GROUP-TREE HAZARD ANALYSIS

by Stephen R. Bakken

Abstract. Tree hazard control programs focus on individual tree risk analysis. Although microsite conditions are often evaluated, whole forests or groups of trees are rarely considered. A tree hazard program was initiated at a northern California state park in 1969. Since then, hundreds of trees have been removed from the campground to reduce the agency's liability. Nevertheless, hundreds more trees have failed, causing injury and property damage. Traditional single tree risk assessment proved to be inadequate to stabilize this forest. Consequently, the environmental dynamics of the entire forest were assessed, and every tree was evaluated for its positive or negative contribution to the long term stability of the forest.

Each tree is dynamic. Its architecture is strongly guided by its genotype (e.g., decurrent versus excurrent growth forms); yet the form of each tree is also the culmination of all the environmental influences during its life. Any change in the physical environment surrounding a tree will affect the tree. The ability of a tree to adapt to changes depends upon it health and structural strength. Severe environmental changes may cause stunted growth, death, or failure even in healthy trees. For example, a nursery tree, grown in a protected environment, will tend to have a small root system and tall low taper trunks. When transplanted to a harsher site, the dramatic change in water supply, wind and temperature may be detrimental.

Traditional tree hazard programs tend not to emphasize the environment surrounding a tree, rather they are single-tree risk analyses, which focus on the structural attributes of the subject tree (1,8,10,13). A single-tree risk assessment program based upon Paine's methodology (9) was initiated about 1969 in all state park units in California where visitor use was significant, with formal inspections conducted every two years or less since that time (3). At one park unit, MacKerricher State Park, hundreds of trees which exceeded the program's risk threshold have been removed or pruned to reduce the agency's liability, yet the forest continued to experience tree failures by the hundreds, including many that were considered low risk by trained department inspectors. The single-tree risk analysis approach failed to predict a significant number of tree failures or reduce the Department's liability to an acceptable level (2).

Study Site

MacKerricher State Park is located on the California coast 130 miles north of San Francisco. It is a destination park popular for its miles of beach, sand dunes, and pleasant climate. The visitor use facilities were inserted into an unmanaged native coastal pine forest composed of Bishop pine (*Pinus muricata*) and shore pine (*Pinus contorta* var. *contorta*), and associated species including tanoak (*Lithocarpus densiflorus*), grand fir (*Abies grandis*), and Douglas-fir (*Pseudotsuga menziesii*) between 1953 and 1961. The facilities have subdivided the ecosystem and forty years of high human impact have produced a level of wear and tear equal to many urban sites (2).

The Department's single-tree risk assessment program evaluates 1) target value, 2) target occupancy, 3) damage potential, and 4) probability of failure. The criteria for determining the probability of failure from each tree at this park, using this system, are given in Table 1.

Since the existing tree risk program was not preventing significant numbers of tree failures at the park, the failure records and environmental conditions were analyzed for new risk criteria. Records of 425 tree failures that occurred from 1970 through 1990 at the park were examined (5). Almost two third's of the failures occurred at the roots. The forest exists on old, stabilized sand dunes and coastal terrace of 0 to 7 % slope. The soils are composed of loamy sands and sandy

Table 1. Primary criteria for single tree risk assessment at MacKerricher State Park, Mendocino County, California. Trees with one or more of the high risk of failure characteristics which are predicted to cause injury or damage within the 2 year inspection interval are removed or pruned.

Criteria	Low risk of failure	High risk of failure
Phellinus pini [a]	< 3 conk clusters along trunk	> 3 conk clusters along trunk
Peridermium harknessii [b]	< 50% trunk circumference	> 50% of trunk circumference
Phaeolus schweinitzii [c]	< 50% structural roots	> 50% structural roots
Ganoderma applanatum [d]	absence or small conk	large conk(s) at trunk base
Heartrot in hardwood	< 33% strength loss	> 33% strength loss
Bark beetles in pines [e]	absence	presence
Physical deformities	absence	presence
Lean	absence or natural lean	change in lean evident
Size	increasing size raises risk	very large trees
Health	survive longer than 2 years	death or near death

a) a heart rot of the trunks of the conifers.
b) a canker disease in the pines which causes trunk deformation.
c) a heart rot of the roots and lower trunk of the pines.
d) a heart rot of the roots and lower trunk of hardwoods (2).
e) *Ips radiatae* and *I. plastographus*, have occasionally causing group pine mortality (2,7).

loams which do not adhere well to tree roots. This site is typical for Bishop pine (12).

Results

Ninety-one percent of the failures (388 trees) occurred during the wet season, from November through April, indicating that saturated soils are also a predisposing factor. Annual rainfall averages 40 inches, with 50% occurring between December and February (4). The subsurface soil exhibits poor permeability and hardpan formation causing the surface soil to remain saturated with water for long periods of time following episodes of heavy rain. This temporary high water table prevents deep root penetration of all tree species.

Wind was a factor in the vast majority of these failures (93%), either directly, or indirectly (i.e., tree striking tree). Many of the tree failures were multiple failures occurring during storm events. Peak wind velocities in this area reach speeds greater than 40 mph once every two years, and over 80 mph every fifty years (4). Many times peak storm winds, which can come from any direction, coincide with significant episodes of rainfall.

The wood decay and canker diseases had some influence on tree failures although this was difficult to quantify. Unfortunately, past tree failures were recorded by untrained people (5), so the data have a higher error rate than would have occurred in a more controlled study. The location of the failure on the tree was probably recorded accurately, but the estimates of wind speed, the species of tree, and the presence of wood rot and canker may have had a significant error rate. Nevertheless, the records indicate that wood rot was implicated in about 25 % of the pine failures that occurred at the roots or trunk base. Wood rot or canker was implicated in about 40 % of the pine failures that occurred at the trunk or crown. Wood rot was implicated in only about 15 % of all failures in tanoak.

Discussion

Strong winds and poor soil anchoring are the two predisposing factors affecting tree failures at this site that cannot be changed. Other predisposing factors such as wood rot, lean and physical deformities can be minimized by lowering the acceptable threshold for most of the single-tree risk criteria. However, this alone will not stabilize the forest in the long term. New criteria are necessary to evaluate the long term stability of each tree when the environment is altered. Any new risk criteria for this forest must evaluate the interaction of wind and plant growth.

Plants, like landform, influence the speed and pattern of air flow. Plants exert a drag on the wind, creating turbulence and reducing the microsite windspeed. Individual plants alter their growth pattern in response to the mechanical stress of wind. In the absence of wind a tree bole would assume a shape solely to support the tree weight, cylindrical below the crown and conical above the base of the crown. However since every tree is exposed to some wind, the trunk actually adds cross-section wood in a modified paraboloid form (11).

Wind can also affect the shape of tree crowns. An individual tree established on a perpetually windy site will have much of its upwind and terminal foliage killed or stunted by desiccation. Over many years this will produce a lopsided crown shape, as the growth on the windward side is inhibited, while the growth on the leeward side continues.

The goal of this project is to create and maintain a forest community which provides a reasonably safe environment for the park visitors and mimics the esthetics and dynamics of a native forest (2). This forest community should have an upper tier of foliage that is evergreen, is able to tolerate desiccating, salty wind, and is contiguous and smooth so as to reduce turbulence. Taking clues from nature, an aerodynamic wedge-shaped profile offers the least resistance to wind friction and deflects the wind over the campground. Figure 1 shows the desired forest profile: roughly wedge shaped and oriented in line with the prevailing onshore winds, along a northwest-southeast axis. While the goal is relatively easy to describe, it is difficult to achieve and maintain.

A group-tree hazard analysis was employed. It evaluates the same criteria as the single tree assessment, but lowers the acceptable risk threshold for most criteria (Table 2). It also includes new criteria to evaluate the interactions of each tree with its surrounding environment, particularly wind and saturated sandy soil with hardpan formation. Each tree is evaluated for its positive or negative contribution to achieving the desired stable forest. It is important to be able to visualize how the removal of a given tree will affect the growth of its neighbors for at least a decade into the future.

Species is one of the new criteria in the group tree risk analysis. Table 3 provides different attributes of the two primary and three associate native tree species. All five species are evergreen, but the pines are most tolerant of the salt wind. The pines also have rounded tops of ball shaped foliage clusters which offer less resistance to the wind than the sharp terminal leaders of the associated species. The associate species provide diversity and campsite screening, but do not make suitable dominants in this stand be-

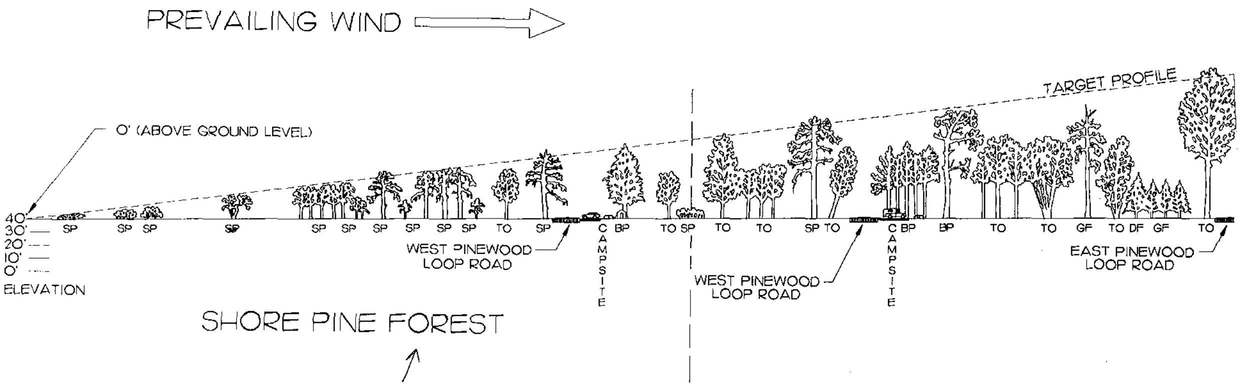


Figure 1. Representation of the desired forest profile at MacKerricher State Park

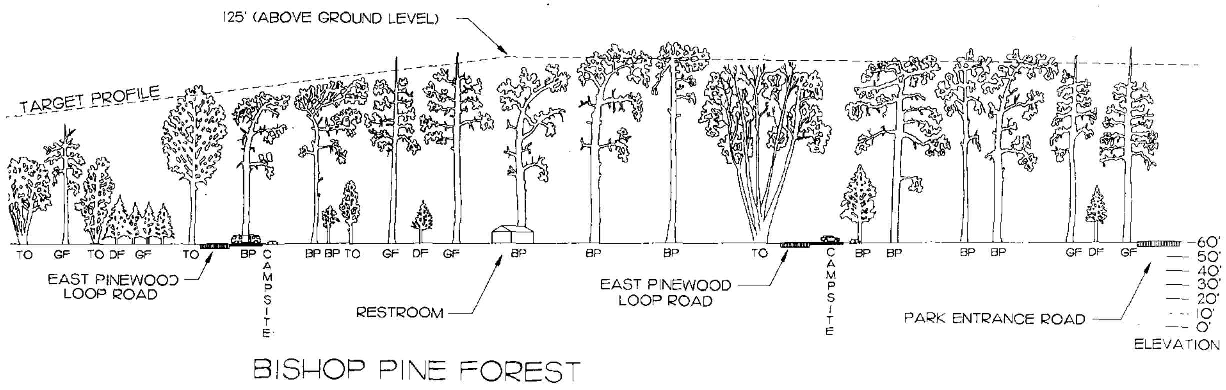
Table 2. Primary criteria for group tree risk assessment at MacKerricher State Park, Mendocino County, California. Trees with one or more high risk of failure characteristics which are likely to produce a negative contribution to forest stability within the next 5 year inspection interval and are removed or pruned.

Criteria	Low risk of failure	High risk of failure
Phellinus pini	< = 1 conk cluster along trunk	> 1 conk cluster along trunk
Peridermium harknessii	< 25% trunk circumference	> 25% of trunk circumference
Phaeolus schweinitzii	absence	presence
Ganoderma applanatum	absence	presence
heartrot in hardwoods	< 33% strength loss	> 33% strength loss
Bark beetles in pines	absence	presence
Physical deformities	absence	presence
Lean	absent	> 10 degrees
Size	increasing size raises risk	> 25 " dbh suspect
Health	high vigor	low vigor or death
Species	native	non-native
pines	all tiers	dominant (other pines present)
associates	understory (pines present) other tiers (pines absent)	dominant, co-dominant, or intermediate with pines present
Tree density (sq ft/ac)	BA = 50 to 200[a]	BA > 200 or BA < 50 if *recently isolated trees*

[a] BA: Basal area per acre equals cross sectional area of wood at breast height (4.5 ft above ground) of all trees on an acre of land.

cause they are top killed when exposed to severe winds.

Tree density is another new criterion. While a closed upper tier forest canopy is desirable from a wind deflection perspective, it does not promote long term forest stability because it will not perpetuate itself. If the cover is too dense, shade will inhibit both seedling germination and the vigor and taper of the understory pines which will be needed to replace the existing dominant pines (See Table 3). High tree density restricts the horizontal distribution of the root systems of all trees and reduces air movement through the forest understory which is important to the devel-



(SP = shore pine, BP = Bishop pine, TO = tanoak, GF = grand fir, DF = Douglas-fir).

Table 3. Characteristics of *primary* and associated tree species (5).

Species	Tolerance to shade	Tolerance to wind	Germination requirements	Significant insects/diseases
Shore pine	Low	High	mineral soil	*Ips radiatae, Ips plastographus, Phellinus pini Peridermium harknessii, Phaeolus schweinitzii*
Bishop pine	Low	High	mineral soil	*Ips radiatae, Ips plastographus, Phellinus pini Peridermium harknessii, Phaeolus schweinitzii*
Tanoak	High	Low	thin duff or stump sprout	*Ganoderma applanatum*
Grand fir	High	Low	thin duff	*Phellinus pini*
Douglas-fir	Medium	Medium	mineral soil	*Phellinus pini, Phaeolus schweinitzii*

opment of taper in the individual trees. Consequently, the upper tier canopy must be sufficiently open to allow light penetration and rooting space, and to allow some wind to move through the understory.

The 87 acre forest at the start of this project was significantly different from the desired conditions (Figure 1). Were it not for the high frequency of storms, conversion of the forest to the desired conditions could have been done all at once. Instead, tree removals using the group tree hazard analysis were done in three steps: 400+ trees were removed in 1991, 600+ in 1992, and 400+ in 1994. The conversion phase is a vulnerable period; a very severe storm during the first winter following tree removals can precipitate a multi-tree blowdown. It takes several years for a tree to adjust to the loss of its close neighbors. Initially, the tree is de-stabilized because of higher winds speeds and longer soil saturation. Eventually the tree will adjust to the greater wind stress by expanding its root system, increasing trunk taper, and widening its crown to fill the space.

A secondary objective of group-tree hazard analysis was to improve program efficiency. With the forest conversion complete, management of the remaining trees can now change to less intrusive maintenance actions at five year intervals. By lowering the acceptable risk threshold of the criteria of single tree risk assessment and by adding new criteria, group tree hazard analysis should allow the department to extend it's inspection interval to 5 years without increasing the department's liability.

Conclusions

Single tree risk rating works well in an urban landscaped area with isolated trees. This approach may be inadequate for groups of trees or contiguous forests. Single tree risk analysis at MacKerricher State Park has not decreased liability risk for the Department. Such a system may indeed increase the risk over the long term if much of the pine stand were replaced by less suitable associate species.

Knowledge of forest ecosystem dynamics is valuable. Nationwide, houses are being installed into previously undisturbed native forest communities. The ecosystem is being subdivided creating extensive urban-wildland interface zones. Furthermore, in older residential housing where the original vegetation has been replaced with an association of plants that does not coexist in the wild, many property owners have too many trees for their land area. The arborist who understands the basic ecological requirements of each species and the effects of changes in the micro-environment will be able to advise clients of the long term effects of several proposed actions.

Literature Cited

1. Albers, J. and E. Hayes. 1993. How to detect, assess and correct hazard trees in recreational areas. Minnesota Department of Natural Resources. Saint Paul, MN. 63 p.
2. Bakken, S.R. 1991. MacKerricher state park developed facilities zone vegetation management plan. California Department of Parks and Recreation. Sacramento, CA. 39 p.
3. Bakken, S.R. 1986. Tree hazard control program. guidelines and standards for the California department of parks and recreation. California Department of Parks and Recre-

ation. Sacramento, CA 44 p. + Appendices.
4. Bowcutt, F. and M. Swezy. 1989. Meteorology of MacKerricher state park and Westport-union landing state beach. Resource Inventory. California Department of Parks and Recreation. Sacramento, CA.
5. California Department of Parks and Recreation. 1991. Report of tree failure records - 1970-1990. Sacramento, CA.
6. Fowells, H.A. 1975. *Silvics of forest trees of the United States.* USDA Forest Service Agricultural Handbook Number 271. 762 p.
7. Furniss, R.L, and V.M. Carolin. 1977. *Western forest insects.* USDA Forest Service Misc. Publ. 1339. 654 p.
8. Mills, L.J. and K. Russell. 1981. *Detection and correction of hazard trees in Washington's recreation areas.* Washington Department of Natural Resources. DNR Report Number 42. Olympia, WA. 37 p.
9. Paine, L.A. 1971. Accident hazard. Evaluation and control decisions on forested recreation sites. U.S.D.A. Forest Service Res. Pap. PSW-68. 11p.
10. Robbins, K. 1986. *How to recognize and reduce tree hazards in recreation sites.* USDA Forest Service. NA-FR-31. 28 p.
11. Smith, David M., 1962. *The Practice of Silviculture.* 7th Edition. John Wiley and Sons, Inc., New York, NY. 578 p.
12. Vogl, R.J., K.L. White, W.P. Armstrong, and K.L. Cole. 1977. *The Closed-cone pines and cypress.* in (M.G. Barbour and J. Major, eds.) Terrestrial Vegetation of California. John Wiley and Sons. New York. pp 295-358.
13. Wallis, G.W., D.J. Morrison, and D.W. Ross. 1987. *Tree hazards in recreation sites in British Columbia.* Management Guidelines. Ministry of Environment and Parks. Victoria, British Columbia, Canada. 52 p.

Forester
California Department of Parks and Recreation
P.O. Box 942896
Sacramento, California 94296-0001

Résumé. Un programme de détection des arbres dangereux était initié dans un parc du Nord de la Californie en 1969. Depuis, plusieurs centaines d'arbres ont été abattus autour du terrain de camping pour réduire le risque de responsabilité civile de l'agence gouvernementale. Néanmoins, des centaines d'autres arbres sont tombés, causant blessures et dommages à la propriété. La méthode traditionnelle d'évaluation des risques de chutes s'est donc révélée inadéquate pour sécuriser cette forêt. En lieu et place, la dynamique environnementale de la forêt entière a été évaluée et tous les arbres ont été évalués pour leur contribution individuelle à la stabilité à long terme de cette forêt.