Estimating the Total Economic Impact of Black Bear Peeling in Western Oregon Using GIS and REMI

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ABSTRACT: In parts of the Pacific Northwest, black bears emerge from winter dens with depleted fat reserves and feed on mature conifers by stripping bark and consuming sugar-rich sapwood. Peeling by bears affects commercial conifers through direct loss of the tree or degraded log quality at stand harvest. Bears generally peel trees from 15-30 years old in intensively managed forests until preferred foods such as fruits and berries are available, and a single bear can peel several trees per day. Dying trees have a signature red canopy and are detected in annual aerial forest health surveys; however, trees that scar over peeling are not detected by aerial surveys. Previous studies reported results of damage summaries for northwest Oregon from flights, adjusted for bias; however, they offered no estimates of economic impact. Using landowner survey data, another study estimated an annual timber loss to bears at approximately \$11.5 million across part of western Oregon. While informative, these estimates used broad assumptions to derive primary impacts and did not address secondary impacts. We used aerial health surveys, the national land cover database, and the Regional Economic Models Inc. (REMI) PI+ model to estimate the primary and secondary (indirect and induced) impacts of bear peeling in western Oregon. Because the accuracy and precision of aerial estimates (i.e., percentage of dead trees/polygon) was unknown, we calculated 4 scenarios of loss: 1%, 10%, 30%, and 100% loss. Under these scenarios, black bear damage to commercial forests negatively impacted Oregon's gross domestic product between \$0.9-\$89 million annually, and resulted in an annual loss of between 11 and 1,012 jobs in the state. We will explain our methodology in this study as well as current efforts to improve the accuracy and precision of damage estimates, and ultimately our understanding of the economic impacts of black bear peeling.

KEY WORDS: black bear, damage, economics, forestry, geographic information systems, GIS, Oregon, peeling, *Ursus americanus*

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INTRODUCTION

Although the true origin of black bear damage to trees in Oregon is unknown, Kanaskie et al. (1990) traced written accounts back as early as the mid-19th century. Damage begins annually as bears emerge from winter dens with depleted fat reserves and feed on mature conifers by stripping bark and consuming sugar-rich vascular tissue (Radwan 1969, Poelker and Hartwell 1973). Bears generally peel trees from 15-30 years old in intensively managed forests until preferred foods such as fruits and berries are available (Flowers 1987, Nolte et al. 1998). Most peeling occurs at the base of trees, which represents the most valuable log, but bears also climb and peel higher portions of trees. A single bear can reportedly peel as many as 70 trees per day (Schmidt and Gourley 1992).

Bear peeling affects Pacific Northwest conifers in either of 2 ways: direct loss of the tree, or degraded log quality of the tree. Exclusion, repellents, and toxicants are not practical for reducing peeling by bears. Therefore, managers rely on habitat manipulation and hunting/ trapping to reduce impacts. Silvicultural practices that promote tree vigor, such as fertilization and thinning, increase peeling of Douglas-fir (*Pseudotsuga menziesii*) by bears (Kimball et al. 1998b), while pruning decreases probability of peeling Douglas-fir (Kimball et al. 1998a). In Oregon, black bears may be hunted in spring under controlled hunt regulations (i.e., limited opportunities) and fall under general hunt regulations. Baiting and use of dogs is not legal in Oregon, thus hunters must spot-and-stalk, or they use a sit-and-wait strategy to harvest bears. Landowners who experience damage by black bears may use a predator statute under Oregon law to take "nuisance" bears on their property. In such cases, landowners generally choose to contract a professional trapper to capture and euthanize problem bears. Use of hounds to target problem bears, although legal under the predator statute, is generally avoided due to historical problems with property access, property damage, and unethical behavior.

To date, some efforts have been made to assess total damage caused to timber by black bears spatially and economically. In Oregon, the Oregon Department of Forestry (ODF) conducts annual aerial surveys of Oregon to assess forest health. Historically, these surveys focused mainly on identifying tree mortality by disease pathogens, but they began incorporating estimates of mortality by black bear peeling in the 1980s. Douglas-fir, the most common conifer in western Oregon, shows a red crown within a year of being peeled. This signature is commonly referred to as "red flagging" and may be confused by the untrained observer with stress caused by other causal agents. Aerial damage data since 1996 are available in spatial layers for public use and include estimates of black bear damage to trees. Kanaskie et al. (1990, 2001) reported results of damage summaries for northwest Oregon from flights, adjusted for bias. However, those summaries offered no estimates of economic impact. Using landowner survey data, Nolte and Dykzeul (2002) estimated an annual timber loss to bears at approximately \$11.5 million across part of western Oregon. Furthermore, they projected that loss of lethal bear management techniques would increase forest protection expenditures by 332-400% annually (Nolte and Dykzeul 2002). While informative, these estimates used broad assumptions to derive primary impacts (e.g., direct loss of timber) but did not account for stochasticity in time or secondary impacts (see below). Similarly, Ziegltrum (2006) evaluated cost-effectiveness of one management tool (supplemental feeding) in western Washington but did not address secondary impacts.

Secondary impacts are the broader economic impacts that arise from primary impacts. For example, when black bear damage is avoided in western Oregon, additional board feet of lumber at rotation age is the primary benefit, and secondary benefits are created when the greater revenue and profit earned by timber producers ripples through the rest of the economy. When damage occurs, board feet and log quality are reduced. Additionally, rotation length may be extended to allow compensatory tree growth, which increases interest payments of landowners. ODFW (2012) estimated that bear peeling in Coos and Curry Counties, Oregon resulted in an annual loss of 1.499 million board feet of wood, resulting in an estimated annual loss of 10.64 jobs and \$476,528. While this study addressed job loss (a secondary effect), it reported several constraints and limitations that likely affected results and interpretation (ODFW 2012).

One way to quantify economic impacts of bear peeling is through the use of input-output (IO) models. These models have long been used by economists to quantify the economic impact that results from "shocks" to a regional economy. Input-output modeling creates a mathematical representation of the regional economy, which then can be used to "model" how loss of timber revenue can affect jobs and personal income, for example. The IO model allows the analyst to consider 3 rounds of impact: direct, indirect, and induced. Direct effects are the initial shock from the damage caused by peeling; indirect effects represent the second round of impact as the local economy responds to the initial shock caused by the lost product as a result of peeling; and induced effects are the third and final round of the direct shock as it diffuses through the wider regional economy. The total impact to the economy is the sum of all 3 effects.

METHODS

We used the Regional Economic Models Inc. (REMI) PI+ model to estimate primary and secondary (indirect and induced) impacts of bear peeling. Critical for this analysis, and unlike standard IO models, REMI PI+ is a dynamic model allowing for the estimation of impacts across multiple years. This is an important feature for two reasons: the benefits of reducing tree loss accumulate over time as stands are managed on long rotation ages of approximately 40-60 years; and the secondary benefits can last for many years as the additional spending due to cost savings works its way around the regional economy.

We estimated bear peeling damage for 1 year only, because large-scale annual time-step land cover data layers with national-level standard classification systems (i.e., National Land Cover Data (NLCD), USGS at http://www.mrlc.gov/) are not available for use in geographic information systems. Thus we chose 2006, as this was the most recent NLCD dataset available at a regional scale (Homer et al. 2012). Our study area was western Oregon, from the Oregon Coast east to the crest of the Cascade Mountains. Using the 30-m resolution, multi-spectral Landsat-based imagery for western Oregon, we summed total area (ac) of forested lands by species, age class, and ownership using ArcMap 10 (ESRI 2011).

We acquired estimates of black bear damage from Oregon Department of Forestry's (ODF) 2006 Statewide Aerial Survey (http://www.oregon.gov/odf/privateforests /pages/ fhmaps.aspx). Damage polygons were intersected with land cover data using ArcMap 10 (ESRI 2011) and a feature attribute table of damaged area by forest type was exported to Microsoft Excel (Microsoft 2010). NLCD data provided ranges for tree diameters by size classes, thus we used fixed values (in) of 4, 8, 13, 18, 27, and 36 for sapling, pole, small tree, medium tree, large tree, and giant tree diameter at breast height (dbh), respectively. We used a height/diameter ratio of 70 to estimate tree height, and we estimated trees per acre based on diameter class and typical stocking densities used in operational forestry. We used log scaling tables (Bell and Dilworth 1993) to estimate board feet per tree. For mixed stands containing Douglas-fir, we assumed the damage trees were Douglas-fir as this is the most commonly peeled conifer in western Oregon.

To estimate potential economic value of "damaged" timber among damage polygons, we used ODF timber sale records (http://www.oregon.gov/ODF/Pages/state_ forests/ timber_sales/ logpage.aspx) to obtain pond value estimates by species and log grade. Pond value refers to the price of logs delivered to a mill, not the price received by landowners (i.e., stumpage price). Forest practices differ greatly between private and public lands, as does the value of timber at harvest. Timber values for public timber sales were not available for this study, thus our estimates of economic loss are limited to private timberlands in western Oregon only. We used the following equation to estimate value in loss of standing timber by conifer species and size class:

$$(\textit{total acres damaged} \times \textit{trees per acre} \times \textit{board feet per tree}) / 1000) \times \textit{pond value}$$

The sum of all size classes and species was the estimated total loss in value of conifers in western Oregon for 2006. We reported all units of measurement in U.S. customary units, as this is common in operational forestry in the U.S.

We input estimates of total value of standing timber, total value of damaged timber, and typical annual production for western Oregon into REMI. We ran 4 simulations that would encompass a range of aerial observer accuracy (i.e., actual proportion of trees dead per polygon). We assumed the actual proportions of trees damaged in polygons were 0.01, 0.1, 0.3, and 1.0. We report changes in annual employment and annual gross domestic product (GDP) for Oregon, averaged over a 10-year period.

RESULTS

Based on NLCD data, we estimated approximately 15,322,729 ac of forestland in western Oregon, and 14,294,517 ac (93.2%) represented coniferous stand types (Table 1). We estimated that 76.3% (11,695,778 ac) of all forestland in western Oregon was dominated by Douglas-fir. Approximately 46% (6,992,507 ac) of western Oregon forests were private timberlands. Approximately 6,549,627 acres of private timberlands were in conifer production, of which 5,745,020 acres were dominated by Douglas-fir. We estimated the current standing value of conifers in western Oregon was \$215.0B with a typical annual production of \$1.3B.

The sum acreage of all bear damage polygons in western Oregon was 97,312 ac. Approximately 96.1% (93,605 ac) of damaged polygons were in coniferous stand types, while 86.2% (83,941 ac) of all damaged polygons were pure Douglas-fir or Douglas-fir mixed stands. We estimated that 50,265 ac of standing timber were damaged by bear peeling on private timberlands, of which 47,709 ac were conifers.

Under all simulations, bear peeling resulted in <1% annual loss of standing conifers (across all age classes). Bear damage to private timberlands caused annual GDP in Oregon to decline by \$0.9M-\$88.5M annually, and bear peeling caused between 11 and 1,012 fewer jobs to be available in western Oregon each year (Table 2).

DISCUSSION

Loss of timber to bears is of great concern to private landowners in western Oregon, and accurate estimates of loss are necessary to make management decisions. Our estimate of loss by bear peeling improves upon previous attempts by including a regional approach that includes secondary effects. Even if true annual economic loss falls within our estimated range of \$0.9M-\$88.5M, more research to improve our method is needed. To help improve estimates of economic loss to peeling, we recently initiated a new graduate student research study at Oregon State University. Several lessons learned from our initial efforts are reported here and will be addressed in the graduate research and subsequent discussion.

One major shortfall of our study is that we focused only on red-flag trees observed from the aerial forest health surveys. Kanaskie et al. (1990, 2001) found that for every tree killed by bears, 2 others were damaged nearby with partial peeling. Partial peeling negatively affects wood quality but may not kill the tree. Our models did not estimate loss to board defects at the mill. Kanaskie et al. (2001) also noted a large number of trees in damage polygons were damaged by root disease, a factor which may overestimate bear damage where both agents are present in the same stands. To improve estimates of true bear damage (mortality and scarring), we will ground-truth randomly selected stands using forest cruising techniques to help inform estimates from the air.

In addition, we will estimate the true location of damage polygons on the ground by navigating to them with global positioning systems. This study assumed aerial estimates were spatially reliable, as we did not ground-truth the data. Kanaskie et al. (2001) reported that polygons captured by observers in forest health aerial surveys are ≤0.75 miles from their true locations and may be conservative in mountainous terrain. This likely led to misclassification in our study, as some polygons fell in stand types where peeling is impossible (i.e., clearcuts) or highly unlikely (i.e., mature stands). Additionally, our study showed that more than half of bear damage occurred on public lands. While bear peeling does occur on public forestlands, it is not as common as on private

Table 1. Total area of standing timber by cover type in western Oregon, calculated from National Land Cover Data (NLCD) 2006.

Cover type	Total hectares	Total acres
Alder	148,210	366,235
Bigleaf Maple	17,490	43,218
Douglas Fir / Grand Fir	14,272	35,268
Douglas Fir/ Alder	34,556	85,390
Douglas Fir Mix	326,216	806,095
Douglas Fir / Oak	1,744	4,309
Douglas Fir / White Fir	236,844	585,251
Douglas Fir / Western Hemlock	15,735	38,883
Douglas Fir	4,103,765	10,140,583
Mountain Hemlock	183,977	454,616
Oak	56,106	138,641
Ponderosa	18,067	44,644
Red Fir / White Fir	121,547	300,348
Silver Fir Mix	368,574	910,764
Sitka Spruce	22,141	54,711
Tan Oak	194,298	480,118
Western Hemlock	335,789	829,751
White Pine	1,581	3,906
TOTAL	**6,200,913**	**15,322,729**
Douglas Fir - all types combined	**4,733,132**	**11,695,778**

Table 2. Estimated economic impact from black bear damage to private industrial timber in western Oregon[1].

	Assumed Total Loss Per Damage Polygon[2]			
	1	**0.3**	**0.1**	**0.01**
Change in Annual Employment (persons)	-1,012	-303	-101	-11
Change in Annual GDP[3]	-\$88,515,200	-\$26,534,400	-\$8,832,000	-\$907,200

[1] Values are 10-year means.
[2] Simulations include 4 scenarios that assume the proportion of actual tree damage per polygon observed from forest health surveys are 0.01; 0.1; 0.3; and 1.0.
[3] GDP (Gross domestic product) is equal to the value of all final goods and services produced in the state economy and the sum of everyone's income in the state.

timberlands due to age class distributions and silvicultural practices. In other words, public lands have older age classes and do not use thinning and fertilizing prescriptions as much as industrial private landowners. Thus, public lands generally have fewer trees susceptible to peeling. Our distribution of damage polygons was likely skewed due to error in aerial observations, which could have underestimated economic impact on private lands. Our new study is using low level aerial photography to complement aerial surveys. Ortho-rectified photographs will be added as layers in our GIS in order to match red tree crowns between aerial surveys and photos. This will reduce the distance between estimated and realized damage locations, prior to intersecting damage locations with land cover layers.

We relied on NLCD 2006 for land cover data, as this was the only known source of available data for a study of this scale. For our new study, we are obtaining finer scale land cover data from industrial forest landowners to improve accuracy and precision of our estimates of standing volume and damage. With the addition of these new vector-based files, we can integrate knowledge of stand history and management practices into our analyses to reduce our assumptions (e.g., species planted, trees per acre, etc.). We will compare stand scale qualities of selected stand between land cover data sources to detect differences in projected volume and loss.

Our modeling simulations suggested that bears peel <1% of the standing crop annually. While this may seem acceptable to some, one must realize that not all standing trees are susceptible to peeling. Bears generally peel young Douglas-fir between 15-30 years old (Nolte et al. 1998), roughly representing ⅓-½ of the standing crop in western Oregon. Additionally, damage is not uniformly distributed and bears peel the same stands for multiple years while trees are in the prime peeling range. Thus, certain tree farms may sustain the majority of bear damage while others may experience little to no damage. Small woodland landowners may experience the worst damage, as damage may be concentrated on small areas with most trees in the vulnerable age range. Our future analyses will incorporate cumulative damage by bears and will attempt to identify zones of susceptibility in western Oregon where management actions may be directed. Additionally, our improved estimates of standing volume and damage will be used to model management scenarios in growth and yield models to weigh the potential benefits of different silvicultural practices where bear damage is high (e.g., delayed thinning, wider spacing, etc.).

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