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Effective Tree Hazard Control on Forested Recreation Sites . . .

losses and protection costs evaluated

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ABSTRACT: Effectiveness of hazard control was evaluated by analyzing data on tree failures, accidents, and control costs on California recreation sites. Results indicate that reduction of limb hazard in oaks and bole hazard in conifers is the most effective form of control. Least effective is limb hazard reduction in conifers. After hazard control goals or control budgets have been set, the optimum allocation of funds and efforts can be determined.

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RETRIEVAL TERMS: dangerous trees; defective-tree hazard; hazard potential (tree); recreation; accident costs; control costs; forest safety; tree failures; accident prevention; California.

Programs to reduce hazard from defective trees have been adopted on most forested recreation sites in California. But recreation managers are generally hampered by lack of information on how often tree failures occur, on the factors that affect such failures, and on their consequences.

To help fill that gap, Federal land agencies in California are cooperating in a continuing study of hazard control on forested recreation sites. The study itself is being made jointly by the Station's Forest Disease Research and Forest Recreation Research staffs. We requested from each agency (Forest Service, National Park Service, Bureau of Land Management, Army Corps of Engineers) data on all cases of in-season limb, stem, or root failures that required clean-up work or resulted in property damage or bodily injury. We did not consider tree failures unless they occurred during a season in which visitors used the site. The data include failures occurring in 1964 through early 1967 as well as some earlier accidents.

This report summarizes the losses resulting from each type of failure, evaluates the various costs of protection, and provides recommendations for planning hazard control programs.

WHAT ARE WE UP AGAINST?

From 1964 through 1966 (the 3 years for which full data are available), there was one injury or fatality for every 21 reported failures, and property damage in 1 out of every 2 to 3 failures. Conifer failures caused all the bodily injuries. They resulted in 1 injury or fatality out of every 13 failures--including limb failures.

These findings do not reflect the effectiveness of hazard control, since they depend primarily on the "target area," i.e., the number of people and amount of property on the sites at the times of failure. Consequently, while hazard control will result in fewer failures and fewer accidents, the accident/failure figures will not be affected greatly except by changes in the concentration of visitors on recreation sites.

GENERA INVOLVED IN FAILURES AND ACCIDENTS

In this report, the term "failure" refers to a tree or portion thereof which represented a hazard as it fell, both by virtue of frequent occupancy of the site, and because the failure allocation of hazard control efforts, by genus, the data in figure 1 must be applied to actual stocking figures. For areas with known stocking, it will be possible to assign control priorities, by genus as well as by type of defect.

TYPES OF FAILURE

Uprooting was the most common failure, followed by bole, limb, and butt failures. This pattern was true both for trees involved in accidents and for trees in nonaccident failures. The occurrence of each type of failure varied somewhat with the genus involved. In fact, it was possible to separate one group in which uprooting was the predominant form of failure--45 percent or more of the failures within each genus. This category included pine, fir, Douglas-fir, and "other hardwoods." Within this group, limb failure was relatively infrequent.

In the second category, uprooting was less common, and limb failure held a relatively important position. The oaks presented the outstanding example, with limb failures adding up to 48 percent of all failures in the genus. If incense-cedar and sequoia are arbitrarily excluded, oaks remain the only representative of this category (fig. 2).

Incense-cedar (with nearly equal numbers of each type of failure) and sequoia (with no reported uprooting) were included in the first group as a matter of convenience (fig. 2). These two genera, however, may represent an intermediate category with roughly equivalent numbers of failures of each type. They were also the only genera reported in which limb failures caused bodily injury. The other major departures from the pattern of figure 2 were in higher-than-average proportions of bole failures in fir and limb failures in "other hardwoods."

The involvement of each type of failure in accidents was related to the reported frequency of each type of failure. For example, in the first category, uprooting--the most common failure--caused the most accidents.

Property loss was also closely related to the relative frequency of each type of failure in both categories of trees. In general, we found that the most commonly reported failures in each category resulted in the most accidents and the most property loss (fig. 2).

ALLOCATION OF HAZARD CONTROL EFFORTS

From the reported data we can calculate rate of property loss per failure for each type of failure (table 1).

Table 1 --*Rate of property loss per failure related to type of failure*[1]

Genera	Bole	Uprooting	Butt	Limb
	Dollars			
Conifers and "other hardwoods"	386	263	264	31
Oaks	3	45	0	214

[1]Loss/accident (all years) X accidents/failure (1964-65-66).

Prevention of one bole failure in conifers and "other hardwoods" would have saved, on the average, 12 times as much as the prevention of one limb failure, or about one-half more than prevention of one uprooting or butt failure. The only reported personal injury settlements were made in cases of conifer bole failure. Inclusion of these figures would further raise the value for bole losses to $872 per failure. If the costs for control were the same for each type of failure, we could concentrate on bole failures, uprooting, and butt failures in conifers and "other hardwoods," and on limb failures in oaks.

RELATIONSHIPS OF BENEFITS TO COST

To evaluate the relative effectiveness of expenditures, we may examine the average annual property loss for given hazards with respect to the control cost

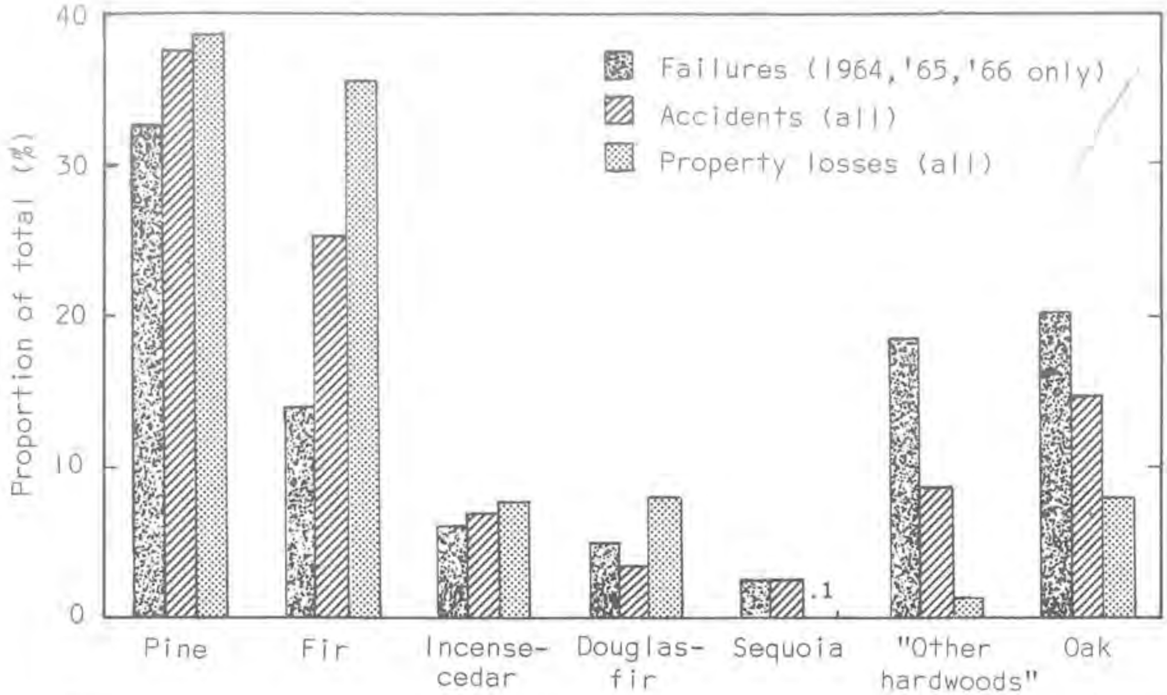

Figure 1.--*Failures, accidents and losses on California recreation sites by genera.*

Figure 2.--*Failures, accidents, and losses by class of failure on California recreation sites.*

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RELATIONSHIPS OF BENEFITS TO COST

To evaluate the relative effectiveness of expenditures, we may examine the average annual property loss for given hazards with respect to the control cost for each type of hazard. This ratio of loss to control cost is presented as a benefit/cost or "effectiveness" ratio for each type of hazard (table 2).

Table 2.—*Benefit/cost ratios for reduction of hazards--total tree population*

Genera	Type of hazard				Assumed population[1]
	Bole	Root	Butt	Limb	
	Percent				
Conifers and 'other hardwoods'	3.5	0.3	2.8	0.2	1,331,000
Oaks	.3	.3	--	40.8	27,000

[1]Number of sawtimber stems (more than 11 inches d.b.h.) per acre on National Forest commercial timberland x 0.8 x acres in developed California Federal recreation sites. Stocking on recreation sites is assumed to be 0.8 of commercial timberland stocking.

A high value indicates that we stand to save more in relation to the control investment. Thus, these figures suggest that limb hazard control in oaks, and bole and butt hazard control in conifers and "other hardwoods" are the most rewarding. With a limited budget, these hazards should get the first priority. Identical results were obtained when the data were subsequently subjected to a linear programing analysis.

Similar figures may be developed for pine and fir (table 3). Again, the figures suggest that control of bole hazard in these conifers would result in the greatest benefit per control dollar. The relationship of bole ratios to limb ratios, for example, is in excess of 100 to 1.

Table 3.—*Benefit/cost ratios for pine and fir hazard reduction*

Genera	Type of hazard				Assumed population
	Bole	Root	Butt	Limb	
	Percent				
Pine	5.7	0.6	0.6	0.0+	400,000
Fir	6.4	.5	1.8	.0+	300,000

BASIS FOR COST FIGURES

These values will not fit all situations since they depend on certain cost assumptions: most important--that it takes half again as long to make a careful inspection of the butt (including any sounding or boring) as of either bole or limbs. Inspection time for roots is assumed to be 15 times longer than for boles.

Interpretation of the figures is also dependent upon two conditions: (a) that the number of failures reported for each type of hazard is proportional to the number of failures prevented by control measures; and (b) that the relative efficiency of detection is reasonably comparable for each type of hazard. To a lesser degree, the above ratios also depend on these five professional estimates:

1. Inspection activity rate (including travel, vehicle), $0.10/min.

2. Number of trees subject to inspection on Federal recreation sites in California: 1,358,000.

3. Oaks as proportion of total trees: 2 percent.

4. Hazard removal cost:[3] oak tree, $175; conifer or "other hardwood," $200; oak limbs (per tree), $75; conifer or "other hardwood" limbs (per tree), $50.

5. Average chargeable time (including travel and plot movement) for bole inspection: 1 minute.

Changes in these five estimates would not greatly affect relationships between the benefit/cost ratios. Changes in items 1, 2, and 5 would have a proportional effect on the magnitude of all the values. Hazard removal costs are generally

[3]Figures suggested by a tree service company in northern California.

lower than inspection costs. Therefore variation in item 4 has a relatively small effect on the results. A change in item 3 produces no appreciable changes except for the oaks, where the relative importance of the limb benefit/cost ratio will still remain high.

Forest managers can develop their own benefit/cost ratios by changing the estimates and assumptions to meet local conditions. Details on the procedure used in calculating ratios and information on individual tree genera are available upon request to the Director, Pacific Southwest Forest and Range Experiment Station, P.O.Box 245, Berkeley, California 94701.

BIAS IN DATA

There is no apparent basis for suspecting bias in reporting data on accident-failures, with respect to either species or type of failure. Any unreported losses in accident failures would have resulted in lower-than-actual figures, and would probably be randomly distributed. Unreported non-accident failures are another possible source of bias in the data. If there is any bias here, it is probably underreporting of limb failures, which may seem less important and be more easily overlooked. Underreporting of non-accident limb failures would affect the ratio only slightly, since limb hazard removal costs (in the examples given) are less than 1 percent of the total limb hazard control costs.

The probable net effect of unreported failures is to provide slightly high benefit/cost ratios for limb hazard control.

The number of hazards removed and failures prevented each year with present procedures has not been considered in the benefit/cost figures. To the extent that the previously stated assumptions and conditions are met, the additional removal costs would be the operative factor. Inclusion of the additional costs would tend to decrease all benefit/cost ratios but would not necessarily affect the relationships between the values, unless hazard removal costs became a major part of the total control costs. This situation occurs under some local circumstances, but it does not appear likely as applied to a population of 1.3 million trees. Nonetheless, actual control costs should be used in finding local benefit/cost relationships.

No data are yet available on the relative efficiency of detection. However, it is reasonable to assume that, even with close inspection, not all hazard will be detected. Lower detection rates will result in lower removal costs but decreased benefits. The net result will be a relatively lower benefit/cost ratio for those hazards which are most difficult to detect.

DISCUSSION

Not all of the trees subject to inspection will be inspected in any one year. This condition does not affect relationships between benefit/cost figures as long as only the inspected areas are considered. Furthermore, since the probability of an accident depends on both the frequency of failures and the density of exposed property and visitors, inspections should be made first, and with greater thoroughness, in areas with a tendency toward excessive hazard and high use.

In oaks, the major efforts should continue to be directed toward reduction of limb failures. Limb failures caused by far the highest property losses in oaks, approaching the losses caused by butt failures in conifers and "other hardwoods." The high unit loss from limb failures in oaks, as compared with conifers, may be traceable to the fact that the average oak branch is larger, heavier, and can inflict greater damage. The same difficulties apply to control of uprooting in oaks as in conifers; fortunately, the loss is relatively small.

In conifers and "other hardwoods," reduction of bole hazard is by far the single most effective form of control. Furthermore, bole failures are responsible for the highest rate of injuries and fatalities--two to three times as many as for any other type of failure. Relative to other control efforts, bole hazard control should be stepped up. This is particularly important when complete hazard control is impossible because of limited budgets or objectives. Assuming inspections are already being made, more detailed bole examinations and application of critical standards will be appropriate.

Butt hazard, with property losses and inspection costs both relatively low, is next in order of priority. Bole and butt failures together accounted for nearly two-thirds of all bodily injury accidents.

In those less frequent situations where uprooting hazard results from tree lean, or from exposure to wind or saturated soil, control efforts may be only slightly less effective than for butt hazard reduction. If comparable inspection costs are assumed for the two types of hazard, reduction of uprooting due to lean provides a benefit/cost ratio of 2.6 percent. Consequently, if budgets and objectives permit, control of uprooting hazard resulting from lean, exposure, or soil saturation should be included in the program.

Efforts at control of uprooting, where this requires inspection for root decay, do not offer a good return. And decay, unfortunately, was the most common condition associated with uprooting. In an area with a very high proportion of losses from this source, it might become economical to work on detection of root decay, or to attack the problem from an entirely different angle. At present, there are no evaluated techniques for making hazardous root inspections.

On the basis of present information, efforts at control of limb hazard in conifers and "other hardwoods" provide such low returns as to indicate the need for a greatly decreased emphasis--providing that equivalent efforts are placed on reduction of bole and butt failures. In conifers, even if limb failures occurred five times as often, they would still be fewer in number than bole and butt failures on recreation sites. And the total property loss--if current relationships continue to hold--would still be only 15 percent as high.

RECOMMENDATIONS

Forest managers are usually operating under restricted budget and personnel ceilings. Consequently, control efforts should be allocated to obtain the greatest possible benefits. As indicated by the benefit/cost ratios, reduction of bole and butt hazard in conifers and limb hazard in oaks should be given first priority. Areas with high use and/or unusual hazard should receive greater emphasis.

Based on the preceding figures, an annual budget of $3,200 would cover oak limb hazard control on Federal recreation sites in California; $275,000 would cover control of bole, butt, and lean-uprooting hazard in conifers and "other hardwoods," as well. This budget is tentative, of course. It implies an annual inspection of the assumed recreation site population and annual removal of only those hazards which previously have been uncontrolled and reported as failures. It does not include current removal expenditures which have resulted in the prevention of failures.

In speaking of protecting the public from fire, California State Forester F. H. Raymond has pointed out that "Protection is not just necessary --it is mandatory in our modern society. The cost of protection goes higher every day. How much protection is enough? When is the system of protection sufficiently efficient...?"[4]

We are near the point where we can realistically evaluate the costs of hazard protection. And we are in a position to estimate the effectiveness of protection efforts and the efficiency in expenditure of control funds. With additional research, we should be able to assess the efficiency of hazard detection and to estimate the lowest failure rates attainable with present techniques. Still unanswered, however, is the question: "How much protection is enough?" On that answer rests our capability for efficient design of programs to attain the designated goals as well as justification for continued research.

[4]Raymond, F. H. *Protection and the public.* J. Forestry 65(3): 169-173. 1967.

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