Characteristics and Selection of Winter Dens by Black Bears in Coastal British Columbia

by

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Abstract

Selection of dens and denning habitat by black bears was examined in the Nimpkish Valley, British Columbia from 1992-1995. Sixty-seven dens were located, 40 dens of 21 radio-collared black bears and 27 dens of unmarked bears. All dens were in or beneath large diameter ($\bar{x}$= 143 cm) trees or wooden structures derived from trees (logs, root boles and stumps). Most dens were in yellow cedar (30%) and redcedar trees (28%). There was 28% reuse of dens by radio-collared bears. Male bears entered dens later in the fall and emerged earlier in the spring than did females.

Bears selected habitat for winter dens at various spatial scales. At the element scale, wooden structures used as dens were larger in diameter than those available near dens. At the patch scale, bears selected for structural complexity contributed by coarse woody debris, stocking densities of trees, percent cover of vegetation, horizontal visibility and slope. Results at the stand scale were similar, but also included avoidance of early seral stages and selection for late successional stages of the Blueberry Moss Black Bear Habitat Type. Selection for mid-elevations, and avoidance of low elevations, was detected at the landscape scale but this may be a result of reduced availability of large diameter trees at low elevations because of past logging. The capability of habitat to supply bears with dens depends not only on the average quality of the habitat, but also on the variance within habitats. It is this variance that allows bears to find and use the relatively rare, but nonetheless critical, habitat elements that provide suitable den sites at multiple spatial scales.

Commercial forest harvesting removes structures used by black bears for winter dens. I provide recommendations for the management of denning habitat for black bears in coastal ecosystems. Landscape level planning is required to ensure that there are suitable distributions of denning habitat both in space and time. Retention of important forest elements in wildlife tree patches, such as den trees with entrances to den cavities above ground level, will ensure that den cavities for black bears occur through future forest rotations.

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Finally, I dedicate this thesis to the black bears that I studied. They were my inspiration and strength but unfortunately also my weakness as many died through the course of this study. I will never forget the joy and pain of this study.

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Introduction

Black bears (*Ursus americanus*) inhabit most of North America, from Mexico to Alaska. They hibernate throughout their geographic range, a behaviour which is rare among Carnivora. Bears survive periods of low food availability and low temperatures by accumulating energy in the form of body fat, entering a period of dormancy in which their metabolic expenditures are lowered, and then drawing on these stored energy reserves. Consequently, winter hibernation is an important aspect of the life history of bears.

Dens play an important role in assisting bears to reduce energy losses during winter hibernation (Lentz et al. 1983). Therefore, dens which minimize energy losses should be preferred by bears. Selecting a den with a favourable microclimate is especially important for females because they have additional energy costs during this period of gestation, whelping, and nursing of cubs (Lentz et al. 1983). The types of structures that black bears can use successfully for denning are dictated, in large part, by the environmental conditions encountered during the denning period. In regions with persistent, deep snow cover, dens are well insulated from cold ambient air and provide relatively warm, stable micro-environments. In areas with warm temperatures, structures that provide micro-environments with good heat retention are probably not as critical to bears because of the relatively low energy losses incurred during denning.

Coastal temperate forests of western North America present black bears with ecological challenges that are different from those elsewhere within their range. The combination of cool and wet climate during the denning period likely places constraints on the type of structures that black bears can use successfully. Because of these climatic differences, black bears in coastal temperate forests are unable to rely upon persistent snow cover or warm temperatures to survive their energy bottleneck. These differences in abiotic conditions compared to elsewhere in their range likely mean that black bears in coastal temperate forests require den structures that are different from those in areas that have less precipitation and warmer temperatures or persistent snow cover.

Anecdotal evidence suggests that black bears in coastal temperate forests rely upon structures common to late successional forests. The broad-scale conversion of these late successional forests into early seral stages through timber harvesting may have impacts on the supply of dens for black bears in coastal forests, especially in heavily modified landscapes. If bears rely upon old-growth structures for denning, forest harvesting activities may have a negative effect on the survival of individuals and populations by reducing both the quantity and quality of structures that are available for denning.

The objective of my thesis is to determine characteristics of dens and features of denning habitat that allow black bears to survive the cool, wet winters of coastal British Columbia. In Chapter 1, I describe and compare characteristics of dens used by black bears in coastal British Columbia. In Chapter 2, I use a multi-scale approach to examine the selection of dens. In Chapter 3, I use the results of Chapters 1 and 2 to derive management recommendations for conserving denning habitat for black bears in coastal British Columbia.

Study Area

The study area is located in the Nimpkish Valley, approximately 40 km south of Port McNeill on northern Vancouver Island, British Columbia (Fig. 1). The 20 000 ha area centres around the south end of Nimpkish Lake. Nimpkish Valley is characteristic of the Northern Island Mountains ecosection of the West Vancouver Island ecoregion (Demarchi 1995). Biogeoclimatic zones represented are: the very dry maritime subzone (CWHxm) of the Coastal Western Hemlock zone, the submontane and montane variants (CWHvm1, CWHvm2) of the very wet maritime Coastal Western Hemlock subzone and the moist maritime (MHmm1) and moist maritime parkland (MHmmp1) subzones of the Mountain Hemlock zone (Nuszdorfer 1991). Topography and land forms of the valley are typical of the North Island Mountains physiographic region, with elevations ranging from 20 m to over 1500 m. Mean annual precipitation at Woss (south of the study area) ranged from 180 to 295 cm over a 15-year period ($\bar{x}$= 229 cm; Rochelle 1980). The six months between April and September account for only 23% of the total annual precipitation (Rochelle 1980).

The boundary of the study area was determined after the first year of data collection and is based on home ranges for radio-collared bears. I drew the boundary to include the spring and breeding ranges of the bears collared at that time because bears may choose den sites near their spring feeding ranges (LeCount 1983). I felt that my selection of the study area boundary satisfied the assumption that the animals used for the analyses had the opportunity to select any of the habitat which was deemed available (Neu et al. 1974). If the study area covered a larger area, this assumption would not have been met for the female black bears that I studied.

Ten species of coniferous trees occur in the study area: Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), mountain hemlock (*Tsuga mertensiana*), western redcedar (*Thuja plicata*), yellow-cedar or cypress (*Chamaecyparis nootkatensis*),

Pacific

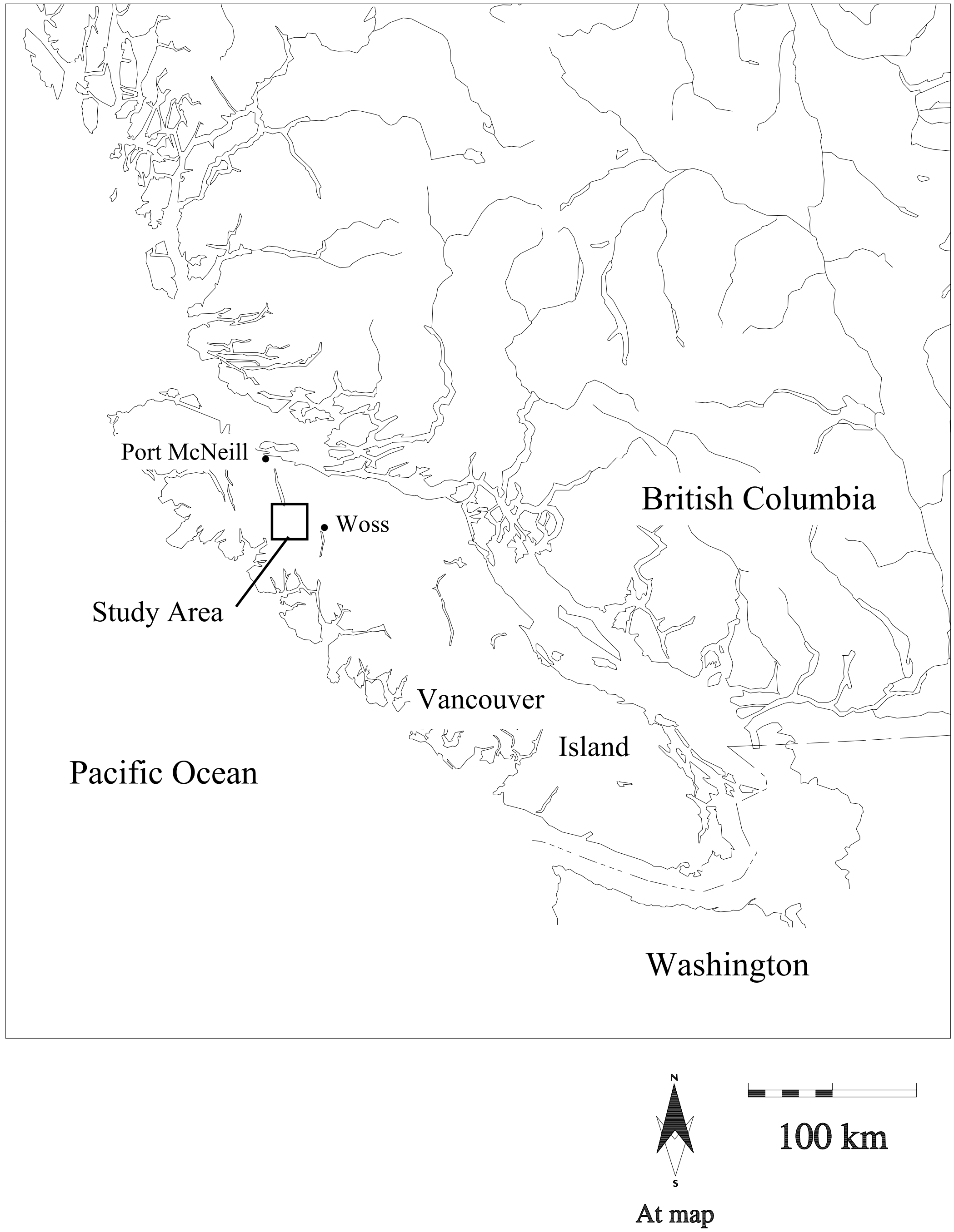

Figure 1. Location of the study area in the Nimpkish Valley on northern Vancouver Island, British Columbia.

silver fir or balsam (*Abies amabilis*), Sitka spruce (*Picea sitchensis*), western white pine (*Pinus monticola*), lodgepole pine (*Pinus contorta*) and Pacific yew (*Taxus brevifolia*). Deciduous species include red alder (*Alnus rubra*), big-leaf maple (*Acer macrophyllum*), black cottonwood (*Populus balsamifera* var. *trichocarpa*) and several species of willow (*Salix* spp.). Dominant shrubs found on nutrient medium to rich sites include: salmonberry (*Rubus spectabilis*), devil's club (*Oplopanax horridus*) and red elderberry (*Sambucus racemosa*). Poor to medium sites may have extensive cover of blueberry and huckleberry shrubs (*Vaccinium ovalifolium*, *V. alaskaense, V. parvifolium,* and *V. membranaceum*). On poor, dry sites, salal (*Gaultheria shallon*) typically dominates the shrub layer.

The CWHxm occurs in the lower valley bottom, generally below 400 m elevation. It has warm, dry summers and moist mild winters with little snowfall. The dominant trees and shrubs are western hemlock, Douglas-fir, western redcedar, salal, and red huckleberry (*Vaccinium parvifolium*). The wetter, cooler CWHvm1 is located above the CWHxm (to approximately 600 m elevation) but reaches down to 140 m elevation along the western portion of the study area. It has wet, cool summers and mild winters with little snowfall. The tree species in this subzone are western hemlock, Pacific silver fir, western redcedar and some yellow-cedar. The understory contains less salal and more *Vaccinium* spp. than the CWHxm.

The CWHvm2 variant is located above the CWHvm1 (to approximately 800 m elevation) with cool, short summers and more persistent snow cover throughout the winter. The Mountain Hemlock zone (MHmm1) occurs above the CWHvm2 and extends up to 1000 m elevation. It has short, cool, moist summers and long, cold, wet winters, with snow packs that last into summer. Tree species consist of Pacific silver fir, mountain hemlock, and yellow-cedar, with the understory dominated by *Vaccinium* spp. (Green and Klinka 1994).

The study area is located within a portion of Tree Farm Licence (TFL) #37, held by Canadian Forest Products Limited (CANFOR). Large scale logging started in the Nimpkish Valley in 1917. TFL #37 contains second growth stands up to 70 years old; some of these stands will be available for harvest within 10 years (Management and Working Plan Number 7, Canadian Forest Products Ltd.). Commercial thinning has begun in some of the older second growth stands. Many second growth stands were juvenile-spaced in the 1980's, leaving large amounts of debris amongst the remaining crop trees.

Road access in the study area is extensive. The North Island Highway runs north-south along the east side of the study area. A high density of logging roads in good condition occurs throughout most of the study area as well as numerous spurs and abandoned roads that are accessible by mountain bike or hiking. Roads occupy approximately 5% of the harvested land base.

Chapter 1. Den Characteristics and Denning Behaviour

Introduction

Dens are used by black bears (*Ursus americanus*) to obtain shelter and security during their over-winter period of dormancy and restricted energy intake. Denning is an important seasonal activity of black bears which affects many aspects of their biology both within the denning period as well as during the rest of the year. Most factors associated with winter denning in some way affect either the accumulation of energy stores prior to denning, the expenditure of energy during denning (Lentz et al. 1983), or the safety of den occupants. Bears survive by managing their energy intake and their energy expenditure within a secure environment.

Prior to denning, bears feed voraciously and accumulate fat deposits that can result in up to 30-40% increase in body weight over a period of two months (Pelton 1993). They become hyperphagic prior to denning so that they amass enough energy to survive the winter dormancy period (Nelson et al. 1983). Daily food intake can double from 8 000 kcal/day up to 15 000-20 000 kcal/day (Nelson et al. 1983). The accumulation of fat stores is critical for over-winter survival of adults and production of cubs. Fall food abundance is directly related to the survivorship and reproductive success of bears (Rogers 1976).

Prior to, during, and after winter hibernation, or denning, black bears go through several physiological changes which affect levels of activity and metabolic rates. Throughout the entire denning period bears do not eat, drink, urinate or defecate (Folk et al. 1976). Although heart rates and metabolic rates decrease during denning, near normal body temperatures are maintained and hence energy expenditures are as high as 4 000 kcal/day (Nelson et al. 1983). Over winter, male bears require only sufficient fat reserves to meet their metabolic needs. However, female bears give birth and suckle their cubs during the denning period and hence must have additional fat reserves beyond those needed by males. Nursing females may lose an additional 9% of body weight in addition to the 15-25% average weight loss by males and non-lactating females (Tietje and Ruff 1980).

The thermal benefits conferred to bears by dens depend on the type and characteristics of dens as well as how long dens are used. The amount of energy expended by bears over winter can be reduced if dens are well insulated (Lentz et al. 1983) and if the ambient temperature is close to that of the body temperature of bears. Climate, in large part, may affect the amount of thermal cover needed by bears in dens. Because climate varies across North America, I expected that black bears on northern Vancouver Island would use different types of dens, for different lengths of time, than do black bears elsewhere in their geographic range.

Duration of the denning period varies regionally and appears to be more constrained for females than it is for males. In southerly portions of the black bear's range, barren females sometimes den for only a few weeks, while pregnant females den as long as 4.5 months (Wooding and Hardisky 1992). Even in very warm regions, female bears den while male bears may not den at all (Mexico: Doan-Crider and Hellgren 1996). The use of dens by females regardless of the regional climate is likely a consequence of their providing secure sites for cubs to grow and strengthen before venturing afield.

Black bears exhibit great flexibility in the types of dens that they use across their geographic range (Table 1). Natural and excavated depressions under tree roots, stumps and fallen logs (Erickson et al. 1964, Lindzey and Meslow 1976*a*), live and dead hollow trees (Jonkel and Cowan 1971, Lindzey and Meslow 1976*a*, Beecham 1980) or tree cavities above ground (Pelton et al. 1980, Johnson and Pelton 1981, Wathen et al. 1986) have all been used for denning. Cavities beneath boulders (Jonkel and Cowan 1971, Novick et al. 1981, LeCount 1983), unsheltered depressions (Hamilton and Marchinton 1980) and cavities excavated into

Table 1. Types of dens used by black bears throughout their geographic range. Only the den type used most frequently in each study is listed.

Type of den and location	Reference
Hollow trees (basal or above ground entrances)	
Montana	Jonkel and Cowan (1971)
Tennessee - eastern	Johnson and Pelton (1981), Wathen et al. (1986)
Arizona - east central	LeCount and Yarchin (1990)
Under or in logs, root boles and root masses	
Alberta - east-central	Tietje and Ruff (1980)
Michigan	Manville (1987)
Oregon	Noble et al. (1990)
Alaska - Mitkof Island	Erickson (1982)
Under stumps	
Washington - Long Island	Lindzey and Meslow (1976*a*)
Rock cavities and cavities beneath boulders	
Arizona - central	LeCount (1983)
Colorado - west-central	Beck (1991)
California - southern	Novick et al. (1981)
Mexico - northern	Doan-Crider and Hellgren (1996)
Open nest or shallow depression	
North Carolina	Hamilton and Marchinton (1980)
Virginia	Hellgren and Vaughan (1989)
Florida - north-central	Wooding and Hardisky (1992)

hillsides (Erickson et al. 1964, Beecham 1980, Tietje and Ruff 1980) have also been used by black bears. Use of man-made structures are rare, but use of a drainage culvert (Barnes and Bray 1966) and a cabin subspace (Jonkel and Cowan 1971) have been documented.

Although many types of dens are used by black bears across North America, in western North America there seems to be a preference for dens associated with large trees. All dens in the following studies were associated with large trees (includes standing trees and snags, logs, and stumps): Mitkof Island, Alaska (Erickson 1982); Long Island, Washington (Lindzey and Meslow 1976*a*); and Oregon (Noble et al. 1990). In some studies in which bears did not use large trees, researchers hypothesized that this may have been due to low availability of den structures (Hamilton and Marchinton 1980, LeCount 1983).

In coastal British Columbia, black bears hibernate through cool, very wet winters. They rely upon denning structures to provide adequate thermal protection during this time. The combination of persistent rainfall, lack of permanent snow cover, and low temperatures found in coastal British Columbia may result in bears selecting for specific den structures that provide protection from these abiotic factors. My objectives are to: describe dens used by black bears during hibernation on northern Vancouver Island; determine if age and sex classes differ in the use of dens; and compare my results to those obtained in other studies of denning black bears in North America. Results from this chapter are important because they will facilitate identification of dens and denning habitat in other areas of coastal British Columbia as well as reveal potential factors which may affect den selection among black bears.

Methods

Bears were trapped as part of the Nimpkish Black Bear Study, Vancouver Island, British Columbia. For my portion of this study, I examined the denning behaviour of black bears in the

Nimpkish Valley from January 1993 to May 1995. Bears were captured either in a culvert trap or with Aldrich foot snares set in baited cubbies or on fresh bear trails (*sensu* Jonkel 1992). Most of the bears were captured in the spring of 1992 and 1993, but selective trapping using a culvert trap continued throughout the study. A jab stick was used to inject the bears with Telazol ($\bar{x}$= 10.1 mg/kg, n = 44, Ayerst Laboratories, Montreal, Que.). Once immobilized, bears were radio-collared (Telonics Inc. Mesa, Ariz.), tattooed in the lip and groin, and weighed. I took blood and hair samples, and recorded body measurements. Collars were fitted with firehose spacers so that they would "drop-away" (Hellgren et al. 1988). I extracted a small premolar tooth to determine age by cementum analyses (Matson's Laboratory, Milltown, Mont.). I classed bears ≤4 years of age as subadults, and those ≥5 years as adults.

I located radio-collared bears by driving roads in the study area until a signal was detected using a 4-element antenna mounted on a vehicle. I took bearings using a hand-held "H" antenna to determine the den location more accurately and then walked in closer to den sites. I did not attempt to approach the dens closely in the spring or fall due to the risk of den abandonment. Dens in remote locations were initially located during aerial survey flights and marked on aerial photographs. Den locations were verified by walking to accessible dens and marking remote dens by helicopter in January of each year. During these helicopter flights, I marked den sites with coloured hoops placed over the tops of trees and dropped radio-collars to aid in location of the dens the following spring. Locations were marked on air photos and transferred to 1:20 000 maps or orthophotos. Universal Transverse Mercator (UTM) coordinates were recorded for each location.

We attempted to immobilize female black bears in their dens during the first week of March 1993 with the intent of replacing radio-collars and determining cub production. We were unsuccessful because the bears were very alert and aware of our presence. Because of this, we did not attempt this procedure in subsequent winters.

In addition to dens found by locating radio-collared bears, dens of unmarked bears were either found by myself during hiking to random points (Chapter 2) or by Canadian Forest Products Ltd. employees during forestry operations. Because these dens could bias some results, but not others, the sample sizes of dens differ among analyses. I was unable to measure all of the dens because some were already logged or were located during timber harvesting. Also, I was unable to determine the sex or age of these bears, except for some females whose cubs were seen or heard. In addition, I was unable to examine hollow tree dens with entrances that were above ground level. Grizzly bears (*Ursus arctos*) do not occur on Vancouver Island, so I assumed all bear dens were used by black bears.

<u>Characteristics of Dens</u>

After the bears emerged from their dens, I visited each den site and recorded the type and diameter of den, species of tree, and whether bedding material was present inside the den. The plant species comprising the bedding material were identified. I compared the diameter of dens among den types using a single-factor analysis of variance test (ANOVA) and used Bonferroni-adjusted *t*-tests for multiple comparisons among means. The diameters of den structures used by males and those used by females were compared with a *t*-test.

I measured: aspect, height and width of the den entrance; heights, lengths and widths of the tunnel and chamber; depth, width and length of the bed. Entrances of most den types were triangular in shape so I estimated the entrance area as one half the product of length and width. For round hollow logs, I estimated the entrance area by calculating the area of a circle. Chamber areas were estimated using the formula for the area of an oval. I compared the entrance and chamber areas among den types using single-factor ANOVAs and used Bonferroni-adjusted *t*-tests for multiple comparisons among means. I used paired-sample t-tests to compare den dimensions (entrance area, chamber area and chamber volume) of three females which had two different dens between years when they bore cubs and years when they did not.

<u>Denning Chronology</u>

Den entrance and emergence dates were determined for the 1993 and 1994 denning periods. Den periods were classified by the year of entrance (e.g., the 1993 denning season includes the entrance into dens in the fall of 1993 through to emergence in the spring of 1994). I assumed bears had entered their dens on the first date that they were located at their eventual den site (determined conclusively during visits of den sites in January). However, because I located some bears in remote locations by airplane only once per week the actual date of entry may have occurred between consecutive radio-telemetry locations. In these cases, den entry dates were defined as be the midpoint between the last recorded movement and the first of the locations at the den site. I defined den emergence dates as the date midpoint between the last location at the den site and the first location away from the den. As with entrance dates, emergence may have occurred over one week because during early spring I located the bears only once per week. With my method of determining both entrance and emergence, bears may not have been inside the den structure but within a maximum of 50 m of it.

I compared the duration of denning between sex and age classes using Mann-Whitney U-tests and tested for a correlation between the duration of denning and elevation. I also examined the time of den entrance between sexes by comparing the frequency at which each sex entered their dens during the following intervals: before 1 November, 1-21 November, and after 21 November. I examined the time of den emergence between sexes by comparing the frequency at which each sex emerged from their dens in the following intervals: before 1 April, 1-30 April, and after 30 April. I used chi-square goodness-of-fit tests to determine differences between the sexes in entrance dates into dens and emergence dates from dens among date intervals. I used Bonferroni-adjusted *Z*-tests to determine the date intervals which were significantly different between sexes.

Reuse of Dens

In addition to following radio-collared bears to determine den reuse, I also investigated den sites for signs of previous use of the den. In many cases, den sites had signs of old markings on trees surrounding the dens, indicating that bears had been at the den site previously. I also examined the age of the bedding material. It was difficult to determine whether vegetation in the den was from previous years. However, in some cases, different layers of vegetation comprising the bed were likely added in different years because the same plant species were in different states of desiccation (e.g., completely brown layers of salal below very green salal leaves).

Location of Dens

I examined the micro-slope, macro-slope, aspect, and elevation of dens. To detect differences between the micro- and macro-slope at dens, I performed paired sample *t*-tests. I compared the micro-slope and elevation among den types with a single-factor ANOVA and performed multiple comparisons with Bonferroni-adjusted *t*-tests. I compared the differences between elevations of den sites used by males and females with a *t*-test. I used a chi-square goodness-of-fit test to examine the aspect of the den entrances partitioned into 12 30^{o}-categories.

Stands in which dens occurred were classified into 29 stand types derived from 46 site series (biogeoclimatic ecosystem classification, Green and Klinka 1994) and 6 seral stages. I combined site series to form 9 Black Bear Habitat Types (BBHTs) based on similarities in moisture and nutrient regimes (Appendix A). The six seral stages were combined into 4 based upon similarities in structural characteristics (Table 2). I compared the frequency of use of BBHTs and seral stages among den types using a chi-square test and Bonferroni-adjusted *Z*-tests.

I plotted locations of dens used by each bear and compared them to the bear's home range to determine proximity of dens to spring forage and fall fishing grounds. Sizes of home ranges were determined using adaptive kernel home range estimation (Seaman and Powell 1991). I measured the distance from bear dens to human activity (traffic, tree falling, or snow plowing) occurring during the period of den use. I compared the distances from human activity between sexes using a Mann-Whitney U-test.

Security Cover At and Around Dens

Vegetation and topography at and around a den affect how easy it is to see the den and thus determine how secure the den is from other bears, predators and humans. I used horizontal

Table 2. Seral stages used for classification of stand types in the Nimpkish Valley, 1993-1995.

Seral stage	Seral classification	Approximate age (yrs)
1/2	herb-shrub	0-10
3	tall shrub	11-30
4	pole-sapling and young forest	31-150
5/6	mature and late successional forest	>150

visibility as a surrogate for the security cover provided by vegetation and topography. At random patches, horizontal visibility was estimated by measuring the distance at which a 1 m tall bear would be obscured by vegetation, debris or topography in the 4 cardinal directions from the plot centre. At den sites horizontal visibility was estimated at two points; once in the 4 cardinal directions at a point centred 10 m away from the den (to indicate the general horizontal visibility of the habitat around the den) and once from the den entrance. At the den entrance, I estimated horizontal visibility in 3 directions, perpendicular and 45^{o} either side, to avoid bias caused by blockage by the den tree. Estimates were averaged to obtain a mean value of horizontal visibility for each plot (n = 4) and den entrance (n = 3).

An inverse relationship exists between my estimate of horizontal visibility and the density of cover, i.e., high visibility of a den indicates sparse cover in the habitat. I used the Mann-Whitney U-test to compare the horizontal visibility between the den entrance and the surrounding habitat and to compare horizontal visibility between dens of males and dens of females. I compared the horizontal visibility at den entrances, among seral stages and different den types using Kruskal-Wallis tests. The 0.05 probability level was accepted as significant for all comparisons.

Results

I located 67 dens between 1992 and 1995; 40 different dens of 21 radio-collared black bears and 27 dens of unmarked bears. Of the dens first located by helicopter in 1992, I was unable to relocate two of the dens during subsequent ground searches. All dens first located by helicopter in 1993 and 1994 were successfully relocated during ground searches.

Types of Dens

I identified 5 types of dens (Table 3) based on the type of structure associated with the den and the location of the den cavity within the structure:

Hollow tree. Thirty seven dens (55%) were located in cavities of hollow trees. Most (n = 34) live and all dead hollow trees that were used as dens were western redcedar or yellow-cedar trees. These species tend to rot in the inside while retaining a hard outer shell, creating a cavity in their centre. Natural openings often occurred in the butts of these trees and some were enlarged by bears so they could gain entry to the interior cavities. Most cavities were at ground level, but some had entrances to the cavity that were above ground. Branch holes created entrances above ground level in some hemlock trees (n = 3) that were used as hollow tree dens.

Log. Four dens (6%) were located inside or under logs. Three of these dens were in Douglas-fir logs; one den was located in a western redcedar log. Two of the dens in Douglas-fir logs were in or under unmerchantable (at the time of harvest) sections of rotten trees that had been felled and left behind after first-growth harvesting. The third den was inside a rotted, hollow Douglas-fir log in a late successional stand.

Root bole. Fifteen dens (22%) were located under the root masses of overturned trees, usually from windthrow. Tree species of this den type were difficult to determine because of decay. Those that could be identified to species were in Douglas-fir, western hemlock and redcedar.

Stump. Eight dens (12%) were inside the base of high cut stumps (1.9-3.4 m from top of cut to ground) of Sitka spruce, Pacific silver fir and western hemlock. With the exception of the Sitka spruce stumps, these stumps were the result of first growth harvesting on a limestone ridge that had unique growing conditions compared to the rest of the study

Table 3. Frequency of use and diameters of 5 den types used by radio-collared and unmarked black bears in the Nimpkish Valley, 1993-1995.

Den type	Number of dens: Radio-collared bears	Number of dens: Unmarked bears	Total	Mean diameter (cm)	SE
Hollow tree[a]	17	20	37	159	8
Log[b]	3	1	4	143	17
Root bole[b]	12	3	15	93	8
Stump	6	2	8	169	12
Under tree[a]	2	1	3	127	9
Total	40	27	67	143	6

[a] Grouped as "standing tree" dens for some analyses.
[b] Grouped as "coarse woody debris" dens for some analyses.

area. Subsequent burning of the area for site preparation removed the soil and duff in places, causing large cavities to form under some of the remaining stumps.

Under tree. Three dens (4%) were located amongst the roots of standing western or mountain hemlock trees. The intertwining roots of the trees formed the sides of the dens. One den was created by a complex of three hemlock trees. These trees did not have hollow centres. The hollow beneath the trees was likely created by the trees growing on a nurse log, which subsequently decayed, leaving a cavity.

For some analyses, I grouped "log" and "root bole" den types into a "coarse woody debris" (CWD) den type and "hollow tree" and "under tree" den types into a "standing tree" den type.

The use of various den types differed between sexes of black bears ($\chi^2 = 10.00$, df = 4, $P = 0.04$). However, none of the differences between sexes were significant within each den type (Bonferroni-adjusted Z-tests).

Dimensions of Dens

The mean diameter of all den structures was 143 cm (SE = 6.0, n = 67, Table 3). Diameters were significantly different among den types (ANOVA; $F = 7.87$, $P = 0.0001$). Stump and hollow tree dens were larger in diameter than root bole dens (Bonferroni-adjusted *t*-test). There was no difference in the diameter of den structures used by male and female bears (*t*-test; $t = 0.87$, $P = 0.39$).

Entrance areas were significantly different among den types (Table 4, ANOVA, $F = 4.27$, $P = 0.0043$). Hollow tree dens had significantly smaller den entrances than did root bole dens (Bonferroni-adjusted *t*-tests). The entrances of dens used by females were not significantly

Table 4. Area of the entrance and chamber by den type and by age and sex classes for dens used by black bears in the Nimpkish Valley, 1993-1995.

	Den entrance area (m^2)			Den chamber area (m^2)		
	Mean	SE	*n*	Mean	SE	*n*
Den type						
Hollow tree	0.11	0.01	32	1.09	0.09	30
Log	0.20	0.04	4	1.35	0.36	4
Root bole	0.21	0.04	15	1.26	0.15	15
Stump	0.13	0.02	8	1.21	0.19	8
Under tree	0.25	0.06	3	4.14	1.54	3
Age and sex class						
Subadult female	0.14	0.09	2	0.43	0.01	2
Subadult male	0.09	0.00	2	0.98	0.20	2
Adult female	0.12	0.02	11	1.11	0.22	11
Adult male	0.18	0.02	25	1.60	0.26	25

different from those of dens used by males (ANOVA, $F = 2.21$, $P = 0.15$). There were no significant differences in entrance areas among age classes (ANOVA, $F = 0.66$, $P = 0.42$), or among age and sex classes combined (ANOVA, $F = 1.20$, $P = 0.32$). Only a few dens had tunnels and these usually extended only the width of the tree itself. Hence, analyses of tunnel dimensions were not included.

Areas of den chambers were significantly different among den types (ANOVA, $F = 11.79$, $P = 0.0001$). Dens located under trees had larger den chamber areas than all other den types (Bonferroni-adjusted *t*-tests). There were no significant differences in chamber areas among age and sex classes (ANOVA, $F = 1.22$, $P = 0.31$). However, the area of the den chambers increased with average body size for each class; subadult females had the smallest chamber areas, then subadult males, adult females and adult males with the largest chamber area (Table 4). Females with cubs chose dens with chamber areas that were larger ($\bar{x} = 1.03$ m^2, SE = 0.13, $n = 3$) than those selected when these bears did not have cubs ($\bar{x} = 0.40$ m^2, SE = 0.01, $n = 3$; paired-sample *t*-test, $t = 2.78$, $P = 0.05$).

<u>Species of Den Trees</u>

Both yellow-cedar and western redcedar were used most commonly as dens (Table 5). Cedars were used as hollow tree and CWD dens, but not for stump dens or under tree dens. Cedar root boles were structurally different from the root boles of other species as well; the flutes of the lower bole of a cedar tree provide low sides to the cavity and a larger chamber. The one den in a hollow redcedar log required the occupant to crawl 4.6 m along the 53-cm diameter “tube” to the bed. All 5 dens in snags were inside western redcedar trees; bears used only live yellow-cedars for dens.

Table 5. Tree species and diameters among different den types used as dens by black bears in the Nimpkish Valley, 1993-1995. All dens that were found are included. This may introduce a bias because hollow tree dens are likely found more easily than other den types by forestry personnel working in late successional forests.

Tree species	Den type (number of dens)					Mean diameter (cm)	SE	*n*
	Hollow tree	Log	Root bole	Stump	Under tree			
Yellow-cedar	20					156	9	20
Western redcedar	14	1	4			155	14	19
Western hemlock	3		2	2	2	139	16	9
Douglas-fir		3	5			115	13	8
Pacific silver fir				2		139	15	2
Sitka spruce				2		190	9	2
Mountain hemlock					1	135	0	1
Unknown			4	2		98	20	6
Total	37	4	15	8	3	143	6	67

Western and mountain hemlock were also used for under tree dens, root boles dens, and hollow tree dens with entrances through branch hole cavities above ground level. Hemlocks had features that allowed them to be used for 4 of the 5 den types. Hemlock logs were not used as den sites. Douglas-fir trees were used for both log and root bole dens. Two Sitka spruce stumps and one stump of an unknown species, likely a Sitka spruce, were used as den sites by one adult male black bear. Two dens each were located in Pacific silver fir and hemlock stumps. Pacific silver fir was not used for any other type of den.

The species of some CWD and stumps dens were difficult to identify because of extensive decay. Wood samples from several of these dens were sent to Dr. Simon Ellis at the University of British Columbia for analyses to determine species.

Bedding Material in Dens

All dens of radio-collared bears contained bedding material, but the amount used varied greatly. Some dens contained only a few scraps of vegetation, while others had cup-like beds up to 75 cm deep. Some dens with deep beds were located by following trails of dropped bedding material leading to den entrances. I was unable to determine the amount of bedding material used in dens with above-ground entrances.

Den bedding consisted of vegetation available in the immediate vicinity of the den and from scrapings of the inside of hollow tree dens. Boughs from small trees (mostly hemlock, Pacific silver fir and cedar), *Vaccinium* spp., sword fern (*Polystichum munitum*), deer fern (*Blechnum spicant*), fireweed (*Epilobium angustifolium*), step moss (*Hylocomium splendens*), lanky moss (*Rhytidiadelphus loreus*) and pipecleaner moss (*Rhytidiopsis robusta*) were used. Piles of bedding material often occurred outside the entrances of dens. This bedding material appeared to have been pulled into the entrance of the dens to block the entrance once the bears were inside.

Denning Chronology

The duration of denning was recorded for 18 bears during the winter of 1993-94 and 12 bears during the winter of 1994-95. Chronology data were pooled across years because there were no significant differences in the duration of denning between the two years (*t*-test, $t = 1.46$, $P = 0.24$). For some adult male black bears, I was unable to accurately determine the den entrance or emergence dates because they either entered or emerged from their den sites when the field camp was not in operation. In these cases, duration of denning was recorded as the maximum period that the bears could have denned (i.e., I assumed they entered their dens the day after field work finished and emerged the day before field work resumed). This method likely overestimated the duration of denning for male bears. Using this overestimate for the period that males remained in their dens, the duration that males denned was still significantly less than that for females (Table 6, Mann-Whitney test, U = 214, $P < 0.0001$). Pregnant females denned for longer periods than did all other classes of females (Mann-Whitney test, U = 25, $P = 0.05$). The length of time that the bears remained in and around their dens varied from <3 to 6 months (<90 to 190 days). The elevation of den sites was not significantly correlated with the duration of denning ($F = 0.033$, $r^2 = 0.0012$, $P = 0.86$).

The frequency of den entry by date interval for male black bears was significantly different than that for females ($\chi^2 = 10.08$, df = 2, $P = 0.006$, Fig. 2). A greater proportion of males entered their dens after November 21 than did females, and a greater proportion of females entered their dens before November 1 than did males (Bonferroni-adjusted *Z*-tests, $P <$

0.05). The frequency of den emergence by date interval for male black bears was also significantly

Table 6. Duration of denning by black bears in the Nimpkish Valley, 1993-1995.

Sex and reproductive class	Mean (days)	SE	*n*	Range (days)
Females				
Pregnant	160	9.04	5	141-190
Solitary	138	6.43	4	127-157
With yearlings	139	5.75	2	133-145
Males	110	3.28	18	<90-130

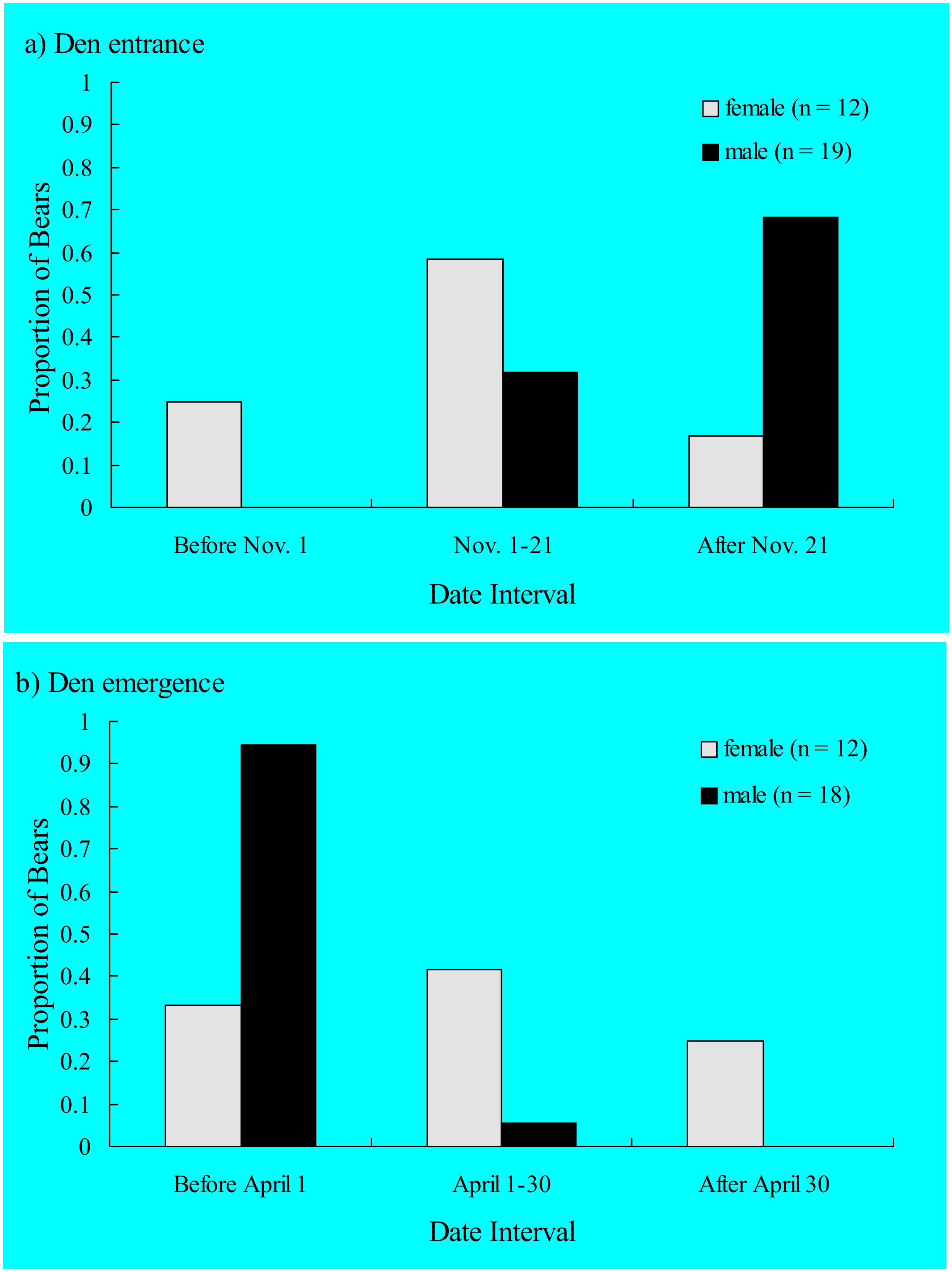

Figure 2. Den a) entrance and b) emergence dates of male and female black bears in the Nimpkish Valley, 1993-1995.

different than that for females ($\chi^2 = 13.04$, df = 2, $P = 0.001$, Fig. 2). A greater proportion of males emerged from their dens before April 1 than did females, and a greater proportion of females emerged after April 1 than did males (Bonferroni-adjusted *Z*-tests, $P < 0.05$).

I was unable to determine the reproductive status for one female bear (F08) during winter 1994/95. For most analyses however, I considered F08 as having cubs for 1994/95 although her status was not positively determined. Based on the date of den emergence, length of den period, and comparison with the length of her denning period the previous year, I concluded that she had likely produced cubs in 1994/95. However, I did not observe F08 with cubs when I sighted her 2 days after emergence. Because I was unsure of her reproductive status, I did not include her duration of denning for 1994/95 in the calculation of mean duration of denning for pregnant females (Table 6).

<u>Reuse of Dens</u>

Reuse of den sites was determined by following radio-collared black bears for more than one winter, but the sample size is small because many bears died or lost their collars during the study. I compared the number of times that bears reused dens with the number of times that I had opportunity to detect reuse. For example, if I found the den for a radio-collared bear in two denning periods then I had one chance of observing reuse. If the dens of a radio-collared bear were located over 3 denning periods then I had 2 chances of observing reuse. From my monitoring of radio-collared bears, I had 25 chances to observe reuse of dens (Table 7). The proportion of reuse between male and female bears was not significantly different (normal approximation to the binomial test, $Z = 1.03$, $P = 0.15$). Five bears used their den twice (3 females, 2 males) and one adult male bear (M12) used one den three times. Of the 31 dens that

Table 7. Reuse of winter den sites by radio-collared black bears in the Nimpkish Valley, 1993-1995.

Sex	Number of chances to observe reuse of dens	Observed reuse of dens	Percent reuse
Female	7	3	43
Male	18	4	22
Total	25	7	28

were not reused by radio-collared bears during the course of the study, 13 appeared to have been used before, 10 had possibly been used before, and 8 dens showed no sign of having been used before the 1993-1995 study. With the inclusion of the 6 dens that were reused during the course of the study (one reused twice), den reuse was 28% between years and could be as high as 51-78% over longer periods.

Four of the 6 dens that were reused occurred in second growth forests (seral stages 3 and 4), while two, including the den that was reused twice, occurred in late successional forests (seral stage 5/6). There was no significant difference in reuse among seral stages ($\chi^2 = 2.71$, df = 2, $P > 0.10$).

Four radio-collared females gave birth during winter of 1993-94. One female and her cubs were killed and eaten by black bears at and near their den site (Davis and Harestad 1996). Of the remaining three females, one lost both her cubs (at least one to cannibalism), one lost one of her 2 cubs, and one had both her cubs survive. Both females that denned with cubs in the fall of 1994 reused the dens in which they had given birth during winter 1993-94. The one female that lost both her cubs during spring 1994 changed den sites for winter 1994-95. One adult female (F05) used the same Douglas-fir log den two years in a row (the only years she was monitored). During the second of the two years, at 19-years of age, she gave birth to one cub in the den.

Slope, Aspect, and Elevation

The slope at den sites was significantly flatter ($\bar{x} = 18^{o}$, SE = 2, $n = 65$) than that of the surrounding stands ($\bar{x} = 23^{o}$, SE = 2, $n = 65$, paired two sample t-test for means, $t = 4.47$, $P = 0.0001$). I compare selectivity for slope at the stand level in Chapter 2. Slope was significantly different among den types (ANOVA, $F = 9.29$, $P = 0.0001$). Stump dens were on flatter slopes ($\bar{x}$= 3°, SE = 2, *n* = 8) than were dens in hollow trees ($\bar{x}$= 23°, SE = 2, *n* = 37) and dens under trees ($\bar{x}$= 26°, SE = 10, *n* = 3). CWD dens were on flatter slopes ($\bar{x}$= 14°, SE = 2, *n* = 19) than were hollow tree dens (Bonferroni-adjusted *t*-tests).

The distribution of aspects of den entrances was not significantly different from uniform (χ^2 = 6.14, df = 11, *P* = 0.86). Elevations were significantly different among den types (ANOVA, *F* = 9.57, *P* = 0.002). Standing tree dens ($\bar{x}$= 543 m, SE = 37, *n* = 40) occurred at higher elevations than CWD dens ($\bar{x}$= 254 m, SE = 41, *n* = 19, Bonferroni-adjusted *t*-tests, *P* = 0.05). Stump dens occurred at a mean elevation of 438 m (SE = 37, *n* = 8). There was no significant difference between the mean elevation of den sites used by males ($\bar{x}$= 437 m, SE = 52, *n* = 27) and those used by females ($\bar{x}$= 326 m, SE = 55, *n* = 17) (t-test, *t* = 1.39, *P* = 0.17).

Habitat Characteristics

In this section, I compare the use of each den type among habitats and seral stages by black bears in coastal British Columbia. I examine the selection of denning habitat at different spatial scales by black bears in Chapter 2.

The frequency of use of each den type by black bears was different among Black Bear Habitat Types (BBHTs, Appendix A) (χ^2 = 31.27, df = 6, *P* = 0.001). CWD dens were used less frequently than expected in the Blueberry Moss BBHT. Hollow tree dens were also used less frequently than expected in the Devil's Club Seepage and Fir Sword fern BBHTs. Stump dens were used less frequently than expected in the Fir Salal BBHT (Bonferroni-adjusted *Z*-tests, *P* = 0.05).

The frequency of use of each den type by black bears was different among seral stages (χ^2 = 53.03, df = 4, *P* = 0.001). CWD dens were used less frequently than expected in late successional seral stages (seral stage 5/6). Hollow tree dens were used less frequently than expected in seral stages 3 and 4 (tall shrub and young forest), but were used more frequently than expected in late successional forests (seral stage 5/6) (Bonferroni-adjusted *Z*-tests, $P = 0.05$). Stumps dens were used less frequently than expected in late successional forests (seral stage 5/6).

<u>Location of Dens Within Home Ranges</u>

Female black bears in the Nimpkish Valley had small home ranges ($\bar{x}$= 10.3 km^2, SE = 0.2, $n = 9$) that were occupied year-round without long movements to fall fishing grounds. Females moved only as far as the Nimpkish River, searching for washed-up salmon carcasses and feeding on berries the rest of the time. Eight of 9 females denned within the home ranges that they used during the non-denning period.

Only one female (F08) made movements out of the home range that she used during the non-denning period. During 2 consecutive years, F08 moved 2-3 km out of her non-denning home range to an unlogged hillside in a remote section of the study area and denned in hollow yellow-cedar trees. She used different dens in each of the two winters. In fall of 1993, F08 was a sub-adult. In the winter of 1994-95, I suspected she bore cubs due to the length of her denning period, but on return to her regular spring feeding area in 1995 (two days following emergence), she was not accompanied by cubs. Another female (F07), of the same age and with a nearly identical home range as F08, made a similar movement in the fall of 1993, to the same area as F08, but returned to her non-denning home range and denned within it.

Male black bears had larger home ranges than did females ($\bar{x}$= 76.3 km^2, SE = 12.9, $n = 15$) and exhibited long seasonal movements. Male black bears tended to use the same areas within their home ranges each spring, which included the breeding season from the end of May through to late June. Most of these males then moved to distinct summer/fall ranges. Four large adult male bears made long distance movements in the fall to fishing areas. In late fall, these male bears usually returned rapidly from their fishing areas and denned close to their spring feeding ranges. One male bear (M15) travelled far to his fishing grounds (approximately 30 km, straight line distance from his spring foraging/breeding home range). In the fall of 1993, M15 returned to den in his spring home range; in the fall of 1994, he denned in his fall fishing area after there were early, deep snowfalls. Upon emergence from the den in the spring, this male returned quickly to his spring home range.

Den Location in Relation to Human Activity

Females denned closer to human activity ($\bar{x}$= 511 m, SE = 140, n = 13) than did males ($\bar{x}$= 952 m, SE = 189, n = 25, Mann-Whitney test, U = 220, $P < 0.05$).

Horizontal Visibility

Horizontal visibility at entrances of dens used by males was not different from that at entrances of dens used by females (Mann-Whitney test, U = 173, $P > 0.20$). Horizontal visibility was significantly different among different seral stages (Table 8, Chi-square approximation to the Kruskal-Wallis test, $\chi^2 = 9.84$, df = 2, $P = 0.007$). Late successional forests (seral stage 5/6) had the greatest horizontal visibility. Seral stage 4 had intermediate visibility, and seral stage 3 had the least horizontal visibility (Table 8). I also detected significant differences in horizontal visibility among different types of dens (Chi-square approximation to the Kruskal-Wallis test, $\chi^2 = 12.98$, df = 4, $P = 0.01$). Hollow tree dens had the greatest horizontal visibility, dens in logs and under trees had less, and root bole and stumps dens had the least.

Table 8. Horizontal visibility (averages of 3 directions) at entrances to dens of black bears among seral stages and den types in the Nimpkish Valley, 1993-1995.

	Mean (m)	SE	*n*
Seral stage			
3	4.25	1.03	4
4	7.88	1.19	17
5/6	9.79	0.83	35
Den type			
Hollow tree	10.54	1.02	26
Log	9.75	4.23	4
Root bole	7.42	0.89	15
Stump	5.17	0.88	8
Under tree	9.22	2.11	3

Discussion

Selection of den sites by black bears is a process involving a complex set of factors. Bears require dens that provide both thermal and security cover and hence, should prefer dens that conserve thermal energy (Lentz et al. 1983) and provide protection from predators. Depending upon the environmental conditions, the relative contribution of each of these factors to the process of den selection may change. Bears that live in warm climates may not have to be concerned about thermoregulatory costs and thus may use a den that is very secure, but offers little thermal cover. Conversely, a bear that is subjected to long, cold winters may need to select the warmest den possible, regardless of the security of the den. Across the geographic range of black bears, from warm southern climates to cold northern climates, the denning requirements of bears may become more stringent, with the thermal features of dens becoming increasingly important compared to their security features. However, despite preferences for thermal and security cover that bears may have for den cavities, availability of dens may constrain selection processes.

Types of Dens

In the Nimpkish Valley, black bears denned exclusively in structures made of wood. Whether in hollow standing trees, stumps, or pieces CWD, every den that I found involved the structure of a large tree. This association between dens and trees is consistent with the behaviour of black bears in coastal Washington and Oregon (Lindzey and Meslow 1976*a*, Noble et al. 1990).

Dens must keep bears warm, dry, and secure. In cool, wet climates, these needs may be particularly stringent and may account for why tree-related structures were the only types of dens that I observed black bears using in the Nimpkish Valley. Elsewhere in their geographic range where climates are mild, such as Florida, black bears may use a broader suite of den types, including ground nests (Wooding and Hardisky 1992). The difference in rainfall between these regions is striking. Bears in Florida are subject to 7-10 cm of rain/month (Wooding and Hardisky 1992), while black bears in coastal B.C. can often receive the same amount in one day. Erickson (1982) hypothesized that the reason for the exclusive use of dens associated with old-growth, decadent trees on Mitkof Island, Alaska, was the thin soils and “near-persistent rainfall.” Black bears in my study area likely den in tree-related structures because these structures were the only type available that would satisfy best the requirements of keeping bears warm, dry, and secure.

Log and root bole dens provided dens of varying quality, mostly related to the security of the den cavity. Entrances to these den types were sometimes very small and defensible, but some root boles were open on both sides of the fallen tree, providing little security to the occupant. Hollow logs that are closed at one end may also provide very secure den sites.

I expect that dens in stumps are the same quality as dens in hollow trees because they are simply hollow trees with the bole cut off. Hollow trees and stumps had very similar entrance dimensions, and therefore likely provide equivalent security from predators. In addition, the stump dens observed in my study appeared to provide a cavity that was as dry as other den types. Cavities under stumps tended to be larger than those in hollow trees, although entrance dimensions of stump dens were nearly equivalent to those of hollow tree dens.

Dens located under trees appeared to be of lower quality than other den types because of multiple entrances which would decrease the ability of the occupant to defend itself. All under tree dens occurred at high elevations. At these high elevations, deeper and more persistent snow pack, may have covered den entrances and enhanced security of the den.

Use of den types was different between sexes. However, this likely is not an indication of differential selection for den types between sexes, but likely a reflection of the availability of den types within the home ranges of male and female black bears. Female bears were radio-collared in areas of extensive second-growth forests that likely had a greater availability of CWD for dens due to the history of timber harvesting in these stands. Male bears had much larger home ranges that incorporated substantial areas of late successional forests with a greater availability of hollow tree dens.

Studies on the denning of black bears have used misleading terms to describe some den types. Occasionally, the term "excavated den" has been used to describe the excavation of soil from under structures related to trees (i.e., the base of a tree or stump, upturned root masses and trunks of fallen or leaning trees) (Tietje and Ruff 1980, Beecham et al. 1983). I recommend that the term "excavated" should only refer to those den types that are excavated into soil and not associated with woody structures. The term "ground" den has also been used to describe dens that were under roots, in stumps, among rocks, and in the base of snags (Johnson and Pelton 1981). This may be potentially misleading because many people would likely interpret "ground" den to refer to an open nest upon the ground and thus draw incorrect conclusions from these studies. I recommend that researchers use terms that convey more accurate information, such as "excavated under tree" instead of "excavated".

Dimensions of Dens

Many physical attributes of dens were different among den types and among sex and age classes of bears. The mean diameter of den structures was 143 cm in the Nimpkish Valley. This size is similar to that of den structures used by black bear in the central coast range of Oregon ($\bar{x}$= 141 cm, Noble et al. 1990).

The average size of structures varied considerably among den types for several reasons. Hollow tree dens, log dens, and stump dens were likely larger in diameter than root bole dens and under tree dens because structures of these former types can only be used after the formation of cavities large enough to house a bear. Trees that create root bole dens may have been smaller in diameter than other types of dens because most of the den chamber was formed by roots of the trees. Hollow trees containing dens with entrances above ground level were large in diameter and, for those that I knew sex of the occupant, were used only by female bears. These dens resulted in an increase in the overall mean diameter of dens used by females. Because of this use of hollow tree dens by females, diameters of den structures did not vary between sexes of bears.

Many of the den structures were modified by bears for use as dens. Bears often chewed or clawed wood from around the entrance, presumably to make it large enough for their body to fit through. However, den entrances were still much smaller than would be anticipated from the body sizes of bears. The smallest den entrance was 40 cm by 20 cm and the smallest entrance to the den of a large adult male (M18: 130 kg, 102 cm shoulder height) was 42 cm by 32 cm. These small entrance sizes are similar to those of dens found in west-central Idaho, where minimum entry heights were 23 to 32 cm for all den types (Beck 1991). It appears that bears often select dens with entrances that are just large enough for them to fit through. Occupying a den with an entrance which will only allow access to the den cavity by bears of similar or smaller sizes is likely an effective method for ensuring against attacks from larger animals.

Because of mild climates in some parts of the geographic range of black bears, one of the strongest selection criteria for dens is likely the ability to defend the den site. Entrance dimensions are likely critical to defense of den sites because dens with small openings protect the occupant of the den from attack by predators. Both Beck (1991) and Lindzey and Meslow (1976*a*) observed that small entrances to bear dens provided a significant advantage in the protection of the occupant within the den. Den entrances are rarely larger than necessary to permit a bear to enter (Beck 1991). Females with newborn cubs are especially vulnerable to attack because cubs can be heard at distances up to 20 m from a den. Kolenosky and Strathearn (1987) found that entrances to dens of pregnant females and females with yearlings were smaller than those of all other sex and age classes. If particular den types are preferred because their small entrances provide highly secure dens, the supply of dens with small entrances for pregnant females may be critical to black bear populations. I found that hollow tree dens had smaller entrances than did root bole dens, suggesting that hollow tree dens provide highly defensible and secure dens.

Results from my own and other studies suggest that bears may prefer tree cavities with above-ground entrances because they provide safe denning environments (Johnson 1978). Dens with entrances above ground level are possibly the safest dens for females and subadult males because the larger adult males cannot climb them as easily (Johnson 1978). I observed several dens in hollow cedar trees with entrances up to 16 m above ground that were used as dens by female black bears. In addition to cedars, I also found dens with entrances above ground level in hollow hemlock trees. Hollow hemlock trees were also used for dens on Mitkof Island, Alaska (Erickson 1982). The retention of hollow trees in managed forests could be beneficial to bear populations because they provide secure sites in which females can give birth to cubs free from disturbance by predators or humans. These den sites may be even more critical in areas where grizzly bears occur because of the increased risk of predation.

There were no consistent trends in the volumes of dens and area of den entrances among females with and without cubs. However, of three females that I monitored, all three used dens with significantly larger chamber areas in the year that they bore cubs than in the years they were barren. Other researchers have also found that females accompanied by young required large dens, similar to the sizes used by adult males (Beecham et al. 1983, Kolenosky and Strathearn 1987). Female bears in the Nimpkish Valley may require dens with larger chamber areas to provide more room for nursing their cubs. Dens of pregnant females also had the least amount of bedding material in their dens, possibly to maximize the size of the chamber.

The need for dens with larger chambers when bearing cubs may be an important factor in selection of dens. Pregnant females may select dens with larger cavities than they would select when not pregnant. However, dens with large chambers that are defensible are likely rare because large cavities may tend to have large entrances. If hollow trees, which have the smallest den entrances and are therefore the most secure, do not occur within home ranges, then pregnant females may have to select dens of other types that have large chambers but less defensible entrances. Because pregnant females and cubs-of-the-year are more physiologically stressed than other age and sex classes of bears during winter hibernation, suitable den structures may affect survival and reproductive success at the population level (Johnson and Pelton 1981, Alt 1984, Wathen et al. 1986). In my study area, bears which denned in structures with large den entrances may have been prone to cannibalistic attacks (Davis and Harestad 1996).

The size of the den chamber has been correlated to the size of the occupant (Tietje and Ruff 1980, Kolenosky and Strathearn 1987). I observed that chamber areas of dens in the

Nimpkish Valley increased with increasing size of the occupant, but differences were not significant. I did not include height measurements of den chambers because of their variability in hollow trees (occasionally >6 m) and because of the difficulty in determining accurate chamber volumes. Large chamber volumes may facilitate movement within the den, but it may also contribute towards excessive heat loss by increasing air circulation (Lentz et al. 1983). Lentz et al. (1983) hypothesized that female black bears may select dens for maximum thermal benefits. However, my observations and those of Beck (1991) do not support this hypothesis. Entrance size and chamber areas of dens appear to be more important factors in den selection by pregnant females.

The thermal regime of dens is important to over-wintering bears. Dens that minimize the energy costs of hibernation will ensure that bears emerge in better condition than do bears from dens that facilitate loss of energy. Because of greater energy stores upon emergence from their dens, these bears would have increased survivorship and greater reproductive success (Rogers 1976). Thermoregulatory costs to bears will be less in dens with thick walls, small entrances, and lasting snow cover for insulation (Lentz et al. 1983). Dens with entrances above ground level may further reduce thermoregulatory costs. Johnson et al. (1978) estimated that tree dens with entrances above ground level afforded bears a 15% energy savings compared to dens at ground level.

Species of Den Trees

Western redcedar and yellow-cedar appear to be the most suitable species for use as dens by black bears in the Nimpkish Valley. Due to their typical decay characteristics, and because these species often reach larger sizes than other tree species, cedar trees form cavities that can be used as dens more frequently than do other species of trees. Cedar trees tend to decay in the heartwood and become hollow while retaining a hard outer shell. This pattern of decay produces den cavities that likely have the most efficient thermal and security cover of any of the den types that I observed in my study. Hollow cedar trees are likely important for continuous den supply because cedars are very resistant to decay (see Minore 1983) which enables bears to use them for many years.

Hemlocks formed two very different types of den structures, each likely supplying dens of differing quality. With their distinct root formations, both species formed "under tree" dens. Also, hemlocks occasionally had hollow centres which provided dens with above ground cavities. Dens under trees are not likely high quality dens because the multiple entrances that are common to this den type reduces security of the den. However, hemlocks with entrances above ground level may be an important component of den supply in areas where cedars are rare or do not occur. My casual observations suggest hemlocks do not decay into suitable den cavities as frequently as cedar trees. Despite the predominance of hemlocks, I did not observe extensive use of hollow hemlock trees with entrances above ground level by bears in my study area. This den type occurred only at higher elevations in a few patches, perhaps in areas with high rates of infection of pathogens that led to cavity formation. I did not have radio-collared female bears with home ranges in these areas and thus was not able to detect use of these hollow hemlocks.

Douglas-fir trees form structures suitable for denning because of their susceptibility to different kinds of pathogens. I observed two scenarios in which Douglas-fir logs formed dens: either in cavities of logs that were left behind during harvesting (due to rot within them), or in fallen trees weakened and hollowed by rot. However, cavities under standing, live Douglas-firs have been used as dens elsewhere on Vancouver Island (Gerry Brunham, pers. commun.). In

Oregon, all bear dens were associated with large diameter Douglas-fir trees; the den types included stumps, logs, and hollow trees (Noble et al. 1990).

Pacific silver fir were not used extensively by bears in my study. The normal growth of this species does not appear to create cavities that are suitable for denning. In my study, the only instances in which Pacific silver fir were used as dens occurred in an area with atypical conditions which facilitated the creation of den cavities. This area was clearcut and cavities developed beneath stumps because the soil and duff was burned. The diameters of these stumps were also some of the largest for this species that I recorded. It is unlikely that stumps of Pacific silver fir trees could have been used by bears without the extensive burning that occurred.

Sitka spruce trees were only used for dens when cavities formed under their stumps. Large Sitka spruce were uncommon in my study area, except on current floodplains and several historic floodplains which were limited to a very small portion of the total study area. Although the growth patterns of Sitka spruce are conducive to use as dens, bears in my study did not often use them for denning. Cavities form under Sitka spruce because this species tends to grow on nurse logs. Following decay of the nurse log, large cavities develop in its absence, beneath the bole of the spruce. However, for Sitka spruce to be used successfully as dens, they must occur in areas that are not prone to flooding. Standing Sitka spruce are likely used as dens more frequently in areas where Sitka spruce are abundant on drier sites (i.e., wetter and cooler subzones of the CWH biogeoclimatic zone).

Bedding Material in Dens

Bedding material was found in all dens of radio-collared bears, with many beds being deep and cup-like, resembling bird nests. Bedding materials are likely used by black bears in dens to reduce conductive heat loss, the pathway of greatest heat loss during denning (Maxwell et al. 1988). Lining dens with vegetation is common in Washington (80% of dens, Lindzey and Meslow 1976*a*), Arizona (91%, LeCount 1983), Alberta (95%, Tietje and Ruff 1980), and Alaska (100%, Schwartz et al. 1987) but less common in other areas. Only one third of the bears observed in Michigan (Erickson et al. 1964) and Montana (Jonkel and Cowan 1971) lined their dens with vegetation. Females and juveniles lined their dens more often than did adult males in Michigan (Erickson et al. 1964). Erickson et al. (1964) hypothesized that this occurred because less denning material was available at the time that males denned. In Arizona, LeCount (1983) found no difference in frequency of lining dens among sex and age classes. I found that some dens had vegetation obscuring the den entrance, as have other studies (Kolenosky and Strathearn 1987, Noble et al. 1990). Bedding material blocking the entrance to the den chamber may reduce heat loss and increase security of the den.

I observed the least amount of bedding material in the dens of female bears with cubs. This is in direct contradiction of Lindzey and Meslow (1976*a*), who hypothesized that bedding material is used to provide greater protection for the cubs from moisture and prevent from them being crushed. In my study, female bears may have been limited by the amount of room in their dens and extra bedding material would have further reduced size of the den chamber. Females with cubs may stretch out more during nursing, and hence do not have as deep beds as those used by bears without cubs.

<u>Denning Chronology</u>

Black bears exhibit a wide variety of denning strategies throughout their distribution in North America. Entrance and emergence dates vary in different climates and for physiological reasons. Most bears den regardless of winter conditions (Novick et al. 1981), but in North Carolina (Hamilton and Marchinton 1980), southern California (Graber 1990), and Mexico

(Doan-Crider and Hellgren 1996), some bears occasionally do not den at all. Researchers in some areas have concluded that low temperatures and increased precipitation initiate the denning process (Erickson et al. 1964, Lindzey and Meslow 1976*b*, Johnson and Pelton 1980, Novick et al. 1981). Others disagree, including Tietje and Ruff (1980) and Beecham (1980). Physical condition of bears has also been proposed as one of the initiating factors (Matson 1946), as well as physical condition in conjunction with weather (Schwartz et al. 1987). The ultimate cause may be linked to circannual rhythms like those that occur in chipmunks and ground squirrels (Johnson 1978, Johnson and Pelton 1980). The decrease in food supplies due to the onset of winter conditions is another hypothesis (Erickson 1965). Decreased food supply has been associated with later den entrance (Matson 1946), earlier den entrance (Johnson and Pelton 1980, Tietje and Ruff 1980, Beecham et al. 1983), or having no effect at all (LeCount 1983).

In the Nimpkish Valley, female black bears denned earlier and emerged later than did males. Pregnant females denned longer than any other age or sex group. In many regions, females den first, followed by sub-adults and then adult males (Amstrup and Beecham 1976, Lindzey and Meslow 1976*b*, Johnson and Pelton 1980,1981, Tietje and Ruff 1980, Reynolds and Beecham 1980). As observed in the Nimpkish Valley, den emergence usually occurs in the opposite sequence of entrance, with adult males emerging first (Johnson and Pelton 1980, LeCount 1983). Variations do occur; for example, one year in west central Idaho non-pregnant females denned after adult males (Beecham et al. 1983). Differences in reproductive status and fat deposition are believed to account for the different denning periods between sex and age classes (Lindzey and Meslow 1976*b*, Johnson and Pelton 1980). However, Beck (1991) found no difference in the length of the denning period among females of different reproductive status. Decreased mobility associated with the presence of cubs is also believed to cause females with cubs to emerge last (Lindzey and Meslow 1976*b*, LeCount 1983).

While earlier entrance into dens may be an advantage because it allows females to choose more protected dens, later den emergence may be a disadvantage because it leaves them potentially vulnerable to attack within their den. This type of attack may be more likely to occur during spring, after male bears emerge from their dens in search of food. A direct relationship may exist between prime tree-denning habitat, reproduction, and survival in some areas (Johnson and Pelton 1981). Johnson (1978) suggested that tree dens "may afford the extra protection necessary to maintain viable black bear populations in islands of dwindling and often marginal habitat." I observed several cases of cannibalism by bears (Davis and Harestad 1996) indicating that predation is likely a factor in den selection and denning chronology.

Twenty to 30 days prior to den entrance, a physiological transition occurs in bears (Nelson and Beck 1984). This transition to a pre-denning lethargy is often observed as loafing around the den site (Lindzey and Meslow 1976*b*, Hamilton and Marchinton 1980, Beecham et al. 1983, Kolenosky and Strathearn 1987). I observed a distinct decrease in activity of some bears before they entered their dens. During one observation of a male bear prior to denning, the bear walked only 30-40 m at a time, sat down for a few minutes and then continued with another short walk. The bear did not appear to be feeding during this period.

Increasing length of days and general warming are factors which may end winter dormancy (Lindzey and Meslow 1976*b*). These conditions may cause flooding of some types of dens, leading to early abandonment (Erickson 1965, Schwartz et al. 1987). The physical condition of denned bears has not been found to cause emergence (Tietje and Ruff 1980). Denning periods are well documented and available for many regions (see Johnson and Pelton 1980 for a summary). For bears that do den, the length of the denning period ranges from 3 months in Tennessee (Johnson and Pelton 1980) to 6.5 months in Montana (Jonkel and Cowan 1971).

Many hypotheses have been put forth to explain differences in den entrance dates between sexes. Females and subadults may be more selective than adult males when choosing den sites (Lindzey and Meslow 1976*a*, Pelton et al. 1980, Johnson and Pelton 1981, Lentz et al. 1983, Alt and Gruttadauria 1984). Females may den earlier so that they can choose dens which are more protected than dens available to the rest of the bear population (Johnson 1978, Pelton et al. 1980). Security and shelter appear to be the most important features of dens to pregnant females because parturition and lactation occur in the den, usually in January (pers. obs., Alt 1983).

How Bears Find Dens

Bears may locate tree cavities using a trial and error approach, possibly learning to associate large trees of particular species with the likelihood of cavities. Johnson (1978) reported that 34% of trees >84 cm dbh were climbed by bears, a significantly higher proportion than of smaller trees. Other researchers have also reported bears actively seeking dens with entrances above ground level (Hamilton and Marchinton 1980). Johnson (1978) provided further evidence for the trial and error hypothesis in that entrances to 24% of his active tree dens (with entrances above ground level) were not visible from the ground.

Bears likely have knowledge of several available den sites within their home ranges (Beecham et al. 1983, LeCount 1983, Alt and Gruttadauria 1984, Carney 1985) and may be checking sites throughout the year to determine their continued existence and suitability. Knowledge of alternate den sites could have survival implications for bears that are disturbed during the denning period (LeCount 1983). Resident males may select the next year's den site before moving far from their current den in the spring (Rogers 1977). Bears may compete for good den sites; Schwartz et al. (1987) observed several bears concurrently at a cave den but only one of the bears denned at the site. In my study, it appeared that bears may re-visit some den locations in early spring and late summer. At den sites that I had visited during early spring, I observed new bear marking and/or chewed site tags when I revisited the sites in early summer. I observed investigative digging at the base of yellow-cedar trees done by black bears in August and September. In addition, I observed a radio-collared black bear walking by her eventual den site several weeks prior to denning.

Reuse of dens by offspring has been documented. Beecham et al. (1983) hypothesized that offspring learn locations of dens from periodic summer visits to old den sites with their mothers. One of the radio-collared bears in my study area did use a den that was previously occupied by a younger female. Due to the overlap in their home ranges and the age difference it is possible that they were related.

Reuse of Dens

A wide range of frequencies of den reuse has been reported. In various studies, rates of reuse have been nonexistent (Tietje and Ruff 1980, Kolenosky and Strathearn 1987), low (Jonkel and Cowan 1971), and high (Schwartz et al. 1987). Of dens in west-central Idaho, 53% had been used in previous years, and the remaining 47% of dens were believed to have been used previously, but evidence was ambiguous (Beck 1991). Despite the evidence of high reuse of the 112 den sites, only 4 were actually reused during the course of the study (1980-86; Beck 1991) . In coastal Alaska, 75% of dens (n = 17) had been used previously, the remaining 25% were of unknown status (Schwartz et al. 1987). Lindzey and Meslow (1976*a*) found a minimum of 50% den reuse in Washington (n = 12). Although a low rate of reuse was observed in Pennsylvania (4.8%; Alt and Gruttadauria 1984), reuse of natal dens may have been very important to females. Alt and Gruttadauria (1984) observed that "five different females reused the same den for whelping consecutive litters, even though many potential den sites existed in their home ranges".

Den reuse is also affected by the longevity of den structures. Reuse can only occur if dens are structurally sound and can be used in subsequent years. Dens excavated into the ground and brushpiles may only last one or two years before collapsing, whereas rock cavities may persist for many years (Alt and Gruttadauria 1984, Beck 1991). Tree den longevity will vary depending on species of the tree and specific site conditions (especially moisture). Of the den types observed in my study, hollow cedar trees are the most resistant to decay (see Minore 1983) and thus are the most likely to be reused.

High reuse may indicate low availability of suitable den sites (Johnson 1978, Beecham et al. 1983, LeCount 1983, Wathen 1983, Alt and Gruttadauria 1984). Johnson and Pelton (1981) suggested reuse was an index to general abundance of dens, reporting no reuse in their study in the southern Appalachians which they determined to have an abundance of den sites. The 28% den reuse that I observed in the Nimpkish Valley, with a possibility of reuse being as high as 51-78%, is relatively high compared to that reported in other studies. This may indicate that the availability of den sites is constrained in the Nimpkish Valley. In portions of my study area with extensive second growth forests, female black bears had a reuse rate of 43%, indicating that den structures may be limited in these seral stages.

Ectoparasites have been suspected as a possible reason for bears not reusing dens in consecutive years (Beck 1991). I encountered fleas (Siphonaptera Vermipsyllidae *Chaetopsylla* spp.) in three black bear dens in the Nimpkish Valley, although the presence of fleas was not assessed in most dens that were surveyed. The fleas that I collected were alive several months after bears had left their dens and may be able to remain dormant in dens for long periods. Infestation of dens with fleas may discourage bears from using dens in consecutive years. In other areas of coastal B.C., dens may be vacant for 3 consecutive winters before being reused (Mike Stini, pers. commun.).

Scraping the insides of cedar trees by bears may help to decrease ectoparasites within dens. Cedar shavings are often used for the filling of domestic animal beds for this purpose; both western redcedar and yellow-cedar contain compounds that repel, or are lethal to, various insects (see Minore 1983, Hennon 1991). The inner surfaces of many cedar dens were scraped despite adequate room inside the den and adequate vegetative bedding material. Perhaps the scraping of the cedar trees that I observed reduced ectoparasites within dens. Because ectoparasites may affect the likelihood of den reuse, studies should be conducted to examine parasites and den reuse.

Slope, Aspect, and Elevation

Black bear dens occur at all elevations, slopes and aspects (Idaho, Beecham 1980). The use of natural cavities may make selection of slope and aspect "largely fortuitous" because the availability of sites, rather than macro variables, may determine den selection (Tietje and Ruff 1980, Wathen et al. 1986). In the Nimpkish Valley, aspects of den entrances were uniformly distributed, likely because almost all entrances were naturally occurring. Johnson and Pelton (1981) and Wathen et al. (1986) also report that aspect of entrances were of little importance in den selection.

The micro-slope (the area immediately surrounding the den site) was significantly flatter than the slope of the surrounding stand. In my study area, dens tended to occur on small flat benches on otherwise steep hillsides. Stump dens occurred on flatter slopes than did standing tree dens likely because logging occurred on slopes that were easier to harvest and utilization standards were lower, allowing high stumps to remain after harvesting . The mean slope of the stands ($\bar{x}$= 23^{o} in the Nimpkish Valley) surrounding dens was very similar to that reported in other studies (between 20^{o} and 40^{o}; Beecham 1980, LeCount 1983, Wathen et al. 1986).

In my study area, dens in standing trees occurred at higher elevations than did other den types. This association between dens in standing trees and elevation likely occurs because timber harvesting began at lower elevations and few large standing trees remain at low elevations. This effect has been reported in other studies of black bear den selection (Pelton et al. 1980, Johnson and Pelton 1981). Consistent with Beck (1991), in the Nimpkish Valley I did not detect a difference in elevations at which males and females denned.

Habitat Characteristics

Hollow tree dens were used less frequently than expected in the two Black Bear Habitat Types (BBHTs) with high nutrient status (rich and very rich actual nutrient regimes and slightly dry to very moist actual moisture regimes). This result was surprising because I anticipated that stands with higher nutrient regimes would produce larger trees and thus good den sites. This does not appear to be true, perhaps because these sites produce trees that may be more structurally sound than do sites with poorer nutrient regimes.

Two den types occurred in specific BBHTs less frequently than expected, likely for very different reasons. Stump dens occurred less frequently than expected in the Fir Salal BBHT (very poor to medium nutrient regimes and moderately dry to very moist moisture regimes). This is surprising because the Fir-Salal BBHT was the most extensively logged BBHT in my study area. This low occurrence of stump dens may indicate that the creation of dens under stumps is a relatively rare event requiring very specific conditions. Dens in and beneath CWD occurred less frequently than expected in the Blueberry Moss BBHT likely because this BBHT supplied almost all of the hollow tree dens, which are probably preferred over CWD dens (see below).

The frequency of use of each den type among seral stages was different from expected because some den types do not occur in some seral stages. For example, by definition, cut stumps do not occur in late successional forests and hollow trees do not occur in early seral stages. However, CWD dens occurred less frequently than expected in late successional forests. This may simply reflect availability of other den types, or it may reflect differences in the suitability of den types. Perhaps hollow trees are more abundant or preferred within late successional forests and thus CWD dens are used only if hollow tree dens are not available (i.e., in earlier seral stages).

Location of Den Sites within Home Ranges

In the Nimpkish Valley, black bears denned close to their eventual spring forage areas. This is consistent with other black bear research (LeCount 1983). During the critical physiological transition period following hibernation (Nelson et al. 1983), long movements to areas of spring forage would increase the chance of contact with other bears. This contact may increase risk to cubs from attacks by predators (Davis and Harestad 1996).

In different regions, black bears den in different parts of their seasonal home ranges. Males may den in the same small area of their home range each year (Rogers 1977) or at sites throughout their home range (Beecham et al. 1983). I did not detect male bears choosing den sites within small portions of their home ranges. Black bears in Alberta exhibited movements prior to denning similar to those that I observed; females denned within their home ranges used during the non-denning period, while males made long movements from fall areas (Tietje and Ruff 1980). Long movements of both males and females were observed in central Arizona

(LeCount 1983); bears moved between 18 and 57 km from their normal home ranges in various years and all rapidly returned to their normal home ranges in late fall, denning soon after their return.

Bears shed foot pads during hibernation (Rogers 1974, Beecham et al. 1983, Kolenosky and Strathearn 1987), which may have implications to the location of their den within their home ranges. I discovered pieces of digital pads, up to a few centimetres in diameter, in the faeces of an adult male (M14) upon investigation of his first telemetry location after den emergence. The rate of foot pad replacement is related to the age, sex and physical condition of the bear (Kolenosky and Strathearn 1987). Some authors have speculated that the digital pads may not be fully keratinized upon den emergence and thus the paws may be tender. This could restrict activities and movements of bears in early spring (Rogers 1974). Others believe restricted movements during spring are merely due to physiological condition, and not tender paws (Beecham et al. 1983). Both of these reasons could be contribute to selection of dens close to spring foraging areas.

Den Clusters

Dens were sometimes in close proximity to one another. I found as many as 3 den sites, of different ages, within 75 m of each other. These dens may have been used by a single bear in different years. Clusters of suitable cavities may occur due to windthrow or site conditions which are ideal for the spread of pathogens and decay processes. Bears may reap added benefits when they den in areas with multiple dens close by. If bears have alternate sites available, they may improve their chances of survival if disturbed during the denning period (Alt and Gruttadauria 1984). This strategy may have been used by one of the adult male bears in my study. M03 was located in a den during spring 1995, but not the same den that he was in earlier that winter. Examination of the first den revealed that large trees around the den had blown down, falling against the den. M03 relocated to a second den less than 75 m away. The same bear denned in one root bole den in a group of three root bole dens the previous year.

Evidence from elsewhere on Vancouver Island suggests that clusters of dens may be important for bears in heavily-modified landscapes. Employees from Timberwest Forest Ltd. found 14 den sites in hollow trees in one 40-ha proposed timber cutblock (Dave Lindsay, pers. commun.). Boundaries of the cutblock were changed to allow all the den trees to remain standing after harvesting. The area of Vancouver Island where this occurred had been heavily harvested in the past. I do not know whether these dens are from one or two bears choosing different dens every year, or a concentration of den sites due to low availability within the landscape.

Den Location in Relation to Human Activity

Many researchers have suggested that bears prefer denning habitat which is remote and free of disturbance (Tietje and Ruff 1980, Johnson and Pelton 1981, Kolenosky and Strathearn 1987, Hellgren and Vaughan 1989). However, from my own observations and those of Noble et al. (1990), some bears tolerate human activity. While many bears in my study denned far from human activity, some female black bears denned close to human activity (generally roads). One female denned within 60 m of the North Island Highway, while another denned 50 m from the main bridge that all logging trucks and public traffic cross when using industrial roads in my study area. The main span of the bridge was replaced while the female denned near it. Various responses of bears to human activity have been observed elsewhere. For instance, Noble et al. (1990) found that female black bears denned farther from human activity than did males, but they reported that one female and cubs denned 30 m from an active road. As noted below, although some female bears denned near concentrations of human activity, bears will often abandon dens if people approach the den site.

Horizontal Visibility

Security of den sites is an important factor that may influence timing of denning, types of dens used, and den location. Disturbance of denned bears can be detrimental because bears are trying to minimize energy expenditures during this period. Denning mortalities appear to be related to security of the den site. Den-related mortality can occur either by natural causes, hunting, cannibalism or predation. Bears in dens may be preyed upon by other black bears (Davis and Harestad 1996) or, where they occur, by grizzly bears (Ross et al. 1988). It is likely that females with cubs that are too small to climb trees are safer inside dens.

Stump dens had less horizontal visibility than did hollow tree dens, but this difference was likely due to forest practices around the stump dens. Stump dens in my study area occurred in two places: 1) a regenerating clearcut with dense vegetation, and 2) a part of the study area which was heavily thinned, leaving behind a large amount of CWD up to 25 cm in diameter. This layer of debris in the area of the stump dens was up to 1.5 m deep.

I, along with other researchers, have found that hollow tree dens have less security cover (i.e., greater horizontal visibility) than do other types of dens (Wathen et al. 1986, Noble et al. 1990). In an area where bears used both tree dens and ground nests, Wathen et al. (1986) reported that bears used tree dens with no understory, while all ground nests were obscured by an understory. Dens with above ground den entrances provide the greatest amount of security (Noble et al. 1990, Johnson 1978) and thus surrounding vegetation is less important in providing security cover (Noble et al. 1990). Johnson and Pelton (1981) found that bears in tree dens were less likely to be disturbed than those occupying other den types. In my study, hollow tree dens had the greatest horizontal visibility, which supports the hypothesis that this den type is more secure and thus does not require other forms of cover.

While few instances of natural mortality during the denning period have been recorded, cannibalism of denning and non-denning bears has been documented. The amount of cannibalism varies among studies (see Garshelis 1994). In the Nimpkish Valley, I found a high rate of cannibalism on denned bears, non-denned bears, and cubs (Davis and Harestad 1996). In areas with a high risk of cannibalistic attacks, security of the den sites may be more critical in selection of den sites.

Predation on denned black bears by wolves is rare but does occur. Of 206 dens in north-eastern Minnesota, one female and her cubs were killed by wolves when the primary prey of wolves, white-tailed deer, were in decline (Rogers and Mech 1981). In northern Alberta, wolves were also observed killing a female bear, orphaning her cubs (Horejsi et al. 1984). In Riding Mountain National Park, Manitoba, a female and cubs and 2 other bears were consumed by wolves (Paquet and Carbyn 1986). Wolf scats containing bear hair and claws were found within my study area, indicating that wolves may be a factor in winter den or spring mortality of bears in the Nimpkish Valley.

If predation during denning is important in an area, some den attributes may decrease this risk. Small openings to dens are more easily defended than large openings. Multiple den openings are likely disadvantageous for protection from wolf predation. Mortality caused by predators excavating the den cavity is also likely lessened as the thickness of the den wall or depth of cover over the den increases. Concealment or closure of dens by snow (Beecham 1980, Johnson and Pelton 1980) and surrounding vegetation (Beecham et al. 1983, Wathen et al. 1986, Kolenosky and Strathearn 1987) further reduces chances of detection and disturbance.

Snow Cover

Closure of den entrances by snow can significantly reduce the metabolic costs of denning for bears (Maxwell et al. 1988). Therefore, bears can potentially reduce metabolic costs by denning at high elevations that are more likely to have continuous snow cover. However, I did not observe selection for specific elevations in my study. Numerous visits to the study area over the winter, revealed that the snow pack was extremely variable, ranging from a depth of 1 m to zero within a week. Within the climatic regime in the Nimpkish Valley, black bears were therefore unable to rely on snow to hide and insulate their den cavities. I visited dens in January and discovered that many of the den entrances were blocked with bedding material. Similar behaviour by black bears in Oregon was reported by Noble et al. (1990). Because black bears in the Nimpkish Valley cannot rely on a continuous snow pack to provide insulation for their dens, they may select den structures based on other characteristics and reduce their metabolic costs by blocking their den entrances with vegetation.

Reaction To Investigator Disturbance

While female black bears may tolerate human activity close to dens, they will react to close approach by humans. Black bears seem capable of tolerating ambient noise caused by humans, but will not tolerate close approach by potential predators. For example, Carney (1985) monitored 6 female bears that denned within 30 m of foot trails that were heavily used by humans, but also reported that 3 females abandoned their cubs in their dens after being disturbed by investigators.

I walked within close range of some of the dens of radio-collared black bears, to locate den sites and place remote-sensing cameras outside dens to determine den emergence dates. Radiotelemetry was very difficult around den sites because den structures and locations of den entrances affected radio signals. Batteries of cameras needed to be changed at some den sites, so these sites were visited more than others. Several den sites were not visited until after den emergence. In most cases, bears were alert and watched me approach but did not attempt to leave their den sites; only one bear that was approached at close range was fully asleep and unaware of our presence (F03). All visits were as short as possible, cameras were assembled in advance and only needed to be switched on once being placed facing the den entrance. No den abandonment occurred as a result of the camera placements.

In the course of my study, two female bears without cubs abandoned their dens when I attempted to immobilize them in March 1992. One adult female black bear left her den following a failed drugging attempt. Another adult female (F02) abandoned her den site before I reached the den. Her den entrance provided her with a clear view of my approach along an unused road 20 m below her den. Adult male bears had already begun emerging from their dens, so the females may have been close to emerging as well.

In west central Idaho, most bears that were approached for immobilization in their dens were lethargic and rarely aggressive (Beecham 1980). Bears that abandoned dens lost more weight, although no over-winter or spring mortalities were observed (Rogers 1977, Tietje and Ruff 1980). Reproductive performance of disturbed females appeared normal in Alberta (Tietje and Ruff 1980). In Arkansas, four of six adult females disturbed from initial dens (before birth of cubs) produced cubs in their alternate dens (Smith 1986).

In the spring of 1995, I caused abandonment of two dens by adult male bears. M11 left his den upon my approach in January, but returned to the den. The same bear did not abandon his den the year before, after I placed a camera outside the den and changed the battery several times. M03 abandoned his den after I circled around the site in early March but he did not return to the den. The den that M03 abandoned was likely his second den that winter. Other adult male bears were already out of their dens at the time.

The physiological state of hibernation may also continue for weeks after den emergence ("walking hibernation" - Nelson and Beck 1984). Nelson and Beck (1984) warned of the effects of disturbance on denned bears. They stress that the physiological state of "hibernation" and the physical and behavioural state of "denning" are two distinct events. Their findings were further supported by field observations in Arkansas (Smith 1986). While bears may be disturbed from their dens, the state of hibernation does not end. Increases in weight loss caused by abandonment of the den are similar in magnitude to those of females that bear and nurse cubs. Increases in weight loss from the norm of 16% to 20-37% (average 25%) represents a 56% increase in normal weight loss (Tietje and Ruff 1980).

Conclusion

Black bears in the Nimpkish Valley used many different structures in which to den, and all of these structures were derived from, or associated with, large diameter trees. My data suggest that black bears in coastal British Columbia must satisfy at least two requirements when selecting dens: thermal cover and security cover. Dens are essential for bears to survive hibernation. Dens supply thermal cover, by keeping bears warm and dry during periods that would otherwise be extremely energetically costly. Dens also must provide adequate security cover to ensure that the occupants are not vulnerable to predators. Secure dens are particularly important for reproducing females. In coastal British Columbia, denning requirements appear to be fulfilled most effectively by structures most commonly found in late successional forests.

Chapter 2. Use and Selection of Den Sites by Black Bears

Introduction

Many studies examine the relationships between a species and its habitat by analyzing the selection of different habitats by the species. Selectivity, the use of habitats or habitat characteristics disproportionately to their availability (Johnson 1980), is commonly used as an inferential tool by researchers examining habitat relationships. Disproportionate use is classified as avoidance if the habitat is used significantly less frequently than expected based upon availability, or preference if the converse is true (Nue et al. 1974).

Most studies of denning by black bears do not report selectivity for dens, but concentrate on the chronology of denning, den types, cavity measurements, and analyses of slope, aspect and elevation (e.g., Hamilton and Marchinton 1980, Wathen et al. 1986, Hellgren and Vaughan 1989). The few studies that examined selectivity of winter dens by black bears were conducted solely at one spatial scale (e.g., Tietje and Ruff 1980, Johnson and Pelton 1981, Carney 1985, LeCount and Yarchin 1990). Some researchers have used measures of availability which were potentially biased; for example, Johnson (1978) determined the availability of individual structures by counting those structures that he determined were “suitable” for denning. To understand the requirements for winter dens by black bears, selectivity of habitat for denning must be examined using unbiased estimators.

Relationships between bears and their habitat can be examined at several spatial scales. Spatial scales are nested; patches are assemblages of elements, stands are assemblages of patches, and landscapes are assemblages of stands. Elements are the structural attributes (logs, stumps, living and dead trees) that may be used as dens. Patches are small groups of trees (usually fewer than 12 trees) less than 1 ha in area. Stands are relatively homogenous land units greater than 1 ha in size with generally homogenous vegetation types with regard to dominant forest cover or seral stage. Landscapes are a watershed or series of similar and interacting watersheds, usually greater than 10 000 ha in size (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995). These levels of spatial scale expand upon the second- through fourth-orders of selection proposed by Johnson (1980). Examining the spatial scales at which habitat features are selected provides insight into the relationship between den supply and habitat alteration.

Habitat and successional alterations influence the availability of habitats for animals. This relationship influences the scale at which animals can select resources from their environment. Therefore, to properly manage habitat for a species, managers need to know the spatial scales that animals select habitat and the availability of these habitats. Evidence from previous studies of black bear denning suggest that habitat elements are important factors in the selection of dens (e.g., Johnson and Pelton 1978). However, few studies (e.g., Carney 1985) have determined if the selection of denning habitat occurs at coarser spatial scales. My objectives are to examine selectivity exhibited by black bears for denning habitat at 4 spatial scales (element, patch, stand, and landscape) and for each spatial scale to determine the features of habitat that bears select to survive the winter denning period.

Methods

I used several techniques at each spatial scale to determine the characteristics of habitats used by bears for denning as well as the availability of these habitats. For landscape and stand scale analyses, I classified stands in my study area on the basis of site series (Green and Klinka 1994), seral stage, and several structural attributes. For analyses of habitat selection at the patch scale, I compared measures of specific structures at random patches within each stand type to those at patches used by bears for denning. For element scale analyses, I compared the structures used by bears for denning to those that were available around each type of den (i.e., within den patches).

I estimated the availability of stands in the study area using random point sampling (Marcum and Loftsgaarden 1980). I classified 536 random points in the study area. Of these, I visited 170 and measured a full range of habitat and structural attributes. These attributes were measured at both den sites and random points. In addition, 153 random points were visited on the ground at which I measured a subset of attributes. A further 213 random points were classified by air photo interpretation and/or during flights over the area by helicopter. Stands were classified by site series (biogeoclimatic ecosystem classification, Green and Klinka 1994) and seral stage (as per Chapter 1). For the purposes of my analyses, I combined 46 site series and 6 seral stages into 29 stand types.

I used features associated with denning to further describe stands in my study area. Slope, aspect and elevation were recorded at each random point and den site. Structural attributes were also sampled (i.e., coarse woody debris, stocking densities of trees, vegetation cover, and horizontal visibility). For the purpose of classifying stands, I considered these attributes to be homogenous within stand types.

Coarse woody debris (CWD) was measured at dens and random points to determine its availability. CWD was measured using two sampling methods at all plots: visual estimation of total percent cover, and by tallying pieces of large CWD along an 80 m (4 20-m) transect. I recorded the diameter and species of each piece of debris >50 cm diameter and classified each piece into one of five decay classes: (1) log elevated on support points, bark present, (2) log elevated on support points but sagging slightly, starting to soften in texture, losing bark, (3) log is sagging near ground, there are still large, hard, pieces but only a trace of bark, (4) all of log on ground, consists of small blocky pieces, bark absent, and (5) all of log on ground, texture is soft and powdery (*sensu* Maser et al. 1979). I calculated the mean number of logs >50 cm diameter within three size categories (50-64 cm, 65-79 cm, >80 cm). Comparisons within abundance classes were performed for each size category (e.g., 0, 0.01-0.50, >0.50 logs/transect in the 65-79 cm diameter category).

I assessed selectivity for different structural attributes by examining attributes of trees in stands used by bears for denning. I gathered mensuration data using variable radius prism cruise plots to estimate the stocking densities of different classes of trees (Bull et al. 1990). I estimated the mean diameter and basal area of the stands from this mensuration data. The diameter of trees and snags >17.5 cm diameter were measured and classified by species and decay class. In addition, I established 30 m by 30 m plots in which I measured the diameter of every tree >17.5 cm at 10 variable radius prism cruise plots to compare the sampling techniques. The two methods yielded similar results and thus I subsequently used variable radius prism cruises at the random points and den sites. I also gathered mensuration data using variable radius prism cruise plots to estimate the stocking densities of stumps only at sites where dens were in stumps. Only stumps >17.5 cm were measured, many were too decayed to be measured.

Vegetation inventories (Luttmerding et al. 1990) were performed at den sites and fully-sampled random points. However, I only used total percent cover of trees (>10 m in height), high shrubs (>2 m in height), and low shrubs (<2 m in height) for analyses of den selection. Horizontal visibility was estimated as per Chapter 1. Comparisons of horizontal visibility were done from measurements taken at both den and random patches for analyses of selectivity at stand and patch spatial scales.

Different sub-samples of dens were used for estimates of selectivity at each spatial scale to avoid potential sampling biases. Only dens of radio-collared black bears were used for analyses of landscape- and stand-level selectivity. I restricted my analyses to the dens from these bears because I knew that they were resident in the study area and thus my availability estimates were biologically relevant. I did not include dens of bears that were not radio-collared because their home ranges were not known and hence I could not estimate the availability of habitats for them. Dens that were found incidentally by timber cruisers may also have been biased because timber cruising occurred solely in old-growth forests that were planned for harvesting. I considered reuse of dens to be independent events at the stand spatial scale and assumed selection of stands was independent of selection of elements. I included dens of both radio-collared and unmarked bears for analyses of selectivity at the patch and element spatial scales because these analyses compared the use of structures across and within patches of the same stand types.

Element Level

At the element level, I compared the mean diameters of den structures to the mean diameters of non-den structures within den patches. The 5 den types were combined into 3 groups for element level analyses: (1) trees and snags, including dens in hollow trees and snags as well as dens beneath standing trees, (2) logs and root boles, and (3) stumps. For each group of den types at the element level, selection was examined by comparing characteristics of these dens to the appropriate types of structures that were available in patches surrounding the dens. For dens in trees or snags, I compared the diameters of trees and snags that contained dens to the diameters of trees and snags in the patches surrounding the dens. I did separate analyses for each species of trees and snags and then all species combined. For dens in logs and root boles, I compared the diameter and decay class of logs that were used as dens to those of logs (>50 cm diameter) that were in the surrounding patches. For dens in stumps, I compared the diameter of stumps used as dens to those of stumps in the surrounding patches. Cruise plots for stumps were skewed towards large stumps, not only due to the inherent bias towards detecting large diameter trees by prisms, but also due to faster rates of decay by small stumps. I used Mann-Whitney U-tests for statistical comparisons at the element level. I used $P \leq 0.05$ as my significance level in all analyses.

Patch Level

My operational definition of a patch was the area of a variable radius prism cruise plot. Patches are assemblages of vegetation less than 1 ha in size that may or may not be structurally or compositionally different from the remainder of the stand. The patch surrounding a randomly located point is a "random patch", while the patch surrounding a den is a "den patch" (Fig. 3). Within patches, I estimated amounts and characteristics of structural attributes and compared the means of these characteristics between random patches and den patches.

To ensure that patch level selectivity was not confounded by stand level selectivity, I classified stands into different categories and classes of categories based upon habitat attributes. I used this stratification so that den patches were compared to random patches within the same kind of stands. By controlling for stand differences, differences in the characteristics of den patches compared to random patches would then reveal patch level selectivity. For example, mean number of logs (>50 cm diameter) is a structural attribute (Table 9). These logs can be placed into one of several structural attribute categories based on diameter intervals. Structural attribute classes were formed by division of these categories into groups based on the number of

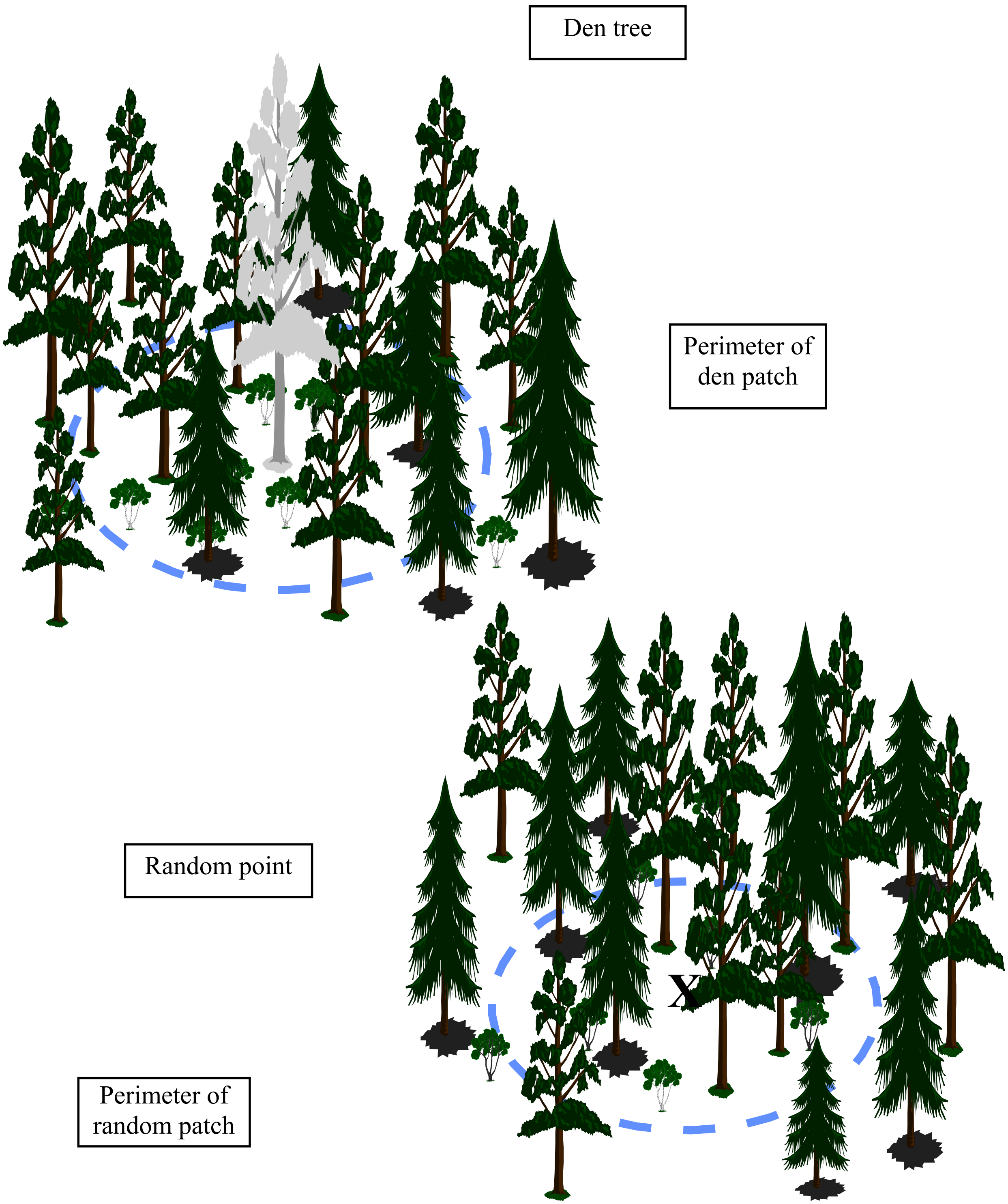

Figure 3. Examples of den patches and random patches used for determining habitat at different spatial scales.

Table 9. Habitat attribute categories and their classes used for selectivity analyses at the stand and patch levels in the Nimpkish Valley.

Habitat attribute categories	Attribute classes within categories
Cover of coarse woody debris (%)	
Total cover	0, 1-15, 16-30, >30
Mean number of logs >50 cm diameter	
50-64 cm diameter	0, 0.01-0.50, 0.51-1.00, 1.01-1.50, >1.50
65-79 cm diameter	0, 0.01-0.50, >0.50
>80 cm diameter	0, 0.01-0.50, >0.50
Tree attributes	
Basal area (m^2/ha)	0, 1-30, 31-60, >60
Mean diameter (cm)	0, 17.5-27, 28-37, >37
Stocking densities of trees (stems/ha)	
17.5-36 cm diameter	0, 1-300, >300
37-56 cm diameter	0, 1-75, >75
57-76 cm diameter	0, 1-25, 26-50, >50
77-96 cm diameter	0, 1-10, >10
>96 cm diameter	0, 1-10, >10
Live trees only	0, 1-300, 301-600, >600
Snags only	0, 1-30, 31-60, >60
Redcedar and yellow-cedar only	0, 1-150, >150
Vegetation cover (%)	
Tree cover	0, 1-30, 31-60, >60
High shrub cover	0, 1-15, 16-30, >30
Low shrub cover	0, 1-15, 16-30, >30
Other habitat attributes	
Total horizontal visibility (m)	1-15, 16-30, 31-45, >45
Slope (degrees)	0, 1-5, 6-10, 11-15, 16-20, 21-25
Aspect (degrees)	1-30, 31-60, 61-90, 91-120, 121-150, 151-180, 181-210, 211-240, 241-270, 271-300, 301-330, 331-360

logs. Patch level analyses were conducted by comparing mean values of structural attribute classes in random patches to those of den patches within the same stand type. For example, if the BBM stand type had a mean of 22% cover of CWD (determined from the random patches within that stand type) then it is within the 16-30% cover class for CWD. This mean of 22% cover of CWD is then compared to the mean at den patches in the BBM stand type. A significant difference from random patches would be detected if, for example, the patches around dens in the BBM stands had 44% cover of CWD. I used Mann-Whitney U-tests for statistical comparisons at the patch level.

Stand Level

Stands were classified into 29 stand types derived from 46 site series (biogeoclimatic ecosystem classification, Green and Klinka 1994) and 6 seral stages. I combined similar site series to form 9 Black Bear Habitat Types (BBHTs) which have similar moisture and nutrient regimes (Appendix A). The six seral stages were combined into 4 based upon similar structural composition (Chapter 1). The few younger, fire-succession stands with veterans and large amounts of CWD were combined with the 5/6 seral stage for analyses by seral stage. When I analyzed selection by bears for stand types and BBHTs alone, I used only those stands comprising greater than 2% of the landscape.

Selectivity at the stand level for habitat attributes was assessed by grouping stand types into categories and comparing use of classes of these categories with their availabilities. Stand types were grouped on the basis of similar mean values of each habitat attribute class (Table 9). These mean values were generated from data collected at plots located randomly throughout the study area. I measured selectivity by comparing use to availability for each habitat attribute class by stand type. On average, 7 plots were used to calculate mean values of habitat attributes for each stand type. Selectivity within stand categories and among stand classes was determined by chi-square analyses and Bonferroni-adjusted Z-tests (Neu et al. 1974) with $P \leq 0.05$. Individual classes of these categories used more than available ($P \leq 0.05$) were considered preferred, while those used less than available ($P \leq 0.05$) were considered avoided.

Landscape Level

I determined selectivity for elevation at the landscape level by comparing the use of elevational classes with their availability within the study area. I examined the distribution of seral stages within the same elevational classes to determine if seral stages were randomly distributed in the study area. Selectivities of elevational classes were determined by chi-square analyses and Bonferroni-adjusted Z-tests (Neu et al. 1974) with $P \leq 0.05$.

Results

Element Level

Results of analyses for selection at the element level were highly significant. Bears selected trees and snags, logs and root boles, and stumps which were significantly larger in diameter than other structures available within the den patches (Table 10). Bears exhibited selectivity for decay classes of CWD ($\chi^2 = 23.74$, df = 4, $P < 0.001$). Logs and root boles of decay class 2 (Maser et al. 1979) were used more frequently than expected based upon availability (Bonferroni-adjusted Z-test, $P = 0.001$, Fig. 4).

Patch Level

I observed considerable selectivity by black bears for denning sites at the patch level. Selectivity for various amounts of structural complexity was apparent within analyses for CWD, stocking densities of trees, vegetation cover, horizontal visibility and slope. The method that I used to compare den patches with random patches occasionally allowed for non-zero values for the mean of structural attribute classes for a den patch when the random patch mean is zero. For example, in stands classified as having no logs >80 cm diameter, random patches had a mean of 0 logs while den patches within the same stand type had a mean of 0.57 logs. This may appear to be a paradox but it can occur when a structure is so rare in a stand type that it is not detected through random sampling, but bears select dens associated with such a rare element.

Den patches had greater amounts of CWD than did random patches (Table 11). The patches around dens had more total percent cover of CWD than did random patches in stands classified as having 16-30% cover of CWD. The mean number of logs in den patches was greater for every structural attribute class in all three size categories but these differences were only

Table 10. Element level comparison of diameters of non-den structures and 58 black bear dens in the Nimpkish Valley, 1993-1995. *P* values are results of Mann-Whitney U-tests.

	Diameter of non-den structures (cm)			Diameter of den structures (cm)			
Den type	Mean	SE	*n*	Mean	SE	*n*	*P*
Stumps	122	7	24	162	13	5	< 0.05
Logs and root boles	66	2	48	106	9	17	< 0.01
Trees and snags	72	2	274	158	8	36	< 0.01
Redcedar	101	8	46	173	19	12	< 0.01
Yellow-cedar	109	8	22	155	9	19	< 0.01
Western hemlock	66	3	100	128	10	3	< 0.01
Mountain hemlock	76	8	16	146	11	2	< 0.05
Other species	55	4	90			0	

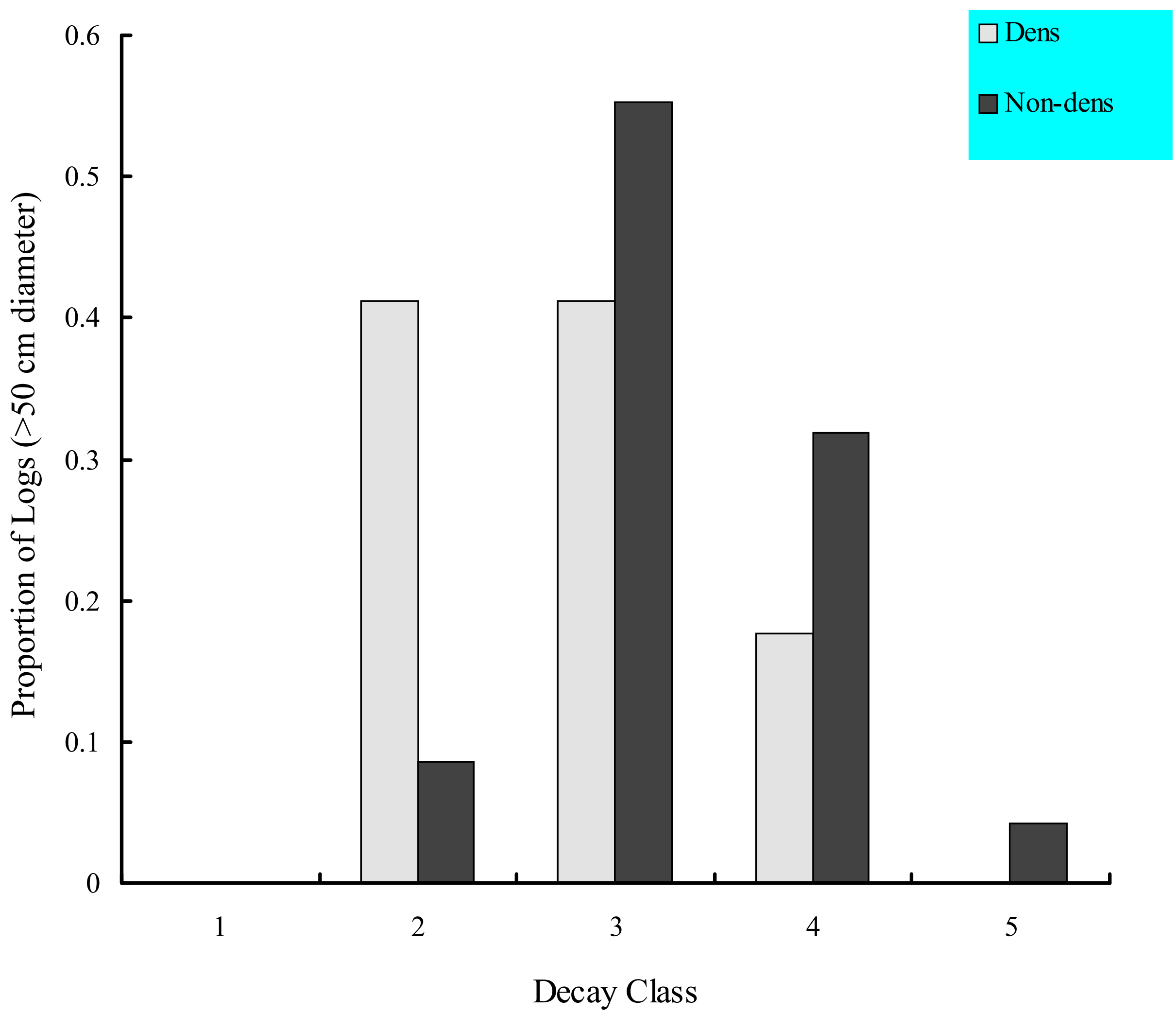

Figure 4. Proportion of dens (n = 17) and non-den (n = 147) logs at den patches in decay classes 1 through 5 in the Nimpkish Valley 1992-1995. Decay classes: (1) log elevated on support points, bark present, (2) log elevated on support points but sagging slightly, starting to soften in texture, losing bark, (3) log is sagging near ground, there are still large, hard, pieces but only a trace of bark, (4) all of log on ground, consists of small blocky pieces, bark absent, and (5) all of log on ground, texture is soft and powdery (*sensu* Maser et al. 1979).

Table 11. Patch level selection by denning black bears for coarse woody debris (% cover) in the Nimpkish Valley, 1993-1995. *P* values are results of Mann-Whitney U-tests. *P* values > 0.10 are not shown.

Total % cover	Random patches			Den patches			
of CWD	Mean	SE	*n*	Mean	SE	*n*	*P* value
0	0.0	0.0	1	-	-	-	-
1-15	11.0	1.3	58	12.4	1.8	31	
16-30	22.8	1.0	178	44.4	6.0	17	< 0.01
>30	37.6	2.4	37	41.3	7.2	15	

significant for some classes (Table 12). Den patches contained more logs than did random patches in the 0.01-0.50 and 0.51-1.00 classes of the 50-64 cm diameter category. Den patches were not significantly different from random patches for any class of the 65-79 cm diameter category. Den patches contained more logs than did random patches in the 0 and 0.01-0.50 classes of the >80 cm diameter category.

Mensuration data for 30 m by 30 m plots were compared with that of variable radius prism plots. I used paired sample t-tests to compare mean diameter, basal area and stems/ha values for 10 plots of the same stand type. No differences were detected in any of the three variables ($P > 0.05$). Although both methods provided similar results, prism plots were faster and easier to do, thus I used them at all random points and den sites. On average, 38 trees were measured in the 30 m by 30 m plots for the particular stand type measured, compared to 7 in the variable radius prism plots. Data from prism cruises were used to examine patch level selectivity for basal area (m^2/ha) and mean diameter (cm). Each attribute was divided into 4 classes; den patches were not significantly different from random patches within stand types.

Black bears exhibited significant patch level selectivity for stocking densities of trees within various diameter categories (Table 13). However, there were no consistent trends in patch level selectivity for stocking densities among diameter categories. In the 17.5-36 cm diameter category, den patches had higher stocking densities than did random patches in the 1-300 stems/ha class, but lower densities in the >300 stems/ha class. In the 37-56 cm diameter category, the den patches had fewer stems/ha than did random patches in the >75 stems/ha class. Den patches had significantly fewer stems/ha than did random patches only in the >50 stems/ha class of the 57-76 cm diameter category. The only significant difference that I detected for the 77-96 cm diameter category of trees was in the 0 stems/ha class. Trees were recorded at den sites

Table 12. Patch level selectivity by denning black bears for the number of logs >50 cm diameter within diameter categories in the Nimpkish Valley, 1993-1995. *P* values are results of Mann-Whitney U-tests. *P* values > 0.10 are not shown.

Diameter category	Class (# of logs)	Number of logs >50 cm diameter: Random patches Mean	SE	*n*	Den patches Mean	SE	*n*	*P* value
<u>50-64 cm</u>								
	0	0.00	0.00	11	-	-	-	-
	0.01-0.50	0.36	0.09	58	1.15	0.20	27	< 0.01
	0.51-1.00	0.78	0.09	27	2.00	0.52	6	< 0.05
	1.01-1.50	1.23	0.16	61	2.00	0.48	17	
	>1.50	1.86	0.40	14	2.00	0.37	9	
<u>65-79 cm</u>								
	0	0.00	0.00	29	-	-	-	-
	0.01-0.50	0.25	0.05	104	0.51	0.13	47	
	>0.50	1.05	0.17	39	1.42	0.38	12	
<u>>80 cm</u>								
	0	0.00	0.00	50	0.57	0.13	37	< 0.01
	0.01-0.50	0.21	0.05	91	1.05	0.26	20	< 0.01
	>0.50	0.70	0.15	30	1.50	0.20	2	

Table 13. Patch level selectivity by denning black bears for stocking densities of trees by diameter categories in the Nimpkish Valley, 1993-1995. *P* values are results of Mann-Whitney U-tests. *P* values > 0.10 are not shown.

Diameter category	Stocking class (stems/ha)	Stocking density (stems/ha) Random patches Mean	SE	*n*	Den patches Mean	SE	*n*	*P* value
17.5-36 cm								
	0	0	0	35	220	220	2	
	1-300	166	20	79	380	100	13	0.03
	>300	437	32	54	306	37	46	< 0.01
37-56 cm								
	0	0	0	57	0	0	2	
	1-75	58	8	57	52	24	15	
	>75	124	12	54	98	16	44	0.04
57-76 cm								
	0	0	0	69	0	0	8	
	1-25	11	2	47	13	5	11	
	26-50	34	5	30	30	9	11	
	>50	58	9	21	37	7	31	0.03
77-96 cm								
	0	0	0	97	0.78	0.54	23	< 0.01
	1-10	6	2	33	15	8	7	
	>10	23	4	37	22	4	31	
>96 cm								
	0	0	0	104	0.70	0.50	23	< 0.01
	1-10	3	1	46	18	3	38	< 0.01
	>10	25	4	17	-	-	-	-

when none were recorded for random point plots in the same stand types. The same is true for the 0 stems/ha class of the >96 cm diameter category. Significantly more trees were recorded at dens than at random point plots (comparing all den sites, not just tree dens) in the 1-10 stems/ha class of the >96 cm diameter category.

In addition to analysis by various size categories, I compared stocking densities of live trees, dead trees (snags), and cedar trees (Table 14). Den patches had significantly fewer live stems/ha than did random patches within the 301-600 stems/ha class. Furthermore, black bears selected den patches with snags (i.e., veterans) within stands in which these structures were uncommon. Den patches had significantly fewer cedar stems/ha (redcedar and yellow-cedar combined) than did random patches in the >150 stems/ha class.

Bears also exhibited patch level selectivity for 3 vegetation strata (Table 15). Percent cover of trees was significantly lower at den patches than at random patches within the 31-60% tree cover class. Percent cover of high shrubs in patches used by bears for denning was significantly greater than that at random patches within the 1-15% high shrub cover class. Low shrub cover was greater at den patches than that at random patches in the 16-30% cover class but less than that at random patches in the >30% class.

Bears exhibited patch level selectivity for horizontal visibility (Table 16). No patch level selectivity was detected in the 1-15 m class (least amount of horizontal visibility). In the 16-30 m class, horizontal visibility was greater at dens than at random points. No significant differences were detected in the two classes with the greatest horizontal visibility (31-45 m and >45 m), although mean horizontal visibility at den patches was less than that at random patches. There were no significant differences between horizontal visibility at the den entrance compared to that in den patches (paired 2-sample *t*-test, $t = 1.34$, df = 53, $P = 0.19$).

Table 14. Patch level selectivity by denning black bears for stocking densities of live trees, snags, and cedar trees in the Nimpkish Valley, 1993-1995. *P* values are results of Mann-Whitney U-tests. *P* values > 0.10 are not shown.

Attribute category	Stocking class (stems/ha)	Stocking density (stems/ha)						*P* value
		Random patches			Den patches			
		Mean	SE	*n*	Mean	SE	*n*	
Live trees								
	0	0	0	36	149	145	3	< 0.10
	1-300	162	25	46	-	-	-	-
	301-600	501	26	82	423	40	48	< 0.01
	>600	640	103	6	636	70	11	
Snags								
	0	0	0	64	0.63	0.63	8	< 0.01
	1-30	20	7	36	10	9	10	
	31-60	46	11	41	49	11	33	
	>60	103	16	28	73	22	11	
Redcedar and yellow-cedar								
	0	0	0	13	59	41	14	
	1-150	70	10	86	79	33	17	
	>150	198	46	17	51	14	31	< 0.01

Table 15. Patch level selectivity by denning black bears for percent vegetation cover in the Nimpkish Valley, 1993-1995. *P* values are results of Mann-Whitney U-tests. *P* values > 0.10 are not shown.

Vegetation layer	Vegetation cover class (%)	Vegetation cover (%) Random patches Mean	SE	*n*	Den patches Mean	SE	*n*	*P* value
Tree (>10 m)								
	0	0	0	50	0	-	1	
	1-30	9	2	39	10	10	3	
	31-60	52	1	161	40	2	51	< 0.01
	>60	63	3	37	54	8	8	
High shrub (2-10 m)								
	0	0	-	1	-	-	-	-
	1-15	9	1	98	27	7	2	0.04
	16-30	18	1	156	16	2	57	
	>30	43	4	31	27	15	4	
Low shrub (<2 m)								
	0	0	0	3	9	4	6	< 0.10
	1-15	8	2	49	10	1	2	
	16-30	18	2	102	31	5	18	0.02
	>30	47	2	132	36	3	37	0.03

Table 16. Patch level selectivity by denning black bears for horizontal visibility and slope in the Nimpkish Valley, 1993-1995. *P* values are results of Mann-Whitney U-tests. *P* values > 0.10 are not shown.

Attribute category	Attribute class	Random patches			Den patches			
		Mean	SE	*n*	Mean	SE	*n*	*P* value
Horizontal visibility (m)								
	1-15	15	2	3	16	1	3	
	16-30	24	1	62	30	2	36	< 0.01
	31-45	40	2	80	34	4	13	
	>45	51	4	25	39	5	8	
Slope (degrees)								
	0	0	0	12	-	-	-	-
	1-5	3	1	16	5	5	3	
	6-10	10	2	29	23	5	6	< 0.10
	11-15	13	1	120	15	3	11	
	16-20	17	1	85	23	2	40	< 0.01
	21-25	23	2	35	32	3	7	< 0.10

Slopes were steeper at den patches than at random patches (Table 16). Patches used for denning had steeper slopes across all slope classes, but results were only significant in the 16-20^{o} slope class.

Stand Level

I tested for selectivity of winter denning habitat by black bears at the stand level by determining use of stands from 43 dens of 23 radio-collared bears monitored over 3 years. Availability was determined from 536 randomly located points within the study area. Black bears exhibited significant selectivity for some stand types ($\chi^2 = 31.3$, df = 11, $P < 0.001$, Table 17). Stand types that were used significantly less than expected by bears for denning were: non-vegetated, Pine Cladina (PCL), Fir Salal (FSA) seral stages 1/2 and 3, Devils Club Seepage (DCS) seral stage 5/6, and Blueberry Moss (BBM) seral stage 1/2. Only one stand type, the Blueberry Moss seral stage 5/6, was preferred. I did not detect selectivity for the 5 remaining stand types.

Black bears did not use BBHTs in proportion to their availabilities at the stand spatial scale ($\chi^2 = 24.3$, df = 7, $P < 0.001$, Table 17). The Blueberry Moss BBHT was preferred, while Floodplain (FLP), Pine Cladina, Skunk Cabbage Swamp (SCS) and Sphagnum Pine Bog (SPB) and non-vegetated were all used less than expected based upon availability. No significant selection was detected in the remaining 3 BBHTs.

Black bears exhibited significant selectivity for some seral stages ($\chi^2 = 42.0$, df = 4, $P < 0.001$, Table 17) when choosing winter den sites. The early seral stage 1/2 and non-vegetated were avoided. No selectivity was detected for seral stages 3, 4 or 5/6. However, late successional stage 5/6 was preferred at a significance level of $P \leq 0.10$.

Table 17. Stand level selectivity by denning black bears for stand types, BBHTs, and seral stages in the Nimpkish Valley, 1993-1995. Categories for which use was significantly less than expected were avoided; those for which use was significantly greater than expected were preferred. Test statistics associated with attribute categories are results of use-availability comparisons. *P* values associated with attribute classes are results of Bonferroni-adjusted Z-tests. Only stand types that comprised >2% of the landscape or contained dens are included. All stand types are listed in Appendix 1.

Categories and classes	Percent of study area	Percent of dens	Bonferroni *P* value	Selectivity
Stand type (χ^2 = 31.3, df = 11, $P < 0.01$)				
BBM 1/2	2.5	0.0	< 0.01	avoided
BBM 4	2.9	9.1	> 0.10	
BBM 5/6	19.3	43.2	0.03	preferred
DCS 4	2.5	2.3	> 0.10	
DCS 5/6	2.1	0.0	< 0.01	avoided
FSA 1/2	2.9	0.0	< 0.01	avoided
FSA 3	2.9	0.0	< 0.01	avoided
FSA 4	18.0	20.4	> 0.10	
FSA 5/6	7.8	9.1	> 0.10	
FSF 3	0.6	11.4		
FSF 4	7.1	4.5	> 0.10	
PCL	5.6	0.0	< 0.01	avoided
Non-vegetated	12.3	0.0	< 0.01	avoided
BBHT (χ^2 = 24.3, df = 7, $P < 0.01$)				
BBM	26.6	52.3	< 0.01	preferred
DCS	6.3	2.3	> 0.10	
FLP	2.1	0.0	< 0.01	avoided
FSA	31.6	29.5	> 0.10	
FSF	10.2	15.9	> 0.10	
PCL	5.6	0.0	< 0.01	avoided
SCS/SPB	2.3	0.0	< 0.01	avoided
Non-vegetated	12.3	0.0	< 0.01	avoided
Seral stage (χ^2 = 42.0, df = 4, $P < 0.01$)				
1/2	7.6	0.0	< 0.05	avoided
3	8.4	11.4	> 0.10	
4	37.4	36.4	> 0.10	
5/6	34.3	52.2	< 0.10	
Non-vegetated	12.3	0.0	< 0.05	avoided

I detected selectivity among many habitat attributes at the stand spatial scale. With the exception of mean diameter (χ^2 = 3.7, df = 3, P = 0.30), stocking densities of snags (χ^2 = 4.2, df = 3, P = 0.24), and aspect (χ^2 = 14.0, df = 12, P < 0.50), all of the habitat attributes categories that I examined were used significantly different than expected at the stand spatial scale (Tables 18 - 24).

Stands in which black bear dens were located had greater amounts of CWD than did randomly located stands (Table 18). Denning black bears avoided stands in the 0% cover class of CWD, while stands in the >30% cover class were preferred. Bears exhibited selectivity for stands classified by the number of logs >50 cm in diameter (Table 19). Stands without logs occurring in the 50-64 cm and 65-79 cm diameter categories were avoided by denning black bears. Stands with >1.50 logs/transect in the 50-64 cm diameter category of were preferred by denning bears, as were those with 0.01-0.50 logs/transect in the 65-79 cm diameter category. No selectivity was detected at the stand level for the number of logs >80 cm in diameter (χ^2 = 3.9, df = 2, P > 0.10). Bears exhibited selectivity for stands classified by basal area of trees >17.5 cm in diameter (Table 20). They avoided stands with low basal area (1-30 m^2/ha) but preferred stands with high basal area (>60 m^2/ha).

Bears exhibited selectivity for stocking density of trees that were divided into diameter categories, although most comparisons at the stand spatial scale for this factor were not statistically significant (Table 21). Bears avoided stands with 1-300 stems/ha stocking densities of the smallest diameter class (17.5-36 cm), but preferred stands with stocking density >300 stems/ha. Bears avoided stands in the 0 stems/ha class of the 37-56 cm diameter category. Bears preferred stands with >50 stems/ha for the 57-76 diameter category. Bears avoided stands with

Table 18. Stand level selectivity by denning black bears for coarse woody debris (% cover) in the Nimpkish Valley, 1993-1995. Stand types for which use was significantly less than expected were avoided; those for which use was greater than expected were preferred. Test statistics associated with attribute categories are results of use-availability comparisons. *P* values associated with attribute classes are results of Bonferroni-adjusted Z-tests.

Attribute Category	Attribute Class (% cover)	Bonferroni *P* value	Selectivity
Total % Cover CWD (χ^2 = 27.3, df = 3, P < 0.01)			
	0	< 0.01	avoided
	1-15	> 0.10	
	16-30	0.06	
	>30	0.02	preferred

Table 19. Stand level selectivity by denning black bears for size class characteristics of the number of logs >50 cm diameter in the Nimpkish Valley, 1993-1995. Stand types for which use was significantly less than expected were avoided; those for which use was greater than expected were preferred. Test statistics associated with attribute categories are results of use-availability comparisons. *P* values associated with attribute classes are results of Bonferroni-adjusted Z-tests.

Diameter category	Attribute class (logs/80 m transect)	Bonferroni *P* value	Selectivity
<u>50-64 cm</u>			
($\chi^2 = 44.4$, df = 4, $P < 0.01$)			
	0	< 0.01	avoided
	0.01-0.50	> 0.10	
	0.51-1.00	< 0.01	avoided
	1.01-1.50	> 0.10	
	>1.50	0.05	preferred
<u>65-79 cm</u>			
($\chi^2 = 14.2$, df = 2, $P < 0.01$)			
	0	< 0.01	avoided
	0.01-0.50	0.02	preferred
	>0.50	> 0.10	

Table 20. Stand level selectivity by denning black bears for basal area of trees in the Nimpkish Valley, 1993-1995. Stand types for which use was significantly less than expected were avoided; those for which use was greater than expected were preferred. Test statistics associated with attribute categories are results of use-availability comparisons. *P* values associated with attribute classes are results of Bonferroni-adjusted Z-tests.

Attribute category	Attribute class (m^2/ha)	Bonferroni *P* value	Selectivity
<u>Basal Area</u>			
($\chi^2 = 15.8$, df = 3, $P < 0.01$)			
	0	> 0.10	
	1-30	< 0.01	avoided
	31-60	> 0.10	
	>60	< 0.01	preferred

Table 21. Stand level selectivity by denning black bears for stocking densities of trees by diameter categories in the Nimpkish Valley, 1993-1995. Stand types for which use was significantly less than expected were avoided; those for which use was greater than expected were preferred. Test statistics associated with attribute categories are results of use-availability comparisons. *P* values associated with attribute classes are results of Bonferroni-adjusted Z-tests.

Diameter category	Attribute class (stems/ha)	Bonferroni *P* value	Selectivity
17.5-36 cm (χ^2 =17.8 , df =2, $P < 0.01$)			
	0	0.10	
	1-300	< 0.01	avoided
	>300	< 0.01	preferred
37-56 cm (χ^2 = 7.4, df = 2, $P = 0.02$)			
	0	< 0.01	avoided
	1-75	> 0.10	
	>75	0.09	
57-76 cm (χ^2 = 12.5, df = 3, $P < 0.01$)			
	0	> 0.10	
	1-25	> 0.10	
	26-50	> 0.10	
	>50	0.02	preferred
77-96 cm (χ^2 = 7.3, df = 2, $P = 0.03$)			
	0	> 0.10	
	1-10	< 0.01	avoided
	>10	> 0.10	

1-10 stems/ha in the 77-96 cm diameter category. At the stand level, selection was not significant ($P = 0.07$) for stocking densities of trees >96 cm in diameter.

Selectivity was detected for some stocking densities of live trees and cedar trees in stands used for denning by black bears (Table 22). There was a significant difference between use and availability of stands for stocking densities of live trees (stands with 1-300 stems/ha were avoided), whereas no differences were detected for snag densities at the stand spatial scale. When I compared the stocking densities of cedar trees (redcedar and yellow-cedar combined), bears preferred stands with >150 stems/ha of cedars, and avoided those with 1-150 stems/ha.

Bears exhibited selection at the stand spatial scale for 3 strata of vegetation cover (Table 23). Bears avoided stands with 0% tree cover and preferred those with 31-60% cover. The 0 and 1-15% cover classes of the high shrub layer were avoided by bears, whereas stands with 16-30% cover were preferred for denning. Although the Chi-square test indicated that bears were selective in their use of stands classified by low shrub cover, no cover classes were used significantly more or less than expected.

Bears preferred stands with 16-30 m horizontal visibility and avoided stands with 31-45 m horizontal visibility (Table 24). I observed no differences in use compared to availability for stands with the least (1-15 m) and greatest (>45 m) horizontal visibilities.

Bears avoided stands on flat terrain and preferred those with 16-20 degree slope (Table 24). Bears did not exhibit selectivity for stands classified by aspect, regardless of grouping by 30° classes ($\chi^2 = 14.0$, df = 12, $P < 0.50$) or 90° classes ($\chi^2 = 7.6$, df = 4, $P < 0.25$).

<u>Landscape Level</u>

Bears did not use elevations in proportion to their availability and thus exhibited selectivity for elevation at the landscape spatial scale ($\chi^2 = 23.02$, df = 4, $P < 0.001$). Bears

Table 22. Stand level selectivity by denning black bears for stocking densities of trees by tree health and species in the Nimpkish Valley, 1993-1995. Stand types for which use was significantly less than expected were avoided; those for which use was greater than expected were preferred. Test statistics associated with attribute categories are results of use-availability comparisons. *P* values associated with attribute classes are results of Bonferroni-adjusted Z-tests.

Attribute category	Attribute class (stems/ha)	Bonferroni *P* value	Selectivity
Live trees ($\chi^2 = 27.2$, df = 3, $P < 0.01$)			
	0	> 0.10	
	1-300	< 0.01	avoided
	301-600	> 0.10	
	>600	> 0.10	
Redcedar and yellow-cedar[a] ($\chi^2 = 14.7$, df = 2, $P < 0.01$)			
	0	> 0.10	
	1-150	0.02	avoided
	>150	< 0.01	preferred

[a] combined because of structural similarities between species.

Table 23. Stand level selectivity by denning black bears for vegetation cover in the Nimpkish Valley, 1993-1995. Stand types for which use was significantly less than expected were avoided; those for which use was greater than expected were preferred. Test statistics associated with attribute categories are results of use-availability comparisons. *P* values associated with attribute classes are results of Bonferroni-adjusted Z-tests.

Attribute category	Attribute class (% cover)	Bonferroni *P* value	Selectivity
Tree (>10 m)			
(χ^2 = 14.0, df = 3, P < 0.01)			
	0	< 0.01	avoided
	1-30	> 0.10	
	31-60	< 0.01	preferred
	>60	> 0.10	
High shrub (2-10 m)			
(χ^2 = 22.1, df = 3, P < 0.01)			
	0	< 0.01	avoided
	1-15	< 0.01	avoided
	16-30	< 0.01	preferred
	>30	> 0.10	
Low shrub (<2 m)			
(χ^2 = 8.4, df = 3, P = 0.04)			
	0	> 0.10	
	1-15	> 0.10	
	16-30	0.08	
	>30	> 0.10	

Table 24. Stand level selectivity by denning black bears for horizontal visibility and slope in the Nimpkish Valley, 1993-1995. Stand types for which use was significantly less than expected were avoided; those for which use was greater than expected were preferred. Test statistics associated with attribute categories are results of use-availability comparisons. *P* values associated with attribute classes are results of Bonferroni-adjusted Z-tests.

Attribute category	Attribute class	Bonferroni *P* value	Selectivity
Horizontal visibility (m)			
($\chi^2 = 36.7$, df = 3, $P < 0.01$)			
	1-15	> 0.10	
	16-30	0.04	preferred
	31-45	0.05	avoided
	>45	> 0.10	
Slope (degrees)			
($\chi^2 = 18.5$, df = 5, $P < 0.01$)			
	0	< 0.01	avoided
	1-5	> 0.10	
	6-10	0.10	
	11-15	> 0.10	
	16-20	0.04	preferred
	21-25	> 0.10	

avoided denning at low elevations (0-199 m) but preferred mid-elevations (600-799 m). No selectivity was exhibited for 200-399 m, 400-599 m and >800 m elevation classes.

The distribution of seral stages in the study area was not independent of elevation ($\chi^2 = 124.98$, df = 9, $P < 0.001$). Young forests (31-150 years) occurred more frequently than expected at low elevations (0-199 m), whereas late successional forests comprised significantly less of the low elevation stands than expected. Conversely, young forests constituted a smaller proportion of the landscape than expected at higher elevations (>400 m) and late successional stages comprised significantly more of the high elevation stands (>600 m) than expected.

Discussion

My objectives are to determine the features of habitat and the spatial scales at which coastal black bears select habitat for denning in coastal forests. Bears selected habitat for dens at several spatial scales. The strongest selectivity was detected at the element spatial scale, but bears also exhibited selectivity at the patch, stand, and landscape spatial scales. Bears preferred den cavities located in large standing trees or their residual structures (root boles, stumps, and logs).

Animals likely express selectivity for resources across more than one spatial scale. They may fulfill their least restrictive habitat requirements at coarser spatial scales (e.g., landscape), while selecting habitat at finer scales to fulfill more stringent requirements (Weir 1995). Den cavities are the most critical habitat components that bears require during winter because they provide protection from disturbance and environmental factors during prolonged winter dormancy. Thus, I expected to find strong selectivity by bears for structures used as den cavities at the element spatial scale.

By examining habitat selection at different scales, researchers acknowledge that habitats used by animals are not homogenous units but rather are complex mosaics across which habitat characteristics vary. Retention of this variability and the processes that generate these mosaics could be important in maintaining suitable habitat for wildlife in managed landscapes. This variance is important for wildlife because species may select habitat at different spatial scales concurrently (Lofroth 1993, Weir 1995). I use a "bottom-up" approach in my discussion of den site selection because element level selection may be the initial scale at which bears choose dens. Specific requirements of bears for den cavities may result in selectivity at the element, or finest, spatial scale. Many results of analyses at coarser spatial scales may be linked to this initial selection.

Element Level

The strongest selectivity for denning habitat occurred at the element spatial scale. Diameters of den structures that were chosen by bears were much greater than other structures within surrounding patches. This selectivity occurred for all classes of dens (standing trees, stumps, logs and root boles). Not only were the structures used as dens larger than those available but bears that denned in coarse woody debris (logs and root boles) preferred structures that were in early to mid-stages of decay (decay class 2, Maser et al. 1979).

In variable radius prism cruises, large trees have larger plot radii and thus are more likely to overlap with the plot centre and be included within the plot than smaller trees (Luttmerding et al. 1990). The variable radius prism cruises that I used to estimate stocking densities of trees have an inherent bias towards the inclusion of large trees. For analyses at coarser spatial scales, I used appropriate formulae to calculate unbiased stocking densities (Bull et al. 1990). At the element level however, this bias may result in comparisons that are conservative, hence differences between den and non-den trees are likely greater than I report. Yet despite this bias, I detected selectivity at the element level, suggesting that the differences must be highly significant.

Black bears selected trees for winter den sites that were larger in diameter than the average tree within den patches. The use of large hollow trees by black bears has been documented in many other studies across North America (see Noble et al. 1990). Although black bears den in large trees, the particular size of tree that they select varies among regions and likely depends on the specific characteristics of the forests present in those regions. In Oregon, the mean diameter of hollow tree dens was 161 cm dbh (Noble et al. 1990), whereas in Idaho, the mean diameter of tree dens was 112 cm (Beecham et al. 1983). This difference is likely due to differences in availabilities of large trees rather than regional differences in the denning requirements of black bears.

Logs selected by black bears for winter dens were larger in diameter than other logs available within patches. The use of large logs in the Nimpkish Valley (mean diameter = 143 cm) for dens is consistent with other studies (e.g., Noble et al. 1990, Oregon, mean diameter = 130 cm). In the Nimpkish Valley and elsewhere (Noble et al. 1990), black bears used logs that were in early to mid-stages of decay. This use of decaying logs by bears is in part due to processes that create logs. In my study area, logs which were used by bears showed signs of diseases that either caused the tree to fall (e.g., root rot), or resulted in the log being left behind when the stand was harvested. The security and shelter provided by logs in early stages of decay were likely factors in the selection of logs by bears. Some decay of logs is necessary to ensure dens can be excavated, but logs with advanced decay may be unsuitable as dens. Excessive decay of logs may increase the entrance size to a potential den cavity and decrease the security of the den.

Large stumps were selected for winter den sites by black bears. Stumps have also been used by bears in other areas that have a history of logging (Lindzey and Meslow 1976*a*, Noble et al. 1990). Stumps that were chosen for winter den sites by black bears in the Nimpkish Valley were high-cut (>2 m from base) and of two distinct, rare varieties. Stumps of large Sitka spruce trees on an old floodplain were used by one adult male. The other variety occurred in a second growth forest that contained very large residual stumps. When this area was logged, site preparation of the clearcuts through burning reduced soil and duff under the stumps, creating large cavities. The utility of these stumps may have also been enhanced by a dense layer of debris generated by pre-commercial thinning of the stands. This layer of small diameter debris may have provided greater security cover to these stump dens. No other stands in my study area had characteristics similar to these areas.

Black bears exhibited strong selectivity for hollow trees. The cavities found in hollow trees provide thermal insulation and shelter from rain, as well as security from predators. Other structures may be less suitable for denning because they are either colder, wetter, or less secure. Hollow tree dens satisfy the most stringent requirements of black bears for winter hibernation.

Selectivity at the element level is the finest spatial scale at which habitat selection can occur and likely reflects the relative importance of resources to the survival of individuals and populations. Selectivity for resources such as denning habitat can have substantial effects on survivorship and thus population viability. Sub-optimal dens may increase cub mortality through flooding of the den site (Alt 1984), predation on the occupants of the den (Davis and Harestad 1996), or physiological stress (Nelson and Beck 1984). Selection of den cavities at the element level allows bears to use habitats that would otherwise be “unsuitable” at coarser spatial scales because they generally lack these elements. For example, elements within otherwise unsuitable stands and patches could supply the only den sites in landscapes with extensive habitat alteration.

Patch and Stand Level

Black bears exhibited selectivity for many habitat attributes at both the stand and patch levels. Patch level selectivity was observed when, for example, bears denned within patches (<1 ha) that were different than the surrounding stand. Bears preferred to den in the late successional stage of the Blueberry Moss (BBM) Black Bear Habitat Type (BBHT), and avoided denning in early seral stages.

The selection of the BBM late successional stand type may have occurred because preferred elements (hollow trees) occurred with greater frequency in the BBM than in any other stand type. Stand types that were avoided did not contain elements, or sufficient numbers of patches containing elements, suitable for den use (e.g., early seral stages or rocky pine bluffs), or had moisture conditions unsuitable for denning (e.g., FLP). Although stand types other than late successional BBM were used by black bears for denning, the dens were often located within patches that were atypical of the stand. For example, large burned out snags within closed canopy second growth forests, or patches of rich growing conditions within stands of poor to medium nutrient status. These patches within stands would not be evident by assessing the general denning habitat quality of the stand type, nor would they be practical to map using current forest inventory systems.

Eleven percent of dens occurred in the FSF 3 stand type. This stand type has a rich nutrient regime that produces large Douglas-fir trees. This stand type was 0.6% of the study area and thus was too small to be included in analyses of stand level selection. However, use of the FSF 3 stand type by bears was substantially different from its availability. Three of the five occurrences of denning in this stand type were in two Sitka spruce stump dens on a historic floodplain. The other two occurrences involved reuse of a single Douglas-fir log. Remnant structures in this stand type provided suitable dens, unfortunately the low availability of FSF 3 in my study area precluded its analysis for selectivity.

Contrary to my results, one other black bear study which compared use with availability to examine denning habitat selection did not detect selectivity for forest types (Carney 1985). Carney (1985) may not have detected selectivity because he used only 5 forest types and did not analyze habitat selection at finer scales. Furthermore, 47.5% of the dens that he observed were in rock cavities which are not forest structures. While slope and geological processes may affect the availability of dens of this type, forest type would not likely have a direct effect. Had his study included availability of elements and a finer-scale analyses, his results may have been different. Carney (1985) did not examine relationships between den types and forest types, and did not report that the study area had been extensively logged before 1935 (M. R. Vaughan, pers. commun.).

Selection by bears for den sites within BBHTs highlighted the effects of environmental conditions on den selection. Bears avoided stands that did not normally contain large trees; these included very dry sites, very wet sites, and non-vegetated sites. BBHTs in which large trees were not common were used, but not significantly more than expected, possibly because these stands did not supply suitable densities of large structures. Only the Blueberry Moss (BBM) BBHT was preferred. This BBHT had greater densities of hollow cedar trees than did other BBHTs in my study area.

Black bears in the Nimpkish Valley exhibited selectivity among seral stages at the stand level. This selectivity was likely due to the density of preferred den structures. Early seral stages (seral stage 1/2) were avoided. These seral stages lacked elements of suitable size and decay classes of CWD and had high horizontal visibility. Although preference for late successional forests was only significant at $P \leq 0.10$, it is likely biologically relevant. In Arizona, black bears exhibited selectivities similar to that which I detected in the Nimpkish Valley; old-growth was preferred and all other seral stages were avoided (LeCount and Yarchin 1990). Late successional forests generally contain large diameter trees, both standing and dead, and large diameter coarse woody debris that provide adequate structures for winter den sites. Black bears in the Nimpkish Valley appear to be selecting these structures at spatial scales finer than the stand scale.

Bears exhibited selectivity for den sites in stands and patches with high frequencies of coarse woody debris (Table 25). Stand types without CWD were avoided, whereas those with greater amounts were preferred. Even in stands where CWD was uncommon, selectivity for CWD was exhibited. In these stands, patches chosen by bears as den sites had greater amounts of CWD than did average patches that comprise the stand. Bears used single, large pieces of CWD for a den or stump dens that occurred in an area that had been pre-commercially thinned. These stands had a very thick layer of small criss-crossing stems suspended up to 2 m above the ground. These stems provided excellent warning of approach from people or potential predators.

At the stand and patch level, black bears selected den sites with more large logs (>50 cm in diameter) than expected (Table 25). Bears chose stands with more large logs than other stands, and in stands with less CWD they chose patches with more logs than the stand average. Selectivity by bears for patches, and not stands, with more logs >80 cm diameter was likely detected because these attributes were so rare that they did not occur in my sample of randomly

Table 25. Comparison of patch and stand level selectivity by black bears for coarse woody debris (% cover) and number of logs > 50 cm in diameter when denning in the Nimpkish Valley, 1993-1995. Patch level selectivity is denoted by either having "more" or "less" of an attribute class at den patches than at random patches.

Attribute category	Attribute class	Patch level selectivity	Stand level selectivity
Total CWD (% cover)			
	0		avoided
	1-15		
	16-30	more at den sites	
	>30		preferred
Logs 50-64 cm diameter (No. of logs/80 m transect)			
	0		avoided
	0.01-0.50	more at den sites	
	0.51-1.00	more at den sites	avoided
	1.01-1.50		
	>1.50		preferred
Logs 65-79 cm diameter (No. of logs/80 m transect)			
	0		avoided
	0.01-0.50		preferred
	>0.50		
Logs >80 cm diameter (No. of logs/80 m transect)			
	0	more at den sites	
	0.01-0.50	more at den sites	
	> 0.50		

located patches within stands. Selection was also detected for stands and patches containing logs that were smaller than the minimum size of CWD dens. Many CWD den sites were in complexes of logs. These complexes were often the result of windfall that involved groups of trees. For example, one den in the Nimpkish Valley was beneath a large tree blown down and lying over a previous windfall (50 cm in diameter). This held the second tree high enough off of the ground to create a cavity under the root bole.

Selectivity by bears for some forest characteristics are not directly related to denning structures. However, these selectivities may be useful for identifying and managing forest types and characteristics associated with denning bears. Selectivity for a structural attribute may be only the result of correlations between this attribute and another more biologically relevant attribute. This is likely the case for selectivity of stocking densities by size category, tree species and tree vigour (i.e., live and dead trees). Large trees, such as those used for den sites, may compete with surrounding trees, resulting in fewer medium-sized trees (i.e., 17.5-76 cm in diameter) in the den patch. This interaction would result in apparent selectivity for patches containing fewer large trees within stands containing high stocking densities of large stems. For example, in the 57-76 cm diameter category, bears preferred stands with more stems within this category but selected patches with fewer trees of this size (Table 26). These differences in selection at different spatial scales could occur if the stand type was capable of growing large trees and other large trees did not tend to grow within the same patches as large trees used for dens. Bears selected patches with trees in the 77-96 cm, and > 96 cm diameter categories within stands that did not normally support such large trees. At the stand level, bears did not exhibit selectivity for stocking densities of trees in the >96 cm diameter category.

Table 26. A comparison of patch and stand level selectivity by black bears for stocking of various size classes of trees when denning in the Nimpkish Valley, 1993-1995. Patch level selectivity is denoted by either having "more" or "less" stems/ha at den patches than at random patches.

Attribute category	Attribute class (stems/ha)	Patch level selectivity	Stand level selectivity
17.5-36 cm			
	0		
	1-300	more at den sites	avoided
	>300	less at den sites	preferred
37-56 cm			
	0		avoided
	1-75		
	>75	less at den sites	
57-76 cm			
	0		
	1-25		
	26-50		
	>50	less at den sites	preferred
77-96 cm			
	0	more at den sites	
	1-10		avoided
	>10		
>96 cm			
	0	more at den sites	
	1-10	more at den sites	
	>10		

Bears selected patches containing remnant cedar snags (veterans) within stand types in which snags were extremely uncommon (Table 27). Veterans typically remain as residual structures after fires. In the Nimpkish Valley, these cedar snags usually occurred at lower elevations (<305 m), where the majority of large cedar trees had been removed by logging. The snags made suitable dens because the centres of the cedars were hollowed out by fire and provided cavities similar to those in live hollow cedar trees.

Stands with greater basal area were likely selected by black bears for denning because of greater numbers of large stems (Table 28). However, basal area alone may not be a good measure of the quality of a site as denning habitat for bears because the basal area of several small trees can be equal to that of one large tree. Selectivity was not detected for mean diameter of trees at either the stand or patch spatial scales likely for similar reasons.

Bears may also have selected stands for den sites with greater amounts of tree cover, but patches with lesser amounts (Table 29), because of correlations with other structural variables. As with comparisons of stocking densities of trees by size categories, stands with more large stems, and therefore greater crown closure, may have less tree cover within a den patch because den trees themselves are often in a state of decline (e.g., cedar den trees often have open canopies with dead tops). Alternatively, because den patches had steeper slopes than surrounding stands, the den patches may have had less tree cover because more open canopies may be associated with steep slopes. While trends in selection for percent cover by shrubs can be attributed to horizontal visibility, selection at the stand spatial scale for vegetation cover may again be the result of correlations among forest characteristics. For example, sites with high

Table 27. A comparison of patch and stand level selectivity by black bears for stocking densities of live trees, snags, and redcedar and yellow-cedar trees when denning in the Nimpkish Valley, 1993-1995. Patch level selectivity is denoted by either having “more” or “less” stems/ha at den patches than at random patches.

Attribute category	Attribute class (stems/ha)	Patch level selectivity	Stand level selectivity
Live trees			
	0		
	1-300		avoided
	301-600	less at den sites	
	>600		
Snags			
	0	more at den sites	
	1-30		
	31-60		
	>60		
Redcedar and yellow-cedar			
	0		
	1-150		avoided
	>150	less at den sites	preferred

Table 28. A comparison of patch and stand level selectivity by black bears for basal area of trees, horizontal visibility, and slope when denning in the Nimpkish Valley, 1993-1995. Patch level selectivity is denoted by either having "more" or "less" of an attribute class at den patches than at random patches.

Attribute category	Attribute class	Patch level selectivity	Stand level selectivity
Basal area (m^2)			
	0		
	1-30		avoided
	31-60		
	>60		preferred
Horizontal visibility (m)			
	1-15		
	16-30	more at den sites	preferred
	31-45		avoided
	>45		
Slope (degrees)			
	0		avoided
	1-5		
	6-10		
	11-15		
	16-20	more at den sites	preferred
	21-25		

Table 29. A comparison of patch and stand level selectivity by black bears for vegetation cover when denning in the Nimpkish Valley, 1993-1995. Patch level selectivity is denoted by either having "more" or "less" vegetation cover at den patches than at random patches.

Vegetation strata	Attribute class (% cover)	Patch level selectivity	Stand level selectivity
Tree (>10 m)			
	0		avoided
	1-30		
	31-60	less at den sites	preferred
	>60		
High shrub (2-10 m)			
	0		avoided
	1-15	more at den sites	avoided
	16-30		preferred
	>30		
Low shrub (< 2 m)			
	0		
	1-15		
	16-30	more at den sites	
	>30	less at den sites	

nutrient regimes have higher cover of herbs, different shrub species and greater tree growth than do sites with lower nutrient regimes.

Bears expressed selectivity for horizontal visibility (Table 28). Stands with greater horizontal visibility were avoided, while those with less horizontal visibility were selected. In stands with greater horizontal visibility, bears selected patches that had less horizontal visibility. Surprisingly, however, horizontal visibility at the patch level was not different than that at den entrances. This suggests that bears rely upon the vegetation within the patch, not that at the den entrance itself, to supply visual cover while denning. Dense cover around den sites has been observed in other black bear studies (e.g., Beecham et al. 1983, LeCount 1983, Hellgren and Vaughan 1989).

Bears avoided denning in stands on flat terrain and preferred those with 16-20 degree slopes, selecting for patches with even steeper slopes within these preferred stands (Table 28). Both Carney (1985) and LeCount and Yarchin (1990) also found slopes at den sites were steeper than at random points. Stands on flat terrain often tend to be valley bottom sites that may be prone to flooding of den sites in winter. Because of better drainage in stands and patches with steep slopes, these sites tend to be drier than surrounding areas and have less risk of flooding. Cubs can be killed by flooding of den sites (Alt 1984). In the Nimpkish Valley, selection for steeper slopes may be a manifestation of logging history because stands on steeper slopes are less heavily logged than flatter valley bottom areas.

Bears did not express selectivity for aspect at the stand scale. While many studies have reported aspects of dens, very few have actually examined the availability of different aspects. Carney (1985) did not find any evidence of selection for aspect when he compared use with availability. In my study area, aspect does not appear to affect selectivity of den sites at the stand scale. Selectivity was affected more by structural attributes than it was by aspect.

I was unable to draw biologically meaningful conclusions from some of the comparisons that I performed. Dens did not occur in some stand types and hence I could not compare den patches with random patches in these stand types (e.g., no dens were located in stand types that had 0 degrees slope). Therefore, no statistical comparisons could be performed for this habitat attribute at the patch scale. Furthermore, the power of some of the comparisons were likely very low, due to low sample size and high variability. For most attribute classes, comparisons between patches and stand means were either very significant or very non-significant, indicating very strong or very little selectivity.

Landscape Level

The composition of the landscape has implications for some patterns of selectivity that I observed in my study. Different stand types occur in predictable patterns in the landscape because their existence is based on climate, slope position, soils and aspect (Appendix A). Because the location of stand types within the landscape is somewhat predictable, landscape level selectivity can reflect selectivity patterns at finer spatial scales, such as the stand level. The history of logging in my study area has affected the distribution and availability of habitat within the landscape. This logging history contributed at least in part to landscape level selectivity for elevation because the distribution of seral stages was not uniform among elevational categories.

At the landscape scale in the Nimpkish Valley, bears preferred higher elevations and avoided lower elevations. One other study that examined selectivity for elevation found no selectivity by black bears (Carney 1985). Although selectivity for elevation that I observed in my study may be due to preferences for areas with greater duration of snow cover (which provides thermal and security cover) and avoidance of valley bottom sites that may be prone to flooding, other factors likely contribute to habitat selection by bears. Furthermore, although denning on valley bottoms may decrease the distance from dens to early spring forage, these areas may be avoided by females because male bears, which emerge prior to females, may jeopardize the security of den sites.

Selectivity for elevation is probably heavily influenced by the logging history of the study area. Seral stages were not equally distributed in the study area because of the 80-year history of logging. Young forests (seral stage 4) were more abundant at lower elevations than expected, and less abundant at higher elevations. The opposite was true for late successional forests (seral stage 5/6). Johnson (1978) reported results similar to those in the Nimpkish Valley with respect to den selection; "ground" dens (mostly root boles and stumps) were found at lower elevations because of the history of logging at these elevations (Johnson and Pelton 1981). Although den availability was reported to be very high in their study (estimates of 1 den/20 ha and 1 den/4.7 ha), Johnson and Pelton (1981) were concerned that the clumped distributions of dens caused by logging, especially at lower elevations, could be detrimental to bear populations.

The availability of den sites within landscapes may also be affected by social organization. Female offspring often inherit portions of the home range of their mothers and rarely disperse great distances from it (Rogers 1977, Schwartz and Franzmann 1992). If suitable denning habitat is not evenly distributed throughout the landscape, some small home ranges (typical of female black bears) will likely contain few, if any, suitable den sites. Restricting the supply of dens may be detrimental to the viability of the bear population, because females may not travel to remote locations to den or return from these locations with cubs upon emergence from the den.

Conclusion

In some studies of den selection by black bears, the scale at which selection occurred was evident but not investigated. Failure to examine the spatial scale may have affected the conclusions. For example, Hellgren and Vaughan (1989) reported that bears denned on dry hummocks within swamps. In my study, bears did not appear to select some structural attributes at the stand scale, however when I analyzed for selectivity of these attributes at the patch spatial scale, selectivity became evident. Some structural attributes that I was comparing occurred so rarely in stands that they were not detected in random plots, but these attributes were located and selected by bears at the patch scale (e.g., logs >80 cm in diameter and snags). Element level analyses further revealed that structures preferred by bears were generally the largest available within patches. Had analyses of selectivity for winter den sites not been performed on a finer spatial scale, selectivity would not have been detected, and my conclusions would likely not have been as definitive. The capability of habitat to supply bears with dens depends not only on the average quality of the habitat, but also on the variance within habitats. It is this variance that allows bears to find and use the relatively rare, but none the less critical, habitat elements that provide suitable den sites at multiple spatial scales.

Habitat managers in coastal B.C. need to know the habitat requirements of bears to predict the effects of industrial forestry and maintain adequate denning habitat for black bears. These requirements include forage supply and cover requirements in addition to winter denning needs. Bears require warm, dry, safe dens within their home ranges. However, bears do not select winter denning habitat at one spatial scale only. Examining the spatial scale at which bears are selecting these dens provides information that will help manage denning habitat at the appropriate scale as well as provide greater flexibility in habitat management prescriptions.

Dependency of populations on habitat has to be viewed across landscapes and through time (Ruggiero et al. 1988). Biologists have come to the conclusion that not only do animals require specific habitats, but that "populations are as dependent on the spatial configuration of habitat as they are on habitat *per se*" (Ruggiero et al. 1988). When interpreting preference data it must be acknowledged that habitat selection is a hierarchical process (Johnson 1980), and that data needs to be interpreted within this context (Ruggiero et al. 1988).

The ability to distinguish selectivity of stand types allows better management of denning habitat for black bears. As the number of unsuitable stand types increase and the number of preferred stand types decline in a landscape, we assume that the overall capability of the landscape in providing denning habitat is decreasing. This assumption is true if we are dealing with homogenous stands. However, variance within stands may partially counteract this diminishing landscape quality. Rather than a monotonically decreasing function, this relationship between stand abundance and denning capability is likely characterized by thresholds. The configuration of stands at which these thresholds occur is unknown. Understanding selectivity for stand characteristics by bears provides means to define potential den habitat from existing forest maps. Inclusion of these denning habitats will help ensure better management for the spatial distribution of denning habitat and its effects on bear populations.

My results provide habitat managers with the ability to distinguish habitat types that have high densities of den structures. These habitats can be identified on terrestrial ecosystem maps, facilitating more effective higher level planning for conservation of habitats within landscapes. However, on-site planning is also required because of the importance of unusual patches within stands that must be recognized and considered for inventory purposes.

The supposition that adequate denning habitat can be maintained solely at the element spatial scale is not consistent with what I have observed. My data suggests that black bears require denning habitat to be supplied across several spatial scales. Provision of denning habitat at these scales will help ensure that the stand level processes which create the element level structures will be retained within landscapes. Prevention or interruption of these processes will diminish the supply of den structures over the long term. Habitat supply models also need to include the social behaviour of bears and its effect on the suitability of den structures. Future research needs to be directed towards examining the relationships between availability of den sites, spatial configuration of den sites, quality of these den sites, and population processes. My research helps to satisfy the initial information needed to fulfill winter den requirements in a time of rapid habitat change.

Chapter 3. Management of Habitats to Supply Dens for Black Bears

Introduction

The most common silvicultural system used currently in coastal British Columbia, clearcutting, involves timber harvesting and stand management practices that alter habitats and thus affect the availability and quality of den sites used by black bears during winter. At the finest spatial scale, these forest practices remove den elements, while at coarser scales, these practices affect the number and distribution of potential den sites within the landscape. As late successional stands are cut in forests managed for timber, large trees and snags with cavities that offer denning opportunities to black bears are removed or felled and hence the number of den potential sites for black bears decrease. The denning structures, such as stumps and logs, that remain after clearcutting will degrade progressively over time. These structural elements will not be replaced in subsequent rotations because crop trees will be harvested before they grow to sizes large enough for use as den sites by bears. The supply of structural elements that can function as dens is severely constrained in forests that are managed only for timber within clearcut silvicultural systems.

The effects of habitat alterations are expressed at several spatial and temporal scales. Mitigation of these effects must be applied at these scales to ensure supply of suitable denning habitat for black bears. My objective in this chapter is to recommend forest management practices which will assist in the management and conservation of denning habitat for black bears in coastal British Columbia.

Methods and Results

The characteristics of black bear dens and habitat selection exhibited by black bears in coastal British Columbia were presented in Chapters 1 and 2. This information was used as the basis for developing recommendations for habitat management. To ensure generality of my results from the Nimpkish Valley to the remainder of coastal British Columbia, I also visited black bear dens outside my study area which had been located during logging operations. In this chapter, I examine the utility of several alternative approaches to habitat management.

Black bears use trees and their related structures for winter den sites throughout coastal British Columbia, as well as parts of Alaska (Erickson 1982), Washington (Lindzey and Meslow 1978b), and Oregon (Noble et al. 1990). To determine whether dens in other coastal areas were similar to those found in the Nimpkish Valley, I visited other areas of Vancouver Island and coastal British Columbia and examined den trees found by forest companies. Hollow cedar trees were used in the Ucluelet area, Gordon River (southwest Vancouver Island), and the Queen Charlotte Islands. All of the dens that I examined in these areas had diameters greater than the average diameter of dens in Nimpkish Valley. Although I was unable to locate den trees on Princess Royal Island, I found several redcedar and yellow-cedar trees that had been investigated by bears, and one western redcedar that was extensively modified by a bear, apparently trying to gain entry to the central cavity of the tree.

In addition to examining den trees in areas of commercial forestry operations, I examined one den that was located about 50 m from a house in Courtenay, British Columbia. The Courtenay River valley has been farmed extensively, with little remaining undeveloped forest land. The den was located in a residual patch of bush that remained from the conversion of the area from forest to agricultural fields. A female bear and her cubs-of-the-year were denned under an upturned root mass which left them partially exposed, occasionally disturbed by people and dogs. Although the den likely provided poor security from disturbance and predators, the landscape was such that secure dens may not have been available.

Timberwest Forest Limited has been innovative in its identification and cataloguing of den sites throughout its timber holdings (Lindsay 1995). The Timberwest data may be biased towards dens in late successional stands because the field crews that submitted data worked predominately in old-growth forests. However, their data do indicate that western redcedar, and less so yellow-cedar, Sitka spruce, and Douglas-fir are important species for black bears in areas other than the Nimpkish Valley. Dens in large trees were located throughout Vancouver Island (Artlish River, Beaver Cove, Caycuse, and Port Renfrew) and the Queen Charlotte Islands. Of 54 tree dens that were located, 47 were in western redcedar (live and snags), 3 in yellow-cedar, 2 in Sitka spruce (1 of which was a stump), and 2 in Douglas-fir. The stands in which these dens occurred were equivalent to my “BBM” (Appendix A) Black Bear Habitat Type (10 of 11 den sites that were classified). Den trees located by Timberwest had a mean dbh of 207 cm (range 100-370 cm; n = 53) which was larger than the hollow tree dens that were located in the Nimpkish Valley (mean dbh 160 cm; range 110-350 cm; n = 37). Forestry workers observed that “bears are selecting the larger trees in the stand, estimates of surrounding tree diameters adjacent to dens sampled average only 82 cm.” This observation is consistent with the strong selectivity for large trees as den sites that was exhibited by black bears at the patch and element spatial scales in the Nimpkish Valley (Chapter 2).

Black bears in the Nimpkish Valley did not den under boulders or in caves, although these elements were available and are used elsewhere in their range (Table 1). This regional difference in choice of den sites may be related to the heavy rainfall that occurs in coastal areas during winter; perhaps dens under boulders or in caves are too cold and/or damp for successful hibernation. One example of preference for wood structures was that of an adult female bear which denned under a large Douglas-fir log for 2 successive years (F09). During the first year that she used this den, she bore cubs. During the second year, she denned with the yearlings.

Upon emergence from her den in 1995, the female and her yearlings moved uphill about 100 m to a large boulder (>4 m diameter) under which they bedded. The structure had 2 small entrances into a central cavity with a bed in the middle. The female and her yearlings used this bed for at least a week.

I was able to test one possible management prescription for an existing bear den. Prior to 1994, one radio-collared adult male bear (M12) used a den for 2 successive years in the base of a hollow yellow-cedar in a late successional stand of western hemlock and Pacific silver fir. This stand was to be harvested in the summer of 1994. Through cooperation with government agencies and CANFOR, the boundary of the cutblock was modified to avoid cutting down the den tree. A 30-m, no-work zone was applied to the area around the den and the cutblock was altered so that the den patch remained contiguous with late successional forest. The management prescription was successful; the cutblock was logged and the bear reused the den in the winter of 1994/95. This was the only radio-collared bear in my study that used one den three years in a row. Other bears changed dens between years, implying that each bear has a suite of dens that they may use. Although dealing with dens on a case-by-case basis (i.e., at the element spatial scale) is helpful, it is a reactive solution and not an efficient, proactive approach to managing denning habitat for bears.

Discussion

In areas where black bears prefer to use large trees and large pieces of CWD for winter den sites, silvicultural systems must include retention of these elements to meet the habitat requirements of bear populations. The importance of denning habitat to black bears has been recognized for a long time; Johnson et al. (1978) proposed that "as suitable habitat declines, more attention on such subtleties as preferred den sites may be necessary to insure viable black bear populations".

Habitat managers need to decide whether or not to manage for the persistence of black bear populations, and for what size of population, and then implement prescriptions to achieve these goals. I recommend the prescriptions listed below to maintain adequate denning habitat for black bears in coastal British Columbia. These recommendations are based upon the best available information to date. In addition to denning habitat, managers must provide adequate forage, security cover and escape trees, and employ sustainable hunting harvest to maintain black bears at their current population size. Wildlife and habitat managers must first decide whether the preservation of current population size of black bears is their management goal.

Black bears in coastal British Columbia use large trees and their related structures for den sites likely because they offer den cavities that are energetically favourable and secure. Two questions that often arise when discussing conservation measures for black bear denning habitat are: “Do black bears require these structures, or do they use these structures simply because they are available?” and “If large trees are not available will black bears use other structures?” This assumed plasticity by black bears is commonly used as a reason to disregard their habitat needs. However, coastal black bears may be of one “ecotype” (ecotypes are populations of a species that are adapted to local conditions, Ruggiero et al. 1988), hence, we cannot expect them to behave the same as bears from other ecotypes (e.g., interior black bears), or assume the same plasticity in reaction to habitat changes. “We cannot assume that adaptations exhibited by one ecotype are within the range of genetic potential of another ecotype” (Ruggiero et al. 1988). Furthermore, habitat preferences which are currently exhibited may reflect the long term needs of a species because each species (and ecotypes of species) has become adapted to its environment over thousands of years of varying environmental conditions (Ruggiero et al. 1988).

The use by black bears of den structures other than those originating from trees does not appear likely in wet coastal environments. Although cavities beneath rocks were used twice as beds in my study area, I did not observe bears using these sites as winter dens. Animals should choose the best habitats available to them. If optimum sites are not available then they should choose the next best. If rock dens provide similar benefits as tree dens to over-wintering bears, I would expect at least some dens of this type would have been used by black bears in my study area or elsewhere in the Pacific Northwest. Over 143 dens of black bears have been found by researchers in the coastal Pacific Northwest (Table 30), none of these dens were in rock cavities or excavated into soil.

Impacts of Forestry on Black Bear Denning Habitat

Forestry activities can affect denning opportunities for black bears in coastal British Columbia in four ways. First, the quality of structures found in logged areas are likely different than those that occur in uncut areas. Second, the type of residual structures found in harvested areas are affected by the forestry activities. Third, both the current and future availability of denning habitat is negatively affected by timber harvesting. Finally, forestry activities can have direct impacts on denning black bears by disturbing occupied dens during harvesting.

Forest harvesting activities change the quality of structures that are suitable for denning in harvested stands. The security of den sites may be an important factor in population persistence because female bears and their cubs determine the reproductive potential for the population. Females are usually less transient with smaller home ranges than males, and are thus more

Table 30. Dens of black bears in structures derived from trees in coastal Pacific Northwest. All the dens reported were in wooden structures.

Region	Number of Dens	Reference
Nimpkish Valley, British Columbia	67	this study
Various locations, coastal British	54	Lindsay 1995
Central Coast Range, Oregon	10	Noble et al. 1990
Long Island, Washington	12	Lindzey and Meslow 1976*a*
Total	143	

vulnerable to habitat alteration caused by intensive forestry practices. While sub-optimal or marginal habitats may appear to support populations for a short time, they may not in the long term due to length of time population processes take to be expressed (Ruggiero et al. 1988).

Forestry activities affect the type of dens found in harvested stands. Under a clearcut silvicultural system, stands that once supplied hollow tree dens will contain only CWD or stumps as potential dens. Also, under current utilization standards, the residual structures that occur in harvested stands are different than those found in stands harvested prior to the implementation of these standards. Timber harvesting in the first half of this century left behind large stumps that could be used for denning. To be used for denning, trees need to be cut high enough so that possible den cavities remain intact (i.e., high stumping). Lower utilization standards in the past left stumps up to 2.5 m high, whereas trees are presently cut close to ground level (30 cm is the maximum allowed under current utilization standards). Stumps are also prone to decay and large diameter stumps will not be replaced in future rotations because of smaller diameter trees in future rotations.

Harvesting of late successional temperate forests affects the current supply of denning habitat for coastal black bears. Clearcutting, the silvicultural system used most commonly in coastal British Columbia, removes all the standing trees in a cutblock in one pass and replaces the forest with an even-aged stand (Clayoquot Sound Scientific Panel 1995). The removal of all standing trees and snags reduces the potential for dens in an area. Logging of late successional forests affects the denning habitat of coastal black bears by removing the structural attributes that bears use for dens (standing trees, snags and coarse woody debris). The availability of preferred den sites in coastal habitats will decrease as rotation lengths shorten in even-aged management systems (i.e., clearcut silvicultural system). Under such forest management practices, trees may not reach sizes adequate for use as dens in future rotations (Lindzey and Meslow 1976*a*, Erickson 1982, Wathen et al. 1986, Noble et al. 1990).

The problems facing forest managers are not only the retention of existing dens, but also the supply of potential den structures in the future. Although rates differ, in second growth the same processes occur as in old-growth; trees grow, die and fall over, and then decay. In old-growth, some trees do not fall until they are large, however, in younger, managed forests there are no large trees. It is these large structures, either standing as trees or lying as logs, that provide dens for black bears on Vancouver Island. Current silvicultural systems truncate natural successional processes, thereby removing the supply of large trees. Large stumps and logs exist because of a supply of large trees, but if the time to create large trees is less than that in which stumps and logs decay, then the supply of stumps and logs will diminish. Spies and Cline (1988) modeled the loss of CWD for coastal Oregon through successive cycles of clearcutting and predicted that the abundance of CWD would be 30% of the pre-harvest level by the end of the first 100-year rotation and 6% after the second. Future rotations will produce trees that, when felled, will not be large enough to produce new den cavities.

Availability of secure den sites at the landscape level may also affect bear behaviour and population processes (Alt 1984), but the effects may take a long time before they are detected. In areas with extensive conversion of habitats from late-successional to early- or mid-successional stages, black bears appear to exhibit a shift in denning behaviour. In North Carolina, bears may have used tree dens exclusively, because of their added protection, before trees were removed by extensive logging (Hamilton and Marchinton 1980).

The distribution of dens within landscapes may not be the only factor which affects den site accessibility; availability of den sites may be further limited by social factors within bear populations. Offspring of female black bears often inherit portions of their mother’s home range and rarely disperse a great distance from it (Rogers 1977, Schwartz and Franzmann 1992). If suitable denning habitat is not evenly distributed throughout the landscape, some small home ranges (typical of female black bears) will likely contain few, if any, suitable den sites.

Forestry operations not only affect denning of black bears by diminishing the availability of den sites but the disturbance of denned black bears during timber harvesting operations can also have negative effects on bears. In Alberta, bears that were forced to abandon their dens during winter had up to 56% increase in normal weight loss (Tietje and Ruff 1980). The disturbance of female bears with cubs should be avoided whenever possible. Female bears with cubs are reluctant to leave their dens during the denning period, often remaining in their dens as timber harvesting occurs around them, but eventually abandon the site (pers. obs.). The effect of disturbance on cubs is difficult to determine, but it is likely that cubs-of-the-year will die if forced to abandon their dens early in the spring.

Protection of the Denning Habitat of Black Bears

Clear direction needs to be provided on how to mitigate the impacts of timber harvesting on black bear denning habitat in coastal British Columbia; current guidelines do not address these concerns. Several methods may be employed to mitigate the negative affects of forestry operations on denning habitat for black bears. Conservation of existing dens is a reactive, fine-scale option. Conservation of denning opportunities throughout the landscape is likely the most appropriate and proactive strategy.

Many black bear studies in North America have determined that large trees are important to black bears and have suggested that logging practices reflect these needs (Johnson and Pelton 1981, Erickson 1982, LeCount and Yarchin 1990, Noble et al. 1990). However, retention of individual den sites (i.e., at the element spatial scale) is not enough; habitat management will be ineffective if it only conserves existing tree dens, because attrition will eventually claim all existing tree dens (Pelton et al. 1980, Johnson and Pelton 1981). A dynamic balance between developing, developed and dead or fallen tree dens would be ideal (Johnson and Pelton 1981). Not only does this reflect the recognition of the habitat needs of black bears, but also the shift towards the conservation of biological diversity for all forest dwelling species (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995).

The information from my research provides managers with guidance to manage for black bear denning habitat at different spatial scales. The scale at which retention is applied should be linked to the scale at which an animal selects resources; if a habitat attribute is selected for at a coarse scale, then coarse scale retention is needed. Although attributes that are selected by bears at one spatial scale can be utilized at coarser scales, the opposite is not necessarily true. Therefore, conservation of habitats must occur at the same, or coarser spatial scale than that at which an animal is selecting. Although bears exhibited the strongest selectivity for denning habitat at the element spatial scale, they also selected stands and patches with high densities of these important elements.

The utility of stands and patches to bears depend upon the densities of preferred elements within them. I found that black bears in the Nimpkish Valley selected for specific stands (e.g., the BBM). The preservation of such stand types will conserve the desired patches and desired elements within them as well as the ecological processes that produce these elements. However, in some landscapes that have been heavily harvested, preferred stand types may be uncommon and therefore unavailable for conservation. In these situations, habitat managers are forced to supply habitat at finer spatial scales (patches and elements). Stand types for which black bears exhibited no selectivity may still provide suitable patches and elements within them. Even unsuitable stand types may contain some den structures, but the density of these structures is far less than densities that occur in preferred stand types.

Coastal black bear populations may become more vulnerable if denning habitat is only supplied at the element level and not at coarser spatial scales. Decreasing habitat supply, caused by the low density of preferred elements, may result in higher mortality and lower reproductive success because bears may have to rely on thermally sub-optimal and less secure den sites. The habitat itself becomes more vulnerable at the same time because the structural integrity of stands may be much greater than that of individual elements. A den conservation strategy which relies upon retention of individual elements within altered stands is much more susceptible to stochastic events. For example, windstorms can topple individual den trees left standing in a cut area, while the same trees might have remained standing when subject to the same winds in the context of an intact stand.

Construction of artificial den sites is often proposed as an alternative to the conservation of adequate natural denning habitat for black bears. The creation of artificial den sites as a conservation tactic should be attempted, but included as supplemental to conservation and recruitment of natural den sites. The benefits to bears conferred by artificial den sites must assessed by examining long term survivorship and reproduction. By depending solely on artificial den sites, habitat and wildlife managers may not achieve expected goals of habitat capability. Retention of natural stands and den sites must be implemented and be the central basis for supplying denning habitat for black bears because we do not know whether artificial dens will be used, and if these dens will provide adequate thermal regimes and security. Experiments which include long term monitoring need to be performed to determine the effects of artificial den structures over the long term on the reproduction and survival of black bears in coastal environments.

Management Recommendations

1. Landscape-level planning is required to identify areas with potentially high densities of dens and to manage the retention of adequate amounts and distributions of denning habitat.

Higher level plans such as landscape plans that include Forest Ecosystem Networks, Wildlife Habitat Areas, Old-Growth Management Areas, Environmentally Sensitive Areas, and Riparian Management Areas (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995) should also include conservation of stands with high den potential. The Biodiversity Guidebook of the Forest Practices Code of B.C. provides recommendations for the percentage of each landscape that should be managed for the distribution of each seral stage (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995). These recommendations depend upon biodiversity emphasis options and the area of land previously harvested and thus may constrain planning directed solely towards managing denning habitat for black bears.

The spatial distribution of the den supply also needs to be addressed to ensure dens are available to black bears within their normal patterns of movements and home ranges. The supply of dens must occur across the landscape, not concentrated into a few patches. Potential den trees should be retained across a range of elevations and aspects. Stands on steeper slopes are preferred ($>15^{o}$) by bears, although dens do occur in stands with $<15^{o}$ slopes. The uniform distribution of potential den sites throughout the landscape will maximize the benefits of den supply to the bear population, especially female bears because of their small home ranges. Retention of late successional forests in only one part of a landscape unit will provide denning habitat for a portion of the black bear population, but will deny access to adequate denning habitat to the remaining portion of the population.

Landscape-level planning for Landscape Units should include the identification of stand types that have high den potential to ensure that denning habitat is supplied across the landscape. It may not be possible to retain adequate denning habitat where, as is the case on the coast, 75% of the area of wildlife tree patches are expected to be incorporated within Riparian Management Areas and other constrained areas (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995) because den sites are broadly distributed and not strongly associated with riparian areas. However, those habitats contained within FENs, WHAs, OGMAs, and ESAs can all contain black bear denning habitat. With proper advance planning to identify and retain stand types that may contain good denning habitat, most of the needs of black bears may be met within the old seral stage requirements for each Natural Disturbance Type (NDT). However, before these areas are considered to be providing adequate denning habitat for black bears, the areas should be critically examined, and possibly surveyed, for their actual den potential.

2. Action should be taken to restore denning habitat in areas of extensive logging.

In areas where a high proportion of the forested landscape has been harvested without regard to conserving large trees and CWD for dens, habitat managers need to implement measures to augment existing dens and retain den "candidate" trees to ensure an adequate supply of dens in the future. Any existing den sites in stumps or CWD must be retained in these situations. To conserve some structures of late-successional forests, stand level biodiversity prescriptions for biodiversity, stand structure and tree species composition (B.C. Ministry of

Forests and B.C. Ministry of Environment, Lands and Parks 1995) should be implemented when planning new clearcuts.

3. Bear dens found in standing trees within areas that are to be clearcut should be retained, whenever possible, in wildlife tree patches. Trees with entrances above ground level are especially important and should always be retained in wind-firm patches.

Retention of individual den trees can be done in several ways. Tree dens within cutblocks may be left standing within "wildlife tree patches" (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995) which should be windfirm. Wildlife tree patches containing den structures should be >0.5 ha. Tree dens that are near the edges of a cutblock can be left standing through minor adjustments to the cutblock boundaries. Known dens can be incorporated into riparian management areas and gully buffers. The retention of these standing trees provides "escape" trees for females with cubs and may reduce inter- and intra-specific predation.

My research on habitat selectivity provides information on which to base management recommendations for the retention of standing trees and CWD within appropriate ecological contexts. While strong element level selectivity was exhibited by bears in my study, I also detected selection for other habitat attributes which cannot be preserved by simply retaining one type of structure. Vegetation which reduces horizontal visibility is important to denning bears and should be retained. While retention of individual den sites (i.e., at patch or element scales) is helpful, management for black bears must include higher-level planning to maintain secure denning habitat across landscapes.

4. Retention of green trees for recruitment of future den trees should focus on large declining green trees.

Living trees should be retained as potential denning structures. These trees should not be removed in future rotations because they will provide a continuing den supply, structural diversity in the future stand, and recruitment of standing dead wildlife trees and CWD. Simply retaining large trees within cutblocks does not ensure that these elements will eventually become den trees. The formation of an entrance into a hollow tree is a rare event. Elements such as declining trees will still be useful for other birds and animals and escape trees for bears if they do not become den structures. However, if den formation is the primary goal of designated wildlife tree patches, specific characteristics of the trees should be considered in the selection of these patches. Selecting patches with trees that are large in comparison to the remainder of the stand, and are exhibiting signs of decay (e.g., heart-rot, conks) and other defects (e.g., butt flare, candelabras), will enhance the likelihood of den cavities forming within the wildlife tree patch. The creation of den cavities in hollow cedar trees may be facilitated by cutting entrances into the hollow centres. The location of patches should be such that they are not subject to flooding and are on zonal sites (of intermediate moisture and nutrient status, Green and Klinka 1994), or only slightly wetter or drier than zonal. The retention of large trees of any species appears to be beneficial for the maintenance of denning habitat, although particular species appear to form den structures more readily than others. Yellow-cedar and western redcedar trees are probably the most important source of den structures because of their decay characteristics (Chapter 1), but other tree species should be considered as management options. Large Douglas-fir, Sitka spruce, black cottonwood (*Populus balsamifera* var. *trichocarpa*), and both mountain and western hemlock have all been used by black bears as winter den sites. Because of different decay characteristics among species, each will likely be used at different periods in their growth and decay. Dens have been located under standing Douglas-fir trees, but most dens in the Nimpkish Valley associated with Douglas-firs were in logs exhibiting various kinds of pathogens (e.g., root-rot and butt-rot). Sitka spruce trees tend to have large cavities beneath their roots, which is caused by their tendency to grow on nurse logs. Because of this, Sitka spruce can be used as standing tree or stump (if cut high enough) dens.

Cottonwood trees may also provide excellent winter den sites. Although there were no large cottonwoods in my study area, cottonwoods have been used by black bears elsewhere in British Columbia (Terrace; pers. obs.) and may be important in areas where other tree species do not commonly have large interior cavities. In Alaska, cottonwoods were used as den trees in two study areas where they were the only trees that were large enough to accommodate den cavities (Schwartz et al. 1987). Large hemlock trees can be used as dens by bears. Den opportunities occur in hollow hemlocks with entrances above ground level or in clumps of hemlocks with intermingled roots. Hemlocks used as den sites are typically much larger (>100 cm dbh) than other hemlocks in the stand.

5. Timber harvesting should avoid causing displacement of denned black bears.

Activities which induce den abandonment should always be avoided. Females with cubs-of-the-year which are encountered during harvesting should not be disturbed. No activity should occur within 30 m of the den site until the bears have left the den site on their own volition. The presence of cubs can be determined by listening for the “chuckling” noises of nursing cubs (which is audible up to 20 m from a den site) and by the presence of bears in dens late in the denning period. In coastal British Columbia, females with cubs-of-the-year may remain in the den into May (Chapter 1).

It is often not possible to identify all potential den sites in a proposed cutblock. Even if potential den structures are identified, den sites may not be used in an upcoming winter. In areas with high densities of den structures, it would be prudent to conduct timber harvesting during summer when bears are not denning.

Besides landscape level plans and wildlife tree patches, the retention of large pieces of CWD (both logs and root boles) and high stumps can augment the supply of dens for bears. Retention of CWD and stumps is important in areas of extensive logging but it is a temporary method of supplying den sites. The retention of these structural legacies can provide den cavities in second growth forests while candidate trees in adjacent second growth stands reach sizes suitable for creating new den cavities that will not be cut in future rotations. Stand tending activities, such as thinning, should not disturb existing pieces of large CWD or residual snags. However, provision of CWD is a reactive approach to den supply management. Conservation of wildlife trees will likely be the method which best mitigates the impacts of forestry operations on den supply in the short to medium term. Recruitment of new den trees is the only long term option.

6. Large pieces of CWD should be retained in new clearcuts.

Retention of large pieces of CWD is important for providing winter denning structures in managed landscapes and helps offset losses of den sites incurred by logging of den trees. Large logs and root boles (the products of windfall) appear to be adequate winter den sites for black bears (Chapter 1). Utilization standards may need to be relaxed to allow the retention of CWD that is large enough to provide dens for bears. Current standards in British Columbia specify that logs >3 m long, and >15 cm diameter must be removed (depending on grade of timber).

Leaving logs at the site that they were felled is likely important because yarding to landings would reduce the utility of CWD to bears because of breakage and by moving it closer to potentially disruptive human activity. Specific requirements for CWD in clearcuts are:

- Logs should be a minimum of 100 cm diameter (at 1.3 m from base) and 5 m long if they are to form adequate winter dens.
- If logs are to be removed from fallen trees they should be cut more than 5 m from the root wad; diameters of the bole of windfallen trees may as small as 75 cm diameter. To enhance security, root bole cavities should be closed on one side so that there is only one entrance to the den cavity.
- Both logs and blowdown retained for potential den sites should be of early decay classes with hard shells. Stand tending activities, such as thinning, should not disturb existing pieces of large CWD.
- Cedar logs that are beginning to exhibit decay at one end or Douglas-fir logs with signs of rot should be retained because these types of structures are used as dens. Because of different decay characteristics, large fallen Sitka spruce, hemlock and Pacific silver fir are not likely to be used by bears.

After clearcutting, firewood cutting and the salvage of cedar for shakes after clearcutting must be regulated so as not to remove structures that have been left to provide habitat for bears and other animals. Restricting access and conducting awareness programs may help reduce post-harvest removal of elements retained for wildlife. Operators salvaging cedar shakes need to be regulated because workers often use helicopters to access harvested areas that have closed roads. Regulations must be enforced to ensure that salvage activities do not significantly deplete the denning capability in a harvested area.

7. When harvesting stands, selected large trees should be cut >2 m above their bases (e.g., high stumping) to allow for the formation of den sites under stumps.

Retention of high stumps should be considered for new cutblocks in areas which have been heavily logged (e.g., outside the proposed seral stage distribution in the Biodiversity Guidebook for that Landscape Unit). Some of the largest diameter trees (>100 cm diameter) should be cut higher than normal (≥2 m from ground level). Because of differences among species, high stump prescriptions should be directed at large hemlock, Sitka spruce and Pacific silver fir, and cedars if the stump will have a solid top. High stumping is an option if windfall is likely to occur, however, retention of standing green trees is preferable to high stumping because of the increased longevity of the structure.

Conclusions

In managed forests, the best approach for maintaining denning habitat for black bears is a combination of landscape planning and a variable-retention silvicultural system proposed by the Clayoquot Sound Scientific Panel (1995). This system will conserve the biodiversity potential of harvested areas for many species of wildlife in addition to black bears. Variable-retention systems allow for retention of habitat elements, including standing trees, snags and CWD. The aggregated variable-retention system is the preferred system for retaining habitat values associated with den trees. This system is more likely to encourage earlier use of den structures by bears than if the area was harvested with a dispersed variable-retention system. If these harvesting systems are not adopted, all of the recommendations prescribed in the Biodiversity Guidebook of the Forest Practices Code of B.C. (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995) should be followed. These prescriptions provide minimum standards for the retention of wildlife tree patches and landscape planning for black bear denning habitat, however they may not be stringent enough to ensure denning capability is not diminished.

Habitat conservation at the landscape spatial scale would preserve sufficient structures required for denning by black bears, however this is not a management option in most areas. As habitat managers attempt to maintain the supply of dens for black bears, management prescriptions can often be applied only at finer spatial scales. Limiting management options to finer spatial scales reduces long term habitat capability, placing bear populations at greater risk from the effects of habitat alteration. The retention of stands within landscapes provides the best means for the maintenance of adequate numbers and supply of dens. Retention of patches within stands provides the next best option, and the retention of elements provides the only option better than supplying none at all. Den structures are created infrequently and thus occur rarely. Attempting to conserve individual elements, hoping that they will turn into suitable den sites is a risk that may result in local declines of black bear populations in coastal ecosystems.

Appendix A. Black Bear Habitat Types

Elevation strongly affects the location and spatial extent of the biogeoclimatic subzones and variants in my study area. In the Nimpkish Valley, the composition of forests changes with elevation; as elevation increases there is an inclusion of Pacific silver fir, then yellow-cedar and mountain hemlock with a concurrent exclusion of Douglas-fir, western redcedar and western hemlock. Cold air outflows can affect the elevation at which variants occur. Orographic lifting also affects the spatial extent of each variant. These trends in location of stand classes is important when considering the supply of stands in the landscape that can provide den cavities. The following Black Bear Habitat Types (BBHT) are the result of combining similar biogeoclimatic site series within and across biogeoclimatic zones, variants and subzones. Table 31 presents the composition of the study area by Black Bear Habitat Type and seral stage.

BBHT Name: **Fir Salal (FSA)**

Biogeoclimatic Variants and Site Series:

CWHxm 01 HwFd - Kindbergia
CWHxm 03 FdHw - Salal
CWHxm 06 HwCw - Deer fern

Description: Poor to medium nutrient sites dominated by western hemlock and Douglas-fir. The shrub understory is characterized by *Gaultheria shallon* and *Vaccinium parvifolium*. Herb coverage is sporadic with *Blechnum spicant* and other ferns common on wetter sites. Moss cover is composed of *Hylocomium splendens*, *Rhytidiadelphus loreus*, and *Kindbergia oregana*.

BBHT Name: **Fir Sword fern (FSF)**

Biogeoclimatic Variants and Site Series:

CWHxm 04 Fd - Sword fern
CWHxm 05 Cw - Sword fern
CWHxm 07 Cw - Foamflower

Description: Rich sites dominated by larger Douglas-fir and western redcedar. Often old floodplains. The understory is characterized by diverse herb cover, predominately *Polystichum munitum*, *Tiarella* spp., *Achlys triphylla* and *Athyrium filix-femina*. On wetter, more open sites, a significant shrub cover of *Rubus spectabilis* and *Rubus parvifolium* occurs.

BBHT Name: **Blueberry Moss (BBM)**

Biogeoclimatic Variants and Site Series:

CWHvm1 01 HwBa - Blueberry
CWHvm1 03 HwCw - Salal
CWHvm1 06 HwBa - Deer fern
CWHvm2 01 HwBa - Blueberry
CWHvm2 03 HwCw - Salal
CWHvm2 06 HwBa - Deer fern
MHmm1 01 HmBa - Blueberry

Description: Poor to medium nutrient sites dominated by overstories of western hemlock, Pacific silver fir and western redcedar. Inclusion of yellow-cedar and mountain hemlock in the CWHvm2 with concurrent exclusion of redcedar. The shrub understory is dominated by extensive cover of *Vaccinium* species. There is little herb cover with the exception of *Blechnum spicant* and other ferns on wetter sites. There is a continuous moss cover of *Hylocomium splendens* and *Rhytidiadelphus loreus*. In the CWHvm2, the moss layer is dominated by *Rhytidiopsis robusta*.

BBHT Name: **Devil's Club Seepage (DCS)**

Biogeoclimatic Variants and Site Series:

CWHvm1 04 CwHw - Swordfern
CWHvm1 05 BaCw - Foamflower
CWHvm1 07 BaCw - Salmonberry
CWHvm1 08 BaSs - Devil's club
CWHvm2 04 CwHw - Swordfern
CWHvm2 05 BaCw - Foamflower
CWHvm2 07 BaCw - Salmonberry
CWHvm2 08 BaSs - Devil's club

Description: Rich sites dominated by Pacific silver fir and western hemlock, and occasionally contain Sitka spruce. The shrub understory consists of *Rubus spectabilis* and *Oplopanax horridus* in areas of impeded drainage. Herb cover is extensive and includes *Tiarella* spp., *Polystichum munitum*, *Coptis aspleniifolia, Athyrium filix-femina* and *Streptopus roseus*.

BBHT Name: **Floodplain (FLP)**

Biogeoclimatic Variants and Site Series:

CWHxm 08 Ss - Salmonberry
CWHxm 09 Act - Red-osier dogwood
CWHxm 10 Act - Willow
CWHvm1 09 Ss - Salmonberry
CWHvm1 10 Act - Red-osier dogwood
CWHvm1 11 Act - Willow

Description: Vegetation cover depends on the frequency of flooding of the site.

High bench floodplains have tree cover of redcedar and Sitka spruce and a variable deciduous component. Shrub cover includes *Rubus spectabilis* and *Sambucus racemosa* in openings. The herb layer is extensive, consisting of *Tiarella* spp., *Maianthemum dilatatum, Achlys triphylla, Dryopteris expansa, Adiantum pedatum,* and *Athyrium filix-femina*. There is generally very little moss cover.

Medium bench floodplains experience more frequent flooding than high bench floodplains. While red alder and cottonwood are often present, vegetation cover is almost exclusively in the shrub layer, consisting of *Cornus stolonifera*, *Lonicera involucrata* and *Rubus spectabilis*.

Low bench floodplains experience flooding every year and consist of red alder and *Salix* spp. growing on gravel bars.

BBHT Name: **Pine Cladina (PCL)**

Biogeoclimatic Variants and Site Series:

CWHxm	02	FdPl - Cladina
CWHvm1	02	HwPl - Cladina
CWHvm2	02	HwPl - Cladina
MHmm1	02	HmBa - Mountain-heather

Description: Poor, dry, rocky sites. The sparse overstory at lower elevation sites are dominated by lodgepole pine and Douglas-fir; Pacific silver fir and mountain hemlock occur at higher elevations. Lower elevation shrub understories are predominately patches of *Gaultheria shallon* and *Holodiscus discolor*. The upper elevations have more *Vaccinium* spp. and mountain heathers. Mosses are dominated by *Cladina* spp. at all elevations.

BBHT Name: **Skunk Cabbage Swamp and Sphagnum Pine Bog (SCS and SPB)**

Biogeoclimatic Variants and Site Series:

CWHxm	11	Pl - Sphagnum
CWHxm	12	CwSs - Skunk cabbage
CWHvm1	12	Pl - Sphagnum
CWHvm1	13	CwSs - Skunk cabbage
CWHvm2	09	CwYc - Goldthread
CWHvm2	10	Pl - Sphagnum
CWHvm2	11	CwSs - Skunk cabbage
MHmm1	08	HmYc - Sphagnum
MHmm1	09	YcHm - Skunk cabbage

Description: Wetlands of poor to rich nutrient status. Tree cover is sporadic and includes lodgepole pine, redcedar, and at higher elevations, Pacific silver fir and yellow-cedar. Surface water is common. Shrub coverage may be dense with *Gaultheria shallon* and can include *Spiraea douglasii* and *Ledum groenlandicum*. Herbs include *Lysichitum americanum*. The dominant moss cover is *Sphagnum* spp.

BBHT Name: **Mountain Hemlock Forested (MHF)**

Biogeoclimatic Variants and Site Series:

MHmm1 03 BaHm - Oak fern
MHmm1 04 HmBa - Bramble
MHmm1 05 BaHm - Twistedstalk
MHmm1 06 HmYc - Deer-cabbage
MHmm1 07 YcHm - Hellebore

Description: The tree cover is generally open and is dominated by mountain hemlock and Pacific silver fir with a varying yellow-cedar component. The shrub understory commonly consists of *Vaccinium* spp., *Menziesia ferruginea*, and *Cladothamnus pyroliflorus*. The most common herb is *Rubus pedatus*, with *Phyllodoce empetriformis* and *Cassiope mertensiana* often present. Moss cover is usually *Rhytidiopsis robusta*, with *Sphagnum* spp. on wetter sites.

BBHT Name: **Mountain Hemlock Parkland (MHP)**

Biogeoclimatic Variants and Site Series:

MHmmp1

Description: Consists of rock outcrops with small patches of stunted, deformed trees, usually mountain hemlock.

Table 31. Proportion of the Nimpkish Valley study area in each Black Bear Habitat Type and seral stage combination (stand types).

BBHT	Seral stage	Percent of study area
BBM	1/2	2.5
BBM	3	1.9
BBM	4	2.9
BBM	5/6	19.3
DCS	2	0.2
DCS	3	1.5
DCS	4	2.5
DCS	5/6	2.1
FLP	1/2	0.2
FLP	3	0.0
FLP	4	1.0
FLP	5/6	1.0
FSA	1/2	2.9
FSA	3	2.9
FSA	4	18.0
FSA	5/6	7.8
FSF	1/2	1.3
FSF	3	0.6
FSF	4	7.1
FSF	5/6	1.1
MHF	2	0.4
MHF	5/6	1.1
MHP	6	1.5
PCL	all	5.6
SCS	2	0.2
SCS	6	1.7
SCS	4C/D	0.4
Non-vegetated		12.3

Appendix B. Glossary

biogeoclimatic zone: "a geographic area having similar patterns of energy flow, vegetation, and soils as a result of a broadly homogenous macro-climate" (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995).

Black Bear Habitat Type (BBHT): compilations of site series within and across biogeoclimatic variants; e.g., the Blueberry Moss (BBM), Appendix A.

coarse woody debris: sound and rotting logs and root boles of fallen trees.

den patch: a patch around a den structure, regardless of the type of den.

habitat attributes: components, both structural and non-structural, that constitute stand structure; e.g., slope, aspect, CWD, standing trees.

landscape: "a watershed or series of similar and interacting watersheds, usually between 10 000 and 1 000 000 ha in size" (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995).

macro-slope: the general slope of a stand.

micro-slope: the slope within a patch, usually within 25 m of the plot centre.

patch: a small group of trees (usually fewer than 12 trees) less than 1 ha in size. Patches were bounded by the area of a variable radius prism cruise plot.

random patch: a patch around a randomly located point.

selectivity: preference or avoidance of a habitat or a habitat characteristic.

seral stage: "the stages of ecological succession of a plant community; the characteristic sequence of biotic communities that successively occupy and replace each other, altering in the process some components of the physical environment over time" (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995).

site series: "sites capable of producing the same late seral or climax plant communities within a biogeoclimatic subzone or variant" (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995); e.g., CWHvm2 01.

stand: relatively homogenous land units greater than 1 ha in area with generally homogenous vegetation types with regard to dominant forest cover or seral stage.

stand types: combinations of Black Bear Habitat Types with seral stages; e.g., BBM 5/6.

structural attribute: "components of a forest stand (including living and dead standing trees, canopy architecture, and fallen dead trees) which together determine stand structure" (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995); e.g., number of logs > 50 cm diameter.

structural attribute category: created by the division of structural attributes into finer groupings; e.g., number of logs 50-64 cm diameter, number of logs 65-79 cm diameter, and number of logs > 80 cm diameter.

structural attribute class: a division of a structural attribute category; e.g., 0.01-0.50 logs between 50 and 64 cm diameter.

wildlife tree patch: "an area specifically identified for the retention and recruitment of suitable wildlife trees. It can contain a single wildlife tree or many. A wildlife tree patch is synonymous with a group reserve" (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995).

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