ESTIMATING COST-EFFECTIVENESS OF CONTROLLING ANIMAL DAMAGE TO CONIFER SEEDLINGS

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ABSTRACT--A model for determining the benefit-cost ratio of controlling damage by vertebrate pests to conifer seedlings requires knowledge of the amount, distribution, and duration of animal damage, reduction in damage associated with control, costs of control, methodology and value of trees at harvest. Because control costs occurring in the present must be compared with savings recovered decades later in the future, the model incorporates procedures for discounting or adjusting future monetary benefits into present net worth valuations. The model allows forest managers to evaluate a wide range of damage costs and savings accruing from use of various control techniques. The model clearly demonstrates that application of controls before damage occurs is more cost-effective than withholding application until it is established that damage will occur.

INTRODUCTION

Damage by vertebrate pests to conifer seedlings is a significant economic loss to the timber industry in the Pacific Northwest (Lawrence 1958, Swift 1960, Dimock and Black 1969, Brodie et al. 1979). The pests have been identified (Lawrence et al. 1961, U.S. Dep. Agric. 1978) and the frequency and distribution of damage, the percentage of trees killed, and the effect on subsequent tree growth have been reported (Munger 1943, Staebler et al. 1954, King 1958, Crouch 1968, Dimock 1970, Mitchell 1974, Black et al. 1979, Evans et al. 1981). There is only one report that provides guidelines for timing of application of controls to reduce or eliminate damages, and that concerned only bear damage to second-growth conifers (Schreuder 1976). One criterion that could prove useful in such decisions--and which we can model and which Schreuder (1976) used--is the benefit-cost ratio.

Benefit-Cost Ratio

We need two figures to estimate benefit-cost ratio: first, cost of control methods; and second, savings resulting from application of those methods. If the savings, in dollars, are higher than the costs, the benefit-cost ratio is greater than 1, and control methods will more than pay for themselves.

Costs of control are fairly easy to compute, as they are generated over a short time, usually less than two years; and they are obvious, usually including labor, travel, equipment and/or materials, and administration.

Savings are more difficult to estimate, because managers must predict how much damage will occur without control and how much damage the control method will eliminate. To avoid this difficulty, the control program may be delayed for a year. Rate of first year damage can be documented and assumed as that for subsequent years. For smaller pests permanently residing on regeneration sites, such as mountain beaver (Aplodontia rufa), voles (Microtus sp.), and rabbits (Sylvilagus sp.), this may be a valid assumption. For larger pests such as deer (Odocoileus sp), elk (Elaphus sp.), and bear (Ursus sp.), which may or may not include specific regeneration sites within a larger, annual home range, rate of damage one year may not be duplicated in following years.

Some conifer seedlings attacked by vertebrate pests die while others are set back in growth, so estimates of

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damage must include the value of trees destroyed and lost before commercial thinning or final harvest, and the value of reduced volume of trees damaged but not killed. More trees are planted on regeneration sites than are removed at final harvest; the remainder are removed at commercial thinning (for a commercial value), at precommercial thinning (no commercial value), and by mortality factors including insects, disease, and vertebrate pests.

Thus, proportionate numbers of seedlings killed or damaged by vertebrate pests must be apportioned to precommercial thinning (no value lost) and commercial thinning (value lost representation of commercial thinning rather than final harvest) as well as to final harvest, and representative loss values assigned.

Usually, damage by vertebrate pests to conifer seedlings (and associated application of control methods) occurs 1-5 years after outplanting, but commercial thinning and final harvest occur decades later. Thus, costs of control in today's dollars must be adjusted for comparison with value of timber saved today, but harvested in the future and inflated in value above today's market prices. Adjustment and comparison of control costs and market values to reflect current comparable values is termed "present net worth valuation" or "discounting."

Conventional timber harvest economics dictate calculation of present net worth valuations on timber. Present net worth of timber harvested in the future is derived by compounding today's stumpage values for n years (numbers of years to harvest) at an expected inflation rate (i) and equating it to the value of an investment compounded at todays's interest rates on conventional investments (r) to arrive at the stumpage value inflated n years into the future. For example, timber harvested in 60 years worth \$100,000 per ha today and inflated by an expected inflation rate of 5% is worth \$100,000 $(1.05)^{60}$ = \$1,867,920 per ha 60 years in the future. This value must be reverse compounded 60 years back to the present at a current investment rate, say 8%. Letting X equal the present net worth value of the timber, X $(1.08)^{60}$ = \$1,867,920; solving for X we arrive at the value of \$18,447 per ha for the present net worth of the timber per ha.

Present net worth of the cost of animal damage control methods is calculated slightly differently. The value of control efforts is equated with that of any ordinary investment, and assigned the prevalent interest rates plus the current inflation rate, compounded forward for the period of expected damage (usually less than 5 years) and then back compounded at the prevalent interest rate. The following calculations, which demonstrate the process of estimating loss to vertebrate pests and determination of the benefit-cost ratio, are based on present net worth valuations.

THE MODEL

Data required to arrive at the benefit-cost ratio include: a) amount, distribution, and duration of expected animal damage, b) reduction in damage associated with control, c) costs of control, and d) value of trees at commercial thinning and at final harvest. The basic model for estimating benefit-cost ratios is represented by the equation:

$$\frac{\text{Value of preventable loss (\$)}}{\text{Cost of control (\$)}}$$

Value of preventable loss (V) may be calculated by multiplying number of trees projected as damaged or killed by pests and saved by control by the value of trees. Value of trees varies at several distinct periods. Trees harvested at precommercial thinning have essentially no market value, whereas trees harvested at commercial thinning have a value (V_c) which is considerably lower than that for trees cut at final harvest (V_f).

Trees killed or damaged by vertebrate pests must be assigned, proportionately, to precommercial thinning, commercial thinning and final harvest.

If K trees are killed or damaged, N_p (number of trees cut per ha at precommercial thinning) trees, divided by N_t (number of trees planted per ha) provides the fraction (N_p/N_t) of K trees killed or damaged assigned to precommercial thinning. By similar logic (N_c/N_t) equals fraction of K trees killed or damaged and assigned to precommercial thinning (N_c = number of trees cut per ha at commercial thinning) and N_f/N_t equals fraction of K trees killed or damaged assigned to final harvest (N_f = number of trees cut per ha at final harvest).

Number of trees saved by control (K) is a function of: 1) the area damaged (D) by the pest, expressed as a fraction of the total regeneration site; 2) the percent reduction in volume of trees killed or damaged by the pest (P) in an area of damage, expressed as a fraction; 3) intensity of damage (I) (number of trees attacked within area of damage), the number of years (N) damage occurs by the pest(s); and 5) efficiency of damage control methods (E) expressed as a fraction, reflecting the fact that control methods are rarely 100 percent effective.

The number of trees saved per ha by control of vertebrate pests (K) can be estimated by the formula: K = DxPxIxExN.

For the purpose of demonstrating the process of estimating cost-effectiveness, 3 periods of tree removal (precommercial thinning, commercial thinning, and final harvest) are utilized. If fewer or greater periods of tree removal occur on specific sites, calculation of values will include fewer or more steps, respectively.

If the corrective mode of control (wait until damage occurs before applying control methods) is utilized, number of trees killed or damaged the first year (K_1) will not be saved and subsequent calculations of value of control will be based on trees potentially saved in the second and succeeding years (K_2). Value (V) of the stand will be lower than when the preventive mode is used because there will be fewer trees left to harvest after the loss of K_1 trees.

Current value of trees saved by application of control methods is computed by summing the value of proportionate numbers of trees saved from commercial thinning [$K(N_c/N_t)$] and from final harvest [$K(N_f/N_t)$]. This summed dollar value is then converted to present net worth value via the discounting procedure described above.

EXAMPLES

Preventative Control

Assume damage is caused by mountain beaver to Douglas-fir seedlings: trees attacked suffer 90% reduction in volume (P), damage occurs over 30% of the area (D), within area of damage 50 trees per ha are attacked (I), and duration of damage is 3 years (N). Assume control method used is vexar tubing (protect seedlings by placing sleeve of rigid plastic mesh, 40 cm high, around them at planting) at 95% efficiency in reducing damages at the cost of $250 per ha.

Number of trees scheduled for commercial thinning represented by these 50 trees is determined by multiplying 50 by the fraction of all trees represented by those commercially thinned (470/1000 = 0.47, Table 1) which equals 50x0.47 = 23.5. Current value of these 23.5 trees saved by application of vexar tubing is: 23.5 trees [number of trees attacked (I) in areas of damage] times 0.9 [reduction in volume (P) of trees attacked] times 0.3 [damage occurs over 30% (D) of area] times 0.95 (efficacy of control method used (E)] times 3 (number of years for which damage is expected) times $2375/470 (value of each tree saved for commercial harvest). This value is $91.38. Present net worth of this timber (X) saved by control, assuming commercial thinning occurs at 15 years and current interest rate on commercial investments is 8% is: $X(1.08)^{15} = \$91.38(1.05)^{15}$; X = $59.89.

Number of trees scheduled for harvest at rotation represented by the 50 trees attacked per ha of areas receiving damage is determined by multiplying by the faction of all trees represented by those harvested at rotation (180/1000 = 0.18) which equals 50x0.18 = 9.0. Current value of these 9 trees saved by application of vexar tubes is 9.0 trees [number of trees attacked (I) in areas of damage] times 0.9 [reduction in volume (P) of trees attacked] times 0.3 [damage occurs over 30% (D) of area] times 0.95 [efficiency of control method used (E) times 3 [number of years for which damage is expected] times $9,000/180 (value of each tree saved for commercial harvest). This value is $346.28.

Present net worth of this timber saved by control, assuming interest and inflation rates given above and that final harvest is 60 years after planting is: $\$X(1.08)^{60} = \$346.28(1.05)^{60}$ = $63.88.

Present net worth of commercially thinned and final harvested timber, saved by application of control methods is $59.89 + $63.88 = $123.77 per ha.

Present net worth of vexar tubing is $\$X(1.05)^3 = \$250(1.08)^3$; X = $272.05. Benefit:cost ratio = $123.77/ $272.05 = 0.45. This value is less than 1.0, so control of damages by vexar tubing, when damage is anticipated for 50 trees, is not cost effective. Multiplying the benefit:cost ratio of 0.45 by 2.2 yields a benefit: cost ratio of 1.0; multiplying any of the values used to compute K (D, P, I, E, or N) by 2.2 will result in a benefit cost ratio equal to or greater than 1.0. Increasing the I value (50) by a factor of 2.2 (2.2 X 50 = 111) results in a number of trees saved that would be cost effective. Increasing the values of 2 or more of the values by factors whose product equals 2.2 will also result in a benefit:cost ratio greater than 1.0: If the D value is increased by 1.75 and the I value by 1.25 (1.75 X 1.25 = 2.2), resulting benefit:cost ratio is greater than 1.0.

Corrective Control

Using the same values as the above example, excepting that no controls are effected the first year of damage, 111 trees per ha will be lost the first year. These 111 trees will represent 111(470/1,000) = 52.2 fewer trees available for commercial thinning and 11(180/1,000) = 20.0 fewer trees available for final harvest.

Value of commercially thinned trees will decrease per ha by an amount comensurate with the reduction in number of trees left to save ($2,375 per ha x 417.8/470 = $2,111.2 per ha). Likewise, value of timber at final harvest will decline to $8,000 per ha. Thus, for the second year of damage fewer trees will be left to save and value of saving the 111 trees will be less. Indeed, present net worth of saving 111 trees the second year is $192.95 per ha. Present net worth of applying vexar tubing for 2 years is $264.49. Benefit:cost ratio is $192.95/264.49 = 0.73.

Thus, delaying implementation of control for one year, with a constant damage level, results in a benefit:cost ratio that is no longer cost effective: corrective control programs, which require waiting one year to assess level of damage before applying controls, are less cost effective than preventive control programs. The implication is obvious: if models were available that allowed prediction of damage by vertebrate pests of conifer seedlings, application of damage control methods would be more cost effective and savings would increase.

The increased use of personal computors, and spread sheet software, should make models such as this one tremendously useful to managers in planning animal damage control programs: multiple evaluations of benefit:cost ratios can be computed rapidly and cheaply so that upper and lower limits of parameters influencing benefit:cost ratios, such as efficiency of control method, or reduction in volume of trees damaged by a pest, can be evaluated to determine a range of damage characterics within which animal damage control efforts will be cost effective.

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Table 1. Data set assumed for estimating losses of trees to vertebrate pests.

Trees/ha	At planting	At precommercial thinning (N_p)	At commercial thinning (N_c)	At final harvest (N_f)
Standing	1000	650	180	0
Cut	0	350	470	180
Value	0	0	$2375	$9000