# Estimating the Economic Value of Recreation Losses in Rocky Mountain National Park Due to a Mountain Pine Beetle Outbreak

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## Introduction

Forest insects have long-standing ecological relationships with their host trees. Many insects have a benign or beneficial relationship with trees, but a few species are characterized by unpredictable population eruptions that have great ecological and economic implications (Logan, Régnière, and Powell 2003). These insect outbreaks are a major agent of natural disturbance in North American forests. In the United States alone the area impacted by forest pests is approximately 45 times larger than the area affected by forest fire, yielding an economic effect that is five times greater than fire (Dale et al. 2001). Forest pests also contribute to the occurrence and severity of wildfires and have adverse effects on nutrient cycling, carbon sequestration, and biodiversity (Ayers and Lombardero 2000).

The forest insect of particular interest to this study is the mountain pine beetle (MPB), *Dendroctonus ponderosae*. Bark beetles of the *Dendroctonus* family, found from sea level to 11,000 feet, co-exist with many tree and wildlife species. MPB are an integral part of forest development and regeneration (Logan, Régnière, and Powell 2003). There are 17 different species of bark beetles native to Rocky Mountain National Park (RMNP) and the western Front Range of Colorado. Periodic outbreaks of MPB have been recorded in RMNP since 1915, but none as excessive as the most recent outbreak. Since 1996 bark beetle outbreaks have killed over 6.6 million acres of forests in Colorado, in particular targeting lodgepole pine (*Pinus contorta*) and ponderosa pine (*Pinus ponderosa*) (Romme et al. 2006). MPB outbreaks have severe consequences on forest ecosystem dynamics through mortality and repressed growth of trees (Kurz et al. 2008). During sporadic outbreaks, MPB can kill a large number of trees over a widespread area. Outbreaks result in a reduction of forest carbon uptake and further increase the level of future carbon emissions from decaying trees (Kurz et al. 2008).

Tree mortality, caused by MPB, also may contribute to short term losses in timber production (Romme, Knight, and Yavitt 1986), pose as hazards in recreation areas (Walsh and Olienyk 1981), reduce the aesthetic beauty of landscapes (Jakus and Smith 1991), and depreciate the value of housing near outbreak areas (Price, McCollum, and Berrens 2010). Long term effects of forest insects on ecosystems may be realized if forest structure changes (i.e., a different mix

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of species after infestation). Romme, Knight, and Yavitt (1986), citing Mattson and Addy (1975) and Moore and Hatch (1981), argued that outbreaks of MPB led to only a brief drop in a forest's primary productivity. Over the short term (5-20 years) MPB populations, in natural or outbreak levels, actually introduce more variation into long term primary production and result in a more equitable distribution of biomass and resources among canopy, sub-canopy, and understory trees (Romme, Knight, and Yavitt 1986). Thus, in the long run, forest ecosystems may benefit from forest insect outbreaks and their residual effects.

The economic literature reveals that there is a negative relationship between the effects of forest insects and the quality and visitation rate for recreation (Rosenberger et al. 2012). These negative effects are associated with visible damages (Haefele, Kramer, and Holmes 1992; Holmes and Kramer 1996; Kramer, Holmes, and Haefele 2003; Michalson 1975; Walsh and Olienyk 1981), tree density (Leuschner and Young 1978; Loomis and Walsh 1988; Walsh and Olienyk 1981; Walsh, Ward, and Olienyk 1989; Walsh et al. 1990; Wickman and Renton 1975), and tree size (Loomis and Walsh 1988; Walsh and Olienyk 1981). MPB infestations can also lead to a reduction in the quality of the recreation experience, measured through decreased consumer surplus and decreased number of total visits.

This study uses the benefit transfer approach to estimate the recreational damages associated with MPB infestation in RMNP, Colorado. Benefit transfer uses existing information from primary and secondary sources to estimate values for nonmarket goods such as recreation (Rosenberger and Loomis, 2003). For an extensive review of benefit transfer, see Johnston and Rosenberger (2010). Here, we measure damages by completing benefit transfers that assume reductions in live tree density per acre are directly correlated with MPB infestation rates. The remainder of this paper provides additional information on MPB in the Rocky Mountain region, sources of data and methods used, results, and conclusions based on this research.

## Methods

In this study the method of benefit transfer is used to retroactively examine the effects of MPB on total recreation value for RMNP. In general, benefit transfer develops information for a policy site (in this case RMNP) from existing data or original research conducted at a different site or for a different purpose (Rosenberger and Loomis 2003). This study combines adjusted point estimate information with reduced form functions that relate changes in consumer surplus per user day and changes in the number of user days with changes in live tree density. The outcomes of this study provide estimates of the total recreation value of RMNP at different levels of MPB infestation rates.

Klutsch et al. (2009) estimate that MPB have infested 5.5 percent (the natural rate of MPB infestation in the Colorado Front Range) to 100 percent of lodgepole pine in areas within the Arapaho National Forest, which borders RMNP to the south. However, infestations are often patchy and do not always kill all of the susceptible trees (Klutsch et al. 2009). We assume live tree density changes occur at some lower rate of infestation rates, calculating changes in 0, 25, 50, and 75 percent reductions in live tree density. Total recreation value estimates for RMNP due to different MPB infestation rates are derived based on changes in the number of live trees per acre in RMNP. Thus, we need an estimate of the number of live trees per acre, total number of user days, and the value of a recreation user day.

The U.S. Forest Service provides estimates of number of live trees greater than 5 inches diameter at breast height (dbh) by tree type for 2009 in RMNP (U.S. Forest Service 2012). The

mean number of live trees per acre is calculated as total number of live trees in RMNP divided by 171,166 acres of forested lands, resulting in a mean of 270 trees per acre. The total number of user days in 2009 for RMNP is 2,822,325 user days as provided by the National Park Service (National Park Service 2012). And the value per user day is \$26.66, which is provided by a contingent valuation study conducted at RMNP by Richardson and Loomis (2005), adjusted to 2009 dollars (in comparison, Walsh and Olienyk (1981) provide an estimate of \$25.25 (adjusted to 2009 dollars) per user day for the Colorado Front Range). Total recreation value is total user days times the value per user day. However, changes in live tree density caused by MPB may have two effects on recreation values: (1) changes in the value per user day, and (2) changes in the number of user days. Thus, functions that link value per user day and total user days with changes in live tree density are needed.

Walsh and Olienyk's (1981) study of MPB infestation in the Colorado Front Range provides the needed functions. They estimated a reduced form function for average value (i.e., consumer surplus (*CS*)) per user day of recreation contingent on the change in number of live trees per acre (T), holding all else constant:

Average daily 
$$CS = -2.97 + 0.0917T - 0.00017T^2$$
 (1)

Equation 1 indicates that an individual would, on average, have disutility of \$2.97 in CS per user day if there were no live trees. With otherwise identical conditions, an individual's consumer surplus would increase by \$0.0917 per user day with each additional live tree (Walsh and Olienyk 1981). The squared term indicates that the increase in consumer surplus per live tree per visit increases at a decreasing rate.

Walsh and Olienyk (1981) also provide a reduced form function for average annual user days (UD) of forest recreation contingent on number of live trees per acre (*T*), holding all else constant:

$$Average \ user \ day \ = 9.32 + 0.0923T - 0.0002T^2.$$

Equation 2 shows that an individual would demand, on average, 9.32 days of recreation per year with no live trees. The individual would increase her demand for recreation by 0.0923 days with every additional live tree per acre, given that all other conditions remain constant. An individual's demand for number of days recreated contingent on number of live trees increases at a decreasing rate, as is indicated by the squared term.

Based on these two reduced form functions, average arc elasticities are calculated. The average arc elasticities approximate the percent change in consumer surplus and total user days for a 1 percent change in total live trees greater than 5 inches dbh per acre. Average arc elasticities are calculated for the intervals 0 - 25, 0 - 50, and 0 - 75 percent reduction in live trees per acre due to MPB damage. It should be noted that Walsh and Olienyk's (1981) equation represents average user days per person per year given live trees per acre. This study uses the Walsh and Olienyk (1981) equation to estimate total user days and the change in total user days for each level of MPB damage. Because Equation 2 is based on average rates per person in the Walsh and Olienyk (1981) study, it is assumed that these elasticities are the same for a person as for a population (i.e., if each person in the relevant population reduced their visitation by 4 percent, then total visitation would also be reduced by 4 percent).

Beginning with Richardson and Loomis' (2005) estimate of \$26.66 per user day (adjusted to 2009 dollars) for recreation in RMNP (CS<sub>2009</sub>) and the calculated elasticity for consumer surplus  $(E_{CS})$ , changes in consumer surplus for different damage rates  $(R_i)$  are estimated following Equation 3:

$$CS_i = CS_{2009} - (R_i * E_{CSi} * CS_{2009}),$$
(3)

where *i* refers to each range of decreased live tree density (i.e., i = 0 - 25, 0 - 50, or 0 - 75percent reduction in live trees per acre). Similarly, total user days for the range of MPB infestation rates are calculated beginning with the National Park Service estimate of 2,822,325 user days in 2009 (UD<sub>2009</sub>), damage rates ( $R_i$ ) and total user days elasticities ( $E_{UD}$ ) following Equation 4:

$$UD_i = UD_{2009} - (R_i * E_{UDi} * UD_{2009}),$$
(4)

where *i* is as previously defined.

The baseline total recreation value is then  $TRV_{2009} = CS_{2009} * UD_{2009}$ . Total recreation value for each level of MPB infestation (i.e., damage as reduced live tree density) is TRV<sub>i</sub> = CS<sub>i</sub> \* UD<sub>i</sub>, for each i = 0 - 25, 0 - 50, and 0 - 75 percent reduction in live trees per acre. Thus, the total recreation damages due to MPB infestation are  $TRV_{di} = TRV_{2009} - TRV_i$ .

#### Results

Table 1 provides the average arc elasticity estimates for consumer surplus and user days with respect to live tree density as they were calculated over the ranges of percent decreases in number of live trees per acre from the mean number of total live trees per acre, 270. The estimated arc elasticities show decreases in CS for reductions in live tree density per acre, including -0.298 percent, -0.589 percent, and -0.978 percent for each 1 percent decrease in number of live trees greater than 5 inches dbh per acre for 25, 50, and 75 percent reductions in live tree density. The guadratic function relating CS to live trees per acre shows an increasing effect of tree density reductions: a 25 percent reduction in live trees results in a 7 percent reduction in CS per user day; whereas a 75 percent reduction in live trees results in a 73 percent reduction in CS per user day (Table 1).

Percent Change in Tree Density	of Consumer Su Elasticity of Consumer Surplus <sup>a</sup>	rplus and User Days Percent Change in Consumer Surplus	Elasticity of User Days <sup>a</sup>	<u>Ive Trees</u> Percent Change in User Days
25	-0.298	-7	0.026	1
50	-0.589	-29	-0.121	-6
75	-0.978	-73	-0.244	-18
a				

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<sup>a</sup>Percent change in consumer surplus or user days for a 1 percent change in trees.

Conversely for total user days, the initial reduction in live trees per acre results in an increase in total user days, then falls with increasing reductions in live trees. User days increase by 0.026 percent for each 1 percent decrease in tree density for a 25 percent change, to a loss in user days of -0.121 and -0.244 percent for each 1 percent decrease in live tree density for 50 and 75 percent reductions, respectively. Overall, user days increased by 1 percent for 25 percent reduction in live tree density, and decreased by 6 and 18 percent for 50 and 75 percent reductions in live tree density, respectively.

The cumulative effects of a MPB infestation on consumer surplus per day, user days, and total value of recreation are provided in Table 2. Following the pattern of elasticity estimates and percent change estimates in Table 1, consumer surplus per user day decreases as live tree density declines. Conversely, total user days initially increase with decreases in live tree density, but then decline as tree density declines. These combined effects result in total recreation value changes of -\$5 million, -\$25 million and -\$59 million with 25, 50 and 75 percent reductions in live tree density. These losses are from a baseline total recreation value of \$75 million.

Percent Change in Tree Density	Consumer Surplus per Day	Total User Days	Total Value	Change in Total Value
0 <sup>a</sup>	\$26.66	2,822,325	\$75,243,185	\$0
25	\$24.67	2,840,907	\$70,092,408	-\$5,150,777
50	\$18.81	2,651,458	\$49,864,257	-\$25,378,927
75	\$7.10	2,305,790	\$16,366,787	-\$58,876,397

#### Table 2 – Consumer Surplus per Day, Total User Days, and Total Value of Recreation

<sup>a</sup>Baseline case of natural infestation rate with 270 total live trees per acre.

### Conclusions

In this article we have provided estimates of the potential economic damages to recreation value within RMNP due to a MPB infestation based on integrating secondary information from several sources. At a minimum these estimates provide a thumbnail sketch of the possible benefits from control programs or policies. This article also provides evidence that MPB outbreaks result in significant losses in recreation values, at least in the short term. Moderate to severe MPB outbreaks can cause losses in the total recreation values from \$5 million to \$59 million, and may reduce recreation visitation by 0.5 million user days at maximum outbreak levels. External validity of these visitation changes would be achieved if actual visitation estimates were similar; however, because of many confounding factors (changes in economic conditions, changes in recreation travel patterns, etc.), actual visitation increased from 2009 to 2010 (National Park Service 2012). Nonetheless, the cost of mitigation strategies and preventative measures should be investigated and warrant comparison against the recreation loss estimates provided in this report.

There are several ways to control MPB outbreaks and mitigate their effects, including dynamic forest management, pesticides use, stand clearing fires, and selective or clear cutting trees. Manipulating the estimates for total recreation value, given in Table 2, we divide by the forested acreage of RMNP (172,751 acres). We find that damages caused by MPB to live trees reduce total recreation value by \$30 - \$341 per acre per year. The loss per acre in recreation value may be compared with the cost per acre of mitigation or prevention.

One method of prevention that has significantly reduced tree mortality (up to 90 percent) in high value forests of Washington, Montana, Idaho and California is the application of the pheromone verbenone. The cost for the application of verbenone is \$107 per acre (McGlynn 2012). This

implies a total cost of \$29,367,670 to apply the pheromone on forested acres in RMNP. Except for the most severe of modeled MPB outbreaks, the cost of applying verbenone exceeds the loss of total recreation value in RMNP. However, as MPB outbreaks intensify, evidence suggests that verbenone becomes ineffective (Bentz et al. 2005). Furthermore, we assume trees, pests, damages, and recreationists are evenly distributed across space. Perceived damages to recreation are likely clustered spatially around high visitation and viewable areas. Thus, the National Park Service's policy to use Integrated Pest Management (e.g., removal of beetle infested or hazardous trees, fuel reduction, prescribed fire) and to apply pesticides to protect high valued trees in high use and unique areas only is a reasonable defense against MPB in comparison with the cost of total control (National Park Service 2005).

Our estimate of total recreation value damages is conservative, but how it is interrelated to other factors affecting recreation value, and other value types, is unknown for this analysis. For example, our assumption is that reductions in live trees per acre, holding all else constant, is associated with these live trees disappearing from the landscape. In reality, beetle killed trees become standing and downed dead trees. Walsh and Olienyk (1981) estimated that dead and down trees reduce recreation demand by 2.3% for every 1 percent increase in dead and down trees per acre. Unfortunately, how dead and down trees interact with live trees per acre in the demand for and value of recreation visits was not modeled in the sources of information we used in this study.

It also should be noted that this comparison does not consider aesthetic, passive-use (option, existence and bequest values) or housing value enhancements generated by live trees within RMNP. The literature also shows that nonuse or passive-use benefits are more than three and a half times greater than recreation-use benefits (Holmes and Kramer 1996; Kramer, Holmes, and Haefele 2003; Walsh et al. 1990). Without the inclusion of passive use values an economic assessment for management or policy use, including only direct use benefits, would understate the true value of a forest and its realized ecosystem services. Without adequate information, a sub-optimal conclusion or decision could be reached. However, even if the results of this project suggested that a park wide treatment of verbenone or insecticide was economically feasible, it may not be technically, physically, or socially feasible.

Confidence in our ability to transfer knowledge may decay over time. As noted by Pendleton, Atiyah, and Moorthy (2007:370), "for values to be relevant to current policy-making, they need to reflect current estimates of nonmarket values." Although the economic value per recreation user day is fairly recent and specific to RMNP, the functional relationships between user days demanded and consumer surplus per trip are based on a study over 30 years old. Because methods for nonmarket valuation have been critiqued and updated, stakeholder preferences may have changed, and the scale and intensity of outbreaks may have increased over time, dependence on older data may affect, whether real or perceived, the accuracy and relevance of values obtained through benefit transfer (Johnston and Rosenberger 2010; Pendleton, Atiyah, and Moorthy 2007). Therefore, not only do we need to expand our stock of knowledge through new primary research, we also need to replenish or verify older results.

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