SPRING FORAGING AND FOREST DAMAGE BY BLACK BEARS IN THE CENTRAL COAST RANGES OF OREGON

WILLIAM O. NOBLE,[1] Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon 97331, USA
E. CHARLES MESLOW,[2] U.S. Fish and Wildlife Service, Cooperative Wildlife Research Unit, Oregon State University, Corvallis, Oregon 97331, USA

Abstract: Damage to trees by black bears (*Ursus americanus*) is an ongoing problem in west-coastal North America. We studied damage to Douglas-fir (*Pseudotsuga menziesii*) during spring by comparing food habits of bears between an area with high damage (north, $\bar{x}_N = 29.4$ trees damaged/ha, SE = 6.9) and an area with low damage (south, $\bar{x}_S = 2.7$ trees damaged/ha, SE = 1.6). We surveyed 40 forested stands in each area to measure and describe bear damage and to determine if site factors were related to damage levels. Analysis of scats revealed differences in spring diets that included a higher frequency of berry-producing shrubs scats from the south area ($P < 0.01$) and a higher frequency of forbs ($P < 0.01$) in the north area. Site characteristics differed between stands with and without bear damage ($P < 0.01$). Forest stands with bear damage ($n = 33$) had a lower density of trees >40 cm dbh ($P < 0.01$), lower total basal area ($P < 0.01$), occurred on less steep slopes ($P < 0.01$), and differed by aspect (cosine[aspect]: $P < 0.01$) compared to forest stands without bear damage ($n = 47$). Most damage occurs during spring, a season frequently associated with nutritionally poor foods for bears. This is also when carbohydrate production peaks in conifers and cambial zones have the most mass. Stands with prominent damage resemble continuous patchy habitats. Clustered food items appear to be efficiently located and exploited in continuous patchy habitats, even if foragers can only poorly estimate resource distribution. Cambium-feeding may be an energetically viable option for some bears. We recommend altering forest structure in stands vulnerable to bear damage and providing patches of nutritious bear foods as a test to decrease bear damage by reducing the foraging efficiency of bears feeding on cambium

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Tree tissues and saps are a common but usually minor element of spring diets of black bears (Landers et al. 1979, Grenfell and Brody 1983). Concentrations of trees damaged by bears have been an ongoing problem in stands of young forests since the 1940s, particularly in regions of west-coastal North America (Lutz 1951, Molnar and McMinn 1960, Nelson 1989). "Bear damage" is the removal of bark and consumption of the cambial zone by bears. Although definitions of cambial zone vary, we use it to designate the entire multi-cellular layer between wood and bark, including phloem and xylem (Wilson 1964:20). In this paper, cambium refers to this zone and the saps flowing within it.

Some researchers have suggested a lack of other forage may relate to densities of trees damaged by bears (Maser 1967, Nelson 1989). If bear damage is related to forage availability, differences other than the presence or absence of cambium should exist between diets of bears from areas with high levels of damage and diets of bears from similar areas with low levels of bear damage.

Characteristics of trees and forest stands damaged by bears are similar between coastal regions of northern California, Alaska, interior British Columbia, the Rocky Mountains, New England, and Japan (Glover 1955, Zeedyk 1957, Molnar and McMinn 1960, Maser 1967, Poelker and Hartwell 1973, Watanabe 1980, Toyoshima 1983, Schmidt 1989, Hennon et al. 1990). Therefore, tree or stand characteristics may influence cambium–feeding by bears and aid in assessing the vulnerability of a stand to bear damage. Our objectives were to (1) identify spring diets of bears in adjacent areas with differing amounts of bear damage, (2) identify the presence and quantify the extent of bear damage within these areas, and (3) test whether site characteristics can discriminate between stands of similar ages classified by presence or absence of bear damage.

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[1]Present address: U.S. Fish and Wildlife Service, 215 Melody Lane, Wenatchee, WA 98801, USA, email: William_Noble@MAIL.FWS.GOV
[2]Present address: Wildlife Management Institute, 8035 NW Oxbow Drive, Corvallis, OR 97330, USA

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STUDY AREAS

We selected 2 adjacent areas, each about 500 km^2, in the central Coast Ranges of Oregon (Fig. 1). Pre-project inspections and input from local resource managers identified the north area as sustaining high levels of bear damage; the south area was identified as having low levels of bear damage. Subsequent timber damage surveys verified these designations. The region has a maritime climate with typically cool, wet winters. Annual rainfall, occurring primarily during winter, ranges from 27 cm in the east portion of the study areas to 39 cm along the western boundaries. Snow is infrequent and ephemeral, generally lasting only days except on high peaks and ridges. Summers are usually dry, with fog occurring often in the valleys (Hemstrom and Logan 1986). The topography is steep and highly dissected; elevations range from 15–1,250 m. The study areas were within the western hemlock (*Tsuga heterophylla*) vegetation zone, but dominated by Douglas-fir (Franklin and Dyrness 1973). The north area was about 2/3 private and state ownership and 1/3 federal land. The south area was about 1/3 pri-

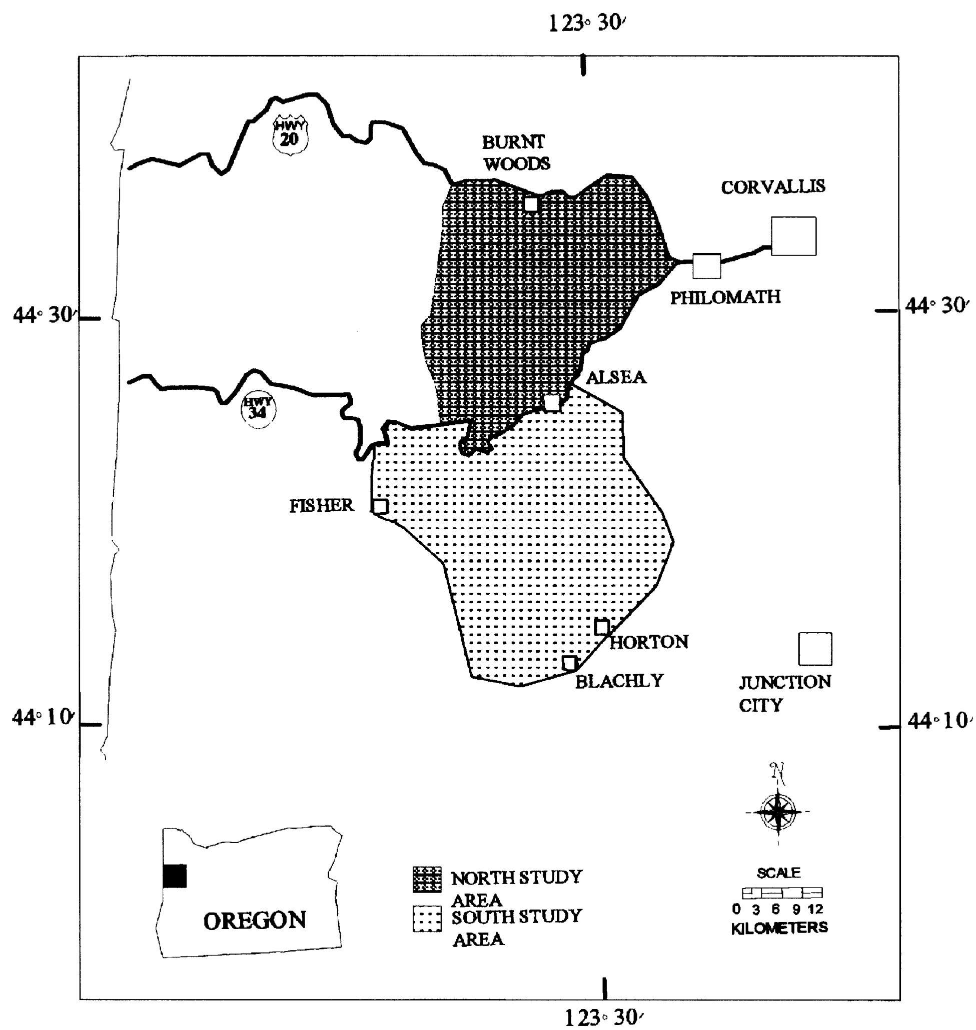

Fig. 1. Location of study areas, central Coast Ranges, Oregon, 1987–90: North area (dark shading) included high amounts of tree damage caused by black bears ($\bar{x}$ = 29.4 trees damaged/ha), and the south area (light shading) had low levels of bear damage ($\bar{x}$ = 2.7 trees damaged/ha).

vate and state land and 2/3 federal ownership. Federal land was managed by the U.S. Department of Agriculture Forest Service. Both areas were primarily Douglas-fir forests managed as a mosaic of 16–48+ ha stands that varied from seedling to mature age classes. Forest stands were typically regenerated by clearcutting at 40- to 80-year rotations, broadcast burning, and planting with Douglas-fir nursery stock. Detailed information at the landscape level (e.g., percent of forested area by age class, by canopy closure, etc.) was not available.

METHODS

Food Habits

Scats were collected in spring (mid-Mar–mid-Jul), 1987–90. Heavy winter rains and rapid decay eliminated scats from the previous fall. The onset of summer was determined by observations of plant phenology and a change in home range use by radiocollared bears (Noble 1994).

Scats were stored frozen then oven dried, and the contents were identified to genus or species (W. Callaghan, Bellvue, Wash.). Frequency of occurrence of food items was tested between study areas with the log-likelihood ratio (Koehler and Larntz 1980, Zar 1984:72).

About 4 kg of fresh cambium was fed to 3 captive black bears at Washington State University on 23 May 1992 to test the effectiveness of identifying cambium in scats. Food had been withheld from the bears during the previous 24 hours. All scats were collected the following morning. Dry matter digestibility was estimated by oven-drying and weighing scat and cambium samples.

Damage Surveys

We defined stands vulnerable to bear damage as having trees 10–50 cm dbh as the predominant size-class based on observations during 2 years of previous field work (Noble 1994). We surveyed 40 randomly selected stands from each study area between 6 November 1989 and 14 March 1990 that met this definition. Observations of bear damage were not dated to time of occurrence and represent all damage incurred to date.

Stands were sampled with 40 circular plots of 40 m^2 spaced at 10-m intervals along four 100-m transects. Transects were spaced 25-m apart and arranged as 4 parallel lines oriented along randomly selected compass bearings. Stand shape forced occasional modifications, although distance between plots and transects remained consistent. Slope and aspect were measured in degrees. Variability in record keeping between land owners, discovered after completing the field work, precluded the use of stand history information in this analysis.

All trees within the 40-m^2 plots >2 cm dbh were identified by species and examined for sign of bear damage. If ≥1 damaged trees were discovered in a sample plot, the stand was classified as "damaged." Wound surface area and percent of circumference damaged were measured on trees damaged by bears. Trees were assigned to dbh size-classes for analysis: <10 cm, 11–20 cm, 21–30 cm, 31–40 cm, and >40 cm. We tested study area designations by comparing numbers of damaged stands (log-likelihood ratio) and comparing numbers of damaged trees (Mann-Whitney *U*-test).

Data from the 40-m^2 plots were averaged to produce stand means. Some variables were transformed to meet assumptions of equal variance. Mean stand aspects were tested for uniform distributions (Batschelet 1965:25–28, Byers et al. 1984) and converted to cosine values for testing with linear statistics (T. Sabin, For. Sci. Dep. Oregon State Univ., Corvallis, pers. commun., 1991).

Use and availability of Douglas-fir was assessed by dbh size class (Neu et al. 1974), with size-classes 31–40 cm and >40 cm combined to avoid biased calculations (Zar 1984:49). Individual size classes were tested with Bonferroni confidence intervals (Byers et al. 1984). Mean dbh of damaged trees was compared with the mean dbh of undamaged trees in stands containing bear damage (Mann-Whitney *U*-test). Site characteristics were tested with multivariate analysis of variance (MANOVA) and classified by study area (*a priori*; $n_1 = 40$, $n_2 = 40$) and by presence or absence of damage (*a posteriori*).

RESULTS

Food Habits

We collected a total of 153 spring season scats ($n_{NORTH} = 61$, $n_{SOUTH} = 92$; Fig.2). Most (≥110) scats were collected in May and June, 1988–89. Scats from the north had a greater frequency of forbs (51%) than did scats from the south (29%; $G = 7.16$, 1 df, $P < 0.01$). Scats from the south had a greater frequency of berry-producing shrubs (50%) than did scats from the north (20%; $G = 15.04$, 1 df, $P < 0.01$). Devil's club (*Oplopanax horridum*) and *Rubus* spp. (primarily salmonberry, *R. spectabilis*) were the only shrubs identified in scats from either study area. Feeding trials indicated cambium was about 50% digestible (dry-weight basis) and readily identifiable in scats. Cambium occurred with a higher frequency (12%) in scats from the north than in scats from the south (2%; $G = 5.71$, 1 df, $P < 0.01$). Percent frequency of vertebrate and in-

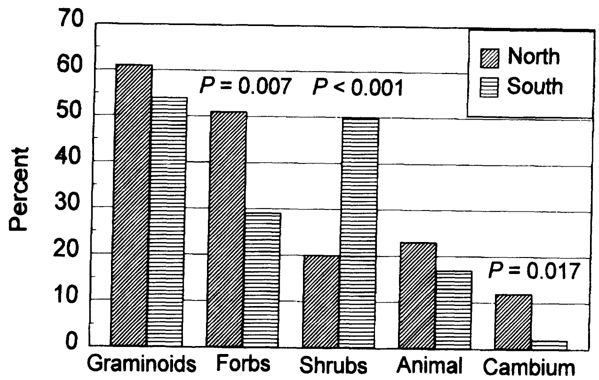

Fig. 2. Forage groups identified in black bear scats, collected Mar–mid-Jul, central Coast Ranges, Oregon, 1987–90, from an area with high levels of bear damage (north; n = 61) and an area with low levels of bear damage (south; n = 92).

vertebrate animal matter was similar between areas (north = 17%, south = 23%, P = 0.40).

Damage to Trees

Because 84% of all trees examined (n = 10,874) and 98% of damaged trees were Douglas-fir, the following analyses were restricted to Douglas-fir. Mean values for 10 site characteristics were calculated for each stand. The south had a lower density of damaged trees/ha ($\bar{x}_S = 2.7$ vs. $\bar{x}_N = 29.4$; $U = -4.89$, 1 df, $P < 0.01$) and fewer stands containing damage ($n_S = 6$ vs. $n_N = 27$; $G = 24.18$, 1 df, $P < 0.01$). The overall hypothesis of no difference between stands classified by study area was not rejected (F for Wilk's $\lambda = 1.10$; 11, 68 df; $P = 0.39$). The null hypothesis was rejected, however, for stands classified by the presence or absence of bear damage (F for Wilk's $\lambda = 2.62$; 11, 68 df; $P < 0.01$). Stands with damage, when compared to stands without damage, had (1) lower density of trees >40 cm dbh; (2) lower total basal area; (3) occurred on less steep slopes; and (4) a non-uniform distribution ($\bar{a} = 31°$; $\chi^2 = 10.5$; $k = 5$, 4 df, $P < 0.05$) with southwesterly aspects (216°–288°) used less than expected (Table 1).

Within stands containing damage (n = 33), bears damaged an average of 39 (SE = 7.7) trees/ha (range = 2–185), peeling an average area of 0.4 m^2 (SE = 0.1)/tree. Average dbh of damaged trees (22 cm, SE = 0.98) differed from the average dbh of undamaged trees (16 cm, SE = 0.95) within stands containing bear damage ($U = 4.23$, 1 df, $P < 0.01$). Bears fed on trees <10 cm dbh less than available ($\chi^2 = 65$, 3 df, $P < 0.01$) and selected trees 21–30 cm dbh ($\chi^2 = 73$, 3 df, $P < 0.01$; Fig. 3).

DISCUSSION

Bear scats from an area with low levels of bear damage contained significantly more berries than did scats from an area with high levels of damage. Conversely, scats from areas where bears commonly fed on cambium contained a higher frequency of forbs than did scats from an area with low levels of damage. Berries are more digestible and typically more nutritious for bears than are grasses and forbs (Rogers 1976, Hewitt 1989).

Despite heavy winter rains, trees in the Coast Ranges commonly experience moisture stress by late spring to early summer (R. Hermann, For. Sci. Dep., Oregon State Univ., Corvallis, pers. commun., 1989). Increased moisture availability increases sucrose production and leads to metabolite storage at lower levels along the tree bole (Wort 1962:94, Kozlowski 1971:107). In general, sites with northerly aspects on less steep slopes should retain more moisture and, on average, stands with bear damage tended to include these characteristics. Bears selected stands with lower total basal area and fed on larger diameter trees. Cambial reserves in vigorous trees can be 2–6 times the thickness of cambium in suppressed trees (Bannon 1962:9). Thinning and fertilizing trees can increase cambium production and can also increase the occurrence of bear damage (Mason and Adams 1989, Nelson 1989). Trees with prominently tapered boles, typical of plantations, concentrate carbohydrate storage at or near ground-level (Kozlowski 1971:109). As trees age and their lower branches become less active physiologically, the area of maximal carbohydrate storage shifts higher up the bole (Kozlowski 1971:107). This may help explain the selection in dbh size-classes: bears appear to select trees offering the largest food rewards at or near ground level.

Pockets of bear damage in stands of evenly spaced, even-aged trees resemble continuous patchy habitats, forming patches with no perceptible boundaries (Benhamou 1992). Clustered food items appear to be efficiently located and exploited in continuous patchy habitats, even if foragers can only poorly estimate resource distribution (Mellgren and Roper 1986, Benhamou 1992).

Many of the stand characteristics associated with bear damage are also associated with maximizing fiber production. Although bears lack a cecum and the microorganisms to digest cellulose (Rogers 1976), they are potentially enhancing their energy intake by selecting trees with the most cambium in stands where search effort is minimized. Bear damage is generally a spring phenomenon, ending with the ripening of summer foods. In our study, cambium-feeding was uncommon in ar-

Table 1. 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, central Coast Ranges, Oregon, 1989–90.

	Stands with damage		Stands without damage		Probability	
Variable	Min/Max	Mean (SE)	Min/Max	Mean (SE)	F	$>F$
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 basal area (m^2)/ha	2.8/51.6	20.3 (1.9)	1.7/71.1	28.8 (2.9)	4.92	0.030
$\bar{x}$ dbh (cm)/stand	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

eas where bears fed on spring berry crops. Cambium-feeding was relatively common, however, where spring diets were dominated by grasses and forbs. Foraging energetics, therefore, may influence cambium-feeding. Under this scenario, in areas where bear damage is present, we would expect damage levels to increase in areas where stand management practices increase the foraging efficiency for bears feeding on cambium. We restrict this argument to areas where bear damage is present because learned and individual behavior, likely strong influences in food selection, are beyond the scope of this paper.

RESEARCH RECOMMENDATIONS

Management strategies we recommend for future research efforts related to cambium-feeding include altering forest structure to reduce foraging efficiency of bears feeding on cambium and providing patches of nutritious foods known to be used by bears.

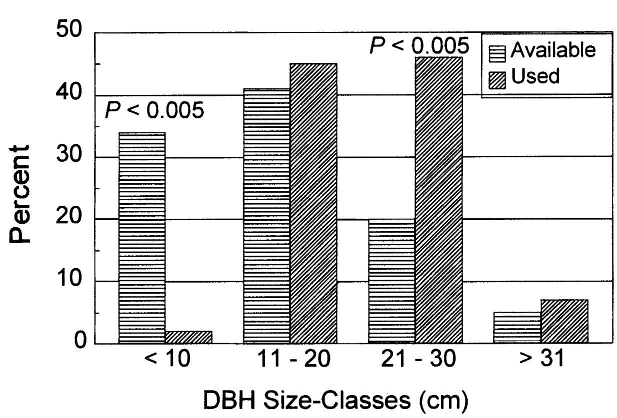

Fig. 3. Use (n = 207) and availability (n = 6,421) of Douglas-fir by dbh size-class for cambium-feeding by black bears, central Coast Ranges, Oregon, 1989–90.

Altering forest structure in areas where bear damage is a management problem could be accomplished by: (1) creating uneven-aged stands and planting a mix of tree species to avoid creating continuous patchy habitat, thereby decreasing foraging efficiency; (2) managing stands at higher stocking levels while trees are in size-classes vulnerable to bear damage to decrease the food reward per individual tree; and (3) limbing lower, physiologically active branches to raise the region of maximal cambium storage higher up the tree bole.

Patches of naturally occurring, key spring foods could be protected or established at the time of stand regeneration. Devil's club and salmonberry produce berries by mid-May in the Oregon Coast Ranges. Given its spotty distribution in the Oregon Coast Ranges, Devil's club could be retained where it naturally occurs. Because Devil's club requires a canopy (Schwartz and Franzmann 1991:38), these areas could be managed in association with snag and green leave tree programs. Both Devil's club and salmonberry occur on moist soils. Allowing forage patches to develop in moist soils would prevent the compaction that frequently results from harvesting these areas and could also facilitate growth of other common bear foods such as cow-parsnip (*Heracleum lanatum*) and horsetail (*Equisetum arvense*). Landings and skid roads could be seeded with foods such as clover (*Trifolium* spp.) and graminoids. Retaining coarse woody debris in openings receiving direct solar radiation may increase the availability of ants (Nielsen 1986).

Each of these measures reduces the potential economic return of a stand managed for timber. Nevertheless, when bears are selecting larger trees in stands with lower basal areas, they are in effect selecting for the most valuable trees in that stand. In areas where bear damage is concentrated, altering stand structure and integrating patches of known bear foods within stands vulnerable to damage could supplement current damage control practices. Bears causing high levels of damage may still prefer the concentrated carbohydrates of cambium over alternate forage, but as bears feeding on cambium are removed from the population, the availability of nutritious foods may also reduce the likelihood of additional bears using trees as spring forage.

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