# EFFECTS OF SEX AND AGE OF AMERICAN BLACK BEAR ON CONIFER DAMAGE AND CONTROL

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***Abstract:*** American black bear (*Ursus americanus*) feeding damage to conifer stands can result in substantial economic losses in the Pacific Northwest. However, little is known about which sex and age classes of bears cause the most damage and the effectiveness of current control methods. We examined the frequency, intensity, and total conifer damage by radio-monitoring 13 male and 9 female black bears from 1998 to 1999 to determine which sex and age classes caused the most damage. We also examined which sex and age classes were affected by control measures (hunting) to determine the efficacy of management actions. Females were associated with greater frequency ($P = 0.078$), intensity ($P = 0.037$), and total conifer damage ($P = 0.015$) than males. Adult females damaged more trees than other sex and age classes combined ($P = 0.092$). Adult males comprised the majority of bears removed by hunting (66%) but caused only 11% of total damage. Current damage control measures do not seem to be as effective as they could be. We recommend that current hunting practices be reexamined as a mechanism for damage control.

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In the Pacific Northwest, black bear feeding damage to second growth conifer stands on private timberlands is a difficult management issue (Ziegltrum and Nolte 2001). Bears strip bark from coniferous trees to feed on underlying vascular tissues during the spring and early summer, especially in young, intensively managed (e.g., thinned and fertilized) sapling and pole-sized stands (Pierson 1966, Mason and Adams 1987, Schmidt 1987, Sullivan 1993, Ziegltrum 1994). Conifer damage coincides with the formation of new sapwood and a relatively low abundance of other available food items during spring (Poelker and Hartwell 1973). Although some forest managers may have suspected that certain sex and age classes were more prone than others to damaging conifers, control methods in use have targeted bears in general and thus carried an implicit assumption that damage was independent of sex and age class. More recently, Stewart (1997) suggested that adult female bears may contribute most of the damage, possibly because the high caloric cost of lactation requires a high energy diet. Therefore, Stewart (1997) suggested that control measures should be targeted toward adult females.

Current methods to control black bear damage include sport bear hunts by the general public and hot-spot depredation hunts by private landowners (Washington Department of Fish and Wildlife 1997). Pressure on the timber industry to pursue non-lethal alternatives resulted in a supplemental or diversionary feeding program (Flowers 1987, Ziegltrum 1994, Partridge et al. 2001). The supplemental feed is formulated with a higher percent of sugar and proteins than conifer cambium (Partridge et al. 2001). Despite implementation of this diversionary feeding program, hunting remains an important control measure (Stewart 1997, Noble and Meslow 1998, Nolte 1999) and is used increasingly to reduce damage in Washington State.

Efficacy of control measures has not been evaluated (i.e., hunting reduces conifer damage by bears), and the hypothesis that female black bears contribute to most conifer damage has not been adequately tested to date. We tested 2 competing hypotheses for association with conifer damage. The null hypothesis predicted that all sex and age classes of bears (adult males, subadult males, subadult females, and adult females) equally engage in conifer damage. Stewart's (1997) contrasting hypothesis predicted that adult female bears cause most of the conifer damage. We also tested the hypothesis that damage control methods (hunting) proportionally target the sex and age classes that cause damage.

## STUDY AREA

The study was conducted on the Olympic Peninsula of Washington State, south of Olympic National Park (47°15'N, 123°30'W). Ownership varies within this study area and ranges from public lands on the Olympic National Forest to private lands currently owned by Rayonier Northwest Forest Resource and Hancock Timber Resource Group.

The region has a maritime climate with typically cold and wet winters and a mean annual precipitation of 3,800 mm (Washington Department of Fish and Wildlife 1997). Elevations range from sea level to 2,370 m (Washington Department of Fish and Wildlife 1997). The study area

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was in the western hemlock (*Tsuga heterophylla*) zone where the subclimax Douglas-fir (*Pseudotsuga menziesii*) was predominant as a long-lived seral species (Poelker and Hartwell 1973) as a result of repeated logging and planting. Predominant understory species were salal (*Gaultheria shallon*), Oregon grape (*Berberis nervosa*), and vine maple (*Acer circinatum*) on mesic sites and ferns and oxalis (*Oxalis oregana*) on moister sites (Poelker and Hartwell 1973).

# METHODS

## Bear Capture and Monitoring

Black bears were captured during the spring and summer (1 Apr–30 Jun), 1997–98 with Aldrich foot snares at sites baited with beaver (*Castor canadensis*) and ungulate carrion. Captured bears were marked with implantable radio transmitters (see Koehler et al. 2001). Sex, weight, and reproductive status were determined at capture. A premolar tooth was extracted for sectioning and aging (Stoneburg and Jonkel 1966). We estimated that sexual maturity, or age at first parturition, occurred at 4 years of age (Poelker and Hartwell 1973); bears 4 years of age and older were classified as adults. We did not use age at first breeding because age at first parturition corresponded to sex and age differences in habitat use for grizzly bears (*Ursus arctos*) and likely does so for black bears (Wielgus and Bunnell 1994, 1995). Bears were handled according to Washington State University Animal Care Permit #2745.

Locations of bears were determined using aerial telemetry flights conducted once or twice each week during 1998 and 1999 (May 15 to Aug 15), weather permitting (Whitehouse and Steven 1977). Locations of bears were documented (1) on 1:24,000 U.S. Geological Survey topographic maps, (2) by global positioning system (GPS) locations, and (3) with aerial instant photographs of the bears' estimated location.

## Site Investigations

Ground investigations of telemetry locations were conducted within one week to determine if radiomarked bears were associated with fresh conifer damage. Investigated sites were located with the estimated telemetry location as the center. A 1-ha plot (100 x 100 m) was searched for evidence of recent (<1 week) bear damage and bear sign (scats, tracks). The plot size was selected based on preliminary estimates of the radiotelemetry error ($\bar{x}$ =116.9 m, SD = 137.3, $n$ = 13) and the probability of documenting conifer damage that could be associated with a marked individual (see Results). Freshness of conifer damage was determined by observing the color and appearance (consistency of exposed sap) of the damaged area based on previous experience.

If fresh bear sign was found, that sign was attributed to the marked bear. Most radiotelemetry investigations attribute fresh sign (e.g., scats, beds, or evidence of feeding) found at radiolocation sites to the radiocollared animal. Because of the potential for overlapping range use among bears, we tested this assumption by comparing the frequency of sign at radiolocation sites, random sites, and revisited radiolocation sites. We documented the presence or absence of fresh bear sign at random locations and compared this with telemetry locations. If fresh sign were found at similar frequencies in both types of locations, the sign observed at a radiolocation site may have the same probability of being from an unknown bear as a known bear. This assumes that a radiolocated bear has no greater probability of leaving sign at its radiolocation site than uncollared bears (an unlikely scenario). This method also assumes that random locations have a similar probability of use by bears as radiolocation sites, an unlikely assumption if habitat use is non-random. We eliminated these potential biases by returning to selected radiolocation sites 1 week after the initial site investigation to document additional damage or sign that was not initially attributed to the radiomarked bear (i.e., after the marked bear had left the area). If the frequency of fresh sign at these revisited sites was significantly less than that observed during the original site investigation (e.g., 20% vs. 80%), the odds were high (e.g., 4:1) that the research bear caused the original conifer damage. This method does not simply assume equal probabilities of sign from collared and uncollared bears (the collared bear is known to have left the area, so the sign is more likely to be from another bear). Furthermore, this method does not assume random habitat use but implicitly incorporates habitat selection by bears. The random and revisited site trials were conducted weekly to assure seasonal representation.

## Frequency, Intensity, and Total Estimates of Conifer Damage

We used 3 measures to test for sex and age class association with damage: (1) damage frequency (number of damaged plots), (2) damage intensity (number of trees damaged within those plots), and (3) estimates of total damage over the damage period ([% of plots with damage] x [damaged trees/plot] x [days within damage period]). The damage period was from 1 April–30 June ($n$ = 90 days).

We tested whether different sex and age classes of radiomarked bears were associated with different frequencies of conifer damage with log-linear models (Knoke and Burke 1980, Systat 1997). Our log–linear model consisted of 3 variables: sex (male, female), age (adult, subadult), and damage (damaged, non-damaged) in an 8-cell table. The damage variable can be considered the dependent variable; we tested for significant age x damage, sex x damage, and sex x age x damage interactions. For example, a significant sex x damage interaction would indicate that damage frequencies were contingent on sex. We used backward selection modeling to determine if removing sex x damage interaction reduced the fit of the model after all other variables and interactions (e.g., sex by age) were accounted for (Knoke and Burke 1980). A sufficiently small $\chi^2$ log-likelihood improvement ($LL_i$: $P < 0.10$) would indicate a significant improvement by fitting the sex by damage interaction. A sufficiently large $\chi^2$ log-likelihood goodness of fit ($LL_g$: $P > 0.20$) would indicate that the model with the interaction term fit the data (Fingleton 1984). We fitted all main effects: sex, age, damage, and the sex x age interaction before testing for damage x age and damage x sex interactions. Statistical significance was set at $P < 0.10$, not $P < 0.05$, because of the large number of cells in this analysis relative to the small sample sizes and the associated reduction in statistical power and increased probabilities of type 2 errors (failure to reject the null hypothesis of damage being independent of sex and age when the null hypothesis is false).

Data were pooled among bears within sex and age classes in a modified type 2 design (Thomas and Taylor 1990) because sample sizes were too small (mean expected values < 2) for analyses of individual bears (Roscoe and Byars 1971). Moreover, the log–linear model structure cannot test for effects of sex and age on damage using individual bears (Knoke and Burke 1980). Pooling of data was justified in this case because the data were not biased toward individual bears but were distributed evenly among bears within sex and age classes. Pooling biased data can result in increased type 2 errors (low statistical power) because of variability in sample size and behavior among animals (White and Garrott 1990, Alldredge et al. 1998). The number of plots per bear was relatively consistent across individual bears within a sex or age class, so these data were not biased toward particular bears. There was a mean of 8.0 plots/adult female (SD = 1.9), 7.8 plots/subadult female (SD = 3.3), 5.0 plots/adult male (SD = 2.9), and 5.0 plots/subadult male (SD = 2.0). Coefficients of variation (SD/mean) for the number of plots/bear were 0.23, 0.42, 0.58, and 0.40 for adult females, subadult females, adult males, and subadult males, respectively.

We tested for differences in damage intensity (i.e., number of damaged trees per damaged plot) among sex and age classes using the Mann-Whitney *U*-test (Steel et al. 1997). Tests for sex and age class differences in total damage were performed with factorial analysis of variance (ANOVA). All tests were performed with SYSTAT 7.0 software (Systat 1997), and we assumed statistical significance at $P < 0.10$, again because of small sample sizes and low statistical power, and a higher probability of type 2 errors (Steel et al. 1997).

### Depredation and Sport Hunts

Information on sex and age classes of harvested bears between 1994 and 1999 was obtained from the Washington Department of Fish and Wildlife based on bear transport tag sales, hunter questionnaires, tag returns, and reports from the Washington Forest Protection Association. We compared the sex and age composition of bears taken during depredation and sport hunts to the sex and age composition of radiomarked bears damaging trees to determine if harvested bears were representative of damaging bears.

## RESULTS

### Site Investigations

We monitored 22 bears during the summer of 1998 (9 females, 13 males) and 19 bears during the 1999 field season (8 females, 11 males). The mean age at first capture was 5.4 years (SD = 3.7) for males and 5.1 (SD = 4.4) for females. Of the 5 subadult females and 5 subadult males monitored in 1998, 1 subadult female and 4 subadult males were reclassified as adults in 1999. Data were pooled within sex and age classes resulting in 5 subadult females, 5 adult females, 5 subadult males, and 12 adult males. A total of 164 site investigations were conducted during the 1998 ($n = 89$) and 1999 ($n = 75$) field seasons to assess damage. This sample comprised a total of 79 site investigations for females (37 subadult, 42 adult) and 85 site investigations for males (22 subadult, 63 adult). Of the 164 site investigations, 132 or 80% (71 of 89 in 1998; 61 of 75 in 1999) had fresh bear damage or sign. None of the sites that were reinvestigated after the known departure of the marked bear ($n = 16$) had new damage or sign (0%). Random sites ($n = 30$) had a 17% occurrence of fresh sign or conifer damage.

### Frequency of Damage

A total of 16 damaged plots were documented (11 in 1998, 5 in 1999), associated with 10 individual bears. A total of 6 bears (2 adult females, 1 subadult female, 2 adult males, and 1 subadult male) contributed to only 1 damaged plot/individual, and 4 individuals (2 adult females, 1 subadult female, and 1 adult male) were associated with multiple damaged plots. Frequency of conifer damage did not differ between years ($\chi^2 = 1.49$, 1 df, $P = 0.221$; Table 1), so data were pooled across years. Percent of total damage frequency was 44% ($n = 7$) for adult females, 25% ($n$ = 4) for subadult females, 19% ($n$ = 3) for adult males, and 12% ($n$ = 2) for subadult males (Table 2). Association between damage and sex was significant; females were associated with a greater frequency of damaged plots ($LL_i\chi^2_1 = 3.10$, 1 df, $P = 0.078$) than males. Association between damage frequency and age was not significant ($LL_i\chi^2 = 0.06$, 1 df, $P = 0.800$). The best log–linear model included all main effects (sex, age, damage) and the sex x age and sex x damage interactions ($LL_i\chi^2 = 1.07$, 2 df, $P = 0.580$). Inclusion of the sex x age x damage interaction did not improve the fit of the model ($LL_i\chi^2 = 1.01$, 2 df, $P = 0.570$).

## Intensity of Damage

A total of 44 damaged trees were observed (28 in 1998, 16 in 1999). Damage intensity estimates were 3.7 trees/adult female/plot (SD = 3.5, $n$ = 7 plots), 3.0 trees/subadult female/plot (SD = 1.4, $n$ = 4 plots), 1.3 trees/adult male/plot (SD = 0.6, $n$ = 3 plots), and 1.0 trees/subadult male/plot (SD = 0.0, $n$ = 2 plots). Percent of total damage intensity (number of trees damaged) was 59% for adult females, 27% for subadult females, 9% for adult males, and 5% for subadult males. Females damaged more trees per plot than males ($U$ = 45, 1 df, $P$ = 0.037). The intensity of damage did not vary according to the age of the bear ($U$ = 27, 1 df, $P$ = 0.617). Adult females damaged more trees per plot than other sex and age classes combined ($U$ = 65, 1 df, $P$ = 0.092).

## Total Conifer Damage

Estimates of total damage by sex and age classes over the damage period ($n$ = 90 days) were 62.2 trees/adult female/period (SD = 63.3, $n$ = 5 bears), 23.3 trees/subadult female/year (SD = 48.5, $n$ = 5 bears), 5.3 trees/adult male/period (SD = 13.5, $n$ = 12 bears), and 4.8 trees/subadult male/period (SD = 6.6, $n$ = 5 bears). Percent of estimated total damage was 65% by adult females, 24% by subadult females, 6% by adult males, and 5% by subadult males. Total estimated conifer damage was associated with sex (1 df, $P$ = 0.015), indicating that females were associated with more total damage than males. The effects of age (1 df, $P$ = 0.184) and the sex x age interaction (1 df, $P$ = 0.193) were not significant.

**Table 1. Observed and expected values for frequency of plots with tree damage and no tree damage by black bears, Olympic Peninsula, Washington, 1998–99. Expected values for $\chi^2$ test of homogeneity were derived from marginal totals (Steel et al. 1997).**

| | Tree damage | | No tree damage | |
|---|---|---|---|---|
| Year | Observed | Expected | Observed | Expected |
| 1998 | 11 | 8.7 | 78 | 80.3 |
| 1999 | 5 | 7.3 | 70 | 67.7 |

## Depredation and Sport Hunts

There were no depredation hunts on the study site during 1998 or 1999. However, 2 adult males and 1 subadult female from our sample population were killed during the fall sport hunting seasons. The state of Washington had a mean of 67% males (SD = 4.8%) and 33% females (SD = 4.8%) in the sport hunt kill from 1994 to1998. Total sport hunting kills per year were 1,073, 1,218, 1,310, 844, and 1,802 for 1994 through 1998, respectively ($\bar{x}$ = 1,249, SD = 355; Washington Department of Fish and Wildlife, Olympia, Washington, USA, unpublished data). Depredation kills on private forest lands of members of the Washington Forest Protection Association (WFPA) were 66% males (SD = 7.5%) and 34% females (SD = 7.5%) for 1994–99. Total depredation kills on WFPA member lands were 42, 56, 84, 109, 137, and 165, respectively, for 1994–99 ($\bar{x}$ = 99, SD = 47 Washington Department of Fish and Wildlife unpublished data). Overall, males comprised approximately 66% of the harvest from 1994 to 1999 for both sport and depredation hunts. The number of kills per year indicated increasing trends for both types of hunts, with the exception of sport hunting kills in 1997.

# DISCUSSION

Tests of random sites for fresh bear sign suggest that up to 17% of the damage (2–3 of 16 instances) at investigated sites may have been caused by unmarked bears. This maximum (17%) assumes that none of the random sign can be attributed to our marked bears and that habitat use

**Table 2. Observed and expected values for frequency of plots with tree damage and no tree damage by black bear sex and age class, Olympic Peninsula, Washington, 1998–99. Expected values for $\chi^2$ test of homogeneity were derived from marginal totals (Steel et al. 1997).**

| | Sex class | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Males | | | | Females | | | |
| | Tree damage | | No tree damage | | Tree damage | | No tree damage | |
| Age class | Obs | Exp | Obs | Exp | Obs | Exp | Obs | Exp |
| Adult | 3 | 6.1 | 60 | 56.9 | 7 | 4.1 | 35 | 37.9 |
| Subadult | 2 | 2.1 | 20 | 19.9 | 4 | 3.3 | 33 | 33.4 |

is random, which is an unlikely scenario. None of the revisit sites (0%) had fresh bear sign. This estimate (0%) includes no unlikely assumptions. Therefore, the worst odds (random tests) are 5:1 (80% vs. 17%) and the best odds (revisit tests) are 100:1 (100% vs. 0%) that the conifer damage we observed was correctly attributed to the marked bear. These results suggest that fresh bear sign observed in our study area within 1 week of a radiolocation can, for the most part, be attributed to the radiomarked bear.

Female bears were associated with conifer damage more frequently and more intensely than expected and males were associated with damage less frequently and intensely than expected if we assume equal likelihood of damage between sexes (null hypothesis). Estimated total conifer damage also was greater for females. All 3 measures of conifer damage were consistent and contradict the null hypothesis. Instead, these results support the hypothesis by Stewart (1997) that adult female black bears cause the majority of conifer damage. Despite small sample sizes, we are confident in our results because a small sample contributes to increased Type 2 not Type 1 errors (Sokal and Rohlf 1981, Steel et al. 1997, Taylor and Gerrodette 1993) and we obtained statistically significant results at Type 1 error rates $<0.10$.

Reasons for greater conifer damage by female black bears remain speculative, but several have been suggested. Stewart (1997) suggested that cambium provides a source of high energy, which may be required by adult females to support lactation. Partridge et al. (2001) demonstrated that cambium is a relatively rich source of digestible energy but a relatively poor source of protein compared with other foods. It was also suggested that male bears are probably too large to efficiently forage on cambium while maintaining a net energy balance (Partridge et al. 2001). Both suggestions are consistent with our data. Another potential explanation rises from research by Wielgus and Bunnell (1994, 1995, 2000) and Wielgus et al. (2001), who found that hunting adult male grizzly bears resulted in increased immigration by potentially infanticidal males and sexual segregation by adult females into food-poor environments. Previous to this work, wildlife managers assumed that the habitats used by female brown bears were relatively food-rich. Perhaps a similar mechanism is operating in hunted black bear populations in the forests of Washington, with adult female bears damaging trees and forgoing other foods and habitats to avoid males. All 3 of these reasons may account for more damage by females than males and all should be tested before assigning causation. An alternative explanation has also been posed suggesting that because of potential differences in home range size between female and male black bears, female-caused conifer damage would be more concentrated and therefore easier to detect than male-caused damage occurring over a larger area (G. Ziegltrum, Washington Forest Protection Association, Olympia, Washington, USA, personal communication, 2002). We have no evidence to support or refute this. Whatever the underlying reason and recognizing the potential problems associated with small samples, female bears were associated with more damage than males and this should be considered in damage control.

Male bears comprised approximately 66% of bear kills but contributed to only 31% ($n = 5$) of damage frequency, 14% of damage intensity, and 11% of total conifer damage. By contrast, female bears comprised only 34% of the harvest but contributed to 69% ($n = 11$) of damage frequency, 86% of damage intensity, and 89% of total damage. These results suggest that the current depredation and sport hunting control programs may not be as effective as they could be in targeting damaging bears and reducing damage.

## MANAGEMENT RECOMMENDATIONS

Our results suggest that depredation and sport hunts may not be targeting the appropriate sex (females) and sex and age class of bears (adult females) associated with the majority of conifer damage. Both sport and depredation hunts may be biased toward inappropriate sex and age classes (adult and subadult males). We recommend that current hunting practices be reexamined as a damage control measure. Damage control hunts may be much more effective if they better targeted adult female bears, but such a harvest strategy may be politically and socially unacceptable compared with methods such as supplemental feeding. We recommend additional research to test the efficacy of supplemental feeding and whether female bears avoid feeders because of potential risks such as inter- or intra-specific predation (see Wielgus and Bunnell 1994, 1995, 2000; Wielgus et al. 2001).

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