SUSTAINING BIOLOGICAL DIVERSITY IN MANAGED SUB-BOREAL SPRUCE LANDSCAPES: RESIDUAL HABITAT STRATEGIES FOR CAVITY NESTING SPECIES

by

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ABSTRACT

I examined the assumption that residual habitat retention strategies can maintain biological diversity in managed forest landscapes of the central interior of British Columbia, as outlined by the Forest Practices Code. Wildlife tree patches are typically located in constrained areas such as mandatory riparian management areas, inoperable zones, gullies and wetlands. To determine whether this is a promising management approach, I examined the diversity, abundance, and habitat use patterns of primary cavity nesters (considered keystone species) in riparian and upland zones of unharvested old-growth Sub-Boreal Spruce mk1 forest stands in the Prince George region. Using point count and call play-back surveys in each zone, I found that upland habitats had greater species diversity, but abundance did not differ between zones. I examined habitat use patterns by recording evidence of nesting and foraging activities within 0.04 ha plots, and conducting cavity surveys between zones of 5 study sites. Upland zones were selected over riparian zones by species that nested in hybrid white-Engelmann spruce and black spruce trees. As well, Red-breasted Sapsuckers selected aspen for nesting in upland zones over riparian zones. Evidence of all other habitat use categories did not differ between zones. Overall I found that, unlike many passerine birds, cavity nesters do not have a strong affinity to riparian habitats, with several life history requirements being performed primarily or exclusively in upland habitats. It is therefore important that forest managers retain wildlife tree patches in both riparian and upland habitats to provide the full complex of habitat attributes required by cavity nesting species, and thereby biodiversity.

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INTRODUCTION AND LITERATURE REVIEW

OVERVIEW

Although forest practices in British Columbia have traditionally been driven by timber production goals, today a shift is underway towards a more holistic approach that seeks to sustain ecosystem integrity as the foundation for a wide variety of sustainable forest uses. These uses include timber production, fish and wildlife habitat, water resources, recreational and cultural values, biological diversity, and many more (Baker 1989). Pursuing new ecological and socio-economic goals requires continual monitoring and improvement of our current forest practices (Hansen *et al.* 1995). British Columbia is striving to hasten this process by moving toward an adaptive management approach (Taylor *et al.* 1997).

Adaptive management refers to a structured process of learning from the results of operational programs and experiments to improve subsequent decisions (Walters 1986, Nyberg 1995). The 2 primary mechanisms by which adaptive management function are: 1) by testing and providing reliable feedback about the effectiveness of current policies, plans, or practices, and 2) by increasing the level of understanding of ecosystem function, and identifying thresholds in ecosystem response (Taylor *et al.* 1997). In British Columbia, the Ministry of Forests has stressed the need to adopt an adaptive management approach to improve the Forest Practices Code, which has many new, previously untested policies (Taylor *et al.* 1997).

The Code outlines the statutory requirements established to ensure that the forest industry and the Ministry of Forests meet goals of sustainable and integrated resource management. The Code also provides a series of guidebooks that contain management recommendations to achieve Code compliance in practices relating to biodiversity, riparian management, soil conservation, mapping and assessing terrain stability, fish-stream identification, watershed assessment procedures, and many more. Although these guidebooks are believed to reflect best management practices, the recommendations and assumptions within them need to be tried, evaluated, and revised when necessary through an adaptive management approach.

Sustaining biological diversity by reducing the impacts of logging is a key goal of the Forest Practices Code. As natural ecosystems become increasingly modified by anthropogenic activities, natural ecological patterns and processes are altered and the risk of losing native species increases. Recommended practices within the Code are intended to provide managers, planners and field staff with methods for reducing such risks and meeting biodiversity objectives at the provincial, landscape, and stand levels (B.C. Ministries 1995a). The recommendations made are based on the underlying assumption that ecosystems will be best maintained by replicating the patterns and processes that have historically shaped the landscapes, which are typically the result of natural disturbances such as fire, wind, pests, and disease.

I examined the residual habitat recommendations (wildlife tree retention and riparian management areas) contained within the Biodiversity Guidebook (B.C. Ministries 1995a) and the Riparian Management Area Guidebook (B.C. Ministries 1995b), which are aimed towards maintaining biological diversity within managed forest landscapes. By examining the habitat use patterns of primary cavity nesters between riparian and upland zones, I was able to assess the above-described assumptions and recommended practices contained within the Code. Primary cavity nesters are considered to be keystone species as their presence influences the presence of many other species that use abandoned cavities for nesting or denning (Hunter 1994, Brewer 1994), and are, therefore, reasonable barometers of biodiversity.

Beyond this practical objective, my study contributes to the understanding of habitat relationships and conditions that affect primary cavity nesters and, thereby, biodiversity in managed Sub-Boreal Spruce forests of British Columbia.

BIOLOGICAL DIVERSITY AND FOREST MANAGEMENT

Biological diversity is the variety of life in all its forms and levels of organisation (Hunter 1990). The components of biodiversity span many scales, including genes, species, populations, communities, ecosystems, and landscapes. The evolutionary and functional processes that link these components are integral in the definition of biodiversity (B.C. Ministries 1995a). Today's concepts of good land stewardship include goals to maintain biological diversity and ecological integrity by ensuring the continued existence of viable populations of native flora and fauna. Managing resources in a sustainable manner is recognised within the global community as an obligation to future generations (Grant 1995). All life forms have ecological values; some have economic value. The long-term costs of biodiversity losses are unknown but potentially vast; the complexities of the interactions among the different levels of diversity are still being discovered. What is known is that all organisms within an ecosystem are interconnected through the food web and through interactions such as competition, predation, and parasitism (Begon *et al.* 1986). Management practices must address the full hierarchy of organisational relationships if biodiversity is to be sustained.

Forest Practices Code Biological Diversity Guidelines: Overview

The Forest Practices Code Biodiversity Guidebook (B.C. Ministries 1995a) takes a hierarchical approach, addressing both the landscape and stand levels of planning, to assist planners and practitioners in managing for diversity in forest systems. Landscape units (LUs) are the fundamental planning units for establishing landscape-level biodiversity objectives, and are characterised as naturally or ecologically contiguous areas between 5000 and 100,000 hectares. The biodiversity objectives within each LU include the maintenance of habitat diversity through: 1) a variety of seral stages with old-growth retention and representativeness; 2) species composition; 3) landscape connectivity with appropriate spatial and temporal distribution of cutblocks; and 4) stand structure through the retention and recruitment of coarse woody debris and wildlife trees (Fenger 1995). At the stand level the focus is on maintaining tree species composition and stand structure.

The underlying assumption of these objectives is that "all native species and ecological processes are more likely to be maintained if managed forests are made to resemble those forests created by the activities of natural disturbance agents such as fire, wind, insects, and disease" (B.C. Ministries 1995a:2). Floral and faunal species composition changes as forest stands develop through time after disturbance. Specialist species tend to be more closely associated with early herb/shrub or mature to old seral stages than with intermediate seral stages. However, forest harvesting decreases the amount of old forests as rotations are typically much shorter than the frequency of natural disturbances, and increases the amount of forests of intermediate seral stages. As well, early seral stages are cut short or eliminated by intensive silvicultural practices. As managed forests diverge from natural disturbance regimes, there may be greater risks of reducing biodiversity (B.C. Ministries

1997). The biodiversity management strategy outlined in the Forest Practices Code includes the following key concepts and components:

1. Natural Disturbance Types:

We need to understand the factors that influence and have historically shaped natural landscapes, then apply that knowledge in management. This approach assumes that plant and animal populations are more likely to persist in managed landscapes if natural patterns, processes, and habitat structures are maintained. Features of forested landscapes that are most often maintained after disturbance include irregular stand edges, island remnants, riparian remnants, a variety of successional stages, vegetative species diversity, and vertical and horizontal structural diversity (Bull and Skovlin 1982, Dutilleul 1993, Parminter 1998).

Five natural disturbance types occur in British Columbia, and each type results in a different stand structure (B.C. Ministries 1995a). It is therefore imperative to understand which natural disturbance types occur in the area of concern before biodiversity management options are applied.

2. Maintenance of Habitat Diversity:

Managing for biodiversity is difficult because the impacts of different forest practices on the broad range of species are largely unknown. Certain practices may negatively affect population size and/or distribution of some species, while positively affecting others. Therefore, the guidelines recommend maintaining habitat diversity as a surrogate for maintaining biodiversity (B.C. Ministries 1995a).

3. Structural Complexity:

Vertical and horizontal variability of the vegetative component of a forested stand provides a range of microhabitats and niches available to organisms, thereby allowing for high levels of biological diversity (Bull and Skovlin 1982, Hansen *et al.* 1995).

4. Coarse Woody Debris:

Coarse woody debris (CWD) is defined as sound and rotting downed logs, which serve as reservoirs of organic matter and nutrients on the forest floor. CWD supports a wide variety of organisms associated with decaying wood, and contributes to soil development (Hunter 1990). Many micro-organisms, invertebrates, mosses, lichens, amphibians, reptiles, and mammals are dependent on CWD for all or part of their life cycle. Maintaining this rich source of nutrients and important habitat is an essential aspect of biodiversity management within forest ecosystems.

5. Wildlife Trees:

Wildlife trees are defined as "any standing dead or live trees with special characteristics that provide valuable habitat for the conservation or enhancement of wildlife" (Wildlife Tree Committee of British Columbia 1994:3). Like CWD, wildlife trees are important habitat for many vertebrates, insects, mosses, lichens, and a wide range of micro-organisms. In particular, cavity nesting species are dependent on snags or decaying trees to meet nesting or denning requirements (Thomas *et al.* 1979a, Lundquist 1988, Stevens 1997). Maintaining wildlife trees is also an essential aspect of biodiversity management within forest ecosystems.

Ecological and Management Importance of Cavity Nesting Wildlife

Cavity nesters constitute 30-45% of avian species in most forested stands (Allaye-Chan 1981). Primary cavity nesters such as woodpeckers, sapsuckers, nuthatches, and chickadees are capable of excavating cavities for nesting or roosting sites, shelter, and foraging sites (Miller *et al.* 1979). Once abandoned, these cavities provide habitat for secondary cavity nesters (species not capable of excavating cavities) which include many species of songbirds, owls, bats, and small mammals (Cunningham *et al.* 1980). In this relationship, primary cavity nesters are considered to be keystone species within the forest ecosystem because their presence determines that of many other species (Peterson and Gauthier 1985, Brewer 1994).

Cavity excavations weaken trees, making them more susceptible to breakage or blow-down. Feeding excavations on live trees create openings in the bark, which serve as receptor sites for fungal spores or diseases (Knight 1958, Shook and Baldwin 1970, Machmer and Steeger 1995). This accelerated progression of standing live or dead trees to downed coarse woody debris (CWD) contributes to the accelerated cycling of nutrients while creating additional habitat for species dependent on CWD.

Several cavity nesters are known to feed on forest insect pests, often maintaining insects at endemic levels by delaying the onset of outbreaks or by accelerating their decline (Machmer and Steeger 1995). Throughout British Columbia, periodic outbreaks of bark beetles (*Dendroctonus rufipennis, D. ponderosae, D. pseudotsugae,* and *Dryocoetes confusus*) are responsible for the death of massive numbers of mature spruce, lodgepole pine, Douglas-fir, and subalpine fir, respectively (Machmer and Steeger 1995, Miller 1997). Within the last 20 years, forest insects have become the greatest disturbance agents currently affecting forests in British Columbia (Parminter 1998). This has coincided with increased wildfire suppression and forest harvesting (Parminter 1998). Wildfires can reduce insect populations by burning stands already weakened by insect attacks, which removes the majority of insects while regenerating a young stand that is resistant to insect attack (e.g. lodgepole pine and hybrid spruce stands). Forest practices that have left substantial amounts of slash, debris, and/or stressed trees adjacent to cutblocks provide increased habitat for insects, which has the potential to facilitate population outbreaks. It is, therefore, imperative to maintain the insectivores that have the potential to minimise these outbreaks.

Cavity nesters are of management concern throughout the world as many species have demonstrated population declines or extinction caused by forest management practices. Loss of old-growth forests in southeastern U.S.A. has caused the extinction of the Ivory-billed Woodpecker (*Campephilus principalis*) (Miller 1985), and endangered the Red-cockaded Woodpecker (*Picoides borealis*) (Jackson *et al.* 1979, Porter *et al.* 1985, Kelly *et al.* 1993, Heppell *et al.* 1994). In Sweden the White-backed Woodpecker (*Picoides leucotos*) is close to extirpation and several other species are experiencing serious declines due to habitat loss (Angelstam 1997). The Pileated Woodpecker is used as a management indicator species by the U.S. Forest Service in the Pacific Northwest Region as it is considered vulnerable in intensively managed landscapes (Bull and Holthausen 1993). In Thailand 5 species of cavity nesting hornbills are considered vulnerable to logging impacts, and parrots in Venezuela and Australia have become threatened as a result of habitat loss (Pattanavibool and Edge 1998, H. Phillipps, Australian Bird Research Centre, pers. comm.). In Australia the cavity nesting ringtail possum disappears from forest fragments that are less than 600 ha within a few decades (Laurance and Gascon 1997).

British Columbia Management Strategies for Cavity Nesting Wildlife

The primary concern of cavity nester management is to retain suitable habitat conditions at both the landscape and stand levels. These include current and future wildlife trees, coarse woody debris, and a diverse vegetative species composition. The conservation of wildlife trees in managed stands faces many impediments, including: 1) the Workers' Compensation Board requires that all snags or leaning trees adjacent to logging or silviculture work areas be removed to reduce safety hazards; 2) old-growth stands, where snags are typically most abundant, are being rapidly removed from managed forest landscapes; 3) new processes for using dead wood, and a diminishing timber supply, have encouraged the removal of snags for economic reasons (Allaye-Chan 1981, Lousier 1989); 4) stand rotation ages are usually too short to maintain sufficient numbers of large snags in managed forest landscapes (Thomas *et al.* 1979a, Lousier 1990) and: 5) snags are commercially and privately harvested for use as firewood (Miller 1985, Lousier 1989, Miller 1997).

The Forest Practices Code Biodiversity Guidebook (B.C. Ministries 1995a) recommends 4 methods of maintaining wildlife trees at the stand level: 1) create wildlife trees, 2) retain individual wildlife trees, 3) retain wildlife tree patches, and 4) retain wildlife trees within riparian management areas.

Creating Wildlife Trees

The most common technique recommended for creating artificial wildlife trees in conjunction with forest operations is to use the feller-buncher to cut trees as high as can be reached safely. Maximum allowable heights for dead trees must be in accordance with Worker's Compensation Board regulations (BC Ministries 1995a). Studies have shown that only a few species use these short stubs (e.g. White-headed Woodpecker, Northern flicker, and chickadees) (Gyug 1996, Wildlife Tree Committee 1994). Explosives have also been used to remove the tops of trees. Trees treated in this manner may also be inoculated by fungal spores to accelerate the decay process in heartwood (Bull and Partridge 1986, Bull *et al.* 1981). This method causes snags to develop characteristics that are selected for by cavity nesting species; however, these studies have also shown that many years are required for the wood to soften and become a suitable substrate for cavity excavation. Herbicides and girdling have also been used in combination with fungal inoculation to kill trees and accelerate the creation of wildlife trees (Conner *et al.* 1981, McComb and Rumsey 1983, Parks *et al.* 1995). Cavity nester responses to these treatments have been variable. Frequently, nest boxes are provided in areas where bird populations have experienced a decline. Nest boxes are often effective for secondary cavity nesters, but not for primary cavity nesters (Lousier 1989).

All references mentioned above indicate that artificial wildlife trees and nest boxes are insufficient for meeting sustainable habitat objectives for cavity nesters, but are useful in supplementing other methods of habitat retention.

Single Tree Retention

Single live trees are retained within the cutblock, with preference usually given to deciduous trees or trees exhibiting characteristics of a valuable recruitment wildlife tree. These trees serve as a seed source for forest regeneration, and provide current and future wildlife trees. Retaining individual wildlife trees has 2 important limitations as a management strategy for maintaining primary cavity nester populations within forest landscapes. First, the trees alone may not provide other habitat requirements, such as stand structure and feeding substrate. Second, individual trees may be vulnerable to windthrow. For these reasons, patch retention is becoming more common in British Columbia.

Tree Patch Retention

The composition of tree species, stand density, and wildlife tree density within a patch should be representative of the surrounding stand. A range of tree diameters, including the upper 10% of the diameter distribution, of both live and dead trees of all decay classes, and trees with evidence of heart rot or wildlife use should be retained. Recommendations for methods and levels of retention are based on the percentage of the proposed block available for harvesting, the percentage of the biogeoclimatic subzone within the landscape unit, and the level and distribution of existing and planned harvesting in the surrounding landscape. Suggested locations of wildlife tree patches are in inoperable or protected areas such as riparian zones, gullies, wet areas, rocky outcroppings, meadow openings, and clumps of deciduous or unmerchantable timber. The maximum allowable distance between patches is 500m.

The wildlife tree patch retention strategy has several advantages over other retention methods. Both live and dead trees are retained, providing current as well as future wildlife trees. Snags within forested reserves are more windfirm, and the surrounding tree buffer also serves to protect timber harvesting or silvicultural crew members working around the patch. Clumps of trees also provide wildlife with greater foraging opportunities and better protection from predators and adverse environmental conditions (B.C. Ministries 1995a).

Tree Retention in Riparian Management Areas

A riparian zone is the transition zone from upland to aquatic ecosystems, identified by the presence of vegetation that requires free or unbound water or conditions that are wetter than normal (Thomas *et al.* 1979b, Naiman *et al.* 1993). The Biodiversity Guidebook (B.C. Ministries 1995a) assumes that up to 50% of recommended wildlife tree patches will be located in mandatory riparian management areas in the interior of British Columbia. In coastal British Columbia, this figure is 75%. In 1997 a directive was given allowing 100% of wildlife tree patch requirements to be met within riparian management or other constrained areas, provided the patches meet Guidebook requirements (Allen and Doyle 1997). The assumption is that viable populations of wildlife can be sustained within managed landscapes by concentrating residual habitat in areas that are already being reserved for other purposes.

BRITISH COLUMBIA MANAGEMENT STRATEGIES FOR RIPARIAN AREAS

Riparian zones have integral roles in ecological health and function because of their abundance of resources such as water, nutrients and often highly productive soils. Vegetative communities along streamsides provide channel stability, structural and biological diversity, large woody debris for fish habitat, temperature buffering, and filtering and absorption of water by tree roots (Thomas *et al.* 1979a, Naiman *et al.* 1993, Knopf and Samson 1994). Riparian ecosystems reduce erosion and decrease the possibility of siltation, which may negatively affect fish spawning habitat (Stevens *et al.* 1995). Riparian areas typically have a unique microclimate characterised by higher humidity, increased rates of plant transpiration, more air movement, and shade. As well, "stream corridors connect and interface with other ecosystems and may facilitate a high level of ecological and genetic exchange" (Spackman and Hughes 1995:325). While riparian areas represent a small proportion of the land base, they are often a critical source of higher plant, animal, and structural diversity within a community.

The riparian management area (RMA) guidelines of the Forest Practices Code (B.C. Ministries 1995b) provide recommendations for delineating RMAs surrounding lakes, streams, and wetlands. RMAs include a management zone, 0 to 100 m wide, where harvesting is restricted to single tree selection, group selection, and other low impact silviculture treatments approved by the forest district manager. Where required by regulation, RMAs also include a reserve zone adjacent to the water body, 0 to 50m wide, where timber harvesting is prohibited. The widths of these zones depend on the stream, lake, or wetland classification. Streams are classified based on width, gradient, slope of bank, fisheries classification, and community watershed association. Lakes are classified based on size, fish species assemblage and surrounding biogeoclimatic zone. Wetlands are classified based on size, whether it is a simple wetland or a wetland complex, and surrounding biogeoclimatic zone.

The RMA guidelines also make recommendations for minimising the risk of windthrow and for retaining important wildlife habitat attributes such as wildlife trees, coarse woody debris, food, shelter and cover.

Cavity Nesting Wildlife and Riparian Habitats

Most studies have found forest bird diversity and abundance to be higher in riparian than upland zones (Stauffer and Best 1980, Emmerich and Vohs 1982, Gates and Giffen 1991, LaRue *et al.* 1995, Kinley and Newhouse 1997). In other forested landscapes, however, researchers have reported higher bird diversity in upland zones (McGarigal and McComb 1992) or no difference in diversity between zones (Hooper 1991, Croonquist and Brooks 1993, Murray and Stauffer 1995). Most studies that examine bird diversity focus on passerine birds; information concerning the use of riparian zones by cavity nesting species is rare.

CAVITY NESTER HABITAT CHARACTERISTICS

Many studies have sought to describe the communities of cavity nesters, and determine the specific habitat requirements of individual species. The activities most extensively studied are foraging, territorial displays, and nesting. Features considered to be important that have been examined in relation to these activities include wildlife tree density, dispersion, and characteristics (level of decay, diameter, height, species, bark loss, limb and top condition); percentage of canopy cover; percentage and composition of ground cover; amount and size of CWD; distance to edge or opening; and presence of scanning perches (Mannan *et al.* 1980, Allaye-Chan 1981, Zarnowitz and Manuwal 1985, Bull 1987, Lundquist 1988, Harestad and Keisker 1989, Linder 1994, Raphael and White 1984). While many researchers have speculated on the habitat requirements of primary cavity nesters specific to the ecosystem within which the study was conducted, it is generally accepted that, to persist within an area, most primary cavity nesters require large diameter trees with some level of decay for excavating cavities and an adequate food source.

Summary

There is a need for field information to substantiate the recommended habitat retention strategies for maintaining biodiversity in Sub-Boreal Spruce (SBS) landscapes (Meidinger and Pojar 1991) of central interior BC. This study responds to those needs by examining the residual habitat strategies and wildlife tree recommendations contained within the Biodiversity Guidebook and Riparian Management Area Guidebook of the Forest Practices Code (B.C. Ministries 1995a,b). The underlying assumption of these recommendations is that retaining structural habitat components throughout the management cycle will maintain viable wildlife populations and overall biodiversity in landscapes managed for timber production. In this study I used extensive habitat surveys to assess how primary cavity nesters use riparian and upland zones within managed SBS landscapes. I investigated whether any habitat relationships occurred exclusively in either riparian or upland zones. This approach provided a basis to evaluate whether the predominant allocation of wildlife tree patches to mandatory riparian reserves is a promising approach for maintaining viable populations of cavity-nesting species.

OBJECTIVES AND HYPOTHESES

The study objectives were:

1. **Determine the species composition and relative abundance of cavity nesters in riparian and upland zones within unharvested SBSmk1 stands.**

Information about primary cavity nester habitat relationships is lacking for SBS forests of British Columbia. These forests are characterised by a unique combination of tree species and cavity nesting species; therefore, it can not be assumed that results found in different ecosystems can be applied to SBS forests. I identified the species of primary cavity nesters that occurred in riparian and upland zones, and compared their frequencies between zones. The null hypothesis was:

H_0: Observed frequency of primary cavity nesters between riparian and upland zones does not significantly differ from expected frequency based on the relative proportions of the 2 zones. There is no evidence of selection between these categories.

Where H_0 was rejected, I analysed the data to identify preferences among zones by examining differences in stand characteristics [tree species, health, diameter-at-breast-height (DBH), decay class, insect presence, wildlife tree density].

2. Characterise primary cavity nester foraging and nesting activities in relation structural habitat features. Determine whether any activities or habitat features are exclusive to riparian or upland zones.

I identified how primary cavity nesters use different structural habitat features such as live trees, snags, tree species, etc. I characterised these structural features by species, size, condition, decay class, and other attributes, and identified characteristics that explain their use by primary cavity nesters. Having described the distribution of structural habitat features and primary cavity nester activities within SBS forests, I identified whether certain habitat features and/or activities were exclusive to riparian or upland settings. The first null hypothesis was:

H_{01}: The types and frequency of activities observed in riparian zones are not significantly different from those in upland zones.

If H_{01} was rejected, then H_{01a}: No primary cavity nester activities are exclusive to either riparian or upland zones.

If H_{01a} was rejected, then H_{01b}: Primary cavity nester activities observed exclusively in riparian or upland zones can not be explained by the distribution of specific structural habitat features associated with those activities.

The second null hypothesis was:

H_{02}: No significant differences in physical and biological attributes exist between the population of structural habitat features used by primary cavity nesters and the population of structural habitat features at large. There is no evidence of selection of structural habitat features.

If H_{02} was rejected, then I identified the physical and biological attributes that help explain significant amounts of variation in primary cavity nester activity.

3. Based on findings from objectives 1 and 2, frame hypotheses for future experimental research to test predicted primary cavity nester responses to different SBS forest harvest scenarios in which riparian area and biodiversity guidelines are applied.

Three response scenarios are possible for cavity nesters. These possibilities can be framed as the following hypotheses:

H_{01a}: Home range size remains unchanged after harvest. Primary cavity nesters are able to conduct all essential activities within the residual forest that remains in their home ranges post-harvest. Activities shift to the places where residual forest remains (riparian areas, wildlife tree patches, etc.), but there are no significant changes in home range size or location. It is likely that viable populations will persist in treated landscapes.

H_{01b}: Home range changes after harvest. Primary cavity nesters are not able to conduct all essential required activities within the residual habitats that remain within their home ranges post-harvest. However, they are able to persist within the general area by enlarging their home ranges or by shifting home range boundaries to compensate for the loss of forested areas. It is likely that viable populations will persist in treated landscapes, although possibly at reduced densities.

H_{11b}: Primary cavity nesters do not persist after harvest. Primary cavity nesters are not able to conduct all essential activities within the residual habitat that remains post-harvest. They abandon their home ranges, and are no longer seen in the area. It is unlikely that viable populations will persist in treated landscapes.

STUDY AREA

The study area consists of old-growth forest stands in the Mossvale Moist Cool variant of the Sub-Boreal Spruce biogeoclimatic zone (SBSmk1) (DeLong *et al.* 1993), located north-west of Prince George, between 53°30' and 55°45' north, and 123°00' and 126°00' west (Fig. 1). Five study sites that met the following criteria were selected: accessible by road or foot; presence of lakes and streams; and dominated by old forest (age class 8: 200-250 years).

The SBSmk1 variant was selected because it is considered representative of the sub-boreal climate, it is one of the largest subzones within the SBS, and it is under heavy harvest pressure (DeLong *et al.* 1993). This variant is characterised by relatively long, snowy winters and moist, cool summers. The climate is influenced by prevailing westerly winds off the Pacific Ocean, with occasional periods of Arctic air in the winter. The mean annual temperature is 3.3°C. Monthly averages range from -12°C in January to 14°C in July. The mean annual precipitation of 621mm, of which 63% falls as snow, is relatively evenly distributed throughout the year. Snow normally covers the ground from mid-November to late April.

The topography is generally flat with a few gently rolling hills. The elevation ranges from 750m to 1070m. The SBS forests consist primarily of hybrid white-Engelmann spruce (*Picea glauca x engelmannii*) (hereafter referred to as hybrid spruce) and subalpine fir (*Abies lasiocarpa*), with extensive successional stands of lodgepole pine (*Pinus contorta*) and trembling aspen (*Populus tremuloides*) caused by recurrent disturbances (MacKinnon *et al.* 1992, DeLong *et al.* 1993).

Logging, mainly clearcutting, has replaced large-scale fires as the second main source of disturbance in these forests (insect attack is the primary source of disturbance) (Parminter 1998). Clearcutting leaves a landscape mosaic of even-aged, single-layered stands that will be $\leq$ 80 years of age, the standard length of a managed rotation.

The primary cavity nesters I observed include the Hairy Woodpecker (*Picoides villosus*), Three-toed Woodpecker (*P. tricactylus*), Black-backed Woodpecker (*P. arcticus*), Pileated Woodpecker (*Dryocopus pileatus*), Northern Flicker (*Colaptes auratus*), Red-breasted Sapsucker (*Sphryapicus ruber*), Red-breasted Nuthatch (*Sitta canadensis*), Black-capped Chickadee (*Parus atricapillus*), and Boreal Chickadee (*P. hudsonicus*).

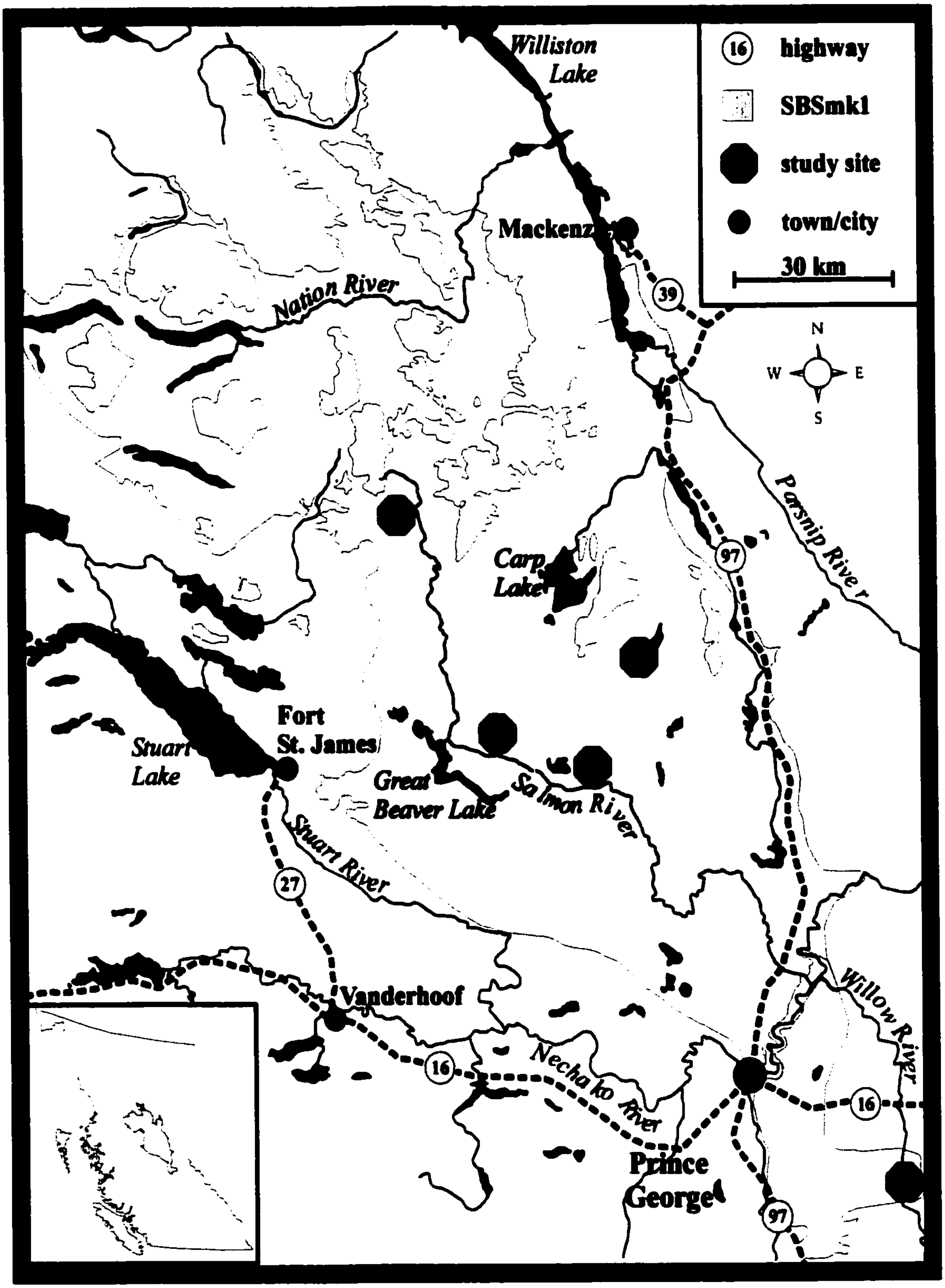


Figure 1. Study site locations within the Sub-boreal Spruce mk1 biogeoclimatic subzone of the Prince George Region.

METHODS

Sampling Strategy

During the 1996 woodpecker breeding season, I intensively sampled study site 1 (Fig. 1), using point-count and call play-back surveys to locate primary cavity nesters, with the intent of radio-tagging individuals to monitor habitat use patterns. Sample stations in the riparian zones were within 20m of a lake or stream edge, and stations within upland zones were ≥ 200m from riparian zones.

Three-toed Woodpeckers were selected for radio-tagging because they have large home-range sizes, are primary cavity-excavators, and are more abundant within the Prince George Region than Pileated, Black-backed, and Hairy Woodpeckers. My attempts to capture Three-toed Woodpeckers were unsuccessful; therefore, I switched to an extensive habitat assessment approach in late summer, 1996 and April-August, 1997.

I expanded the study area to include 4 additional replicate sites. To examine evidence of habitat use patterns between riparian and upland zones, I sampled 16 plots in each zone at each site. I recorded attributes of all live and dead trees with and without evidence of primary cavity nester use. Due to the low density of cavity trees found, I also conducted cavity surveys over a much larger area to sample trees used for cavity excavations. I examined the frequency of "used" relative to "available" trees in each zone to determine whether cavity nesters selected one zone over another.

Primary Cavity Nester Sampling

Point Count Surveys

Sampling Design

In study site 1, surveys were conducted early May to late July, 1996, to coincide with the breeding season, when birds are easily detectable from territorial drumming and calls. The first point count station on each transect was located randomly, with subsequent stations systematically located every 300m along a transect within upland zones, and parallel to shorelines within riparian zones. The distance between stations was based on the approximated auditory range of primary cavity nester calls or drummings. Transects were also spaced a minimum of 300m apart to avoid overlap between transects. One visit was made to each of the 18 stations within each zone. To avoid sampling bias, surveys were not conducted on days with rain or strong winds as these conditions decrease bird detectability.

Procedures

At each station I allowed one minute of silence, and then recorded all observations of primary cavity nesters detected within a 75m radius for 10 minutes. I recorded the species, age group (adult or juvenile), and sex of the individual when possible, approximate distance and compass bearing from observer to bird, and observation type (visual, call, drum, forage, nest site, etc.). Surveys were conducted from 0.5 hour after sunrise until 5.5 hours after sunrise, when birds are most vocal (Steeger and Machmer 1994).

Other Sources of Data

Ken Parker, a post-doctoral fellow at the University of Northern British Columbia, conducted 86 point count stations between 1995 and 1997, in forests of the same area, biogeoclimatic subzone, and age class (Fig. 2). The number of visits to each station ranged from 3 to 5 and several stations were surveyed in 3 consecutive years

Data Analysis

I examined distribution graphs of species diversity and abundance by zone in study site 1. To obtain a sample size adequate for statistical analyses, I combined my data with Ken Parker's data, resulting in a total of 122 stations. This enabled me to test for differences in the number of primary cavity nesters between zones using *G* tests of goodness of fit, with Williams' correction for continuity (Sokal and Rohlf 1987):

$$G = 2\sum^{a} f_i \ln (f_i / f'_i)$$

where f_i = observed values, and f'_i = expected values

Williams' correction for continuity: $q = 1 + 1/\{2(n)\}$; $G_{adjusted} = G/q$

I used the number of stations sampled as the basis for calculating the expected frequency of cavity nesters. Because the number of visits to each site was variable, I used species presence or absence at each station to estimate total occurrence of cavity nesters.

Assumptions and Limitations

The point count technique requires several assumptions: 1) the probability of a species or individual calling or drumming is equal between riparian and upland zones; 2) the

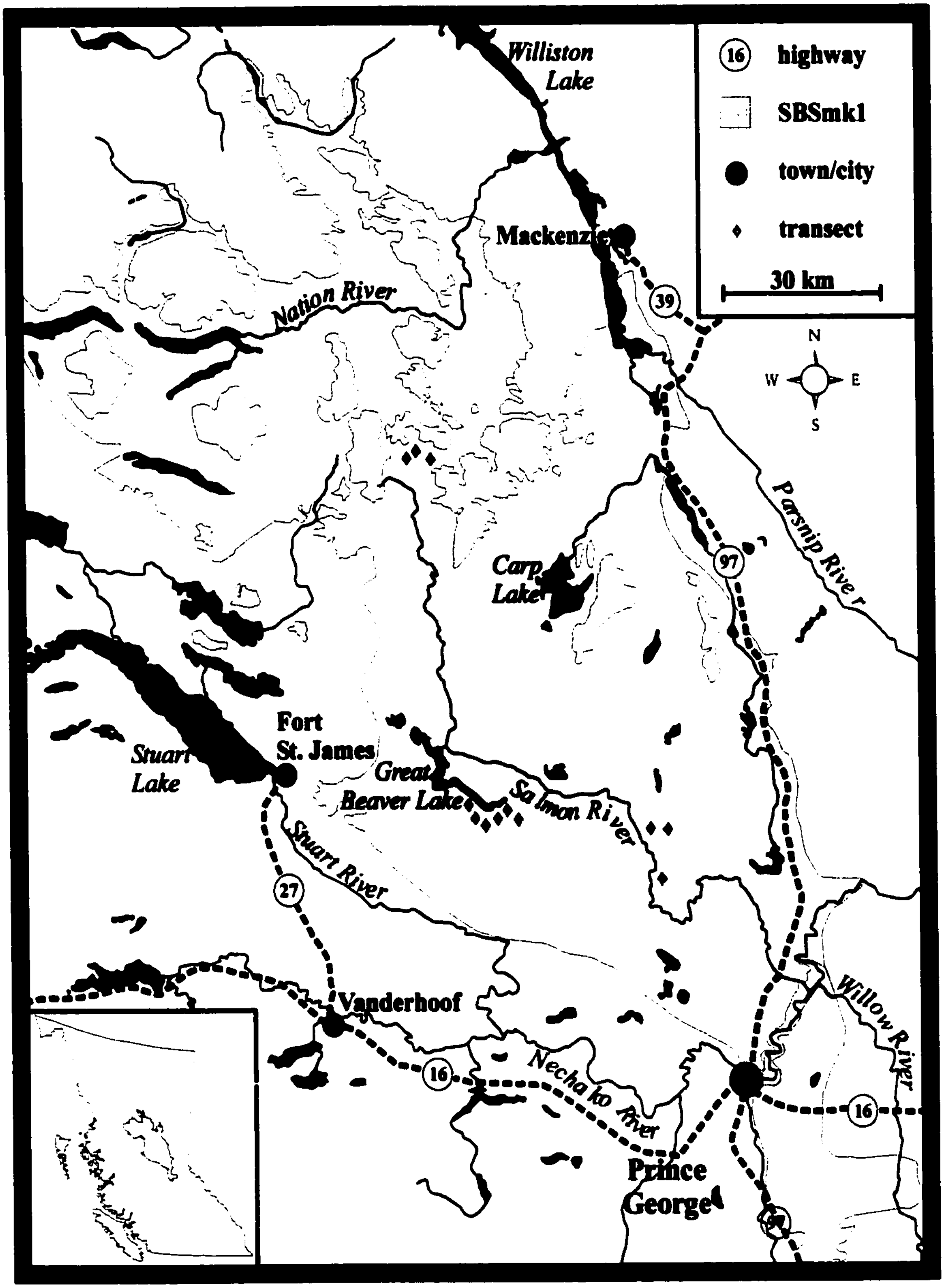


Figure 2. Point count transect locations within the Sub-boreal Spruce mk1 biogeoclimatic subzone of the Prince George Region, 1995-1997. (K. Parker, unpublished data)

probability of calling or drumming is equal between sampling days; and 3) each record indicates a separate individual (i.e. there is no duplication of detections).

Limitations to the point count method are: 1) estimates of absolute density are not obtained due to the irregular frequency of vocalisations observed; however, relative densities between riparian and upland zones can be compared; 2) detection levels may differ between species depending on the volume of their calls or drums; however relative detections between zones can be compared.

Call Play-Back Surveys

The call play-back method is more effective for locating individuals of low density and wide-ranging populations (Steeger and Machmer 1994). Call play-back sampling maximises the observer's ability to detect individuals by soliciting an anti-competitor response, such as territorial calls or approach. This method works well for the Pileated, Black-backed, and Three-toed Woodpeckers.

Sampling Design

I conducted call play-back surveys at the same stations as the point count surveys, but on different days, to compare results between the 2 survey methods. Play-backs were conducted within 4 days before or after point counts. One visit was made to each of the 18 stations completed in each of the riparian and upland zones.

Procedures

At each station I listened and visually scanned the area one minute before playing the calls. Taped territorial calls of the Red-breasted Sapsucker, Three-toed Woodpecker, Black-backed Woodpecker, Hairy Woodpecker, and Pileated Woodpecker were played. This order, smallest to largest bird, was used to avoid competitor interactions, which may inhibit the response or activity of the smaller species. Each species call was broadcasted in 3 directions 120 degrees apart, 30 seconds apart. One minute separated the calls of different species. Observations were recorded as described in the Point Count section. Where several sightings occurred I performed systematic nest searches over an area of 100 m^2. All trees with cavities were checked for nesting activity by knocking the trunk in attempt to flush adult birds.

Data Analysis

I constructed graphs of primary cavity nester diversity and abundance and visually inspected these to compare call play-back and point-count survey results. *T* tests of significance for differences in mean number of primary cavity nester detections between survey methods and between zones were conducted.

Assumptions and Limitations

The call play-back method requires the following assumptions: 1) there is an equal likelihood of response between riparian and upland zones; and 2) observations at each station are of different individuals than those detected at the previous or adjacent stations.

Limitations to the call play-back method are: 1) dominance interactions between similar-sized species may confound the detectability of some species; 2) large areas must be surveyed in order to obtain an adequate sample size; 2) there is a lower response rate during the incubation period, which varies considerably between years and between mating pairs, than when territories are being established and mating occurs, and; 3) the anti-competitor response potentially displaces the individual from its normal activity, resulting in biased observations of habitat use patterns.

Radiotelemetry

I attempted to employ radiotelemetry to examine habitat use, activities, home range size, and production of adult Three-toed Woodpeckers.

Sampling Design

To trap adult woodpeckers, a predictable flight path should be located. The most obvious flight path is to and from an active nest; therefore, I tried to locate nests by following individuals that responded to a call play-back or by walking transect lines and listening for the begging calls of juveniles within cavities. These calls occur continuously at age 2-3 weeks.

Procedures

I attempted to capture adults during the first 2 weeks in June, 1996 and 1997, when their young were approximately 2 weeks old. At this time the adults will not abandon the nest after capture, and the juveniles are old enough that they can miss a feeding (Bull and Pederson 1978). Three methods of capture were tried:

1) I secured a plastic bag around a fishing net frame that was attached to an extendible pole. This device was placed over nest cavities to capture exiting adults. Other researchers most often recommended this technique as it was the least disruptive to the birds (Goggans *et al.* 1989, E. Walters, Florida State University, pers. comm.).
2) A bal cha-tri trap with suet bait was placed on the end of the extendible pole near the nest entrance. The bal cha-tri trap consisted of a 20x20x8-cm wire mesh cage; nooses of fishing line covered the upper surface for capturing birds by their feet. Beef fat was placed within the cage, which was fastened to the extendible pole and placed

approximately 10 m below active nest cavities. This trap was used for 4 consecutive days under constant surveillance.

3) In April, 1997,I attempted to use mist-nets suspended in front of suet feeders, which has successfully been used to capture woodpeckers (Goggans *et al.* 1989). First, however, I suspended the feeders between 2 trees, beyond the reach of non-target species such as pine marten (*Martes americana*). I placed motion detector cameras in front of the feeders to determine their possible use by woodpeckers. The feeders were left undisturbed for 2 weeks to allow individuals to become conditioned to the sites, and to allow the camera to document activity during this time period. If Three-toed Woodpeckers were documented using the feeders, mist-nets would have been suspended in front of the feeder for capture purposes.

HABITAT AVAILABILITY AND USE SAMPLING

Habitat Assessment Plots

Sampling Design

At each of the 5 study sites, 16 plots in each of the riparian and upland zones were examined for evidence of use by primary cavity nesters in each zone, for a total of 160 plots. The first plot was randomly located, and subsequent plots were systematically located every 200m along the transect (Fig. 3). To minimise sampling bias, riparian and upland plots were located relatively close together so that primary cavity nesters would likely have equal access to either zone. This reduced the possibility of sampling where cavity nesters were present in one zone, but absent in the other. Equal sampling effort was expended in interior and edge

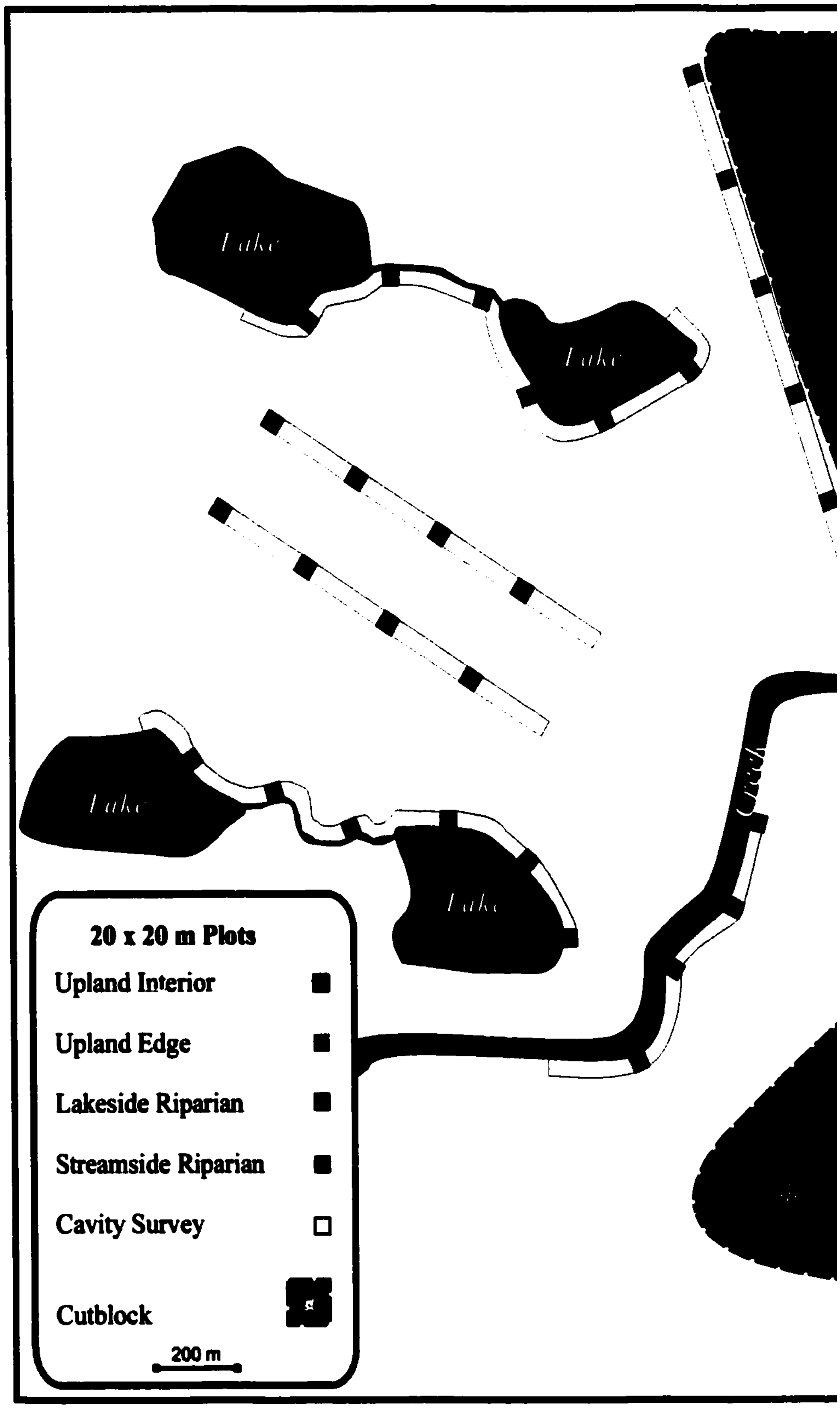


Figure 3. Habitat sampling design for each study site within the SBSmk1 biogeo of the Prince George region, 1996-97.

upland zones, and lakeside and streamside riparian zones, also to minimise sampling bias. Upland edge zones were sampled within forested stands adjacent to large openings, typically clearcuts, and upland interior zones were sampled ≥ 200m from an opening or from riparian zones. Most streamside riparian plots were adjacent to fish bearing streams up to 5m wide.

Procedures

Within each 20 x 20 m (0.04 ha) plot I recorded the following attributes for all live and dead trees greater than 12.0 cm in diameter: tree species, decay class, bark class, DBH, tree health, percent live crown, lean angle, signs of primary cavity nester habitat use, and evidence of insect or fungal invasion. Classifications for decay and bark presence followed provincial government standards (Resource Inventory Committee, 1997). Data forms and descriptions of the variables are included in Appendix A and B.

Habitat Availability Analysis

I graphically examined the species composition and mean density of all trees recorded, by zone and site, to characterise patterns of variation.

Because of the non-normal distribution of the data, I used nonparametric G tests of goodness of fit with Williams' correction for continuity to test for differences in abundance of each tree species between sites and zones that may not have been detected using the parametric nested Analysis of Variance (Zar 1996).

A nested Analysis of Variance was conducted to test for differences in mean DBH (which was normally distributed) of each dominant tree species between sites and between zones nested within sites. Because the data were random, not discrete, the F-ratio of the main factor was re-calculated:

$$F\text{-ratio} = \text{mean square of main factor} / \text{mean square of nested factor}$$

Habitat Use Analysis

Evidence of 4 categories of use were identified and examined separately: 1) Flaked bark and shallow excavations (1-2cm wide and deep) indicated foraging for bark beetles, grubs, and other insects by Three-toed Woodpeckers, Black-backed Woodpeckers, Hairy Woodpeckers, and Pileated Woodpeckers. 2) Large excavations ($\geq$4 cm wide and deep) indicated winter foraging by Pileated Woodpeckers on carpenter ant colonies (*Camponotus* spp.). 3) Sapwells typically indicated foraging by Red-breasted Sapsuckers on sap, although Three-toed Woodpeckers, Black-blacked Woodpeckers, and occasionally Hairy Woodpeckers have also been observed feeding on sap (Villard 1994). 4) Cavity excavations indicated nesting or roosting sites for all cavity nesters.

To test for differences in the number of "used" relative to "available" trees between zones, I first transformed the data to represent the proportion of total trees used. Because proportional data tend to follow a binomial distribution rather than a normal distribution, the square root of each proportion was transformed to its arcsine (in degrees) using a slight modification of the Freeman and Tukey transformation, which is preferable when proportions are small or large (Zar 1996):

$$p' = \tfrac{1}{2}[\arcsin (X/n+1)^{0.5} + \arcsin \{(X+1)/(n+1)\}^{0.5}]$$

The purpose of the transformation was to normalise the underlying distribution. The negatively-skewed histograms and boxplots of the arcsine-square-root-transformed proportions of total trees used for foraging, the non-linear normality plots, and results from the Kolmogorov-Smirnov normality tests (K-S $Z(563) = 10.367$, $p < 0.001$) all indicated that a normal distribution was not achieved by transforming the data (Appendix C). Therefore, for each category of use that was of sufficient sample size, the nonparametric *G* test of goodness of fit was applied to determine whether the proportion of total trees with evidence of use differed between zones for each tree species. I also conducted *G* tests of goodness of fit with 95% Bonferroni Confidence Intervals to determine which species were being selected for use.

I examined tree characteristics, including DBH and decay class distribution, and insect presence, for which relationships to primary cavity nester habitat selection have been documented (Mannan *et al.* 1980, Allaye-Chan 1981, Zarnowitz and Manuwal 1985, Lundquist 1988, Harestad and Keisker 1989, Bull and Holthausen 1993, Linder 1994, Raphael and White 1984). I prepared distribution graphs of these variables for each category of use. I visually inspected the graphs to compare characteristics associated with trees exhibiting evidence of use to characteristics of trees available for use between zones.

Assumptions and Limitations

I assumed that internal validity was maintained, i.e. the sample plots provided data representative of the characteristics of the study site. I also assumed that external validity was maintained, i.e. the data from the 5 study sites were representative of most SBSmk1 old-growth stands.

Limitations to using the habitat assessment plots to determine primary cavity nester habitat use patterns were: 1) I could record use only where evidence was visible. Several activities could not be documented as they do not leave visible signs of use; for example, territorial drumming, perching, and any activities that may occur in dense foliage or high in the tree. 2) Frequency of use was not quantified. On many occasions I encountered trees that had obviously been used repeatedly for foraging; however, only use or no use was recorded. This could limit my ability to detect potential differences in intensity of use between zones. 3) I was unable to determine the time period when the use occurred; i.e., a cavity or sapwell may have been used 1 year ago or 10 years ago. This limitation required that the data be considered as an historical account of habitat use as opposed to current habitat use. 4) My estimation of insect presence was limited to visible evidence at the base of the tree, therefore it was likely that I underestimated this variable, however a relative measure of presence between zones was available using this method.

Cavity Surveys

Sampling Design

Cavity surveys were conducted within as well as between habitat assessment plots. This enabled the use of habitat plots as a surrogate sample of habitat characteristics available to primary cavity nesters. Each survey transect between plots sampled a 20m by 200m area.

Procedures

Two observers walked 10m apart (side by side) along the transect, searching all trees within 5m on each side for cavities. For each cavity tree I recorded the same variables as for the habitat assessment plots. I also recorded approximate height and diameter of the cavity, distance along the transect line, and number of cavities in the tree.

Data Analysis

Density of available trees was estimated from the habitat plot data. Graphs of the density of inactive cavities and of the density of available trees were compared between zones. Because not all trees can be considered available for cavity excavation, I examined the ranges of key characteristics of trees that were actually used for cavity excavation so as to refine my availability estimates to those meeting the basic requirements of cavity nesters. Key characteristics were those which are most widely accepted as influencing cavity tree selection: decay class and DBH (Allaye-Chan 1981, Bull 1987, Lundquist 1988, Harestad and Keisker 1989, Raphael and White 1984). Statistical analyses to test for significant differences in abundance of used relative to available trees between zones were not appropriate because tree availability was only approximated.

I graphically compared rates of insect presence in cavity trees relative to available trees between zones.

Assumptions and Limitations

I assumed that the densities of trees available within plots are representative of availability between plots, where cavity surveys were conducted. One limitation to this analysis was that the estimated number of available trees was likely higher than the number of trees truly suitable for cavity excavation. Keisker (1995) characterised suitable trees as having hard outer wood surrounding decay-softened inner wood, as well as trees with outer and inner wood softened by decay. I did not examine inner wood for decay and, therefore, was not able to assess availability based on these recommendations.

RESULTS

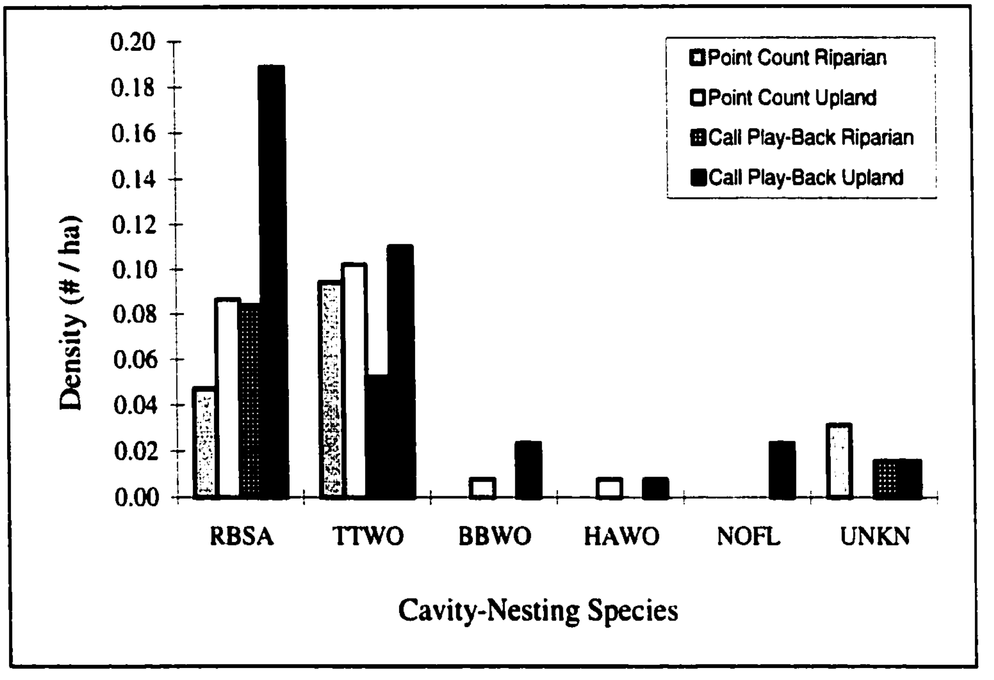
Primary Cavity Nester Observations

Point Count and Call Play-Back Surveys

Three-toed Woodpeckers and Red-breasted Sapsuckers were the most abundant species detected in study site 1, and Black-backed Woodpeckers, Hairy Woodpeckers, and Northern Flickers were detected at very low densities (Fig. 4). There were significantly more detections using call play-back than point count surveys, $t(34) = -2.504$, $p = 0.017$. I combined my point count data with Ken Parker's data to obtain a larger sample size of 122 stations, with 377 visits. A total of 131 primary cavity nester detections resulted, including 6 different species (Red-breasted Nuthatches plus the 5 previously mentioned primary cavity nesters) (Table 1). There was no difference in cavity nester abundance between riparian and upland zones, $p = 0.902$ (Table 2). For each of the 3 most abundant species (Red-breasted Sapsucker, Red-breasted Nuthatch, and Three-toed Woodpecker), there was no significant difference in abundance between zones. Black-backed Woodpeckers occurred exclusively in upland zones. The sample sizes for Northern Flickers and Hairy Woodpeckers were too small for comparisons. Abundance for all species combined was also compared between zones for each of the 3 survey years, and no significant differences were found.

Radiotelemetry

Difficulties with trapping prevented me from radio-tagging woodpeckers for the purpose of monitoring habitat use patterns. The first method, the net-pole trap, was unsuccessful because most nests found were higher than the pole could reach (>10 m). Likewise, my attempts to locate nests from the begging calls of the young failed to facilitate



* RBSA = Red-breasted Sapsucker; TTWO = Three-toed Woodpecker; BBWO = Black-backed Woodpecker; HAWO = Hairy Woodpecker; NOFL = Northern Flicker; UNKN = Unknown

Figure 4. Comparison of mean density of cavity nesting species between survey methods and zones in study site 1 of the SBSmk1 biogeoclimatic subzone. British Columbia, 1996-97 (n = 18 survey stations per zone and survey type).

Table 1. Number of primary cavity nesters observed during point count surveys in the SBSmk1 biogeoclimatic subzone, British Columbia, 1995-97.

Source	Habitat Type	Number of Stations	*BBWO	HAWO	NOFL	PIWO	RBNU	RBSA	TTWO
K. Zimmerman	Riparian	18	0	0	0	0	2	6	10
K. Parker	Riparian	25	0	0	2	0	8	7	5
	Total Riparian	**43**	**0**	**0**	**2**	**0**	**10**	**13**	**15**
K. Zimmerman	Upland	18	1	1	0	0	3	11	13
K. Parker	Upland	61	8	0	0	0	33	11	10
	Total Upland	**79**	**9**	**1**	**0**	**0**	**36**	**22**	**23**

* BBWO = Black-backed Woodpecker; HAWO = Hairy Woodpecker; NOFL = Northern Flicker; PIWO = Pileated Woodpecker; RBNU = Red breasted Nuthatch; RBSA = Red breasted Sapsucker; TTWO = Three-toed Woodpecker

Table 2. Number of primary cavity nesters observed during point count surveys by zone for the 3 main species and for each survey year in the SBSmk1 biogeoclimatic subzone, British Columbia, 1995-97.

	Riparian Zone		Upland Zone			
	Number of Visits	Number of Observations	Number of Visits	Number of Observations	Goodness of Fit G-test Statistic	P
All Observations Combined	114	40	260	91	0.000	0.989
Red-breasted Nuthatch	114	10	260	36	1.750	0.186
Red-breasted Sapsucker	114	13	260	22	0.697	0.404
Three-toed Woodpecker	114	15	260	23	1.366	0.242
1995: (All species combined)	8	6	29	9	2.490	0.114
1996: (All species combined)	32	21	171	75	2.451	0.117
1997: (All species combined)	74	13	60	7	0.770	0.380

trapping of adults because they were no longer entering the cavity at this stage. Perched at the edge of the cavity to feed the young, the adults flew away the instant the net pole moved.

Woodpeckers were not attracted to suet placed in the bal cha-tri traps, probably because natural foods were abundant and available to them while this method was used (June).

The bait and mist-netting technique was also unsuccessful at capturing woodpeckers. No camera detections were recorded during the 2 weeks the suet feeders were suspended, and there was no evidence of activity at the feeders. Failure of the feeders to attract woodpeckers prevented me from using mist-nets for capture purposes.

Home Range Sizes

Although I was unable to trap individuals, information on home range sizes was pertinent to the study. I therefore examined reported home range sizes of primary cavity nesters in other ecosystems, for some of the species that occur in the SBSmk1. All home range sizes were calculated using the minimum convex polygon technique, using either 95 or 100% of the locations. Where multiple home range size estimates were available, I calculated the means. I assumed that average home range sizes across different geographical locations are similar to home range sizes in the SBSmk1. Mean home range sizes ranged from 478 ha to 2310 ha (Table 3).

Several factors that may have influenced home range size, possibly resulting in biased estimates were identified. 1) Information about the forested area available to the radio-tagged individuals was not always given. 2) The radio-tags for primary cavity-nesters are small, transmitting for only 3 months to one or two years. As a result, radio-locations had to be taken more frequently and, therefore, were not independent as they were typically taken

Table 3. Reported home range sizes of primary cavity nester species that commonly occur in the SBSmk1 biogeoclimatic subzone, British Columbia.

Cavity-Nesting Species	Home Range Size (ha)	Source	Geographic Location	Mean Size (ha)
Pileated	1000-4050	Bonar, pers. comm. 1996	Hinton, Alberta	2310
Woodpecker	960, 894, 683, 1123, 863	Aubry and Raley 1995	Olympic Peninsula, Washington	905
	267 - 1056	Mellen *et al.* 1992	W. Oregon	478
	407-597	Bull and Holthausen 1993	N.E. Oregon	502
			Mean Size (ha):	**839**
Three-toed Woodpecker	324, 867, 1856	Goggans *et al.* 1989	Oregon	1209
Black-backed Woodpecker	440, 749, 2002	Goggans *et al.* 1989	Oregon	1064
Red-breasted Sapsucker	* 2.9, 4.9, 4.8	T. Manning, BRANTA Consultants, pers. comm.	Vancouver Island, B.C.	4.2
Hairy Woodpecker	* 1-15	Sousa 1987	Washington, D.C.	8
Northern Flicker	Not Available			

* breeding territory size

every 10 min. This was the reason cited by most for using the non-statistical minimum convex polygon technique to estimate home range size. 3) The number of radio-locations was not always given.

HABITAT AVAILABILITY

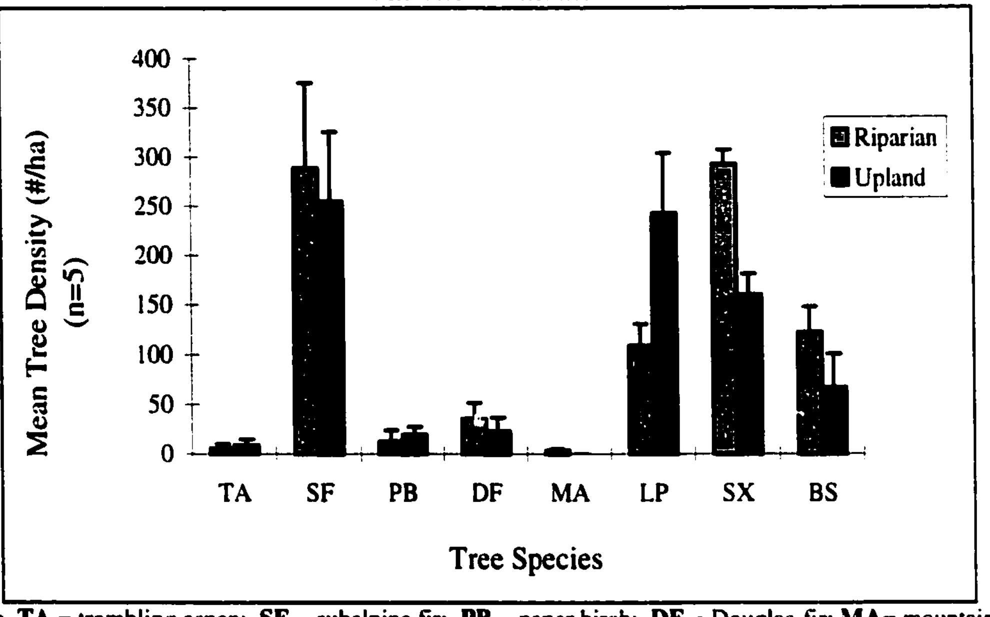
The species composition of available trees was similar between most sites and zones in that subalpine fir, lodgepole pine, hybrid spruce and black spruce (*Picea mariana*) were the most common species. Trembling aspen, black cottonwood (*Populus balsamifera* ssp.*trichocarpa*), paper birch (*Betula papyrifera*), interior Douglas-fir (*Pseudotsuga mensiesii* var. *glauca*), and mountain alder (*Alnus incana* ssp. *tenuifolia*) occurred at low densities in most sites. Tree density in riparian and upland zones combined was greatest for hybrid spruce at 2 sites, subalpine fir at 2 sites, and lodgepole pine at one site (Fig. 5).

Mean densities of each of the 4 common tree species differed among sites (Table 4). Subalpine fir abundance did not differ between zones at 3 out of 5 sites (Table 5). In site 1 subalpine fir were more abundant in upland zones ($p = 0.019$), and in site 4 abundance was higher in riparian zones ($p < 0.001$). Lodgepole pine was more abundant in upland zones at all sites, except site 5 where abundance did not differ between zones ($p = 0.501$). Hybrid spruce trees were more abundant in riparian zones at all sites. Black spruce was more abundant in riparian zones for all sites except site 3, where abundance was higher in upland zones ($p < 0.001$).

Nested Analysis of Variance test results indicated that the mean DBH of each of the 4 main tree species did not significantly differ between zones nested within sites, and all species, except pine ($p = 0.001$), did not differ between sites (Table 6).

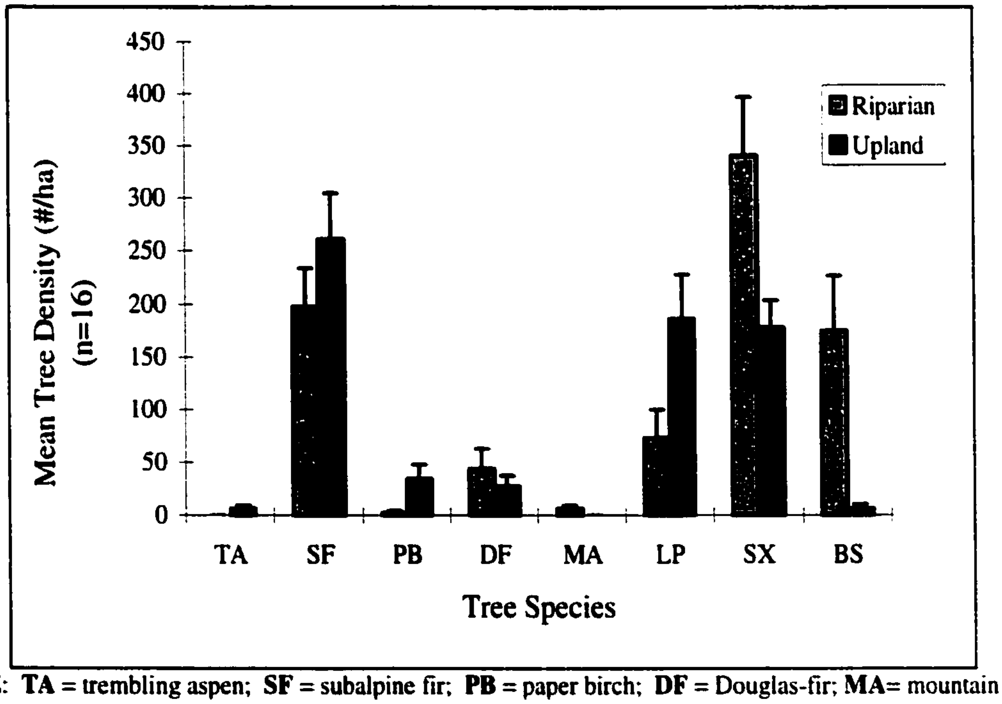
Figure 5. Tree species composition and mean density by zone across all sites (5a) {values are the means of sites (n = 5 ± one standard error)}, and for individual sites (5b-f) {values are the means of plots (n=16 ± one standard error)} in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.

5a. All Sites Combined



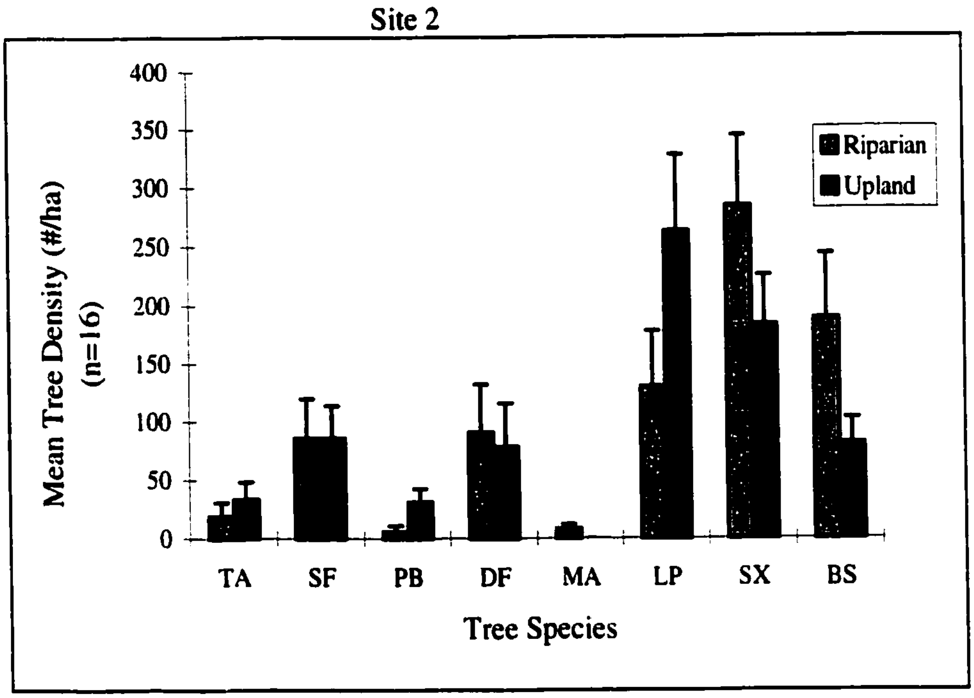
NOTE: **TA** = trembling aspen; **SF** = subalpine fir; **PB** = paper birch; **DF** = Douglas-fir; **MA**= mountain alder; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce.

5b. Site 1



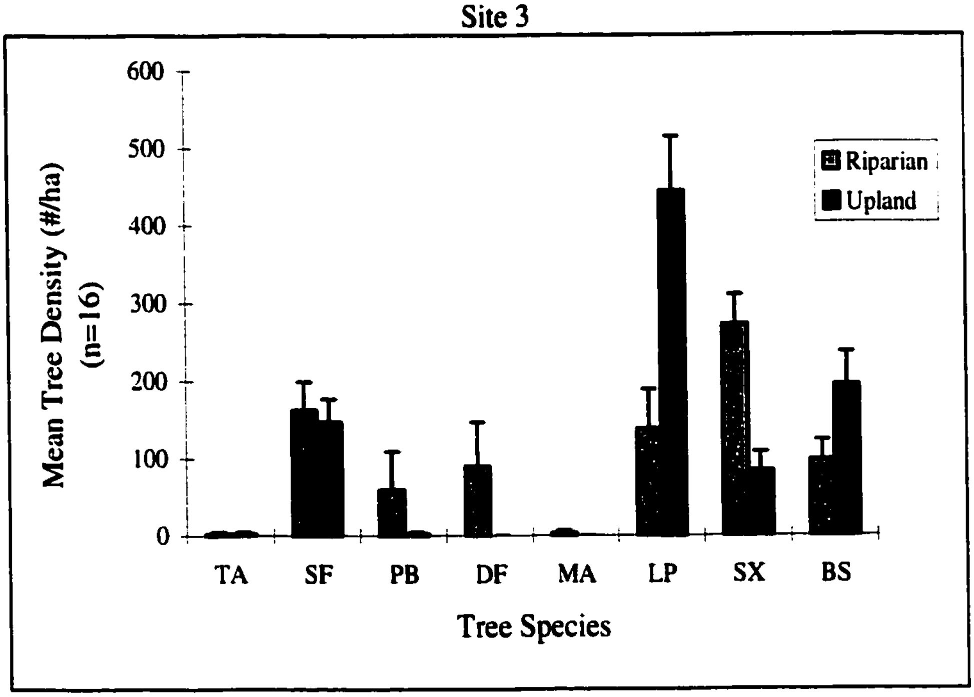
NOTE: **TA** = trembling aspen; **SF** = subalpine fir; **PB** = paper birch; **DF** = Douglas-fir; **MA**= mountain alder; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce.

5c.



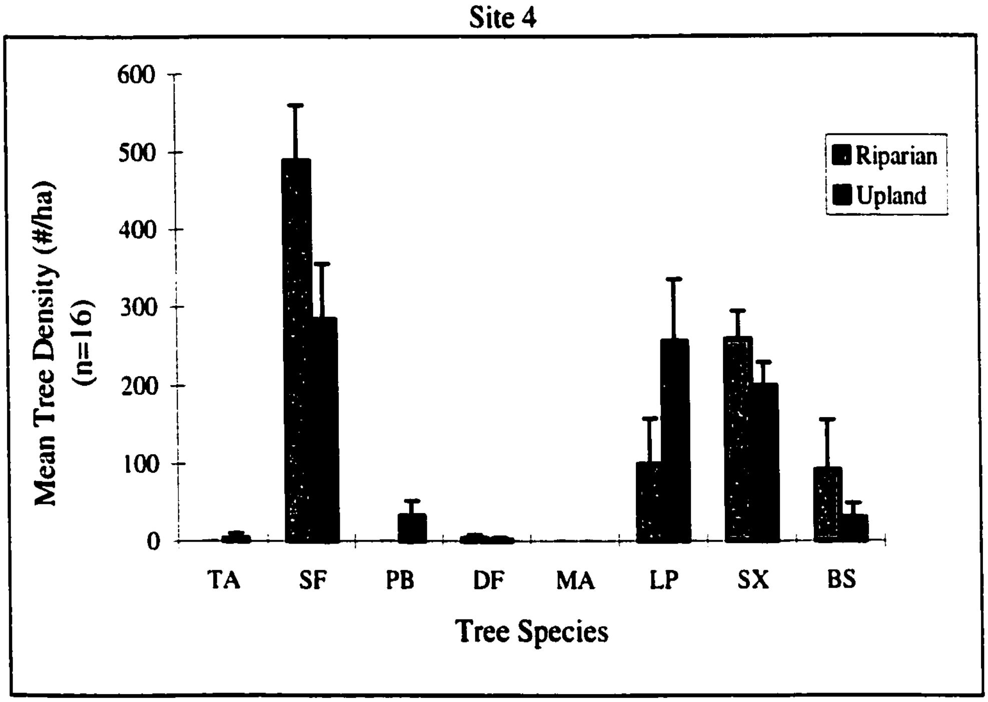
NOTE: **TA** = trembling aspen; **SF** = subalpine fir; **PB** = paper birch; **DF** = Douglas-fir; **MA**= mountain alder; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce.

5d.



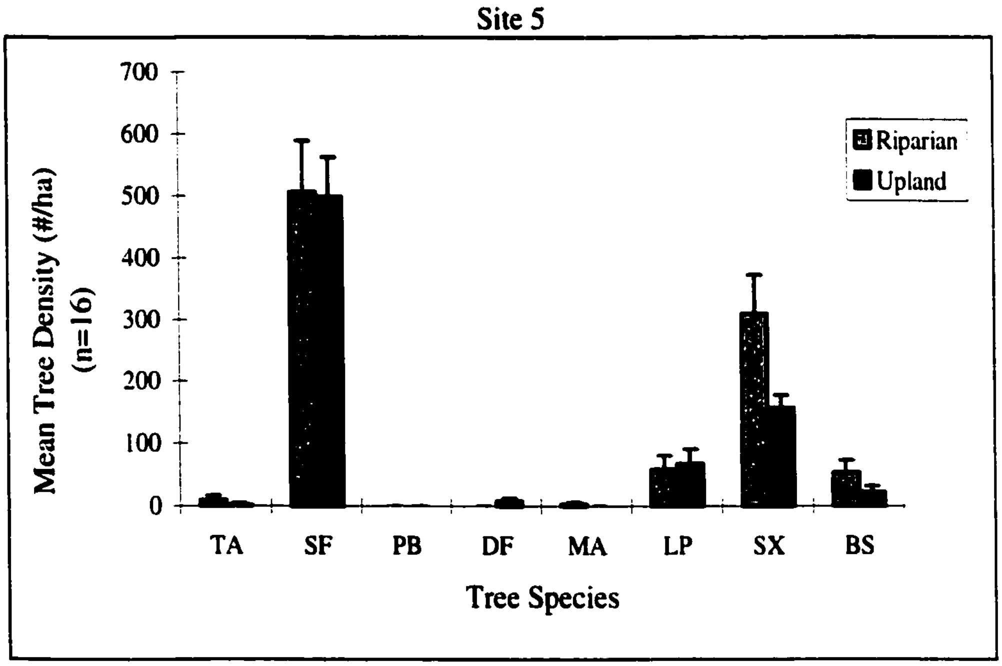
NOTE: **TA** = trembling aspen; **SF** = subalpine fir; **PB** = paper birch; **DF** = Douglas-fir; **MA**= mountain alder; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce.

5e.



NOTE: **TA** = trembling aspen; **SF** = subalpine fir; **PB** = paper birch; **DF** = Douglas-fir; **MA**= mountain alder; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce.

5f.



NOTE: **TA** = trembling aspen; **SF** = subalpine fir; **PB** = paper birch; **DF** = Douglas-fir; **MA**= mountain alder; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce.

Table 4. Number of available trees by site and tree species in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.

# of trees:	site 1	site 2	site 3	site 4	site 5	total	Goodness of Fit *G*-test Statistic	*P*
subalpine fir:								
available	294	110	198	495	643	1740	**562.514**	**< 0.001**
lodgepole pine:								
available	166	251	402	228	80	1127	**257.117**	**< 0.001**
hybrid spruce:								
available	332	299	228	294	298	1451	**20.67397622**	**< 0.001**
black spruce:								
available	116	173	188	79	48	604	**125.4654189**	**< 0.001**

Table 5. Number of available trees by zone and site for each tree species in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.

	Tree Abundance					
	site 1	site 2	site 3	site 4	site 5	All Sites
subalpine fir:						
Riparian Zone	127	55	104	314	324	923
Upland Zone	167	55	94	181	319	817
Riparian vs. Upland Zone	<	=	=	>	=	>
Goodness of Fit *G*-test Statistic	5.450	0.000	0.504	35.050	0.039	6.460
P	0.019	1.000	0.478	< 0.001	0.843	0.001
lodgepole pine:						
Riparian Zone	47	83	118	64	37	349
Upland Zone	119	168	284	164	43	778
Riparian vs. Upland Zone	<	<	<	<	=	<
Goodness of Fit *G*-test Statistic	32.193	29.304	70.554	45.287	0.448	167.419
P	< 0.001	< 0.001	< 0.001	< 0.001	0.503	< 0.001
hybrid spruce:						
Riparian Zone	218	182	174	166	198	938
Upland Zone	114	118	52	128	100	513
Riparian vs. Upland Zone	>	>	>	>	>	>
Goodness of Fit *G*-test Statistic	33.083	14.220	66.310	4.917	32.781	126.284
P	< 0.001	< 0.001	< 0.001	0.026	< 0.001	< 0.001
black spruce:						
Riparian Zone	112	121	63	59	34	389
Upland Zone	4	52	125	20	14	513
Riparian vs. Upland Zone	>	>	<	>	>	>
Goodness of Fit *G*-test Statistic	125.471	28.219	20.779	19.997	8.504	50.801
P	< 0.001	< 0.001	< 0.001	< 0.001	0.003	< 0.001

Table 6. Mean diameter-at-breast-height of available trees for each species, across sites and between habitat types nested within sites in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.

Nested Analysis of Variance Results:

Subalpine Fir (n = 84):

Source	Sum-of-Squares	DF	Mean-Square	*F*-Ratio	*P*
Site	253.309	4	63.327	1.242	0.600
Habitat Type	254.859	5	50.972	1.077	0.380
Error	3503.208	74	47.341		

Lodgepole Pine (n = 87):

Source	Sum-of-Squares	DF	Mean-Square	*F*-Ratio	*P*
Site	1213.878	4	303.469	5.628	0.001
Habitat Type	269.563	5	53.913	0.991	0.429
Error	4187.368	77	54.381		

White-Engelmann Hybrid Spruce (n = 86):

Source	Sum-of-Squares	DF	Mean-Square	*F*-Ratio	*P*
Site	353.983	4	88.496	0.479	0.248
Habitat Type	924.072	5	184.814	2.265	0.056
Error	6200.636	76	81.587		

Black Spruce (n = 38):

Source	Sum-of-Squares	DF	Mean-Square	*F*-Ratio	*P*
Site	212.182	4	53.045	1.380	0.266
Habitat Type	228.218	5	45.644	1.188	0.340
Error	1076.187	28	38.435		

Habitat use patterns were examined for each tree species within riparian and upland zones, and were assessed separately for foraging use (based on evidence of foraging activities) and nesting/roosting use (based on presence of excavated cavities).

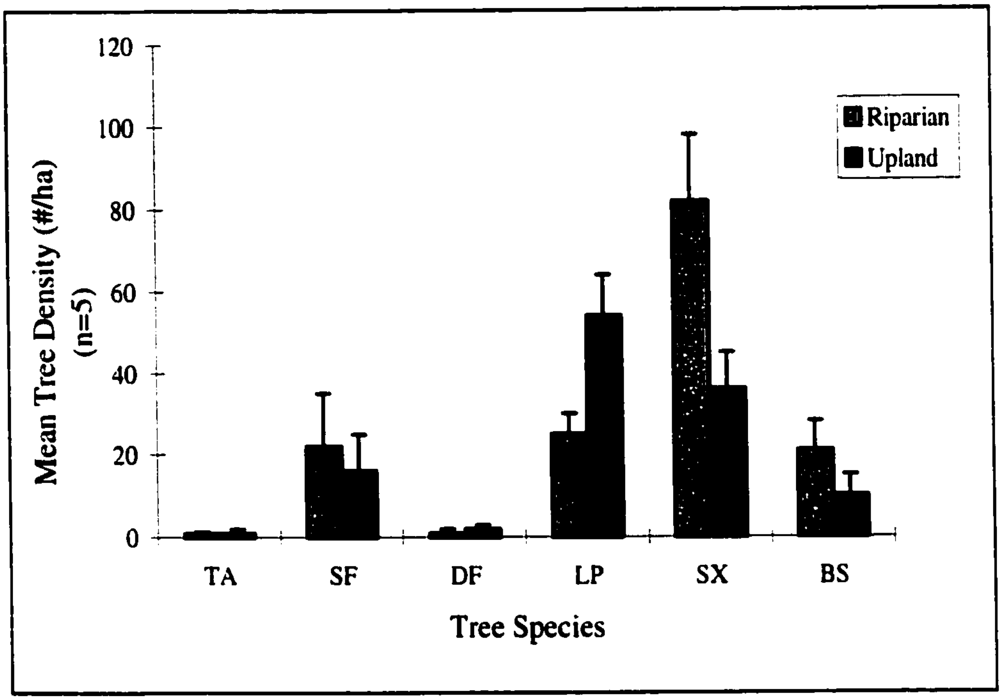
HABITAT USE

Foraging Habitat

Flaking and Shallow Excavations

The 4 tree species that exhibited substantial evidence of flaking and/or shallow excavations were subalpine fir, lodgepole pine, hybrid spruce, and black spruce trees (Fig. 6). There was no exclusive use in either riparian or upland zones. Hybrid spruce had significantly higher proportions of use in riparian than in upland zones at 2 out of 5 sites, while one site had significantly higher proportions of use in upland zones, and 2 sites had no differences in proportions between zones (Table 7). Trends in selection between zones were not found for any other tree species. For all sites combined, all tree species did not significantly differ in their proportions of total trees used between zones.

My results indicated that some tree species were selected for or against (i.e. a greater or lower proportion of stems of one species was used than expected based on proportions of all stems used in the stand) for this foraging technique ($p < 0.001$ (Appendix D). Using 95% Bonferroni Confidence Intervals, I found that subalpine fir was selected against ($p' = 0.352$), lodgepole pine was selected for ($p' = 0.232$), hybrid spruce was selected for ($p' = 0.293$), and black spruce was used in proportion to its availability ($p' = 0.122$).



NOTE: **TA** = trembling aspen; **SF** = subalpine fir; **DF** = Douglas-fir; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce.

Figure 6. Mean density of trees exhibiting flaking and shallow excavations in riparian and upland zones of the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97. Values are the means of sites (n = 5 $\pm$ one standard error).

Table 7. Proportion of total trees used for flaking and shallow excavations by zone for each species and site in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.

	site 1	site 2	site 3	site 4	site 5	All Sites
subalpine fir:						
Riparian Zone	2/198	2/86	3/163	45/489	59/504	71/924
Upland Zone	9/261	2/86	5/147	11/284	52/498	50/816
Goodness of Fit *G*-test Statistic	2.959	0.000	0.690	7.686	0.360	1.514
P	0.085	1.000	0.406	0.005	0.548	0.218
Riparian vs. Upland	=	=	=	>	=	=
lodgepole pine:						
Riparian Zone	11/73	27/30	44/184	23/100	19/58	79/349
Upland Zone	44/186	83/263	66/444	55/256	23/67	173/800
Goodness of Fit *G*-test Statistic	1.933	3.793	5.707	0.074	0.023	0.122
P	0.164	0.051	0.017	0.786	0.879	0.738
Riparian vs. Upland	=	=	>	=	=	=
hybrid spruce:						
Riparian Zone	81/341	133/284	106/272	44/186	47/309	301/938
Upland Zone	36/178	39/183	14/84	59/200	30/156	139/513
Goodness of Fit *G*-test Statistic	0.655	21.161	10.989	7.748	0.982	2.772
P	0.418	<0.001	<0.001	0.005	0.322	0.096
Riparian vs. Upland	=	>	>	<	=	=
black spruce:						
Riparian Zone	11/175	47/189	22/98	16/92	8/53	68/389
Upland Zone	2/6	20/81	23/195	5/31	0/22	32/215
Goodness of Fit *G*-test Statistic	3.087	0.001	4.508	0.021	N/A	0.570
P	0.079	0.975	0.034	0.885	N/A	0.450
Riparian vs. Upland	=	=	>	=	N/A	=

For all tree species combined, the percentage of trees with evidence of use was low (approximately 20%) in trees of DBH classes ≤ 35 cm, with larger diameter trees receiving higher percentages of use (30 - 100%) (Fig. 7). There were no apparent differences in percent use between zones, except in the larger diameter trees, where small sample sizes magnified slight differences. These trends were consistent for each tree species except lodgepole pine, where percent use for trees of the upper DBH classes was only slightly higher than use of the lower classes (Appendix E). While a positive correlation between DBH and percent use is apparent, it is important to recognise that this relationship is confounded by the fact that surface area for trees also increases with DBH, presenting a larger resource surface. As well, there is a higher probability that a large diameter tree is a snag or weakened tree with insects present.

For all species combined, the percentage of trees used was lowest in live trees - decay classes 1 and 2 (10-12%), and highest in snags of decay classes 3-7 (44-62%) (Fig. 8). Percent use in riparian zones was slightly higher than in upland zones for decay classes 1-6, and substantially higher for decay class 7, the most advanced decay class. For each species the upper decay classes exhibited the highest percentages of use, with hybrid spruce having the highest mean percentage of use (74%) (Appendix F).

A high percentage of the trees used for this foraging technique had insects (bark beetles, wood-boring insects, and/or carpenter ants) present (42-100%) (Fig. 9). Selection of trees with insect presence was much more pronounced for tree species with low incidence of flaking and shallow excavations (i.e. aspen, birch, and Douglas-fir). No trend in percentage of trees used with insects was evident between zones.

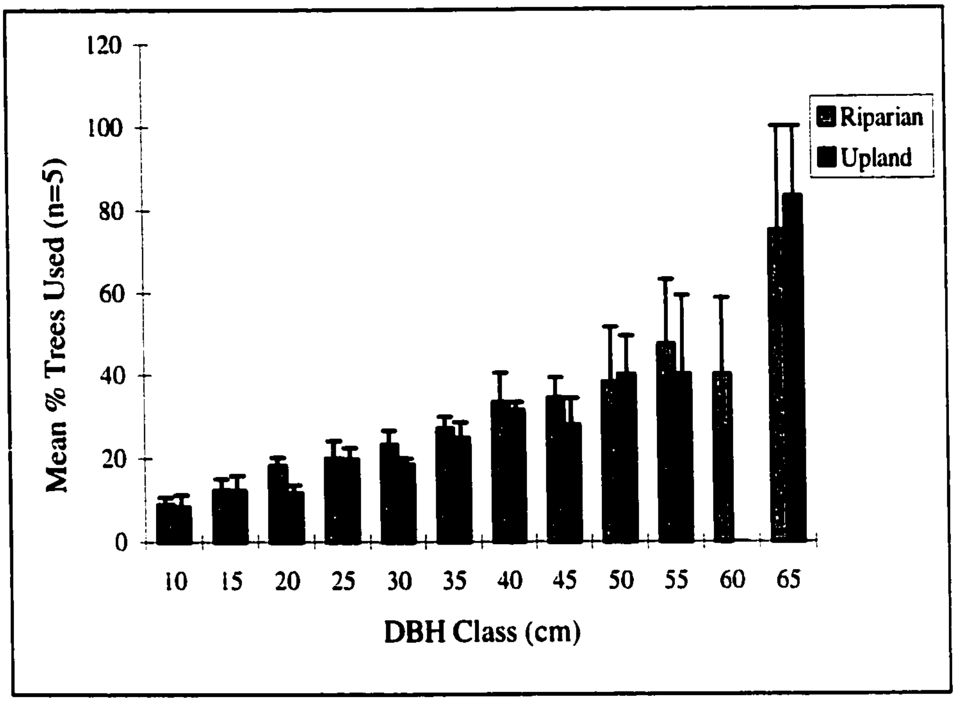


Figure 7. Mean percentage of trees of all species exhibiting flaking and shallow excavations across diameter-at-breast-height (DBH) classes in riparian and upland zones of the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97. Values are the means of sites (n = 5 ± one standard error).

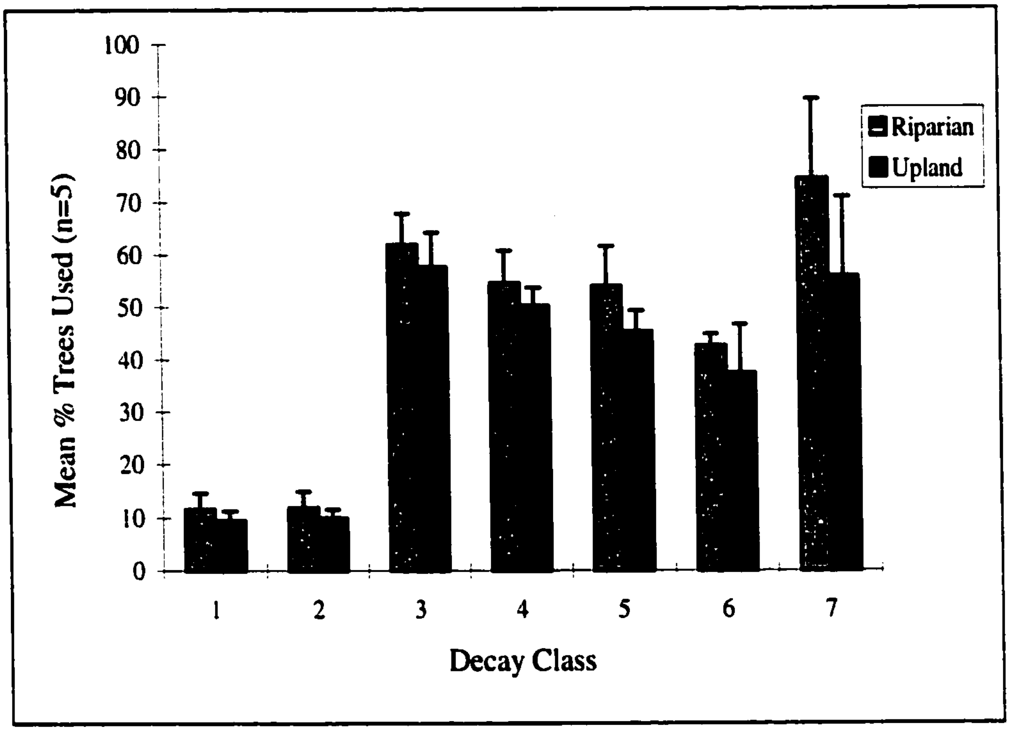
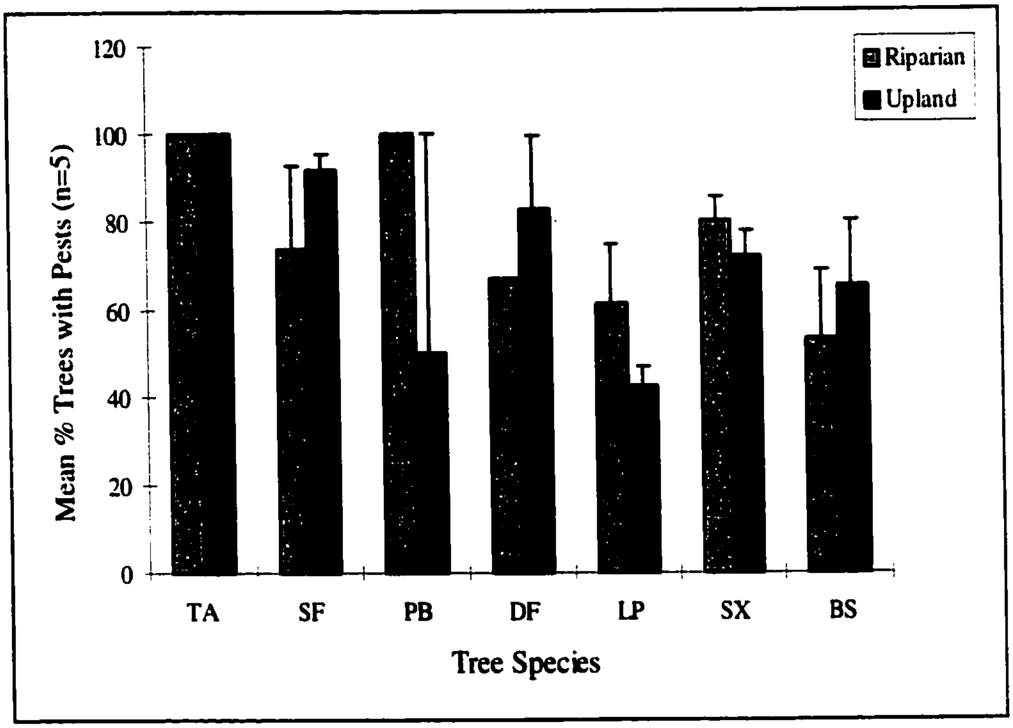


Figure 8. Mean percentage of trees of all species exhibiting flaking and shallow excavations across decay classes in riparian and upland zones of the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97. Values are the means of sites (n = 5 $\pm$ one standard error).



NOTE: **TA** = trembling aspen; **SF** = subalpine fir; **PB** = paper birch; **DF** = Douglas-fir; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce

Figure 9. Mean percentage of trees exhibiting flaking and shallow excavations with insect presence in riparian and upland zones of the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97. Values are the means of sites (n = 5 ± one standard error).

Large Excavations

The mean density of each tree species showing evidence of large excavations across all 5 study sites was compared between riparian and upland zones (Fig. 10). There was no exclusive use in riparian or upland zones, with use between the 2 zones being similar for all species. However, the sample sizes were small (1-6 trees) and, therefore, comparisons were not made.

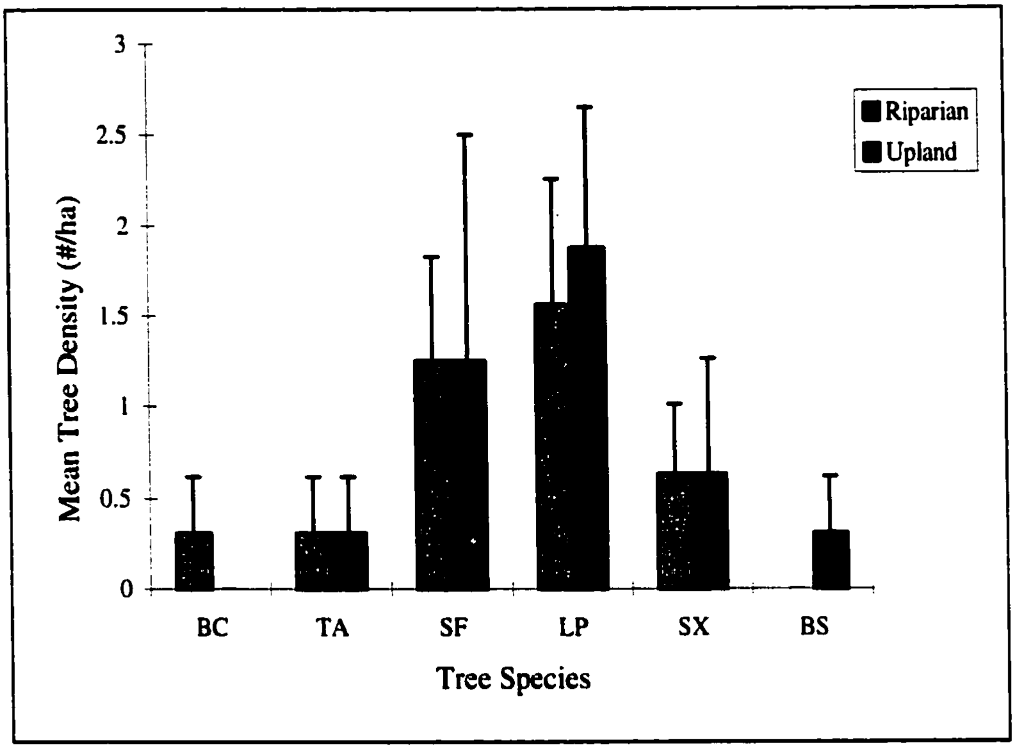
The 2 species that exhibited this foraging technique most often, lodgepole pine and subalpine fir, ranged in diameter from 17.2 to 48.7cm. The sample sizes were too small to examine trends in decay class and DBH distribution or insect presence.

Sapwells

There was no evidence of sap-feeding exclusively in riparian or upland zones for subalpine fir, and low sample sizes for the other 3 species did not allow comparisons (Fig. 11).

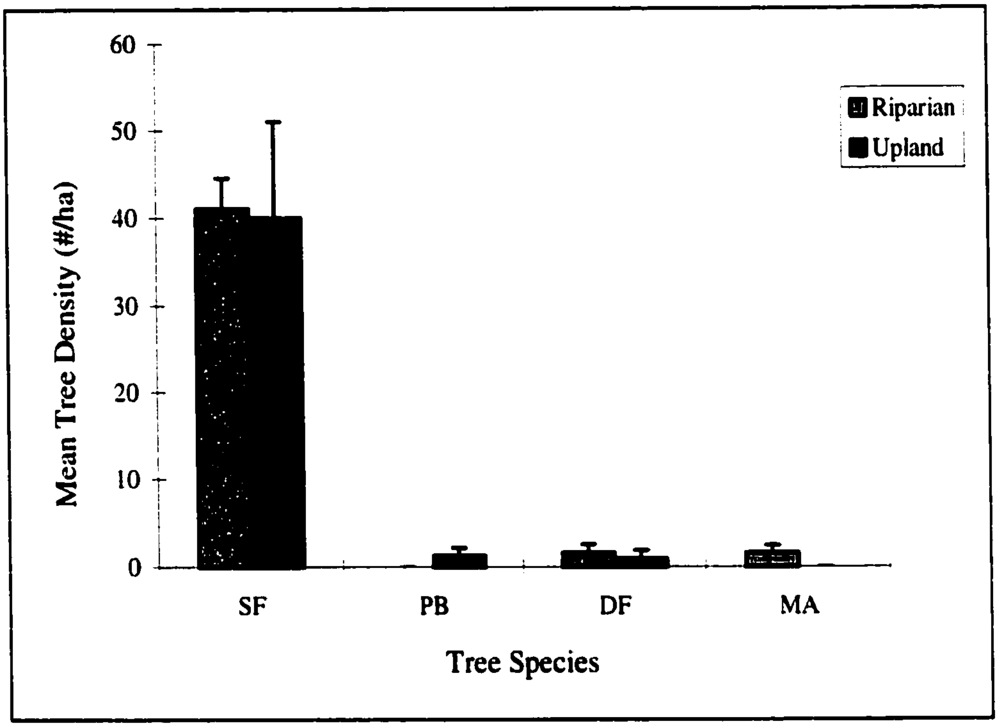
Sapwells were observed almost exclusively in subalpine fir, with the exception of an alder swale in which I found many alders with sapwells. This result did not show up in the data because few alder reached my minimum diameter sampling limit of 12.0cm.

The proportions of total used subalpine fir trees did not differ between riparian and upland zones in 3 out of 5 of the sites (Table 8). Two sites showed significantly higher proportions of total trees used in riparian than upland zones ($p = 0.015$; $p = 0.019$). For all sites combined there was no difference in proportions between zones ($p = 0.310$). These results suggested that for sap feeding, subalpine fir trees were used in proportion to their availability, with no distinct patterns of use between riparian and upland zones.



NOTE: **BC** = black cottonwood; **TA** = trembling aspen; **SF** = subalpine fir; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce

Figure 10. Mean density of trees exhibiting large excavations in riparian and upland zones for all sites combined of the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97. Values are the means of sites (n = 5 ± one standard error).



NOTE: **SF** = subalpine Fir; **PB** = paper birch; **DF** = Douglas-fir; **MA**= mountain alder

Figure 11. Mean density of trees exhibiting sapwells in riparian and upland zones across all sites combined in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97. Values are the means of sites (n = 5 ± one standard error).

Table 8. Proportion of subalpine fir trees exhibiting sapwells by zone in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.

	site 1	site 2	site 3	site 4	site 5	All Sites
Riparian Zone	25/127	24/55	24/104	24/313	36/324	130/924
Upland Zone	21/167	12/55	33/93	5/182	46/319	129/816
Goodness of Fit *G*-test Statistic	2.278	4.022	2.461	5.254	1.375	0.878
P	0.349	0.045	0.117	0.022	0.241	0.349
Riparian vs. Upland	=	>	=	>	=	=

For subalpine fir trees with sapwells, the middle DBH classes received the highest percentage of use, with less use occurring in the large and small DBH classes (Fig. 12). The percentage of subalpine fir trees with sapwells was not compared across decay classes as sap-feeding occurs exclusively on live trees (age classes 1 and 2). Trees within upper decay classes often have evidence of old sapwells that were created while the tree was alive. The percentage of live subalpine fir trees with sapwells and insect presence was low and did not differ between riparian (1%) and upland (7%) zones.

Nesting and Roosting Habitat

Of 21 active nests located at site 1 in 1996 and 1997, 16 were Red-breasted Sapsucker, 3 were Three-toed Woodpecker, and 2 were Northern Flicker nests. All Red-breasted Sapsucker nests were located in live trembling aspen with evidence of fungal decay. Diameters of these trees ranged from 25.0 cm to 36.6 cm. Three-toed Woodpecker nests were all located in recently dead (decay class 3 or 4) lodgepole pine trees that ranged in diameter from 29.5 cm to 37.1 cm. The 2 Northern Flicker nests were in snags of decay class 5, located in clearcuts adjacent to forest edges. Only one Three-toed Woodpecker nest was located in a riparian zone. All other nests were found in upland zones.

Cavity survey results were pooled with habitat plot data to estimate density of inactive cavities. I used the key characteristics of cavity trees, DBH and decay class, to delimit tree availability estimates. Based on this analysis, aspen trees of all decay classes were considered suitable and available, and other tree species of decay class 3 or more were considered suitable and available (Appendix G). In addition, trees had to have a diameter $\geq$ 16 cm to be considered suitable and available, as no cavity was ever found in a tree smaller

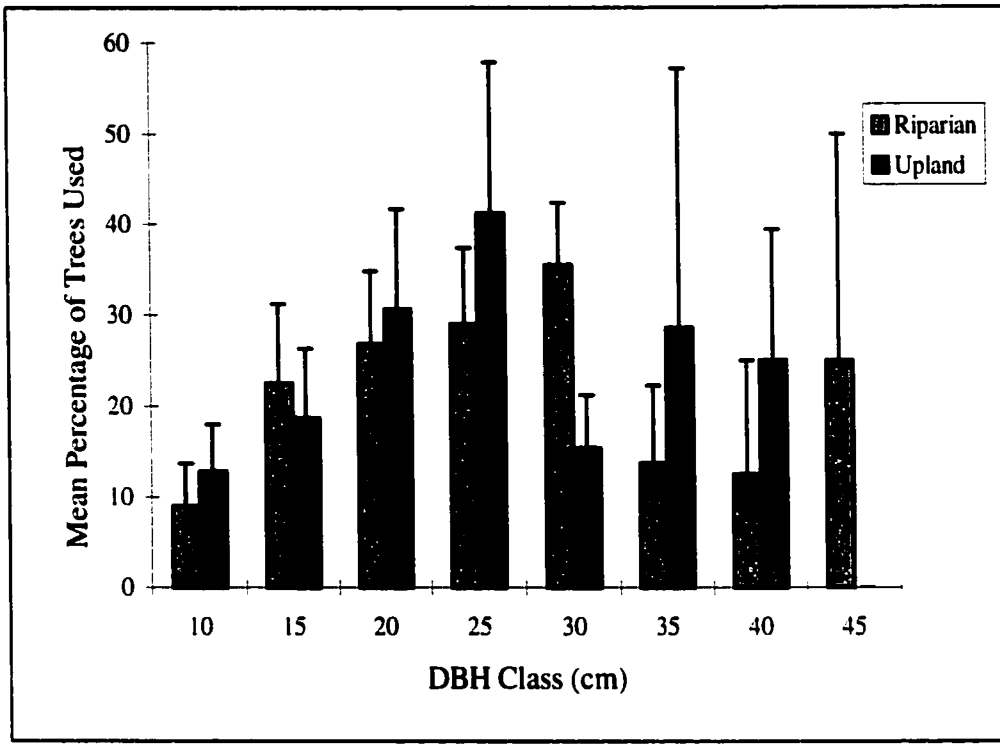


Figure 12. Percentage of subalpine fir trees with sapwells across diameter-at-breast-height (DBH) classes in riparian and upland zones of the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97. Values are the means of sites (n = 5 $\pm$ one standard error).

than this. Cavity excavations occurred most frequently in the larger diameter trees for all species (Appendix H). These restrictions yielded a more biologically meaningful estimate of tree availability.

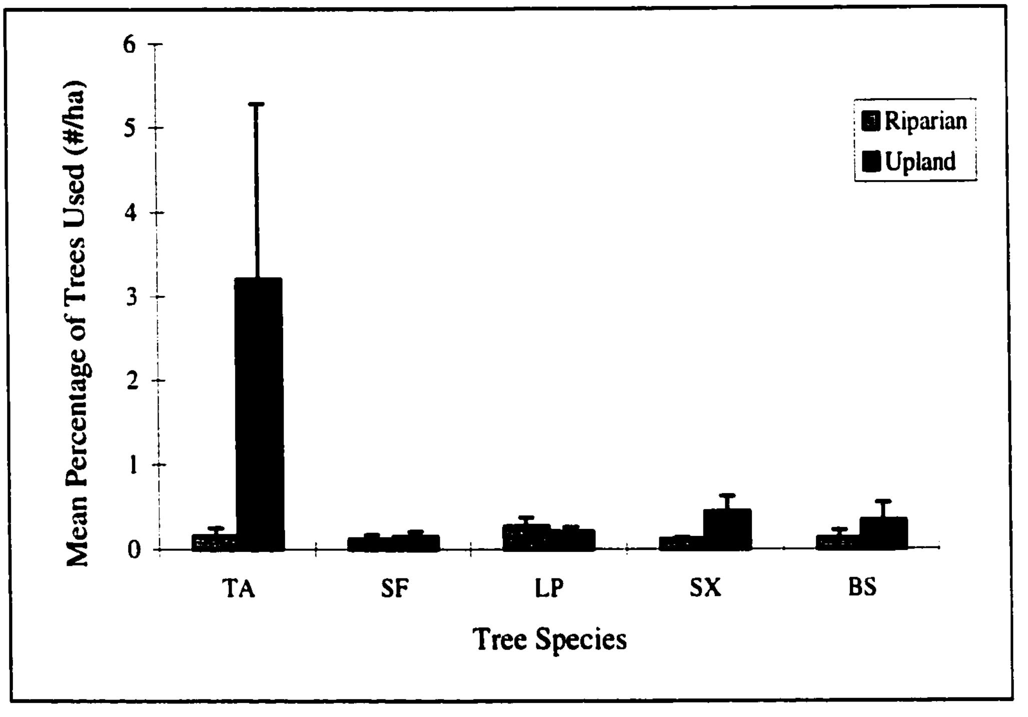
The density of used trees was graphically compared with the density of trees available in habitat plots by plotting the percentage of trees exhibiting cavity excavations in riparian and upland zones (Fig. 13). Although no tree species showed exclusive use in either riparian or upland zones for cavity excavation, some trees had differential use between the 2 zones. The percentage of aspen trees with cavity excavations was 20 times higher in upland than in riparian zones. Compared to other tree species, aspen exhibited the highest percentage of trees used. The percentage of both hybrid spruce and black spruce trees with cavities was approximately 3 times higher in upland than in riparian zones. Lodgepole pine and subalpine fir exhibited no differences in percentage of total trees used between zones. The sample sizes for paper birch and Douglas-fir were too small for comparisons.

A high percentage of cavity trees had insects present (88-97%), except aspen, which had insects present in only 29-33% of the trees (Appendix I). Insect presence in cavity trees did not differ between zones.

DISCUSSION

Primary Cavity Nester Use of Riparian and Upland Zones

In general, I found that use of trees for nesting and foraging did not differ between riparian and upland zones; however, there were some instances of exclusive or selective use of upland zones. Black-backed Woodpeckers were observed only in upland zones during point count surveys. This may be partially explained by the close association found between these



NOTE: **TA** = trembling aspen; **SF** = subalpine fir; **LP** = lodgepole pine; **SX** = hybrid white-Engelmann spruce; **BS** = black spruce

Figure 13. Mean percentage of trees exhibiting cavity excavations in riparian and upland zones in all sites combined of the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97. Values are the means of sites (n = 5 ± one standard error).

woodpeckers and pine trees infested with mountain pine beetles by Goggans *et al.* (1989). I found that lodgepole pine trees were twice as abundant in upland zones, and evidence of mountain pine beetles was present within the study area. No other species differed significantly in abundance between zones. In site 1 where nest searches were conducted, active Red-breasted Sapsucker nests were found exclusively in aspen in the upland zones. I attribute this to the higher density of aspen in upland zones compared to riparian zones in this site. However, K. Parker (University of Northern British Columbia, unpublished data) found active Red-breasted Sapsucker nests in both riparian and upland zones throughout the SBSmk1. As well, inactive Red-breasted Sapsucker cavities were located in both riparian and upland zones throughout all 5 study sites, although the percentage of aspen with cavities was 4 times higher in upland areas. It is therefore evident that Red-breasted Sapsuckers selected upland over riparian zones for nesting, even though both zones were used.

For all other categories of use there were no relationships exclusive to either zone. The habitat assessment plots and cavity surveys revealed that the percentage of both hybrid and black spruce trees used for cavity excavations was 3 times higher in upland than riparian zones.

These findings differ from a large number of studies that have found species diversity and abundance to be higher in riparian zones (Geier and Best 1980, Stauffer and Best 1980, Emmerich and Vohs 1982, Gates and Giffen 1991, LaRue *et al.* 1995, Kinley and Newhouse 1997). However, these studies focused on passerine birds or small mammals and the difference between zones may have, in part, been because riparian zones tend to have higher diversity and abundance of herbs, shrubs, and associated food sources (e.g. seeds and berries), which are used by many other birds, but are only a minor habitat component for most primary cavity nesters (Morgan and Wetmore 1986, LaRue *et al.* 1995). For the studies where species-specific results were available, I also found little difference in diversity and abundance of primary cavity nesters between riparian and upland zones. In unmanaged cedar/hemlock forests of the central Oregon coast range, McGarigal and McComb (1992) found that Red-breasted Sapsuckers also occurred only in upland zones, Hairy Woodpeckers were more abundant in upland zones, and Pileated Woodpeckers showed equal occurrence between the 2 zones. In the boreal balsam fir forests of eastern Quebec, LaRue *et al.* (1995) observed 3 passerine primary cavity nesters: Red-Breasted Nuthatches did not differ in abundance between zones; Black-capped Chickadees were more abundant in riparian zones; and Boreal Chickadees were more abundant in upland zones. In the elm/maple/oak forests of Iowa, Stauffer and Best (1980) found that Downy Woodpeckers, Hairy Woodpeckers, and Black-capped Chickadees were more abundant in riparian zones, Common Flickers were more abundant in upland zones, and the 3 species that do not occur in my study area (White-breasted Nuthatches, Red-headed Woodpeckers, and Red-bellied Woodpeckers) did not differ in abundance between zones. In the oak/hickory/maple forests of southeastern Virginia, Murray and Stauffer (1995) found that Downy Woodpeckers, Pileated Woodpeckers and White-breasted Nuthatches did not differ in abundance between zones. Alternatively, Bull (1978) found that several cavity nesters preferred or occurred exclusively in riparian zones.

Management Recommendations

Unlike many passerine birds, primary cavity nesters did not exhibit a strong affinity to riparian zones, and in some instances were more abundant in upland zones. It is therefore important that wildlife tree patches are allocated to both riparian and upland zones to provide the full complex of habitat attributes used by primary cavity nesters.

In British Columbia, tree retention in upland areas has typically been distributed among several small reserves (1-5ha) -- a practice that results in large amounts of undesirable edge habitat. While edge habitats are often characterised by high species diversity, they can also be associated with increased predation, parasitism, and more extreme micro-climatic effects (Gates and Giffen 1991, B.C. Ministries 1997, Voller 1998). Patches should be designed with minimal amounts of edge habitat by providing fewer and larger patches of relatively circular shape to reduce the proportion of edge to interior habitat.

Radiotelemetry studies have reported average primary cavity nester home range sizes varying from as small as 60ha to as large as 2300ha, with territory size (the nesting or feeding area that is actively defended by an individual or pair) being considerably smaller than home range sizes. It is possible for primary cavity nesters with small home ranges to establish territories within wildlife tree patches. This presents another reason to retain fewer and larger patches where possible.

While it is important to ensure the retention of upland patches, recent findings of a study conducted by the B.C. Ministry of Forests indicated that in post-Code harvested cutblocks only 25% of all wildlife tree patches were located in riparian areas (P. Bradford, B.C. Ministry of Forests, unpublished data). This is because a low percentage of the land base is composed of riparian areas. Riparian reserves also serve the unique purpose of providing channel stability, large woody debris for fish habitat, temperature buffering, and filtering and absorption of water by tree roots (Thomas *et al.* 1979a, Naiman *et al.* 1993, Knopf and Samson 1994). It is therefore important to ensure that riparian reserves and management zones are properly established, providing long-term forested riparian zones.

Windthrow is of considerable concern in riparian management areas. Large merchantable trees within riparian management zones are often entirely removed, leaving riparian reserve zones vulnerable to windthrow (D. Lousier, UNBC, pers. comm.). Higher levels of tree retention in the riparian management zones should be applied, and forest managers should consult the Riparian Management Area (RMA) Guidebook (B.C. Ministries 1995b) and the Windthrow Handbook for British Columbia Forests (Strathers *et al.* 1994) prior to the harvest planning stage.

The original Biodiversity Guidelines (B.C. Ministries 1995a) stated that in the interior of B.C. up to 50% of wildlife tree patches could be located in RMAs. Recent policy changes now allow all wildlife tree patches to be located in RMAs or other constrained areas. The data and related studies I have presented support the original recommendations (50% of patches in RMAs), which ensure that upland patches will be retained.

Provision of riparian and upland zones should also be made at the landscape level. Proposed landscape level planning units are currently being established. Each landscape unit (LU) will be designated as having a high, medium or low biodiversity emphasis option based on topographic and ecosystem complexity, fish and wildlife species diversity, significance of key management species and social and economic considerations (B.C. Ministries 1995a). The distribution of biodiversity emphasis options within a subregional planning area (Forest District) will be 10% high, an average of 45% medium, and an average of 45% low. Landscape level planning objectives include maintaining a range of seral stages ensuring old seral stage retention and representativeness, temporal and spatial distribution of cut and leave areas, species composition, landscape connectivity, and stand structure. Forest managers should be advised as soon as LUs have been delineated so that the associated biodiversity objectives and emphasis options may be implemented.

RIPARIAN MANAGEMENT AREA WIDTH

In response to the forest regulations throughout Canada and the United States that restrict timber harvesting in riparian zones, research has been conducted to examine wildlife abundance and species composition in riparian reserves of variable widths to determine the minimum size required to maintain all wildlife species. Most studies have shown that current prescribed riparian reserves are too narrow to meet the biodiversity objectives for many breeding bird species. Kinley and Newhouse (1997) examined bird density and diversity in riparian reserves (14, 37, and 70m in width) in southeastern British Columbia. They concluded that RMAs prescribed by the current Forest Practices Code would have lower densities of total birds and riparian-associated birds than if reserves were required to average 70m in width. Working in the boreal forests of Quebec, Darveau *et al.* (1995) compared bird abundance and species composition in 5 riparian forest strips of differing widths following harvest of the surrounding area. Results indicated that by the third year after harvesting, the narrowest strips experienced the fastest decrease in bird densities, with several species becoming nearly extirpated. They recommend retaining strips of at least 60m in width. Stauffer and Best (1980) found bird species richness increased with the width of wooded riparian zones of Iowa, and that the minimum mean widths necessary to support breeding populations of Downy and Hairy Woodpeckers were 15 and 40 m, respectively. In west-central South Carolina, Kilgo *et al.* (1998) examined breeding bird species diversity and abundance in bottomland hardwoods (oak, gum, and cypress trees), ranging in width from <

50m to >1000m. They concluded that "even narrow riparian zones can support an abundant and diverse avian community, but that conservation of wide (≥ 500m) riparian zones is necessary to maintain the complete avian community" (Kilgo *et al.* 1998:72). In Georgia, Hodges and Krementz (1996) found that species richness and abundance of neotropical migratory breeding birds increased with increasing riparian corridor width. They recommended retaining 100m forested riparian strips. Spackman and Hughes (1995) found that corridor widths of at least 150m along mid-order streams (~S3 - see p. 5 of B.C. Ministries 1995b) were required to conserve interior forest species such as the Pileated Woodpecker. Thurmond *et al.* (1995) found a positive relationship between riparian buffer widths and diversity of interior forest bird species.

Primary cavity nesters such as the Pileated Woodpecker, which has been documented to occupy home ranges up to 4000ha (R.L. Bonar, Weldwood of Canada, unpublished data), will certainly be influenced by the size inadequacies of narrow riparian reserves. Because primary cavity nesters are a keystone species guild providing habitat for so many other species, appropriate management decisions must be aimed at meeting their habitat requirements.

Management Recommendations

Current riparian management areas in British Columbia range from 0 to 100m wide, composed of 0-50m-reserve zones and 0-100m-management zones. However, most trees within management zones are harvested. These widths are much smaller than the widths recommended by researchers (see above) to maintain the full diversity of breeding birds.

Where possible, wildlife tree patches should be located within and adjacent to the RMA to provide wider buffer strips, while ensuring that wildlife tree patches are also provided in upland zones. Several models for designing site-specific riparian buffer strips are currently available and should be consulted by forest managers (Belt *et al.* 1992). Voller (1998) identified the need for more research regarding the advantages of varied-width versus fixed-width buffer strips.

CAVITY NESTER HABITAT CHARACTERISTICS

I found that wildlife tree density, species, diameter-at-breast-height, presence of heartwood decay and insects, and decay class are the characteristics most likely to influence cavity nester presence, which is supported by the findings of many other researchers (Mannan *et al.* 1980, Allaye-Chan 1981, Zarnowitz and Manuwal 1985, Bull 1987, Lundquist 1988, Harestad and Keisker 1989, Linder 1994, Raphael and White 1984).

Suitable nest trees are believed to be a limiting factor to cavity nester population size in most managed forest stands (Conner *et al.* 1975, Allaye-Chan 1981, Stauffer and Best 1982, Bull and Partridge 1986, Newton 1994, Parks *et al.* 1995). Miller (1985) and Bonar (Weldwood of Canada, pers. comm.) hypothesised that winter foraging habitat may be even more limiting than nest sites for non-migratory cavity nesters; however, ecological information on winter activities and habitat requirements is generally lacking. Effective management for cavity nesters will require better information on the factors that limit their populations and distributions.

Management Recommendations

The Biodiversity Guidebook (1995a) recommends that features of prime importance to cavity nesters should be retained. One of these key features is a range of tree diameters, including the upper 10% of the diameter distribution of the stand. My data confirm that both foraging and nesting by primary cavity nesters occur most frequently in the largest trees of the stand. In the SBSmk1 biogeoclimatic subzone, the upper 10% diameter range that should be targeted for retention include: subalpine fir > 29cm, lodgepole pine > 41cm, hybrid spruce > 48cm, Douglas-fir > 46cm, and black spruce > 31cm.

Recommendations for retaining both live and dead trees representing a range of wildlife tree classes within patches are also made (BC Ministries 1995a). My finding that both nesting and foraging occurred most frequently in trees of more advanced decay classes supports this recommendation. Care should be taken to include as many snags as possible in wildlife tree patches.

A variety of tree species, including deciduous, should be represented (BC Ministries 1995a). This recommendation is supported by my finding that all tree species except willow (*Salix* spp.) exhibited evidence of use by PCNs, with certain tree species fulfilling specific habitat requirements, such as the use of subalpine fir for sap feeding, and the exclusive use of trembling aspen for Red-breasted Sapsucker nests. The largest percentage of trees used for cavity excavations occurred in trembling aspen, a species typically eliminated from regenerating managed stands by herbiciding, brushing and weeding. Large diameter lodgepole pine and hybrid spruce trees also exhibited a high percentage of use for cavity excavations; however, these are the trees most typically targeted for harvest in SBS forests. Management should strive to provide adequate retention of stand level tree diversity.

The guidebook also states that trees exhibiting evidence of wildlife use or presence of heart rot, and those with a large size and well-branched structure should be retained. I recommend that trees with evidence of endemic levels of insect populations should be included in this category, as these insects are the primary food source for most primary cavity nesters. Caution is required in the case of insects such as bark beetles and several wood-boring insects, which are capable of episodic outbreaks causing major damage to forests. Managers need to be mindful that outbreaks can be indicative of an unhealthy forest that has been weakened by other diseases, fungi, or pests. Those species that do not present such threats (e.g. carpenter ants) should be retained wherever possible. Evidence of carpenter ants includes entrance holes 2-3 mm wide, and honey-comb-like galleries found at the base of the tree, usually within the heartwood. When selecting trees for retention, managers should distinguish between potential forest health threats (e.g. beetle outbreaks) and those situations (e.g. carpenter ants) that are indicative of a normal, healthy forest condition. Evidence of insect presence should be recent (i.e. look for the insects themselves below bark flakes or fresh wood dust near the entrance holes).

Study Design Limitations and Recommended Improvements

My examination of habitat use patterns was limited to examining evidence of use because I was unable to capture or radio-tag individuals. For the net pole method to be effective, active cavities should be located while juveniles are 1-3 weeks old and the adults are fully entering the cavities. This would allow the researcher to place the net over the cavity, capturing the bird as it flies out. I do not recommend using the bal cha-tri method unless active roost cavities are located in late winter or early spring, allowing trapping to occur in early spring when birds may be attracted to bait. Also, bait stations should be placed in the trapping area for at least 1 or 2 months, allowing woodpeckers to find and become conditioned to feeding on the bait. For the mist netting method I recommend placing and monitoring the bait station in the trapping area 2 months before trapping (February -April). I also recommend using the bal cha-tri trap in combination with the mist nets once target individuals have become conditioned to feeding at the trap site.

I recommend using point count surveys for the study of primary cavity nester habitat use patterns. This method involves passive observation without bias, whereas call play-back surveys often displace birds from their activities.

For the habitat assessment plots I recommend sampling more sites (SBSmk1 replicates) with fewer plots (site replicates) to provide a larger statistical sample size.

When assessing trees for evidence of foraging, an index of the intensity of use should be recorded for each tree (e.g. 1-low, 2-moderate, 3-high) so that appropriate comparisons of the intensity of use between zones can be made.

SUMMARY AND CONCLUSIONS

Current forestry guidelines do not have firm provisions for retaining wildlife tree patches in forested upland zones. My findings indicate that retention provisions are required in both riparian and upland zones to provide the full range of habitat needs of cavity nesting wildlife. Upland zones provide several important features that are selected for by primary cavity nesters. Riparian zones also provide unique floral and faunal species diversity, and play an integral ecological role in the health and function of aquatic ecosystems. I recommend reverting back to the original biodiversity guidelines recommendation of placing up to 50%, instead of the current 100%, of wildlife tree patches in riparian management areas. RMA widths should be increased where possible by placing wildlife tree patch requirements adjacent to RMAs, and reducing the amount of harvesting in riparian management zones, while still retaining approximately equal portions of upland zones. My results support the recommendations concerning important characteristics that should be retained in wildlife tree patches. Trees with evidence of insect presence should also be considered important for retention when consistent with forest health objectives.

By focusing on biodiversity management as it relates to cavity nesting species, I identified several deficiencies in existing guidelines aimed at sustaining biodiversity. By continually evaluating and improving forestry practices in British Columbia through an adaptive management process, we can move closer to achieving sustainable forestry while maintaining ecosystem health and function.

Assuming that the current forest harvest scenarios in which RMA and Biodiversity Guidelines are applied and the above recommendations are implemented, I suggest that it is possible for primary cavity nesters to persist within the post-harvest general area by enlarging or moving their home ranges to compensate for the loss of forested areas. It is likely that viable populations will persist in treated landscapes, although possibly at reduced densities. Each harvest scenario will result in a unique set of residual features; the persistence of cavity nesters will depend on the amount of remaining forested area surrounding the cutblock, the home range size of the cavity nester, the habitat suitability of the residual and surrounding areas, and the ability of the cavity nester to adjust.

LITERATURE CITED

Allaye-Chan, A. C. 1981. Snag use by cavity-nesting birds in the Chemainus woodlands of southern Vancouver Island, British Columbia. B.S.For. Thesis, Univ. British Columbia, Vancouver, B.C., Canada. 171 p.

Allen, J. and C. Doyle. 1997. Memorandum to Field Operations, Ministry of Forests, from the Deputy Ministers Re: Achieving acceptable biodiversity timber impacts.

Angelstam, P. 1997. Landscape analysis as a tool for the scientific management of biodiversity. *Ecological Bulletins* 46:140-170.

Aubry, K. B. and C. M. Raley. 1995. Ecology of pileated woodpeckers in managed landscapes on the Olympic Peninsula. USDA, For. Serv. Olympia, Washington, USA.

Baker, W. L. 1989. Landscape ecology and nature reserve design in the Boundary Waters Canoe Area, Minnesota. *Ecology* 70(1):23-35.

Begon, M., J. L. Harper and C. R. Townsend. 1986. Ecology: Individuals, populations, and communities. Sinauer Associates, Inc., Publishers. Sunderland Massachusetts, USA.

B.C. Ministries. 1995a. Biodiversity Guidebook. Forest Practices Code of British Columbia. B.C. Ministry of Forests and B.C. Environment, Victoria, B.C., Canada. 99pp.

B.C. Ministries. 1995b. Riparian Management Area Guidebook. Forest Practices Code of British Columbia. B.C. Ministry of Forests and B.C. Environment, Victoria, B.C., Canada. 68pp.

B.C. Ministries. 1997. Stand Level Biodiversity for Forest Managers, Course Workbook. B.C. Ministry of Forests and B.C. Environment, Victoria, B.C., Canada. 96 p.

Belt, G. H., J. O'Laughlin and T. Merrill. 1992. Design of forest riparian buffer strips for the protection of water quality: Analysis of scientific literature. Idaho Forest, Wildlife and Range Policy Analysis Group, University of Idaho, Report No. 8. 35 pp.

Brewer, R. 1994. The science of ecology. Second edition. Saunders College Publishing, Toronto, Ont.

Bull, E. L. 1978. Specialized habitat requirements of birds; snag management, old growth, and riparian habitat. Pages 74-82 *in* R. M. DeGraaf (tech. coord.). Nongame bird habitat management in coniferous forests of the western United States: Proceedings of a workshop. 7-9 February 1977. U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. PNW-GTR-64. Portland, Oregon, USA.

Bull, E. L. 1987. Ecology of the Pileated Woodpecker in northeastern Oregon. *Journal of Wildlife Management* 51(2):472-481.

Bull, E. L. and R. S. Holthausen. 1993. Habitat use and management of Pileated woodpeckers in northeastern Oregon. *Journal of Wildlife Management* 57(2):335-345.

Bull, E. L. and A. D. Partridge. 1986. Methods of killing trees for use by cavity nesters. *Wildlife Society Bulletin.* 14(2):142-146.

Bull, E. L., A. D. Partridge and W. G. Williams. 1981. Creating snags with explosives. U.S. Dep. Agric. For. Serv., Res. Note PNW-393, Pac. Northwest For. and Range Exp. Stn. Portland, OR. 4 p.

Bull, E. L. and R. J. Pedersen. 1978. Two methods of trapping adult Pileated Woodpeckers at their nest cavities. *North American Bird Bander* 3(3):95-99.

Bull, E. L. and J. M. Skovlin. 1982. Relationships between avifauna and streamside vegetation. Transactions North American Wildlife and Natural Resources Conference, 47:496-506.

Conner, R. N., J. G. Dickson and B. A. Locke. 1981. Herbicide-killed trees infected by fungi: Potential cavity sites for woodpeckers. *Wildlife Society Bulletin.* 9(4):308-310.

Conner, R. N., R. G. Hooper, H. S. Crawford and H. S. Mosby. 1975. Woodpecker nesting habitat in cut and uncut woodlands in Virginia. *Journal of Wildlife Management* 39:144-150.

Croonquist, M. J. and R. P. Brooks. 1993. Effects of habitat disturbance on bird communities in riparian corridors. *Journal of Soil and Water Conservation* 48:65-70.

Cunningham, J. B., R. P. Balda and W. S. Gaud. 1980. Selection and use of snags by secondary cavity-nesting birds of the ponderosa pine forest. U.S. Dep. Agric. For. Serv. Research Paper RM-222. Fort Collins, CO. 15 p.

Darveau, M., P. Beauchesne, L. Belanger, J. Huot and P. LaRue. 1995. Riparian forest strips as habitat for breeding birds in boreal forests. *Journal of Wildlife Management* 59(1):67-78.

Delong, C., D. Tanner and M. J. Jull. 1993. A field guide for site identification and interpretation for the southwest portion of the Prince George Forest Region. BC Ministry of Forests, Land Management Handbook No. 24.

Dutilleul, P. 1993. Spatial heterogeneity and the design of ecological field experiments. *Ecology* 74(6):1646-1658.

Emmerich, J. M. and P. A. Vohs. 1982. Comparative use of four woodland habitats by birds. *Journal of Wildlife Management* 46:43-49.

Fenger, M. 1995. Implementing biodiversity conservation through the British Columbia Forest Practices Code. Page 1 *in*: Wildlife Tree / Stand Level Biodiversity Workshop Proceedings. Victoria, B.C., Canada.

Gates, J. E. and N. R. Giffen. 1991. Neotropical migrant birds and edge effects at a forest-stream ecotone. *Wilson Bull*etin 103:204-217.

Geier, A.R. and L.B. Best. 1980. Habitat selection by small mammals of riparian communities: evaluating effects of habitat alterations. *J. Wildl. Manage.* 44(1):16-24.

Goggans, R., Dixon, R. D. and L. C. Seminara. 1989. Habitat use by Three-toed Woodpeckers and Black-backed Woodpeckers, Deschutes National Forest, U.S. Dep. Agric., Fish and Wildlife. Tech. Rep. #87-3-02. Oregon, USA.

Grant, W. 1995. Caring for the earth for tomorrow. *In:* Proceeding: Exploring Multiple Use and Ecosystem Management: From Policy to Operational Practices. FAO/ECE/ILO International Forestry Seminar, Prince George, B.C., Canada.

Gyug, L. W. 1996. Cavity nesting bird habitat use and nest search surveys in Donna Creek. DRAFT. March 1996.

Hansen, A. J., S. L. Garman, J. F. Weigand, D. L. Urban, W. C. McComb and M. G. Raphael. 1995. Alternative silvicultural regimes in the Pacific Northwest: Simulations of ecological and economic effects. *Ecological Applications* 5(3):535-554.

Harestad, A. S. and D. G. Keisker. 1989. Nest tree use by primary cavity-nesting birds in south central British Columbia. *Canadian Journal of Zoology* 67:1067-1073.

Harrison, S. and Voller, J. 1998. Connectivity. Pages 76-97 *in* Voller, J. and S. Harrison, editors. 1998. Conservation biology principles for forested landscapes. University of British Columbia Press, Vancouver, B.C., Canada. 243 pp.

Heppell, S. S., J. R. Walters and L. B. Crowder. 1994. Evaluating management alternatives for red-cockaded woodpeckers: a modelling approach. *Journal of Wildlife Management* 58(3): 479-487.

Hodges, M. F. and D. G. Krementz. 1996. Neotropical migratory breeding bird communities in riparian forests of different widths along the Altamaha River, Georgia. *Wilson Bulletin* 108:496-506.

Hooper, S. T. 1991. Distribution of songbirds in riparian forests of central Maine. M.S. Thesis, University of Maine, Maine, USA. 90pp.

Hunter, M. L. 1990. Wildlife, forests, and forestry: Principles of managing forests for biological diversity. Prentice Hall, Englewood Cliffs, New Jersey, USA. 370 p.

Jackson, A. J., M. R. Lennartz and R.G. Hooper. 1979. Tree age and cavity initiation by Red-cockaded Woodpeckers. *Journal of Forestry* 77:102-103.

Keisker, D.G. 1995. Information base on habitat requirements of forest-using wildlife in the sub-boreal spruce (SBS) biogeoclimatic zone. Ministry of Environment, Lands and Parks. March 1995 DRAFT.

Kelly, J. F., S. M. Pletschet and D. M. Leslie, Jr. 1993. Habitat associations of red-cockaded woodpecker cavity trees in an old-growth forest of Oklahoma. *Journal of Wildlife Management* 57(1):122-128.

Kilgo, J. C., R. A. Sargent, B. R. Chapman and K. V. Miller. 1998. Effect of stand width and adjacent habitat on breeding bird communities in bottomland hardwoods. *Journal of Wildlife Management* 62:72-83.

Kinley, T. A. and N. J. Newhouse. 1997. Relationship of riparian reserve zone width to bird density and diversity in southeastern British Columbia. *Northwest Science* 71(2):75-86.

Klenner, W. and D. J. Huggard. 1997. Three-toed Woodpecker nesting and foraging at Sicamous Ck. DRAFT. Ministry of Forests, Kamloops, BC., Canada.

Knight, F.B. 1958. The effects of woodpecker populations on the Engelmann spruce beetle. *Journal of Economic Entomology* 51:603-607.

Knopf, F. L. and F. B. Samson. 1994. Scale perspectives on avian diversity in western riparian ecosystems. *Conservation Biology* 8(3):669-676.

LaRue, P., L. Belanger and J. Huot. 1995. Riparian edge effects on boreal balsam fir bird communities. *Canadian Journal of Forest Research* 25:555-566.

Laurance, W. F. and C. Gascon. 1997. Diversity: How to creatively fragment a landscape. *Conservation Biology* 11(2):577-579.

Linder, K. A. 1994. Habitat utilization and behavior of nesting Lewis' Woodpeckers (*Melanerpes lewis*) in the Laramie Range, Southeast Wyoming. MS Thesis, University of Wyoming, Wyoming, USA.

Lousier, J. D. 1989. Snags, wildlife trees and silviculture. Phase 1 - Preliminary Analysis. Silviculture Branch, Min. of Forests. Victoria, B.C., Canada. 34 p.

Lousier, J. D. 1990. Snag management in silviculture operations. Ministry of Forests, Victoria, B.C., Canada. 75 pp.

Lundquist, R. W. 1988. Habitat use by cavity-nesting birds in the southern Washington Cascades. M.Sc. Thesis, Univ. of Washington, Washington, USA. 157 p.

McComb, W. C. and R. L. Rumsey. 1983. Characteristics and cavity-nesting bird use of picloram-created snags in the central Appalachians. *Southern Journal of Applied Forestry* 7:34-37.

McGarigal, K. and W. C. McComb. 1992. Streamside versus upslope breeding bird communities in the central Oregon coast range. *Journal of Wildlife Management* 56(1):10-23.

Machmer, M. M. and C. Steeger. 1995. The ecological roles of wildlife tree users in forest ecosystems. Ministry of Forests Research Program, Victoria, B.C., Canada. Land Management Handbook No. 35. 54 p.

MacKinnon, A., J. Pojar and R. Coupe, editors. 1992. Plants of northern British Columbia. B.C. Min. For., Victoria, B.C. Lone Pine Publishers, Edmonton, Alta., Canada.

Mannan, R. W., E. C. Meslow and H. M. Wight. 1980. Use of snags by birds in Douglas-fir forests, western Oregon. *Journal of Wildlife Management* 44(4):787-797.

Meidinger, D. and Pojar, J. 1991. Ecosystems of British Columbia. Special Report Series 6. B.C. Ministry of Forests. 330 pp.

Mellen, T. K., E. C. Meslow and R. W. Mannan. 1992. Summertime home range and habitat use of Pileated woodpeckers in western Oregon. *Journal of Wildlife Management* 56(1): 96-103.

Miller, J. W. 1985. Managing wildlife trees in British Columbia: A problem analysis. M.Nat. Res. Man. Thesis, Simon Fraser Univ., Vancouver, B.C., Canada. 178 p.

Miller, D. R. 1997. Proceedings of a workshop on the potential of woodpeckers in managing bark beetles. Richmond, B.C., Canada. 31pp.

Miller, E., A. D. Partridge and E. L. Bull. 1979. The relationship of primary cavity nesters and decay. *Trans. Northeast Sect. Wildl. Soc.* 36:60-68.

Morgan, K.H. and S.P. Wetmore. 1986. A study of riparian bird communities from the dry interior of British Columbia. Tech. Rep. Ser. No. 11. Can. Wildl. Serv., Pac. and Yukon Reg., Delta, B.C. 28pp.

Murray, N.L. and D.F. Stauffer. 1995. Nongame bird use of habitat in central Applalachian riparian forests. *Journal of Wildlife Management* 59(1):78-88.

Naiman, R. J., H. Decamps and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications* 3(2):209-212.

Newton, I. 1994. The role of nest sites in limiting the numbers of hole-nesting birds: A review. *Biological Conservation* 70:265-276.

Nyberg, B. 1995. Adaptive management of wildlife trees: Prospects and partnerships. *In:* Proceeding for Stand Level Biodiversity Technical Workshop. Victoria, B.C., Canada

Parks, C. A., E. L. Bull and G. M. Filip. 1995. Creating wildlife trees in managed forests using decay fungi. Gen. Tech. Rep. RM-GTR-226. U.S. Dep. Agric., For. Serv., Rocky Mtn. For. and Range Exp. Stn. Fort Collins, Colorado, USA. 201 p.

Parminter, J. 1998. Natural disturbance ecology. Pages 3-41 *in* Voller, J. and S. Harrison, editors. 1998. Conservation biology principles for forested landscapes. University of British Columbia Press, Vancouver, B.C., Canada. 243 pp.

Pattanavibool, A. and W. D. Edge. 1998. Single-tree selection silviculture affects cavity resources in mixed deciduous forest in Thailand. *Journal of Wildlife Management* 60(1):67-73.

Peterson, B. and G. Gauthier. 1985. Nest site use by cavity-nesting birds of the Cariboo Parkland, British Columbia. *Wilson Bulletin* 97(3):319-331.

Porter, M. L., M. W. Collopy, R. F. Labisky and R. C. Littell. 1985. Foraging behaviour of red-cockaded woodpeckers: an evaluation of research methodologies. *Journal of Wildlife Management* 49(2):505-507.

Raphael, M. G. and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. *Wildlife Monographs* 86:1-66.

Renken, R. B. and E. P. Wiggers. 1993. Habitat characteristics related to Pileated Woodpecker densities in Missouri. *Wilson Bulletin* 105(1):77-83.

Resource Inventory Committee. 1997. Vegetation resource inventory: Ground sampling procedures. Province of B.C. Resource Inventory Committee. Victoria, B.C.

Shook, R.S. and P.H. Baldwin. 1970. Woodpecker predation on bark beetles in Engelmann spruce logs as related to stand density. *The Canadian Entomologist* 102:1345-1354.

Sokal, R. R. and F. J. Rohlf. 1987. Introduction to Biostatistics. Second edition. W.H. Freeman and Co., New York, USA. 363 pp.

Sousa, P.J. 1987. Habitat suitability index models: Hairy Woodpecker. U.S. Fish and Wildlife Service. Washington, D.C., USA. Biological Report 82.

Spackman, S. C. and J. W. Hughes. 1995. Assessment of minimum stream corridor width for biological conservation: Species richness and distribution along mid-order streams in Vermont, USA. *Biological Conservation* 71:325-332.

Stauffer, D. F. and L. B. Best. 1980. Habitat selection by birds of riparian communities: Evaluating effects of habitat alterations. *Journal of Wildlife Management* 44(1):1-15.

Stauffer, D. F. and L. B. Best. 1982. Nest-site selection by cavity-nesting birds of riparian habitats in Iowa. *Wilson Bulletin* 94:329-337.

Steeger, C. and M. Machmer. 1994. A methodology for surveying woodpeckers in British Columbia. Resource Inventory Committee, Ministry of Environment, Lands and Parks, Victoria, B.C., Canada. DRAFT. 57 pp.

Stevens, V. 1997. The ecological role of coarse woody debris: An overview of the ecological importance of CWD in B.C. forests. Res. Br., B.C. Min. For., Victoria, B.C., Canada. Work. Pap. 30. 26 pp.

Stevens, V., F. Backhouse and A. Eriksson. 1995. Riparian management in British Columbia: An important step towards maintaining biodiversity. B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks, Victoria, B.C., Canada. Work. Pap. 13/1995.

Strathers, R. J., T. P. Rollerson and S. J. Mitchell. 1994. Windthrow handbook for British Columbia forests. Ministry of Forests, Research Program, Victoria, B.C. 31 pp.

Taylor, B., L. Kremsater, and R. Ellis. 1997. Adaptive management of forests in British Columbia. Ministry of Forests, Forest Practices Branch, Victoria, B.C. 93 pp.

Thomas, J. W., R. G. Anderson, C. Maser and E. L. Bull. 1979a. Snags. Pages 60-77 *in* J. W. Thomas, editor. Wildlife habitats in managed forests: The Blue Mountains of Oregon and Washington. U.S. Dep. Agric. For. Serv., Handbook 553. Portland, Oregon, USA. 512 p.

Thomas, J. W., C. Maser and J. E. Rodiek. 1979b. Riparian zones. Pages 40-59 *in* J.W. Thomas, editor. Wildlife habitats in managed forests: The Blue Mountains of Oregon and Washington. U.S. Dep. Agric. For. Serv., Handbook 553. Portland, Oregon, USA. 512 p.

Thurmond, D. P., K. V. Miller and T. G. Harris. 1995. Effect of streamside management zone width on avifauna communities. *Southern Journal of Applied Forestry* 19(4):166-169.

Villard, P. 1994. Foraging behaviour of Black-backed and Three-toed woodpeckers during spring and summer in a Canadian boreal forest. *Canadian Journal of Zoology* 72:1957-1959.

Voller, J. 1998. Managing for edge effects. Pages 215-233 *in* Voller, J. and S. Harrison, editors. 1998. Conservation biology principles for forested landscapes. University of British Columbia Press, Vancouver, B.C., Canada. 243 pp.

Voller, J. 1998. Riparian areas. Pages 98-129 *in* Voller, J. and S. Harrison, editors. 1998. Conservation biology principles for forested landscapes. University of British Columbia Press, Vancouver, B.C., Canada. 243 pp.

von Sacken, A. 1998. Interior habitat. Pages 130-145 *in* Voller, J. and S. Harrison, editors. 1998. Conservation biology principles for forested landscapes. University of British Columbia Press, Vancouver, B.C., Canada. 243 pp.

Walters, C.J. 1986. Adaptive management of renewable resources. McMillan, New York, N.Y., U.S.A.

Wildlife Tree Committee of British Columbia. 1994. Methods for the conservation and management of wildlife trees in British Columbia. BC Environment, Worker's Compensation Board and Silviculture Branch of the Min. of Forests. March 1994, DRAFT.

Zar, J. H. 1996. Biostatistical analysis. Second edition. Prentice-Hall, Inc., Engelwood Cliffs, New Jersey, USA.

Zarnowitz, J. E. and D. A. Manuwal. 1985. The effects of forest management on cavity-nesting birds in northwestern Washington. *Journal of Wildlife Management* 49:255-263.

APPENDIX A. Habitat assessment data form.

Date	Rip/Upl	Plot #	Tree #	Species	Decay Cl.	Ht Class	Bark	DBH	Tree Hlth	% Live Cr	Lean Ang	Sign	Pest	Comment

LOCATION / SHRUB / COMMENTS:

APPENDIX B. Definitions of habitat assessment form variables.

Rip/Upl: riparian or upland habitat. Riparian plots are adjacent to a lake or stream and upland plots are a minimum of 100m from any riparian areas.

Tree # : every tree in each plot will be designated a number

Species: a 2-digit code based on the common name of the tree:

BC	- black cottonwood	MA	- mountain alder
TA	- trembling aspen	LP	- lodgepole pine
SF	- subalpine fir	SX	- hybrid white-Engelmann spruce
PB	- paper birch	Salix	- willow species
DF	- Douglas-fir	SB	- black spruce

DecayCl: Wildlife tree decay class categorizes upright trees based on their level of decay and structure, determined using the following categories (BC Ministries, 1995a):

1. **Live/healthy** - no decay. All foliage, twigs and branches present
2. **Live/unhealthy** - internal decay or growth deformities. Some or foliage lost or dead, possibly some twigs lost, most branches present, possible broken top.
3. **Dead** - hard heartwood. Dead needles and twigs present; roots stable. Most branches present, possible broken top
4. **Dead** - hard heartwood. No needles or twigs; 50% of branches lost, loose bark; top usually broken; roots stable
5. **Dead** - spongy heartwood. Most branches and bark absent; roots stable for larger trees, beginning to soften in smaller trees; broken top.
6. **Dead** - soft heartwood. No branches or bark; sapwood/heartwood sloughing from upper bole; lateral roots of large trees softening, unstable in small trees; broken top.
7. **Dead** - soft heartwood; studs; extensive internal decay; outer shell may be hard; lateral roots completely decomposed; hollow or nearly hollow shells.

Ht Class: height class indicates where a particular tree stands relative to the rest of the canopy represented by the following letters:

A0 - dominant; a veteran tree standing above the main canopy
A1 - co-dominant; part of the main canopy
A2 - intermediate; below the main canopy
B1 - less than 15m in height

Bark: classification of the proportion of bark remaining on the tree, coded from 1-7:

1- all bark present (100%)
2- bark lost on damaged areas only (> 95 % present)
3- most bark present, bare patches, some bark may be loose (75-95% present)
4- bare sections, firm and loose bark remains (50-74% present)
5- most bark gone, firm and loose bark remains (25-49% present)
6- trace of bark remains (1-24% present)
7- no bark (100% lost)

DBH: diameter at breast height (1.3 m), measured in cm using a DBH tape.

Tree health: presence of diagnostic signs such as pathogen attack or previous damage or injury were recorded:

BT - broken top
BU - burl
CA - canker
CO - conk
CR - crook
FC - frost crack
FO - fork
FSC - fire scar
GA - gall
MI - mistletoe
SC - scar

% live crown: an estimate of the percentage of the tree that has live canopy relative to the entire height of the tree

Lean angle: deviation from 90 degrees from the ground measured in degrees from the base of the tree to the top of the main stem (i.e. a slight lean is typically 5%)

Sign: indirect evidence of cavity nester presence or use of habitat:

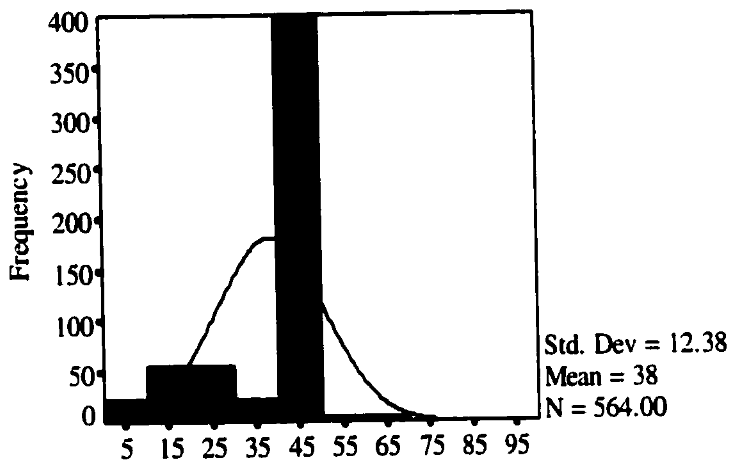
C - cavity
CL - territorial call
D - drum
FL - bark has been flaked off the tree by woodpeckers foraging for arthropods
FS - false start; a hole in a tree or snag, similar to a cavity, but incomplete
HFL- foraging by bark flaking is evident high in the tree, typically found in lodgepole pine trees, > 5m high.

Pest: sign of insect infestations which might influence the tree's susceptibility to being excavated or foraged upon:

BB - bark beetles
WB - woodboring insects
A - carpenter ants

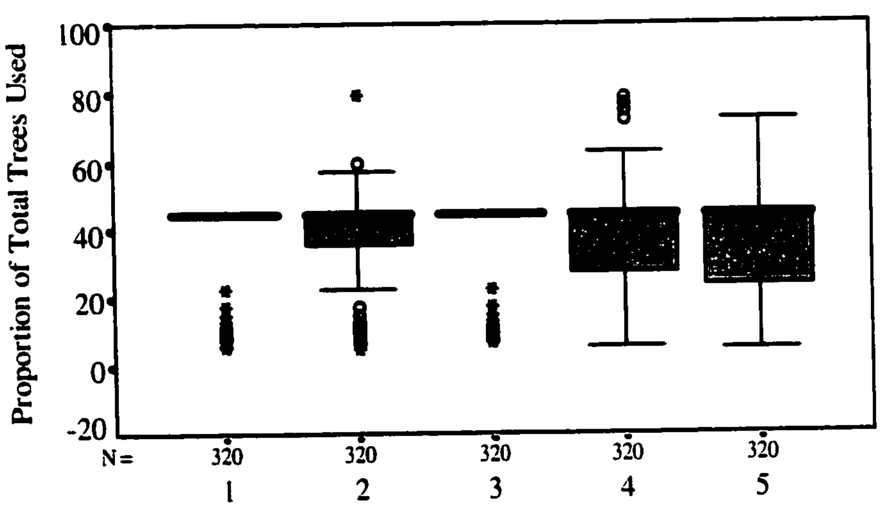
Comments: general comments, plot location and observations for which a category is not provided.

APPENDIX C. Tests for normality of the proportions of total trees exhibiting flaking and/or shallow excavations in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.



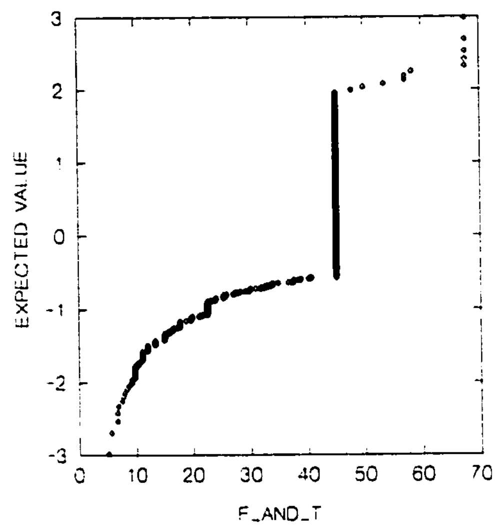
a) Distribution of the Freeman and Tukey arcsine square root transformed proportions of total trees exhibiting flaking/shallow excavations, with normal curve overlaid.

(It is evident that these data were not normally distributed as the frequency distribution did not follow approximately the same distribution as the overlaid normal curve.)



b) Boxplot of the Freeman and Tukey arcsine square root transformed proportions of total trees exhibiting flaking/shallow excavations.

(The negatively skewed boxplots indicate that the data do not follow a normal distribution.)



c) Normal probability plot of the Freeman and Tukey arcsine square root transformed proportions of total trees exhibiting flaking/shallow excavations.

(The data exhibit non-normal distribution in this plot as the points do not follow a linear relationship with a 45 degree slope.)

d) Kolmogorov-Smirnov goodness of fit test for normality of the Freeman and Tukey arcsine square root transformed proportions of total trees exhibiting flaking/shallow excavations:

Test distribution - Normal Mean: 38.4012 Cases: 564 Standard Deviation: 12.3798

Most extreme differences:

Absolute	Positive	Negative	K-S Z	2-Tailed *P*
0.42108	0.27750	-0.42108	10.0001	**0.0000**

(This test also suggests that the data are not normally distributed ($P \leq 0.001$).)

APPENDIX D. Proportions of total trees exhibiting flaking and shallow excavations by species for all sites combined in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.

	Tree Species*				
# of trees:	SF	LP	SX	BS	**total**
used	121	252	440	100	**913**
expected	321.3	212.1838592	267.95	111.54	
available	1740	1149	1451	604	**4944**

G = 264.929
p < 0.001

* SF = subalpine fir; LP = lodgepole pine; SX = hybrid white-Engelmann spruce; BS = black spruce

Bonferroni Confidence Intervals:

$$p' - Z_{\alpha}/2k * (p'(1-p')/n)^{0.5} \leq p \leq p' + Z_{\alpha}/2k * (p'(1-p')/n)^{0.5}$$

p' = species used / total used   k = 4 species $\alpha = 0.05$
$Z = 2.722$ $\alpha/2k = 0.0063$ $n = 913$

subalpine fir
p': 121/913 = 0.133
Lower CL: 0.102   Upper CL: 0.163

The expected p' is 321.32 / 913 = **0.3519** which falls above the confidence interval, suggesting subalpine fir was selected against.

lodgepole pine:
p': 252/913 = 0.276 Z = 2.722   n = 913
Lower CL: **0.236** Upper CL: **0.3163**

The expected p' is 212.18/913 = **0.2324** which falls just below the confidence interval, suggesting lodgepole pine was selected for.

hybrid white-Engelmann spruce:
p': 440/913 = 0.482   Z = 2.722   n = 913
Lower CL: **0.437** Upper CL: **0.5269**

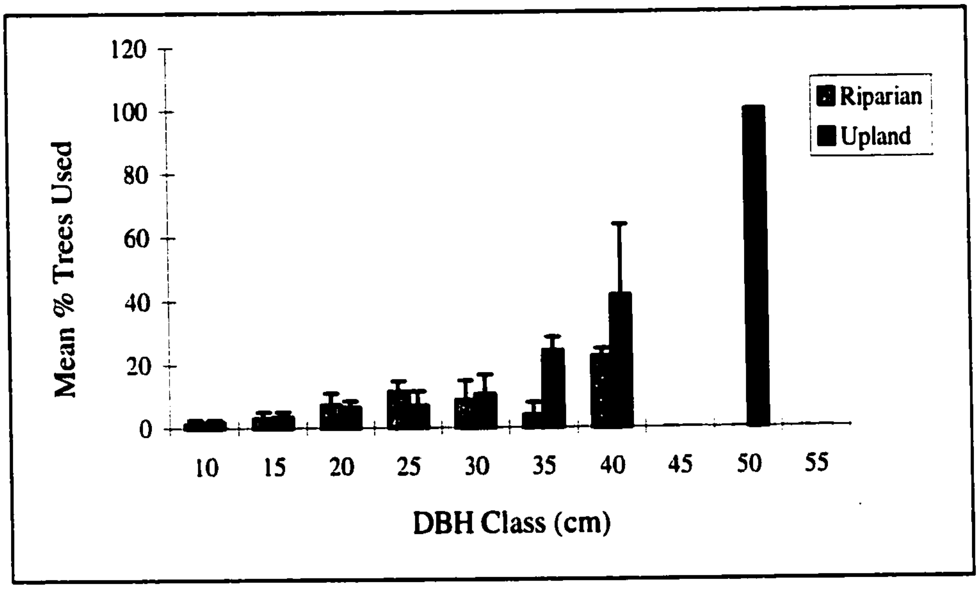
The expected p' is 267.95/913 = **0.2935** which falls well below the confidence interval, suggesting hybrid spruce was selected for.

black spruce:
p': 100/913 = 0.11   Z = 2.722   n = 913
Lower CL: **0.081** Upper CL: **0.1377**

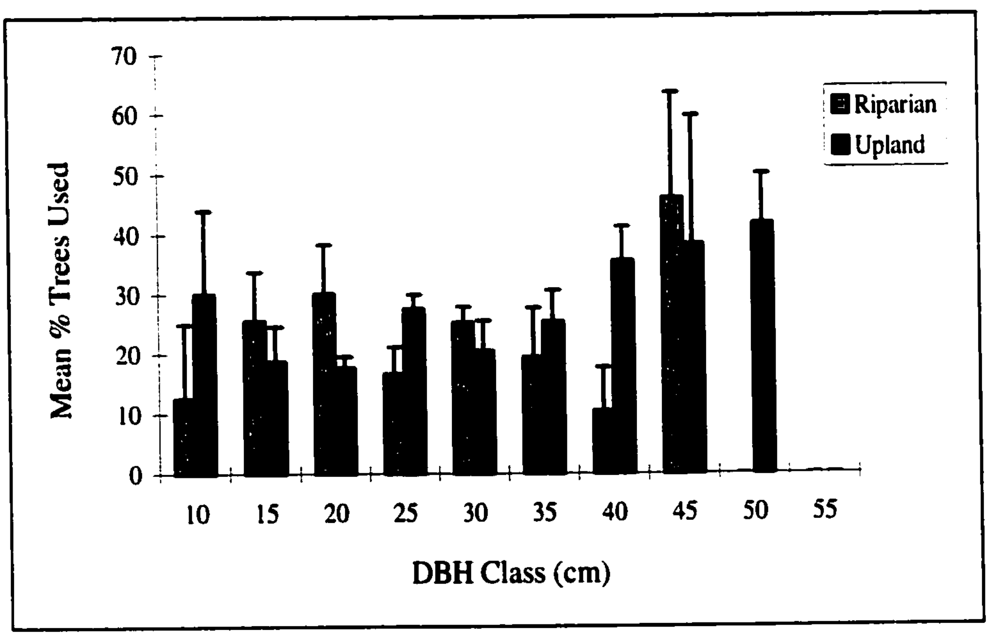
The expected p' is 111.54/913 = **0.1222** which falls within the confidence interval,suggesting black spruce is being used in proportion to its availability.

Appendix E

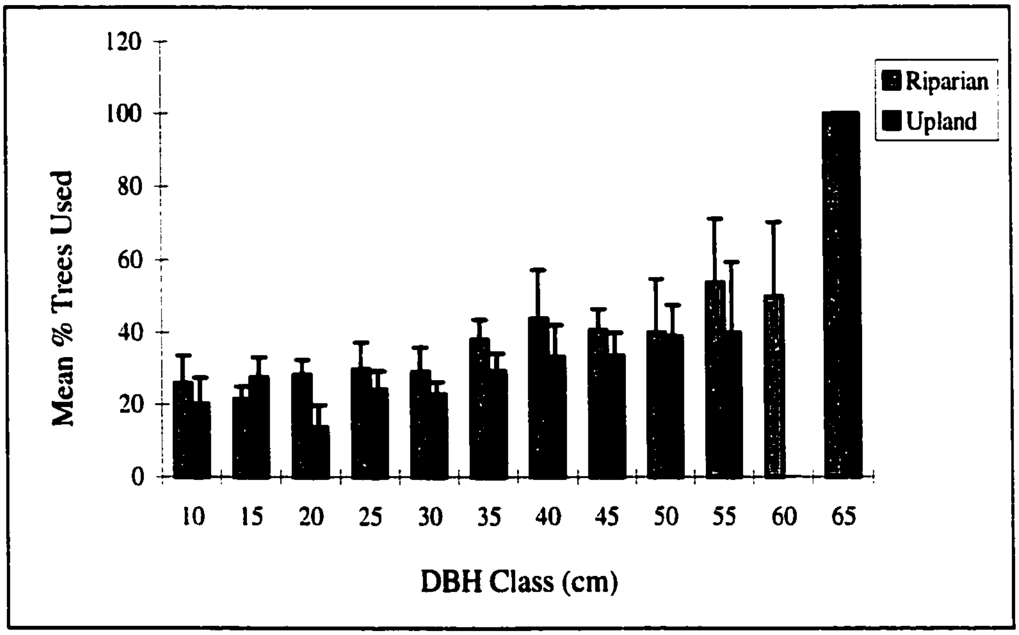
a) Mean percentage of subalpine fir trees exhibiting flaking and shallow excavations by DBH class and zone in the SBSmk1, British Columbia, 1996-97 (n = 5).



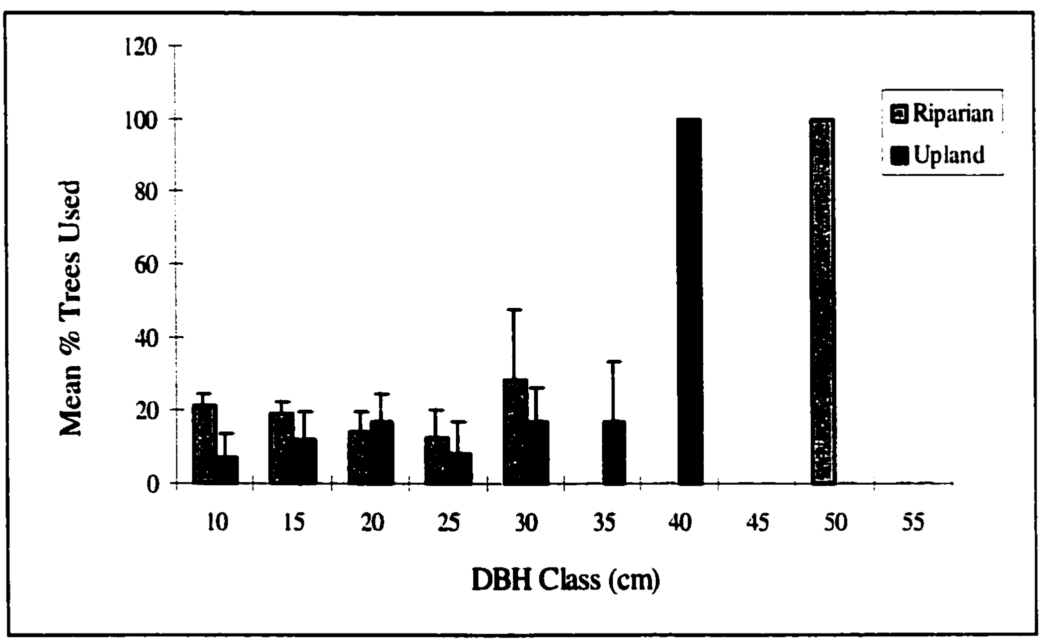
b) Mean percentage of lodgepole pine trees exhibiting flaking and shallow excavations by DBH class and zone in the SBSmk1, British Columbia, 1996-97 (n = 5).



c) Mean percentage of hybrid spruce trees exhibiting flaking and shallow excavations by DBH class and zone in the SBSmk1, British Columbia, 1996-97 (n = 5).

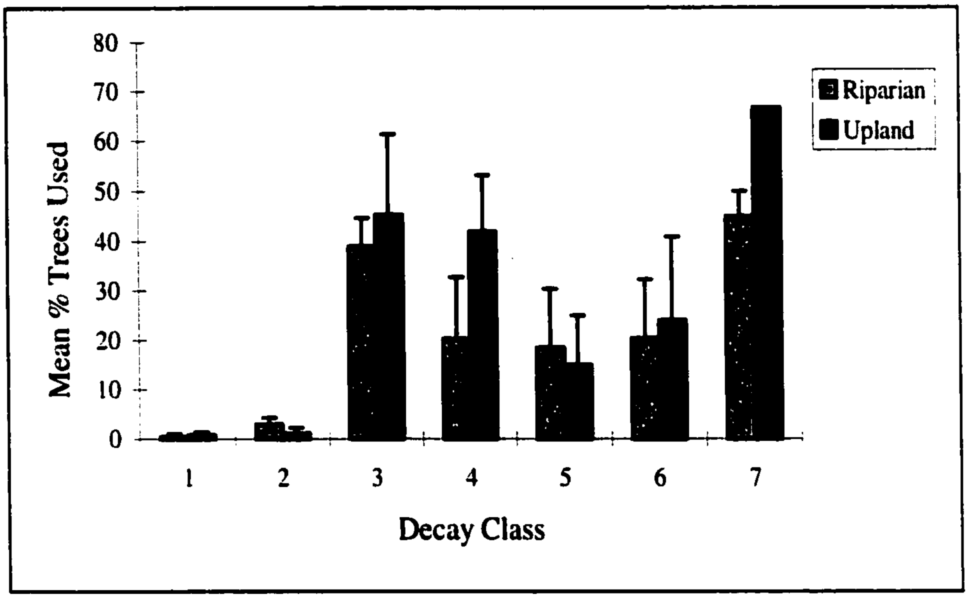


d) Mean percentage of black spruce trees exhibiting flaking and shallow excavations by DBH class and zone in the SBSmk1, British Columbia, 1996-97 (n = 5).

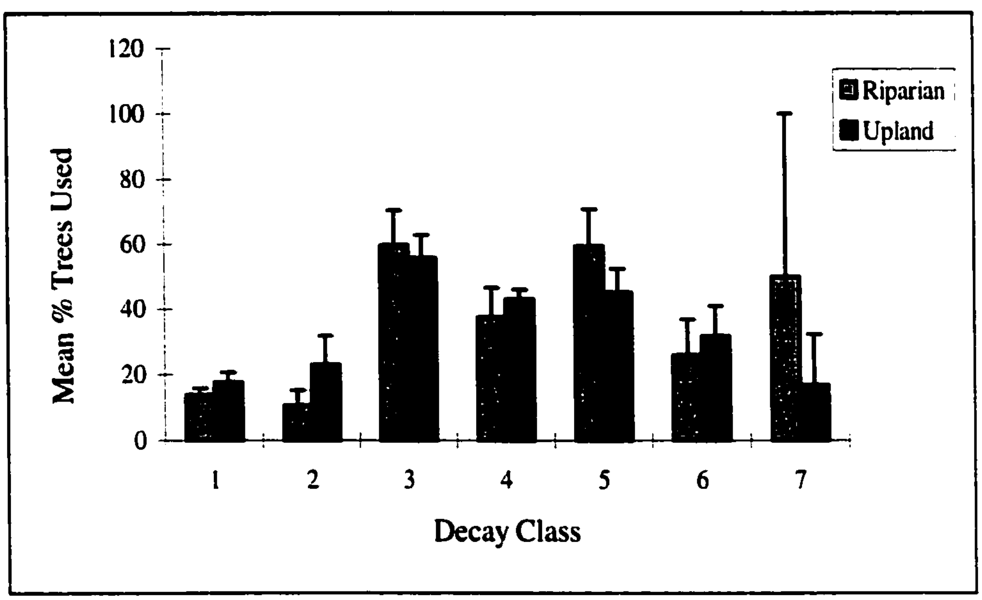


Appendix F

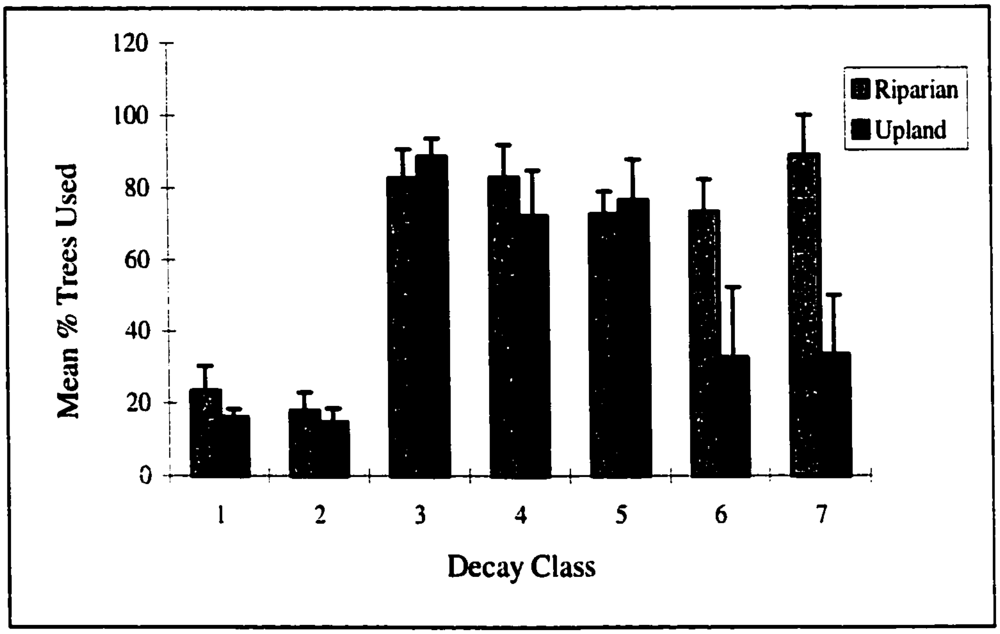
a) Mean percentage of subalpine fir trees exhibiting flaking and shallow excavations by decay class and zone in the SBSmk1, British Columbia, 1996-97 (n = 5).



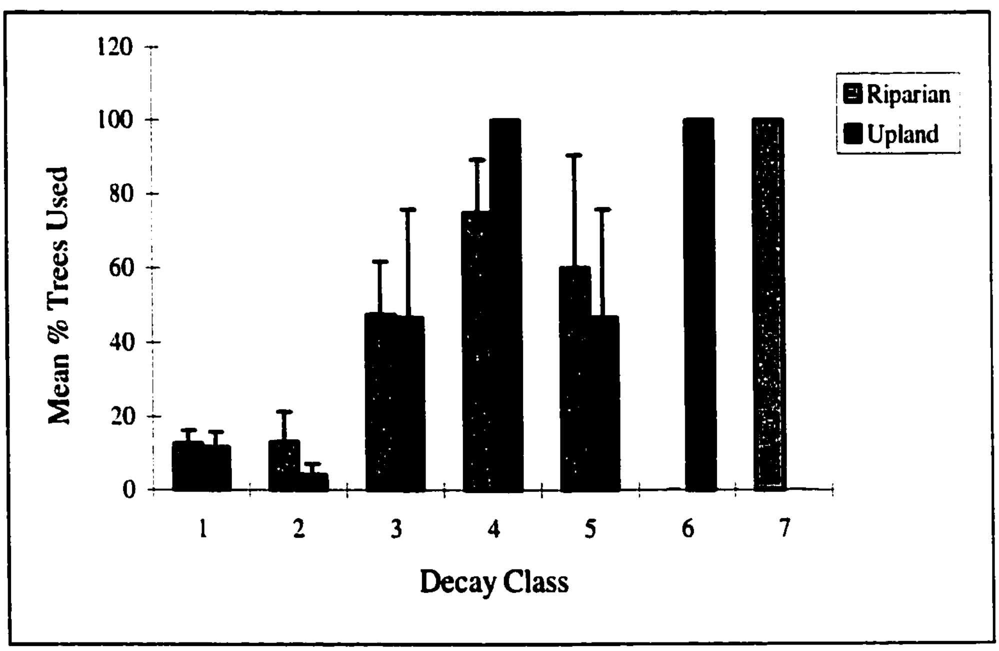
b) Mean percentage of lodgepole pine trees exhibiting flaking and shallow excavations by decay class and zone in the SBSmk1, British Columbia, 1996-97 (n = 5).



c) Mean percentage of hybrid spruce trees exhibiting flaking and shallow excavations by decay class and zone in the SBSmk1, British Columbia, 1996-97 (n = 5).

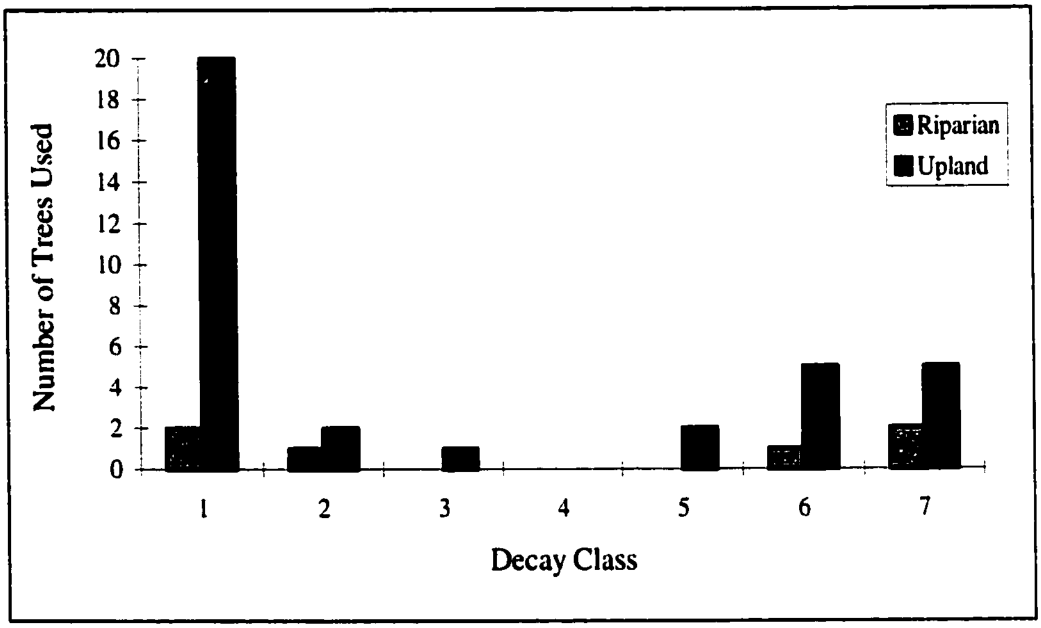


d) Mean percentage of black spruce trees exhibiting flaking and shallow excavations by decay class and zone in the SBSmk1, British Columbia, 1996-97 (n = 5).

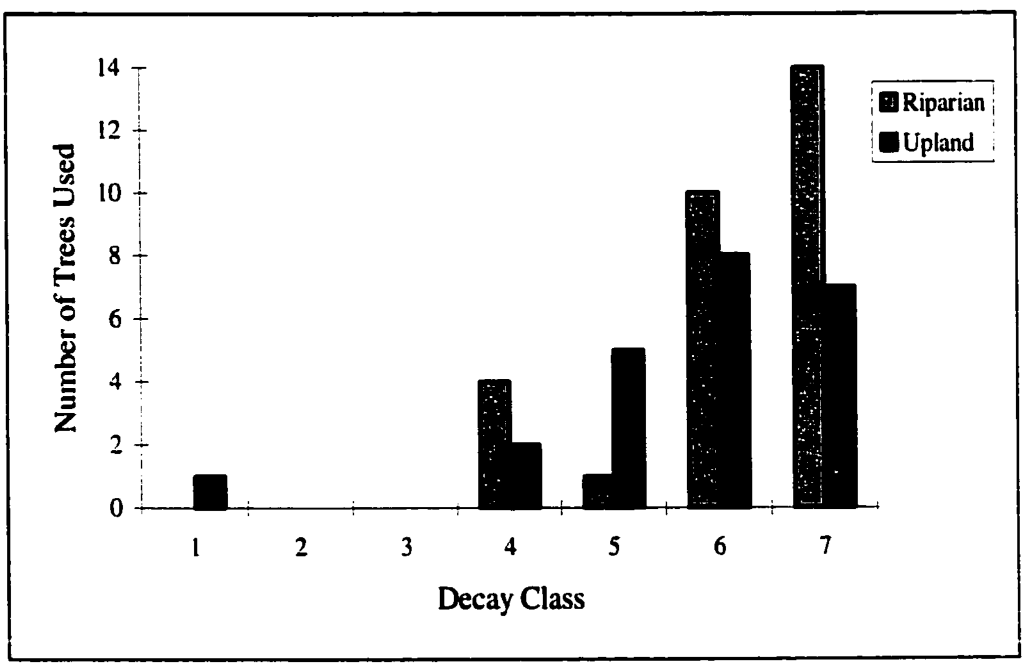


APPENDIX G

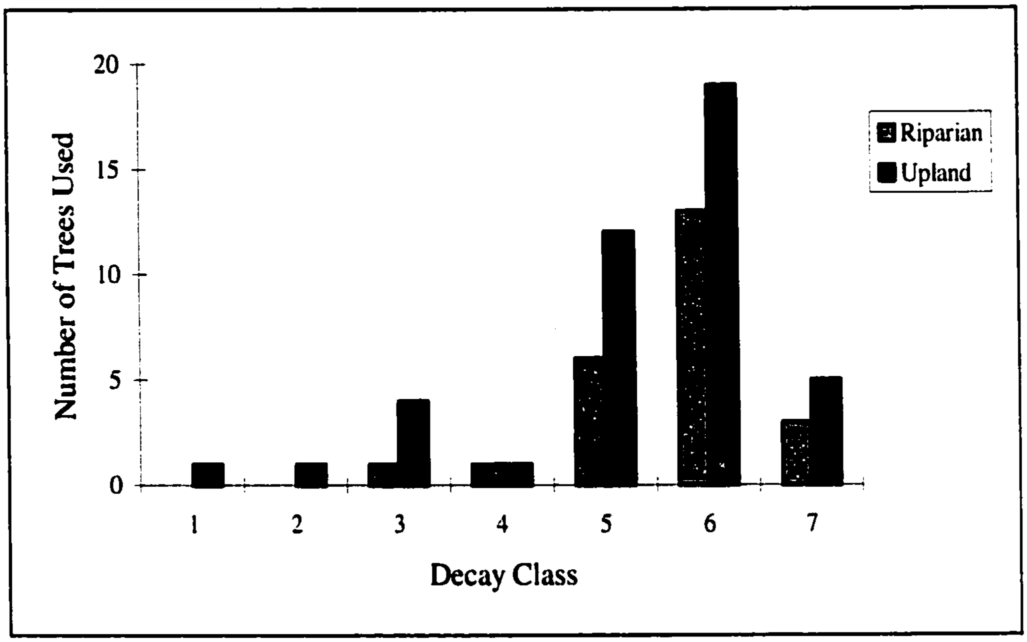
a) Number of trembling aspen trees used for cavity excavation by decay class and zone in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.



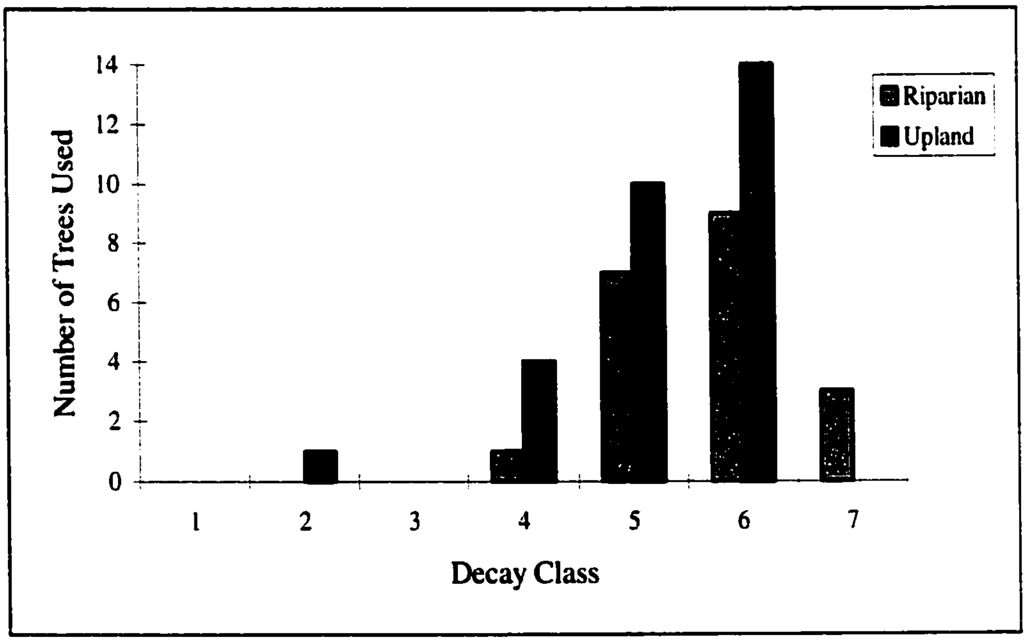
b) Number of subalpine fir trees used for cavity excavation by decay class and zone in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.



c) Number of lodgepole pine trees used for cavity excavation by decay class and zone in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.

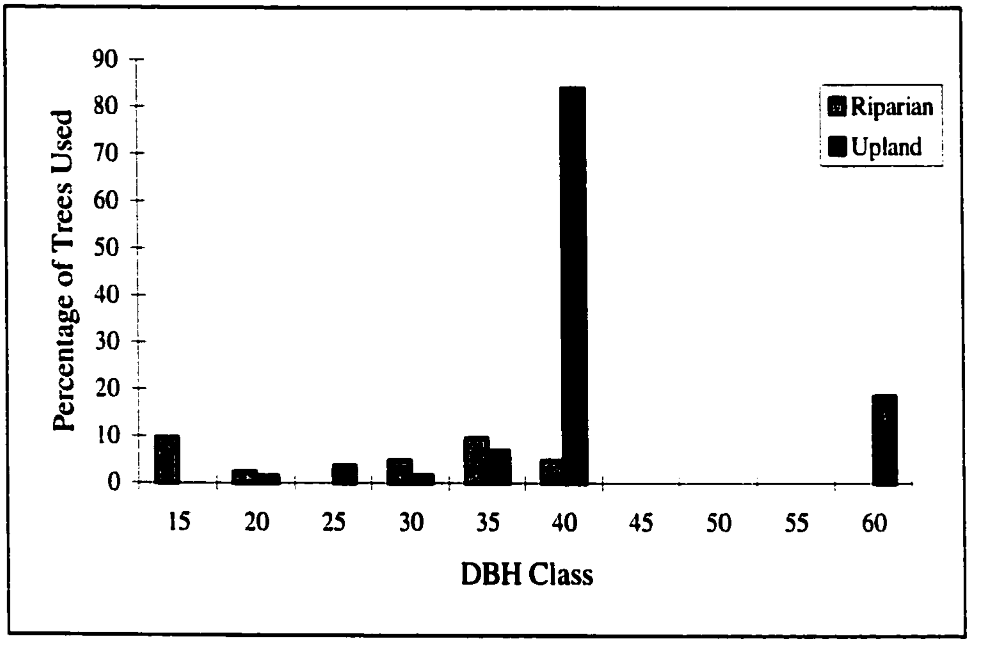


d) Number of hybrid spruce trees used for cavity excavation by decay class and zone in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.

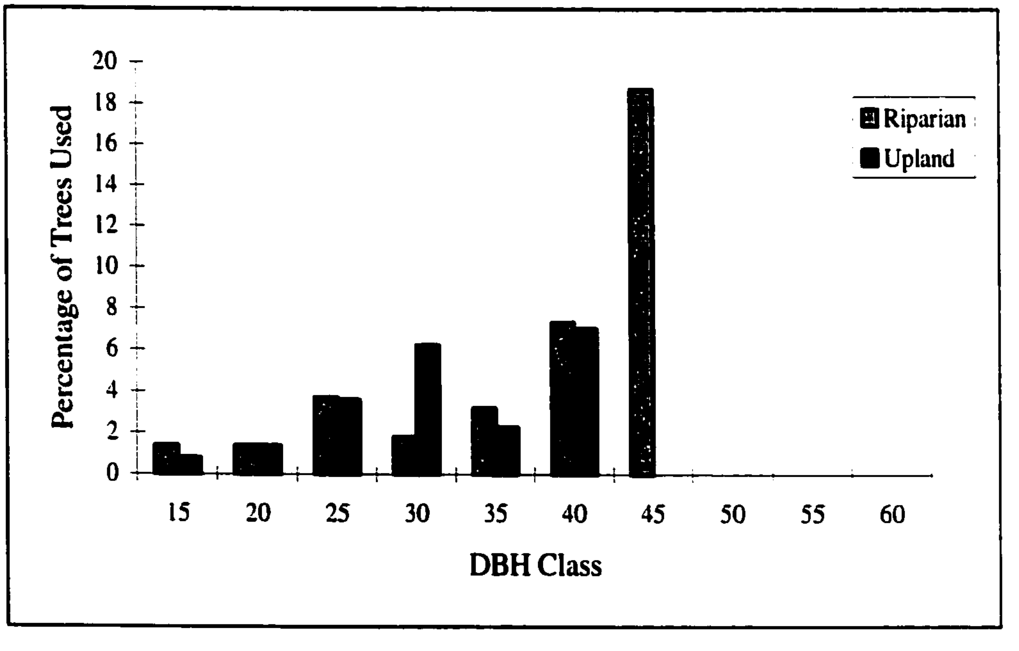


APPENDIX H

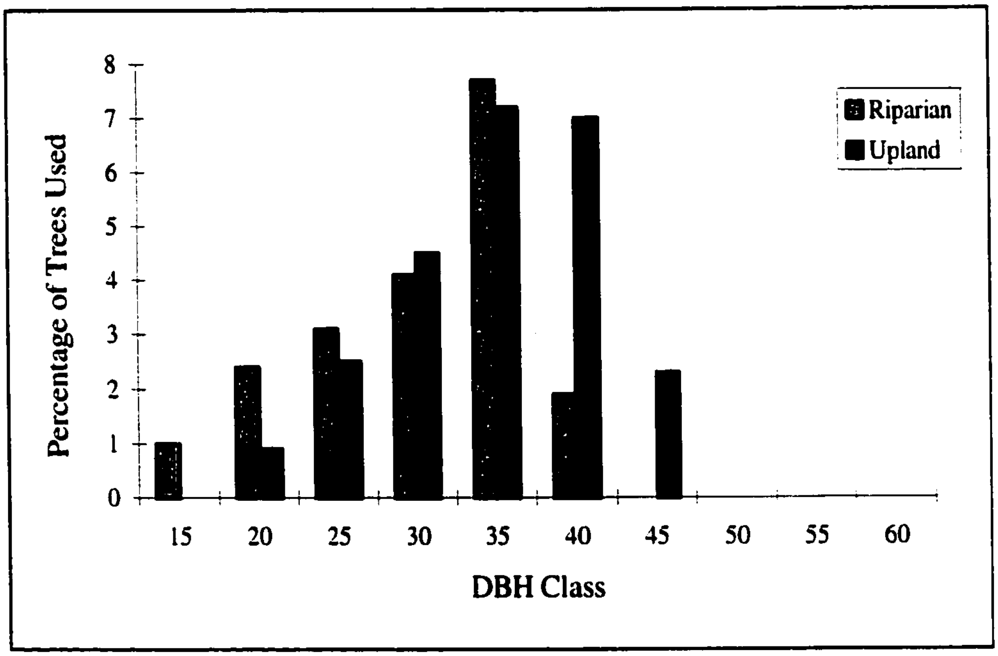
a) Percentage of aspen trees with cavities by DBH class and zone in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.



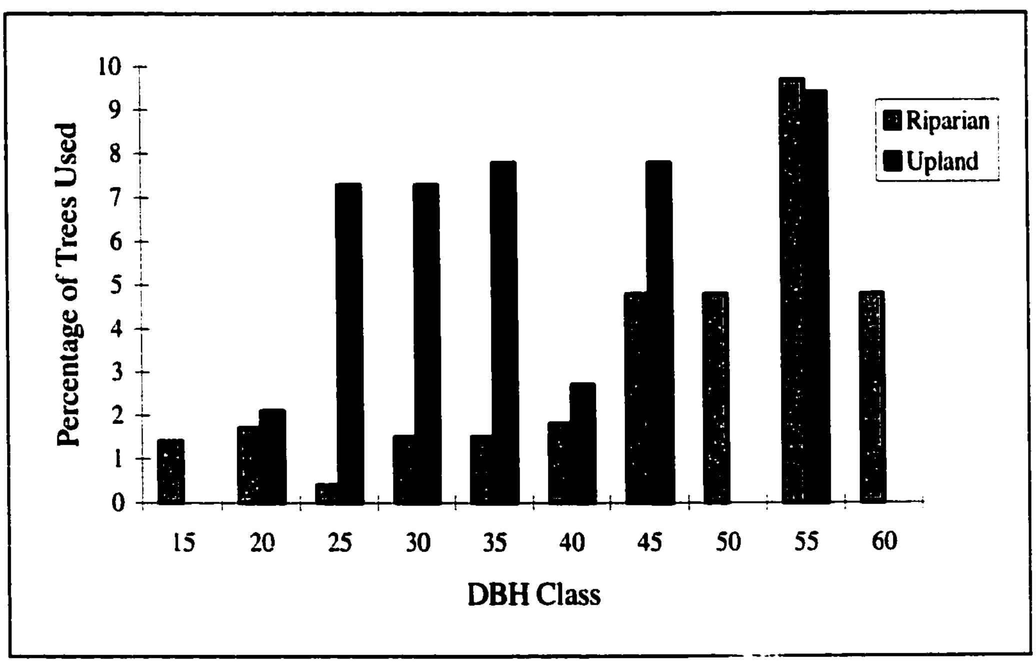
b) Percentage of subalpine fir trees with cavities by DBH class and zone in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.



c) Percentage of lodgepole pine trees with cavities by DBH class and zone in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.



d) Percentage of hybrid spruce trees with cavities by DBH class and zone in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.



Appendix I. Percentage of trees used for cavity excavations with insect presence in riparian and upland zones in the SBSmk1 biogeoclimatic subzone, British Columbia, 1996-97.