AN ABSTRACT OF THE THESIS OF

William O. Noble for the degree of Master of Science in Wildlife Science presented on November 23, 1993

Title: Characteristics of Spring Foraging Ecology Among Black Bears in the Central Coast Ranges of Oregon

Abstract approved: Signature redacted for privacy.
E. Charles Meslow

I studied spring food habits, focusing on cambium-feeding, of black bears (*Ursus americanus*) in the Central Coast Ranges of Oregon (1987-90) by comparing an area with high levels of timber damage caused by bears (north area) with an adjacent area of low levels of bear damage (south area). I also conducted a survey of forest stands in both areas to measure levels of bear damage, describe damage and forest stand characteristics, and determine if site characteristics were useful in predicting future bear damage.

I compared the contents of black bear scats collected in spring (March - mid-July) from the north area ($\underline{n}$ = 61) with scats from the south area ($\underline{n}$ = 92). I also fed cambium to captive black bears to establish whether cambium was readily identifiable in scats and determined it was about 50% digestible, dry matter basis. Scats from the north area had a higher percent frequency (51%) of forbs than did scats from the south area (29%) ($\underline{G}$ = 7.16, 1 df, $\underline{P}$ = 0.007). Scats from the north area included small quantities (≤5% frequency) of many species of forbs: only clover (*Trifolium repens*) seemed important (12%). Cow parsnips (*Heracleum lanatum*) was the most common forb (10% frequency) in scats from the south area. Scats from the south area had a higher frequency (50%) of shrubs than did scats from the north area (20%) ($\underline{G}$ = 15.04, 1 df, $\underline{P}$ < 0.001), although the only shrubs

occurring in scats from either study area were the leaves, stems, and fruits of Devil's club (*Oplopanax horridum*) and *Rubus spp.* Cambium occurred at a higher frequency (12%) in scats from the north area than in scats from the south area (2%) ($\underline{G}$ = 5.71, 1 df, $\underline{P}$ = 0.017). Animal matter consisted primarily of black-tailed deer (*Odocoileus hemionus columbianus*), a variety of small mammals, and ants (Formicidae).

Forty randomly selected forested stands with dominant trees ranging from 10-50 cm dbh were surveyed in each of the 2 study areas. Overall site characteristics differed between stands classified by the presence or absence of bear damage ($\underline{F}$ for Wilk's λ = 2.62, 11,68 df, $\underline{P}$ = 0.008). Forest stands with bear damage ($\underline{n}$ = 33) had lower densities of trees >40 cm dbh ($\underline{F}$ = 5.97, 1,78 df, $\underline{P}$ = 0.017), lower total basal area ($\underline{F}$ = 4.92, 1,78 df, $\underline{P}$ = 0.030), occurred on less steep slopes ($\underline{F}$ = 3.80, 1,78 df, $\underline{P}$ = 0.055), and differed by aspect (cosine(aspect): $\underline{F}$ = 5.28, 1,78 df, $\underline{P}$ = 0.022) compared to forest stands without bear damage ($\underline{n}$ = 47). Forest stands had a random distribution of aspects when examined by total sample ($\underline{n}$ = 80), study area ($\underline{n}$ = 40 for each area), and all stands without bear damage. Only stands with bear damage had a non-random distribution of aspects ($\bar{a}$ = 31°; χ^2 = 10.5, $\underline{k}$ = 5, 4 df, $\underline{P}$ < 0.05). Average dbh of damaged trees (22 cm ± 0.98 SE) differed from the average dbh of undamaged trees (16 cm ± 0.95) within stands containing bear damage ($\underline{U}$ = 4.23, 1 df, $\underline{P}$ = 0.0001). Bears fed on trees <10 cm dbh less than available (χ^2 = 65, 3 df, $\underline{P}$ < 0.005), trees 11-20 cm dbh in a ratio equal to their availability and bears selected for trees 21-30 cm dbh (χ^2 = 73, 3 df, $\underline{P}$ < 0.005). Most damage (91%) occurred on trees 11-30 cm dbh. Bears damaged from 7-185 trees/ha ($\bar{x}$ = 39 ± 7.7) and 19% of trees damaged were completely girdled. Measured site characteristics were poor predictors (R^2 = 0.14; correct classification rates = 70%) of a stand's potential vulnerability to damage by bears.

Retaining or creating patches of known bear foods, including planting skid roads and log-landings to grasses and forbs and retaining coarse woody material as substrate for wood-nesting insects, could supplement animal damage control efforts by providing nutritious spring forage. The similarity of bear damage descriptions in the literature from regions across western North America suggest site characteristics may influence feeding behavior of bears. Identifying these characteristics, which may include parameters related to carbohydrate production, and combining them with characteristics discussed here, may allow prediction of future bear damage.

Characteristics of Spring Foraging Ecology Among Black Bears in the Central Coast Ranges of Oregon

by

William O. Noble

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed November 23, 1993
Commencement June, 1994

APPROVED:

Signature redacted for privacy.

Professor of Wildlife Ecology, in charge of major

Signature redacted for privacy.

Head of Department of Fisheries and Wildlife

Dean of Graduate School

Date thesis is presented: November 23, 1993

Typed by author: William O. Noble

ACKNOWLEDGEMENTS

Financial support making this research possible was provided by a consortium of state and federal agencies and private companies concerned with the management of forests in western Oregon. I would like to thank: my major professor, Dr Charles Meslow, and Dr Dan Edge and Dr Bill McComb for all their input and assistance during this project; Tom Sabin (Dep. of Forest Science) for the many discussions regarding SAS and multivariate statistics; and Dr Logan Norris, Dep. of Forest Science, for his flexibility, understanding, continued support, and especially his patience.

The field work would have been far more burdensome without: the efforts of Michael Pope, whose work regularly went above and beyond the call..., the countless volunteer hours provided by Jim Minter (Oregon United Sporting Dogs Association), the volunteer assistance of Steve McConnel and Randy Sether, the logistical support provided by Mark Gourley (Starker Forests) and Daryl Adams (Willamette Industries), Jerry Chetok (OR Dep. Forestry) approving <u>every</u> repair needed to keep the project vehicle rolling, and the OR Dep. of Fish and Wildlife for assisting with housing.

As with most projects, this work would have long ago ground to a halt if not for the office staff, including Adrian Hunter (retired), LaVon Mauer, Jan Mosley, Robin Sether, and Chris Sinnett.

I would very much like to thank Bob Steidl for hurling a raft and life-vest when a sea of statistics came swirling at my door.

Many thanks are owed to Marty and Ellen Main, Dan Rosenberg, Mike Scola, and Bob Steidl for opening their homes to me, providing moments of respite, and listening to me go on and on (and on) about bears.

The path from Chicago, Illinois, to Oregon's thorny Coast Ranges has been a long and seldom direct journey and one that would never have occurred without the love, guidance, and spiritual support of my mother, father, and brother. Thank-you for knowing when to bolster and when to question my stated courses of action.

And to my wife, Sandy, and my step-daughter, Leah, whose love and strength provided the support and encouragement to carry me through this protracted program. And thank-you Sandy, for all the years of love, friendship, and companionship that continues to enrich my daily life.

This thesis is dedicated to my wife, Sandra Marie Noble.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHARACTERISTICS OF SPRING FORAGING ECOLOGY AMONG BLACK BEARS IN THE CENTRAL COAST RANGES OF OREGON

CHAPTER I.

GENERAL INTRODUCTION

Cambium is a common, but usually minor element in black bear (*Ursus americanus*) diets (Tisch 1961, Landers et al. 1979, Grenfell and Brody 1983). Since the 1940's, however, concentrations of bear damage have been reported in young stands of regenerated forests (Moore 1940, Bear Facts Comm. 1951, Lutz 1951, Molnar and McMinn 1960, Poelker and Hartwell 1973, Nelson 1989). "Bear damage" is the removal of bark and consumption of cambial tissue and saps by bears; bear damage is nearly always limited to conifers and is distinct from bears merely marking trees (Burst and Pelton 1983, Rogers 1987:26). Bear damage usually occurs on the basal portion of a bole, is triangular to fusiform in shape, and is often characterized by vertical incisor marks in the wood and large strips of bark on the ground.

Bears tend to select open-grown or understocked stands 10- to 40-years-old and feed on the more vigorous trees (Levin 1954, Lauckhart 1955, Lawrence et al. 1961). Bears have reportedly damaged 40% to 60% of the crop trees in some stands (Levin 1954, Childs and Worthington 1955, Maser 1967). These factors equate to bears damaging stands with the highest monetary investment (relative to time of harvest) and damaging or killing the most valuable trees within stands. Whether stands originated from fire disturbance (Childs and Worthington 1955, Mason and Adams 1989) or silvicultural practices (Maser 1967, Nelson 1989), nearly all reports of concentrations of bear damage describe even-aged stands. Plantation-type tree farms grow boles that taper quickly, therefore much of the volume of these trees is contained in the butt log--the portion most often damaged by bears. At times, more than 30% of the trees damaged may die from girdling (Lauckhart 1955, Schmidt 1989). Growth rates are reduced when ≥50% of the bole circumference is peeled (Nelson 1989). Basal scars are vulnerable to decay and wood-boring insects (Thomas and Thomas 1954, Poelker and Hartwell 1973:34-37, Hennon et al. 1990), further reducing wood volume at harvest.

Cambium-feeding usually occurs in stands of young timber during or after the period of forest canopy closure. Some researchers believe a lack of suitable forage may relate to densities of trees damaged by bears (Maser 1967, Nelson 1989), but not all investigators agree (Lutz 1951, Tisch 1961). If bear damage is related to forage availability, then differences other than the mere presence or absence of cambium should exist between diets of bears from areas with high levels of damage and bears from areas with little or no bear damage.

It is not understood why concentrated pockets of damage occur in some stands but not in nearby stands of similar age and structure (Molnar and McMinn 1960, Poelker and Hartwell 1973:27). Learned behavior and individual behavior of bears are potential factors in the use of cambium as food. Nevertheless, descriptions of bear damage, both for individual trees and at the stand level, are very similar between regions as disparate as New England (Zeedyk 1957), the Rocky Mountains (Schmidt 1989), interior British Columbia (Molnar and McMinn 1960), and in Japan (Furubayashi et al. 1980, Watanabe 1980). Therefore, stand or tree characteristics may influence the rate at which bears feed on cambium. Identifying such characteristics may allow assessing a stand's vulnerability to bear damage.

I compared food habits (scat analysis) between an area containing high levels of bear damage and an adjacent area with low levels of bear damage. I also documented levels of bear damage in the 2 study areas, described damage attributes, and investigated the use of site characteristics to predict future potential of bear damage.

CHAPTER II

SPRING FOOD HABITS OF BLACK BEARS

ABSTRACT

Black bear (*Ursus americanus*) damage to Douglas-fir (*Pseudotsuga menziesii*), resulting from cambium-feeding during spring, is a reoccurring problem in the Pacific Northwest. Previous investigators hypothesized that bear damage increased as the availability of other forage items was reduced due to forest canopy closure. I compared the contents of black bear scats collected in spring (March - mid-July) from an area with high levels of bear damage (north; $\underline{n}$ = 61) with scats from an adjacent area with low levels of damage (south; $\underline{n}$ = 92). I also fed cambium to captive black bears and determined it was 50% digestible (dry matter) and therefore readily identifiable in scats. Scats from the north area had a higher frequency (51%) of forbs than did scats from the south area (29%) ($\underline{G}$ = 7.16, 1 df, $\underline{P}$ = 0.007). Scats from both areas included small quantities (≤5% total volume) of many species of forbs: only clover (*Trifolium repens*) seemed important (12%) in the north area and cow parsnips (*Heracleum lanatum*) was the most common forb (10%) in scats from the south area. Scats from the south area had a higher frequency (50%) of shrubs than did scats from the north area (20%) ($\underline{G}$ = 15.04, 1 df, $\underline{P}$ < 0.001), although the only shrubs occurring in scats from either area were the leaves, stems, and fruits of Devil's club (*Oplopanax horridum*) and *Rubus spp.* Cambium occurred with a higher frequency (12%) in scats from the north area than in scats from the south area (2%) ($\underline{G}$ = 5.71, 1 df, $\underline{P}$ = 0.017). Animal matter included black-tailed deer (*Odocoileus hemionus columbianus*), a variety of small mammals, and ants (Formicidae). Retaining or creating patches of known bear foods--including planting roads and log-landings to grasses and forbs, maintaining patches of shrubs, and retaining coarse woody material as substrate for wood

nesting insects--could supplement animal damage control efforts in an attempt to reduce the numbers of trees damaged by bears and the numbers of bears killed in control measures.

INTRODUCTION

Spring has been termed a "negative foraging period" for black bears due to the generally poor nutritional quality of available foods (Poelker and Hartwell 1973:116, Eagle and Pelton 1983). During spring, some bears peel bark from trees and feed on cambium. Bear damage associated with cambium-feeding has been documented throughout the Pacific Northwest (Glover 1955, Maser 1967, Poelker and Hartwell 1973), but the levels of damage caused by bears in western Oregon apparently increased sharply during the 1980's (Gourley and Vomocil 1987). Maser (1967) and Nelson (1989) reasoned that, because damage usually occurs after canopy closure in stands of young timber, a lack of suitable forage may relate to bear damage. Not all investigators agree (Lutz 1951, Tisch 1961) and at least 1 study hypothesized bear damage may reflect the need for a certain chemical constituent(s) found in cambium (Fritz 1951). If an increase in cambium-feeding is due to decreased availability of other forage, a difference should exist between diets of bears that do and those that do not eat cambium other than the mere presence or absence of cambial tissue. The purpose of this study was to compare the food habits of black bears in neighboring areas with high and low levels of tree damage caused by bears eating cambium.

STUDY AREAS

I selected 2 adjacent areas, each about 500 km^2, in the Central Coast Ranges of western Oregon (Figure 1). The north area was identified by local resource managers as sustaining high levels of tree damage by bears feeding on cambium and the south area was reported as having little bear damage. The region has a maritime climate with typically cool, wet winters. Snow is infrequent and ephemeral, generally lasting for a few days except on the higher peaks and ridges. Summers are usually dry with fog occurring often in the river valleys (Hemstrom and Logan 1986). The topography is steep and highly dissected with elevations ranging from 15 to 1,250 m. The study areas were within the western hemlock (*Tsuga heterophylla*) vegetation zone, but dominated by Douglas-fir (Franklin and Dyrness 1973). Levels of bear damage in the 2 study areas were verified during surveys of 80 randomly located forest stands (unpubl. data). Land ownership differed between study areas with the north area about 2/3 private and state ownership and 1/3 federal lands. The south area was 1/3 private and state lands and 2/3 federal land. Federal land was managed by the U.S.D.A. Forest Service and U.S.D.I. Bureau of Land Management. Forests within the study areas have usually been harvested by clearcutting on 40- to 80-year rotations and planted with nursery stock.

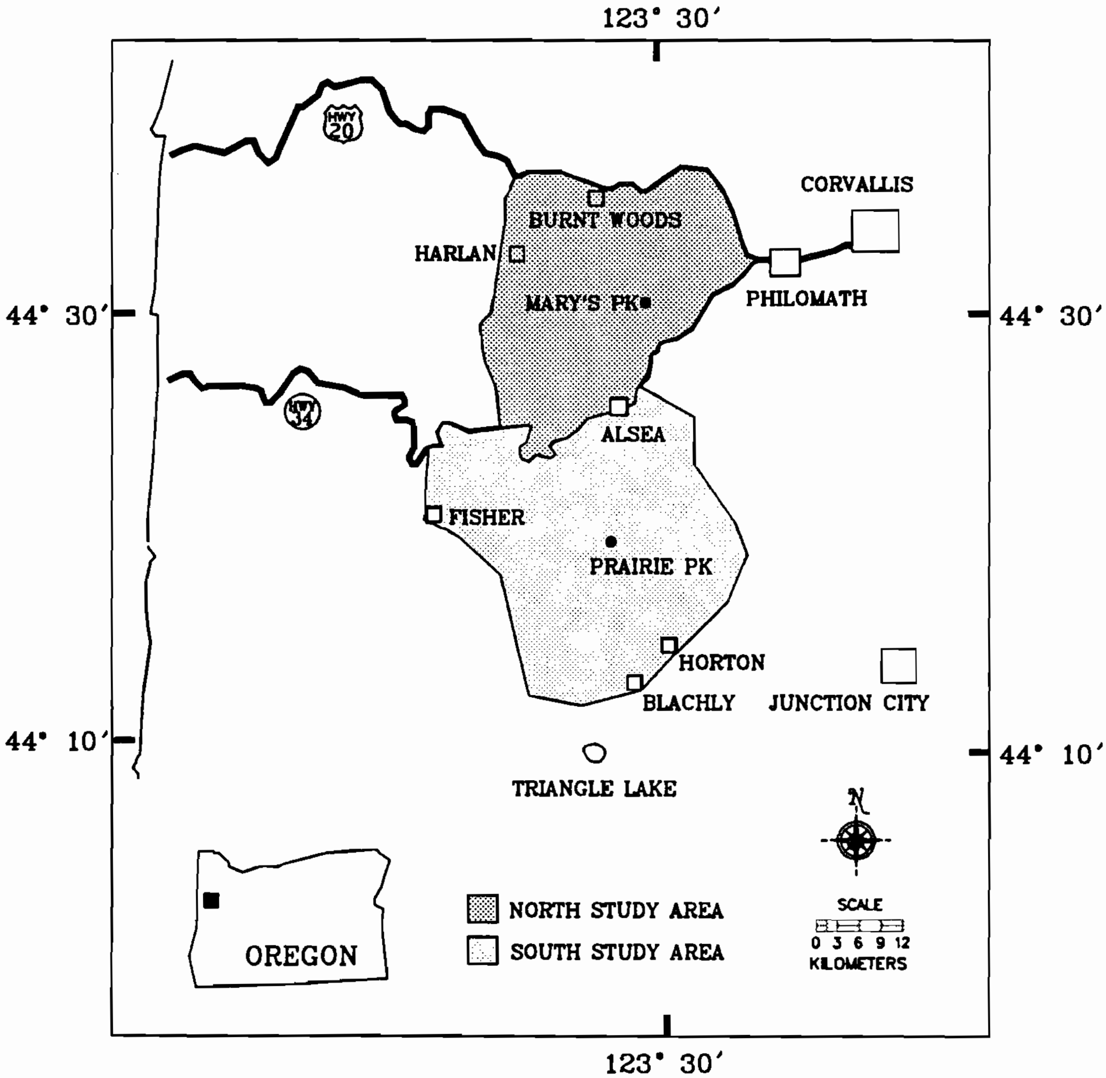

Figure 1. Location of study areas: north area included high amounts of timber damage caused by bears and the south area had low levels of bear damage, Central Coast Ranges, Oregon, 1987-90.

METHODS

Scats were collected from March - mid-July, the period from den emergence until summer when most bear damage occurs. Movements of radio-collared bears and observations of plant phenology supported this demarcation (unpubl. data). Most scats were collected near or along roads and many of these were located by sportsmen using trained hounds. Heavy winter rains and rapid decay rates eliminated scats from previous seasons.

Scats were stored frozen then oven dried before shipping to a commercial laboratory (William Callaghan, Bellvue, WA). Scats were then soaked and washed through 3.1 mm mesh and 0.8 mm mesh screens. The contents were suspended in cold water and separated in a white porcelain pan. Contents were usually identified to genus or species and the plant part(s) (leaf, stem, fruit, etc.) identified using dissecting and compound microscopes. Percent volume was visually estimated (Martin et al. 1946).

The following parameters were calculated for <u>each study area</u>:

Frequency = The number of scats containing a specific food item.

$$\% \text{ Frequency} = \frac{\text{Frequency}}{\text{Total \# of scats}} * 100$$

$$\% \text{ Vol} = \frac{\text{Sum of volumes in all scats for a specific item}}{\text{Total \# of scats}} * 100$$

$$\bar{x} \text{ Vol/Scat} = \frac{\text{Sum of volumes in all scats for a specific item}}{\text{Total \# of scats containing that item}}$$

Forage items were compared individually and by forage categories. Herbaceous matter was classified as graminoids (including sedges, *Carex spp*), forbs (including horsetail, *Equisetum arvense*), shrubs, and cambium. Animal matter included vertebrate and invertebrate remains.

Frequency of occurrence was tested with the log-likelihood ratio following Zar (1984:72) and Koehler and Larntz (1980). Volumes were compared using the Mann-Whitney test.

The effectiveness of scat analysis in determining the presence of cambium in bear diets was assessed by feeding fresh cambium to captive black bears. Douglas-fir cambium was collected (19 May 1992) in a stand containing fresh bear damage in the north area. The cambium, easily separated from the underlying wood, was peeled with a drawknife, wrapped in aluminum foil and plastic to retain moisture, and kept chilled. About 4 kg of cambium was fed to 3 captive black bears at the Washington State University Department of Natural Resource Sciences in Pullman (23 May 1992). Food had been withheld from the bears during the previous 24 hrs. All scats and remaining cambium were collected the following morning. Dry matter digestibility was estimated by oven-drying and weighing subsamples of the scats and cambium.

RESULTS

I collected 61 scats from the north area and 92 scats from the south area during spring, 1987-90 (Table 1). Over 1/2 the scats from each area contained graminoids (Figure 2) and over 1/3 the total volume from each area was composed of graminoids. Because a scat typically contained 2 or more food items, total percent frequency exceeded 100% when summed by forage items or forage categories.

The frequency of forbs was higher in scats from the north area than in scats from the south area (G = 7.16, 1 df, P = 0.007). The most common forbs in scats from both areas were clover (north area: n = 7, 12%; south area: n = 2, 2%) and cow parsnips (north area: n = 3, 5%; south area: n = 9, 10%). Scats from both areas contained low frequencies (≤5%) of many species of forbs. The group "unknown forbs" contained a mix of species and was not dominated by any one forb.

Shrubs, as a category, were used more (G = 15.04, 1 df, P < 0.001) by bears in the south area than bears in the north area. The genus *Rubus* could not be consistently identified to species, but the leaves, stems, and fruit of salmonberry (*Rubus spectabilis*) and the leaves and stems of trailing blackberry (*Rubus ursinus*) seemed to be the species most often eaten by black bears. The *Rubus* genus was identified in more scats from the south area (n = 23 scats, 25%) than in scats from the north area (n = 4 scats, 7%; G = 9.60, 1 df, P = 0.002). Devil's club, the only other shrub to appear in scats from either study area, was also identified more frequently in scats from the south area (n = 23 scats, 25%) than in scats from the north area (n = 8 scats, 13%; G = 3.35, 1 df, P = 0.067). Scats from the south area had a greater volume (21% total volume) of Devil's club (U = 1.95, 1 df, P = 0.051) than scats from the north area (8% total volume) and all scats containing Devil's club from the south area (n = 23) contained berries in addition to stems and leaves, whereas 5 of 8 scats with Devil's club from the north area included berries.

Table 1. Percent frequency (% of scats with item), percent volume (sum of volumes in all scats for a specific item ÷ total number of scats), and average percent volume per scat (sum of volumes in all scats for a specific item ÷ total number of scats with that item) for spring (March - mid-July) foods of black bears from an area with high amounts of timber damage caused by bears feeding on cambium (north) and an area with low amounts of timber damage caused by bears feeding on cambium (south), Central Coast Ranges, Oregon, 1987-90. Items present in trace amounts (<0.5%) are denoted by "t".

	North Study Area (n = 61)			South Study Area (n = 92)		
Forage item	%Freq	% Vol	%Vol/Scat	%Freq	% Vol	%Vol/Scat
GRAMINOIDS	**61**	**38**	**63**	**54**	**37**	**69**
Gramineae	58	37	64	51	35	69
Carex spp	3	2	48	3	2	65
FORBS	**51**	**32**	**62**	**29**	**20**	**66**
Cirsium arvense	2	1	80	2	1	35
Equisetum arvense	5	4	80	2	1	53
Heracleum lanatum	5	5	95	10	9	91
Hypochaeris radicata	--	--	--	1	1	100
Lotus spp	2	t	20	2	2	85
Osmorhiza spp	3	3	100	--	--	--
Ranunculus spp	5	1	22	--	--	--
Rumex spp	--	--	--	1	t	40
Taraxacum officinale	3	2	60	--	--	--
Trifolium repens	12	4	38	2	1	35
Vicia spp	--	--	--	1	1	75
Viola glabella	2	2	100	--	--	--
Unknown forbs	13	9	69	7	4	47
SHRUBS	**20**	**12**	**61**	**50**	**38**	**76**
Oplopanax horridum	13	8	61	25	21	85
Rubus spp	7	4	63	25	17	66
CAMBIUM	**12**	**9**	**78**	**2**	**1**	**50**
ANIMAL MATTER	**23**	**8**	**36**	**17**	**4**	**25**
Formicidae	7	1	14	7	t	4
Hymenoptera	1	t	t	--	--	--
Coleoptera	--	--	--	2	t	4
Small Mammal	8	4	47	5	1	31
Odocoileus hemionus	7	3	49	3	2	48
OTHER	**3**	**1**	**25**	**1**	**t**	**5**
Debris	1	1	30	1	t	5
Bryophyte	2	t	20	--	--	--

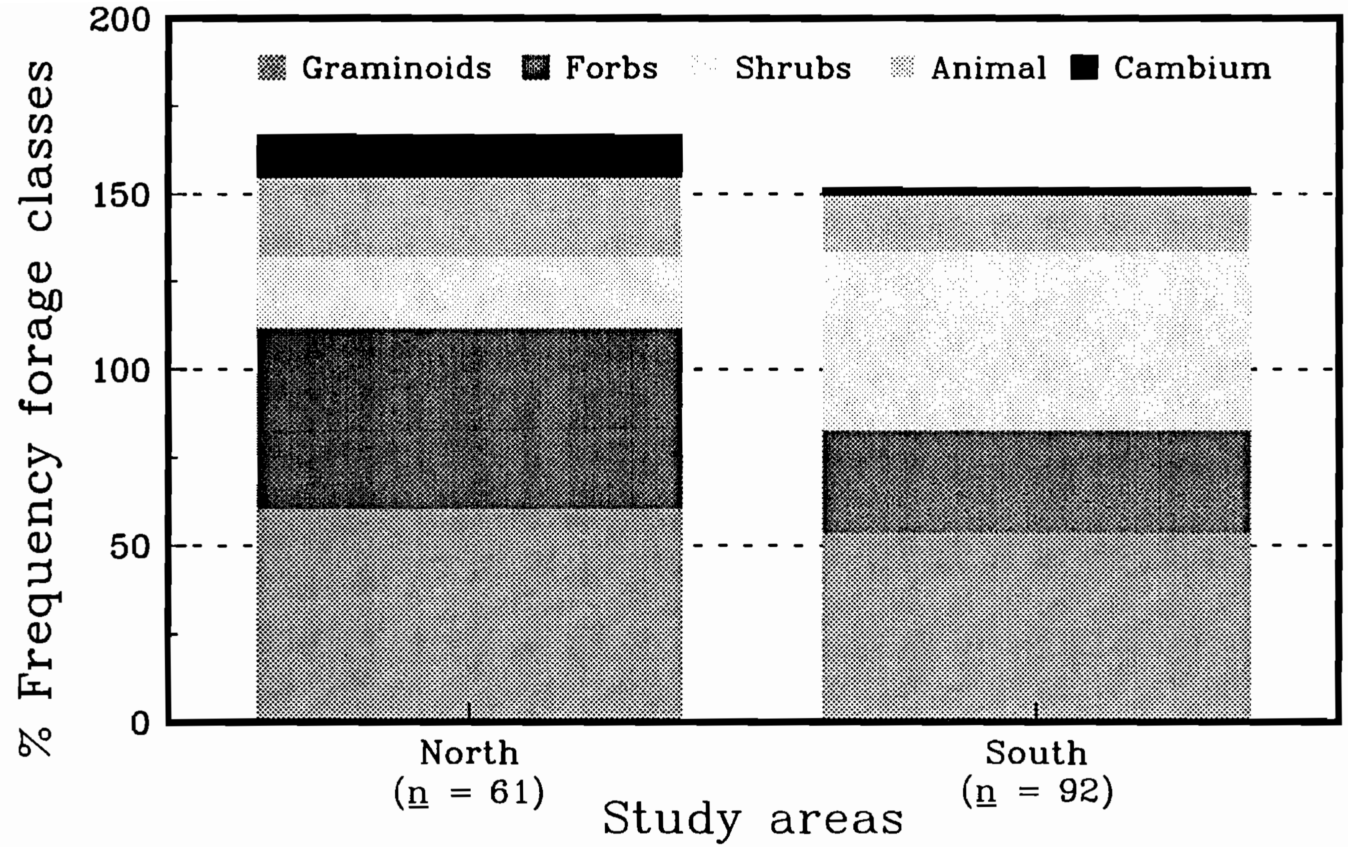

Figure 2. Forage groups identified in black bear scats from an area with high levels of bear damage (north) and an area with low levels of bear damage (south). All scats were collected March - mid-July, Central Coast Ranges, Oregon, 1987-1990.

Cambium was readily identifiable in bear scats. Nearly all the cambium fed to captive bears was consumed. I estimated cambium to be about 50% digestible on a dry matter basis. Passage of feces containing undigested portions of cambium began about 6 hrs after feeding. More scats from the north area had cambium (n = 7 scats, 12%; G = 5.71, 1 df, P = 0.017) than did scats from the south area (n = 2 scats, 2%).

The percent frequency of animal matter was similar between the north (n = 14, 17%) and the south areas (n = 16, 23%). Scats with vertebrate remains from the north area included 4 with black-tailed deer, 3 with microtines, and 2 with unidentified small mammals. Scats with vertebrate remains from the south area included 3 with deer, 1 with porcupine (*Erethizon dorsatum*), 2 with microtines, 1 sciurid, and 1 unidentified mammal.

Invertebrates occurred in 5 (36%) and 8 (50%) of the scats with animal matter in the north and south areas, respectively. Ants were found in 4 scats and wasps (Vespidae) in 1 scat from the north area. Six scats from the south area included ants and 2 scats had beetles (Coleoptera). Samples of ants collected from 3 scats in the south area in 1990 were all identified as *Formica subnuda*. Large diameter galleries exposed in stumps and logs torn open by bears suggest carpenter ants (*Camponotus spp*) were also eaten.

DISCUSSION

The dominance of herbaceous matter, largely graminoids, is typical of spring diets of black bears (Barber 1983:35, Eagle and Pelton 1983, Irwin and Hammond 1985, Schwartz and Franzmann 1991). The primary difference in scat contents between study areas was the use of forbs by bears in the north area versus the use of shrubs by bears in the south area. The evidence from scat analysis suggesting salmonberry and trailing blackberry were the key species of the *Rubus* genus consumed by bears corroborated field observations. The 2 species are among those identified as the most palatable of the *Rubus* genus (Hayes and Garrison 1960:211). Trailing blackberry, the only blackberry native to Oregon, is abundant in clearings, burns, and clearcuts (Hitchcock and Cronquist 1981:225). Salmonberry is common on moist, well drained soils (Viereck and Little 1972:176). Salmonberry responds quickly to canopy removal, reaching heights of 0.6 m in the first year after disturbance, and is the shrub most often associated with Douglas-fir seedling mortality in western Oregon (Hemstrom and Logan 1986:42,50).

The berries, leaves, and stems of Devil's club were important forage items for bears in Oregon. Only bears in Washington have also been described as selecting for Devil's club stems and leaves (Poelker and Hartwell 1973:114). Although Devil's club is a key food for black bears in Alaska (Smith 1984:77, Schwartz and Franzmann 1991:38), the ingestion of plant parts other than berries was reported as incidental (Smith 1984:94). Devil's club has a spotty distribution in west central Oregon, generally occurring on poorly drained, shallow soils and is associated with openings in mature and old-growth forests (Hemstrom and Logan 1986:75, Schwartz and Franzmann 1991:38). Devil's club is sensitive to fire and canopy removal (Viereck and Little 1972:198, Schwartz and Franzmann 1991:38).

Cow parsnips, the most commonly eaten forb in the south area, grows on moist soils and can reach heights >2 m (Gilkey and Dennis 1973:291, Hitchcock and Cronquist 1981:326). Leaves and stems of cow parsnips may contain up to 30% protein (Hamer and Herrero 1983:256). Cow parsnips comprised up to 46% of the spring diet of black bears in northwestern Montana (Tisch 1961:53), but were not reported in the diets of bears in western Washington (Poelker and Hartwell 1973, Barber 1983). Conversely, skunk cabbage (*Lysichitum americanum*), a common forb within both study areas and present in 12-40% of scats examined in 4 food habits studies in western Washington (Poelker and Hartwell 1973:114-116, Barber 1983:35), did not occur in any scats examined here. Likewise, false dandelion (*Hypochaeris radicata*), a common forb that occurred in only 1 scat here, was identified in 12-44% of scats from western Washington (Poelker and Hartwell 1973:115-116, Barber 1983:35).

Protein levels for graminoids peak at about 13-19% and are low in nutritive value for bears (Hamer and Herrero 1983:255). About 1/3 the volume of the diets of bears from both study areas was grasses and sedges. Because of the low digestibility of graminoids, however, scat analysis over-estimates the volume actually ingested (Hewitt 1989). Hewitt (1989) concluded that multiplying the volume of graminoids in bear scats by 0.26 yielded a better estimate of the amount of grass actually ingested, relative to the other diet items. Using this correction factor, less than 10% of the foods eaten by bears in the Coast Ranges were graminoids.

Conversely, highly digestible foods such as animal matter are underrepresented by scat analysis (Hatler 1972, Hewitt 1989). Animal matter is difficult to identify by scat analysis and estimates of the quantity of matter consumed rely on the quantities of hair recovered from the scats. Bears, however, do not consistently remove the hide from a carcass before feeding (Graber and White 1983, Schwartz and Franzmann 1991:36), creating marked variability in the amount of hair present in the scats. This variability precludes establishing a correction factor for large ungulates (Hewitt 1989). In addition, whereas small mammals are usually entirely consumed in 1 feeding period, bears frequently remain in the vicinity of a large carcass for longer periods. Scats containing remains of large mammals are thus concentrated in a limited area, so relatively few scats are deposited once the bear leaves the site (Hamer and Herrero 1983:57). Because most scats in this study were collected on or near roads, scats containing remains of large mammals were probably less likely to be discovered. This high-energy food, therefore, may be underrepresented in the diets described here.

Ants have been identified as important spring/summer forage in virtually every black bear food habits study in North America. Visual and telemetric observations of bears in western Oregon indicate they spend considerable time ripping open stumps and logs and overturning rocks and woody debris in search of insects (pers. observ.). Ants are 55% protein dry matter (Southwood 1973) and colonies of ants are common in the Oregon Coast Ranges wherever adequate nesting substrate is available (Nielsen 1986:93). Rather than eating the largely undigestible adult ants, black bears have been observed selecting for masses of eggs, larvae, and pupae (L. Rogers, wildlife biologist, U.S.D.A. Forest Service, Ely, MN, pers. commun.). The easily digestible larvae and pupae, high in nutritive value, can be identified in stomach samples, but are rarely evident in intestinal or scat samples (Poelker and Hartwell 1973:114, Landers et al. 1979). As spring progresses, maturing vegetation becomes less digestible to bears, most berries are still scarce, and the nutritive content of ants increases (Brian 1970).

Bears nearly always scrapped exposed cambial tissue with their teeth when feeding on cambium (pers. observ.). The large proportion of undigestible wood fiber makes cambium easy to identify in bear scats, contrary to previous assumptions (Raine and Kansas 1989), except where bears peel the bark and lick the exuded cambial saps (Zeedyk 1957, Hennon et al. 1990). Cambium appeared in 2 scats (2%) collected in the south area. Cambium has previously been reported as a minor element in spring diets of black bears in Montana (Tisch 1961:29) and Alaska (Smith 1984:60).

Although cambium is easy to identify in scats, only 7 scats from the north area (12%) contained cambium. Any annual variation in damage levels should have been assuaged by collecting scats during 4 consecutive spring seasons. The apparent discrepancy between the abundance of trees damaged by bears and the low frequency of cambium detected by scat analysis may result from a bias related to most scats being collected near roads. Cambium-feeding bears may also retreat to a localized area to rest between feeding periods. Scats containing cambium would then be concentrated in a limited area in a fashion analogous to bears feeding on large carcasses and therefore less likely to be encountered. I have observed similar behavior for bears feeding on apples in remnants of homesteader's orchards that occur in scattered pockets throughout the Central Oregon Coast Ranges.

Significant differences existed in the use of forbs and shrubs by bears in the north and south areas. Nutritive values of forbs peak during the early portion of the growing season. Forbs lose their nutritive value earlier and the decline occurs more rapidly than in shrubs (Oelberg 1956). In addition to the leaves and shoots of Devil's club and salmonberry retaining their nutritive value, relative to forbs, both species develop berries by mid-May in western Oregon (pers. observ.). Potential differences in protein values identified by blood analysis (Appendix 1) suggested bears from the south area may be in better nutritional condition than bears in the north area. Differences in food selection, including cambium use, may therefore reflect differences in forage availability.

Differences in land ownership may relate to differences in forage availability between study areas. Management practices vary widely among state and federal agencies and private industry (e.g. herbicides were not used on the federally-owned lands in the study areas from 1984-1991). Management activities may have affected the availability of shrubs and influenced the selection of spring foods by bears.

MANAGEMENT IMPLICATIONS

It is assumed that natural selection favors animals that maximize their foraging efficiencies (Krebs and Davies 1984:87). The quality, density, and distribution of food should influence an animal's foraging strategy so that it matches the time spent in an area to the rewards received from that area (Krebs and McCleery 1984). Previous bear research supports this theory (Rogers 1976, Landers et al. 1979, Eagle and Pelton 1983, Maehr and Brady 1984). Providing or retaining patches of abundant quality forage could potentially induce bears to select these foods and avoid generating the concentrations of bears that have occurred around sources of human-related foods (R. Flowers, Washington Forest Protection Association, pers. commun.).

Skid roads and log landings, where tree seedling survival is often reduced due to soil compaction, could be seeded to grasses, clover, and trailing blackberry. Black bears have been observed grazing along roadsides planted with clover (Tisch 1961:28, Poelker and Hartwell 1973:114, Graber and White 1983). Salmonberry can be allowed to reestablish in forage patches. Moist areas producing key forage species (e.g. Devil's club, salmonberry, and cow parsnips) could be left as forage patches. Increased moisture availability can produce more palatable plants (Oelberg 1956, Heady 1964) and many of these sites are prone to soil compaction or erosion during timber harvest activities (Hemstrom and Logan 1986:76).

Given its negative response to fire and canopy removal, maintaining Devil's club may require additional attention. The inherent spotty distribution of this shrub could be coordinated with a management program for snags and green leave trees. Leaving groups of trees around pockets of Devil's club could be tested as a means of providing the necessary canopy within cutting units.

Snag retention, along with stumps and coarse woody debris, would provide nesting habitat for up to 19 species of wood nesting ants that occur in the Central Coast Ranges (Nielsen 1986:i). Availability of nesting substrate may play a key role in determining ant distributions (Nielsen 1986:47, Schwartz and Franzmann 1991:35). In the Central Oregon Coast Ranges, numbers of ant nests increased more than 10-fold in areas receiving direct solar radiation versus forest floors beneath closed canopies (Nielsen 1986:35). Ants colonized sites 6-12 months after opening or removal of canopy cover (Nielsen 1986:92). Snags and coarse woody debris in open forage patches would aid in maintaining foraging substrate for bears as ant colonies decline under surrounding forest canopies. Perpetuating ant colonies in forest stands can also provide substantial insect pest control (Campbell and Torgersen 1982, Takekawa et al. 1982, Carlson et al. 1984, Langelier and Garton 1986).

Maintaining pockets of forage when a stand is regenerated would provide quality foods years before the trees become vulnerable to bears. Bears causing high levels of damage may prefer the concentrated carbohydrates in cambial tissue to alternate forage. Nevertheless, patches of known seasonal bear foods may reduce both the numbers of bears that feed on cambium and the amount of cambium consumed by those bears that continue to exploit trees as food. It is unlikely that providing pockets of forage would, in itself, replace lethal bear damage control efforts. Rather, integrating patches of quality forage in forest stands could supplement damage control activities, potentially increasing their effectiveness while decreasing the loss of bears. As damage-causing bears are removed from the population, the availability of nutritious forage may also reduce the likelihood of new bears using trees as spring food. Identifying the optimum size and density of forage patches and their relationship to damage patterns requires investigation.

LITERATURE CITED

Barber, K. R. 1983. Use of clearcut habitats by black bears in the Pacific Northwest. M.S. Thesis, Utah State Univ., Logan. 169pp.

Brian, M. V. 1970. Measuring population and energy flow in ants and termites. Pages 231-234 in J. Phillipson, ed. Methods of Study in Soil Ecology. UNESCO, Paris.

Campbell, R. W., and T. R. Torgersen. 1982. Some effects of predaceous ants on western spruce budworm pupae in north central Washington. Environ. Entomol. 11:111-114.

Carlson, C. E., R. W. Campbell, L. J. Theroux, and T. H. Egan. 1984. Ants and birds reduce western spruce budworm feeding injury to small Douglas-fir and western larch in Montana. For. Ecol. and Manage. 9:185-192.

Eagle, T. C., and M. R. Pelton. 1983. Seasonal nutrition of black bears in the Great Smoky Mountains National Park. Int. Conf. Bear Res. and Manage. 5:94-101.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. U.S. Dep. of Agric. For. Serv., Gen. Tech. Rpt. PNW-8. 417pp.

Fritz, E. 1951. Bear and squirrel damage to young redwoods. J. For. 49:651-652.

Gilkey, H. M., and L. J. Dennis. 1973. Handbook of northwestern plants. Oregon State Univ. Bookstores, Inc., Corvallis. 505pp.

Glover, F. A. 1955. Black bear damage to redwood reproduction. J. Wildl. Manage. 19:437-43.

Gourley, M., and M. Vomocil. 1987. Public involvement in a black bear damage control program on private land. Pages 149-153 in D. M. Baumgartner, R. L. Mahoney, J. Evans, and D. W. Breuer, Symp co-chairs. Animal Damage Management in Pacific Northwest Forests. Washington State Univ. Press, Pullman.

Graber, D. M., and M. White. 1983. Black bear food habits in Yosemite National Park. Int. Conf. Bear Res. and Manage. 5:1-10.

Hamer, D., and S. Herrero. 1983. Ecological studies of the grizzly bear in Banff National Park. Parks Canada Contract WR 4-80. Univ. of Calgary, Alberta. 303pp.

Hatler, D. F. 1972. Food habits of black bears in interior Alaska. Can. Field-Nat. 86:17-31.

Hayes, D. W., and G. A. Garrison. 1960. Key to important woody plants of Oregon and Washington. U.S. Dep. of Agric. For. Serv. Handbook No. 148. 227pp.

Heady, H. F. 1964. Palatability of herbage and animal preference. J. Range Manage. 17:76-82.

Hemstrom, M. A., and S. E. Logan. 1986. Plant association and management guide, Siuslaw National Forest. U.S. Dep. Agric. For. Serv. PNW-Reg. R6-Ecol. 220-1986a. 121pp.

Hennon, P. E., E. M. Hansen, and C. G. Shaw III. 1990. Causes of basal scars on Chamaecyparis nootkatensis in Southeast Alaska. Northwest Sci. 64:45-54.

Hewitt, D. G. 1989. Correcting grizzly bear fecal analysis to observed food habits. M.S. Thesis, Washington State Univ., Pullman. 20pp.

Hitchcock, C. L., and A. Cronquist. 1981. Flora of the Pacific Northwest. Univ. of Wash. Press, Seattle, WA. 730pp.

Irwin, L. L., and F. M. Hammond. 1985. Managing black bear habitats for food items in Wyoming. Wildl. Soc. Bull. 13:477-483.

Koehler, K. J., and K. Larntz. 1980. An empirical investigation of goodness-of-fit statistics for sparse multinomials. J. Am. Stat. Assoc. 75:336-344.

Krebs, J. R., and N. B. Davis, editors. 1984. Behavioral ecology, an evolutionary approach. Sinauer Assoc., Publ., Sunderland, Mass. 493pp.

_____, and R. H. McCleery. 1984. Optimization in behavioral ecology. Pages 91-121 in J. R. Krebs and N. B. Davies eds. Behavioral Ecology, an Evolutionary Approach. Sinauer Assoc., Publ., Sunderland, Mass.

Landers, J. L., R. J. Hamilton, A. S. Johnson, and R. L. Marchinton. 1979. Foods and habitat of black bears in southeastern North Carolina. J. Wildl. Manage. 43:143-153.

Langelier, L. A., and E. O. Garton. 1986. Management guidelines for increasing populations of birds that feed on western spruce budworm. U. S. Dep. of Agric. For. Serv. Handbook No. 653. 19pp.

Lauckhart, J. B. 1955. The effect of logging old-growth timber on bear. Soc. Am. For. Proc. 54:128-130.

Lutz, H. J. 1951. Damage to trees by black bears in Alaska. J. For. 49:522-533.

Maehr, D. S., and J. R. Brady. 1984. Food habits of Florida black bears. J. Wildl. Manage. 48:230-235.

Martin, A. C., R. H. Gensch, and C. P. Brown. 1946. Alternative methods in upland gamebird food analysis. J. Wildl. Manage. 10:8-12.

Maser, C. 1967. Black bear damage to Douglas-fir in Oregon. Murrelet 48:34-38.

Nelson, E. E. 1989. Black bears prefer urea-fertilized trees. West. J. Appl. For. 4:13-15.

Nielsen, G. R. 1986. The spatial distribution of wood-nesting ants. Ph.D. thesis, Oregon State Univ., Corvallis. 102pp.

Oelberg, K. 1956. Factors affecting the nutritive value of range forage. J. Range Manage. 9:220-225.

Poelker, R. J., and H. D. Hartwell. 1973. Black bear of Washington. Washington State Game Dep. Bull. 14. 180pp.

Raine, R. M., and J. L. Kansas. 1989. Black bear seasonal food habits and distribution by elevation in Banff National Park, Alberta. Int. Conf. Bear Res. and Manage. 8:297-304.

Rogers, L. L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. Trans. North Am. Wildl. and Nat. Resour. Conf. 41:431-438.

Schwartz, C. C., and A. W. Franzmann. 1991. Interrelationship of black bears to moose and forest succession in the northern coniferous forest. Wildl. Monogr. No. 113. 58pp.

Smith, P. A. 1984. Kenai black bears and cranberries: bear food habits and densities. M.S. Thesis. Univ. of Alaska, Fairbanks. 144pp.

Southwood, T. R. E. 1973. The insect/plant relationship--an evolutionary perspective. Symp. R. Entomol. Soc. London 6:3-30.

Takekawa, J. Y., E. O. Garton, and L. A. Langelier. 1982. Biological control of forest insect outbreaks: The use of avian predators. Trans. North Am. Wildl. and Nat. Res. Conf. 47:393-409.

Tisch, E. L. 1961. Seasonal food habits of the black bear in the Whitefish Range of northwestern Montana. M.S. Thesis, Montana State Univ., Missoula. 108pp.

Viereck, L. A., and E. L. Little, Jr. 1972. Alaska trees and shrubs. U.S. Dep. Agric. For. Serv. Handbook No. 410. 265pp.

Zar, J. H. 1984. Biostatistical analysis. Second ed. Prentice-Hall, Inc. Engelwood Cliffs, N.J. 718pp.

Zeedyk, W. D. 1957. Why do bears girdle balsam-fir in Maine? J. For. 55:731-732.

CHAPTER III

COMPARISON OF FOREST STANDS DAMAGED BY BLACK BEARS AND FOREST STANDS WITHOUT DAMAGE BY BLACK BEARS

ABSTRACT

I investigated damage to Douglas-fir (*Pseudotsuga menziesii*) by black bears (*Ursus americanus*) feeding on cambium in the Central Oregon Coast Ranges in 1989-90. Forested stands (n = 80) with dominant trees ranging from 10-50 cm dbh were surveyed in 2 adjacent areas: one area reportedly contained high levels of bear damage (north area) and one area was thought to have incurred little or no bear damage (south area). Overall site characteristics differed between stands classified by the presence or absence of bear damage (F for Wilk's λ = 2.62, 11,68 df, P = 0.008). Forest stands with bear damage (n = 33) had lower densities of trees >40 cm dbh (F = 5.97, 1,78 df, P = 0.017), lower total basal area (F = 4.92, 1,78 df, P = 0.030), occurred on slopes less steep (F = 3.80, 1,78 df, P = 0.055), and differed by aspect (F = 5.48, 1,78 df, P = 0.022) compared to stands without bear damage (n = 47). Forest stands had a random distribution of aspects when examined by total sample (n = 80), study area (n = 40 for each area), and all stands without bear damage. Only stands with bear damage had a non-random distribution of aspects ($\bar{a}$ = 31°; χ^2 = 10.5, k = 5, 4 df, P < 0.05). Damaged trees averaged 22 cm (± 0.98 SE) dbh whereas undamaged trees averaged 16 cm (± 0.95) dbh within stands containing bear damage (U = 4.23, 1 df, P = 0.0001). Bears fed on trees <10 cm dbh less than available (χ^2 = 65, 3 df, P < 0.005), trees 11-20 cm dbh in a ratio equal to their availability, and bears selected for trees 21-30 cm dbh (χ^2 = 73, 3 df, P < 0.005). Most damage (91%) occurred on trees 11-30 cm dbh. Bears damaged from

7-185 trees/ha ($\bar{x}$ = 39 ± 7.7) and 19% of the trees damaged were completely girdled. Measured site characteristics were poor predictors of a stand's potential vulnerability to damage by bears. Measurements of tree vigor and related carbohydrate production may provide better estimators of future vulnerability of a stand to bear damage.

INTRODUCTION

Damage to trees by black bears has been an ongoing problem in the central west coastal region of North America since at least the 1940's (Lutz 1951, Glover 1955, Lauckhart 1955). "Bear damage" typically consists of bears peeling bark off the basal portion of trees to feed on cambium. Using cambial tissues as food is distinct from simply marking trees, which, it has been hypothesized, serves as a form of social communication among bears (Burst and Pelton 1983). Cambium is used here in broad terms, referring to the cell-producing system and the derivatives forming the wood (xylem) and inner-bark (phloem) of trees (Bannon 1962, Wilson 1964). Bears have reportedly damaged over 40% of the trees in some stands (i.e., aggregations of trees sufficiently uniform in age, size, and condition as to be distinguishable from adjoining areas) while feeding on cambium (Childs and Worthington 1955, Molnar and McMinn 1960, Maser 1967). Bears select conifer species and display an interspecies preference that varies by region (Lauckhart 1955, Poelker and Hartwell 1973, Mason and Adams 1989). Bears also exhibit an intraspecies preference, feeding on the more vigorous or open-grown trees (Fritz 1951, Nelson 1989, Schmidt 1989). Generally, 10- to 40-year-old stands of regenerated forests receive the most damage (Lawrence et al. 1961, Poelker and Hartwell 1973, Nelson 1989) and lower densities of trees are consistently linked to increased levels of damage (Poelker and Hartwell 1973, Schmidt 1989, Mason and Adams 1989).

In the early 1980's, increasing amounts of bear damage were discovered in the North Fork Alsea River Drainage in the Central Coast Ranges of western Oregon (Gourley and Vomocil 1987). Little or no damage was known to exist in the neighboring South Fork Alsea River Drainage. My objectives were to quantify damage levels in the North and South Fork Alsea River drainages, measure and characterize trees damaged by bears, and determine whether site characteristics could be used to predict vulnerability of a stand to future bear damage.

STUDY AREAS

I selected 2 adjacent areas, each about 500-km^2 (Figure 1), in the Central Coast Ranges of western Oregon. The north area was within a region identified by local resource managers as sustaining high levels of bear damage and the south area was within a region identified as sustaining low levels of bear damage. Both areas were within the western hemlock (*Tsuga heterophylla*) vegetation zone and were dominated by subclimax Douglas-fir (*Psuedotsuga menziesii*) (Franklin and Dyrness 1973). Annual precipitation exceeded 200 cm, most of which occurred during winter and spring; the mean minimum January temperature is -1 C and the mean maximum July temperature is 27 C (NOAA 1985:1488). Snow is infrequent and ephemeral, generally lasting only a few days except on the higher peaks and ridges (Hemstrom and Logan 1986). Topography is steep and highly dissected with elevations ranging from 15-1,250 m. Based on interviews with land managers in the region, forests within the study areas have usually been regenerated by clearcutting on 40- to 80-year rotations and planted with nursery stock. Densities of black bears seemed similar between study areas, as indicated by the results from: efforts to capture bears with foot-snares during spring, 1988; operation of a scent station program during the springs of 1988-89; and driving established survey routes in both study areas with hounds trained to recognize bear scent (unpubl. data).

METHODS

Data Collection

I defined forested stands vulnerable to bear damage as having dominant trees ranging from 10-50 cm dbh, based on minimum and maximum-sized trees damaged by bears that I observed during previous field work within the study areas. Forty random points were generated for each study area and plotted on 1:24000 topographic maps. Stands closest to these points with dominant trees ranging from 10-50 cm dbh were identified using aerial photos and stand-age maps. Eighty stands were surveyed between 6 Nov 1989 and 14 March 1990. Observations of bear damage were not dated to time of occurrence and, therefore, represent all damage incurred to date.

Stands were sampled with forty 40-m^2 (0.01-ac) circular plots organized at 10 m intervals along 100 m long transects. Transects were arranged in 4 parallel lines 25 m apart. Stand shape would, on occasion, force slight modifications, but distances between plots and between transects remained consistent. Slope and aspect, measured in degrees, were recorded at the beginning, middle and end of each transect and averaged to produce stand means (Batschelet 1965:12-13).

All trees (woody plants having 1 well defined stem and attaining breast height) >2 cm dbh within the 40-m^2 plots were identified by species and assigned to dbh size-classes: <10 cm, 11-20 cm, 21-30 cm, 31-40 cm, and >40 cm. The dbh and area peeled were measured on trees with bear damage. Percent of bole circumference damaged was estimated using 6 classes: 1-10%, 11-25%, 26-50%, 51-75%, 76-99%, and 100%.

Given the suspected patchy distribution of bear damage within a stand, I evaluated the effectiveness of 40-m^2 plots in registering or missing trees damaged by bears by recording the presence or absence of damaged trees along the length of each transect. While pacing the 10 m between plots, 2 observers maintained a maximum distance apart that allowed a full view of the bole circumference of all trees along the transect. A tally--subdivided by species, presence/absence of bear damage, and whether or not damaged trees were girdled--was kept for trees examined along these variable-width transects. Varying the width allowed us to maximize the number of trees examined while gauging the effectiveness of the circular plots.

Variability in record keeping by landowners/managers prohibited the inclusion of basic stand-history information such as age of trees, type of stock planted, herbicide use, etc.

Statistical Analyses

All references to comparisons between study areas represent my original intent (i.e., *a priori*) regarding study design. It became apparent during the analysis (*a posteriori*), however, that classifying forest stands by the presence or absence of bear damage was more efficacious in the identification of potential relationships between site characteristics and bear damage.

The information recorded in the 40-m^2 plots was averaged to produce means for each stand, generally expressed as per ha values. I estimated total basal area (ba; measured outside the bark) for each stand based on the mid-point value of each diameter class (Daubenmire 1968). Some variables were transformed to meet the assumption of equal variance for parametric tests (Table 2).

I compared the amount of bear damage between study areas in terms of the number of stands with bear damage and total numbers of trees damaged by bears. Damaged and undamaged stands were compared with the log-likelihood ratio test and the numbers of damaged trees were compared with a Mann-Whitney test.

Mean aspects were calculated for each stand using circular statistics (Batschelet 1965:11). Mean stand aspects were grouped together (n = 80), grouped by study area (n = 40 per study area), and by the presence (n = 33) and absence (n = 47) of bear damage. Each grouping was tested for random distribution using 5 equidistant

Table 2. Transformations for forest stand site characteristics used to test between study areas and between stands with and stands without bear damage, Central Coast Ranges, Oregon, 1989-90.

Parameter	Transformation
Douglas-fir/ha <10 cm dbh	Square root(Douglas-fir/ha <10 cm dbh)
Douglas-fir/ha 11-20 cm dbh	None
Douglas-fir/ha 21-30 cm dbh	Log(Douglas-fir/ha 21-30 cm dbh)
Douglas-fir/ha 31-40 cm dbh	Log(Douglas-fir/ha 31-40 cm dbh)
Douglas-fir/ha >40 cm dbh	Log(Douglas-fir/ha >40 cm dbh)
Total Douglas-fir/ha	None
Total basal area/ha	None
$\bar{x}$ Overall dbh	None
Aspect	Cos(aspect); Sin(aspect)
$\bar{x}$ Slope	Log($\bar{x}$ slope)
$\bar{x}$ Elevation	Log($\bar{x}$ elevation)
$\bar{x}$ % Deciduous trees	Log[(% deciduous trees)/ 1-(% deciduous trees)]

subdivisions of the unit circle (Batschelet 1965:25-26); mean aspects within individual subdivisions of the unit circle were tested for significance (Byers et al. 1984). A second-order mean aspect was calculated for non-uniform circular distributions (Zar 1984:434-435). Aspect was converted to sine and cosine values when tested with linear multivariate statistics.

Trees damaged by bears were compared with undamaged trees within stands containing bear damage. Mean dbh of all trees damaged by bears was compared with mean dbh of all undamaged trees with a Mann-Whitney test. Use and availability of Douglas-fir was assessed by dbh size-class (Neu et al. 1974); dbh size-classes 31-40 cm and >40 cm were combined to ensure adequate sample size (Zar 1984:49). Individual size-classes were tested for significance with Bonferroni confidence intervals (Byers et al. 1984).

Site characteristics were compared with Multivariate Analysis of Variance (MANOVA) and classified by study area ($\underline{n}_1$ = 40, $\underline{n}_2$ = 40) and by presence ($\underline{n}$ = 33) or absence ($\underline{n}$ = 47) of damage. Stands with bear damage were further explored by comparing site characteristics between levels of bear damage with a Wilcoxon Rank-Sum test. Light to moderate bear damage was defined as ≤25 trees damaged/ha (≤10 trees/ac) and heavy bear damage were defined as >25 trees damaged/ha (D. R. Jessup, Control of the western black bear in northwest Oregon for the reduction of damage to forest trees resulting from bark peeling by bears, Oregon Forest Protection Association, Portland, 1970). Stand average dimensional relationships were displayed using density management diagrams for coast Douglas-fir (Long et al. 1988).

Regression analyses were used to test whether site characteristics could be used to assess a stand's potential vulnerability to bear damage. Logistic regression was used to test whether site characteristics could predict the probability of future bear damage. Stepwise multiple regression was used to investigate whether site characteristics could predict what proportion of a stand might be damaged. Only stands with bear damage were tested with multiple regression, using the density of damaged trees as the dependent variable. Variables with a correlation coefficient having a probability of occurring by chance alone of $P < 0.05$ were not included in the models to avoid problems of collinearity (Zar 1984:338). I used P-values to evaluate the strength of a relationship between variables rather than the actual correlation coefficients because the significance of a correlation coefficient is a function of the magnitude of the correlation and sample size (Cody and Smith 1987:71). Multiple regression equations were evaluated by assessing the adjusted r^2 (the proportion of variance in damaged Douglas-fir explained by the variance in the independent variables).

RESULTS

We examined 29,609 trees along variable-width transects while surveying 80 stands. Stands, on average, consisted of 84% Douglas-fir, 6.5% red alder, 4% western hemlock, 2% bigleaf maple (*Acer macrophyllum*), 1% bitter cherry (*Prunus emarginata*), 1% golden chinkapin (*Castanopsis chrysophylla*), ≈0.5% Oregon white oak (*Quercus garryana*), and 1% other conifers (western red cedar (*Thuja plicata*), noble fir (*Abies procera*), grand-fir (*Abies grandis*), Sitka spruce (*Picea sitchensis*), and Pacific yew (*Taxus brevifolia*)). We encountered 540 trees (1.8%) damaged by bears along the variable-width transects: 529 Douglas-fir, 10 hemlock, and 1 red alder. Bears completely girdled 108 Douglas-fir (20.4% of damaged and 0.4% of total Douglas-fir) and 1 hemlock (10% of damaged and 0.9% of total hemlock). Bear-damaged trees seemed to have a patchy distribution within apparently homogeneous stands of timber.

Because 84% of total trees and 98% of damaged trees were Douglas-fir, the remaining analyses deal only with Douglas-fir. We individually examined and measured 10,874 Douglas-fir in 3,200 plots, from which mean values for 10 site characteristics (= 11 variables with aspect expressed as sine and cosine) were calculated for each stand. Bears damaged 207 Douglas-fir (1.9%), completely girdling 39 of them (19% of damaged and 0.4% of total Douglas-fir) (Table 3). An average of 16.1 trees were damaged per ha across the combined study areas (≈1,000 km^2). The south study area had fewer stands containing damage ($\underline{n}_S = 6$ vs $\underline{n}_N = 27$; $\underline{G} = 24.18$, 1 df, $\underline{P} < 0.001$) and a lower density of damaged trees per ha ($\underline{\bar{x}}_S = 2.7$ vs $\underline{\bar{x}}_N = 29.4$; $\underline{U} = -4.89$, 1 df, $\underline{P} = 0.0001$) than the north area.

Correlation analysis revealed strong multicollinearity (Appendix 3). Stand values for total ba and overall average dbh (i.e., average of all dbh size-classes combined) were correlated with individual dbh

Table 3. Percent of tree circumference peeled by black bears for Douglas-fir damaged in the Central Coast Ranges, Oregon, 1989-90.

Circumference class damaged	South study area	North study area	Total	% Total
1 - 10	7	29	36	17.4
11 - 25	1	42	43	20.8
26 - 50	2	45	47	22.7
51 - 75	2	31	33	15.9
76 - 99	2	7	9	4.4
100	3	36	39	18.8
	17	190	207	100.0

size-classes ($0.0001 \le P \le 0.17$). Average density of Douglas-fir damaged by bears was correlated with density of trees 11-20 cm dbh ($P = 0.07$). Negative correlations were implied between average density of Douglas-fir damaged by bears and densities of trees >30 cm dbh, overall average dbh, and total ba for each stand.

My *a priori* intention of determining whether site characteristics were useful in predicting future bear damage was to compare average stand values of site characteristics between study areas (Table 4). The overall hypothesis of no difference between stands classified by study area was not rejected (F for Wilk's λ = 1.10, 11,68 df, $P = 0.39$). Log(slope) was the only site characteristic to differ ($F = 4.35$, 1,78 df, $P = 0.040$) between study areas.

The *a posteriori* use of site characteristics to identify conditions vulnerable to bear damage consisted of stands grouped by the presence or absence of bear damage (Table 5). Stands with damage (33) were comprised of 27 stands from the north area and 6 stands from the south area. Stands without damage (47) included 13 north area stands and 34 south area stands. The hypothesis of no difference between stands with and stands without bear damage was rejected (F for Wilk's λ = 2.62, 11,68 df, $P = 0.008$). Site characteristics that differed between groups were Log(density of trees >40 cm dbh) (F = 5.97, 1,78 df, $P = 0.017$), total ba ($F = 4.92$, 1,78 df, $P = 0.030$), cosine of the aspect ($F = 5.48$, 1,78 df, $P = 0.022$), and Log(slope) (F = 3.80, 1,78 df, $P = 0.055$).

To test the effectiveness of site characteristics in predicting the vulnerability of a stand to future bear damage, stepwise logistic regression selected the variables Log(density of trees >40 cm dbh), cos(aspect), and Log(slope) yielding a correct classification rate of 68.7% (Table 6). Stands were correctly classified 70% of the time by not using the stepwise function and adding the variables Log(density of trees 21-30 cm dbh) and Log(density of trees 31-40 cm dbh).

Table 4. Summary statistics for site characteristics measured in stands of Douglas-fir (PSME) from adjacent north (n = 40) and south (n = 40) study areas with ANOVA test statistics[a], Central Coast Ranges, Oregon, 1989-90.

	North study area		South study area			
Variable	Min/Max	Mean ± SE	Min/Max	Mean ± SE	F	Prob > F
PSME <10 cm dbh/ha	6/1710	304 ± 58	6/988	203 ± 37	1.85	0.178
PSME 11-20 cm dbh/ha	68/877	363 ± 37	25/902	312 ± 34	0.98	0.324
PSME 21-30 cm dbh/ha	0/556	152 ± 21	0/476	185 ± 20	0.22	0.640
PSME 31-40 cm dbh/ha	0/309	53 ± 13	0/252	72 ± 13	0.90	0.345
PSME >40 cm dbh/ha	0/111	10 ± 4	0/185	24 ± 7	1.43	0.236
Total ba/ha (m^2)	2.8/70	22.5 ± 2.4	1.7/71.1	28.1 ± 3.0	2.11	0.150
$\bar{x}$ dbh/Stand (cm)	6/30	17 ± 1	6/31	19 ± 1	2.45	0.121
% Deciduous Trees	0/49	10 ± 2	0/44	12 ± 2	1.75	0.189
$\bar{x}$ Slope (°)	10/40	25 ± 1	15/55	30 ± 2	4.35	0.040
Elevation (m)	110/850	400 ± 28	150/790	350 ± 25	0.92	0.340
Cosine(aspect)	---	---	---	---	2.40	0.126

[a]Test statistics based on transformed variables defined in Table 2.

Table 5. Summary statistics for site characteristics measured in stands of Douglas-fir (PSME) with bear damage (n = 33) and stands of Douglas-fir without bear damage (n = 47) with ANOVA test statistics[a], Central Coast Ranges, Oregon, 1989-90.

	Stands with damage		Stands without damage			
Variable	Min/Max	Mean ± SE	Min/Max	Mean ± SE	F	Prob > F
PSME <10 cm dbh/ha	6/1710	291 ± 64	6/1008	227 ± 38	0.65	0.423
PSME 11-20 cm dbh/ha	68/877	345 ± 40	25/902	332 ± 33	0.36	0.553
PSME 21-30 cm dbh/ha	0/476	166 ± 21	0/556	170 ± 20	0.48	0.491
PSME 31-40 cm dbh/ha	0/309	40 ± 12	0/252	79 ± 13	0.00	0.950
PSME >40 cm dbh/ha	0/62	5 ± 2	0/185	26 ± 6	5.97	0.017
Total ba/ha (m^2)	2.8/51.6	20.3 ± 1.9	1.7/71.1	28.8 ± 2.9	4.92	0.030
$\bar{x}$ dbh/stand (cm)	6/27	16 ± 1	6/31	19 ± 1	2.17	0.150
% Deciduous trees	0/49	10 ± 2	0/44	11 ± 2	0.01	0.910
$\bar{x}$ slope (°)	10/40	23 ± 1	10/55	28 ± 1	3.80	0.055
Elevation (m)	150/850	390 ± 25	110/790	360 ± 26	1.37	0.245
Cosine (aspect)	---	---	---	---	5.48	0.022

[a]Test statistics based on transformed variables defined in Table 2.

Table 6. Analysis of maximum likelihood estimates for stepwise logistic regression parameters Log(Douglas-fir 21-30 cm dbh), Log(Douglas-fir 31-40 cm dbh), Log(Douglas-fir >40 cm dbh), Cosine(aspect), and Log(slope), regressed on presence/absence of bear damage in 80 forest stands, Central Coast Ranges, Oregon, 1989-90.

Model		Parameter estimate	Wald χ^2	Prob > χ^2	Correct classification	Sensitivity[a]	Specificity[b]
Eq 1	Intercept	1.118 ±0.43	6.70	0.009	68.7%	78.7%	54.5%
	Log(40+)	0.023 ±0.01	4.80	0.028			
	Cos(asp)	-1.052 ±0.50	4.35	0.037			
Eq 2	Intercept	-2.639 ±2.37	1.24	0.266	70.0%	80.9%	54.5%
	Log(21-30)	-0.021 ±0.02	1.24	0.266			
	Log(31-40)	-0.014 ±0.01	1.24	0.265			
	Log(40+)	0.034 ±0.01	7.38	0.007			
	Cos(asp)	-1.049 ±0.53	3.91	0.048			
	Log(slope)	1.221 ±0.74	2.70	0.100			

[a]Sensitivity = proportion of stands with timber damage caused by bears predicted to contain damage.

[b]Specificity = proportion of stands without timber damage caused by bears predicted to be free of damage.

Site characteristics were ineffectual at predicting what proportion of a stand might be damaged in the future. The response variable, densities of Douglas-fir damaged by bears, limited the dataset to only those stands receiving bear damage (n = 33). Multicollinearity limited the selection to ≤ 5 independent variables. All equations produced adjusted r^2 values less than 0.15.

Twenty of 33 stands with bear damage had light to moderate damage levels (11.6 ± 1.3 trees/ha) and 13 stands had heavy damage levels (81.4 ± 12.4 trees/ha). A relative increase in percentage of trees completely girdled occurred as numbers of damaged trees increased (13% ± 0.1 vs 20% ± 0.1; Wilcoxon scores: Z = 2.36, P = 0.02). Stands without bear damage had a wide range of stand density index (SDI) values; 32 of 33 stands with damage, however, had a SDI < 300 (Figure 3).

The mean dbh of damaged trees was larger than the mean dbh of undamaged trees within stands containing bear damage (U = 4.23, 1 df, P = 0.0001) (Table 7). Most trees damaged by bears (91%) ranged from 11-30 cm dbh (Figure 4). Use of trees differed from their availability (χ^2 = 141, 4 df, P < 0.001). Trees <10 cm dbh were used less than available (χ^2 = 65, 3 df, P < 0.005) and trees 21-30 cm dbh were used more than (χ^2 = 73, 3 df, P < 0.005) available. The 11-20 cm dbh size-class alone accounted for 50-55% of all trees damaged whether stands were classified by study area, level of damage, or all stands containing damage.

Mean aspects for all stands containing bear damage exhibited a non-random distribution (χ^2 = 10.5, k = 5, 4 df, 0.025 < P < 0.05). The second-order mean aspect (grand mean) for stands with bear damage was $\bar{a}$ = 31° (Figure 5). Bonferroni confidence intervals, based on 5 equidistant subdivisions of the unit circle, identified stands with west southwest aspects (216°-288°) as damaged less than would be expected by chance alone. Mean aspects were uniformly distributed

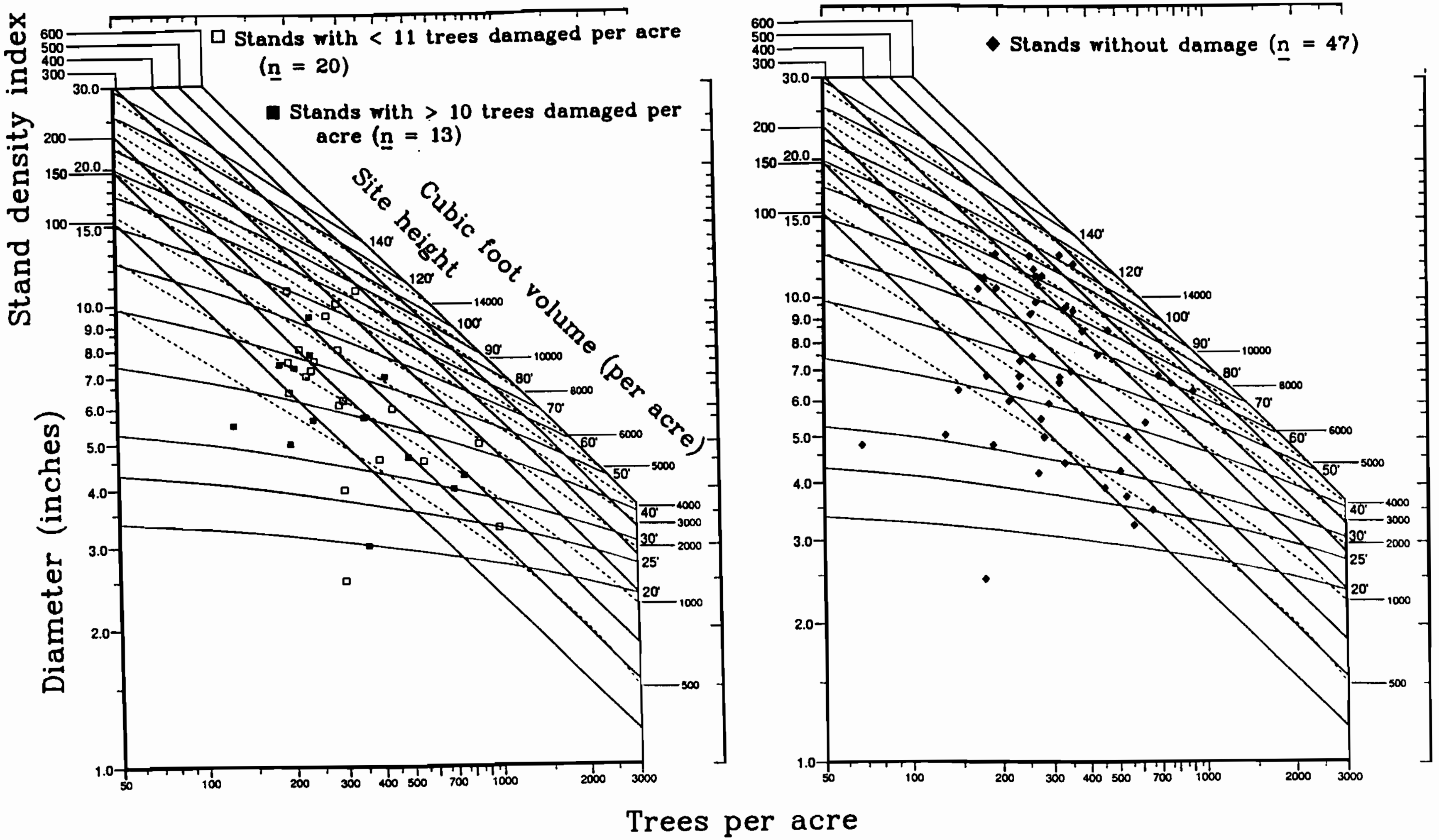

Figure 3. Relationships of coast Douglas-fir stand structure (after Long et al. 1988) and presence or absence of bear damage, Central Coast Ranges, Oregon, 1989-90.

Table 7. Characteristics of Douglas-fir trees (n = 207) damaged by black bears (DPSME) from 33 forest stands in the Central Coast Ranges, Oregon, 1989-90.

Parameter	Min/Max	Mean	SE
DPSME/ha	2/185	38.9	7.7
DPSME/ha <10 cm dbh	0/18	0.6	0.6
DPSME/ha 11-20 cm dbh	0/111	17.6	5.3
DPSME/ha 21-30 cm dbh	0/74	17.8	3.7
DPSME/ha 31-40 cm dbh	0/18	2.2	0.8
DPSME/ha >40 cm dbh	0/6	0.6	0.3
$\bar{x}$ stand dbh UPSME[a] (cm)	6/27	16	0.9
$\bar{x}$ stand dbh DPSME (cm)	12/33	22	1.0
$\bar{x}$ % of circumference peeled	5/100	43	4.3
% of DPSME girdled	0/100	19	7.2
No. of DPSME/ha girdled	0/31	7.3	1.7
$\bar{x}$ surface area peeled (m^2)	0.0/1.1	0.4	0.1

[a]UPSME = Undamaged Douglas-fir.

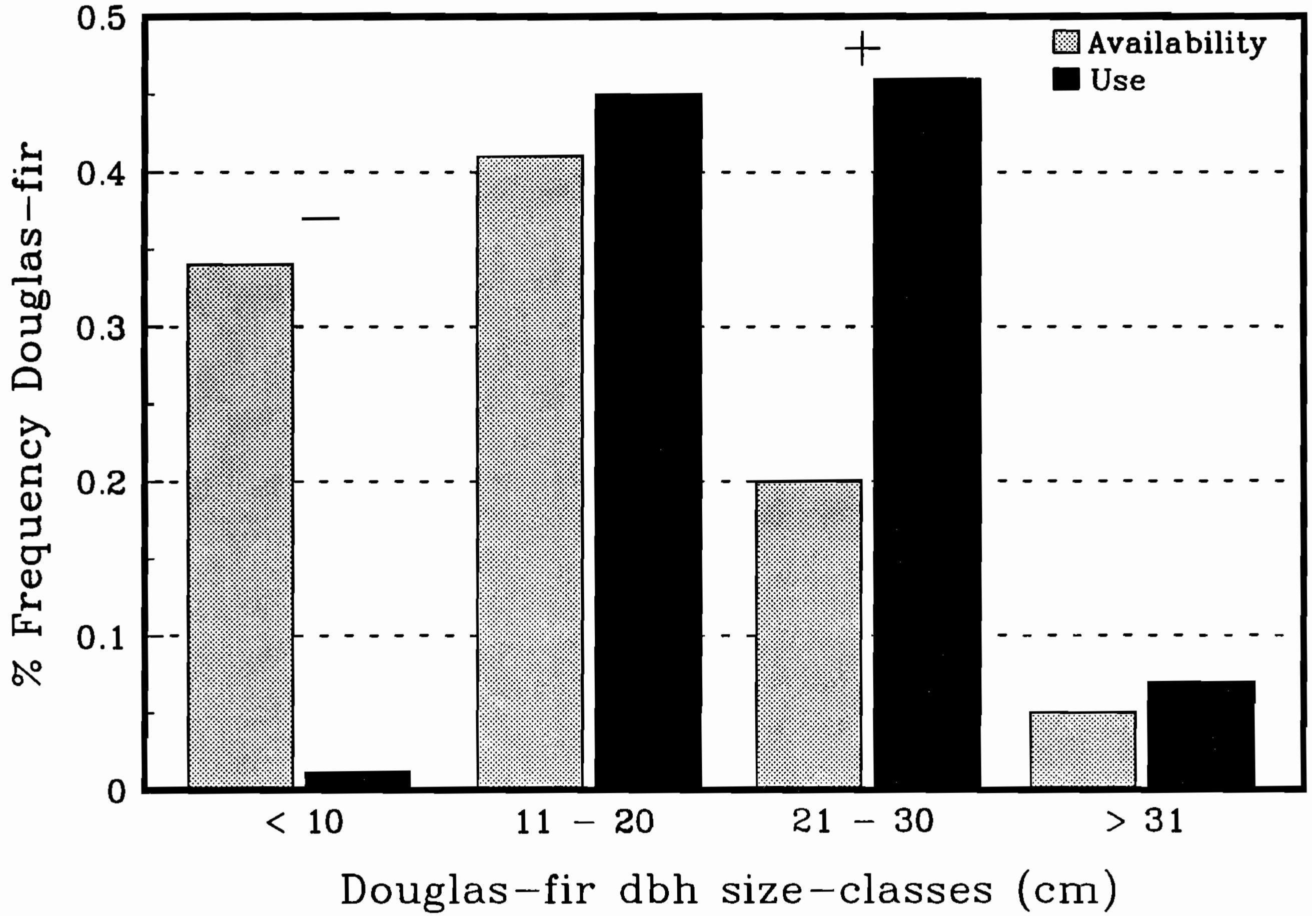

Figure 4. Use ($\underline{n}$ = 207) and availability ($\underline{n}$ = 6,421) of Douglas-fir by dbh size-class for cambium-feeding by black bears, Central Coast Ranges, Oregon, 1989-90. Observed frequencies significantly ($\underline{P}$ <0.05) greater or less than expected are denoted by plus or minus sign, respectively.

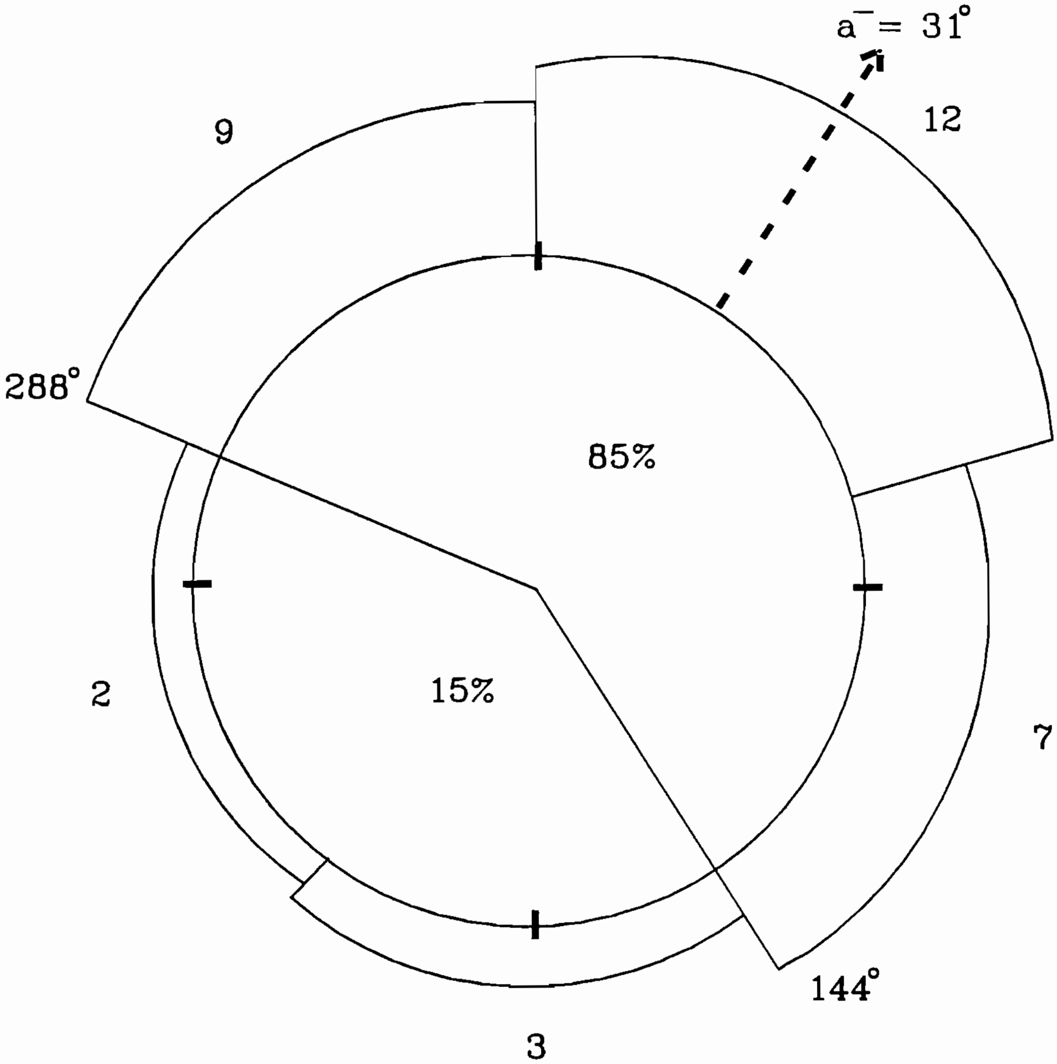

Figure 5. Distribution of mean aspects around the compass circle for forest stands with bear damage, Central Coast Ranges, Oregon, 1989-90.

when circular distributions were tested for: all stands combined, all stands in the north area, all stands in the south area, and all stands without damage.

DISCUSSION

Bear damage, although substantial in some stands, occurred at a relatively low frequency across the combined study areas. Most stands had a similar mix of tree species dominated by relatively equal sized and evenly spaced Douglas-fir. The 40-m^2 plots were effective in sampling bear damage. Percentages of total Douglas-fir, damaged Douglas-fir, and Douglas-fir girdled by bears were about equal for trees in the 40-m^2 plots and trees along the variable-width transects. There was only one stand where bear damage was encountered along the transects but not in the 40-m^2 plots, we observed 1 tree damaged by bears in that stand out of 482 trees examined on the transects.

Slope was the only site characteristic to differ between study areas. This occurred despite a significant difference in amounts of damage between the north and south study areas and despite the classifying variables study area and presence or absence of damage being highly correlated.

Correct classification rates (logistic regression) and adjusted r^2 values (multiple regression) indicate measured site characteristics are of little utility as predictors of bear damage. Nevertheless, correct classification rates and the rejection of the null hypothesis, classified by the presence or absence of bear damage (MANOVA), suggest something more than chance alone differs between stands damaged by bears and undamaged stands. Whether the difference is due solely to the effects of the densities trees >40-cm dbh, total ba, slope, and aspect, or whether these characteristics are also correlated with parameters not measured cannot be ascertained by this study.

I did not find a correlation between tree density and the occurrence of bear damage, although other studies have established an association between these factors (cf. Childs and Worthington 1955, Levin 1954, Mason and Adams 1989, Schmidt 1989). Tree densities by dbh size-class, however, were important in western Oregon. In stands dominated by trees 10-50 cm dbh: densities of trees <10 cm dbh do not affect levels of bear damage; bears damage trees 11-20 cm dbh in a ratio equal to their availability; bears selectively damage trees 21-30 cm dbh; densities of trees >30 cm dbh seem negatively correlated with densities of damaged Douglas-fir; and bears select trees >30 cm in a ratio approximately equal to their availability. Although species and size-classes vary by region, the selection of a specific tree species and dbh size-classes is consistent with previously reported results (e.g. Poelker and Hartwell 1973:40, Mason and Adams 1989, Nelson 1989).

In terms of economic impact, bear-damaged trees had an average dbh larger than the average dbh of undamaged trees, suggesting bears select more vigorous trees. Financial ramifications of bear damage also includes lowered growth rates, secondary losses of wood volume due to fungal infection and decay, vulnerability to attack from wood-boring insects, and increased probability of windthrow. Little or no reduction in growth rates occurs for trees with <50% of their bole circumference peeled by bears (Molnar and McMinn 1960, Poelker and Hartwell 1973:18); 61% of the trees I examined had <50% of the bole circumference peeled. However, 20% of the damaged trees in this study had scars extending from >50% to 99% of the bole circumference and can be expected to have reduced growth rates (Nelson 1989) and 19% were completely girdled.

Estimates of volume loss due to decay vary widely in the literature, but basal scars and wounds with surface areas >0.09 m^2 have the highest likelihood of infection (Wright and Isaac 1956, Hunt and Krueger 1962). Most scars I documented started near ground level. The mean area of bark removal was 0.4 m^2 and 47% of damaged trees had wounds ≥0.09 m^2.

Given potential variation in behavior of individual bears (Fagen and Fagen 1989), it seems likely that behavior affects patterns of bear damage across a given landscape. Nevertheless, similarity in management practices and bear damage characteristics in situations as diverse as redwood (*Sequoia sempervirens*) in California (Fritz 1951, Glover 1955), Douglas-fir in Oregon and Washington (this study, Maser 1967, Poelker and Hartwell 1973:17-48), white pine (*Pinus monticola*) in British Columbia (Molnar and McMinn 1960), white spruce (*Picea glauca*) in Alaska (Lutz 1951), and western larch (*Larix occidentalis*) in Montana (Mason and Adams 1989, Schmidt 1989), suggest site conditions relate to occurrence of bear damage within a given stand. Similar descriptions of bear damage by brown bears (*Ursus arctos*) feeding on cedar (*Chamaecyparis nooktkatensis*) in Alaska (Hennon et al. 1990) and Asiatic black bears (*Selenacrtos thibetanus*) feeding on cedar (*Cryptomeria japonica*) and cypress (*Chamaecyparis obtusa*) in Japan (Furubayashi et al. 1980, Watanabe 1980) further suggest that site conditions may influence feeding behavior. Forest management practices and associated bear damage problems in Japan are analogous to the problems in the U.S. Descriptions of damage to trees in Japan are nearly identical to descriptions of damaged trees in the U.S. In Japan, even-aged monocultures regenerated by clearcutting during the 1950's replaced many natural forests. Concentrations of bear damage, occurring with clumped distributions within forest plantations, increased during the 1960's and 1970's. The prevention of bear damage has since been identified as one of the most significant challenges in Japanese forests (Furubayashi et al. 1980, Watanabe 1981, Toyoshima and Narita 1982, Toyoshima 1983).

When I compared the distribution of average aspects for stands with damage, stands with a southeast to west aspect were selected least by bears. These are typically the driest aspects. Trees on sites with increased moisture availability have increased rates of sucrose production (Wort 1962:94). The added metabolites are translocated to the lower stem; as growing conditions improve, including increased moisture availability, the point of maximum xylem increment occurs at a lower level on the tree bole (Kozlowski 1971:107). The slippage or peelability of bark persists longer for trees on moist, well-drained soils than for trees on dry or swampy sites (Wilcox 1962:64). Accordingly, as moisture becomes less available in mid- to late spring, growth rates of trees on drier sites decrease relative to sites with greater moisture availability. Therefore, trees on drier aspects could be expected to have lower carbohydrate production, translocate sugars to higher levels in the bole, and have a shorter period when bark is readily removable than trees on more mesic sites.

Previous studies identify bears selecting trees in open-grown, under-stocked, or recently thinned stands (Levin 1954, Lawrence et al. 1961, Mason and Adams 1989). These conditions produce trees with increased levels of carbohydrates of which a higher proportion is concentrated in the lower stem (Kozlowski 1971:109-111). This can result in a 2- to 6-fold increase in cambial width relative to slower growing trees (Bannon 1962:9). Most bear damage occurs on the lower bole (this study, Lutz 1951, Maser 1967). In suppressed trees, diameter increase begins later, proceeds slower, ends sooner, and fewer carbohydrates are concentrated in the lower stem than in dominant trees (Kozlowski 1971:16). Maser (1967) noted bear damage was common in stands where crowns extended nearly to the ground, but in stands where tree density reduced crowns to about ½ the length of the stem, bear damage was uncommon. In trees with physiologically active branches along most of the main stem, carbohydrate storage occurs low in the stem, but as lower branches become physiologically inefficient, maximal ring thickness moves upward along the bole (Kozlowski 1971:107).

Nutrient availability affects the production and storage of carbohydrates as well as the incidence of bear damage. About 98% of the carbon absorbed during photosynthesis is stored in the stem as sugar (Nelson 1964:251). Photosynthetic efficiency, hence carbohydrate production, is increased with increased nitrogen (N) availability (Stegemoeller and Chappell 1989, Cole et al. 1990).

Additional N availability also directs more carbohydrates to the stem, whereas N deficiency results in a sharp decrease in sugar transport and a higher allocation directed to root production (Zimmermann 1974:317, Cole et al. 1990). Nelson (1989), working in a stand damaged by bears before N application, found tree mortality from bear damage 4 times more severe after urea was applied than in areas of the same stand that were not treated with fertilizer. Marshall et al. (1992) documented increases in both volume growth and stem damage by snowshoe hares (*Lepus americanus*) and red squirrels (*Tamiasciurus hudsonicus*) after application of nitrogenous fertilizers to lodgepole pine (*Pinus contorta*).

Bears primarily feed on cambium during the spring, when translocation of sugars from crown to stem is highest (Nelson 1964:252) and, due to cambial activity, physical resistance to bark-peeling is decreased (Wilcox 1962:63, Wort 1962:90). Captive black bears (Bacon and Burghardt 1983), as well as grizzlies (*Ursus arctos*) (Hamer and Herrero 1983:89), snowshoe hares (Radwan and Campbell 1968) and red squirrels (Heinrich 1992) observed in the wild, selected for foods rich in carbohydrates. Douglas-fir cambium is 43% sugar, dry weight (Radwan 1969). Thus the relationship between levels of bear damage and lands intensively managed for timber production may be more specifically a relationship between bear damage and sugar production.

In areas in the Central Coast Ranges of Oregon with bear damage and stands of Douglas-fir between 10-50 cm dbh, the likelihood of additional damage increases as slope, total ba, and densities of trees >40 cm dbh decrease. Trees 11-30 cm dbh are most vulnerable to damage by bears, as are sites with a northerly aspect ($\bar{a} = 31°$). Damage can be expected to decrease as trees grow beyond 40 cm dbh. Because bears seem to prefer specific tree species and select for individual trees within apparently homogeneous stands, additional research focusing on factors more strongly correlated to tree growth rates (e.g. height, nutrient availability, effects of pruning) and measurements of tree physiology (initiation of cambial growth, width of cambial layer, height of maximal ring thickness) may provide predictors of the potential vulnerability of a stand to bear damage.

LITERATURE CITED

Bacon, E. S., and G. M. Burghardt. 1983. Food preference testing of black bears. Int. Conf. Bear Res. and Manage. 5:102-105.

Bannon, M. W. 1962. The vascular cambium and tree-ring development. Pages 3-21 in T. T. Kozlowski, ed. Tree Growth. The Ronald Press Co., New York, N.Y. 442pp.

Batschelet, E. 1965. Statistical methods for the analysis of problems in animal orientation and certain biological rhythms. Am. Instit. of Biol. Sci. Washington, D.C. 57pp.

Burst, T. L., and M. R. Pelton. 1983. Black bear mark trees in the Smoky Mountains. Int. Conf. Bear Res. and Manage. 5:45-53.

Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050-1053.

Childs, T. W., and N. P. Worthington 1955. Bear damage to young Douglas-fir. U.S. Dep. of Agric. For. Serv. Res. Note 113. 4pp.

Cody, R.P., and J. K. Smith. 1987. Applied statistics and the SAS programming language. North-Holland, New York, N.Y. 280pp.

Cole, D. W., E. D. Ford, and J. Turner. 1990. Nutrients, moisture and productivity of established forests. For. Ecol. Manage. 30: 283-299.

Daubenmire, R. 1968. Plant communities: a textbook of plant synecology. Harper & Row, New York, N.Y. 300pp.

Fagen, R. and J. Fagen. 1989. Play behavior in brown bears (Ursus arctos) and human presence at Pack Creek, Admiralty Island, Alaska. Int. Conf. Bear Res. and Manage. 8:315-319.

Franklin, J. F. and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. U.S. Dep. of Agric. For. Serv., Gen. Tech. Rpt. PNW-8. 417pp.

Fritz, E. 1951. Bear and squirrel damage to young redwoods. J. For. 49:651-652.

Furubayashi, K., K. Hirai, K. Ikeda, and T. Mizuguchi. 1980. Relationships between occurrence of bear damage and clearcutting in central Honshu, Japan. Int. Conf. Bear Res. and Manage. 4: 81-84.

Glover, F. A. 1955. Black bear damage to redwood reproduction. J. Wildl. Manage. 19:437-43.

Gourley, M. and M. Vomocil. 1987. Public involvement in a black bear damage control program on private land. Pages 149-153 in D. M. Baumgartner, R. L. Mahoney, J. Evans, and D. W. Breuer, Symp co-chairs. Animal Damage Management in Pacific Northwest Forests. Washington State Univ. Press, Pullman.

Hamer, D., and S. Herrero. 1983. Ecological studies of the grizzly bear in Banff National Park. Parks Canada Contract WR 4-80. Univ. of Calgary, Alberta. 303pp.

Heinrich, B. 1992. Maple sugaring by red squirrels. J. Mamm. 73:51-54.

Hemstrom, M. A., and S. E. Logan. 1986. Plant association and management guide, Siuslaw National Forest. U.S. Dep. Agric. For. Serv. PNW-Reg. R6-Ecol. 220-1986a. 121pp.

Hennon, P. E., E. M. Hansen, and C. G. Shaw. 1990. Causes of basal scars on Chamaecyparis nootkatensis in Southeast Alaska. Northwest Sci. 64:45-54.

Hunt, J., and K. W. Krueger. 1962. Decay associated with thinning wounds in young-growth western hemlock and Douglas-fir. J. For. 60:336-340.

Kozlowski, T. T. 1971. Growth and Development of Trees, Vol.2. Academic Press, New York, NY. 514pp.

Lauckhart, J. B. 1955. The effect of logging old-growth timber on bear. Soc. Am. For. Proc. 54:128-130.

Lawrence, W. H., N. B. Kverno, and H. D. Hartwell. 1961. Guide to wildlife feeding injuries on conifers in the Pacific Northwest. West. For. Conserv. Assoc., Portland, Ore. 44pp.

Levin, O. R. 1954. The south Olympic tree farm. J. For. 52:243-249.

Long, J. N., J. B. McCarter, and S. B. Jack. 1988. A modified density management diagram for coast Douglas-fir. West. J. Appl. For. 3:88-89.

Lutz, H. J. 1951. Damage to trees by black bears in Alaska. J. For. 49:522-533.

Marshall, V. G., H. J Barclay, and E. D. Hetherington. 1992. Lodgepole pine response to nitrogenous fertilizers applied on and off snow, and to associated damage by small mammals. For. Ecol. and Manage. 54:225-238.

Maser, C. 1967. Black bear damage to Douglas-fir in Oregon. Murrelet 48:34-38.

Mason, A. C., and D. L. Adams. 1989. Black bear damage to thinned timber stands in northwest Montana. West. J. Appl. For. 4:10-13.

Molnar, A. C., and R. G. McMinn. 1960. The origin of basal scars in the British Columbia interior white pine type. For. Chron. 36: 50-60.

National Oceanic and Atmospheric Administration. 1985. Climates of the states. Third ed., Vol. 2. 1572pp.

Nelson, C. D. 1964. The production and translocation of photosynthate-C^{14} in conifers. Pages 243-257 in M. H. Zimmerman, ed. The Formation of Wood in Forest Trees. Academic Press, New York, N.Y.

Nelson, E. E. 1989. Black bears prefer urea-fertilized trees. West. J. Appl. For. 4:13-15.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Poelker, R. J. and H. D. Hartwell. 1973. Black bear of Washington. Washington State Game Dep. Bull. 14. 180pp.

Radwan, M. A. 1969. Chemical composition of the sapwood of four tree species in relation to feeding by the black bear. For. Sci. 15:11-16.

Radwan, M. A., and D. L. Campbell. 1968. Snowshoe hare preference for spotted catsear flowers in western Washington. J. Wildl. Manage. 32:104-108.

Schmidt, W. C. 1989. Management of young Larix occidentalis forests in the northern Rocky Mountains of the United States. Int. Union For. Res. Organ. Working Party S 1.05-03:246-253.

Stegemoeller, K. A., and H. N. Chappell. 1989. Growth response of unthinned and thinned Douglas-fir stands to single and multiple applications of nitrogen. Can. J. For. Res. 20:343-349.

Toyoshima, J. 1983. Research on taking-bark-off by bear in a sugi plantation (2)--on the condition and distribution of trees damaged by bears. Bull. Niigata Univ. For. 16:43-55.

Toyoshima, J., and S. Narita. 1982. Research on taking-bark-off by bear in a sugi plantation. Bull. Niigata Univ. For. 15:83-91.

Watanabe, H. 1980. Damage to conifers by the Japanese black bear. Int. Conf. Bear Res. and Manage. 4:67-70.

Watanabe, H. 1981. Black bear damage to artificial regeneration in Japan--conflict between control and reservation. Proc. Int. Union For. Res. Organ. World Congress. 17:581-586.

Wilcox, H. 1962. Cambial growth characteristics. Pages 57-88 in T. T. Kozlowski, ed. Tree Growth. The Ronald Press Co., New York, NY.

Wilson, B. F. 1964. A model for cell production by the cambium of conifers. Pages 19-36 in M. H. Zimmermann, ed. The formation of wood in forest trees. Academic Press, New York, N.Y. 562pp.

Wort, D. J. 1962. Physiology of cambial activity. Pages 89-95 in T. T. Kozlowski, ed. Tree Growth. The Ronald Press Co., New York, NY.

Wright, E., and L. A. Isaac. 1956. Decay following logging injury to western hemlock, spruce, and true firs. U.S. Dep. of Agric. Tech. Bull. No. 1148. 34pp.

Zar, J. H. 1984. Biostatistical analysis. 2d ed. Prentice-Hall, Inc., Engelwood Cliffs, NJ. 718pp.

Zimmermann, M. H. 1974. Storage, mobilization, and circulation of assimilates. Pages 307-322 in M. H. Zimmermann and C. L. Brown, eds. Trees: Structure and Function. Springer-Verlag, New York, N.Y.

CHAPTER IV

GENERAL SUMMARY AND MANAGEMENT IMPLICATIONS

Bears that damage trees to feed on cambium continue to be a problem for forest managers in the western U.S. It remains unclear why bears damage trees in some stands but not in neighboring stands that appear similar in age and structure. In this chapter, I present a hypothesis regarding bear feeding ecology and suggest practices that may reduce cambium-feeding.

Bear scats were collected during spring from 2 adjacent areas within the Central Coast Ranges: the north area had high levels of bear damage due to cambium-feeding and the south area had low levels of bear damage. Differences in spring food habits were documented between study areas. Scats from the south area contained significantly more shrubs than did scats from the north area, whereas scats from the north area contained significantly more forbs than did scats from the south area. Grass was a principal forage component in both areas, as it is in nearly every study of spring bear diets, but the nutritional value of graminoids is limited because of the relative indigestibility of grass to bears. Devil's club and salmonberry seem to be key spring forage items for bears in the south area. In contrast to many bear food habits studies, there were no clear key seasonal spring food items for bears in the north area, except perhaps for clover. Instead, bears in the north area ate small quantities of a variety of different forbs. The nutritive content of forbs, like grasses, peaks early in the spring and thereafter forbs become increasing less digestible to bears. In addition to shrubs retaining their nutritive value and digestibility longer into the season, the differences in shrub use also represent a difference in the use of early emerging berries associated with these shrubs. I do not have data on availability of spring food items, but differences clearly exist in the use of foods between bears from the 2 areas. If berries were equally available in both areas, it seems unlikely bears would forgo this high quality food item during a season of generally poor quality forage.

The impact of spring feeding behavior of bears on forest lands was documented by surveys of randomly selected stands. Differences in individual behavior of bears could explain the patchy distribution of damaged stands across a landscape. Behavior alone, however, does not explain why one forest stand might have high levels of damage while similar stands in close proximity are not damaged by bears. Nor does it account for similarities of bear damage and stand characteristics reported in the literature for widely disparate regions. I propose that forage availability may be instrumental in initiating feeding strategies that focus on cambium use.

Blood analysis was performed on a limited number of bears from both study areas (Appendix 1). Mean values for the protein albumin and the albumin/globulin ratio were significantly higher for bears in the south area than for bears in the north area. Other studies have correlated blood protein measures with nutritional condition of black bears. Bears are thought to feed selectively to maximize protein intake in spring, a season when bears may lose weight because of generally low nutritive value of available forage. These differences probably are not important to bears over the course of their annual cycle of activity; the prolificacy of berries from early summer to early fall should ameliorate differences in spring diets. Nevertheless, if the selectivity for protein occurs equally among bears in both study areas (as it seems to do in black and grizzly bear populations across North America), then the apparent disparity in blood proteins implies a difference in food availability. Although small sample size and the limitations inherent in blood analysis make it difficult to identify biological significance where statistical significance was detected, these results support the hypothesis of differences in forage availability between the 2 study areas.

Forestry practices that produce stands of fast growing trees may also be attracting bears for the same reason: accelerated cambium development. Stands with even-aged, optimally spaced trees minimize the suppression of one tree by surrounding trees. As fiber production is maximized, so is bear forage in terms of both quantity (volume of cambium per tree) and quality (carbohydrate production). The vigorous trees translocate more material to the basal portion of the stem and the increased physiologic activity decreases the effort required to feed on the cambium. It seems that the more efficient a manager becomes at growing trees for wood products, the more vulnerable the stand becomes as potential bear food.

As bears seek alternative foods, site characteristics correlated to cambium development may influence stand selection and within-stand damage by bears. A test for whether bears are specifically targeting trees with copious cambium production could include limbing branches along the lower ½ of tree stems in stands with ongoing bear damage. If carbohydrate stores are reallocated higher in the stem, bear damage would be expected to either decrease or occur higher on the tree bole, matching the height of maximal ring thickness. The null hypothesis would be no difference in damage levels. Because of its effect on carbohydrate production and storage, pruning may be a viable tool for reducing levels of bear damage within stands vulnerable to bears.

Forests could be grown less efficiently, in terms of fiber production, by varying tree ages, spacing, density (managing for a stand density index > 300), or tree species, all of which would probably reduce the number of stands damaged and the amount of damage any one stand would incur. Assuring the availability of nutritionally superior foods within forest stands, however, may also prevent some bears from incorporating cambium into their spring diets and reduce the volume of cambium ingested by other bears. Devil's club could be retained where it is encountered, but given its spotty distribution in the Coast Ranges, it may require additional effort to establish new patches in areas with high levels of bear damage. This effort could include coordinating snag management plans, including green leave trees, to provide the necessary shading to promote Devil's club. Patches of salmonberry, a prolific shrub in the Coast Ranges, could also be left scattered throughout new stands. Survival and productivity of forage patches would depend on the coordination of other stand maintenance projects (e.g., spraying, pre-commercial thinning).

Two ridge systems in the south study area, managed by the Forest Service, had a number of cutting units seeded with grasses and forbs blended for ungulate forage. Black bears regularly grazed these units. Stumps and coarse woody debris remained exposed to direct sunlight since shrub cover was reduced. This allowed ants to colonize many stumps and logs, thereby providing additional forage high in protein. I monitored bears in these units that almost literally left no log unturned in their active search for insects. Seeding roads and landings with wildlife forage mixtures would provide more spring foods, as would retention of coarse woody debris. The protection of wet areas would provide additional spring foods for bears such as cow parsnips and horsetails.

Damage levels may, in part, be reduced by altering a bear's behavioral patterns while trees are still seedlings. Providing forage for bears could be coordinated with reforestation efforts in areas with concentrations of bear damage. Bears foraging within these stands, including females with young, may exploit the forage patches for years before trees reach sizes vulnerable to bear damage. I do not believe these actions alone will stop bears from feeding on cambium. I do think this is a hypothesis worth testing that, combined with other control measures, may reduce levels of bear damage and decrease the numbers of bears killed in control measures.

LITERATURE CITED

Anon. 1951. Bear facts committee finds stripping bad. J. For. 49:382.

Bacon, E. S., and G. M. Burghardt. 1983. Food preference testing of black bears. Int. Conf. Bear Res. and Manage. 5:102-105.

Bannon, M. W. 1962. The vascular cambium and tree-ring development. Pages 3-21 in T. T. Kozlowski, ed. Tree Growth. The Ronald Press Co., New York, N.Y.

Barber, K. R. 1983. Use of clearcut habitats by black bears in the Pacific Northwest. M.S. Thesis, Utah State Univ., Logan. 169pp.

Batschelet, E. 1965. Statistical methods for the analysis of problems in animal orientation and certain biological rhythms. Am. Instit. of Biol. Sci. Washington, D.C. 57pp.

Brian, M. V. 1970. Measuring population and energy flow in ants and termites. Pages 231-234 in J. Phillipson, ed. Methods of Study in Soil Ecology. UNESCO, Paris.

Burst, T. L., and M. R. Pelton. 1983. Black bear mark trees in the Smoky Mountains. Int. Conf. Bear Res. and Manage. 5:45-53.

Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050-1053.

Campbell, R. W., and T. R. Torgersen. 1982. Some effects of predaceous ants on western spruce budworm pupae in north central Washington. Environ. Entomol. 11:111-114.

Carlson, C. E., R. W. Campbell, L. J. Theroux, and T. H. Egan. 1984. Ants and birds reduce western spruce budworm feeding injury to small Douglas-fir and western larch in Montana. For. Ecol. and Manage. 9:185-192.

Childs, T. W., and N. P. Worthington 1955. Bear damage to young Douglas-fir. U.S. Dep. of Agric. For. Serv. Res. Note 113. 4pp.

Cody, R.P., and J. K. Smith. 1987. Applied statistics and the SAS programming language. North-Holland, New York, N.Y. 280pp.

Cole, D. W., E. D. Ford, and J. Turner. 1990. Nutrients, moisture and productivity of established forests. For. Ecol. Manage. 30:283-299.

Daubenmire, R. 1968. Plant communities: a textbook of plant synecology. Harper & Row, New York, N.Y. 300pp.

Eagle, T. C. and M. R. Pelton. 1983. Seasonal nutrition of black bears in the Great Smoky Mountains National Park. Int. Conf. Bear Res. and Manage. 5:94-101.

Fagen, R. and J. Fagen. 1989. Play behavior in brown bears (Ursus arctos) and human presence at Pack Creek, Admiralty Island, Alaska. Int. Conf. Bear Res. and Manage. 8:315-319.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. U.S. Dep. of Agric. For. Serv., Gen. Tech. Rpt. PNW-8. 417pp.

Fritz, E. 1951. Bear and squirrel damage to young redwoods. J. For. 49:651-652.

Furubayashi, K., K. Hirai, K. Ikeda, and T. Mizuguchi. 1980. Relationships between occurrence of bear damage and clearcutting in central Honshu, Japan. Int. Conf. Bear Res. and Manage. 4: 81-84.

Gilkey, H. M., and L. J. Dennis. 1973. Handbook of northwestern plants. Oregon State Univ. Bookstores, Inc., Corvallis. 505pp.

Glover, F. A. 1955. Black bear damage to redwood reproduction. J. Wildl. Manage. 19:437-43.

Gourley, M., and M. Vomocil. 1987. Public involvement in a black bear damage control program on private land. Pages 149-153 in D. M. Baumgartner, R. L. Mahoney, J. Evans, J. Caslick, and D. W. Breuer, eds. Animal Damage management in Pacific Northwest Forests.

Graber, D. M., and M. White. 1983. Black bear food habits in Yosemite National Park. Int. Conf. Bear Res. and Manage. 5:1-10.

Grenfell, W. E., and A. J. Brody. 1983. Seasonal foods of black bears in Tahoe National Forest, California. Calif. Fish and Game 69:132-150.

Hamer, D., and S. Herrero. 1983. Ecological studies of the grizzly bear in Banff National Park. Parks Canada Contract WR 4-80. Univ. of Calgary, Alberta. 303pp.

Hatler, D. F. 1972. Food habits of black bears in interior Alaska. Can. Field-Nat. 86:17-31.

Hayes, D. W., and G. A. Garrison. 1960. Key to important woody plants of Oregon and Washington. U.S. Dep. of Agric. For. Serv. Handbook No. 148. 227pp.

Heady, H. F. 1964. Palatability of herbage and animal preference. J. Range Manage. 17:76-82.

Heinrich, B. 1992. Mapel sugaring by red squirrels. J. Mamm. 73:51-54.

Hemstrom, M. A., and S. E. Logan. 1986. Plant association and management guide Siuslaw National Forest. U.S. Dep. Agric. For. Serv. PNW-Reg. R6-Ecol 220-1986a. 121pp.

Hennon, P. E., E. M. Hansen, and C. G. Shaw III. 1990. Causes of basal scars on Chamaecyparis nootkatensis in Southeast Alaska. Northwest Sci. 64:45-54.

Hewitt, D. G. 1989. Correcting grizzly bear fecal analysis to observed food habits. M.S. Thesis, Washington State Univ., Pullman. 20pp.

Hitchcock, C. L., and A. Cronquist. 1981. Flora of the Pacific Northwest. Univ. of Wash. Press, Seattle, WA. 730pp.

Hunt, J., and K. W. Krueger. 1962. Decay associated with thinning wounds in young-growth western hemlock and Douglas-fir. J. For. 60:336-340.

Irwin, L. L., and F. M. Hammond. 1985. Managing black bear habitats for food items in Wyoming. Wildl. Soc. Bull. 13:477-483.

Koehler, K. J., and K. Larntz. 1980. An empirical investigation of goodness-of-fit statistics for sparse multinomials. J. Am. Stat. Assoc. 75:336-344.

Kozlowski, T. T. 1971. Growth and Development of Trees, Vol.2. Academic Press, New York, NY. 514pp.

Krebs, J. R. and N. B. Davis, editors. 1984. Behavioral ecology, an evolutionary approach. Sinauer Assoc., Publ., Sunderland, Mass. 493pp.

_____, and R. H. McCleery. 1984. Optimization in behavioral ecology. Pages 91-121 in J. R. Krebs and N. B. Davies, eds. Behavioral Ecology, an Evolutionary Approach. Sinauer Assoc., Publ., Sunderland, Mass.

Landers, J. L., R. J. Hamilton, A. S. Johnson, and R. L. Marchinton. 1979. Foods and habitat of black bears in southeastern North Carolina. J. Wildl. Manage. 43:143-153.

Langelier, L. A., and E. O. Garton. 1986. Management guidelines for increasing populations of birds that feed on Western spruce budworm. U. S. Dep. of Agric. For. Serv. Handbook No. 653. 19pp.

Lauckhart, J. B. 1955. The effect of logging old-growth timber on bear. Soc. Am. For. Proc. 54:128-130.

Lawrence, W. H., N. B. Kverno, and H. D. Hartwell. 1961. Guide to wildlife feeding injuries on conifers in the Pacific Northwest. West. For. Conserv. Assoc., Portland, Ore. 44pp.

Levin, O. R. 1954. The south Olympic tree farm. J. For. 52:243-249.

Long, J. N., J. B. McCarter, and S. B. Jack. 1988. A modified density management diagram for coast Douglas-fir. West. J. Appl. For. 3:88-89.

Lutz, H. J. 1951. Damage to trees by black bears in Alaska. J. For. 49:522-533.

Maehr, D. S., and J. R. Brady. 1984. Food habits of Florida black bears. J. Wildl. Manage. 48:230-235.

Marshall, V. G., H. J Barclay, and E. D. Hetherington. 1992. Lodgepole pine response to nitrogenous fertilizers applied on and off snow, and to associated damage by small mammals. For. Ecol. and Manage. 54:225-238.

Martin, A. C., R. H. Gensch, and C. P. Brown. 1946. Alternative methods in upland gamebird food analysis. J. Wildl. Manage. 10:8-12.

Maser, C. 1967. Black bear damage to Douglas-fir in Oregon. Murrelet 48:34-38.

Mason, A. C., and D. L. Adams. 1989. Black bear damage to thinned timber stands in northwest Montana. West. J. Appl. For. 4:10-13.

Molnar, A. C., and R. G. McMinn. 1960. The origin of basal scars in the British Columbia interior white pine type. For. Chron. 36:

50-60.

Moore, A. W. 1940. Wild animal damage to seeds and seedlings on cut-over Douglas-fir lands of Oregon and Washington. U.S. Dep. Agric. Tech. Bull. 706. 28pp.

National Oceanic and Atmospheric Administration. 1985. Climates of the states. Third ed., Vol. 2. 1572pp.

Nelson, C. D. 1964. The production and translocation of photosynthate-C^{14} in conifers. Pages 243-257 in M. H. Zimmerman, ed. The Formation of Wood in Forest Trees. Academic Press, New York, N.Y.

Nelson, E. E. 1989. Black bears prefer urea-fertilized trees. West. J. Appl. For. 4:13-15.

Neu C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Nielsen, G. R. 1986. The spatial distribution of wood-nesting ants. Ph.D. thesis, Oregon State Univ., Corvallis. 102pp.

Oelberg, K. 1956. Factors affecting the nutritive value of range forage. J. Range Manage. 9:220-225.

Poelker, R. J., and H. D. Hartwell. 1973. Black bear of Washington. Washington State Game Dep. Bull. 14. 180pp.

Radwan, M. A. 1969. Chemical composition of the sapwood of four tree species in relation to feeding by the black bear. For. Sci. 15:11-16.

Radwan, M. A., and D. L. Campbell. 1968. Snowshoe hare preference for spotted catsear flowers in western Washington. J. Wildl. Manage. 32:104-108.

Raine, R. M., and J. L. Kansas. 1989. Black bear seasonal food habits and distribution by elevation in Banff National Park, Alberta. Int. Conf. Bear Res. and Manage. 8:297-304.

Rogers, L. L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. Trans. North Am. Wildl. and Nat. Resour. Conf. 41:431-438.

Rogers, L. L. 1987. Effects of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. Wildl. Monogr. 97. 72pp.

Schmidt, W. C. 1989. Management of young *Larix occidentalis* forests in the northern Rocky Mountains of the United States. Int. Union For. Res. Organ. Working Party S 1.05-03:246-253.

Schwartz, C. C., and A. W. Franzmann. 1991. Interrelationship of black bears to moose and forest succession in the northern coniferous forest. Wildl. Monogr. 113. 64pp.

Smith, P. A. 1984. Kenai black bears and cranberries: bear food habits and densities. M.S. Thesis. Univ. of Alaska, Fairbanks. 144pp.

Southwood, T. R. E. 1973. The insect/plant relationship--an evolutionary perspective. Symp. R. Entomol. Soc. London 6:3-30.

Stegemoeller, K. A., and H. N. Chappell. 1989. Growth response of unthinned and thinned Douglas-fir stands to single and multiple applications of nitrogen. Can. J. For. Res. 20:343-349.

Takekawa, J. Y., E. O. Garton, and L. A. Langelier. 1982. Biological control of forest insect outbreaks: The use of avian predators. Trans. North Am. Wildl. and Nat. Res. Conf. 47:393-409.

Thomas, G. P., and R. W. Thomas. 1954. Decay of Douglas-fir in the coastal region of British Columbia. Can. J. Bot. 32:630-653.

Tisch, E. L. 1961. Seasonal food habits of the black bear in the Whitefish Range of northwestern Montana. M.S. Thesis, Montana State Univ., Missoula. 108pp.

Toyoshima, J. 1983. Research on taking-bark-off by bear in a sugi plantation (2)--on the condition and distribution of trees damaged by bears. Bull. Niigata Univ. For. 16:43-55.

Toyoshima, J., and S. Narita. 1982. Research on taking-bark-off by bear in a sugi plantation. Bull. Niigata Univ. For. 15:83-91.

Viereck, L. A., and E. L. Little, Jr. 1972. Alaska trees and shrubs. U.S. Dep. Agric. For. Serv. Handbook No. 410. 265pp.

Watanabe, H. 1980. Damage to conifers by the Japanese black bear. Int. Conf. Bear Res. and Manage. 4:67-70.

Watanabe, H. 1981. Black bear damage to artificial regeneration in Japan--conflict between control and reservation. Proc. Int. Union For. Res. Organ. World Congress. 17:581-586.

Wilcox, H. 1962. Cambial growth characteristics. Pages 57-88 <u>in</u> T. T. Kozlowski, ed. Tree Growth. The Ronald Press Co., New York, N.Y.

Wilson, B. F. 1964. A model for cell production by the cambium of conifers. Pages 19-36 <u>in</u> M. H. Zimmermann, ed. The formation of wood in forest trees. Academic Press, New York, N.Y. 562pp.

Wort, D. J. 1962. Physiology of cambial activity. Pages 89-95 <u>in</u> T. T. Kozlowski, ed. Tree Growth. The Ronald Press Co., New York, N.Y.

Wright, E., and L. A. Isaac. 1956. Decay following logging injury to western hemlock, spruce, and true firs. U.S. Dep. of Agric. Tech. Bull. No. 1148. 34pp.

Zar, J. H. 1984. Biostatistical analysis. 2d ed. Prentice-Hall, Inc., Engelwood Cliffs, NJ. 718pp.

Zeedyk, W. D. 1957. Why do bears girdle balsam-fir in Maine? J. For. 55:731-732.

Zimmermann, M. H. 1974. Storage, mobilization, and circulation of assimilates. Pages 307-322 <u>in</u> M. H. Zimmermann and C. L. Brown, eds. Trees: Structure and Function. Springer-Verlag, New York, N.Y.

APPENDICIES

APPENDIX 1

BLOOD ANALYSIS OF BLACK BEARS IN THE CENTRAL COAST RANGES OF OREGON

ABSTRACT

Black bears (*Ursus americanus*) damage some stands of timber in portions of the Central Coast Ranges of Oregon by peeling the bark off trees and feeding on the cambium during spring and early summer. I compared blood parameters from wild black bears captured during the cambium-feeding season (May - mid-July) in an area with high amounts of bear damage ($\underline{n}$ = 9) to an area with low amounts of bear damage ($\underline{n}$ = 5). Bears from the low damage area had greater levels of albumin ($\underline{F}$ = 32.00, 1,10 df, $\underline{P}$ = 0.001) and albumin/globulin ratio ($\underline{F}$ = 10.31, 1,10 df, $\underline{P}$ = 0.015), suggesting better nutritional condition over bears in the high damage area. Bears from the high damage area had higher levels of alkaline phosphatase ($\underline{F}$ = 9.40, 1,10 df, $\underline{P}$ = 0.016), which may relate to the younger mean age of this group relative to bears from the low damage area. Creatinine phosphokinase values were 6 times greater for bears from the low damage area than from the high damage area. These values, however, may be a result of the dilution process necessary for samples with high serum activity levels. Although many variables within and between study areas are unaccounted for (e.g. limited number of bears sampled, differences in forage availability between study areas, annual fluctuation in seasonal conditions, etc.), these results suggest bears from areas with low amounts of bear damage may have a slight nutritional advantage in spring and early summer over bears in areas where cambium feeding is more common.

INTRODUCTION

Black bear damage to Douglas-fir (*Psuedotsuga menzeisii*) trees is an on-going problem in the Pacific Northwest (Maser 1967, Nelson 1989). Amounts of bear damage and areas reporting damage both increased in western Oregon during the 1980's (Gourley and Vomocil 1987). Some bears peel bark off live trees and feed on cambium from the time of den emergence until early summer. Trees completely girdled die in about 1 yr and trees with lesser injuries can suffer reduced growth rates (Nelson 1989) or produce inferior wood due to secondary infections.

Natural selection presumably favors animals that maximize their foraging efficiencies (Krebs and Davies 1984:87). Forage quality, density, and distribution clearly influence black bear feeding habits (Landers et al. 1979, Eagle and Pelton 1983, Schwartz and Franzmann 1991). The amount of bear damage present in regions of the Oregon Coast Ranges suggests cambium is an important food source for some bears. It is unknown, however, what the energetic costs or benefits may be for bears using cambium as a spring forage. My objectives were to determine baseline values for whole blood and serum from bears in the Central Coast Ranges of Oregon and to test for nutritional differences between bears from an area with high amounts of bear damage and a neighboring area with low amounts of bear damage to Douglas-fir trees.

STUDY AREAS

I selected 2 adjacent areas, each about 500 km^2, in the Central Coast Ranges of western Oregon (Figure 1). The north area was identified by local resource managers as sustaining high levels of bear damage and the south area was reported as having little bear damage. These assessments were later verified (Chapter 3). The region has a maritime climate with typically cool, wet winters. The topography is steep and highly dissected. Elevations range from 15 to 1,250 m. The study areas were within the western hemlock (*Tsuga heterophylla*) vegetation zone, but dominated by subclimax Douglas-fir (Franklin and Dyrness 1973). Forests within the study areas are typically regenerated by clearcutting on 40- to 80-year rotations and planted with nursery stock.

METHODS

Black bears were captured with foot snares baited primarily with animal matter and immobilized with a 2:1 mixture of Ketamine hydrochloride (HCL) and Xylazine HCL, administered at 300 mg/45 Kg of estimated bear weight. Bears were injected by using either a 1.8 m "jab-stick" or a powder-charge projectile syringe. Although capture and handling techniques were similar for all animals, different individuals required different relative doses of the immobilizing agents.

I fitted radio-collars and removed a premolar for estimating age of captured bears. Blood was then collected from the femoral vein in evacuated glass tubes <1 hr after immobilization. Hematological samples were preserved with ethylenediamine tetra-acetate (EDTA). Blood for serum glucose analysis was collected in tubes containing Na^+ fluoride. Additional samples were allowed to coagulate for serum analysis. All samples were centrifuged 12 minutes at 2,000 rpms ≤4 hrs after collection and usually analyzed ≤24 hrs by the Veterinary Diagnostic Laboratory at the College of Veterinary Medicine, Oregon State University (OSU), Corvallis. Samples that could not be analyzed ≤24 hrs were refrigerated until the next business day. Small sample volumes prohibited complete profiles for 2 bears.

Hematological values measured by electron laser techniques included hemoglobin (HB), red blood count (RBC), packed cell volume (PCV), and white blood count (WBC). Differential counts of segmented neutrophils (SNEU), lymphocytes (LYMP), and monocytes (MONO) were determined by blood smears stained with a modified Wright's stain using an automated slide stainer. Plasma protein (PPRO) was assessed by refractometry and fibrinogen (FIB) was calculated by heat precipitation (Schalm and Jain 1986:56-59). Measurements of serum concentrations of albumin (ALB), albumin/globulin ratio (A/G), total protein (TP), total bilirubin (BIL), blood urea nitrogen (BUN), creatinine (CREA), cholesterol (CHOL), glucose (GLUC), calcium (CA), and serum activities of alkaline phosphatase (ALP), creatinine phosphokinase (CPK), and alanine aminotransferase (ALT) (formerly serum glutamic-pyruvic transaminase, SGPT) were made with a random access auto-analyzer. Serum chloride (Cl^-), potassium (K^+), phosphorous (P^+), and sodium (Na^+) concentrations were measured by ion selective electrode. Serum urea (U), used to calculate the urea/creatinine (U/C) ratio, was estimated by dividing BUN by 0.466 (Nelson et al. 1984).

Parameters identified in the literature as indicative of condition of black bears (ALB, A/G, TP, BUN, CA, the CA/P^+ ratio (CAP), CHOL, K^+, ALP, HB, PCV, and RBC) were compared between bears classified by study area and by sex using analysis of variance (ANOVA). Likewise, 5 stress factors (WBC, SEG, LYMPH, MONO, and ALT) were also compared with ANOVA. Because of 3 extremely high readings that may have been an artifact of the dilution process necessary for samples with high serum activity levels (Kachmar and Moss 1976:686), CPK was excluded from comparative analysis; FIB was also excluded from this analysis because of the crude level of precision inherent in measuring this parameter (B. Smith, professor of veterinary medicine, OSU, pers. commun.).

RESULTS

Nine bears from the north area and 5 south area bears were captured between 3 May and 16 July, 1988 (Table 8). Black bears in Oregon are considered reproductively mature by age 4 (Lindzey and Meslow 1980): 4 of 9 bears (45%) from the north area were $\leq$ 4 years-old while only 1 animal (20%) was $\leq$ 4-years-old from the south area. There were no known instances of marked animals moving between study areas during subsequent radio-telemetry work in 1988 and 1989.

Twenty-six serum and hematological characteristics were measured (Table 9, Appendix 2). All bears had U/C ratios $\geq$ 20, indicating they were beyond the physiologic influences of hibernation (Nelson et al. 1984, Ensrud et al. 1986). Serum values that differed between study areas were ALB (F = 32.00, 1,10 df, P = 0.0005), A/G (F = 10.31, 1,10 df, P = 0.015), and ALP (F = 9.40, 1,10 df, P = 0.016). Serum values that differed between sexes were ALB (F = 61.73, 1,10 df, P = 0.0001) and TP (F = 5.45, 1,10 df, P = 0.048). Blood parameters compared between study areas and sexes commonly had similar means and large variances.

Table 8. Physical parameters and capture conditions of black bears snared in an area of high amounts of timber damage caused by bears (north) and an area of low levels of bear damage (south), Central Coast Ranges, Oregon, May - mid-July, 1988.

Study area	Date of capture	Sex	Age	Reproductive status[a]	Mass (Kg)	Maximum time in trap (hrs)	Max. holding time of blood (hrs)[c]
North	3 May	M	5	M	115[b]	≤ 48	< 12
	11 May	M	6	M	115[b]	≤ 24	≈ 18
	13 May	M	2	I	70	≤ 48	≤ 72
	22 May	M	4	M	80[b]	≤ 24	≤ 24
	1 June	F	1	I	36	≤ 24	≈ 18
	4 June	M	8	M	125[b]	≤ 24	≤ 48
	5 June	F	6	L	75	≤ 24	≈ 18
	13 June	M	8	M	125[b]	≤ 24	< 4
	14 June	M	4	M	73	< 15	< 8
South	17 May	F	3	M	59	≤ 48	≈ 17
	26 May	M	5	M	120	≤ 24	≈ 12
	29 June	F	5	C	46	≤ 24	≈ 18
	8 July	M	5	M	72	≤ 24	≤ 72
	16 July	M	7	M	100[b]	≤ 48	≤ 48

[a] C = ≥2 cubs accompanied the female, I = immature, L = lactating, M = mature.

[b] Estimates.

[c] Esitmate of time between collection and delivery to lab. All stored samples were kept refrigerated.

Table 9. Serum chemistry and hematology of black bears snared in an area of high amounts of timber damage caused by bears (north) and an area of low levels of bear damage (south), Central Coast Ranges, Oregon, May - mid-July, 1988.

	North Area		South Area	
Parameter	$\bar{X}$ ± SE	Range	$\bar{X}$ ± SE	Range
Total Protein[a] (TP) g/dl	7.2 ± 0.2	6.4/7.9	6.9 ± 0.2	6.1/7.4
Albumin[a,b] (ALB) g/dl	3.6 ± 0.2	2.6/4.0	3.8 ± 0.1	3.5/4.2
Albumin:Globulin[b] (A/G) ratio	1.0 ± 0.1	0.7/1.4	1.3 ± 0.0	1.3/1.4
Blood Urea Nitrogen (BUN) mg/dl	18.5 ± 2.9	10.9/32.5	22.6 ± 7.3	11.0/51.0
Creatinine (CREA) mg/dl	1.3 ± 0.3	0.7/2.4	1.1 ± 0.1	0.9/1.4
Chloride (CL^-) mEq/l	114 ± 1.8	108/122	113 ± 5.1	105/133
Cholesterol (CHOL) mg/dl	183 ± 39	29/255	238 ± 24	178/290
Glucose (GLUC) mg/dl	140 ± 12	103/194	124 ± 12	82/145
Total Bilirubin (BIL) mg/dl	0.1 ± 0.0	0.0/0.2	0.4 ± 0.2	0.1/1.1
Calcium (CA) mg/dl	7.0 ± 0.3	5.5/8.3	7.0 ± 0.4	6.5/8.0
Potassium (K^+) mEq/l	4.7 ± 0.1	4.3/5.3	4.3 ± 0.1	4.0/4.6
Sodium (NA^+) mEq/l	147 ± 2.3	142/157	148 ± 5.1	140/168
Phosphorous (P) mg/dl	4.4 ± 0.5	3.0/6.0	5.2 ± 0.5	3.8/6.6
Alkaline Phosphatase[b] (ALP) IU/L	45 ± 3.7	27/56	27 ± 4.8	13/41
Creatine Phosphokinase[b] (CPK) IU/L	3961 ± 1436	1134/10680	35109 ± 15267	4578/50750
Alanine Aminotransferase (ALT) IU/L	198 ± 79	16/532	140 ± 42	44/254
Hemoglobin (HB) g/dl	16.1 ± 0.6	13.8/18.5	16.4 ± 0.4	14.9/17.4
Packed Cell Vol (PCV) %	40.4 ± 1.0	35.5/43.8	39.5 ± 0.9	37.6/42.9
Red Blood Count (RBC) $10^6/mm^3$	7.20 ± 0.2	6.35/8.04	7.22 ± 0.2	6.74/7.59
White Blood Count (WBC) $10^3/mm^3$	11.9 ± 1.5	5.1/18.3	16.8 ± 1.5	13.2/23.7
Lymphocytes (LYMP) %	1.55 ± 2.4	0.71/4.40	1.51 ± 1.8	0.83/2.45
Monocytes (MONO) %	0.26 ± 0.7	0.08/0.80	0.09 ± 0.0	0.05/0.16
Segmented Neutrophils (SNEU) %	11.2 ± 2.5	6.44/18.9	8.01 ± 1.7	4.65/13.28
Fibrinogen (FIB) mg/dl	300+ ± 42	200/500	250+ ± 60	100/400
Plasma Protein g/dl	8.2 ± 0.3	6.9/9.3	8.0 ± 0.3	7.3/8.78

[a]Factors differing between sexes ($p < 0.05$).

[b]Factors differing between areas ($p < 0.02$).

DISCUSSION

ALB has been correlated with dietary protein intake in black bears (Beeman 1981:37, Schroeder 1987). Both ALB and the ratio in proteins of A/G are considered useful for evaluating the condition of black bears (Schroeder 1987, Franzmann and Schwartz 1988, Hellgren et al. 1989). Spring diets of bears are generally low in protein, despite bears seeming to feed selectively to maximize protein intake (Landers et al. 1979, Beeman and Pelton 1980, Eagle and Pelton 1983). If this selectivity is occurring equally among black bears in the Central Coast Ranges of Oregon, then the elevated protein levels for bears in the south area suggests a difference in forage availability between the 2 study areas.

Age has been correlated with ALP levels in black, grizzly (*Ursus arctos*), and polar bears (*U. maritimus*) (Lee et al. 1977, Brannon 1985, Storm et al. 1988). Levels of ALP and K^+ have been found to be greater in young bears (Beeman 1981:27, Schroeder 1987). The elevated ALP level in the sample from the north area, along with higher levels of K^+, may result from the difference in mean ages between the 2 groups of animals.

Mean levels of TP and ALB were higher in males than females. TP, which responds to environmental changes over a course of weeks (Seal 1978), has been linked with dietary changes in bears (Matula et al. 1980, Brannon 1985, Schroeder 1987). TP and ALB are influenced by age (Matula et al. 1980, Brannon 1985, Schroeder 1987), but TP levels for bears have not been reported to be influenced by sex. The difference in TP levels between sexes reported here may be a spurious relationship with mean ages of females ($\bar{x}$ = 3 yrs) and males ($\bar{x}$ = 5 yrs).

Elevated levels of CPK usually indicate stress and trauma and have been associated with capture injuries, particularly with cable snares (Lee et al. 1977). During sustained activity, CPK is critical in maintaining supplies of ATP for the active muscles by the rephosphorylation of ADP (Ekert and Randall 1983:370). When striated muscle trauma occurs, CPK levels are further boosted as injured cells release their enzyme content into the serum (Lee et al. 1977, Beeman 1981:36). Mental stress can also increase CPK levels (Kramer 1980). A 10- to 200-fold increase in CPK and associated enzymes occurred in white-tailed deer (*Odocoilius virginiana*) despite no visible injury or apparent differences in overt behavior between groups of deer (Seal et al. 1972a). Elevated CPK levels may persist for several days after the original stimulus (Seal et al. 1972b, Lassen et al. 1986). Although the actual time bears spent snared is unknown, bears from the south area averaged a maximum of 33.6 hrs snared while bears from the north area averaged a maximum of 28.3 hrs. If an actual difference in the amount of time bears spent snared exists between areas, it could explain the higher CPK levels found in bears from the south area.

Stress can cause physiologic leukocytosis by increasing respiration and heart rate (Schalm et al. 1975). This raises the number of circulating white blood cells by flushing capillary beds where leukocytes collect during periods of inactivity. The increased levels of WBC and SNEU in bears from the south area may again relate to time spent captured and indicate increased snare trauma (Beeman 1981:24, Lassen et al. 1986).

Bears from both study areas had ALT levels higher than values reported in the literature. Like CPK, ALT is influenced by stress and excitability (Seal et al. 1972a, Franzmann and Schwartz 1988), but ALT levels can return to normal within an hour (Brannon 1985). Eubanks et al. (1976) warned that enzymes may be influenced by elapsed time between collection and centrifugation, a possible source of variation in this study. Nevertheless, once snared, bears from both study areas appear to have been highly stressed.

HB, PCV, and RBC values were similar between study areas. The PCV values presented here were the laboratory determinations and not adjusted for storage times (Kerr and Pace 1987). Along with ALB, they are the most sensitive indicators of nutritional plane in black bears (Matula and Lindzey 1976, Schroeder 1987, Franzmann and Schwartz 1988). Stress and exercise can, however, temporarily inflate these hematologic values by causing the spleen to contract, releasing a pool of red cells into circulation (Karns and Crichton 1978, Beeman 1981:19). If a difference exists in time spent snared between bears from the north and south areas, bears from the south area may have biased hematological values.

Nutritional effects need to persist for weeks to months before becoming apparent in erythrocyte measurements due to the cells half-life of 120 days (Seal 1978). Concentrations of hematologic characteristics in black bears reach a seasonal low in the early summer when the delayed effects of low quality spring forage become apparent (Erickson and Youatt 1961, Hellgren et al. 1989). The mean capture date for bears from the north area (May 28) was 23 days earlier than the mean capture date from the south area (June 20). This time difference may inflate earlier samples (north area bears) and depress later samples (south area bears) due to the annual cycle in bear hematology. Therefore, despite the similarity in mean values between bears from both study areas and its usefulness in defining condition, no clear conclusions can be drawn from the hematology results.

Dehydration also influences hematology and can occur in captured animals due to elevated metabolic rates, denial of access to water, and protein metabolism resulting from the digestion of meat used as bait (Nelson et al. 1973). Dehydration, however, also affects ALB, BUN, TP, Na^+, K^+, Urea, and U/C (Matula and Lindzey 1976, Lassen et al. 1986, Storm et al. 1988). There was no consistent pattern among these components to suggest dehydration was an important element.

When interpreting these results, it is important to recognize extant limitations and biases. An underlying assumption to this work is foraging behavior of all bears was representative of the area in which they were snared. I feel subsequent radio-telemetry work (unpubl. data) and the quantities of bark-peeling in the north area justifies this generalization, but the limited sample of bears makes it uncertain whether, and to what degree, each bear sampled actually fed on cambium. Subsequent field work from September, 1988, through March, 1990, failed to identify any radio-marked bears from the south area as cambium feeders. Stress, trauma, and season can alter blood profiles. The piece-meal measurements and single point sampling of physiologic functions overlooks the inter-relatedness of these systems. These influences, combined with small sample size, make it difficult to interpret biological significance where statistical significance is indicated.

SUMMARY

Bears from the south area had higher ALB and A/G values. Previous research has linked both these protein measures with nutritional condition. The means of most blood values, however, appeared similar between study areas. Bears from the south area had significantly higher CPK values than bears from the north area and both study areas had high CPK and ALT levels relative to values reported in the literature. Both serum enzymes are indicators of stress and trauma. It is impossible to separate the confounding influences of season, stress, and injury on the hematologic values. However, within the limits imposed by small sample size and unaccounted variables inherent in this study, these results suggest bears in the south area have a nutritional advantage over bears from the north area.

LITERATURE CITED

Beeman, D. K. 1981. Serum and whole parameters of black bears in the Great Smoky Mountains National Park. M.S. Thesis. Univ. of Tennessee, Knoxville. 84pp.

Beeman, L. E. and M. R. Pelton. 1980. Seasonal foods and feeding ecology of black bear in the Great Smoky Mountains. Int. Conf. Bear Res. and Manage. 4:141-147.

Brannon, R. D. 1985. Serum chemistry of central and northeastern grizzly bears. J. Wildl. Manage. 49:893-900.

Eagle, T. C. and M. R. Pelton. 1983. Seasonal nutrition of black bears in the Great Smoky Mountains National Park. Int. Conf. Bear Res. and Manage. 5:94-101.

Ekert, R., and D. Randall 1983. Animal physiology. W. H. Freeman and Co., San Francisco. 830pp.

Ensrud, E. R., R. A. Nelson, G. Alt, T. Beck, G. Matula, and L. Rogers. 1986. Seasonal variations in the ratio of serum urea to creatinine (U/C) in black bears. Physiol. 29:116 (Abstract only).

Erickson, A. W., and W. G. Youatt. 1961. Seasonal variation in the hematology and physiology of black bears. J. Mammal. 42:198-203.

Eubanks, A. L., J. C. Sparks, and M. R. Pelton. 1976. Selected chemical analyses of black bear serum. J. Tenn. Acad. Sci. 51:29-31.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. U.S. Dep. of Agric. For. Serv., Gen. Tech. Rpt. PNW-8. 417pp.

Franzmann, A. W., and C. C. Schwartz. 1988. Evaluating condition of Alaskan black bears with blood profiles. J. Wildl. Manage. 52:63-70.

Gourley, M., and M. Vomocil. 1987. Public involvement in a black bear damage control program on private land. Pages 149-153 <u>in</u> D. M. Baumgartner, R. L. Mahoney, J. Evans, J. Caslick, and D. W. Breuer, eds. Animal Damage management in Pacific Northwest Forests.

Hellgren, E. C., M. R. Vaughan, and R. L. Kirkpatrick. 1989. Seasonal patterns of physiology and nutrition of black bears in Great Dismal Swamp, Virginia - North Carolina. Can. J. Zool. 67:1837-1850.

Kachmar, J. F., and D. W. Moss. 1976. Enzymes. Pages 565-698 <u>in</u> N. W. Tietz, ed. Fundamentals of clinical chemistry. W. B. Saunders Co., Philadelphia.

Karns, P. D., and V. F. J. Crichton. 1978. Effects of handling and physical restraint on blood parameters in woodland caribou. J. Wildl. Manage. 42:904-908.

Kerr, D. K., and R. M. Pace, III. 1987. Error in hematocrit of EDTA-preserved whole blood from black bears caused by delayed analysis. J. Wildl. Dis. 23:344-346.

Kramer, J. W. 1980. Clinical enzymology. Pages 175-196 in J. J. Kaneko, ed. Clinical biochemistry of domestic animals, third edition. Academic Press, San Francisco, CA.

Krebs, J. R. and N. B. Davis. 1984. Behavioral ecology, an evolutionary approach. Sinauer Assoc., Publ., Sunderland, Mass. 493pp.

Landers, J. L., R. J. Hamilton, A. S. Johnson, and R. L. Marchinton. 1979. Foods and habitat of black bears in southeastern North Carolina. J. Wildl. Manage. 43:143-153.

Lassen, E. D., A. M. Craig, and L. L. Blythe. 1986. Effects of racing on hematologic and serum biochemical values in greyhounds. 1986. J. Am. Vet. Med. Assoc. 188:1299-1303.

Lee, J., K. Ronald, and N. A. Oritsland. 1977. Some blood values of wild polar bears. J. Wildl. Manage. 41:520-526.

Lindzey, F. G., and E. C. Meslow. 1980. Harvest and population characteristics of black bears in Oregon (1971-74). Int. Conf. Bear Res. and Manage. 3:213-219.

Maser, C. 1967. Black bear damage to Douglas-fir in Oregon. Murrelet 48:34-38.

Matula, G. J., J. S. Lindzey, and H. Rothenbacher. 1980. Sex, age, and seasonal differences in the blood profile of black bears captured in northeastern Pennsylvania. Int. Conf. Bear Res. and Manage. 4:49-56.

_____, and J. S. Lindzey. 1976. Blood analysis, a potential research tool for studies of black bears. Trans. Northeast Sec. Wildl. Soc. 33:57-69.

Nelson, E. E. 1989. Black bears prefer urea-fertilized trees. West. J. Appl. For. 4:13-15.

Nelson, R. A., H. W. Wahner, J. D. Jones, R. D. Ellefson, and Paul E. Zollman. 1973. Metabolism of bears before during and after winter sleep. Am. J. Physiol. 224:491-496.

_____, T. D. I. Beck, and D. L. Steigler. 1984. Ratio of serum urea to serum nitrogen in wild black bears. Sci. 226:841-842.

Schalm, O. W., N. C. Jain, and E. J. Carroll. 1975. Veterinary hematology, third edition. Lea and Febiger, Philadelphia, PA. 807pp.

_____, and _____. 1986. Veterinary hematology. Fourth edition. Lea and Febiger, Philadelphia, PA. 1221pp.

Schroeder, M. T. 1987. Blood chemistry, hematology, and condition evaluation of black bears in northcoastal California. Int. Conf. Bear Res. and Manage. 7:333-349.

Schwartz, C. C., and A. W. Franzmann. 1991. Interrelationship of black bears to moose and forest succession in the northern coniferous forest. Wildl. Monogr. 113. 64pp.

Seal, U. S. 1978. Assessment of habitat condition by measurement of biochemical and endocrine indicators of the nutritional, reproductive, and disease status of free-ranging animal populations. Proc. Symp. on Classification, Inventory, and Analysis of Fish and Wildlife Habitat, Off. Biol. Serv., U.S. Fish and Wildl. Serv., Washington, D.C. Pages 305-328.

_____, J. J. Ozoga, A. W. Erickson, and L. J. Verme. 1972a. Effects of immobilization on blood analyses of white-tailed deer. J. Wildl. Manage. 36:1034-1040.

_____, L. J. Verme, J. J. Ozoga, and A. W. Erickson. 1972b. Nutritional effects on thyroid activity and blood of white-tailed deer. J. Wildl. Manage. 36:1041-1052.

Storm, G. L., G. L. Alt, G. J. Matula, Jr., and R. A. Nelson. 1988. Blood chemistry of black bears from Pennsylvania during winter dormancy. J. Wildl. Dis. 24:515-521.

Appendix 2. Hematology and serum chemistry of black bears captured (April - mid-July) in an area with high levels of timber damage caused by bears (A) and an area with low bear damage levels (B), Central Coast Ranges, Oregon, 1988.

Bear	TP[b]	Alb	A/G	BUN	CREA	CL^-	CHOL	GLUC	BIL	Ca^+	K^+	Na^+	P^+	ALP
	mg/dl	g/dl	ratio	mg/dl	mg/dl	mEq/l	mg/dl	mg/dl	mg/dl	mg/dl	mEq/l	mg/dl	IU/L	
1A	7.0	4.0	1.3	32.5	0.9	108	---	194	0.1	5.5	4.9	144	3.0	51
2A	7.9	3.8	0.9	12.6	1.0	113	255	160	0.1	6.6	5.3	145	3.8	46
3A	7.4	3.8	1.1	14.8	0.8	112	193	103	0.1	7.2	4.3	143	4.4	50
4A	7.3	3.7	1.0	10.9	1.0	117	152	150	0.1	7.7	4.4	144	4.8	38
5A	6.4	2.6	0.7	14.5	0.7	110	168	150	0.2	6.9	4.4	142	6.0	56
6A	---	---	---	---	---	---	---	---	---	---	---	---	---	--
7A	---	---	---	---	---	---	---	---	---	---	---	---	---	--
8A	7.8	3.6	0.9	21.9	2.4	116	303	122	0.0	6.7	4.8	155	5.7	27
9A[a]	6.5	3.8	1.4	22.2	2.3	122	29	104	0.2	8.3	4.9	157	3.0	49
AVG	7.2[c]	3.6[d]	1.0[e]	18.5	1.3	114	183	140	0.1	7.0	4.7	147	4.4	45[f]
1B	6.8	3.6	---	11.0	0.9	112	183	145	1.1	7.7	4.0	140	4.4	13
2B	7.3	4.1	1.3	13.5	1.2	107	178	142	0.2	6.5	4.3	143	3.8	25
3B	6.1	3.5	1.4	19.7	1.0	105	275	140	0.1	6.0	4.6	143	5.1	41
4B[a]	7.4	4.2	1.3	51.0	1.4	133	264	82	0.1	8.0	4.2	168	6.3	22
5B	6.7	3.8	1.3	18.0	0.9	109	290	111	0.3	7.0	4.3	144	6.6	33
AVG	6.9[c]	3.8[d]	1.3[e]	22.6	1.1	113	238	124	0.4	7.0	4.3	148	5.2	27[f]
TOTAL AVG	7.1	3.7	1.1	20.2	1.2	114	208	134	0.2	7.0	4.5	147	4.7	38

[a]Bear lost paw while snared.

[b]TP = total protein; Alb = albumin; A/G = albumin:globulin ratio; BUN = blood urea nitrogen; Crea = creatinine; Cl^- = chloride; Chol = cholesterol; Gluc = glucose; Bil = total bilirubin; TP = total protein; Ca^+ = calcium; K^+ = potassium; Na^+ = sodium; P^+ = phosphorous; ALP = alkaline phosphatase; CPK = creatine phosphokinase; ALT = alanine aminotransferase; C/A = calcium:albumin ratio; U/C = urea:creatinine ratio; Hb = hemoglobin; PCV = packed cell volume; RBC = red blood count; WBC = white blood count; Lymp = lymphocytes; Mono = monocytes; SNeu = segmented neutrophils; Fib = fibrinogen; PPro = plasma protein.

Appendix 2 continued.

BEAR	CPK IU/L	ALT IU/L	C/A RATIO	U/C RATIO	HB g/dl	PCV %	RBC $10^6/mm^3$	WBC $10^3/mm^3$	LYMP %	MONO %	SNEU %	FIB mg/dl	PPRO g/dl
1A	6590	---	1.4	77.5	17.0	39.7	7.40	16.0	--	5	94	200	7.8
2A	1134	229	1.7	27.0	17.0	42.0	8.04	8.4	9	1	88	400	8.7
3A	1810	275	1.9	39.7	14.3	40.3	7.02	5.1	15	--	85	300	8.1
4A	1782	78	2.1	23.4	17.1	43.8	7.83	13.7	9	1	90	200	8.0
5A	5587	56	2.7	44.5	13.9	35.6	6.35	8.0	13	1	79	300	6.9
6A	----	---	---	----	18.5	41.7	7.19	16.3	27	2	70	200	8.9
7A	----	---	---	----	16.6	42.3	6.80	10.2	7	--	92	500	9.3
8A	10680	532	1.9	19.6	16.8	42.8	7.82	18.3	9	1	87	500	8.7
9A	142	16	2.2	20.7	13.8	35.5	6.31	11.5	12	--	88	200	7.6
AVG	3691	198	2.0	36.1	16.1	40.4	7.20	11.9	13	2	86	>300	8.2
1B	-----	156	2.1	26.2	17.0	38.4	7.50	15.2	8	--	91	400	7.4
2B	50750	201	1.6	24.1	17.4	42.9	7.59	16.6	5	1	93	200	8.0
3B	-----	47	1.7	42.3	16.1	38.8	6.99	13.2	8	1	90	400	7.3
4B	4578	44	1.9	78.2	14.9	37.6	6.74	15.3	16	1	83	100	8.8
5B	50000	254	1.8	42.9	16.4	39.8	7.26	23.7	9	1	90	200	8.7
AVG	35109	140	1.8	42.8	16.4	39.5	7.22	16.8	9	1	89	>250	8.0
TOTAL AVG	13305	172	1.9	38.8	16.2	40.1	7.20	13.7	11	1.5	87	<300	8.2

[c]Mean TP values different (F = 5.45, p = 0.048) between sexes.

[d]Mean Alb values different between area (F = 32.00, p = 0.0005) and sex (F = 61.73, p = 0.0001).

[e]Mean A/G values different (F = 10.31, p = 0.015) between area.

[f]Mean Alp values different (F = 9.40, p = 0.016) between area.

Appendix 3. Pearson's Correlation Coefficient and associated P-values ($P \le 0.15$); R-values < 0.01 were classified as having no linear relationship (NLR); remaining correlations are designated according to the implied nature of the relationship (i.e. +/-) for site characteristics of 80 of Douglas-fir stands, Central Coast Ranges, Oregon, 1989-90.

	DPSME	UPSME	SPS≤10	LOG11-20	LOG21-30	LOG31-40	LOG40+	TOTTREES	TOTBA	LOGDBH	LOGITDE
DPSME	1.0 0.0										
UPSME	+	1.0 0.0									
SPS≤10	0.18 0.1159	0.80 0.0001	1.0 0.0								
LOG11-20	0.20 0.0717	0.66 0.0001	0.63 0.0001	1.0 0.0							
LOG21-30	-	-	-0.38 0.0004	+	1.0 0.0						
LOG31-40	-0.17 0.1401	-	-0.36 0.0009	-0.34 0.0018	0.44 0.0001	1.0 0.0					
LOG40+	-	+	-0.20 0.0685	-0.25 0.0240	0.26 0.0198	0.55 0.0001	1.0				
TOTTREES	+	1.00 0.0001	0.80 0.0001	0.67 0.0001	-	-	+	1.0			
TOTBA	-	0.29 0.0088	-0.23 0.0402	-	0.37 0.0007	0.64 0.0001	0.78 0.0001	0.28 0.0131	1.0		
LOGDBH	-0.22 0.0550	-0.35 0.0016	-0.79 0.0001	-0.49 0.0001	0.70 0.0001	0.70 0.0001	0.61 0.0001	-0.36 0.0010	0.76 0.0001	1.0	
LOGITDE	+	-0.29 0.0074	-0.30 0.0061	-	0.23 0.0384	+	0.13 0.2384	-0.29 0.0092	+	0.25 0.0240	1.0

Appendix 3 continued.

	DPSME	UPSME	SPS≤10	LOG11-20	LOG21-30	LOG31-40	LOG40+	TOTTREES	TOTBA	LOGDBH	LOGITDE
LOGSLOPE	NLR	-0.18 0.1028	-	-	+	NLR	+	-0.18 0.1045	-	-	0.42 0.0001
COS(ASP)	0.20 0.0805	-0.27 0.0150	-	-0.26 0.0182	-	-	-	-0.26 0.0181	NLR	+	NLR
LOGELEV	+	+	0.16 0.1545	-	NLR	+	NLR	-0.36 0.0009	0.70 0.0001	-	NLR

	LOGSLOPE	COS(ASP)	LOGELEV
LOGSLOPE	1.0 0.0		
COS(ASP)	-	1.0 0.0	
LOGELEV	+	-	1.0 0.0

[a]AREA = Study areas: Area with low levels of bear damage = 0 and Area with high levels of bear damage = 1; DAMCAT = Damage category: Bear damage absent = 0, bear damage present = 1; DPSME = Density of Douglas-fir/ha with bear damage; UPSME = Density of Douglas-fir/ha without bear damage; SPS≤10 = Square root transformation of density of Douglas-fir/ha with dbh ≤ 10-cm; LOG11-20 = Log transformation of density of Douglas-fir/ha with 11 ≤ dbh ≤ 20-cm; LOG21-30 = Density of Douglas-fir/ha with 21 ≤ dbh ≤30; LOG31-40 = Log transformation of density of Douglas-fir/ha with 31 ≤ dbh ≤ 40-cm; LOG40+ = Log transformation of density of Douglas-fir/ha with dbh > 40-cm; TOTTREES = Total number of Douglas-fir/ha; LOGBA = Log transformation of basal area/ha; LOGDBH = Log transformation of overall avg dbh; LOGITDE = Logit transformation of % deciduous trees in stand; LOGSLOPE = Log transformation of avg slope; COS(ASP) = cosine(avg aspect); LOGELEV = Log transformation of avg elevation.

APPENDIX 4

CHARACTERISTICS OF BLACK BEARS DENS IN THE CENTRAL COAST RANGES OF OREGON

ABSTRACT

I examined 10 black bear (*Ursus americanus*) dens in the Central Coast Ranges of Oregon, all of which used the structure of large Douglas-fir ($\bar{x}$ diameter = 142 cm). Bears denned primarily on northerly aspects (Rayleigh's $Z = 9.26$, $P < 0.001$). Four types of dens were used: hollow trees and logs and excavations under stumps and logs. Hollow trees had less horizontal cover than other den-types combined ($t = 4.04$, 7 df, $P = 0.005$). Females used mature stands more often than males ($t = 2.78$, 7 df, $P = 0.05$). All dens ($n = 34$) investigated in this region (including 24 dens described by other researchers) used the structure of large trees. Forestry practices that reduce large woody structure are common in the Coast Ranges. Management policies that perpetuate large trees should ensure future availability of large woody structure for bear dens after existing woody debris decays.

INTRODUCTION

Den selection by bears is influenced by site conditions, including protection from wind and precipitation (Lindzey and Meslow 1976, Lentz et al. 1983, Manville 1987). Although bears are adaptable in their choice of den types, human disturbance can further limit site selection (Novick et al. 1981, Alt 1984, Smith 1986, Mack 1990).

Bears in the Central Coast Ranges of Oregon den for up to 6 months (D. Wheeler, Ore. Dept of Fish and Wildlife, pers commun., this study). Forests within this region are commonly managed for timber production on 40- to 80-year rotations, producing trees averaging 30-53 cm in diameter at breast height (dbh). Forests are usually regenerated by clearcutting and broadcast burning; both practices impact the quality and quantity of future den sites. The purpose of this study was to examine the characteristics of den sites used by black bears in the intensively managed forests of the Central Coast Ranges of Oregon.

STUDY AREA

The 1000-km^2 study area was located in the Central Coast Ranges of western Oregon (Figure 6) within the western hemlock (*Tsuga heterophylla*) vegetation zone but dominated by subclimax Douglas-fir (*Psuedotsuga menziesii*) (Franklin and Dyrness 1973). Annual precipitation exceeds 200 cm, most of which occurs during winter and spring. The mean minimum January temperature is -1 C (NOAA 1985:1488). Snow is infrequent and ephemeral, generally lasting only a few days except on the higher peaks and ridges (Hemstrom and Logan 1986). The topography is steep and highly dissected with elevations ranging from 15 to 1,250 m.

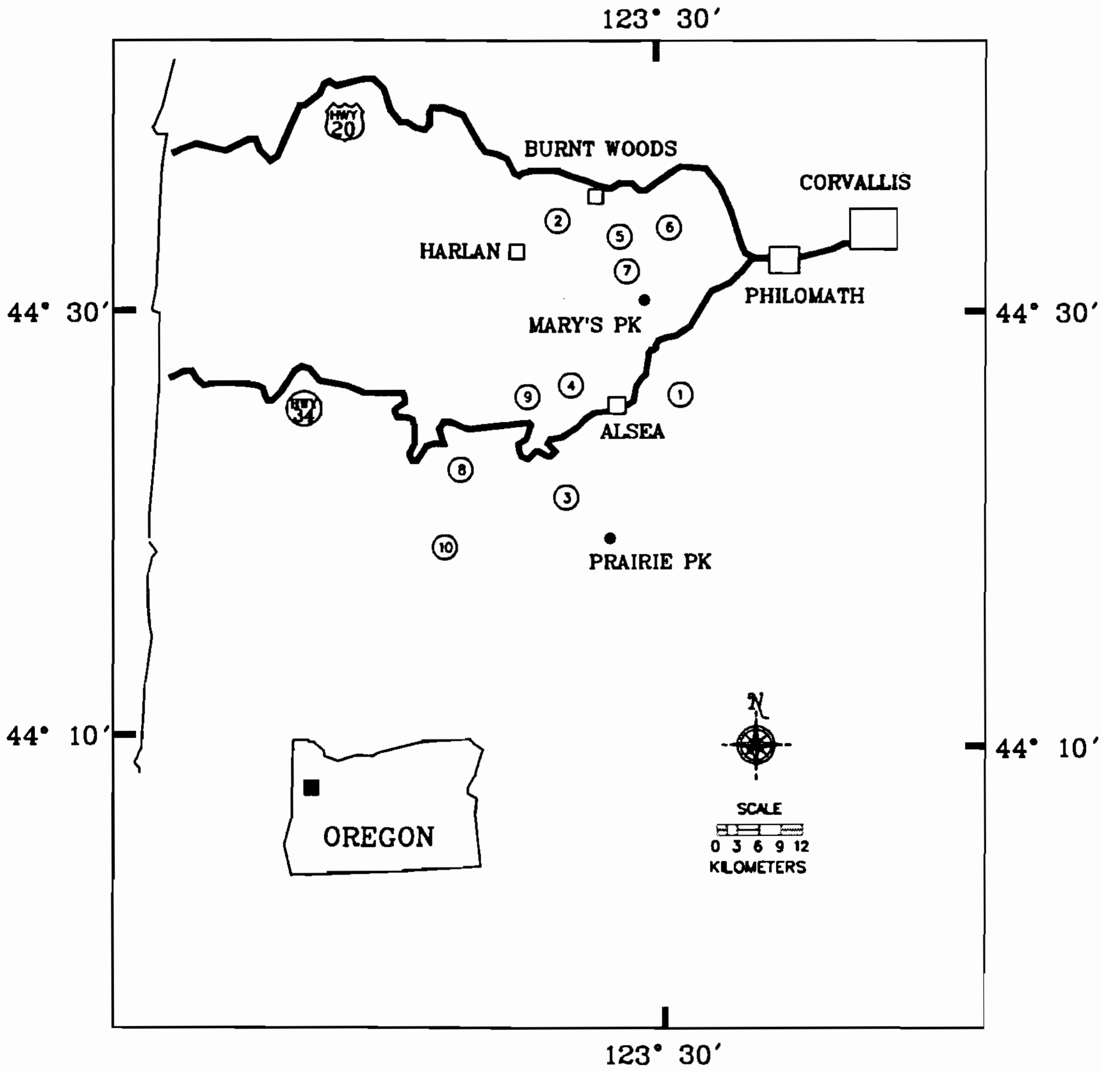

Figure 6. Black bear den locations investigated in the Central Coast Ranges, Oregon, winter 1989-90. Numbers inside circles denote individual bears.

METHODS

In January 1990, 9 previously radio-collared bears were located from aircraft. Each den was subsequently located on the ground. A tenth den, occupied by a radio-collared bear in 1989, was also measured. Physical and vegetational characteristics of the dens and den sites (i.e. ≤15 m from the den) were recorded between 15 and 30 March, 1990, before bud-burst. Vegetational characteristics at 1 den, occupied by a family group until after bud-burst, were not measured. Den measurements included entrance aspect (degrees) and decay class of the woody structure associated with the den (Maser et al. 1979, Cline et al. 1980). The dbh of trees and stumps was measured; log diameters were measured along the portion associated with the den.

Aspect, slope (degrees), and vegetation cover estimates were recorded at each den. Horizontal cover and percent canopy cover were measured along each of 4 transects at 90° intervals oriented to the axis of the den opening. Horizontal cover was estimated with a vegetation profile board (Nudds 1977) positioned 15 m from the den. Horizontal cover values were averaged from the 4 transects to produce a mean cover profile for each den. A single mean cover code value was calculated for each den based on the cover profile values. Percent canopy cover was recorded using a "moosehorn" ocular sighting device (Vales and Bunnell 1985) at 5, 10, and 15 m along each transect. Elevation and position on slope (i.e. drainage bottom, lower 1/4 of slope, mid-slope, and upper 1/4 of slope) were obtained from 1:24,000 topographic maps (U.S. Geological Survey). Stand ages were acquired from landowner's forest stand examinations.

I used t-tests to compare mean cover codes between den types and between mean stand ages selected by males and females. Aspects were tested using statistics for circular distributions (Batschelet 1965).

RESULTS

We located the dens of 5 adult males, 4 adult females, and 1 subadult (< 3-yrs-old) female (Table 10). Three adult females each gave birth to ≥2 cubs in 1990. The female located in 1989 denned with 2 yearlings. Dens were of 4 types: cavities excavated under stumps ("stump dens," n = 2), cavities excavated below logs ("log dens," n = 3), dens inside hollow logs ("hollow logs," n = 2), and ground-level cavities inside live, hollow trees ("tree dens," n = 3). All dens used the structure of large Douglas-fir ($\bar{x}$ diameter = 142 cm). The mean dbh for tree dens was 161 cm.

Mean stand-age for all dens was 66 years (range = 23-110 yrs). Mean stand-age for males was 50 years and females averaged 98 years (t = 2.78, 7 df, P = 0.05). Mean canopy cover was 54% (range = 16-78%) for both sexes combined.

All dens were located on mid- to upper slopes at an average elevation of 370 m (range = 185-550 m) and a mean slope of 23° (range = 6-49°). Nine of 10 dens were on northerly facing slopes (Figure 7), rejecting the hypothesis of a random distribution with respect to aspect (Rayleigh's Z = 9.26, P < 0.001). Nine of 10 entrance aspects were between 280° and 80° (Figure 7).

A pattern in horizontal cover profiles (Figure 8) indicated less cover around hollow trees. Horizontal cover code value for tree dens ($\bar{x}$ = 2.2) differed significantly from the cover code value for all other den types combined ($\bar{x}$ = 4.3; t = 4.04, 7 df, P < 0.005).

Decay classes (Maser et al. 1979, Cline et al. 1980) of stumps and logs ranged from 2 (bark and sapwood mostly intact) to 4 (old, decayed).

Table 10. Characteristics of black bears and bear dens investigated, Central Coast Ranges, Oregon, winter 1989-90.

Bear	Sex	Age est[a]	Den type	Diameter (cm)	Decay class[b]
1	M	10	Hollow log	132	2
2	M	8	Hollow tree	191	
3	M	7	Hollow tree	150	
4	M	8	Under stump	165	3
5	M	6	Under log	97	4
6[c]	F	9	Hollow log	160	4
7	F	3	Hollow tree	142	
8	F	5	Under stump	165	4
9	F	9	Under log	117	4
10	F	7	Hollow log	97	2

[a]Ages based on tooth annuli counts.

[b]Decay classes for logs from Maser et al. 1979; decay classes for stumps from Cline et al. 1980.

[c]Female located in 1989.

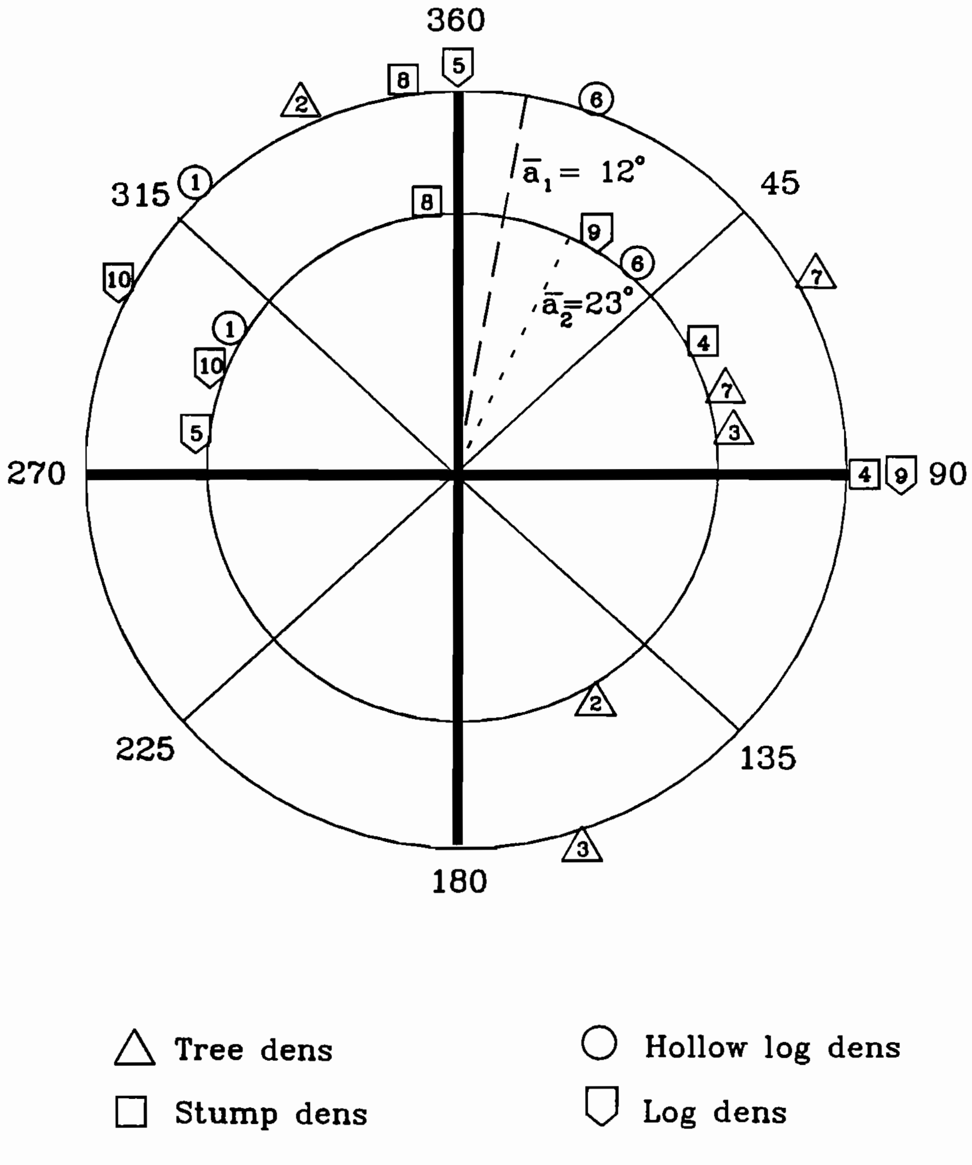

Figure 7. Aspects of entrances (inner circle) and prevailing slope (outer circle) for black bear dens, Central Coast Ranges, Oregon, 1989-90. Numbers inside symbols denote individual bears. Dotted lines represent aspect means.

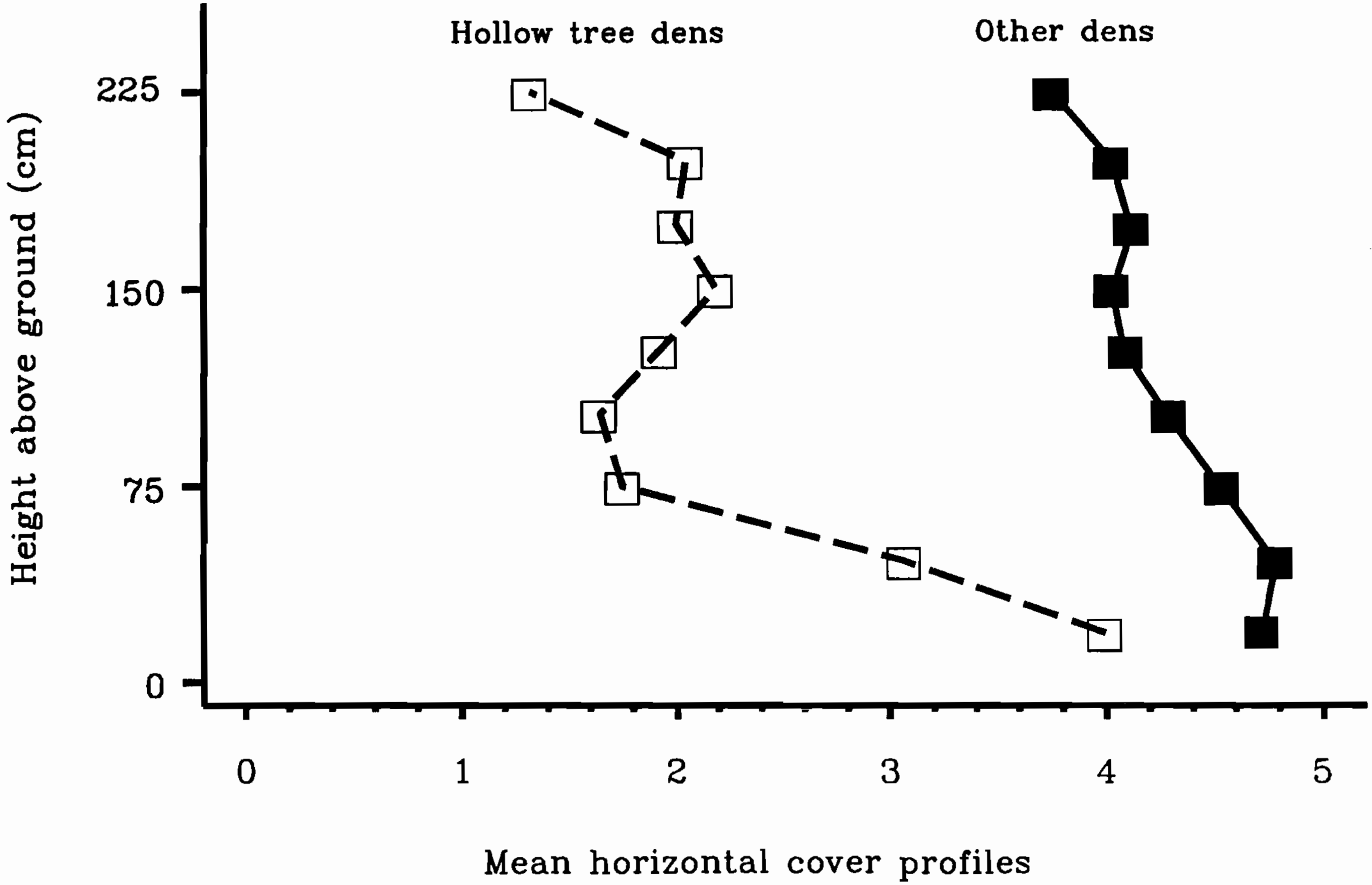

Figure 8. Cover profiles (Nudds 1977) for hollow tree dens (n = 3) and all other dens (n = 7) for black bears, Central Coast Ranges, Oregon, winter 1989-90.

DISCUSSION

In addition to the dens examined here, 10 other dens investigated in western Oregon (D. Wheeler, Ore. Dept. of Fish and Wildlife, pers commun.), 12 dens examined on Long Island, Washington ($\bar{x}$ diameter = 163 cm; Lindzey and Meslow 1976), and 2 other dens described in western Washington (Poelker and Hartwell 1973) all included the structure of large trees. A total of 34 dens described in western Oregon and Washington have all used the structure of large trees, stumps, or logs.

Tree dens were the only exceptions to the distribution patterns of den entrance and den site aspects. Horizontal cover was significantly lower around tree dens than other den types. Male bears denning in hollow trees seemed oblivious to our initial approach (based on the radio-collar activity signals) while the males in other den types abandoned their dens when we were 5-10 m away from their dens (with their collars switching to active while we were 20-100 m away from the den). I believe hollow trees provide a more secure den type for bears in the Coast Ranges; this is consistent with observations by researchers in other regions (Johnson and Pelton 1981, Smith 1986, Wathen et al. 1986).

The predominance of northerly exposures may be an artifact of micro-site moisture conditions. Spies et al. (1988) reported total coarse woody debris in western Oregon and Washington differed significantly between aspects and suggested north-facing sites inherit more woody debris because they are less fire prone. Biomass of coarse woody debris was found to be significantly influenced by forest age class: stands <80-years-old had 32 metric tons/ha, stands 80- to 120-years-old had 46 metric tons/ha, and stands 120- to 500-years-old had 95 metric tons/ha (Spies et al. 1988). Relatively few stands in my study area were over 100-years-old (based on cover-type maps). The already limited availability of large woody debris will continue to decrease as remaining stands are converted to 40- to 80-year rotations and the remnant woody material from previous stands decays.

The use of mature stands by females may be related to availability of large trees upon den emergence. Large trees provide sites for resting, nursing, and escape refugia for cubs (Kolenosky and Strathearn 1987, Mollohagn 1987). The climbing ability of a bear cub may be influenced by the texture of tree bark (Rogers 1993). If this is true, then rough-barked trees like Douglas-fir would provide more effective refugia.

Dens can minimize caloric expenditures during dormancy by protecting the bears from moisture, a particularly important function for pregnant females and new-born cubs (Tietje and Ruff 1980, Alt 1984). A secure site also reduces the likelihood of human disturbance and its associated metabolic costs (Johnson and Pelton 1981, Schoen et al. 1987, Watts and Jonkel 1988). The Coast Ranges have cool winters typified by heavy rains. Road densities that can exceed 6 mi/mi^2 facilitate hunting bears with hounds, a popular sport in this region during spring and fall bear seasons. The same hounds are often used to hunt bobcat (*Lynx rufus*) and raccoon (*Procyon lotor*) during winter and early spring. These factors make secure den sites an important consideration for bear management in western Oregon.

Although interpretation of results obtained from small sample sizes are tenuous, the tests reported here were included because of their agreement with findings reported in the literature. Land management policies that retain snags and logs to ensure future availability and wide distribution of potential den sites may enhance habitat suitability for black bears. Retention of woody structure 100 to 200 cm in diameter and individual trees with hollow boles on mid- to upper level slopes should increase the likelihood of use by bears. Additional research is recommended to define densities of large woody structures necessary to affect use by bears.

LITERATURE CITED

Alt, G. L. 1984. Black bear cub mortality due to flooding of natal dens. J. Wildl. Manage. 48:1432-1434.

Batschelet, E. 1965. Statistical methods for the analysis of problems in animal orientation and certain biological rhythms. Am. Instit. of Biol. Sci. Washington, D.C. 57pp.

Cline, S. P., A. B. Berg, and H. M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44:773-786.

Franklin, J. F. and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. U.S. Dep. Agric. For. Serv. Gen. Tech. Rpt. PNW-8. 417pp.

Hemstrom, M. A. and S. E. Logan. 1986. Plant association and management guide Siuslaw National Forest. U.S. Dep. Agric. For. Serv. PNW-Reg. R6-Ecol 220-1986a. 121pp.

Johnson, K. G. and M. R. Pelton. 1981. Selection and availability of dens for black bears in Tennessee. J. Wildl. Manage. 45:111-119.

Kolenosky, G. B. and S. M. Strathearn. 1987. Winter denning of black bears in east-central Ontario. Int. Conf. Bear Res. and Manage. 7:305-316.

Lentz, W. M., R. L. Marchinton, and R. E. Smith. 1983. Thermodynamic analysis of northeastern Georgia black bear dens. J. Wildl. Manage. 47:545-550.

Lindzey, F. G., and E. C. Meslow. 1976. Characteristics of black bear dens on Long Island, Washington. Northwest Sci. 50:236-242.

Mack, J. A. 1990. Black bear dens in the beartooth face, south-central Montana. Int. Conf. Bear Res. and Manage. 8:273-277

Manville, A. M. 1987. Den selection and use by black bears in Michigan's northern lower peninsula. Int. Conf. Bear Res. and Manage. 7:317-322.

Maser, C., R. G. Anderson, K. Cromak, Jr., J. T. Williams, and R. E. Martin. 1979. Dead and down woody material. Pages 78-95 *in* J. W. Thomas, ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. U. S. Dep. Agric. For. Serv. Agric. Handb. 553.

Mollohagn, C. M. 1987. Characteristics of adult female black bear daybeds in northern Arizona. Int. Conf. Bear Res. and Manage. 7:145-150.

National Oceanic and Atmospheric Administration 1985. Climates of the states. 3rd ed., Vol. 2. 1572pp.

Novick, H. J., J. M. Siperek, and G. R. Stewart. 1981. Denning characteristics of black bears, *Ursus americanus*, in the San Bernadino Mountains of southern California. Calif. Fish and Game 67:52-61.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildl. Soc. Bull. 5:113-117.

Poelker, R. J., and H. D. Hartwell. 1973. Black bear of Washington. Washington State Game Dep. Bull. 14. 180pp.

Rogers, L. L. 1993. The role of habitat quality in the natural regulation of black bear populations. Pages 95-102 in J. A. Keay, ed., Proc. of the fourth western black bear workshop. Natl. Park Serv. West. Region NRTR-93/12.

Schoen, J. W., L. R. Beier, J. W. Lentfer, and L. J. Johnson. 1987. Denning ecology of brown bears on Admiralty and Chichagof Islands. Int. Conf. Bear Res. and Manage. 7:293-304.

Smith, T. R. 1986. Activity and behavior of denned black bears in the lower Mississippi River Valley. Int Conf. Bear Res. and Manage. 6:137-143.

Spies, T. A., J. F. Franklin, and T. B. Thomas. 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecol. 69:1689-1702.

Tietje W. D., and R. L. Ruff. 1980. Denning behavior of black bears in boreal forest of Alberta. J. Wildl. Manage. 44:858-870.

Vales, D. J., and F. L. Bunnell. 1985. Comparisons of methods for estimating forest overstory cover. Research, Min. of Environ. and For. IWIFR-20. Victoria, B.C. 101pp.

Wathen, W. G., K. G. Johnson, and M. R. Pelton. 1986. Characteristics of black bear dens in the southern Appalachian Region. Int. Conf. Bear Res. and Manage. 6:119-127.

Watts, P. D., and C. J. Jonkel. 1988. Energetic cost of winter dormancy in grizzly bear. J. Wildl. Manage. 52:654-656.