A Preliminary Field Evaluation of Candidate Repellents to Reduce Black Bear Damage to Western Larch Trees

Gary W. Witmer
USDA APHIS, National Wildlife Research Center, Fort Collins, Colorado
Michael J. Pipas
USDA APHIS, Wildlife Services, Casper, Wyoming

ABSTRACT: Bear damage to western larch trees on intensively managed public and private forest lands of the Intermountain West continues to be a problem for forest managers. Bark stripping and subsequent cambium feeding by bears commences upon den emergence in the spring, when foraging options are most restrictive. Various damage reduction methods are often controversial (snaring, hunting, supplemental feeding), or do not always adequately resolve the problem (silvicultural strategies); hence, a need exists for the development of alternative nonlethal techniques to reduce damage. We tested the efficacy of three candidate repellents (Hot Sauce®, Tree Guard™, and grizzly bear feces) to reduce spring/summer bear damage to western larch trees on reforestation units in northern Idaho. Plots were laid out and treated in early June and examined for damage four months later. Thirty-four of 300 (11.3%) treated trees were damaged by black bears. Of the newly damaged trees, the highest damage rates were on the control plots: 15 of 75 (20%) trees. Damage levels to trees on treatment plots were 8-9.3%. Mean area of damage, or bark removal, on newly damaged trees only, was 452.8 cm^2. Almost half (47%) of the bear-damaged trees were completely girdled. Chi-square contingency table analysis showed that the damage rate of treated trees was less than of control trees. No difference in mean surface area of damage was detected among treatments. Further testing is necessary to reveal the true potential of chemical repellents for reducing black bear damage to conifers in the spring. A wide array of chemicals should be evaluated for their potential.

KEY WORDS: black bear, forest damage, *Larix occidentalis*, repellents, *Ursus americanus*, western larch

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INTRODUCTION

On intensively managed public and private forest lands of the Pacific Northwest and Intermountain West, black bear (*Ursus americanus*) damage to conifer trees caused by feeding on the cambium is a long-standing problem, and probably one of increasing scale. The problem also occurs from the western end of Canada (Sullivan 1993) to the eastern end (Manning and Baltzer 2011). Bear damage is not confined to North America, but occurs throughout the northern hemisphere (e.g., Kobashikawa and Koike 2016, Zysk-Gorczynska and Jakubiec 2018). This feeding phenomenon commences with den emergence in the spring, when foraging options are limited, and usually ceases by the end of June (Stewart 1997, Noble and Meslow 1998, Stewart et al. 1999). The sudden termination of cambium feeding is attributable in part to physiological changes in the condition of the bark and cambium that makes it more difficult to remove as well as the ripening of many varieties of wild fruits and increasing availability of other forages (Flowers 1987). After the bark is peeled off in strips with the claws of the front feet, the lower and upper incisors are used to scrape the exposed cambium in a vertical direction (Ziegltrum and Nolte 1997, Stewart et al. 2002). The damage is manifested as a partially or completely girdled tree base.

Excessive tree damage can hinder successful reforestation in damage-prone areas. Interestingly enough, intensive, modern forestry methods may exacerbate this problem. Logging practices which have removed large expanses of old growth timber since the late 1800s have fragmented extensive areas of continuous, mature forest, resulting in an interspersion of stands of various age and size classes (Stewart 1997, Stewart et al. 1999). Such habitat conditions may favor increasing bear populations (Kanaskie et al. 1990). Pierson (1966) observed that higher levels of damage are often associated with large clear-cuts.

Bears are selective of many tree and site variables when foraging, including tree species, vigor, diameter at breast height (dbh), tree age and stand density (Stewart 1997, Stewart et al. 1999). Species preference varies not only by region, but elevation (Stewart 1997). It is the younger (15-50 year age range; Schmidt and Gourley 1992), smaller diameter trees (13-64 cm dbh; Giusti 1990) which are the most accessible and palatable to bears, and hence suffer disproportionate damage. Damage levels are inversely related to stand density (Stewart 1997, Stewart et al. 1999). Mason and Adams (1987) noted damage values at least five times higher in thinned blocks than in adjacent unthinned blocks of western larch (*Larix occidentalis*) in northwest Montana. Additionally, damage is often clumped and scattered across the landscape (Giusti 1990).

Bears are presumably attracted to the energy-rich carbohydrate content of tree cambium during a forage period of limited opportunities. Stewart (1997) and Stewart and others (1999) suggested that genetic selection by timber companies for fast-growing trees may actually increase damage levels because bears are more attracted to these "super trees", which may be characterized by higher concentrations of sugars. Kimball et al. (1999) demonstrated that the interaction of environment (site) and genetics influenced the sugars present in vascular tissue.

The bottom line from a financial standpoint is the loss of timber revenues. The financial costs associated with bear damage include reduced growth rates, direct loss of

trees (when completely girdled), secondary losses due to fungal/insect infestations and increased probability of wind-throw (Noble and Meslow 1998). Mason and Adams (1987), using a stand prognosis model to calculate growth and yield through a 50-year rotation, determined a 13% reduction in yield of a thinned stand in northwest Montana attributed to bear damage (17% with loss to butt rot included), compared to a hypothetical undamaged stand. However, in some cases the greatest loss in yield may not be due to bear damage alone, but to understocking caused by pre-commercial thinning (Mason and Adams 1987). Subsequent damage caused by bears attracted to the fast-growing, palatable trees of the thinned stand aggravates this problem. Thus, forest managers must evaluate the long-term benefits of pre-commercial thinning, taking into account the potential loss of yield due to the operation itself and subsequent losses from increased bear activity. In addition to its economic value, western larch has important aesthetic and ecological significance (Schmidt and Shearer 1990).

Various methods have been employed to reduce bear damage to trees (Hygnstrom 1994, Witmer and Whittaker 2001). Historically, direct control methods such as hunting and snaring, both reactive approaches, have been most commonly used (Stewart 1997, Stewart et al. 1999). Hunting typically is not used as a proactive method; special damage hunts are usually designated in problem areas where tree damage becomes severe. Snaring, whereby bears are captured and removed from areas exhibiting tree damage, is a successful and selective method targeting specific problem bears (Schmidt and Gourley 1992). Furthermore, snares are light, inexpensive, and safe to both bears and people (Hygnstrom 1984, Stewart 1997). Hunting not only provides recreational opportunities but generates revenues for state wildlife agencies and stimulates local economies. From a management standpoint, however, hunting, which tends to be overly selective of adult males, may actually exacerbate the problem by not targeting the cohorts (females and subadults) postulated to cause the majority of the tree damage (Flowers 1987, Stewart et al. 2002). In addition, if bark peeling is a learned behavior, females remaining in the population perpetuate the problem by passing this information to their offspring (Stewart 1997). A negative aspect to both of these reactive approaches is that they are unpopular with the general public (Gourley and Vomocil 1987). Ballot initiatives in both Oregon and Washington have banned the use of baiting, dogs and spring hunts as black bear management tools.

Proactive approaches are nonlethal, and consequently more widely acceptable to the general public. Silvicultural approaches include delaying the thinning age of stands, maintaining higher stocking densities, planting species that are less preferred by bears (Stewart 1997) and pruning lower branches, which limits allocation of sugars in the lower bole (Kimball et al. 1998). Currently the most widely practiced proactive approach is supplemental feeding (Ziegltrum 1994, 2006). Since its inception in the mid-1980s, it has been considered in some cases to be quite effective at curbing damage to trees (Ziegltrum 1994, Ziegltrum and Nolte 1997, Ziegltrum 2006). The rationale behind this method is that if an adequate alternative food source (a high energy, nutritionally-balanced pelleted feed provided in strategically located feeders) is provided for bears in the spring, bears will not rely as heavily on trees as a food source (Stewart 1997). This approach may have drawbacks, however, in addition to being impaired by high start-up and annual maintenance costs, Stewart (1997) suggested that artificial feeding programs may congregate bears, which could facilitate breeding, and possibly increase survival rates.

Repellents are another proactive approach that may offer promise. Little work has been done with bear repellents, and none are registered for use on trees or structures (Hygnstrom 1994). Capsaicin, a concentrated red pepper spray, has been tested and used effectively only in direct encounters with bears (Hygnstrom 1994). Topical repellents applied to the boles of trees, though expensive to develop and apply, may reduce damage to individual, high-value trees through taste or odor deterrence. Winter snowpack, often severely curtails forester accessibility to damage-prone sites until well into the spring, often after bear emergence. Because of this, it is important that candidate repellents show long-term efficacy so they can be applied in the fall and still be effective when bears emerge. Freezing conditions may help prolong the longevity of candidate repellents, especially those which are highly volatile.

The objective of this study was to test the hypothesis that three candidate repellents (Hot Sauce®, Tree Guard™, and grizzly bear feces) would reduce spring black bear damage to western larch trees on reforestation units in northern Idaho. We hypothesized that some repellents tested would significantly reduce bear damage compared to control tree damage.

METHODS

Study Site

The study site was located in Boundary County, Idaho (T61°N, R1°W Section 32), approximately eight km northwest of Naples, Idaho in the Highland Creek drainage. The property, acquired from the U.S. Forest Service in a land exchange in 1983, is now owned and administered by the Idaho Department of Lands. The area was logged in the early 1970s as a timber sale and most of it was restocked with Douglas-fir (*Pseudotsuga menziesii*) in the late 1970s. Natural regeneration was important in establishment of a large number of western white pine (*Pinus monticola*). In 1993 or 1994, fire crews, using chainsaws, thinned crop trees to a 3.6 by 3.6-m spacing. Foresters purposefully attempted to maintain a large component of western larch because of its aesthetic, ecological and economic values. Based on the forest management strategy, targeted retention of trees, from the most- to least-preferred species was: western larch (*Larix occidentalis*), western white pine (*Pinus monticola*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), western hemlock (*Tsuga heterophylla*), Engelmann spruce (*Picea enelmannii*), and lodgepole pine (*Pinus contorta*). Plots were located in four nearly contiguous blocks ranging in size from 2.8-25 ha, known collectively as the Brown's Mill Thinning. Aspect of the four blocks varied, with east and south exposure dominating. Slope averaged 25% and elevation was approximately 1,150 m. The potential vegetation (habitat

type) is *Thuja plicata-Clintonia uniflora*. Soils are sandy loams.

Treatments

The three treatments selected for testing were: Hot Sauce®, Tree Guard™, and grizzly bear feces. These were matched with a control (water). Hot Sauce® (Miller Chemical and Fertilizer Corporation, Hanover, PA; CAS No. 404-86-4) is an animal repellent containing 2.5% capsaicin (the active ingredient as found in hot peppers). Tree Guard™ (Nortech Forest Products, Inc., St. Louis Park, MN; CAS No. 3734-33-6), which is marketed primarily as a deer repellent, contains denatonium benzoate, a bittering agent, as the active ingredient (0.2%). Grizzly bear feces were collected from captive animals maintained on a meat diet at Washington State University. Hot Sauce® was prepared by diluting with water (one part Hot Sauce®: seven parts water), to which 0.1 liters of BOND (Loveland Industries Inc., Greeley, CO), a latex binding agent added to enhance adhesion of the treatment to the substrate, was added following the label directions of one pint per 100 gallons of water. The final concentration of capsaicin was about 0.25%. Tree Guard™ was ready-to-use from the container. Included in its formulation is a binding agent. Grizzly bear feces were diluted with water to make 15.1 liters of a slurry, to which approximately 0.1 liters of BOND was added.

Both the Hot Sauce® and Tree Guard™ treatments were applied as a mist using a spray bottle. Water (serving as the control) was also applied as a spray. The grizzly feces mixture, because of its consistency, was applied with a large paintbrush. Treatments were applied to the bole of each tree, from ground level to a height of about 60 cm. Because of the self-pruning nature of the stand, limbs in the treatment zone were minimal and small in size; such limbs were removed prior to application of the treatments.

Each plot, consisting of 25 western larch trees, received a single treatment. This was done, rather than using all three repellents on each plot, to avoid the effect of confounding or mixing of odors. Each treatment was replicated on three plots. Most treated trees were in the ten to 20 cm dbh class. Stand composition (a mixture of species) and tree spacing dictated a variable plot size. Trees with preexisting bear damage (either fresh or from current or past years) were selected only when necessary to keep the plots of tolerable dimensions and only if <50% of the bole was girdled. When necessitated by large distances between sequential trees in a given plot, compass bearings were taken to aid in relocating treated trees. After treatment, each tree was marked with an aluminum tree tag (labeled with the plot/treatment letters and tree number) wired to one of the branches above the treatment zone and was spray-painted with a band of orange paint about two meters above ground level. Prior damage (especially fresh damage) was demarcated by spraying the perimeter of the damaged area with orange spray paint. After each plot was established, an untreated tree in the center (subjectively determined) of the plot was marked with orange plastic streamers and two bands of orange spray paint to facilitate future relocation of treated trees. Plots were treated in June of 1997 and inspected for damage in October of 1997. Presence or absence of bear damage was noted, in addition to the area of fresh damage (in cm^2) on injured trees. We originally planned to treat the trees in the fall of 1996, but heavy fall rains and a long, hard winter precluded that approach.

Chi-square analysis of contingency table data was used to evaluate whether the number of trees damaged differed by treatment. An analysis of variance (ANOVA) was used to test for treatment differences in tree surface areas of fresh damage. To examine whether plot size (e.g., number of trees/plot) had any influence on treatment effect, as well as to determine the most efficient plot size and number of plots for future related work, a restricted maximum likelihood variance components estimation procedure was used to examine the contribution of each of the random effects to the variance of the dependent variable, area of damage. This procedure computes estimates of the variance components in the general linear model which describes the experimental design.

RESULTS

Thirty-four of 300 (11.3%) trees had fresh damage by black bears (Table 1). Twenty-six of 300 (8.7%) treated trees exhibited previous damage. Of the 34 treated trees exhibiting fresh damage only six (18%) had evidence of previous damage. The majority of the newly damaged trees (20%) were on the control plots (15 of 75 trees). On each of the Hot Sauce®- and grizzly feces-treated plots, 8% (six of 75) of the trees sustained new bear damage. Tree Guard™-treated trees suffered 9.3% (seven of 75 trees) new bear damage. Mean area of new damage (bark removal) was 452.8 cm^2, ranging from 4-1440 cm^2. Almost half (47%) of the bear-damaged trees were completely girdled. Although bear damage was also noted on lodgepole pine, western white pine, and Douglas-fir, the combined damage level for these three species appeared to have been less than that sustained by western larch.

Chi-square analysis of contingency data suggested the three repellent treatments may have provided greater protection than no chemical treatment ($X^2 = 7.56$, df = 3, P = 0.056). Damage rates to trees in the control plots were

Table 1. Black bear damage to western larch trees treated with chemical repellents* in Boundary County, Idaho, 1997.

Treatment	No. of Trees Treated	No. of Trees (%) with New Damage	No. of Trees (%) with Preexisting Damage	Average Area (cm^2) of Bark Peeled (SD; Range)**
Control (= water)	75	15 (20.0)	8 (10.7)	407.1 (401.6; 8-1440)
Hot Sauce®	75	6 (8.0)	7 (9.3)	558.7 (369.1; 80-1050)
Grizzly bear feces	75	6 (8.0)	5 (6.7)	341.4 (388.8; 24-1053)
Tree Guard™	75	7 (9.3)	6 (8.0)	555.7 (349.4; 4-1302)

*Repellents sprayed or brushed on bole from ground level to ~60 cm in height

**New damage only

roughly twice as high as on trees receiving the repellent treatments. This suggests a treatment effect, although damage in one of the control plots was disproportionately high (13 of 25 trees), inflating the damage rate.

Evaluating fresh damage area of bear-injured trees, including all 300 trees in the analysis, no difference in mean damage area between treatments was noted ($F = 0.24$, $df = 3$, $P = 0.866$). Examining damaged trees ($n = 34$) only, we likewise observed no difference in mean damage area between treatments ($F = 1.11$, $df = 3$, $P = 0.426$).

The restricted maximum likelihood variance components estimation procedure on surface area damaged revealed that the variability attributable to the nested effect of plot within-treatment (4969.1) was considerably smaller than the tree within plot variability (34868.0). This implies that bears vary greatly in the amount of damage they inflict from tree to tree and that this damage is not distributed evenly over a stand.

DISCUSSION

One concern in conducting studies with large, free-ranging animals is the difficulty of predicting numbers and movements of animals in a study area over a period of time. With a small number of plots to begin with, the effects of bear movements and feeding behavior have the potential to bias the data. For example, one of the control plots received a disproportionately high level of damage (52% of trees in the plot). Three other plots received no damage at all, but these included different treatments (a Tree Guard™ plot, a Hot Sauce® plot, and a control plot). In the former case, this could be an example of a single bear (or a mother and cubs) feeding through the stand; a single bear can peel between 50 and 70 trees a day (Schmidt and Gourley 1992). For plots receiving no damage, it can't be determined whether the experimental trees were not exposed to the foraging activity of any bears or whether the repellents had the desired effect. Nevertheless, one thing is certain: bear activity was noticeable in the area. This was evidenced by the occurrence of fresh damage not only on the immediate study site, but in a much larger encompassing area.

Whether all bears cause feeding damage, or merely a subset of those present in a given area, is unclear. In any event, because a single bear can damage between 50 and 70 trees a day (Schmidt and Gourley 1992), even a few bears can inflict substantial damage in a stand. Hence, bear densities are not an indicator of the scope of damage.

An abundance of fresh damage was already evident when treatments were applied in the spring. An attempt was made to treat late in the fall before the first snows fell. By so doing, trees may have been protected commencing with emergence of bears in the spring. Serious rains prevented such early application of the treatments, as tree boles must be dry for repellents to be effectively applied. The drawback to early application, however, is the uncertainty of the duration of efficacy. With a late fall application, wet or melting snows or frequent rains in the spring may remove the repellents. The latex binding agent specifically designed to enhance adhesion of the chemical may or may not aid in long term (over-winter) repellent efficacy.

Preexisting damage on some of the treated trees does not appear to influence subsequent feeding on the same trees. In a study of a 0.8-ha stand of 110-year-old Douglas-fir in Skamania County, Washington, some trees were damaged two to five times over a two to 46-year period (Schmidt and Gourley 1992). On the west slope of the Cascade Range in Washington, Stewart (1997) documented repeated feeding on 26.4% of randomly sampled plots. In this study, only 18% (six of 34) of freshly damaged trees exhibited prior bear damage.

It has been suggested that bears key in on chemical cues (carbohydrate levels, plant defense compounds) of trees (Stewart 1997). Chemical, and perhaps other, feeding cues are most likely important determinants of the distribution and scope of damage (Kimball et al. 1998). This might explain why some stands with a certain combination of stand and site conditions are heavily damaged by bears, while other similar stands are not damaged (Schmidt and Gourley 1992). Conversely, differential foraging could be a result of variations in quantities of alternative (non-woody) forage between sites with otherwise similar conditions (Noble and Meslow 1998).

Completely girdled trees (direct mortalities) were commonly encountered in this study. Almost half (47%) of the bear-damaged trees were completely girdled. This is much higher than the figure of 18.8% from the Washington Cascades (Stewart 1997) or 33% from northwestern Oregon (Kanaskie et al. 1990). With a thinning operation leaving fast-growing western larch, and bear selection for this species in the study area, the resultant high damage levels could seriously impact harvest yields and the ability of foresters to maintain a significant western larch component in forest stands.

Further testing is necessary to reveal the true potential of chemical repellents for reducing black bear feeding damage to conifers in the spring. A wide array of chemicals should be evaluated for their potential. Further investigation is needed to determine a method of prolonging the efficacy of repellents so that they can be applied in the fall and still be protective from the time bears first emerge in the spring. A better understanding of bear behavior, especially as related to feeding habits and movement patterns, would facilitate more efficient study designs to address the effectiveness of chemical repellents applied to trees to reduce black bear cambium feeding. A study using the same plots for several consecutive years in areas of known high bear densities would dampen the "hit-or-miss" aspect of bear movements and damage. It must also be determined if the use of repellents applied to individual trees may not be a cost-effective solution unless some of the aforementioned problems are overcome or unless only a small portion of the trees in the stand (e.g., western larch) need to be treated. Maintaining western larch as an important component of Intermountain West forestlands is problematic as long as stands are pre-commercially thinned and black bear damage cannot be substantially reduced.

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LITERATURE CITED

Flowers, R. H. 1987. Supplemental feeding of black bear in tree-damaged areas of western Washington. Pages 147-148 *in* D. M. Baumgartner, R. L. Mahoney, J. Evans, J. Caslick, and D. W. Breuer, symposium co-chairs. Animal damage management in Pacific Northwest forests. Cooperative Extension, Washington State University Press, Pullman, WA.

Giusti, G. A. 1990. Black bear feeding on second growth redwoods: a critical assessment. Proceedings of Vertebrate Pest Conference 14:214-217.

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, symposium co-chairs. Animal Damage Management in Pacific Northwest Forests. Cooperative Extension, Washington State University Press, Pullman, WA.

Hygnstrom, S. E. 1994. Black bears. Pages C5-C15 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, editors. Prevention and control of wildlife damage. Cooperative Extension Division, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, NE.

Kanaskie, A., J. Chetock, G. Irwin, and D. Overhulser. 1990. Black bear damage to forest trees in northwest Oregon, 1988-1989. Pest Management Report 90-1. Oregon Department of Forestry, Salem., OR

Kimball, B. A., G. R. Johnson, D. L. Nolte, and D. L. Griffin. 1999. An examination of the genetic control of Douglas-fir vascular tissue phytochemicals: implications for black bear foraging. Forest Ecology and Management 123:245-251.

Kimball, B. A., D. L. Nolte, D. L. Griffin, S. M. Dutton, and S. Ferguson. 1998. Impacts of live canopy pruning on the chemical constituents of Douglas-fir vascular tissues: implications for black bear tree selection. Forest Ecology and Management 109:51-56.

Kobashikawa, S., and S. Koike. 2016. Spatiotemporal factors affecting bark stripping of conifer trees by Asiatic black bears (*Ursus thibetanus*) in Japan. Forest Ecology and Management 380:100-106.

Manning, J. L., and J. L. Baltzer. 2011. Impacts of black bear baiting on Acadian forest dynamics: an indirect edge effect? Forest Ecology and Management 262:838-844.

Mason, A. C., and D. L. Adams. 1987. Black bear damage to managed timber stands in northwest Montana. Pages 137-144 *in* D. M. Baumgartner, R. L. Mahoney, J. Evans, J. Caslick and D. W. Breuer, symposium co-chairs. Animal damage management in Pacific Northwest forests. Cooperative Extension, Washington State University Press, Pullman, WA.

Noble, W. O., and E. C. Meslow. 1998. Spring foraging and forest damage by black bears in the central coast ranges of Oregon. Ursus 10:293-298.

Pierson, D. J. 1966. Washington's black bear problem. Pages 96-100 *in* F. H. Dunkle, B. Glading, M. Takata, and F. Groves, officers. Proceedings of the 46th Annual Conference of Western Association of State Game and Fish Commissioners, Butte, MT.

Schmidt, W. C., and M. Gourley. 1992. Black bear. Pages 309-331 *in* H. C. Black, editor. Silvicultural approaches to animal damage management in Pacific Northwest forests. General Technical Report PNW-GTR-287. USDA Dept. of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Schmidt, W. C., and R. Shearer. 1990. *Larix occidentalis* Nutt. western larch. Pages 160-172 *in* R. Burns and B. Honkala, technical coordinators. Silvics of North America. Agriculture Handbook 654. USDA Dept. of Agriculture, Forest Service, Washington, D.C.

Stewart, W. S. 1997. An investigation of black bear damage to forest stands in western Washington. M. S. thesis. Washington State University, Pullman, WA.

Stewart, W. S., G. W. Witmer, and G. M. Koehler. 1999. Black bear damage to forest stands in western Washington. Western Journal of Applied Forestry 14:128-131.

Stewart, W. S., G. W. Witmer, and G. M. Koehler. 2002. Incisor analysis technique to predict the gender of black bears damaging trees. International Biodeterioration and Degradation 49:209-212.

Sullivan, T. P. 1993. Feeding damage by bears in managed forests of western hemlock-western red cedar in midcoastal British Columbia. Canadian Journal of Forest Research 23: 49-54.

Witmer, G. W., and D. G. Whittaker. 2001. Dealing with nuisance and depredating black bears. Western Black Bear Workshop 16:7:73-81.

Ziegltrum, G. J. 1994. Supplemental bear feeding program in western Washington. Proceedings of Vertebrate Pest Conference 16:36-40.

Ziegltrum, G. J. 2006. Cost-effectiveness of the black bear supplemental feeding program in western Washington. Wildlife Society Bulletin 34:375-379.

Ziegltrum, G. J., and D. L. Nolte. 1997. Black bear damage management in Washington State. Proceedings of Eastern Wildlife Damage Control Conference 7:104-107.

Zysk-Gorczynska, E., and Z. Jakubiec. 2018. Multi-scale approach to brown bear (*Ursus arctos*) foraging on trees: characteristics of damage to trees and stands in the north-eastern Carpathians. Forestry 91:185-192.