = 0.90) tall on the 10 trees that were examined. Cavities averaged 116.6 cm (SE = 19.6 cm) deep and 26.0 cm (SE = 2.37 cm) in internal diameter for the 6 trees that I was able to measure.

A range of tree species was used for whelping including lodgepole pine, trembling aspen, and Douglas-fir. The number of reproductive dens by tree species, reproductive type, and estimated age are shown in Table 3. Most den trees had decay at the height (1.3 m) that I bored the tree preventing accurate aging; therefore, other trees in the plot of the same size and species were included to estimate the den tree's age. Usually, the den tree was much larger in diameter than all other trees in the patch, and thus it is likely that the mean age of reproductive trees is underestimated. Conifers similar in age to den trees were rare on the landscape. For example, 56 trees were aged in 28 random plots yielding only one tree >150 years and twelve 100 - 150 years. Other data collected at reproductive dens are presented in Appendix 1.

Within reproductive den patches, most natal den trees (8 out of 12) were wildlife tree class 2 (live tree with defects) or had recently been killed in the case of one lodgepole pine (mountain pine beetle – red attack), while a wider range of wildlife tree classes characterized maternal den trees (range: 2 – 6). I compared den tree diameters to other trees in the reproductive den patch for natal den trees, both natal and maternal den trees, and for each tree species used for denning (Figure 3,Table 4). Both natal and all reproductive (natal and maternal) den trees were significantly larger in diameter (DBH) than other trees in the same patch. When diameters of den trees were compared by species, trembling aspen that contained dens were significantly larger than other aspen in the patches, whereas Douglas-fir that contained dens were not larger than the other Douglas-fir present. For lodgepole pine, the analysis did not reach convergence; however, all pine containing dens were the largest tree in the patches and ranged between

3.4 – 25.3 cm greater in diameter than the next largest tree. I also compared den trees to the largest 4 other trees in the patch to reduce the influence of small trees on the results. Den trees were significantly larger than other large trees in the patch (Table 4).

I compared site characteristics between reproductive den plots (natal and maternal) and plots located in random locations of fisher home ranges. Age class, the number of large CWD (coarse woody debris), the number of large trees/ha (>27.5 cm DBH) and average tree height were the continuous variables with the greatest predictive ability for fisher den patches (Table 5). For categorical data, stratum and aspect were significant predictors of fisher den patches (Table 6). Lodgepole pine stands were less likely to contain fisher den trees than other stand types. Warm (southerly) aspects were much more likely to contain fisher den trees than were areas classified as cold (northerly) or no aspect (< 5% slope) (Table 7).

Multivariate analysis on continuous variables with P values < 0.25 revealed high (≥ 0.6) correlations between basal area, tree height, tree cover, and several other variables. Removing basal area and tree height resulted in all remaining correlations dropping below 0.6. Modelling using the remaining variables identified 3 models that were ranked within 4 units of the top model (Table 8). Aspect was found in all 4 top models with warm aspects having 5 – 9 times the odds of having a reproductive den tree (Table 9). When all den sites are examined, 9 were on warm aspects, 7 had no aspect (*i.e.*, flat), and only one den was found on a cold aspect. Age class was found in 3 of the top 4 models with increases in stand age class associated with an increase of 4 – 4.5 times the odds of a reproductive den. Seventeen of the den trees were located in stands >100 years old and 3 were in stands aged between 60 – 100 years. Increases in the number of large trees (>27.5 cm DBH) was also found in three of the top models. An increase of 100 large trees/ha resulted in the odds of a fisher den tree increasing by 70%. Large CWD (>27.5 cm diameter) was found in two of the top models.

2.5 Discussion

Reproductive dens of fisher in my study were generally within the largest tree in a patch. The dens were all in heart rot cavities and most frequently were in a live declining tree. Other research has also identified greater use of live trees than dead trees for natal dens (Weir 2003, Aubry and Raley 2006). The harder wood associated with live trees may provide greater security from potential predators and greater tree stability than dead trees. In the Chilcotin, lodgepole pine, trembling aspen, and Douglas-fir are the most prevalent trees that have large heart rot cavities. Fisher natal and maternal denning occurs almost exclusively in tree cavities across the species range (Powell 1993, Weir 2000, Aubry and Raley 2006). My study is the first to document fisher use of coniferous trees for whelping and rearing in British Columbia (Weir 2003), although coniferous trees are used in the Northwest United States (Aubry and Raley 2006).

Trees used for reproductive denning in the Chilcotin have smaller diameter boles than any previously reported in western North America (Weir and Harestad 2003, Aubry and Raley 2006). In the Chilcotin, den trees were old compared to other trees in the landscape despite their small size. Considerable time is required for trees to reach sufficient diameter for fisher denning and for decay fungi to produce heart rot cavities large enough for fisher dens. Heart rot cavities only develop in live trees and take many years to reach states suitable for wildlife (Manion 1991, Bull *et al.* 1997). When the decay becomes advanced, the interior core of heartwood collapses creating internal cavities in the tree. In my study areas, access to internal cavities was created by pileated woodpeckers (*Dryocopus pileatus*), broken branches, and cracks in the tree bole.

Deciduous trees provide important reproductive denning habitat across the fisher's range (Powell 1993, Weir and Harestad 2003, Weir 2003). In the Chilcotin, trembling aspen are locally abundant on mesic sites; however, large diameter aspen are most abundant in moist, productive locations near streams and wetlands. Even compared to the larger trees found in den patches, the aspen den trees were still among the largest trees available. Often aspen is found with white spruce in the Chilcotin; however, fisher dens were not found in white spruce although large mistletoe brooms on this species are frequently used as rest sites (Weir and Harestad 2003, Chapter 3). Furthermore, there are no records of fisher reproductive dens in spruce anywhere in North America. Although small cavity openings were observed in white spruce during surveys of random plots, the species does not appear to develop the large internal cavity with hard exterior shell that appears necessary for denning by animals the size of fisher.

Large diameter trees are rare in the Chilcotin, especially in dry, pine dominated stands. The lodgepole pine den trees used by fisher during my study were smaller in diameter than other species used in the Chilcotin, but much larger than those trees found in the same patch. As well, large trees were more abundant in den patches than in random plots. Den sites in lodgepole pine tended to be in older forest often within small patches that escaped fire or had low intensity ground fires as revealed by fire scars at bases of the trees. Soil conditions were mesic to dry at most lodgepole pine den patches resulting in open stands with relatively low stem densities that may have decreased the potential for crown fires and, thus, allowing the trees to survive longer than those in denser stands.

Similar to the den sites in lodgepole pine patches, den sites in Douglas-fir patches were always in areas with mesic to dry soil conditions. Historically, open stands of Douglas-fir were maintained by frequent low intensity fire in the BC interior (Wong *et al.* 2003) with stand replacement fires estimated to occur every 250 years (BC Ministry of Forests and BC Ministry of Environment 1995). Fire scars were common on most trees at den sites and the mean age of trees in these forests patches is much older (372 years) than the estimated stand replacing return interval. The forest patches containing Douglas-fir den trees generally were composed of large diameter, declining, or dead trees reflecting the advanced stand age.

Several researchers have found that fisher select stands of forest with a continuous canopy that provides security cover (Coulter 1966, Kelly 1977, Arthur et al. 1989, Weir and Harestad 2003). In my study areas, den trees were generally in continuous stands of mature to old forest, although one natal den was located in a patch of trees isolated by recent harvesting and three others were isolated veterans in 60 – 100 year old stands. Canopy cover of forested stands in my study is low (*e.g.*,10 – 20% tree cover in most Chilcotin pine stands) compared to fisher habitats in other regions where forests are more productive. Perhaps the presence of vertical escape terrain, in the form of trees, is more important to fisher than high values of crown closure. For example, a female in the

Anahim study area travelled along a narrow corridor of small residual trees within a clear cut to access her den that had been isolated by harvesting.

Variables other than forest cover also appear to influence the selection of den sites. Aspect and slope position are 2 physical variables which are easy to measure and readily available from terrestrial databases throughout British Columbia. Their relationships to factors such as thermal regime (shelter and microclimate), plant communities, and prey abundance and diversity are important because aspect and slope position can be, in part, surrogates for habitat quality. For example, only one of the 20 fisher dens in the Chilcotin was located on a cold aspect, with the rest found on warm aspects or locations with flat terrain. This finding may reflect the cold temperatures that are common across the Chilcotin Plateau during late winter and early spring when whelping occurs. Fisher kits are altricial (*i.e.,* born blind and helpless with only a sparse covering of fine hair) (Coulter 1966). Female fisher must leave their young in the den tree after birth to forage and mate. Females mate within 10 days following parturition (Hall 1942, Powell 1993) and were recorded far from their den in the weeks following whelping (L. R. Davis, unpublished data). Temperatures in the Chilcotin have been recorded as low as -15˚ C during this period and den trees located on southern aspects would benefit from solar radiation. Many den trees were located in fire remnant patches and warm aspects may also have greater numbers of larger trees if warm aspects are more prone to low severity ground fires than other aspects. However, post hoc comparisons of tree diameter at random plots revealed no differences in the number of large trees among flat terrain, north, and south aspects.

Like aspect, slope position also appeared to influence the selection of reproductive den sites. Many den sites were located on the toe of slopes above wetlands and watercourses, although other slope positions were also used. Riparian locations were used by fisher that denned in black cottonwood trees in the Cariboo area of BC (Weir and Harestad 2003). These riparian stands are among the most productive in the dry climate of the Chilcotin and deciduous trees are likely to grow larger in these stands than in upland areas. Riparian forests may also have more abundant and diverse prey populations due to the availability of water, increased productivity, and presence of edge habitat (Stevens *et. al.* 1995). Reconnaissance level surveys near the Puntzi study area found greater bird and small mammal diversity near riparian features (L. R. Davis unpublished data). Reproductive dens located at the lower to toe position near riparian areas would be close to a greater prey base that may allow female fisher to spend less time foraging.

Other slope positions were also used by fisher for denning and this choice appears to be related to the tree species used for dens. Lodgepole pine and Douglas-fir den trees were typically in mid to upper mesoslope positions and all were in patches classified as mesic to dry. These species are more competitive on these sites allowing survival to greater sizes and ages. Ultimately, availability of suitable den trees is most strongly related to the presence of large, old trees and this will occur in different locations for different tree species.

Aspect and slope position are useful as coarse habitat indices, but other characteristics of trees important to fisher are only revealed at fine levels of resolution. Old trees are more likely to have attained sufficient size for fisher denning; however, tree age is also related to susceptibility to decay by heart rot fungi. Infection by heart rot fungi typically requires damage to the bole. Young healthy trees can often heal wounds and thus protect the tree from infection, whereas older, unhealthy trees are less capable of responding to injuries and infection by heart rot fungi (Wagener and Davidson 1954, Manion 1991). In general, older stands have much higher rates of heart rot decay than younger stands although heart rot fungal spores are abundant in all ages of forest (Wagener and Davidson 1954, Manion 1991). Fisher denning habitat in the Chilcotin is consistent with this pattern because den trees were generally in mature to old stands that contained greater numbers of large trees in advanced stages of decay. These types of trees and stands are detected by more direct measures of forests that comprise denning habitat of fisher.

The habitat models that I tested thus contain both coarse and fine scale variables that appear to influence habitat choice by fisher. Variables in the top multivariate models indicated that tree diameter, stand age, aspect, and the number of large CWD were the most important predictors of the presence of fisher den trees in the Chilcotin. Large diameter trees are typically old and more likely to have heart rot. Large trees with heart rot cavities are rare in the Chilcotin and the location of suitable den trees depends on tree species. Older deciduous and mixed species stands in the lower to toe mesoslope position are likely locations for potential den trees. Dens in lodgepole pine may occur in any slope position where small patches of old forest have escaped fire. Often, these stands are dryer and more open which decreases the potential for crown fires allowing the trees to survive to greater age. Patches of old Douglas-fir and younger stands with large remnant Douglas-fir are also likely areas to find den trees. As with lodgepole pine, den trees in Douglas-fir may be in any slope position, but most will be on mesic to dry sites with open stand conditions that decreases the probability of crown fire. For all three species (lodgepole pine, Douglas-fir and trembling aspen), den trees are more likely to be on flat to sloping terrain with south aspects that provide warmer sites in spring.

The cavities used by fisher as reproductive dens are products of ecological processes such as forest growth, disease (*e.g*., heart rot), and fire regime. When abandoned by fisher, these cavities can also be used by a host of other species (*e.g.*, flying squirrels, owls). Hence, forest management prescriptions that retain and recruit den trees for fisher will also benefit other cavity dependent wildlife.

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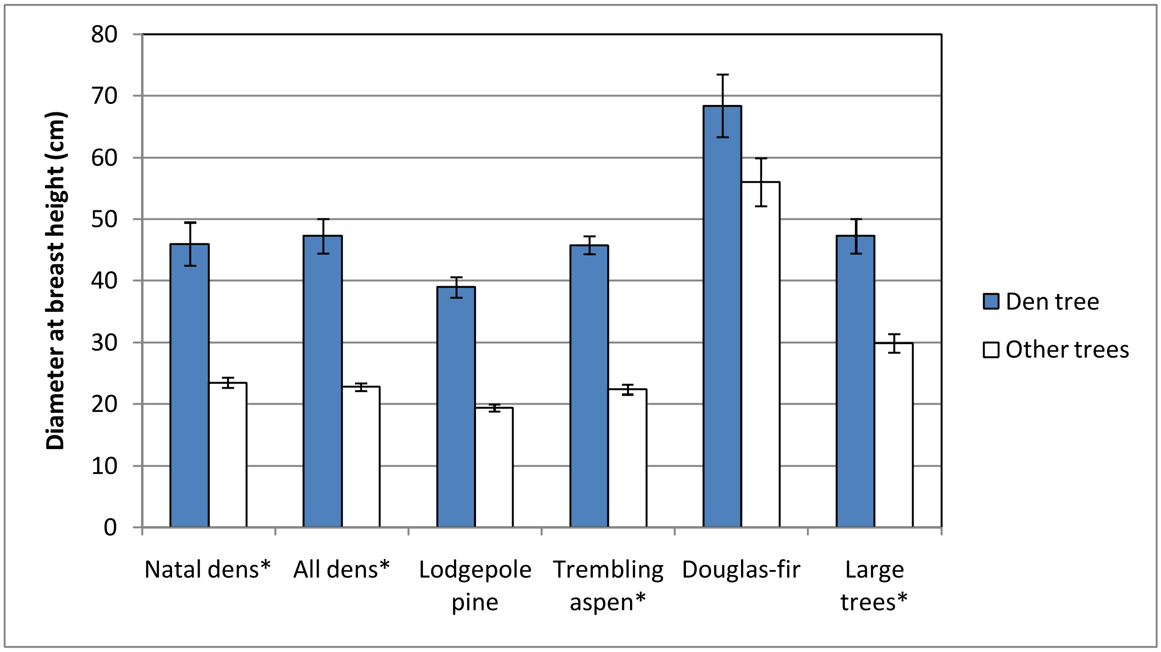

Figure 3. Comparison of fisher den tree diameter at breast height (1.3 m) between den trees and other trees in the 11.28-m radius plot with standard error. Significant (α=0.05) comparisons made using Proc Phreg (SAS 9.1.3) are indicated with an asterisk (*).

Table 1: Habitat attributes measured at den sites of fisher. Attributes surveyed using methodology in *Field Manual for Describing Terrestrial Ecosystems – Land Management Handbook 25* (BC Ministry Environment, Lands, and Parks and BC Ministry of Forests 1998).

Attribute	Description
GPS position	UTM coordinates (NAD 83)
Ave tree height	Average height of trees in plot (m).
Slope	Percentage slope of 11.28-m radius plot
Aspect	Warm: 91 - 269˚; cold: 270 - 90˚; none: sites with a slope <6%.
Structural stage	Dominant structural stage in 11.28-m radius plot. Reduced to 2 categories for analysis: young: 1-5; old: 6-7.
Surface topography	Shape of slope.
BEU	Broad ecosystem unit that best describes the 11.28-m radius plot
Elevation	Elevation in meters
BEC Unit	Biogeoclimatic subzone.
Mesoslope	Slope position of site in local catchment area.
Site series	Base on BEC unit, the sites position on edatopic grid determined by moisture and nutrient regime.
Moisture/nutrient	Soil moisture and nutrient level
Variable radius plot	Trees were tallied by species, size class (small: 12.5-27.4 cm, large >27.5 cm DBH*), and decay class.
Fixed radius plot	11.28-m fixed radius plot with information on DBH, height, crown condition, bark condition, wildlife tree class, wood condition, and wildlife activity for each tree in plot.
Vegetation	Estimated percentage cover by layer in 11.28-m radius plot with the 3 dominant species present listed in order of greatest percentage cover to least.
%CWD cover	Estimated percentage woody debris cover in an 11.28-m radius plot by category (0%, 1-5%, 5-15%, 15-25%, >25%).
CWD/30m	Number of pieces >7.5 cm diameter by decay class in 30-m transect centered on plot and oriented in a random direction.
Canopy cover	Percentage canopy cover using a canopy densitometer (Teti and Pike 2005).
Snow depth	Snow depth in cm at random location on animal's trail.
Prey presence	Evidence of prey species present within 5.64 m of plot center.
Tree age	Three trees were aged at each fisher den site and at every 10^{th} random plot.
Comments	Any additional information on how the animal is using the habitat.

*DBH: diameter at breast height (1.3 m).

Table 2: Sampling stratification used to obtain random samples from fisher home ranges in the Chilcotin area of BC.

Stratum	Description
Spruce-Aspen	Habitats containing >25% white spruce or >50% trembling aspen.
Lodgepole pine	Pine dominated (>75% lodgepole pine).
Douglas-fir	Douglas-fir dominated (>50% Douglas-fir).
Age class 1	Forest age class 1 (0-20 years)/ structural stages 1-3.
Age class 2	Forest age class 2-3 (20-60 years)/ structural stage 4.
Age class 3	Forest age class 4-5 (60-100 years)/ structural stage 5.
Age class 4	Forest age class 6-8 (100+ years)/ structural stages 6 - 7.

Table 3: Number of fisher reproductive dens and estimated age by tree species and type.

Tree species	Natal	Maternal	Mean age (range) (years)
Lodgepole pine	4	5	176.6 (112-275)
Trembling aspen	6	1	95.5 (80-111)
Douglas-fir	2	2	371.9 (279-419)

Table 4: Comparison of fisher den tree diameter at breast height (1.3 m) using Proc Phreg (SAS 9.1.3) between den trees and other trees in the 11.28-m radius plot. Significant (α=0.05) comparisons in bold and the odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase/ decrease of 0.01 indicates that the odds of choosing a rest site changed by 1% for each unit change in the attribute.

Group	Type	Mean (cm)	SE	n	P-value	Odds ratio
Natal	Den	46.0	3.50	12	<0.0001	1.250
	Other trees	23.5	0.81	177		
All dens	Den	47.3	2.81	20	<0.0001	1.282
	Other trees	22.8	0.60	319		
Lodgepole pine*	Den	39.0	1.65	9		
	Other trees	19.4	0.55	127		
Trembling aspen	Den	45.8	1.44	7	0.0104	1.287
	Other trees	22.4	0.80	118		
Douglas-fir	Den	68.4	5.07	4	0.2147	1.079
	Other trees	56.0	3.88	13		
Large trees**	Den	47.3	2.81	20	0.0012	1.310
	Other trees	29.9	1.51	71		

*The lodgepole pine analysis did not reach convergence.

**Large trees compared the den tree to the four largest trees in the plot that were not used.

Table 5: Comparison of habitat variables using Proc Phreg (SAS 9.1.3) between all den sites and random sites in fisher home ranges. Significant (α=0.05) variables in bold and the odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase/decrease of 0.01 indicates that the odds of choosing a den site changed by 1% for each unit change in the attribute.

Variable	Type	Mean	SE	n	P-value	Odds ratio
Age class[1]	Den	3.82	0.10	17	**0.0026**	**6.785**
	Random	3.12	0.05	293		
Slope[2]	Den	9.41	2.35	17	0.3409	1.021
	Random	7.24	0.59	293		
Tree cover[3]	Den	20.29	3.81	17	0.0650	1.035
	Random	14.59	0.75	293		
Shrub cover[4]	Den	25.65	3.91	17	0.5554	0.989
	Random	27.43	0.99	292		
Small CWD[5]	Den	5.35	1.23	17	0.2057	1.068
	Random	4.23	0.26	293		
Large CWD[6]	Den	0.53	0.17	17	**0.0007**	**4.081**
	Random	0.12	0.02	293		
Basal area[7]	Den	24.18	4.92	17	0.1126	0.999
	Random	14.52	0.74	293		
Small trees/ha[8]	Den	286.07	85.30	17	0.0833	0.999
	Random	432.38	23.14	293		
Large trees/ha[9]	Den	186.41	50.66	17	**0.0001**	**1.013**
	Random	40.81	4.62	293		
Tree height[10]	Den	16.08	0.81	17	**0.0131**	**1.164**
	Random	13.09	0.31	293		
Large sapling[11]	Den	376.47	101.29	17	0.7251	1.000
	Random	419.11	35.81	293		
Small sapling[12]	Den	2111.76	463.12	17	0.3229	1.000
	Random	2809.90	159.06	293		

[1]Age class: Four class system based on structural stage (BC Ministry Environment, Lands, and Parks and BC Ministry of Forests 1998) (1: structural stages 1 – 3; 2: structural stage 4; 3: structural stage 5; and 4: structural stages 6-7).
[2]Slope: percentage gradient of terrain in 11.28-m radius plot.
[3]Tree cover: percentage cover of trees >12.5 cm DBH (diameter at 1.3 m height from the ground) in 11.28-m radius plot.
[4]Shrub cover: percentage cover of shrubs in 11.28-m radius plot.
[5]Small CWD: number of pieces of small woody debris (7.5 – 27.4 cm diameter) encountered on a 30-m transect.
[6]Large CWD: number of pieces of woody debris (> 27.4 cm diameter) encountered on a 30-m transect.
[7]Basal area: the cross sectional area of trees per hectare measured at DBH (m^2/ha).
[8]Small trees/ha: number of trees <27.6 cm DBH per hectare.
[9]Large trees/ha: number of trees >27.5 cm DBH per hectare.
[10]Tree height: average height of co-dominant trees in a 11.28-m radius plot.
[11]Large sapling: number of large tree saplings/ha (>2 m tall).
[12]Small sapling: number of small tree saplings/ha (<2 m tall).

Table 6: Comparison of categorical habitat variables using Proc Phreg (SAS 9.1.3) between den tree sites and random sites in fisher home ranges. Significant (α=0.05) variables are in bold.

Attribute	Level	Count (proportion)		P-value
		Rest	Random	
Stratum[1]	Douglas-fir	3 (0.18)	16 (0.05)	
	Lodgepole pine	7 (0.41)	208 (0.71)	**0.0274**
	Spruce-aspen	7 (0.41)	69 (0.24)	
Aspect[2]	Cold	1 (0.06)	47 (0.16)	
	None	7 (0.41)	186 (0.63)	**0.0130**
	Warm	9 (0.53)	60 (0.21)	
Mesoslope[3]	Lower	8 (0.47	106 (0.36)	
	Mid	7 (0.41)	147 (0.50)	0.5999
	Upper	2 (0.12)	40 (0.14)	
Site Series[4]	Dry	2 (0.12)	106 (0.36)	
	Mesic	7 (0.41)	147 (0.50)	0.1573
	Wet	8 (0.47)	40 (0.14)	
Prey[5]	Present	8 (0.47)	93 (0.32)	0.1625
	Absent	9 (0.53)	200 (0.68)	

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) (Douglas-fir: ≥30% cover in Douglas-fir; Lodgepole pine: ≥70% cover in lodgepole pine; Spruce-aspen: ≥30% cover in either white spruce or trembling aspen).

[2]Aspect: describes the direction of slope (none: areas with less than 5% slope; cold: >5% slope and 270-90˚; warm: >5% slope and 91-269˚ azimuth).

[3]Mesoslope: Slope position is a 3 class system based on *Field Manual for Describing Terrestrial Ecosystems* (BC Ministry Environment, Lands, and Parks and BC Ministry of Forests 1998): Upper: crest and upper; Mid: mid and level; Lower: lower, toe, and depression)

[5]Site series: classification of moisture and nutrient regime at den site (BC Ministry Environment, Lands, and Parks and BC Ministry of Forests 1998).

[6]Prey: presence of prey sign within 5.64 m of plot centre.

Table 7: Contrasts for rest tree categorical habitat variables using Proc Phreg (SAS 9.1.3). Significant (α=0.05/3 = 0.0167) contrasts are in bold.

Attribute	Contrast	DF	Chi-square	P-value
Stratum	**Lodgepole pine vs others**	1	6.6766	**0.0098**
	Douglas-fir vs others	1	2.8987	0.0886
	Spruce-aspen vs others	1	0.0767	0.7819
Aspect	**Warm vs others**	1	6.9492	**0.0084**
	Cold vs others	1	1.5408	0.2145
	None vs others	1	0.3793	0.5380

Table 8: Test of models used to predict the probability of a fisher den tree site in the Chilcotin area of BC. K is the number of parameters (including a constant). Akaike Information Criterion (AIC) values are a relative index of model parsimony with ΔAIC values giving the distance between any model and the most parsimonious model. AICώ is the relative strength of each model, and rank gives the ratio of evidence relative to the best model (n = 360) (Burnham and Anderson 2002). Top models and significant parameters are in bold **type.**

Model	K	Description	AIC	ΔAIC	AICώ	Rank
1	6	**Aspect +** Prey + **Ageclass +** Tree cover + **Large CWD + Large trees**	76.24	0.00	1.00	1.0
2	3	**Aspect + Ageclass + Large trees**	77.45	1.21	0.55	1.8
Full	10	Stratum[1] + **Aspect[2] +** Site Series[3] + Prey[4] + **Ageclass[5] +** Tree cover[6] + Small CWD[7] + **Large CWD[8] +** Small trees[9] + Large trees[10]	77.79	1.55	0.46	2.2
5	4	Stratum + **Aspect +** Ageclass + **Large trees**	78	1.76	0.41	2.4
6	2	Aspect + Large trees	81.42	5.18	0.08	13.3
10	3	Aspect + Tree cover + Large trees	83.19	6.95	0.03	32.3
4	3	Stratum + Aspect + Ageclass	85.81	9.57	0.01	119.7

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water Land and Air Protection 2004) with model based on Lodgepole pine versus Douglas-fir and Spruce-aspen stratum (Douglas-fir: ≥30% cover in Douglas-fir; Lodgepole pine: ≥70% cover in lodgepole pine; Spruce-aspen: ≥30% cover in either white spruce or trembling aspen).

[2]Aspect: describes the direction of slope (none: areas with less than 5% slope; cold: >5% slope and 270-90˚; warm: >5% slope and 91-269˚ azimuth) with model based on warm versus none and cold.

Age class: Four class system based on structural stage (BC Ministry Environment, Lands, and Parks and BC Ministry of Forests 1998) (1: structural stages 1 – 3; 2: structural stage 4; 3: structural stage 5; and 4: structural stages 6-7).

[3]Site series: classification of moisture and nutrient regime.

[4]Prey: presence of prey sign within 5.64 m of plot centre.

[5]Age class: Four class system based on structural stage (BC Ministry Environment, Lands, and Parks and BC Ministry of Forests 1998) (1: structural stages 1 – 3; 2: structural stage 4; 3: structural stage 5; and 4: structural stages 6-7).

[6]Tree cover: percentage cover of trees >12.5cm DBH (diameter at 1.3 m height from the ground) in 11.28-m radius plot.

[7]Small CWD: number of pieces of small woody debris (7.5 – 27.4 cm diameter) encountered on a 30-m transect.

[8]Large CWD: number of pieces of woody debris (> 27.4 cm diameter) encountered on a 30-m transect.

[9]Small trees: number of trees <27.6 cm DBH per hectare.

[10]Large trees: number of trees >27.5 cm DBH per hectare

Table 9: Odds ratio for significant (α=0.05) attributes in the top four models for fisher den tree plots. The odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase/decrease of 0.01 indicates that the odds of choosing a den site changed by 1% for each unit of change in the attribute.

Attribute	Odds ratio
Aspect (warm vs other aspects)[1]	5.110 – 9.280
Large CWD[2]	4.035 – 5.042
Age class[3]	4.225 – 4.473
Large Trees[4]	1.007 – 1.008

[1]Aspect: describes the direction of slope (none: areas with less than 5% slope; cold: >5% slope and 270-90˚; warm: >5% slope and 91-269˚ azimuth) with model based on warm versus none and cold.

[2]Large CWD: number of pieces of woody debris (> 27.4 cm diameter) encountered on a 30-m transect.

[3]Age class: Four class system based on structural stage (BC Ministry Environment, Lands, and Parks and BC Ministry of Forests 1998) (1: structural stages 1 – 3; 2: structural stage 4; 3: structural stage 5; and 4: structural stages 6-7).

[4]Large trees: number of trees >27.5 cm DBH per hectare

3: Rest Site Selection by Fisher (*Martes pennanti*) in the Chilcotin Area of British Columbia

3.1 Abstract

Rest sites provide fisher (*Martes pennanti*) with shelter from inclement weather and protection from predators. I used radiotelemetry to identify 105 rest sites of 17 fisher in the Chilcotin area between 2005 - 2008. More terrestrial sites were used than arboreal sites for resting during winter which may be due to the cold climate. Fisher did not use terrestrial rest sites preferentially during cold periods, but did use terrestrial sites more than expected when snow was deep. Temperatures <-15°C commonly occur in the Chilcotin at times when there is little snow and, hence, terrestrial sites may not provide suitable microclimates unless snow is deep. Spruce and aspen stands and number of large logs (>27.5 cm diameter) were important predictors of terrestrial rest sites. Trees used by fisher for resting were among the largest in the rest plot. White spruce (*Picea glauca*) was used more than expected, but other species were also used. Rust brooms (*Chrysomyxa arctostaphyli*) were the most often used structure when fisher rested in spruce trees. Large branches, cavities, and squirrel nests were used on other tree species. Spruce , trembling aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziesii var. glauca*), and mixed forest stands were more likely to contain arboreal rest sites. Rest sites were rarely in lodgepole pine (*Pinus contorta*) stands.

3.2 Introduction

Rest sites provide fisher with protection from predators and unfavourable weather (Kilpatrick and Rego 1994; Weir *et al.* 2004). Rest sites used by fisher are often associated with elements of old forest including cavities in trees, large limbs on live trees, hollow logs, piles of woody debris, and animal burrows (Arthur *et al.* 1989; Kilpatrick and Rego 1994; Seglund 1995; Gilbert et al. 1997; Weir *et al.* 2004; Zielinski *et al*. 2004; Yaeger 2005). Trees used by fisher are generally large compared to available trees and have structural features that facilitate fisher use (Seglund 1995; Gilbert *et al.* 1997; Zielinski *et al*. 2004; Weir and Harestad 2003; Yaeger 2005). Arboreal rest sites (*i.e.*, rest locations in trees) provide fisher with positions from where approaching predators can be detected and, as well, may offer protection from predators that are primarily ground based (Raphael and Jones 1997).

Use of terrestrial rest sites (*i.e.*, rest locations at ground level), such as woody debris piles, is generally greater in regions and seasons with colder temperatures (Arthur *et al.* 1989; Jones 1991; Kilpatrick and Rego 1994; Weir *et al.* 2004). Subnivean (below the snow) rest sites can have a warmer local ambient temperature depending on snow depth and wind velocity than arboreal locations (Taylor and Buskirk 1994; Raine 1981). Powell (1979) estimated that resting fishers could theoretically tolerate temperatures as low as -60° C for females and -120° C for males. Ambient temperatures experienced by fisher are generally well above this value; however, fisher may still minimize energy losses by selecting habitats that provide protection from cold temperatures and wind.

Many of the structural elements associated with fisher rest sites can be affected by forest harvesting practices. Forest harvesting has the greatest potential to negatively affect fisher habitat in British Columbia (BC) due to the prevalence of clear-cut harvesting (Weir 2003). Clear-cut harvesting affects the temporal availability of forest cover and, generally, results in a decrease in the abundance of late successional forest attributes over time. The current mountain pine beetle (*Dendroctonus ponderosae*) infestation affecting BC is expected to result in accelerated harvesting over a large portion of the fisher's range and exacerbate these effects. The loss of mature forest stands due to mountain pine beetle and associated salvage harvesting has the potential to reduce fisher resting sites in pine dominated landscapes. Therefore, understanding fisher resting requirements is important in maintaining this species in the Central Interior of BC.

My objectives are to:

1. Identify and describe fisher resting habitat in the Chilcotin region of British Columbia.

2. Describe the abundance and distribution of resting habitat elements within adult female fisher home ranges.

3. Provide recommendations to forest managers that will maintain rest sites in pine-dominated areas of the Central Interior.

3.3 Methods

I used radio telemetry to collect data on the location and site characteristics of fisher rest sites between November and August over 3 years (2005/2006, 2006/2007 and 2007/2008). At known rest locations (determined by visual detection or isolation to one structure), information about slope, topography, aspect, broad ecosystem unit, structural stage, biogeoclimatic unit, percentage cover vegetation, tree characteristics, presence of prey, temperature, and element used for resting were collected (Table 10) as recommended by BC Ministry of Forests and BC Ministry of Environment (1998). I collected habitat information and variable radius plot data at a random distance (1-10 m) and direction from the rest location.

Fisher often rest in large trees (Seglund 1995; Weir and Harestad 2003; Zielinski *et al*. 2004; Yaeger 2005) which has the potential to bias some habitat parameters (*e.g.*, crown closure). Offsetting the plot allowed me to compare site information with random plots that were also not centered on a large tree. For a subset of trees, methods also included an 11.28-m fixed radius plot centered on the rest tree where detailed wildlife tree information was collected (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998). All rest sites had a variable radius plot conducted, but a fixed radius plot was not conducted at terrestrial rest sites. Within each fisher's home range, I collected the same data at random plots so I could conduct analyses for habitat selectivity. However, the random fixed radius plots were not tree centered and wildlife tree data were collected only on trees >27.5 cm diameter at breast height (DBH, *i.e.*, 1.3 m above the ground) for 9 out of 10 plots with a full plot conducted on every 10^{th} plot.

This procedure was used because fisher rarely used trees smaller than 27.5 cm DBH for resting.

I collected information on site characteristics at random points in the home ranges of fisher with sufficient sample sizes (*i.e.*, > 25 relocations) for comparisons with locations used by fisher. Some forest types are relatively rare in the study areas, but were considered important for fisher resting. To ensure that I obtained sufficient data on rare habitat types, I used map-based stratification to obtain at least 5 plots in each stratum in a fisher's home range. Habitat was stratified based on stand age and tree species composition data on forest cover maps (Table 11).

3.3.1 Data Analyses

I compared characteristics of the element, patch, and stand between rest sites and available locations using conditional exact logistic regression (Proc Phreg, SAS 9.1) in a case – control framework. I compared the rest trees of individual fisher to other trees within the fisher rest plots and compared characteristics of rest plots to random plots within the fisher's home range. To develop and test models predicting rest site use by fisher, I first conducted univariate analyses on individual habitat variables thought to affect rest site use. I made multivariate comparisons using variables that appeared to influence fisher rest site selection in univariate analyses ($P < 0.25$) after removing highly correlated variables. I used the remaining variables to develop models that were compared using an information-theoretic approach (Burnham and Anderson 2002). Models that are ranked within 2-4 units of the "best" model contain attributes likely to have a significant effect on selection of resting structures by fisher.

3.4 Results

I live trapped and implanted 24 fishers with radio transmitters between 2005 and 2007. Seventeen of these fishers were recorded using 105 resting sites during this period. The majority of fisher locations were from winter (November 1st – March 31st); however, I also had a portion of locations from the spring (April 1st – June 30th) and summer (July 1st– August 31st). Fishers used significantly (α =0.05) different proportions of terrestrial and arboreal rest sites by season. During spring and summer, 20% of rest sites were terrestrial, whereas, 52% of rest sites were terrestrial during winter (χ^2 = 9.31, P = 0.002). I compared ambient temperatures during rest structure use between arboreal and terrestrial sites (Table 12). In the Chilcotin, use of arboreal rest sites did not vary with temperature when compared to terrestrial sites (α =0.05). In contrast, snow depths were twice as deep when terrestrial rest sites were used than when arboreal sites were used (Figure 4).

Trees were the most often used element for resting (54%) and rest trees were mostly white spruce (*Picea glauca*) (Figure 5, Table 13). When using spruce, fisher rested primarily on brooms caused by spruce broom rust (*Chrysomyxa arctostaphyli*). For Douglas-fir (*Pseudotsuga menziesii var. glauca*), cavities and large diameter branches were the majority of rest structures. In lodgepole pine (*Pinus contorta*), broom structures caused by abnormal growth patterns associated with dwarf pine mistletoe (*Arceuthobium americanum*), and red squirrel nests were the structures most often used. The average diameter (DBH) of rest trees varied by tree species with Douglas-fir having the largest and most variable diameters (Table 14). When rest tree DBH was compared to other trees in the rest plot, rest trees were significantly (α =0.05) larger at almost double the diameter of the other trees in the plot (Table 15). However, this relationship was not significant when rest trees were compared to the four largest trees in the plot that were not used. Coarse woody debris (CWD) comprised 30% of the total rest sites with most terrestrial rest sites found in cull piles located in areas recently harvested and usually within 50 m of forest cover (Table 13).

Most continuous habitat variables differed between rest tree patches and random plots (Table 16). Age class, tree cover, basal area, number of large trees, and presence of a large tree were significant variables that had a positive influence on probability of an arboreal rest patch. Percentage shrub cover was the only variable that had a negative influence on odds of fisher use. Of the categorical variables examined, stratum and mesoslope had the greatest influence on arboreal rest patches (Table 17). Contrasts on stratum indicate that the Douglas-fir and spruce – aspen strata are much more likely to contain a rest patch than the lodgepole pine stratum (Table 18). For mesoslope, lower slope positions were more likely to have an arboreal rest patch than the middle slope position.

Correlation analysis on continuous variables indicated that tree cover, basal area, number of large trees and presence of a large tree were highly correlated ($r > 0.6$). Removing tree cover and number of large trees resulted in correlation coefficients of < 0.6 for all remaining variables. Table 19 shows the results of model comparisons used to predict the probability of an arboreal rest patch. Stratum and basal area are the only significant ($\alpha = 0.05$) variables in the top models. For this analysis, stratum was coded for Douglas-fir and spruce-aspen versus lodgepole pine. Lodgepole pine stands were 21-22 times less likely to contain an arboreal rest patch (Table 20). For basal area, increasing the basal area by 1 m^2 resulted in a 3 – 3.5% increase in the odds of a patch containing a rest tree.

Comparison of habitat variables between terrestrial rest patches and random locations indicated that the number of large CWD (>27.5 cm diameter) was the only continuous variable with a significant ($\alpha = 0.05$) positive influence on terrestrial rest patch presence (Table 21). Age class, tree cover, shrub cover, number of trees/ha, and number of small CWD all had significant ($\alpha = 0.05$) negative influences on rest patch presence. For categorical variables, stratum was the only variable that influenced rest sites (Table 22). Spruce-aspen stands had a much greater probability of having a terrestrial rest site than lodgepole pine (Table 23).

Two habitat variables thought to influence terrestrial rest site use (*i.e.*, tree cover and number of trees/ha) were highly correlated (r >0.6). Hence, tree cover was dropped from further analysis and all correlation coefficients among the remaining variables were <0.6. Only the model incorporating all variables (full model) showed any predictive ability during multivariate modeling (Table 24). Within the full model, all attributes except the number of trees/ha was significant ($\alpha = 0.05$). Stratum had a significant ($\alpha = 0.0167$) positive influence on the odds of a terrestrial rest site with spruce-aspen sites 15 times as likely to be a rest site as the lodgepole pine and Douglas-fir strata (Table 25). Large CWD was also a positive indicator of rest sites along with increases in age class, and shrub cover, but small CWD was a negative indicator of terrestrial rest site presence.

Cull piles associated with harvesting of mountain pine beetle impacted stands dominated the data on terrestrial rest sites (65%) and this bias may have had an influence on site characteristics. "Natural" terrestrial rest sites comprised approximately half (17 of 31) of terrestrial rest sites allowing an examination of site factors associated with only these habitats. Table 26 shows the results of a univariate analysis on natural rest sites. Again, the number of large CWD was the only continuous variable with a significant ($\alpha = 0.05$) positive relationship with rest sites. Shrub cover, number of trees/ha, and number of small CWD all had significant ($\alpha = 0.05$) negative relationships with natural terrestrial rest sites. For categorical variables, stratum was the only variable with a significant ($\alpha = 0.0167$) influence on rest sites (Table 27) with spruce-aspen sites having a greater probability than lodgepole pine sites of having a terrestrial rest site (Table 28).

Of the habitat variables predicting natural terrestrial rest sites, tree cover, basal area, number of trees/ha, and number small trees/ha were highly correlated ($r > 0.6$). Retaining only the number of tree/ha for use in the model resulted in correlation coefficients <0.6 between all remaining variables. Similar to the analysis using all terrestrial rest sites, only the full model exhibited any predictive ability for natural sites (Table 29). Again, stratum had the greatest influence on natural rest sites with the spruce-aspen stratum having 10 times the odds of containing a rest site over lodgepole pine and Douglas-fir (Table 30). Numbers of large CWD also had a strong positive influence on the presence of rest sites while increases in the number of small CWD and shrub cover were associated with decreased odds of the presence of terrestrial rest sites.

3.5 Discussion

In the Chilcotin, fishers used a greater proportion of arboreal rest sites during spring and summer than during winter, similar to fishers in other regions with cold winter temperatures (Arthur *et al.* 1989; Jones 1991; Kilpatrick and Rego 1994; Weir *et al.* 2004). Unlike other regions, fishers in the Chilcotin during winter used a greater proportion of terrestrial rest sites than arboreal rest sites. The greater use of terrestrial rest sites that I observed may be due to the Chilcotin's extreme climate. The SBPS Biogeoclimatic Zone comprised the majority of the study area and has a frost free period of only 12 days (the shortest of any forested BEC zone in BC), has 5 – 7 months of the year when the mean monthly temperature is below 0°C, and has relatively low mean annual precipitation (464-517 mm) (Meidinger and Pojar 1991). Use of rest sites by fisher that are subnivean has been suggested as a thermoregulatory behaviour that minimizes heat loss (Kilpatrick and Rego 1994; Weir *et al*. 2004). Taylor and Buskirk (1994) examined the thermal properties of branch, cavity, and CWD rest elements for American marten (*Martes americana*). In their study, CWD rest sites (terrestrial rest sites associated with large woody debris) had the warmest microenvironments only during periods when temperatures were < 5°C, the snowpack was >15 cm, and wind speeds were high. I found that the choice of rest location was independent of air temperature; however, fisher made much greater use of terrestrial sites elements when snow depths were deep. Temperatures in the Chilcotin can drop to – 5°C during any month of the year[4] often when little or no snow is present. At these times, terrestrial sites may not provide a warmer microclimate than arboreal sites as predicted by Taylor and Buskirk (1994). My findings suggest that multiple factors affect the selection of optimal resting location and these factors are likely to change with season. For example, fisher in my study used terrestrial rest sites during summer when temperatures were very warm (>25°C) when they may have been selecting for habitats with cooler microclimates, or responding to other factors.

In the Chilcotin, rest trees used by fisher had larger diameters than trees available in the surrounding forest, similar to findings of other studies (Seglund 1994; Weir and Harestad 2003; Zielinski *et al*. 2004; Yaeger 2005). Some of these studies have also compared rest tree diameter to that of the largest 4 trees in the plot that were not used (Seglund 1994; Yaeger 2005), because the trees used as rest sites were often very large and this could influence the analysis. Unlike those studies, rest trees in my study were similar in diameter to the four other large trees in the plot indicating that the rest tree was not likely to have had an undue influence on other plot characteristics. As well, my comparison used a randomly located plot in the vicinity of the rest tree which is likely to reduce biases associated with measuring site characteristics close to a large tree. Rest trees used by fisher in the Chilcotin are generally small compared to trees used elsewhere in western North America (Seglund 1994; Weir and Harestad 2003; Zielinski *et al*. 2004; Yaeger 2005) with the exception of the Douglas-fir rest trees. These differences suggest that,

[4] Environment Canada. 2009. Data from Puntzi Mountain weather station, 20 year Normals.

although fishers generally choose larger trees for resting, diameter is not the only factor influencing choice of rest trees.

Other researchers have examined the abundance of structural features associated with rest trees compared to trees not used by fishers. Weir and Harestad (2003) found that spruce trees used for resting had greater numbers of rust brooms than trees not used for resting within the rest plot. Zielinski *et al*. (2004) found that female fishers used cavities more often than males and males used platforms more often than females. Kilpatrick and Rego (1994) found that fisher selected trees with platforms for resting on and avoided trees with cavities during summer but there was no difference in selectivity for these structures during winter. Variability in use among structure types, sexes, and seasons indicates that fishers use a variety of tree based sites to meet their needs annually and across the landscape. Spruce were the most often used rest trees in the Chilcotin area of BC and this affinity for spruce trees has also been noted in other areas of the BC interior (Weir and Harestad 2003; Weir *et al*. 2004). Generally, suitable structures for resting are in large diameter trees (Seglund 1995; Weir and Harestad 2003; Zielinski *et al*. 2004; Yaeger 2005). However, this association may be confounded with age because older trees have had longer exposure to disease and decay processes that are associated with the development of many rest structures.

Douglas-fir and spruce-aspen forest types and stands with greater basal area had the greatest influence on the probability of an arboreal rest site being used by fisher in the Chilcotin. Given that spruce was the most often used rest tree and that Douglas-fir was the second most used tree species, this result is not surprising because stands of these species tend to have greater basal area then lodgepole pine. Likewise, spruce in the Chilcotin generally grows on wetter, more productive sites than lodgepole pine, resulting in larger tree diameters, increased stocking densities, and greater basal area. Other researchers have also found that fisher rest sites are associated with high basal area and are often found in riparian ecosystems which are more productive locations (Seglund 1995, Zielinski *et al.* 2004, Yaeger 2005).

The probability of use of terrestrial rest elements was influenced by the presence of the spruce-aspen habitat type and high numbers of large logs (>27.5 cm diameter). This relationship was significant even when man-made CWD piles were removed from the analysis. Other researchers have also reported fishers using large diameter logs at subnivean rest sites (Jones 1991, Weir and Harestad 2003). Fishers in my study areas used terrestrial rest elements in all seasons indicating that microclimate is likely only one factor influencing rest site use. Weir *et al*. (2004) proposed that fishers would select rest structures based upon factors other than temperature when thermoregulatory demands were not restrictive, and a number of other researchers have suggested that fishers locate rests sites close to food sources (de Vos 1952; Coulter 1966; Powell 1993).

Some of the terrestrial rest sites used by fisher in my study were close to where fisher were feeding on winter killed animals (*e.g.*, moose and domestic cattle). These rest locations may have provided protection from other predators that were also feeding on the carrion, and I observed tracks indicating canids may have chased a fisher into a CWD pile close to a carcass on one occasion. Some prey species may also be more abundant and/or accessible in terrestrial rest sites. Complex CWD piles that include large diameter pieces would allow fisher to enter subnivean sites in winter and hunt prey that would otherwise be inaccessible. A recent study near Williams Lake, BC found that small mammals made extensive use of the man-made piles located in clear cut areas (Davis and Calabrese 2009). Red-backed voles (*Clethrionomys gapperi*) are a prey of fisher that is associated with CWD and makes greater use of larger diameter logs (Hayes and Cross 1987; L.R. Davis unpublished data). Some of the rest elements in my study were in animal burrows, such as red squirrel (*Tamiasciurus hudsonicus*) middens, and these structures may have provided both cover and prey for fisher. This suggests that rest locations serve multiple functions for fishers that include providing a suitable microclimate, secure location from other predators, and accessible prey.

3.6 References

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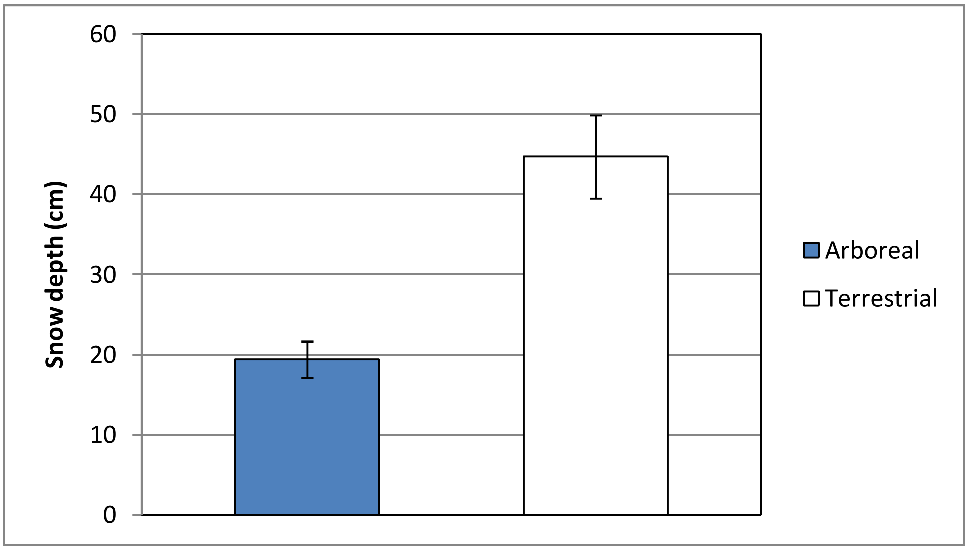

Figure 4. Rest structure use and snow depth (+/- SE) at fisher locations in the Chilcotin area of British Columbia (2005 – 2008). Comparison based on data collected between November 1st and April 30th. Snow depth was significantly (α=0.05) deeper when terrestrial rest site were used (Proc Phreg (SAS 9.1.3)).

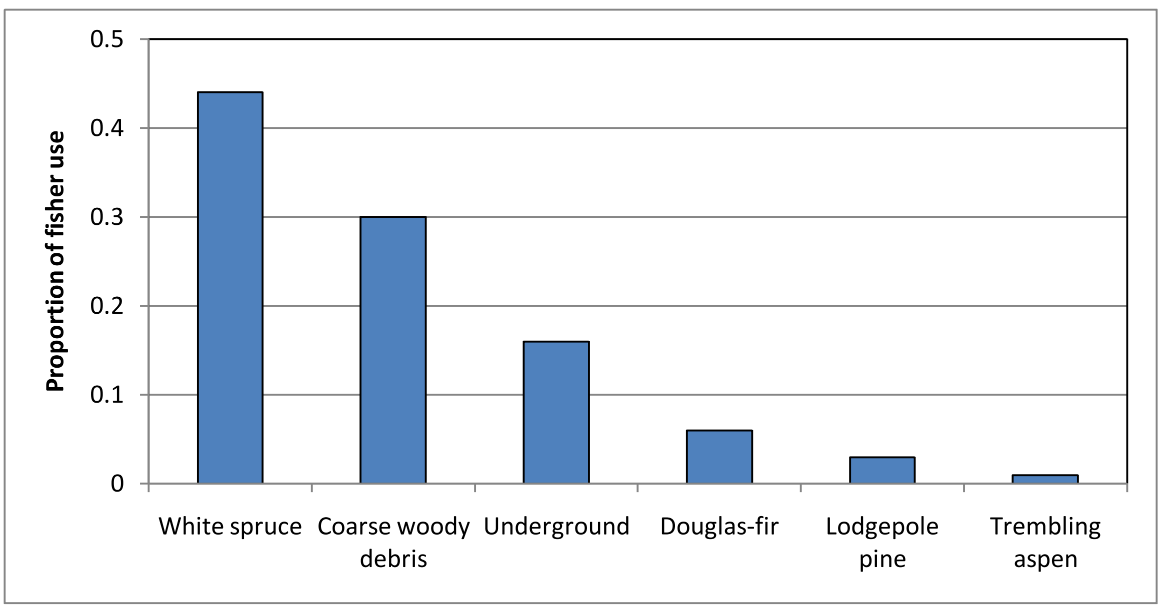

Figure 5. Proportion of rest site use by structure for the 105 sites fisher used in the Chilcotin area of British Columbia (2005 – 2008).

Table 10: Habitat attributes measured at fisher rest sites in the Chilcotin area of British Columbia, Canada. Attributes surveyed using methodology in Field Manual for Describing Terrestrial Ecosystems – Land Management Handbook 25 (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998).

Attribute	Description
GPS position	UTM coordinates (NAD 83)
Average tree height	Average height of trees in plot (m).
Slope	Percentage slope of 11.28-m radius plot
Aspect	Warm: 91 - 269˚; cold: 270 - 90˚; none: sites with a slope <6%.
Structural stage	Dominant structural stage in 11.28-m radius plot.
Surface topography	Shape of slope (Province of BC 1998).
BEU	Broad ecosystem unit that best describes the 11.28-m radius plot.
Elevation	Elevation in meters.
BEC Unit	Biogeoclimatic subzone.
Mesoslope	Slope position of site in local catchment area.
Site series	Base on BEC unit, the sites position on edatopic grid determined by moisture and nutrient regime.
Moisture/nutrient	Soil moisture and nutrient level.
Variable radius plot	Trees were tallied by species, size class (small: 12.5-27.4 cm, large >27.5 cm DBH*), and decay class.
Fixed radius plot	11.28-m fixed radius plot with information on diameter at breast height (DBH), height, crown condition, bark condition, wildlife tree class, wood condition, and wildlife activity for each tree in plot.
Vegetation	Estimated percentage cover by layer in 11.28-m radius plot with the 3 dominant species present listed in order of greatest to least percentage cover.
%CWD cover	Estimated percentage woody debris cover in an 11.28-m radius plot by category (0%, 1-5%, 5-15%, 15-25%, >25%).
CWD/30 m	Number of pieces >7.5 cm diameter by decay class in 30-m transect centred on plot and oriented in a random direction.
Canopy cover	Percentage canopy cover using a canopy densitometer (Teti and Pike 2005).
Snow depth	Snow depth in centimeters at a random location along the fisher's trail.
Temperature	Ambient temperature in Celsius.
Prey presence	Evidence of prey species present within 5.64 m of plot centre.
Tree age	Three trees were aged at each fisher den site and at every 10^{th} random plot.

*DBH: diameter at breast height (1.3 m).

Table 11: Stratification used to obtain random samples from fisher home ranges in the Chilcotin area of British Columbia.

	Stratum	Description
Leading species	Spruce-Aspen	Habitats containing >25% white spruce or >50% trembling aspen.
	Lodgepole pine	Pine dominated (>75% lodgepole pine).
	Douglas-fir	Douglas-fir dominated (>50% Douglas-fir)
Age class	Age class 1	Forest age class 1 (0-20 years)/ structural stages[1] 1-3.
	Age class 2	Forest age class 2-3 (20-60 years)/ structural stage 4.
	Age class 3	Forest age class 4-5 (60-100)/ structural stage 5.
	Age class 4	Forest age class 6-8 (100+)/ structural stages 6 - 7.

[1]Structural stage: Seven-class stratification of stand structure from *Field Manual for Describing Terrestrial Ecosystems – Land Management Handbook 25* (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998).

Table 12: Comparison of structure use and weather characteristics at fisher rests locations in the Chilcotin area of British Columbia (2005 – 2008). Ambient temperature (°C) and snow depth (cm) were compared using Proc Phreg (SAS 9.1.3). Terrestrial sites include burrows and woody debris piles. Comparisons are based on data collected between November 1st and April 30th. Significant (α=0.05) variables in bold and the odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase or decrease of 0.01 indicates that the odds of choosing a rest site changed by 1% for each unit change in the attribute.

Variable	Type	Mean	SE	n	P value	Odds ratio
Temperature	Arboreal	-0.45° C	2.53	11	0.4101	1.050
	Terrestrial	-2.50° C	2.05	12		
Snow depth	Arboreal	19.42 cm	2.26	42	0.0071	0.975
	Terrestrial	44.74 cm	5.20	31		

Table 13: Rest structures used by fisher in the Chilcotin area of British Columbia, Canada between December 2005 and July 2008. Structures listed are in order of greatest to least use.

Rest site	Total Number Uses	Number times Re-used	% Use	Structures used
White spruce	44	1	0.44	Broom, squirrel nest, branch
Coarse woody debris	30	12	0.30	Cull pile, natural pile, hollow log, beaver hutch, packrat nest
Underground	16		0.16	Squirrel midden, muskrat den, other ground
Lodgepole pine	8	4	0.03	Broom, squirrel nest
Douglas-fir	6		0.06	Cavity, branch, squirrel nest
Trembling aspen	1		0.01	Cavity
Total	105			

Table 14: Average diameter at breast height (1.3 m) of rest trees used by fisher in the Chilcotin area of British Columbia, Canada (2005-2008). For trees used more than once, only one entry was used in this analysis (CV: coefficient of variation).

Species	Mean (cm)	SE	CV	n
White spruce	36.7	1.8	0.28	33
Douglas-fir	67.9	16.6	0.55	5
Lodgepole pine	23.8	1.5	0.13	4
Trembling aspen	40.2			1

Table 15: Comparison of fisher rest tree diameter at breast height (1.3 m) between rest trees and other trees in the 11.28-m radius plot. Significant (α=0.05) comparisons in bold and the odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase/decrease of 0.01 indicates that the odds of choosing a rest site changed by 1% for each unit change in the attribute.

Type	Mean (cm)	SE	n	P value	Odds ratio
Rest trees	43.8	6.97	14		
All other trees	23.0	0.55	310	<0.0001	1.138
Other large trees*	37.1	0.164	56	0.1012	1.048

*Other large trees compared the rest tree to the four largest trees in the plot that were not used.

Table 16: Comparison of habitat variables at rest tree sites and random sites in fisher home ranges in the Chilcotin area of British Columbia, Canada. Significant (α=0.05) variables in bold and the odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase or decrease of 0.01 indicates that the odds of choosing a rest site changed by 1% for each unit change in the attribute.

Variable	Type	Mean	SE	n	P value	Odds ratio
Age class[1]	Rest	3.70	0.09	47	**0.0003**	2.876
	Random	3.07	0.05	324		
% Slope[2]	Rest	7.98	1.10	46	0.4087	1.014
	Random	7.29	0.54	324		
% Tree cover[3]	Rest	23.59	1.97	46	**<0.0001**	1.053
	Random	13.74	0.72	324		
% Shrub cover[4]	Rest	21.04	2.24	45	**0.0052**	0.964
	Random	26.81	0.94	323		
Basal area[5]	Rest	29.16	3.22	38	**<0.0001**	1.063
	Random	13.89	0.71	324		
# Small trees/ha[6]	Rest	581.95	96.15	38	0.0833	0.999
	Random	662.31	34.29	324		
# Large trees/ha[7]	Rest	122.50	19.34	38	**<0.0001**	1.002
	Random	38.94	4.57	324		
Presence large tree[8]	Rest	0.76	0.07	324	**0.0002**	4.792
	Random	0.38	0.03	38		
# CWD[9]	Rest	4.09	1.42	11	0.6245	0.961
	Random	4.26	0.23	324		

[1]Age class: Four class system based on structural stage (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998). 1= structural stages 1 – 3; 2= structural stage 4; 3= structural stage 5; and 4= structural stages 6-7.
[2]% Slope: percentage gradient of terrain in 11.28-m radius plot.
[3]% Tree cover: percentage cover of trees >12.5 cm DBH (diameter at 1.3 m height above the ground) in 11.28-m radius plot.
[4]% Shrub cover: percentage cover of shrubs in 11.28-m radius plot.
[5]Basal area: the cross sectional area of trees per hectare measured at DBH (m^2/ha).
[6]Number Small trees/ha: number of trees <27.6 cm DBH per hectare.
[7]Number Large trees/ha: number of trees >27.5 cm DBH per hectare.
[8]Presence large tree: denotes presence of at least one tree >27.5 cm DBH.
[9]Number CWD: number of pieces of woody debris >7.4 cm diameter encountered in a 30-m transect.

Table 17: Comparison of categorical habitat variables at rest tree sites and random sites in fisher home ranges in the Chilcotin area of British Columbia, Canada. Significant (α=0.05) variables are in bold.

Attribute	Level	Count (proportion)		P value
		Rest	Random	
Stratum[1]	Douglas-fir	7 (0.14)	16 (0.05)	
	Lodgepole pine	4 (0.09)	232 (0.72)	**<0.0001**
	Spruce-aspen	36 (0.77)	76 (0.23)	
Aspect[2]	Cold	12 (0.26)	57 (0.18)	
	None	26 (0.55)	198 (0.61)	0.2790
	Warm	9 (0.19)	69 (0.21)	
Mesoslope[3]	Lower	26 (0.55)	113 (0.35)	
	Middle	16 (0.32)	164 (0.50)	**0.0375**
	Upper	6 (0.13)	47 (0.15)	

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004)(Douglas-fir: ≥30% cover in Douglas-fir; Lodgepole pine: ≥70% cover in lodgepole pine; Spruce-aspen: ≥30% cover in either white spruce or trembling aspen).
[2]Aspect: describes the direction of slope (none: areas with less than 5% slope; cold: >5% slope and 270-90˚; warm: >5% slope and 91-269˚ azimuth).
[3]Mesoslope: Slope position is a 3 class system based on *Field Manual for Describing Terrestrial Ecosystems* (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998). Upper=crest and upper; Middle= middle and level; Lower=lower, toe, and depression).

Table 18: Contrasts for rest tree categorical habitat variables using Proc Phreg (SAS 9.1.3). Significant (α=0.05/3 = 0.0167) contrasts are in bold.

Attribute	Contrast	DF	Chi-square	P-value
Stratum[1]	Douglas-fir vs Spruce-aspen	1	0.7297	0.3930
	Douglas-fir vs Lodgepole pine	1	18.6734	**<0.0001**
	Lodgepole pine vs Spruce-aspen	1	34.0523	**<0.0001**
Mesoslope[2]	Lower vs Upper	1	1.4983	0.2209
	Lower vs Middle	1	6.4182	**0.0113**
	Middle vs Upper	1	0.4644	0.4956

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) (Douglas-fir: ≥30% cover in Douglas-fir; Lodgepole pine: ≥70% cover in lodgepole pine; Spruce-aspen: ≥30% cover in either white spruce or trembling aspen).
[2]Mesoslope: Slope position is a 3 class system based on *Field Manual for Describing Terrestrial Ecosystems* (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998). Upper=crest and upper; Middle= middle and level; Lower=lower, toe, and depression).

Table 19: Test of models used to predict the probability of a fisher rest tree site in the Chilcotin area of British Columbia, Canada. K is the number of parameters (including a constant). Akaike Information Criterion (AIC) values are a relative index of model parsimony with ΔAIC values giving the distance between any model and the most parsimonious model. AICώ is the relative strength of each model, and rank gives the ratio of evidence relative to the best model (n = 360). Top models and significant parameters are in bold type.

Model	K	Description	AIC	ΔAIC	AICώ	Rank
1	4	**Stratum**[1] + Shrub cover + **Basal area**	135.23	0.00	1.00	1.0
4	3	**Stratum** + **Basal area**	136.87	1.64	0.44	2.3
Full	7	Stratum[1] + Ageclass[2] + Mesoslope[3] + Shrub cover[4] + Basal area[5] + Large tree[6]	140.98	5.75	0.06	17.7
5	3	Stratum + Large tree	143.42	8.19	0.02	60.0
6	5	Ageclass +Mesoslope + Shrub cover + Basal area	172.00	36.77	<0.01	>100.0
2	3	Ageclass + Large tree	180.56	45.33	<0.01	>100.0
3	3	Mesoslope + Large tree	183.51	48.28	<0.01	>100.0

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) with model based on Douglas-fir and Spruce-aspen versus Lodgepole pine stratum (Douglas-fir= ≥30% cover in Douglas-fir; Lodgepole pine= ≥70% cover in lodgepole pine; Spruce-aspen= ≥30% cover in either white spruce or trembling aspen).
[2]Age class: Four class system based on structural stage (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998) (1= structural stages 1 – 3; 2= structural stage 4; 3= structural stage 5; and 4= structural stages 6-7).
[3]Mesoslope: Slope position is a 3-class system based on *Field Manual for Describing Terrestrial Ecosystems* (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998): Upper= crest and upper; Mid = middle and level; Lower = lower, toe, and depression).
[4]Shrub cover: percentage cover of shrubs in 11.28-m radius plot
[5]Basal area: the cross sectional area of trees per hectare measured at 1.3 m (DBH).
[6]Large tree: denotes presence of at least one tree >27.5 cm DBH.

Table 20: Odds ratio for significant (α=0.05) attributes in the top two models for fisher rest tree sites in the Chilcotin area of British Columbia, Canada. The odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase/decrease of 0.01 indicates that the odds of choosing a rest site changed by 1% for each unit of change in the attribute.

Attribute	Odds ratio
Spruce-aspen and Douglas-fir vs. Lodgepole pine stratum[1]	21.134 – 22.409
Basal area[2]	1.030 – 1.035

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) with model based on Douglas-fir and Spruce-aspen versus Lodgepole pine stratum (Douglas-fir= ≥30% cover in Douglas-fir; Lodgepole pine= ≥70% cover in lodgepole pine; Spruce-aspen= ≥30% cover in either white spruce or trembling aspen).
[2]Basal area: the cross sectional area of trees per hectare measured at 1.3 m (DBH).

Table 21: Comparison of habitat variables at terrestrial rest sites and random sites in fisher home ranges in the Chilcotin area of British Columbia, Canada. Significant (α=0.05) variables in bold and the odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase or decrease of 0.01 indicates that the odds of choosing a rest site changed by 1% for each unit change in the attribute.

Variable	Type	Mean	SE	n	P value	Odds ratio
Age class[1]	Rest	2.65	1.36	31	**0.0017**	0.546
	Random	3.10	0.05	281		
Slope[2]	Rest	7.00	1.74	31	0.6023	1.010
	Random	7.00	0.58	281		
Tree cover[3]	Rest	10.16	1.75	31	**0.0006**	0.931
	Random	14.53	0.53	281		
Shrub cover[4]	Rest	15.03	3.73	29	**<0.0001**	0.917
	Random	29.72	1.02	280		
Basal area[5]	Rest	14.00	2.72	27	0.5755	0.990
	Random	14.81	0.78	281		
Trees/ha[6]	Rest	406.72	76.40	27	**<0.0001**	0.998
	Random	814.00	38.84	281		
Small CWD[7]	Rest	1.96	0.52	26	**0.0054**	0.787
	Random	4.66	0.27	281		
Large CWD[8]	Rest	0.48	0.17	26	**0.0017**	2.528
	Random	0.14	0.02	281		

[1]Age class: Four-class system based on structural stage (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998) (1= structural stages 1 – 3; 2= structural stage 4; 3= structural stage 5; and 4= structural stages 6-7).
[2]Slope: percent gradient of terrain in 11.28-m radius plot.
[3]Tree cover: percentage cover of trees >12.5 cm DBH (diameter at 1.3 m height from the ground) in 11.28-m radius plot.
[4]Shrub cover: percentage cover of shrubs in 11.28-m radius plot.
[5]Basal area: cross sectional area of trees per hectare measured at DBH (m^2/ha).
[6]Trees/ha: number of trees >12.4 cm DBH per hectare.
[7]Small CWD: number of pieces of woody debris between 7.4 - 27.6 cm diameter encountered along a 30-m transect.
[8] Large CWD: number of pieces of woody debris >27.5 cm diameter encountered along a 30-m transect.

Table 22: Comparison of categorical habitat variables at terrestrial rest sites and random sites in fisher home ranges in the Chilcotin area of British Columbia, Canada. Significant (α=0.05) variables are in bold.

Attribute	Level	Count (proportion)		P value
		Rest	Random	
Stratum[1]	Douglas-fir	0 (0.00)	16 (0.06)	
	Lodgepole pine	12 (0.39)	297 (0.70)	**0.0013**
	Spruce-aspen	19 (0.61)	68 (0.24)	
Aspect[2]	Cold	4 (0.13)	45 (0.16)	
	None	21 (0.68)	180 (0.64)	0.9043
	Warm	6 (0.19)	56 (0.20)	
Mesoslope[3]	Lower	12 (0.39)	111 (0.40)	
	Mid	11 (0.35)	122 (0.43)	0.4384
	Upper	8 (0.26)	48 (0.17)	

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) (Douglas-fir= ≥30% cover in Douglas-fir; Lodgepole pine= ≥70% cover in lodgepole pine; Spruce-aspen= ≥30% cover in either white spruce or trembling aspen).

[2]Aspect: describes the direction of slope (none= areas with less than 5% slope; cold= >5% slope and 270-90˚; warm= >5% slope and 91-269˚ azimuth).

[3]Mesoslope: Slope position is a 3-class system based on *Field Manual for Describing Terrestrial Ecosystems* (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998): Upper= crest and upper; Mid = middle and level; Lower = lower, toe, and depression).

Table 23: Contrasts for terrestrial rest site categorical habitat variables at terrestrial rest sites and random sites in fisher home ranges in the Chilcotin area of British Columbia, Canada. Significant (α=0.05/3 = 0.0167) contrasts are in bold.

Attribute	Contrast	DF	Chi-square	P-value
Stratum[1]	Douglas-fir vs. Spruce-aspen	1	0.0002	0.9901
	Douglas-fir vs. Lodgepole pine	1	0.0001	0.9911
	Lodgepole pine vs. Spruce-aspen	1	13.2398	**0.0003**

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) (Douglas-fir= ≥30% cover in Douglas-fir; Lodgepole pine= ≥70% cover in lodgepole pine; Spruce-aspen= ≥30% cover in either white spruce or trembling aspen).

Table 24: Test of models used to predict the probability of a fisher terrestrial rest site in the Chilcotin area of British Columbia, Canada. K is the number of parameters (including a constant). Akaike Information Criterion (AIC) values are a relative index of model parsimony with ΔAIC values giving the distance between any model and the most parsimonious model. AICώ is the relative strength of each model, and rank gives the ratio of evidence relative to the best model (n = 360). Top models and significant parameters are in bold type.

Model	K	Description	AIC	ΔAIC	AICώ	Rank
Full	7	**Stratum**[1] + **Ageclass**[2] + **Shrub cover**[3] + Trees/ha[4] + **Small CWD**[5] + **Large CWD**[6]	55.3	0.00	1.0	1
1	4	Stratum + Shrub cover + Trees/ha + Large CWD	71.8	16.51	2.6×10^{-4}	3.8×10^{3}
5	3	Shrub cover + Small CWD + Large CWD[6]	78.0	22.66	1.2×10^{-5}	8.3×10^{4}
3	3	Stratum + Shrub cover + large CWD	88.8	33.51	5.3×10^{-8}	1.9×10^{7}
6	5	Age class + Trees/ha + Large CWD	95.7	40.40	1.7×10^{-9}	5.9×10^{8}
2	3	Stratum + Age class	108.0	52.66	3.7×10^{-12}	2.7×10^{11}
4	3	Stratum + Large CWD	112.9	57.56	3.2×10^{-13}	3.2×10^{12}

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) with model based on Spruce-aspen versus Lodgepole pine and Douglas-fir strata (Douglas-fir= ≥30% cover in Douglas-fir; Lodgepole pine= ≥70% cover in lodgepole pine; Spruce-aspen= ≥30% cover in either white spruce or trembling aspen).

[2]Age class: Four-class system based on structural stage (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998) (1= structural stages 1 – 3; 2= structural stage 4; 3= structural stage 5; and 4= structural stages 6-7).

[3] Shrub cover: percentage cover of shrubs in 11.28-m radius plot.

[4] Trees/ha: number of trees >12.5 cm diameter at 1.3 m per ha.

[5]Small CWD: number of pieces of woody debris between 7.4- 27.6 cm diameter along a 30-m transect.

[6]Large CWD: number of pieces of woody debris >27.5 cm diameter along a 30-m transect.

Table 25: Odds ratio for significant (α=0.05) attributes in the top model for fisher terrestrial rest sites in the Chilcotin area of British Columbia, Canada. The odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase or decrease of 0.01 indicates that the odds of choosing a rest site changed by 1% for each unit change in the attribute.

Attribute	Odds ratio
Spruce-aspen vs. Lodgepole pine/Douglas-fir strata[1]	15.084
Age class	0.325
Shrub cover	0.912
Small CWD	0.529
Large CWD	3.511

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) with model based on spruce-aspen versus lodgepole pine and Douglas-fir strata (Douglas-fir= ≥30% cover in Douglas-fir; lodgepole pine= ≥70% cover in lodgepole pine; spruce-aspen= ≥30% cover in either white spruce or trembling aspen).

Table 26: Comparison of habitat variables using Proc Phreg (SAS 9.1.3) at 'natural' terrestrial rest sites and random sites in fisher home ranges that had >25 re-locations. Significant (α=0.05) variables in bold and the odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase or decrease of 0.01 indicates that the odds of choosing a rest site changed by 1% for each unit change in the attribute..

Variable	Type	Mean	SE	n	P value	Odds ratio
Age class[1]	Rest	3.47	0.23	17	0.2627	1.473
	Random	3.16	0.07	179		
Slope[2]	Rest	8.65	3.08	17	0.3175	1.022
	Random	6.44	0.74	179		
Tree cover[3]	Rest	15.06	2.27	17	0.1814	0.970
	Random	18.07	1.03	179		
Shrub cover[4]	Rest	19.47	3.66	15	**0.0022**	0.934
	Random	33.16	1.32	178		
Basal area[5]	Rest	19.71	3.87	14	0.1337	1.032
	Random	15.74	1.01	179		
Trees/ha[6]	Rest	550.03	101.44	14	**0.0174**	0.999
	Random	953.53	51.10	179		
Small tree/ha	Rest	498.82	90.40	14	**0.0158**	0.999
	Random	909.46	51.58	179		
Large tree/ha	Rest	51.21	16.92	14	0.5209	1.002
	Random	44.05	6.13	179		
Small CWD[7]	Rest	1.83	1.53	12	**0.0370**	0.745
	Random	4.56	0.35	179		
Large CWD[8]	Rest	0.67	0.36	12	**0.0022**	3.248
	Random	0.12	0.03	179		

[1]Age class: Four-class system based on structural stage (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998) (1= structural stages 1 – 3; 2= structural stage 4; 3= structural stage 5; and 4= structural stages 6-7).

[2]Slope: percentage gradient of terrain in 11.28-m radius plot

[3]Tree cover: percentage cover of trees >12.5 cm DBH (diameter at 1.3 m height from the ground) in 11.28-m radius plot.

[4]Shrub cover: percentage cover of shrubs in 11.28-m radius plot.

[5]Basal area: the cross sectional area of trees per hectare measured at DBH (m^2/ha).

[6]Trees/ha: number of trees >12.4 cm DBH per hectare.

[7]Small CWD: number of pieces of woody debris between 7.4-27.6 cm diameter along a 30-m transect.

[8] Large CWD: number of pieces of woody debris >27.5 cm diameter along a 30-m transect.

Table 27: Comparison of categorical habitat variables at 'natural' terrestrial rest sites and random sites in fisher home ranges in the Chilcotin area of British Columbia, Canada. Significant (α=0.05) variables are in bold.

Attribute	Level	Count (proportion)		P value
		Rest	Random	
Stratum[1]	Douglas-fir	0 (0.00)	3 (0.02)	
	Lodgepole pine	4 (0.24)	130 (0.73)	**0.0012**
	Spruce-aspen	13 (0.76)	46 (0.25)	
Aspect[2]	Cold	1 (0.06)	24 (0.13)	
	None	11 (0.65)	126 (0.71)	0.2703
	Warm	5 (0.29)	29 (0.16)	
Mesoslope[3]	Lower	6 (0.35)	88 (0.49)	
	Middle	6 (0.35)	62 (0.34)	0.3212
	Upper	5 (0.30)	29 (0.16)	

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) (Douglas-fir= ≥30% cover in Douglas-fir; lodgepole pine= ≥70% cover in lodgepole pine; spruce-aspen= ≥30% cover in either white spruce or trembling aspen).

[2]Aspect: describes the direction of slope (none= areas with less than 5% slope; cold= >5% slope and 270-90˚; warm= >5% slope and 91-269˚ azimuth).

[3]Mesoslope: Slope position is a 3-class system based on *Field Manual for Describing Terrestrial Ecosystems* (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998): Upper = crest and upper; Mid = middle and level; Lower = lower, toe, and depression).

Table 28: Contrasts for 'natural' terrestrial rest site categorical habitat variables with significant (α=0.05) results using Proc Phreg (SAS 9.1.3). Significant (α=.05/3 = 0.0167) contrasts are in bold.

Attribute	Contrast	DF	Chi-square	P-value
Stratum[1]	Douglas-fir vs. Spruce-aspen	1	0.0000	0.9944
	Douglas-fir vs. Lodgepole pine	1	0.0000	0.9952
	Lodgepole pine vs. Spruce-aspen	1	13.5034	**0.0002**

[1]Stratum: Distinct vegetation cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) (Douglas-fir= ≥30% cover in Douglas-fir; Lodgepole pine= ≥70% cover in lodgepole pine; Spruce-aspen= ≥30% cover in either white spruce or trembling aspen).

Table 29: Test of models used to predict the probability of fisher using a 'natural' terrestrial rest site in the Chilcotin area of British Columbia, Canada. K is the number of parameters (including a constant). Akaike Information Criterion (AIC) values are a relative index of model parsimony with ΔAIC values giving the distance between any model and the most parsimonious model. AICώ is the relative strength of each model, and rank gives the ratio of evidence relative to the best model (n = 360). Top models and significant parameters are in bold type.

Model	K	Description	AIC	ΔAIC	AICώ	Rank
Full	5	**Stratum**[1] + Trees/ha[2] + **Large CWD**[3] + Small CWD[4] + **Shrub cover**[5]	32.9	0.00	1.00	1.0
1	4	Stratum + Shrub cover + Trees/ha + Large CWD	38.7	5.81	0.055	18.3
5	3	Shrub cover + Small CWD + Large CWD[6]	40.1	7.21	0.027	36.8
3	3	Stratum + Shrub cover + large CWD	44.8	11.91	0.003	385.7
6	5	Age class + Trees/ha + Large CWD	53.6	20.76	3.1×10^{-5}	3.2×10^{4}
2	3	Stratum + Age class	58.0	25.13	3.5×10^{-6}	2.9×10^{5}
4	3	Stratum + Large CWD	63.9	31.01	1.8×10^{-7}	5.4×10^{6}

[1]Stratum: Distinct vegetative cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) with model based on Spruce-aspen versus Lodgepole pine and Douglas-fir strata (Douglas-fir= ≥30% cover in Douglas-fir; Lodgepole pine= ≥70% cover in lodgepole pine; Spruce-aspen= ≥30% cover in either white spruce or trembling aspen).
[2] Trees/ha: number of trees >12.5 cm diameter at 1.3 m per ha.
[3] Large CWD: number of pieces of woody debris >27.5 cm diameter along a 30-m transect.
[4]Small CWD: number of pieces of woody debris between 7.4-27.6 cm diameter along a 30-m transect.
[5]Shrub cover: percentage cover of shrubs in 11.28-m radius plot.

Table 30: Odds ratio for significant (α=0.05) attributes in the top model for 'natural' terrestrial rest sites used by fisher in the Chilcotin area of British Columbia, Canada. The odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase or decrease of 0.01 indicates that the odds of choosing a rest site changed by 1% for each unit change in the attribute.

Attribute	Odds ratio
Spruce-aspen vs. Lodgepole pine/Douglas-fir strata[1]	10.083
Large CWD[2]	4.194
Small CWD[3]	0.626
Shrub cover[4]	0.922

[1]Stratum: Distinct vegetative cover based on broad ecosystem units (BC Ministry of Water, Land and Air Protection 2004) with model based on Spruce-aspen versus Lodgepole pine and Douglas-fir strata (Douglas-fir= ≥30% cover in Douglas-fir; Lodgepole pine= ≥70% cover in lodgepole pine; Spruce-aspen= ≥30% cover in either white spruce or trembling aspen).
[2] Large CWD: number of pieces of woody debris >27.5 cm diameter along a 30-m transect.
[3]Small CWD: number of pieces of woody debris between 7.4-27.6 cm diameter along a 30-m transect.
[4]Shrub cover: percentage cover of shrubs in 11.28-m radius plot.

4: Home Range Level Selectivity by Fisher (*Martes pennanti*) in the Chilcotin Area of British Columbia, Canada

4.1 Abstract

Home range size of fisher in the Chilcotin area of BC averaged 30.6 km^2 for females (n = 9) and was 166.4 km^2 for the one male monitored in my study. Within home ranges, fisher had an affinity for habitats closer to streams, but selection was not detected for locations closer to wetlands, although both features are associated with the spruce – aspen stands that are preferred by fisher. This disparity in selectivity for riparian habitats may be due to differences in the distribution of these features. In the Chilcotin, wetlands are often isolated from stream networks requiring fisher to access them by crossing upland areas. In contrast, streams provide linear arrangements of habitat that generally connect headwater areas to valley bottoms. Fisher using stream networks to travel would generally always be close to preferred habitat.

Selection was not shown for stand age or forest type when fisher home ranges were compared to random home ranges. This lack of selectivity may be due to habitats in fisher home ranges being relatively fine grained. Fine grained habitats create landscapes that have small average patch sizes relative to fisher home ranges. Thus, fisher would have access to high quality habitats from most places in their home range. The use of

stream networks likely facilitates exploitation of preferred resources by providing linear arrays of high quality habitat.

4.2 Introduction

Fisher (*Martes pennanti*) are predators that can travel long distances on a daily basis and have large home ranges. These large home ranges are related to a fisher's body mass, sex, food habits and, as well, are mediated by the availability of food (Harestad and Bunnell 1979). Across North America, fishers require forests with overhead cover (de Vos 1952; Coulter 1966; Kelly 1977; Powell 1977; Arthur *et al.* 1989; Weir 1995a). In the east, suitable fisher habitat is characterized by mid-successional mixed deciduous and coniferous forest (Arthur *et al.* 1989; Buskirk and Powell 1994; Krohn *et al.* 1994). However, research in the west has suggested that fishers are associated with large tracts of mature coniferous forests that contain habitat elements, such as snags, large diameter woody debris, and large old trees, that are characteristic of late seral stands (Jones 1991, Buck *et al.* 1983; Ruggiero *et al.* 1994).

Habitat selection at the landscape level is constrained by the composition of the landscape (Weir and Harestad 1997). Viable populations are maintained in landscapes that provide sufficient habitat for animals to establish home ranges, survive and reproduce, and successfully disperse to unoccupied territories (Ebenhard 1991). Forest management practices can affect the temporal availability of late seral forest stands resulting in the loss of suitable habitat for fisher. Understanding the requirements of fisher at the home range and landscape level will allow forest managers to maintain fisher populations in managed forests.

The data for this study were collected in three biogeoclimatic (BEC) zones: Sub-Boreal Pine Spruce (SBPS), the Interior Douglas-fir (IDF), and the Montane Spruce (MS) zones. However, sample sizes were very low in the IDF zone (one fisher) and the study animals only made marginal use of the MS zone. The IDF is likely to see increased pressure for access to timber once salvage of beetle-killed trees is complete in the other BEC units. Further study within the IDF BEC unit would provide greater ability to identify patterns and confidence in the results. Despite this problem, the SBPS zone is an area of British Columbia that is rated as moderate to high value for fisher and is highly impacted by mountain pine beetle. Understanding fisher habitat needs in the SBPS will be important in maintaining this species in pine dominated landscapes.

The objectives of this chapter are to:

1. Describe fisher home ranges and their spatial arrangement.
2. Compare the habitat composition of fisher home ranges to availability in the landscape.
3. Provide recommendations for forest management in pine-dominated areas of the Central Interior.

4.3 Methods

I collected data on the location and site characteristics of fisher use sites between November and April over three years (2005/2006 to 2007/2008). Additional data were also collected between May and August in 2006, 2007, and 2008 to document habitat use during the maternal season. I used ArcMap 9.3 and Home Range Tools for ArcGIS. Version 1.1 (Rodgers *et al.* 2007) to examine fisher habitat use patterns at the home range and landscape scales. Home range estimates are based on 100% Minimum Convex

Polygons (MCP) and 95% fixed kernel isopleths with bandwidth set by least squares cross validation. Mapping data are based on standard forest cover and Vegetation Resource Inventory data (2006). I generated paired random plots within the home ranges of all fishers with >25 locations to examine habitat use within home ranges. To examine home range selection at the landscape level, I selected 108 random locations in the Anahim study area and 108 in the Puntzi study area using the distribution of home ranges and the upper limit of the Sub-Boreal Pine Spruce biogeoclimatic unit boundary to define each study area. Random home ranges were circular areas based on the average size of female home ranges. Both fisher home ranges and random home ranges were stratified based on stand age and tree species composition data using forest cover and VRI information (Table 31). Each fisher was then randomly assigned 21 – 22 of the random home ranges from its own study area for comparison of composition. Granularity of fisher home ranges was also assessed using an index of the mean stand area compared to home range area (Weir and Harestad 1997).

4.3.1 Data Analyses

I paired random locations with fisher use sites for fisher with >25 radio-telemetry locations. I compared distance to wetlands and streams between locations used by fisher and random locations using conditional exact logistic regression (Proc Phreg, SAS 9.1) in a case – control framework. Similarly, I compared fisher home range composition between fisher home ranges and randomly located circular home ranges in the same study area as the fisher using conditional exact logistic regression.

4.4 Results

I live trapped and implanted with radio transmitters 24 fisher between 2005 and 2007. Eight fishers had established home ranges near their capture point (1 male and 7 female) and two sub-adult female fishers established home ranges after dispersing (Table 32, animals A3 and P9). These 2 fishers moved 30 km and 50 km, respectively, during late March – April from areas that were shared with adult females. Both dispersing females established reproductive dens the following April. Home range sizes of females were between 13.1 – 47.8 km^2 using 95% fixed kernel estimates and 19.9 – 56.2 km^2 using 100% MCP estimates (Table 33). The male fisher had a home range of 166 km^2 using 95% fixed kernel estimates and 136 km^2 using 100% MCP estimates. The male's home range overlapped the home ranges of at least 3 female fishers; however, there was little overlap between most adult female fishers. There was no difference in home range size between study areas based on fixed kernel estimates (α=0.05, Table 33).

The difference in distance to wetland/lakes between fisher locations and random locations in home ranges was not significant (Figure 4.1); however, a greater proportion of fisher locations were found closer to streams than for random points (α=0.05, Figure 4.2). Contrasts comparing the number of fisher locations within 50 m of a stream to those >50 m were significant as was the contrast for a linear trend of decreasing use with distance from stream (α=0.05, Table 34).

Habitat compositions of fisher home ranges, based on area of habitat types and age class, were not significantly different from those of random home ranges (Table 35). The mean granularity ratio (mean stand area: home range area) was 0.0043 (SE=0.0007, n=9) for fisher home ranges and on average there were 275 stands (SE=43.3, n=9) in the home ranges of each fisher.

4.5 Discussion

Female home ranges in the Chilcotin are similar in size to those of other studies in BC (Weir and Harestad 1997) and Idaho (Jones 1991), but are approximately twice the size of fisher home ranges in California (Zielinski *et al.* 2004). Larger home range sizes in northern latitudes may, in part, reflect differences in prey abundance and diversity (Harestad and Bunnell 1979). Similar to other studies, the one Chilcotin male fisher had a home range that was much larger than those of the females (Zielinski *et al*. 2004, Seglund 1995; Jones 1991; Weir 1995a). I monitored other males in the Chilcotin study; however, I obtained relatively few locations for these animals which I attribute to their large home ranges and poor access for telemetry. Two sub-adult female fisher dispersed relatively long distances in the Chilcotin compared to a study in eastern North America (Arthur *et al.* 1993). Animals in that study were subjected to relatively high harvest and so vacant territories were likely available close to the fisher's natal areas. Harvest by trapping in the Chilcotin is relatively light and most fisher home ranges may already be occupied, thus promoting further dispersal by the sub-adult females.

At the stand level, fishers in the Chilcotin showed positive selection for riparian spruce – aspen stands, *i.e.*, use was greater than expected based on habitat availability (Chapters 2 and 3). This finding is consistent with studies elsewhere in western North America that show fisher have an affinity for riparian habitats (Buck *et al.* 1983; Jones 1991; Jones and Garton 1994; Weir 1995b). At the home range level in my study areas, fisher did not select for locations closer to wetlands and lakes, but show a trend of increased use of forest stands closer to streams. The reason for this difference in selection may be due to poor of connectivity of wetlands in many areas of the Chilcotin Plateau. On an area basis, wetlands and lakes comprised 16% of home range areas, but made up 23% of the frequency of habitat polygons indicating that there are greater numbers of small wetlands than other habitat units. In contrast, streams are relatively rare in most areas of the Chilcotin and have features that may have increased value for fishers. Streams are linear and provide continuous travel corridors for fisher and prey that generally connect larger rivers to upland areas. Although wetlands are often associated with streams, many are isolated and do not provide continuous corridors of riparian habitat. Further, these isolated wetlands are often only seasonally inundated with water resulting in lower forest productivity than streamside habitats which may also lead to decreased use by prey of fisher.

At the landscape level, fisher in the Chilcotin did not show selectivity for the composition of home ranges based on stand age or forest type. Despite this lack of habitat selectivity, fishers selected for mature-old forest and spruce-aspen forest types at the stand level (Chapters 2 and 3). Weir and Harestad (1997) also found that fisher did not exhibit habitat selectivity at the landscape level, but did exhibit selectivity at the stand and patch scales (Weir and Harestad 2003). They attributed the lack of selection at the landscape level to the small size of habitat units relative to the home range size which affected the researcher's ability to detect differences in habitat selection (Weir and Harestad 1997). The granularity ratio for my study is similar to that found by Weir and Harestad (1997) indicating that the Sub-Boreal Pine Spruce biogeoclimatic (BEC) zone is similar to the Sub-boreal Spruce BEC zone with respect to this characteristic. Fine grained landscapes are composed of many small interspersed stands resulting in any point not being far from suitable habitat and individual animals not being constrained by access to resources (Weir and Harestad 1997).

Fine grained landscapes may also contribute to larger home range sizes where preferred habitats are limited in availability. Thompson and Harestad (1994) suggest that energy costs of acquiring resources in good habitat are lower than in poor habitat and home ranges with greater proportions of good habitat should have increased survival and reproduction for individual marten, and this relationship likely applies to fisher as well. Spruce – aspen associations comprise only a small proportion of the Chilcotin landscape, had the smallest average stand size of all habitats, and are well distributed across the landscape. Individual fishers that seek to maximize their fitness in this environment cannot include greater area in good habitat without having increased home range size that also includes greater amounts of poor habitat and associated increased energy costs. However, the spatial arrangements of preferred habitats may ameliorate those effects. Spruce – aspen stands are often associated with the increased moisture associated with streams and the dendritic nature of stream networks likely provides greater continuity in preferred habitat. Fisher using habitat that is close to streams would never be far from preferred habitat and could access most areas of their home range by following this habitat feature. This pattern of habitat use may explain the larger home range sizes seen in some areas of North America.

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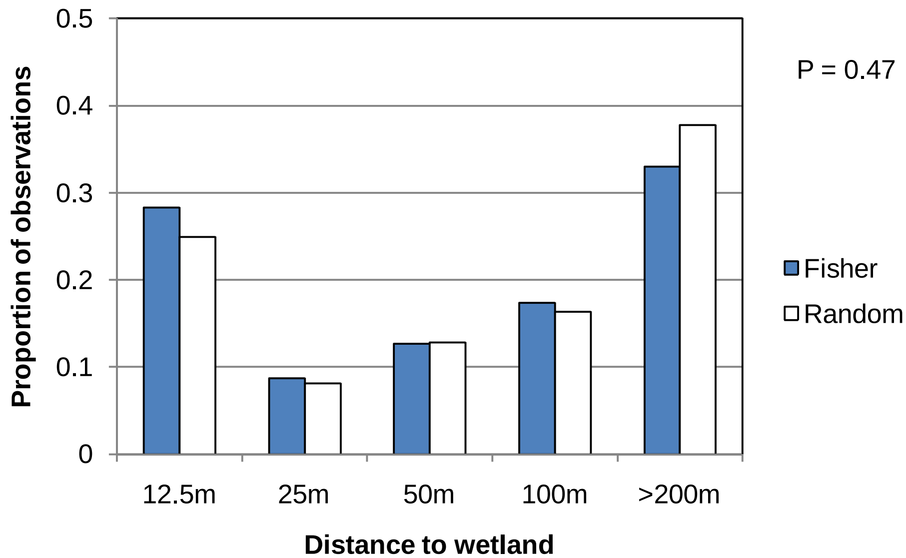

Figure 6. Distance to wetlands for fisher locations and random locations. Repeated observations of fisher at one location (*e.g.*, den sites and rest sites) were not used.

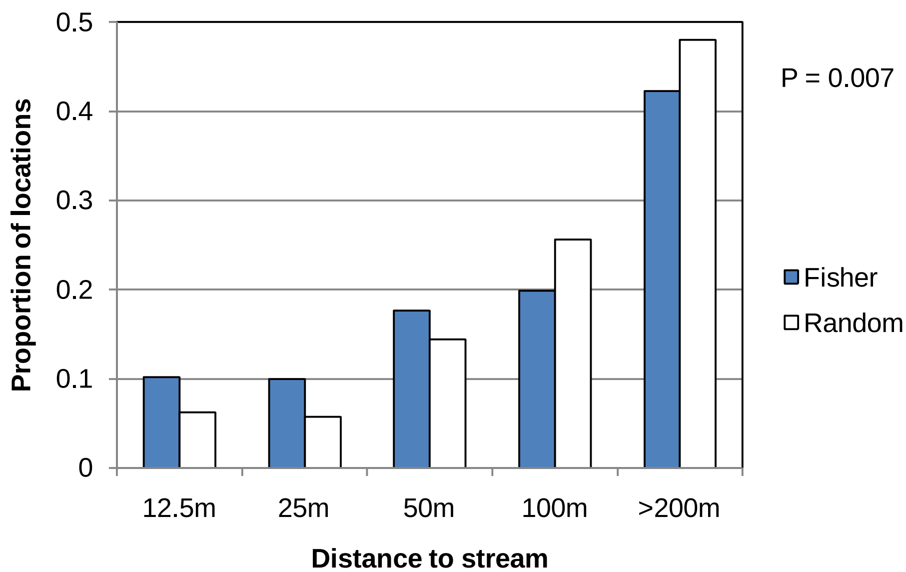

Figure 7. Distance to streams for fisher locations and random locations. Repeated observations of fisher at one location (*e.g.*, den sites and rest sites) were not used.

Table 31: Stratification used to obtain random samples from fisher home ranges in the Chilcotin area of British Columbia, Canada.

Stratum		Description
Leading species	Spruce-Aspen	Habitats containing >25% white spruce or >50% trembling aspen.
	Lodgepole pine	Pine dominated (>75% lodgepole pine).
	Douglas-fir	Douglas-fir dominated (>50% Douglas-fir)
Age class	Age class 1	Forest age class 1 (0-20 years)/ structural stages[1] 1-3.
	Age class 2	Forest age class 2-3 (20-60 years)/ structural stage 4.
	Age class 3	Forest age class 4-5 (60-100)/ structural stage 5.
	Age class 4	Forest age class 6-8 (100+)/ structural stages 6 - 7.

[1]Structural stage: Seven-class stratification of stand structure from *Field Manual for Describing Terrestrial Ecosystems – Land Management Handbook 25* (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests. 1998)

Table 32: Home range size (km^2) estimates of fisher in the Chilcotin area of British Columbia, Canada between 2005 and 2008.

Study area	Fisher ID	Sex	n	100% Minimum convex polygon	95% Fixed kernel
Anahim	A1	F	35	31.3	42.3
Anahim	A2	M	38	136.3	166.4
Anahim	A3	F	45	20.1	20.3
Anahim	A4	F	65	23.3	13.1
Anahim	A5	F	68	56.2	45.0
Puntzi	P1	F	44	19.9	20.8
Puntzi	P2	F	36	48.0	47.8
Puntzi	P8	F	20	35.6	17.6
Puntzi	P9	F	36	20.8	28.7
Puntzi	P10	F	40	35.8	40.0

Table 33: Comparison of mean home range size estimates (km^2) for female fisher between study areas in the Chilcotin area of BC based on data collected between 2005 and 2008. There was no difference in the area of home ranges between study areas using T – test (P = 0.47).

Study area	Sex	100% Minimum convex polygon	SE	95% Fixed kernel	SE	n
Anahim	F	32.0	8.17	30.2	7.94	4
Puntzi	F	32.7	5.27	31.0	5.72	5
Combined	F	32.3	4.43	30.6	4.43	9

Table 34: Contrasts for distance to stream for fisher locations and random locations in the Chilcotin Area of British Columbia, Canada. Significant (α=0.05/3 = 0.0167) contrasts are in bold.

Attribute	Contrast	DF	Chi-square	P-value
Stream	≤25 m vs >25 m to stream	1	2.3325	0.1267
	≤50 m vs >50 m to stream	1	12.5306	**0.0004**
	Linear trend	1	10.9661	**0.0009**

Table 35: Comparison of area in land cover categories between fisher home ranges and random home ranges located in the same study area in the Chilcotin area of British Columbia, Canada. Structural stages based on standards in BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests (1998). The odds ratio indicates the direction and magnitude of an effect with no effect equal to 1. An increase/decrease of 0.01 indicates that the odds of choosing a site changed by 1% for each unit change in the attribute.

Variable	Type	Mean	SE	n	P value	Odds ratio
Shrub-herb[1]	Fisher	0.149	0.025	9	0.2931	27.599
	Random	0.113	0.008	192		
Pole-sapling[2]	Fisher	0.029	0.007	9	0.3260	0.000
	Random	0.047	0.004	192		
Young forest[3]	Fisher	0.238	0.034	9	0.3890	0.140
	Random	0.287	0.012	192		
Mature-old[4]	Fisher	0.424	0.031	9	0.3920	8.573
	Random	0.385	0.010	192		
Other habitat[5]	Fisher	0.161	0.023	9	0.8066	0.380
	Random	0.169	0.007	192		
Spruce aspen[6]	Fisher	0.134	0.029	9	0.2211	83.672
	Random	0.100	0.006	192		
Lodgepole pine[7]	Fisher	0.679	0.034	9	0.3136	0.078
	Random	0.722	0.010	192		
Other habitat and Douglas-fir[8]	Fisher	0.187	0.019	9	0.7662	2.970
	Random	0.179	0.007	192		

[1]Shrub-herb: area of forest age class 1 (0-20 years)/ structural stages 2-3.
[2]Pole-sapling: area of forest age class 2-3 (20-60 years)/ structural stage 4.
[3]Young forest: area of forest age class 4-5 (60-100)/ structural stage 5.
[4]Mature-old: area of forest age class 6-8 (100+)/ structural stages 6+.
[5]Other habitat: area of wetlands, non-productive brush, open range, meadow, and other areas with no forest cover.
[6]Spruce aspen: area of forest containing >25% white spruce or >50% trembling aspen.
[7]Lodgepole pine: area of forest dominated by pine (>75% lodgepole pine).
[8]Other habitat and Douglas-fir: area of forest dominated by Douglas-fir (>50% Douglas-fir) and areas with no forest cover.

5: Summary and Forest Management Implications

The conservation status of fisher was recently changed from S2 to S2S3 (BC Conservation Data Centre 2006). S2 is the British Columbia Provincial designation for imperiled species whereas S3 indicates that a species is vulnerable to extirpation. The combined classification shows uncertainty in the status assessment and a requirement for more information to guide management and conservation options for fishers. Among the key knowledge gaps identified are the lack of information on fisher habitat use and denning ecology, particularly in areas without significant stands of black cottonwood (*Populus balsamifera spp trichocarpa*) such as the Chilcotin Plateau (BC Conservation Data Centre 2006). A significant component of core fisher range in British Columbia occurs in this area, and the long-term effects of the mountain pine beetle (*Dendroctonus ponderosae*) kill of lodgepole pine and subsequent forest harvest upon fisher populations and habitat is of management concern. Currently, 46% of the pine volume in British Columbia has been killed by mountain pine beetle and 70% of the volume will be killed in pine leading districts of the Province by 2017 (Walton 2009). It is generally accepted that the mountain pine beetle epidemic will result in accelerated forest harvesting and that areas with extensive mature pine forests will be converted to younger seral stands by a combination of beetle and human activities. Under this scenario, forest managers will require information on habitats that are important to fisher ecology.

Forestry has the greatest potential to affect fisher habitat in BC (Weir 2003). Forest harvesting generally results in lower numbers of large diameter dead and dying trees, downed wood, and hardwoods that are important to a broad range of wildlife (Bunnell *et al.* 1999). Habitat features such as these are used by fishers for denning, resting, and foraging (Jones 1991; Seglund 1995; Weir and Harestad 2003; Weir *et al.* 2004; Zielinski *et al*. 2004a; Zielinski *et al*. 2004b; Yaeger 2005; Chapters 2 and 3). The effects of typical forest harvesting may be compounded by the combined effects of the mountain pine beetle epidemic followed by salvage harvesting of impacted stands. Lindemeyer *et al*. (2004) reviewed studies on salvage harvesting following natural disasters and identified several examples of species that can withstand the effects of natural disturbances, but are impacted by subsequent salvage harvesting of affected areas. The Chilcotin has a history of extensive fire, mountain pine beetle attack and some salvage harvesting. Information on fisher ecology collected in this type of landscape provides a baseline for the assessment of the impact of Mountain Pine Beetle on fisher ecology and provides the foundation for habitat supply analyses and habitat management.

5.1 Reproductive Denning Ecology

Fisher prefer large diameter trees with heart rot cavities for reproductive dens. Trees with these attributes are rare in the Chilcotin, but are met by old lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii var. glauca*), and trembling aspen trees (*Populus tremuloides*). It is also likely that fishers use black cottonwood in the Chilcotin, which is available at lower elevations. Suitable trees for denning will usually be in older stands located in a variety of slope positions that likely vary with tree species, but most frequently will be on flat to sloping terrain with a south aspect. Both live and dead trees are used, but recruitment of potential den trees only comes from living trees with defects (Manion 1991). The choice of den tree species depends on the availability within each fisher's home range, and most fisher will use more than one reproductive den tree within a season. Sustaining viable fisher populations in managed landscapes will require maintaining a supply of suitable den trees through time in a variety of landscape positions.

Large diameter deciduous trees are most likely to be found in older riparian forests. In the Chilcotin, deciduous den trees are usually beside streams, lakes, wetlands and in moist depressions. Retaining pure deciduous and mixed deciduous – coniferous stands along streams and wetlands will provide a supply of suitable den trees, foraging habitat, and travel corridors for fisher to access den sites. Such stands are also important to many other species of mammals and birds (Hunter 1999).

Fisher home ranges cover a variety of habitats and in the Chilcotin some fisher made extensive use of conifers as den trees in upland habitats. Most lodgepole pine den trees were in small open, mesic to dry sites that had escaped previous fires allowing the trees to reach older ages. Identifying and protecting these patches of old forest will be important in maintaining lodgepole pine den trees in the Chilcotin. Lodgepole pine den trees were generally in a patch that was much older than the surrounding forest matrix and typically of poor timber quality. Candidate patches for retention should have at least one tree >30 cm in diameter (DBH), preferably alive and exhibiting characteristics of decay; however, preserving large snags is also important. Ensuring that suitable den trees are present through time will also require identifying and preserving some small live trees, because heart rot does not develop once the tree is dead. Therefore, reserving some smaller live trees with defects will be important in providing suitable den trees for the future.

Old Douglas-fir patches in the areas examined, often had abundant large live and dead trees with heart rot characteristics. As with lodgepole pine, these trees were usually in open patches of forest on mesic to dry sites in a variety of mesoslope positions. Retaining patches of large old live and dead Douglas-fir trees on southern aspects will provide upland denning habitat for fisher in the Chilcotin. Currently, bark beetle is heavily impacting areas of the Interior Douglas-fir biogeoclimatic zone. Salvage activities should avoid the removal of large diameter Douglas-fir that show evidence of heart rot. Such trees will have low timber value and may still be used by fisher and other wildlife for decades after tree death. Where salvage activities must take place, extra care should be taken in planning the harvest to maintain large wildlife trees.

Where den sites are identified, the site should be buffered to maintain the trees' integrity. Most fisher dens identified in my study have been placed in reserves with 100-m buffers, although some den trees were found closer to cut blocks. Ideally, the den area should be connected to riparian habitats, or other constrained areas, to provide corridors with overhead cover for accessing the den site. Silviculture operations should not occur within 500-m of known fisher den sites between March 1st and June 15th to avoid disturbing reproductive females.

Specific recommendations to maintain fisher reproductive denning habitat in the Chilcotin are:

- Retain pure deciduous and mixed deciduous – coniferous stands along streams and wetlands to provide a supply of suitable den trees, foraging habitat, and travel corridors.

- Identify and protect patches of old forest pine forest on southern aspects to maintain lodgepole pine den trees. Patches should have at least one tree >30 cm in diameter (DBH), preferably alive and exhibiting characteristics of decay; however, preserving large snags is also important.

- Retain patches of large old live and dead Douglas-fir trees on southern aspects to provide upland denning habitat.

- Bark beetle salvage activities should avoid the removal of large diameter Douglas-fir that show evidence of heart rot.

- Where den sites are identified, the site should have a 100m buffer to maintain the trees' integrity and provide security cover. Ideally, the den area should be connected to riparian habitats, or other constrained areas.

- Silviculture operations should not occur within 500-m of known fisher den sites between March 1st and June 15th to avoid disturbing reproductive females and kits.

5.2 Maintaining Rest Sites

Rest sites provide fisher with protection from predators and unfavourable weather (Kilpatrick and Rego 1994; Weir *et al*. 2004) and are also likely to facilitate access to food sources (de Vos 1952; Coulter 1966; Powell 1993). In the Chilcotin, arboreal rest sites are usually on rust brooms in white spruce, in cavities in Douglas-fir or aspen, on large limbs in Douglas-fir, or on other platform features such as nests. Trees containing rest structures are generally among the largest in a forest patch. Rest trees are typically in patches of spruce, aspen, Douglas-fir, and mixed species stands that have high basal area. Spruce rest trees are generally located in riparian stands and seepage areas, whereas Douglas-fir rest trees are often in mid to upper slope positions. Areas managed for fisher should retain spruce trees >30 cm diameter at breast height (DBH), especially those with rust brooms > 40 cm diameter. As well, Douglas-fir >50 cm DBH should be retained, especially "wolfy" trees with large branches and signs of decay. Trembling aspen > 40 cm DBH can provide cavities for rest sites and these large trees are usually associated with riparian stands. All rest trees used in the Chilcotin were in forest stands; indicating that it is important to maintain continuous forest cover around rest trees in managed stands. Old, large diameter trees may also be left in clear cuts for recruitment of rest sites, however, they likely will not be used until the new stand re-grows to sufficient heights and densities that it provides concealment cover.

Trees were the most often used rest structure in my study and others (Arthur *et al.* 1989; Kilpatrick and Rego 1994; Weir and Harestad 2003). Sustaining viable fisher populations in managed landscapes will require maintaining a supply of suitable rest trees across the landscape and through time. Hence, not only should trees that are currently suitable as rest sites be retained, but so should trees that will become suitable as they mature and become diseased and decayed.

Terrestrial sites were the most often used rest structure during winter in the Chilcotin when thermal stresses are expected to be greatest, and other studies have also found greater use of terrestrial sites during winter (Arthur *et al.* 1989; Jones 1991; Kilpatrick and Rego 1994; Weir *et al*. 2004). Spruce and aspen site associations appear to be important for terrestrial rest sites perhaps due to the greater productivity associated with this habitat in the Chilcotin and, hence, the production of large diameter trees. Large diameter logs (>27.5 cm diameter) were important in the Chilcotin and elsewhere (Jones 1991, Weir and Harestad 2003). Large diameter logs supply greater cover for concealment of both predators and prey while providing access for fisher through the larger interstitial spaces among these pieces. Cull piles in clear cut areas were used regularly as rest sites by fisher with the use occurring during all seasons. A component of cull piles should be retained after harvest to provide terrestrial resting habitat in harvested areas. Cull piles will have the greatest utility for fisher if they are located in or near spruce and aspen types. The piles should be composed of a variety of piece sizes including logs >27.5 cm diameter. The cull piles used by fisher in this study were generally greater than 2 m high and 5 m in diameter. Smaller piles can provide foraging habitat, but larger piles are more likely to provide secure resting sites.

Specific recommendations to maintain fisher resting habitat in the Chilcotin are:

- Retain spruce trees >30 cm, Douglas-fir >50 cm, and trembling aspen >40 cm DBH, especially those with brooms > 40 cm diameter, large branches, and signs of decay.

- Maintain security cover around rest trees where possible. Large diameter trees may also be left in clear cuts for recruitment of rest sites, however, they are unlikely to be used until the new stand re-grows sufficiently to provide concealment cover.

- Plan for recruitment of rest trees by retaining some smaller diameter trees that have attributes associated with rest sites (*i.e.*, disease and decay factors).

- Locations for retention should include spruce and aspen forest types as they are important for both terrestrial and arboreal rest sites.

- Retain a component of dispersed large diameter logs (>27.5 cm diameter) in harvested areas to provide cover for both predators and prey.

- A component of cull piles should be retained after harvest to provide terrestrial resting habitat in harvested areas. The piles should be composed of a variety of piece sizes including logs >27.5 cm diameter and be generally greater than 2 m high and 5 m in diameter.

5.3 Home Range and Landscape

Fishers are solitary animals that generally do not interact with conspecifics other than during territorial defence, mating and when females raise young, resulting in home ranges that are intrasexually exclusive (Powell 1993). Fishers in the Chilcotin followed this pattern with most females having little overlap with other females. Home ranges for females average 31 km^2 while the male fisher I monitored had a home range that was 166 km^2 in area and overlapped at least 3 females. These home range areas are large compared to the average area in North America (15 km^2 for females and 38 km^2 for males; Powell 1994), but are similar to the areas reported elsewhere in British Columbia (Weir 2003). Fisher are reported to have poor dispersal capability (Arthur *et al*. 1993); however, the population that was studied was heavily harvested and the presence of vacant territories likely limited the distance that animals were required to travel to find unoccupied habitat. Two female fisher successfully dispersed and then raised young in the following year during my study with both fishers moving relatively long distances (30 km and 50 km). Fishers in the Chilcotin generally have low trapping pressure at the current time and this coupled with an absence of vacant territories may have resulted in greater dispersal distances.

Within home ranges, fisher showed an affinity for locations close to streams whereas habitats closer to wetlands were used in proportion to availability. The difference in this selectivity for riparian habitat is likely related to differences in habitat characteristics associated with these features. In the dry Chilcotin climate, both streams and wetlands have characteristic forest habitat that includes increased area in spruce and spruce – aspen stands that were preferred by fisher at the stand level (Chapters 2 and 3). However, streams are linear features that generally connect valley bottoms to upland areas and fishers traveling along streams are likely to be closer to preferred habitat than fishers crossing upland to upland. Although wetlands are often associated with streams, isolated wetlands are found throughout the Chilcotin Plateau. Fishers using isolated wetlands must travel across areas that are less likely to contain preferred habitat, whereas, the dendritic nature of stream networks can provide access to most areas of fisher's home ranges and allow the animal to stay close to good habitat. This pattern of habitat use may allow fishers to exploit preferred resources in landscapes where this habitat is limited in extent and widely distributed.

Given the preference of fishers for habitats close to streams, forest management that promotes continuity of forest cover and the retention of important habitats along these features is required to maintain fisher in the Chilcotin. Fisher avoid areas without forest cover (deVos 1952; Coulter 1966; Kelly 1977; Powell 1977; Arthur *et al*. 1989; Weir 1995), and require structures associated with late successional stands in western coniferous forests (Jones 1991; Buck *et al*. 1983; Ruggiero *et al*. 1994; Weir and Harestad 2003). Fisher in the Chilcotin avoided areas that lacked forest cover and, when in unsuitable habitat, exploited residual forest structures such as wildlife tree patches and woody debris piles (Davis, unpublished data). Fishers in the Chilcotin also used large diameter trees found in residual patches of old forest for reproductive dens (Chapter 2), and showed a preference for spruce – aspen stands for rest sites (Chapter 3) and foraging habitat (Davis unpublished data).

Managing riparian forests to maintain continuity and late successional habitat attributes will require planning at the landscape scale. Not all areas of a landscape need to be simultaneously connected, because stand level harvesting practices can provide security cover allowing fishers to cross safely through young stands (Davis unpublished data; Weir and Harestad 2003). Further, practices that retain late successional features, such as large old trees and complex woody debris, within harvested areas are likely to produce stands that will provide suitable habitat for fisher in the future. Advice on planning landscapes to meet these objectives are found in the *Biodiversity Guidebook's* (British Columbia Ministry of Forests and British Columbia Ministry of Environment 1995) chapter on designing forest ecosystem networks.

Specific recommendations to maintain fisher habitat at the home range and landscape level are:

- Promote the continuity of forest cover along streams and the retention of important habitats (i.e., spruce and aspen forest types) along these features.

- Plan at the landscape scale to maintain the continuity of riparian habitats and late successional habitat attributes. Not all areas of a landscape need to be simultaneously connected, if stand level harvesting practices provide security cover allowing fishers to cross safely through young stands.

5.4 Mountain Pine Beetle Salvage and Fisher Habitat Management

Current guidance on salvage harvesting in mountain pine beetle impacted landscapes is focused on avoiding the harvest of non-pine tree species, maintenance of structural features associated with old forest, and increased retention for landscapes with high levels of salvaged stands. Specific recommendations for salvage harvesting include: the continued protection of riparian forests and increased riparian reserve widths where mixed species stands are present (Eng 2004, Bunnell *et al.* 2004, Klenner 2006); avoiding harvesting of mixed species with less than 30-40% pine (Eng 2004, Bunnell *et al.* 2004); partial cutting in mixed species stands where pine forms less than 70% of the stand (Klenner 2006); retaining small patches of dead pine in harvested areas to provide future CWD (Bunnell *et al.* 2004, Klenner 2006); and maintaining important legacies such as large diameter declining and dead trees in managed stands (Bunnell *et al.* 2004, Klenner 2006).

These recommendations will help sustain fisher denning habitat; however, more specific recommendations are also required to help retain habitat elements that will support reproduction of fisher. Fisher require large diameter trees with heart rot cavities for reproductive dens. In the Chilcotin, den trees are usually lodgepole pine, Douglas-fir, and trembling aspen trees. The protection of riparian forests will help retain trembling aspen den trees, but most coniferous den trees were located in mid to upper slope positions. Coniferous den trees were often found in remnant patches of old forest within a younger stand. Identifying and protecting patches of old coniferous forest in mid to upper slope positions will help provide den trees in all slope positions. Suitable patches will have trees >30 cm DBH for lodgepole pine, >40 cm DBH for trembling aspen, and >50 cm for Douglas-fir. Ideally, these trees should be protected in reserves that are contiguous with adjacent forest cover or in wildlife tree patches close to block boundaries (<100 m) that also provide protective cover for fisher approaching the den. The supply of future den trees may also be assured by reserving single trees that meet these criteria in harvested areas. In addition to large trees with cavities, smaller trees with defects must also be retained for the recruitment of den trees over time. Adequate training of field crews to recognize and reserve suitable den trees is crucial in maintaining denning habitat in the Chilcotin.

Resting habitat for fisher in the Chilcotin is concentrated in spruce – aspen forest types located primarily along riparian features. Most arboreal rest sites were on brooms in spruce while the majority of terrestrial sites were associated with CWD in this forest type. If mixed tree species stands are retained after harvesting, these elements are likely to be maintained. Where harvesting occurs in these types, partial cutting that protects larger spruce with brooms and the retention of cull piles close to cover will help provide resting habitat for fisher. Cull piles should also be retained in large salvage cutblocks to provide structural legacies as the new stand develops.

At the home range level, fisher in the Chilcotin study areas did not appear to be constrained by the disturbance history in this area. Industrial scale forest harvesting has only been conducted for approximately 20 years in the West Chilcotin and the area in young forest (0 – 20 years) is still relatively small. Increases in the proportion of young forest over a short period, as salvage harvesting of mountain pine beetle impacted stands proceeds, is likely to temporally constrain the amount of fisher habitat that is available. As well, this effect is expected to be greater in areas closer to timber processing facilities where harvesting is currently focused.

Increased area in reserves will be required to maintain fisher habitat in landscapes that are heavily impacted by both mountain pine beetle and salvage harvesting. These reserves may not provide enough habitat to maintain viable populations of fishers, but will help maintain connectivity across the landscape. Powell and Zielinski (1994) estimated that in the Rocky Mountains at least 2000 km^2 of suitable habitat would be required to maintain a viable sub-population of 50 fisher. Fisher made little use of young stands in the Chilcotin until cover values recovered sufficiently to provide abundant prey (>20 years post harvest) and most fisher use was concentrated in mature to old forest. Given this relationship with seral stage, planning is required to ensure that sufficient area in suitable habitat is reserved to maintain viable populations of fisher. Retaining connectivity in areas managed more intensively through increased area in reserves will help ensure that fisher can disperse across landscapes and repopulate areas where numbers are low. These forest management prescriptions, including the retention of stands and structures, will help sustain fisher in the Chilcotin and will also benefit other wildlife species. Habitat features important to fisher are also important to many species of cavity dwelling birds and mammals (Thomas 1979).

The recommendations made by others for salvage harvesting (Bunnell *et al.* 2004, Eng 2004, Klenner 2006) will help maintain wildlife habitat in areas impacted by mountain pine beetle. Specific recommendations to maintain fisher habitat at the home range and landscape level are:

- Identify and protecting patches of old coniferous forest in mid to upper slope positions. Suitable patches will have trees >30 cm DBH for lodgepole pine, >40 cm DBH for trembling aspen, and >50 cm for Douglas-fir.

- Ideally, retention patches should be contiguous with adjacent forest cover or in wildlife tree patches close to block boundaries (<100 m) to provide protective cover for fisher approaching the den.

- In addition to large trees with cavities, smaller trees with defects must also be retained for the recruitment of wildlife trees over time.

- Retain spruce – aspen forest types. Where harvesting occurs in these types, use partial cutting to protect larger spruce, Douglas-fir, and trembling aspen.

- Cull piles should also be retained in large salvage cut blocks to provide structural legacies as the new stand develops. Ideally, cull piles should be retained within 50 m of forest cover, but piles farther from cover will provide important habitat when forest cover values return.

- Increase retention in landscapes heavily impacted by mountain pine beetle and salvage harvesting to provide habitat for fisher. Retain >20% in forested reserves in these landscapes to provide habitat for fisher and connectivity.

5.5 Limitations

My study is based on a relatively small sample size of fisher and covers three BEC units. Larger sample sizes within each BEC unit would provide greater ability to identify further patterns that could be used to predict the distribution of important forest attributes within each subzone. Despite this constraint, fisher exhibited patterns of resource selection that are consistent with studies from other areas. For example, most female fisher chose den trees that were large relative to available trees and thus exhibited habitat selection consistent with other research in western North America (Weir and Harestad 2003, Aubry and Raley 2006). Protecting trees that are large and old relative to those available in a stand is likely to benefit fisher and other cavity using species across the fisher's range.

The den trees used by fisher in my study areas are smaller in diameter than those used elsewhere. Despite the small external diameter, the trees used by fisher in my study were much older than other trees on the landscape. Old trees are more susceptible to heart rot fungi, and the greater age also allows more time for extensive heart rot to develop. Moreover, it is likely that the internal dimensions of tree cavities determines the minimum requirement for fisher natal dens instead of the external diameter. Further work is required to identify the size range of cavities used by reproductive fisher;

however, protecting trees that are large and old relative to the remainder of the stand is likely to maintain denning opportunities for fisher.

Rest tree selection in the Chilcotin also followed patterns exhibited by fisher in areas of BC (Weir and Harestad 2003; Weir *et al*. 2004) and North America (Arthur *et al*. 1989; Kilpatrick and Rego 1994) with cold winter climates. Arboreal rest sites are often in larger diameter trees, but the presence of a structure (*e.g.*, witches broom, nest, large branch, etc.) is the most important factor in the selection of arboreal rest sites. As with reproductive cavities, advanced tree age and decay is likely to be the most important factors influencing the presence of these features. For terrestrial rest sites, maintaining patches of coarse woody debris that contain large elements (>27.5 cm diameter) will help provide microhabitats that help maintain positive energy budgets for fisher in cold climates.

At the landscape level, fisher in the Chilcotin did not show selectivity for the composition of home ranges based on stand age or forest type. Despite this lack of habitat selectivity, fishers selected for mature-old forest and spruce-aspen forest types at the stand level (Chapters 2 and 3). Weir and Harestad (1997) also found that fisher did not exhibit habitat selectivity at the landscape level, but did exhibit selectivity at the stand and patch scales (Weir and Harestad 2003). They attributed the lack of selection at the landscape level to the small size of habitat units relative to the home range size which affected the researcher's ability to detect differences in habitat selection (Weir and Harestad 1997). The habitat units in my study were similar in size to those found by Weir and Harestad (1997), supporting their hypothesis. However, this result may also be due to the relatively small area of young forest habitat present in the study area which may be below thresholds that would influence landscape level home range composition. Further studies are required in landscapes that have a greater distribution of young age classes and sizes of habitat patches to determine if there are landscape-level thresholds of habitat suitability below which fisher cannot be sustained.

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Appendices

Appendix 1: **Characteristics of den sites used by fisher for reproduction in the Chilcotin area of British Columbia.**

Fisher	Type	Den tree species	Den tree diameter (cm)	BEU*	Structural stage	Site series	Slope (%)	Aspect	Meso slope	Ave. tree height (m)	Trees /ha	% Tree cover	Basal area (m^2/ha)
A1	Natal	At	39.5	WR	7	04	11	SW	Toe	30	675	10	38.2
A3	Natal	At	48.5	WR	6	05	2	None	Toe	17	525	25	31.6
A4	Natal	At	47.3	WR	6	05	5	None	Toe	27	625	20	51.2
A5	Natal	Pl	40.0	LP	5	01	5	None	Mid	13	275	5	10.1
P1	Natal	Fd	77.9	DF	7	03	28	E	Upper	20	100	15	25.4
P10	Natal	Pl	34.0	LP	6	01	14	S	Upper	10	100	1	3.5
P2	Natal	Pl	35.5	LP	6	02	30	SE	Mid	13	275	5	10.5
P3	Natal	Pl	33.8	LP	6	01	6	W	Mid	14	250	17	10.7
P7	Natal	Fd	54.5	DF	7	05	15	S	Mid	25	100	40	32.2
P9	Natal	At	44.2	AC	5	04	2	None	Toe	20	975	32	36.2
A3	Mat. 1	Pl	38.8	WR	7	03	2	None	Toe	20	750	55	29.6
A4	Mat. 1	At	44.6	WR	7	04	1	None	Toe	20	750	15	41.1
A5	Mat. 1	Pl	39.1	LP	6	01	9	SW	Mid	16	600	25	24.9
P1	Mat. 1	Fd	67.9	DF	6	01	23	SE	Mid	19	125	25	34.4
P9	Mat. 1	Pl	36.5	LP	6	03	3	None	DP	17	700	25	15.6
A5	Mat. 2	Pl	45.5	LP	5	01	5	None	Mid	14	375	10	15.0
P1	Mat. 2	Fd	73.4	DF	7	01	17	S	Mid	18	200	15	32.6
P9	Mat. 2	Pl	48.1	LP	6	01	2	None	Lower	13	250	15	10.8

*Broad Ecosystem Unit (BC Ministry of Water Land and Air Protection. 2004): WR: Riparian – Spruce – Deciduous; LP: lodgepole pine; AC: aspen copse; DF: Douglas-fir.