Structural failure profile: Coast live oak (*Quercus agrifolia*)

L. R. Costello and K. S. Jones

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 a tree management program 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 pruning branches weakened by wood decay, cabling or bracing, and avoiding root damage.

All tree species do not fail in similar ways, however. Some are 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 --- exceeding the load tolerance of the wood. Knowing the particular failure patterns or traits of species can help tree managers identify key defects that may lead to failure.

By collecting detailed information following the failure of a tree, data can be compiled and then used to develop structural failure profiles for a species. Such a profile has been developed here for coast live oak (*Quercus agrifolia*) using data from the California Tree Failure Report Program (CTFRP). Arborists and foresters can use this information to develop structural management strategies for coast live oak. The development of this profile was commissioned by the Britton Fund of the Western Chapter of the International Society of Arboriculture.

Coast live oak distribution

Coast live oak occurs mostly within a 50-mile corridor along the Coast, Transverse, and Peninsula Ranges from Sonoma County to Baja California and two Channel Islands, with a few inland populations in or near the Delta region in the Central Valley. It is a member of the black oak section.

General statistics

Tree failures can be divided into 3 groups based on the part that fails: branch, trunk, and root. Of the 619 reports for coast live oak, 145 are branch failures (23%), 226 trunk failures (37%), and 248 root failures (40%). The greatest number of failures (47%) occurred in residential settings. Most failed trees (61%) ranged in age from 26 to 100 years, with 73% in a DBH (diameter at breast height) class ranging from 13 to 42 inches. Most failures occurred between October and March (66%), with the remainder from April to September. Table 1 gives general statistics for all coast live oak failures (trunk, branch and root).

By collecting detailed information following the failure of a tree, data can be compiled and then used to develop structural failure profiles for a species.

Figure 1. Many coast live oak failures occur in residential settings. (*Photo J. Kipping*)

Table 1. General statistics for coast live oak

Variable	Mean
Age	89 years
Height	48 feet
DBH	32 inches
Crown spread	48 feet

Table 2. General statistics for branch failures	
Variable	Mean
Age	103 years
Height	52 feet
DBH	38 inches
Temperature	61 °F

Decay was reported to be a contributing factor in 76% of all coast live oak failures. Aside from decay, key defects for all failure types include multiple trunks (18%), leaning trunk (12%), failed portion dead (11%), heavy lateral limbs (11%), and dense crown (9%). Most failures occurred during low wind conditions (39%), while 31% and 29% occurred during moderate and high wind, respectively.

A. BRANCH FAILURE

Branch failures represent 23% of all coast live oak failure reports. **Table 2** provides general statistics for branch failures.

Branch failure location

Branch failures can occur either at the point of attachment to the trunk or along the branch (**Fig. 2**). Reports indicate that 49% occurred at the attachment, while 51% occurred along the branch. Of the breaks occurring along the branch, the majority (56%) occurred at a distance from the attachment ranging from 1 to 6 feet. **Tables 3 and 4** give general statistics for each type of failure.

Decay

Decay was reported to contribute to branch failure in 74% of all cases.

Figure 2. Branch failures occur at the point of attachment (arrow) or along the branch. (*Photo B. Glen*)

Table 3. Failures along the branch	
Variable	Mean
Branch diameter	16 inches
Age	107 years
Height	52 feet
DBH	40 inches
Temperature	62 °F

Table 4. Failures at the attachment	
Variable	Mean
Branch diameter	20 inches
Age	99 years
Height	51 feet
DBH	37 inches
Temperature	59 °F

For failures along the branch, decay was present in 79% of cases, while no decay was reported in 21%. For failures at the attachment, decay was present in 69% of cases, and not present in 31%.

Although many failed branches have decay, a sporophore (fruiting body) is not commonly found associated with branch failures: only 12% of cases reported a sporophore being present.

Heavy lateral limbs with embedded bark are among the defects reported to contribute to the majority of branch failures (**Table 5**). Most trees (44%) had not been pruned. Cable or hardware failure was reported in 23 cases.

Wind and branch failures

The majority of coast live oak branch failures (50%) occur during low wind conditions (< 5 mph), while 26% occur

Table 5. Most commonly reported defects contributing to branch failure (excluding decay)	
Defect	Frequency of occurrence
Heavy lateral limbs	33%
Included bark	12%
Multi-stems	12%
Dense crown	11%
Failed portion dead	7%

Table 6. General statistics for trunk failures	
Variable	Mean
Age	81 years
Height	44 feet
DBH	29 inches
Crown spread	43 feet
Temperature	57 °F

during moderate wind (5-25 mph) and 24% during high wind (> 25 mph). For failures at the branch attachment, 46% occurred during low wind conditions, while 30% and 24% occurred during moderate and high wind, respectively.

Precipitation and branch failures

Most branch failures (74%) occurred during dry conditions. The remainder occurred when rain or fog/mist was present. For failures at the attachment and along the branch, 27% and 22% occurred during a rainfall event, respectively.

B. TRUNK FAILURE

Trunk failures accounted for 37% of all coast live oak failure reports. Although most failures occurred above ground level (57%), many occurred at ground level (43%). Trunk diameter at the break ranged from 6 to 72 inches, with the majority (85%) in the 7 to 36 inch diameter range. **Table 6** gives general statistics associated with trunk failures.

Decay and trunk failure

Decay was reported to be a contributing factor in 80% of all trunk failures. The cross-sectional area (CSA) of the trunk affected by decay varied considerably from less than 25% to greater than 76% (**Table 7**). Over 40% of failures occurred when decay was less than 50% of the cross-sectional area.

Defects and trunk failure

Multiple trunks or codominant stems (**Fig. 3**) were the defects most commonly reported to contribute to trunk failure (**Table 8**). In a number of cases, the failed portion was dead (14%) or the tree was leaning (9%), while there were no apparent defects in 8% of trunk failures. In the majority of cases (74%), the trees had not been pruned. In 11 cases, a cavity treatment was noted, while cable/hardware failure occurred in 9 cases.

Figure 3. Codominant stems is a common defect contributing to trunk failure in coast live oak. (*Photo C. Rippey*)

Precipitation and trunk failures

Most trunk failures occurred when it was not raining (63%). Failures during rain or fog/mist events accounted 37% of the total.

Wind and trunk failures

The majority of trunk failures occurred under low wind conditions (43%). During moderate and high wind conditions, 30% and 27% of failures were reported to have occurred (**Table 9**). For failures at ground level, 40% occurred during low wind, while 38% and 23% occurred during moderate and high wind, respectively. For failures above ground level, 41% occurred during low wind, 30% during moderate wind, and 29% during high wind.

C. ROOT FAILURE

Root failure was the most common type of failure reported for coast live oak (40%), with most failures (72%) occurring

Table 7. Cross-sectional area of trunk with decay and failure occurrence	
Cross-sectional area with decay	Frequency of occurrence
< 25%	19%
26-50%	24%
51-76%	21%
> 76%	36%

Table 8. Defects most commonly reported to contribute to trunk failure	
Defect	Frequency of occurrence
Multiple trunks/codominant stems	35%
Failed portion dead	14%
Lean	9%
None	8%

Table 9. Wind speed and trunk failure.	
Wind speed	Frequency of occurrence
Low wind (<5 mph)	43%
Moderate wind (5-25 mph)	30%
High wind (>25 mph)	27%

Table 10. General statistics for coast live oak root failures.	
Variable	Mean
Age	85 years
Height	49 feet
DBH	31 inches
Crown spread	45 feet
Temperature	50 °F
Wind speed	15 mph

between December and March. Trunk diameter for most failures (83%) ranged from 13 to 42 inches. **Table 10** provides general information regarding root failures. In most cases (72%), injuries to roots (mechanical, insect, fire, etc.) were not associated with failures.

Decay and root failures

Decay was associated with the majority of root failures (73%) (**Fig. 4**). For roots with decay, the cross-sectional area (CSA) of decay ranged from less than 25% to more than 76%, with the majority (55%) having less than 50% (**Table 11**). Sporophores were found in only 20% of root failure cases.

Figure 4. Decay is a key factor contributing to 73% of root failures in coast live oak. (*Photo D.Wist*)

Table 11. Cross-sectional area of root with decay and frequency of occurrence.	
Cross-sectional area with decay	Frequency of occurrence
< 25%	23%
26-50%	32%
51-75%	25%
> 76%	20%

Table 12. Wind and root failure	
Wind Speed	Frequency of occurrence
Low (<5 mph)	30%
Moderate (5-25 mph)	30%
High (>25 mph)	37%

Table 13. Soil moisture and root failure	
Variable	Frequency of occurrence
Saturated soil	59%
Dry	5%

Wind and root failures

Moderate and high winds contributed to 67% of root failures (**Table 12**). Although failures occurred under low wind conditions (33%), the frequency was not as high as that for branch (50%) and trunk failures (43%).

Soil moisture and precipitation

The majority of root failure cases in coast live oak are associated with saturated soil (**Table 13**). This data is virtually the same as that for valley oak.

Rainfall occurred during 67% of root failure cases, while 33% occurred when it was dry.

Site changes

Site changes (cuts, fills, excavations) were reported to have contributed to 38% of root failure cases, while no site changes occurred in 57% of cases.

Tree structural defects and root failures

Lean was reported as the most common structural defect associated with root failure (27%). Other defects included failed portion dead (16%), one-sided crown (asymmetric) (15%), dense crown (12%), and multiple trunks (12%).

L. R. Costello and K. S. Jones

Summary of key findings

- Root failure was the most common type of failure for coast live oak, followed by trunk and branch failure.
- Decay was the most commonly reported defect associated with root, trunk, and branch failure.
- Sporophores were not found in the majority of failures associated with decay.
- Many failures occur during dry and calm conditions.
- Branch failures occur along the branch almost as frequently as they occur at the attachment. Heavy lateral limbs and embedded bark are key defects associated with branch failure.
- Decay was associated with 80% of trunk failures. Over 40% of these failures occurred when less than half of the cross-sectional area was decayed.
- Multiple trunks/codominant stems are key defects associated with trunk failure.
- Many root failures are associated with decay, with 55% having less than 50% of the cross-sectional area decayed.
- Saturated soil and wind (moderate and high) are key factors contributing to root failures.

Regional conference sponsorships now available

WCISA IS NOW OFFERING REGIONAL CONFERENCE SPONSORSHIPS TO companies who want to maximize their industry presence. Reach your key decision makers with a regional focus!

Contact Rose Epperson or Ryan Pendleton for more information.