2015

Structural Failure Profile: Valley Oak (Quercus lobata)

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The BRITTON Fund

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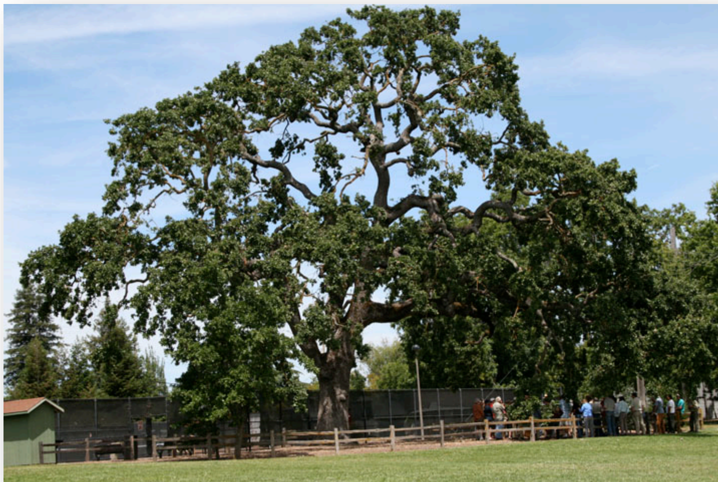

Each year, the structural failure of trees in urban and forested recreation areas results in personal injuries and property damage (Fig. 1). A key objective of tree management programs is to reduce the potential for failure to the extent possible. One important element of failure reduction strategies is to prevent or mitigate conditions that may lead to failure, such as removing branches that are weakened by wood decay.

All tree species do not fail in similar ways, however. Some are more prone to fail as a result of weak architecture, such as codominant stems. Others have a greater propensity to fail because they develop large end weights on branches that exceed the load tolerance of wood. Knowing the particular failure patterns or traits of species can help tree managers identify key defects that may lead to failure.

Fig. 1. Property damage and personal injuries can occur when valley oaks fail.

By collecting detailed information following the failure of a tree, data can be compiled and then used to develop structural failure profiles for the species. Such a profile has been developed for valley oak (*Quercus lobata*) using data from the International Tree Failure Database (ITFD). With this profile, arborists and foresters can apply the information to the structural management of valley oak.

The development of this profile was commissioned by the Britton Fund of the Western Chapter of the International Society of Arboriculture. The process for developing the profile is described in the following section.

Methods

The ITFD was established in 2003 to serve as a repository of data collected by project cooperators following the failure of a tree in urban or forested recreation areas. Its predecessor, the California Tree Failure Database, was initiated in 1987 and is the source of many of the reports in the ITFD. As of 2013, the database contains 6, 680 failure reports (http://svinetfc8.fs.fed.us/natfdb/). Of these, 251 are for valley oak. These reports were used here to develop the valley oak failure profile.

Data for valley oak failures was segregated from the database and analyzed statistically. Several statistical tests were used to identify significant associations, including t-test where appropriate, Wilcoxon Mann Whitney test, Chi-square and Fisher's exact test. In addition, descriptive statistics for continuous (quantitative) and discrete (qualitative) date were used to provide descriptive information about the species.

Typically, statistical analyses are limited by the size of the data set and this is no exception. Although the number of failure reports for valley oak (251) is substantial, it is limiting for statistical purposes. Some questions regarding factors associated with failures cannot be answered because of insufficient data. As more reports are entered and comparisons between tree species become available, however, a broader statistical treatment can be achieved.

In addition to limitations associated with the size of the data set, the nature of the data is also limiting. Reports are filed only for trees that have failed. No data has been collected for trees that have not failed. As a result, certain questions concerning statistical associations between a defect and failure occurrence cannot be answered. For instance, data has been collected for valley oak branch failures and decay occurrence. However, data has not been collected for decay presence or absence in branches that have not failed. Therefore, an association between decay occurrence and branch failures cannot be assessed.

Fig. 2. Valley oak is the largest of all oak species and is a signature species in California landscapes.

Nonetheless, associations between factors that contribute to a type of failure can be analyzed, such as whether decay plays a role in branch breaks at the attachment versus branch breaks along the branch. Such types of associations are included in this profile.

Findings

Valley oak is distributed widely in California from Shasta County to the Channel Islands and is common in the Central Valley and foothills below 6,000 ft. It is a member of the white oak section and is the largest of all oak species.


Fig. 3. Mean age for valley oak failure is 150 years.

Tree failures can be divided into 3 groups based on the part that fails: branch, trunk, and root. Of the 251 reports for valley oak, 107 are branch failures, 62 are trunk failures, and 82 are root failures. Table 1 gives general statistics for all valley oak failures.

Table 1. General statistics for valley oak.

Variable	Mean
Age	150 years
Height	62 feet
DBH	44 inches

A. BRANCH FAILURES

Branch failures represent 43% of all valley oak failure reports. Table 2 provides general statistics for branch failures.


Fig. 4. Branch failure is the most commonly reported failure for valley oak.

Table 2. General statistics for branch failures.

Variable	Mean
Age	163 years
Height	66 feet
DBH	47 inches
Temperature	63 ^{0}F
Wind speed	9 mph

Time of year and branch failures

The month with the greatest number branch failures is August (22). From May to October, 81 failures occurred, while from November to April, 15 failures were reported. Clearly, fewer branch failures occur in the winter months, while the frequency increases in the summer.

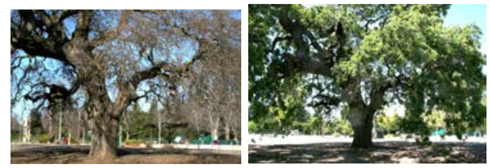

Fig. 5. Valley oak branch failures are more common in the summer months than the winter months.

Branch Failure Location

Branch failures can occur either at the point of attachment to the trunk or along the branch. Tables 3 and 4 give general statistics for each type of failure.

Table 3. Failures along the branch.

Variable	Mean
Branch diameter	20 inches
Age	165 years
Height	68 feet
DBH	46 inches
Temperature	74 ^{0}F

Table 4. Failures at the attachment.

Variable	Mean
Branch diameter	27 inches
Age	160 years
Height	62 feet
DBH	50 inches
Temperature	69 ^{0}F

Fig. 6. Branch failures occur at the attachment or along the branch.

Failures along the branch (68) versus at attachment (37) are not statistically related to tree height, DBH, or air temperature. They are related to branch diameter, however. Failures at the attachment have a significantly larger mean diameter than those along the branch.

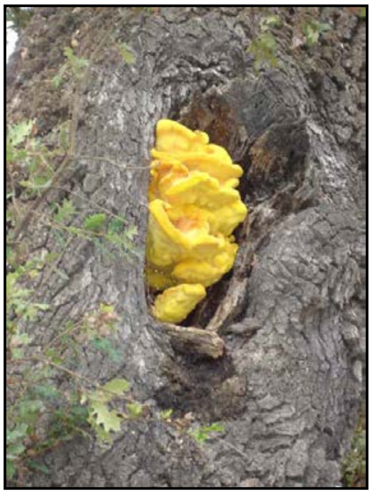

Fig. 7 Sporophores are not commonly found on branches that have failed.

Live vs Dead Branches

The great majority of branch failure reports are for live branches: 95% live branches, and 5% dead branches. No statistical association was found between the location of failure and whether a branch was alive or dead. Both live and dead branches failed at the attachment and along the branch.

Decay

Wood decay was reported to be a factor contributing to branch failure in 61% of all cases, while no decay was reported in 39% of cases. For failures along the branch, decay was present in 57% of cases, while no decay was reported in 43% of cases. For failures at the attachment, decay was present in 70% of cases, while decay was not present in 30% of cases. Only 5% of all branch failures were associated with the failed portion being dead. Statistically, decay is as likely to occur in failures along the branch as at the attachment.

Although many failed branches have decay, a sporophore (fruiting body) is not commonly found. No sporophores were reported in 93% of all cases of branch failures associated with decay, while only 6 cases reported a sporophore being present.

Fig. 8. Although included bark is found on this branch failure, it is not commonly reported for valley oak failures.

Included Bark

Included bark does not appear to be a key factor associated with branch failures in valley oak. Included bark was reported in only 5% of all cases of branch failure at the attachment, while no included bark was found in 95% of cases.

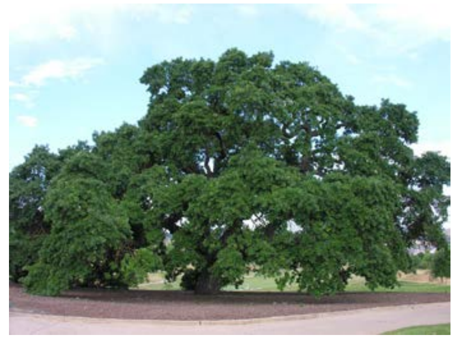

Fig. 9. Dense crown is not reported to be a key factor associated with branch breaks.

Dense Crown

The majority of branch failure cases are not associated with a dense crown. A dense crown was reported to be a contributing factor in 14% of branch break cases, while in 86% of cases the crown was not considered to be dense. Failures along the branch occur at a much greater frequency than failures at the attachment when the crown is dense, however.

Fig. 10. Heavy lateral limbs are reported as a common factor contributing to branch failure in valley oak.

Heavy lateral limbs

Heavy lateral limbs are associated with the majority of branch failures (75%). More than 3 times as many cases of heavy lateral limbs (72) were reported to contribute to failures than no heavy lateral limbs (23). The ratio of 3:1 was consistent for failures along the limb as well as those at the point of attachment. However, no statistical association was found between heavy lateral limbs and location of attachment.

Defect Visible?

Reporters are asked if the defect associated with a branch failure would have been visible from a ground inspection. In 46% of the cases, the defect was thought to be visible, while in 35% of the cases it was not. This evaluation was not reported in the remainder of cases (18%).

Fig. 11. Defects associated with branch failure are not always visible

B. TRUNK FAILURES

Trunk failures (62) are fewer in number than branch failures (107). Table 5 gives general statistics associated with trunk failures.

Table 5. General statistics for trunk failures.

Variable	Mean
Age	153 years
Height	62 feet
DBH	44 inches
Crown spread	57 feet
Temperature	60 ^{0}F
Wind speed	12 mph
Break diameter	35 inches

Tree Condition
In 94% of all trunk failure reports, the tree was not considered to be declining. In other words, it was in relatively good health. Only 5% of the trunk failure reports indicated that the tree was declining.

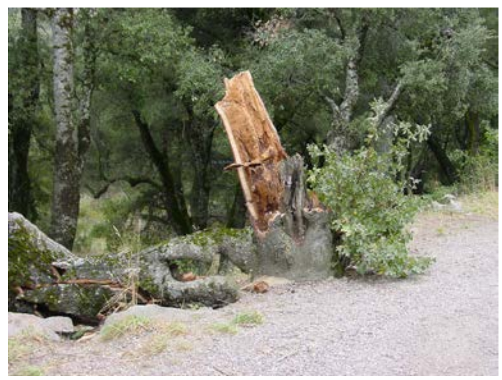
Fig. 12. Trunk failure in valley oak occurs more commonly above the ground line than at the ground line.

Failure Location and Size
Trunk failures occur more commonly above the ground line than at the ground line. In 80% of cases, the failure occurred above the ground line and mean diameter was 32 inches. In 20% of cases, the failure occurred at the ground line and mean diameter was 46 inches. As may be expected, trunk diameter is larger for ground line failures.

Decay
Decay plays a role in many valley oak trunk failures. In 75% of cases, wood decay was reported to play a role in the failure. Conversely, in 25% of cases, the wood was sound at the failure location. No statistical association was found between decay and the location of failure, however. Decay is as likely to occur in ground line failures as it is in failures above the ground line. Similar to branch failures, fruiting bodies or sporophores were found in a small percentage (10%) of cases.


Fig. 13. Decay occurs in 75% of trunk failures reported for valley oak.

Multiple Trunks
Although more cases of trunk failures are reported for single-trunk trees, 37% of trunk failures are linked to multiple trunks.

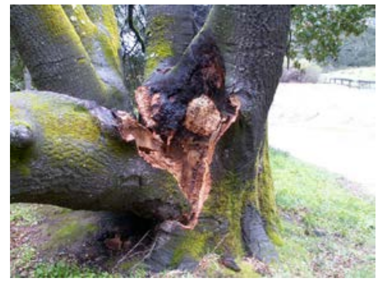
Fig. 13. Multiple trunks occur in 37% of trunk failures reported for valley oak.

Precipitation and Trunk Failures
Precipitation was not linked to trunk failures in 70% of cases reported. A statistical association was found between precipitation and failure location, however: trunk failures at ground line and above ground line are more likely to occur during dry conditions than during wet conditions. In fact, the most common trunk failure was above the ground line during dry conditions.

Wind Speed
No statistical association was found between wind speed and failure location. Valley oaks are as likely to fail in high or low wind at ground line as above ground line. Trunk failures above ground line and low wind conditions were most common. Overall, the greatest number of trunk failures occurred under low wind conditions (Table 6).

Table 6. Wind speed and trunk failures.

Wind Speed	Cases
High wind (>25 mph)	13 (24%)
Moderate wind (5-25 mph)	15 cases (27%)
Low wind (<5 mph)	27 cases (49%)

C. ROOT FAILURES

Root failures are the second most common type of failure for valley oak (81). Table 7 provides general information regarding root failures.

Table 7. General statistics for valley oak root failures.

Variable	Mean
Age	143 years
Height	60 feet
DBH	41 inches
Crown spread	48 feet
Temperature	54 ^{0}F
Wind speed	15 mph

Tree Condition
In 94% of all cases reported, valley oaks were considered not to be declining, while in 6% of cases, they were declining.

Decay
Decay was associated with the majority of root failures. In 81% of cases reported, decay played a role, while no decay was found in 19% of cases. In other words, four times more failures were associated with decay than failures without decay. Similar to branch and trunk failures associated with decay, sporophores were found in only 27% of all root failures reported for valley oak.


Fig. 14. Decay plays a role in many cases of root failure in valley oak.


Fig. 15. Root cutting is an important factor associated with root failure in valley oak.

Root Cutting, Lifting, and Breaking
Mechanical injury to roots or restrictions to root development played a role in valley oak root failures. In 40% of cases, roots had been cut or severed. In 26% of cases, they had been broken, in 13% of cases, they were lifted, and in 11% of cases they were restricted and broken.

Wind
Although wind contributes to root failure of valley oak, there are many cases of failure when wind was less than 5 mph. Table 8 shows root failure cases associated with wind speeds.

Table 8. Wind and root failure of valley oak.

Wind Speed	Cases
Low (<5 mph)	24 (35%)
Moderate (5-25 mph)	26 (39%)
High (>24 mph)	18 (26%)

As shown in Table 8, the least number of cases of root failure occurred in high wind conditions. This suggests that many valley oak root failures are not precipitated by wind events.

Soil Moisture and Precipitation
The majority of root failure cases for valley oak are associated with saturated soil, while few cases occur when the soil is dry (Table 9).

Table 9. Soil moisture and root failure of valley oak.

Variable	Percent of Cases
Saturated soil	83%
Flooded	2%
Moist	10%
Dry	6%

Similarly, rainfall occurred during 72% of root failure cases, while 28% did not occur during a rain.

Grade Changes (Fills)
Some level of grade change (fill) was reported in 38% of root failure cases, while most (62%) did not have fill.

Fig. 16. Saturated soil is reported to occur in 83% of root failure cases for valley oak.

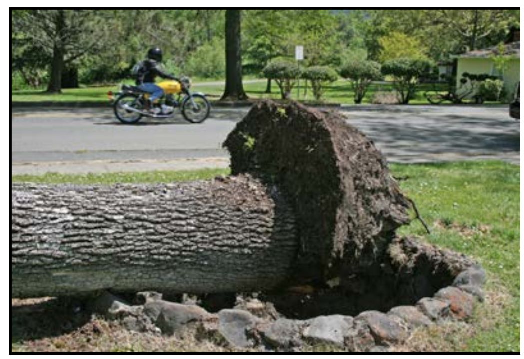

Fig. 17. Fill soils are reported to have been associated with 38% of root failures in valley oak.