July 1999

Black Bear Damage to Forest Stands in Western Washington

William B. Stewart
U.S. Fish and Wildlife Service

Gary W. Witmer
USDA-APHIS-Wildlife Services, gary.w.witmer@usda.gov

Gary M. Koehler
Washington Department of Fish and Wildlife

Black Bear Damage to Forest Stands in Western Washington

William B. Stewart, *U.S. Fish and Wildlife Service, 517 S. Buchanan, Moses Lake, WA 98837;* **Gary W. Witmer,** *USDA/APHIS/WS/ National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521-2154; and* **Gary M. Koehler,** *Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA 98501-1091.*

ABSTRACT: *Cambium-feeding behavior by black bears* (Ursus americanus)*, or bear damage, is a major reforestation problem in the Pacific Northwest. Historically, studies have measured the cumulative effects of damage over time, but few have viewed damage in the frame of one season. Bear damage occurring in 1996 was surveyed in areas of radio-marked bears in western Washington. Fresh damage occurred on 48% of bear location plots (n = 96). Douglas-fir* (Pseudotsuga menziesii) *(69%), western hemlock* (Tsuga heterophylla) *(19%), and Pacific silver fir* (Abies amabilis) *(10%) with a mean dbh of 25.1, 29.5, and 30.7 cm, respectively, were most frequently damaged. Random plots were surveyed from mid-July to mid-August to measure habitat availability. Stand and site variables were measured on freshly damaged bear location plots, random plots, and nondamaged bear location plots. This study identified several variables that make forest stands vulnerable to bear damage: conifer dbh, conifer density, stand age, and canopy cover. Awareness of such stand characteristics can assist natural resource managers with animal damage prevention and control programs. West. J. Appl. For.14(3):128–131.*

Black bear damage to conifers caused by cambium-feeding behavior (i.e., bear damage) is a concern to forest managers in the Pacific Northwest. Bear damage occurs during spring and early summer, but levels decline substantially as fruits and berries ripen (Flowers 1987). Tree species preferred by black bears vary not only by region, but also with elevation. Bears commonly feed on Douglas-fir trees in western Oregon and western Washington (Noble 1994, Stewart 1997). Pacific silver fir is the dominant species damaged by bears on the upper slopes of the Olympic and Cascade Mountains (Pierson 1966, Schreuder 1976).

Bears damage a variety of age classes but concentrate on younger, faster growing trees. High levels of bear damage most often occur on more productive sites and to faster growing trees (Noble 1994). Damage levels have been observed to be higher in thinned stands (Mason and Adams 1989, Kanaskie et al. 1990), potentially negating the economic returns of thinning practices (Schreuder 1976).

Bear damage has been recognized as a problem in western Washington since 1951 (Lutz 1951) and was defined as a problem near the North Fork of the Snoqualmie River, the site of the current study (Poelker and Hartwell 1973). Spring hunts that target areas with high levels of bear damage and a supplemental feeding program were initiated in this area, but bear damage continued to be a problem.

Bear damage occurring during the 1996 season (fresh damage) was surveyed and identified by the presence of incisor grooves on the sapwood as well as an abundance of moisture in the exposed cambium. The objectives of this study were to identify habitat attributes associated with bear damage by testing for differences individually and in combination between: (1) freshly damaged bear location plots and random plots, and (2) freshly damaged bear location plots and nondamaged bear location plots. The hypotheses tested were: (1) there is no difference in habitat attributes between freshly damaged bear location plots and random plots, and (2) there is no difference in habitat attributes between freshly damaged bear location plots and nondamaged bear location plots. This was a cooperative effort undertaken by the USDA/APHIS/WS/National Wildlife Research Center, Washington Department of Fish and Wildlife, and Washington State University.

Study Area and Methods

This study was conducted from May to August 1996, in the South Fork Tolt River watershed in the west Cascade Mountains, King County, Washington. Elevations of the overall study site range from 91 to 1160 m. Mean annual precipitation is 131 cm at 235 m and occurs primarily as rain

NOTE: W.B. Stewart, the corresponding author, can be reached at (509) 765-6125; Fax: (509) 765-9043; and E-mail: Bill_Stewart@mail.fws.gov.

between October and May. Average temperatures are 3.5°C in January and 17.4°C in July (NOAA 1996).

The Tolt River watershed consists of two vegetation associations: the western hemlock zone occurs below to 610 m elevation and is dominated by Douglas-fir; the Pacific silver fir zone extends approximately 610 m and above on the study site and is dominated by Pacific silver fir. Common understory plants include sword fern (*Polystichum munitum*), salal (*Gaultheria shallon*), Alaska huckleberry (*Vaccinium alaskaense*), rosey twisted stalk (*Streptopus roseus*), devil's club (*Oplopanax horridum*), and salmonberry (*Rubus spectabilis*). Study plots occurred in both vegetative zones. The majority of the study area is managed intensively for timber production.

Regenerating stands greater than 20 yr old were considered vulnerable to bear damage (Pierson 1966, Poelker and Hartwell 1973). Ten females and ten males were monitored twice weekly. Damage searches occurred when bears were located in "vulnerable" stands. Three field workers walked parallel transects approximately 75 m apart for a length of 400 m; the bear's location was in the approximate center of the total quadrilateral searched (8.0 ha). Physical barriers, such as roads, steep slopes, clearcuts, or major waterways, restricted some searches to < 8.0 ha; the area and shape of damage searches were arbitrarily selected to maximize efficiency of the field crew.

Searches ceased when heavy bear damage was found, which was defined as > 25 stems/ha damaged (Noble 1994). When fresh damage occurred below the heavy damage threshold, searches continued; if heavy damage was not observed, the plot was placed at the site of fresh damage. Only freshly damaged trees were recorded as damaged; bear damage that occurred in prior years was not recorded. Freshly damaged trees were assessed by using a 0.09 ha circular plot, the center of which was arbitrarily placed to encompass the maximum number of damaged trees. The damage assessment consisted of recording the species and dbh of each freshly damaged tree.

Within the 0.09 ha damage plot, one-quarter of the circular damage plot was randomly selected and subsampled for a stand inventory (plot size of 0.02 ha). Some stand inventories did include freshly damaged trees. When no damage was found, a nondamaged bear location plot was established in the approximate center of the search area to inventory stand and site characteristics.

All trees ≥ 10.2 cm dbh were identified and measured. Stand characteristics measured included tree species, dbh, and canopy cover (using a hand-held densiometer). Site characteristics identified included site index and elevation. Overall conifer density and density of individual species were calculated for each plot. Elevations were taken from 1:24000 U.S. Geological Survey topographic maps. Stand age and productivity, as measured by site index (based on the growth of Douglas-fir in 50 yr), were taken from GIS maps of the study site.

Random plots were surveyed mid-July to mid-August to determine habitat availability within the study area. Random plots were placed in the study area using UTM coordinates computer-generated by a random numbers generator. Stand characteristics were inventoried in a 0.02 ha plot following the same methodology as in the bear location plots and using the UTM coordinates as the approximate plot center. Occasionally, random plots contained freshly damaged trees and were included as part of the inventory.

Using two sample t-tests, characteristics were compared of (1) freshly damaged and nondamaged bear location plots as well as (2) freshly damaged bear location plots and random plots. The Mann-Whitney test was used on nonparametric datasets. Multivariate logistic regression analyses were also performed to identify, in combination, the variables most important in making stands vulnerable to black bear damage. Pearson's product-moment correlation was applied to calculate correlations between variables. Variables perceived to be highly correlated ($r > 0.60$) to another included variable were excluded from the multivariate model. Variables in which no significant differences ($P > 0.05$) occurred were not included in tables. For additional information on study results, including bear food habits and the sex of bears causing the damage, readers are referred to Stewart (1997).

Results

Ninety-six bear location plots were examined. Fresh damage was observed from the first week in May into the third week of July and occurred on 48% ($n = 46$) of the plots. Stands consisted primarily of western hemlock (49%) and Douglas-fir (32%). Average conifer density (> 10.2 cm dbh) on bear location plots was 479 stems/ha. One-hundred-four random plots were assessed between mid-July and mid-August. Random plots had an average conifer density of 649 stems/ha. Stands were comprised primarily of western hemlock (56%) and Douglas-fir (24%).

A total of 239 freshly damaged trees was measured: 69% Douglas-fir ($n = 165$), 19% western hemlock ($n = 46$), 10% Pacific silver fir ($n = 23$), and 2% other conifers ($n = 5$). Average stem dbh of freshly damaged trees was 25.1 cm for Douglas-fir, 29.5 cm for western hemlock, and 30.7 cm for Pacific silver fir. The number of freshly damaged trees or stems per plot ranged from 1 to19. On average, freshly damaged bear location plots had 14% (55.5 stems/ha) of trees damaged during the 1996 season. The highest level of damage found in the damage searches was a plot that had 59% of trees freshly peeled (203 freshly damaged stems/ha). This value is not representative of overall damage as bear location plots selected for high levels of damage.

An analysis comparing freshly damaged bear location plots ($n = 46$) with random plots ($n = 104$) tested the hypothesis of no difference in the means of stand and site characteristics. It was assumed that random plots were representative of the study area. Significant differences were found in the means of both stand and site characteristics (Table 1). Stand characteristics that differed ($P > 0.05$) were average conifer density ($P < 0.0001$), average density of western hemlock ($P = 0.0036$), and stand age ($P = 0.0006$). Site index ($P = 0.0197$) was the only site variable examined that differed between the two groups of plots. A multivariate

Table 1. Summary statistics for site and stand characteristics of random plots (n = 104) and freshly damaged bear location plots (n = 46), King County, Washington, 1996.

	Random plots		Freshly damaged plots			
Variables	Mean	SE	Mean	SE	Z^1	Prob>Z
Stand variables						
Average conifer dbh (cm)	28.2	6.9	25.9	5.3	-1.8660^2	0.0640
Average conifer density (stems/ha)	649.4	363.1	401.6	158.1	−4.4641	<0.0001
Average W. hemlock density (stems/ha)	384.5	414.4	179.4	166.6	−2.9334	0.0036
Stand age	39.8	13.1	32.2	7.6	−3.4292	0.0006
Canopy cover (%)	86.1	10.7	82.8	11.4	-1.9032^3	0.0570
Site variables						
Site index (m/50 yr)[4]	30.5	6.0	27.9	4.8	−2.3327	0.0197
Elevation (m)	577.7	303.2	664.2	250.8	1.7773	0.0755

1 Test statistic based on Mann-Whitney test except where otherwise noted.
2 Test statistic based on parametric t-test.
3 Test statistic based on arcsine transformed variables.
4 Measure of productivity based on the growth of Douglas-fir in 50 yr.

logistic regression model revealed that average conifer dbh (P = 0.0002, Likelihood ratio (L-R) ChiSquare =14.2367), average conifer density (P < 0.0001, L-R ChiSquare = 40.0875), site index P = 0.0002, L-R ChiSquare = 14.2884), and canopy cover (P = 0.0166, L-R ChiSquare = 5.7375) were significant indicators of freshly damaged bear location plots.

Because it is unclear whether all random plots contained black bears during the damage season, an additional analysis was performed to look specifically at areas known to be inhabited by radio monitored bears to see if intersite selection occurred. Freshly damaged bear location plots (n = 46) were compared with nondamaged bear location plots (n = 50) to test the hypothesis of no difference in the means of stand and site characteristics. Stand characteristics that differed significantly included average conifer dbh (P = 0.0003), average conifer density (P = 0.0336), average density of western hemlock (P = 0.0100), stand age (P < 0.0001), and canopy cover (P = 0.0264) (Table 2). Site characteristics that differed significantly in the intersite selection analysis included both site index (P = 0.0099) and elevation (P = 0.0042). In the multivariate logistic regression model, average conifer dbh (P < 0.0001, L-R ChiSquare = 18.3176), average conifer density (P = 0.0004, L-R ChiSquare = 12.4453), stand age (P < 0.0001, L-R ChiSquare = 18.9736), canopy cover (P = 0.0349, L-R ChiSquare = 4.4504), and site index (P = 0.0073, L-R ChiSquare = 7.2085) were all significant variables of freshly damaged sites within bear occupied areas.

Densities of Pacific silver fir and Douglas-fir were not significantly different (P > 0.05) within either comparison. Slope, measured as degrees with a clinometer and treated with an arcsine transformation, and aspect, tested in a contingency table analysis, did not differ significantly (P > 0.05) within either comparison.

Discussion

This study examined freshly damaged trees measured within the same season that cambium feeding took place. There was a late greenup in 1996 due to heavy snow loads and below average temperatures in May and June (NOAA 1996). The late greenup probably resulted in an extension of the spring-like conditions and delayed, and possibly diminished, fruit and berry crops that are essential for black bear nutrition and survival. This may have extended the period of time that bears damage trees.

Although the results were strikingly similar, the intersite selection analysis (freshly damaged versus nondamaged bear location plots) revealed more habitat variables that differed significantly when viewed singly (7 vs. 4) and combined in the multivariate analysis (5 vs. 4), than the freshly damaged bear location plots versus random plots comparison. The

Table 2. Summary statistics for site and stand characteristics of nondamaged (n = 50) and freshly damaged (n = 46) bear location plots, King County, Washington, 1996.

	Nondamaged plots		Freshly damaged plots			
Variables	Mean	SE	Mean	SE	Z^1	Prob.>Z
Stand variables						
Average conifer dbh (cm)	31.8	9.4	25.9	5.3	−3.5948	0.0003
Average conifer density (stems/ha)	551.1	286.2	401.6	158.1	−2.1243	0.0336
Average W. hemlock density (stems/ha)	320.4	277.7	179.4	166.6	−2.5766	0.0100
Stand age	44.0	12.3	32.2	7.6	4.7196	<0.0001
Canopy cover (%)	85.0	11.2	82.8	11.4	-2.2203^2	0.0264
Site variables						
Site index (m/50 yr)[3]	31.4	6.4	27.9	4.8	2.5747	0.0099
Elevation (m)	503.5	300.9	664.2	250.8	2.8610	0.0042

1 Test statistic based on Mann-Whitney test.
2 Test statistic based on arcsine transformed variables.
3 Measure of productivity based on the growth of Douglas-fir in 50 yr.

intersite selection analysis was a finer look at selection criteria because black bears were known to be present in the areas of all plots; it is unclear whether black bears were present on random plots during the damage season. Of the two statistical methods utilized, the results from the multivariate analysis are probably a better representation of selection criteria for freshly damaged sites because the multivariate analysis accounts for interactions among variables.

Black bears selected trees based on species. Douglas-fir was most frequently damaged on the Snoqualmie study area, even though western hemlock was the most abundant conifer species. Poelker and Hartwell (1973) and Noble (1994) have also documented preference for Douglas-fir west of the Cascade crest. Freshly damaged areas were younger, overall, and had a smaller average conifer dbh than random plots and nondamaged bear location plots. Freshly damaged bear location plots also had a significantly lower density of conifers and a more open canopy. Nelson (1989) revealed that bear damage typically occurs in more open grown stands where faster growing trees, with higher sap flow, and more understory vegetation occurs.

Freshly damaged bear location plots were higher, overall, in elevation than random plots and nondamaged bear location plots. This is probably a function of the distribution of stand age throughout the study site. Stands most vulnerable to bear damage (21–40 yr old) tended to be concentrated in higher elevations; lower elevations had been harvested earlier in the century. Therefore, past logging activities and time of plantings dictated which areas were vulnerable to bear damage. Also, the delay in the phenological development of trees with increasing elevation may result in a delay of tree damage with respect to age at higher elevations (Schmidt and Gourley 1992).

Fresh damage occurred on sites significantly lower in productivity, as measured by the site indices. This is a contradiction to Mason and Adams (1989) and Nelson (1989), who found that bears tended to damage more productive sites. The relationship found in this study can be explained by the fact that freshly damaged bear location plots were at high elevations; site productivity decreases with increasing elevation due to the shortening of the growing season. Elevation is the most important variable to express climatic change in this region, directly influencing site index (Steinbrenner 1979).

The bear location plot method focused on areas more likely to receive heavy damage. Therefore, the high damage levels observed in some areas may not be representative of overall damage levels, but nonetheless warrant concern by foresters. High levels of bear damage have also been reported by Schmidt (1987), who observed cumulative damage of up to 70% of a stand.

The Snoqualmie study area has traditionally relied on spring bear hunts and a supplemental feeding program to reduce bear depredation on trees (D. Brandt, pers. comm.). Despite these efforts, heavy levels of damage occurred on more than 75% of the freshly damaged sites examined. The observed frequency of high damage levels suggests that in some areas the current methods to reduce black bear damage are only marginally successful. Forest managers are concerned with losing a substantial portion of wood fiber production because stands remain vulnerable to bear depredation for several years. In addition, black bear populations in western Washington and Oregon continue to grow, further compounding the problem (Wash. Dept. Fish and Wildl. 1996).

Several methods have been used to reduce bear damage to trees. Direct control methods include snaring, either to relocate or to lethally remove the bear, and hunting. These reactive methods have aroused controversy in the past. Supplemental feeding, topical repellents applied to the bark of the trees, and several silvicultural practices may provide a proactive, indirect method of black bear damage control. It is essential for forest managers to weigh the costs and the benefits of each method before choosing which, if any, is appropriate for their situation. Furthermore, a combination of methods may most effectively reduce damage.

Damage prevention and management practices should be concentrated in areas that have historically sustained black bear damage as well as in those stands that show a potential vulnerability to bear depredation, based on an assessment of key habitat variables. This will provide more efficient, integrated forest and wildlife management. Further research into black bear damage will provide more knowledge to aid natural resource managers in future management.

Literature Cited

Flowers, R.H. 1987. Supplemental feeding of black bear in tree-damaged areas of western Washington. P. 147–148 *in* Animal damage management in Pacific Northwest forestry, Baumgartner, D.M., et al. (symp. co-chairs). Coop. Extension, Wash. State Univ. Press, Pullman.

Kanaskie, A., J. Chetock, G. Irwin, and D. Overhulser. 1990. Black bear damage to forest trees in northwest Oregon 1988–1989. Pest Manage. Rep. 90-1. Oreg. Dept. of For., Salem, OR. 34 p.

Lutz, H. J. 1951. Damage to trees by black bears in Alaska. J. For. 49:522–523.

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.

National Oceanic and Atmospheric Administration (NOAA). 1996. Climatological data: Washington. Vol. 100.

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

Noble, W.O. 1994. Characteristics of spring foraging ecology among black bears in the central coast ranges of Oregon. M.S. Thesis, Oreg. State Univ., Corvallis. 96 p.

Pierson, D.J. 1966. Washington's black bear problem. Proc. Conf. West. Assoc. State Game and Fish Comm. 46:96–100.

Poelker, R.J., and H.D. Hartwell. 1973. Black bear of Washington. Wash. State Game Dept. Bull. 14. Olympia, WA. 180 p.

Schmidt, W.C. 1987. Bear damage—a function of stand density in young larch forests? P. 145 *in* Animal damage management in Pacific Northwest forestry, Baumgartner, D.M., et al. (symp. co-chairs). Coop. Extension, Wash. State Univ. Press, Pullman.

Schmidt, W.C., and M. Gourley. 1992. Black bear. P. 309-331 *in* Silvicultural approaches to animal damage management in Pacific Northwest forests, Black, H.C. (ed.). USDA For. Serv. Gen. Tech. Rep. PNW-GTR-287.

Schreuder, G.F. 1976. Economic decision making in black bear damage control. Wash. For. Prot. Assoc. Seattle, WA. 43 p.

Steinbrenner, E.C. 1979. Forest soil productivity relationships. P. 199–229 in Forest soils of the Douglas-fir region, *in* Heilman, P.E, H.W. Anderson, and D.M. Baumgartner (eds.). Wash. State Univ., Coop. Ext. Serv., Pullman.

Stewart, W.B. 1997. An investigation of black bear damage to forest stands in western Washington. M.S. Thesis, Wash. State Univ., Pullman. 120 p.

Washington Department of Fish and Wildlife. 1996. Environmental impact statement for the Washington state management plan for black bear. Wildl. Manage. Prog., Wash. Dep. Fish and Wildl., Olympia. 274 p.