

# Comparison of actual and predicted blue oak age structures

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## Abstract

There is increasing interest in understanding the role of management on the current lack of blue oak (*Quercus douglasii* H. & A.) recruitment on California foothill rangelands. Age structure analysis has been suggested to relate when and how much recruitment occurred under past management as an indication of current management effects on recruitment. Previous estimates of blue oak age structure were based on unquantified correlations between age and diameter. Using regression analysis we found that diameter at breast height (DBH) accounted for 42–71% of the variation in tree age at 2 sites. Actual age structures were significantly different than age structures predicted from all regression equations at both sites. We suggest that the use of age structures to infer the role of management on blue oak population dynamics requires direct age measurement.

**Key Words:** *Quercus douglasii*, age-size relationships, California foothill rangeland

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Blue oak (*Quercus douglasii* H. & A.) recruitment since the 1920's has been described as rare on most of its 1 million hectare distribution on California foothill rangelands (Bartolome et al. 1987). As the dominant and often only woody species in the oak-annual grassland savanna, blue oak is considered desirable because it can provide important browse, mast, and cover for wildlife and livestock (McClaran 1986) and increases herbaceous understory production in low rainfall areas (Bartolome 1987). Unlike the more common situation of increased woody species density on western rangelands in the past century and concomitant emphasis on management to curtail recruitment, the lack of blue oak recruitment has stimulated interest in management that is compatible with recruitment. Increased interest in the role of management on recruitment problems of this California endemic have helped stimulate 2 symposia in the last decade (Plumb 1980, Plumb and Pillsbury 1987), proposals for state regulation of fuelwood cutting (Walt et al. 1985), suggestions for reduced livestock grazing, and solicitation of State sponsored research (Bartolome 1987).

Griffin (1977) suggested that current low blue oak recruitment can best be understood by using age structures to describe when and how much past recruitment occurred. Previous age structure studies used unquantified relationships between tree age and diameter, calculated from a subsample of the population, to predict tree ages in the remaining sample population (White 1966,

**Table 1. Correlation coefficients (*r*), regression equations (age = a + b<sub>1</sub>x<sub>1</sub> + b<sub>2</sub>x<sub>2</sub>) predicting blue oak age at 5 cm height, and goodness-of-fit probability for actual and predicted age structures in 2 central Sierra Nevada sites. Values in parentheses are 1 standard error of the mean.**

Site	N	Independent variable(s)	Regression Estimates				Goodness-of-fit Smirnov P-value
			r	a	b <sub>1</sub>	b <sub>2</sub>	
Campbell	95	DBH	0.66 (0.08)	48.3 (4.3)	0.6 (0.1)		<0.001
		DBH + DBH <sup>2</sup>	0.71 (0.07)	28.4 (6.3)	1.5 (0.2)	0.01 (0.01)	<0.001
		log <sub>10</sub> DBH	0.70 (0.07)	-41.6 (13.1)	75.1 (8.0)		<0.001
Koch	278	DBH	0.84 (0.03)	22.9 (1.8)	3.2 (0.1)		<0.001
		DBH + DBH <sup>2</sup>	0.84 (0.03)	22.3 (3.0)	3.3 (0.4)	-0.01 (0.01)	<0.001
		log <sub>10</sub> DBH	0.74 (0.04)	-14.6 (4.4)	78.1 (4.2)		<0.001

Vankat and Major 1978). This approach was taken because increment core samples were believed to be too difficult or time consuming to obtain. Unfortunately, these authors did not include correlation coefficients, predictive equations, or goodness-of-fit estimates for the relationship between age and size for reference or review. Predicting age structures from size structures through the use of predictive equations from population sub-samples is common, but it has also been criticized for being too inaccurate to reliably describe actual age structures (Harper 1977, Lorimer 1985).

Because current and future research in the role of management on blue oak recruitment will likely focus on age structure analysis, our objective is to evaluate the predictive relationship between blue oak age and size by comparing actual age structures with age structures predicted from age-size relationships.

### Materials and Methods

We studied blue oak age structures and predictive age-size relationships on 2 sites within the University of California Sierra Foothill Range Field Station (39° N, 121° W) 30 km east of Marysville, California, in the Sierra Nevada foothills. Station rainfall and temperature patterns are typical of a mediterranean climate, with hot dry summers and cool wet winters that average 73 cm precipitation annually. The two 5-ha study areas were approximately 5 km apart on ≤10° slopes, with the Koch site at 500 m elevation and the Campbell site at 300 m. Soils on both sites are Sobrante rocky loam, a mollic haploxeralf developed from granitic parent material. Blue oak cover (from ocular estimates) and basal area on the Koch site was 25% (SE = 4.3) and 13.5 m<sup>2</sup> ha<sup>-1</sup> (SE = 1.5), and 22% (SE = 3.3) and 62 m<sup>2</sup> ha<sup>-1</sup> (SE = 8.8) on the Campbell site. On both sites tree height was ≤12 m, and over 90% of the trees were blue oak. The pattern of spatial arrangement of the trees was not measured, but we estimated that it was between a contagious and random pattern. Introduced herbaceous annuals, ≤1 m tall and 1,000–3,000 kg ha<sup>-1</sup>, dominated the understory and savanna openings.

In July 1983 and 1984, we measured diameter to the nearest centimeter at 135 cm (breast-height, DBH), 60 cm, and 5 cm aboveground, cut, and removed the cross section at 5 cm aboveground from all blue oak trees in nine 0.05-ha plots on Campbell (N = 95 trees) and six 0.1-ha plots on Koch (N = 278 trees). Plots were located randomly on both study sites. Trees were cut to maximize dating accuracy. We dated each cross-section by counting annual increments along 2 radii (Stokes 1980) after sanding with 200 grit paper.

To describe blue oak age-size relationships at each site, we calculated regression equations and correlation coefficients (Steel and Torrie 1980) with age as the dependent variable and diameter as the independent variable. After assessing a scattergram of the size and age data, and in reference to previous studies (e.g., Leak 1985) we decided to evaluate the age-size relationship using actual diameters and log<sub>10</sub> transformation of diameter in separate simple regression analyses, and a curvilinear description with diameter +

diameter<sup>2</sup> as independent variables in a multiple regression analysis. We restricted our sample to trees less than 200 yr because there were only 8 trees older than 200 yr, and these outliers had a significant effect on the regression estimates. We also excluded approximately 10% of the trees from the analysis because they had rotten centers or multiple trunks.

To compare the actual and predicted age structures we assessed the goodness-of-fit for these regression equations. We used the Smirnov test (Lehmann 1975) to evaluate the goodness-of-fit for each equation.

### Results and Discussion

Diameter at breast height (DBH) proved to be more strongly related to tree age than diameters taken at lower heights, therefore we will restrict our presentation to results of analyses using DBH. All correlation coefficients (*r*) were different (*p* ≤ 0.01) from zero, but only 42–71% (*R*<sup>2</sup>) of the variation in age was associated with DBH. The highest *r* values were with DBH, and DBH + DBH<sup>2</sup> as the independent variables on the Koch site (Table 1), where all 4 simple regression equations (age = a + b<sub>1</sub>x<sub>1</sub>) were different for each independent variable at each site. The curvilinear equation, however, was different from the simple DBH equation only at Campbell (Table 1).

All 6 regression equations produced predicted age structures significantly different from the actual age structure (Table 1). In all cases, predicted age structures from the regression equations were more continuous and broadly uneven than the actual age structures at both sites (e.g., Fig. 1).

Low correlation coefficient values and poor goodness-of-fit suggest that blue oak age or age structure cannot be accurately estimated from tree diameter. In addition, our results suggest that blue oak age and diameter relationships vary geographically.

Lorimer (1985) suggested that correlation between tree age and diameter would be better if the stand was broadly uneven aged. Our results agree; we found a higher correlation between blue oak age and diameter in the stand with a greater range of ages (Koch). The lack of improvement in the *r* values when using a curvilinear (DBH + DBH<sup>2</sup>) equation agrees with Leak's (1985) study of age and diameter relationships in 10 taxa.

Difficulty in predicting tree age from tree size is not surprising (Harper 1977, Lorimer 1985), but ramifications of this problem have focused on accurate dating without much attention to age structure shape. Accurate dating along with relative abundance in each age class (age structure shape) are critical to describing the timing, duration, and reoccurrence of management practices and natural events that might affect an age structure. Therefore the search for management and natural events that affect an age structure will be led astray by both inaccurate dating and shape of age structures. In the case of blue oak, previous age structure estimates generated from age-diameter relationships suggested abundant recruitment occurred between 1880–1920, and management and

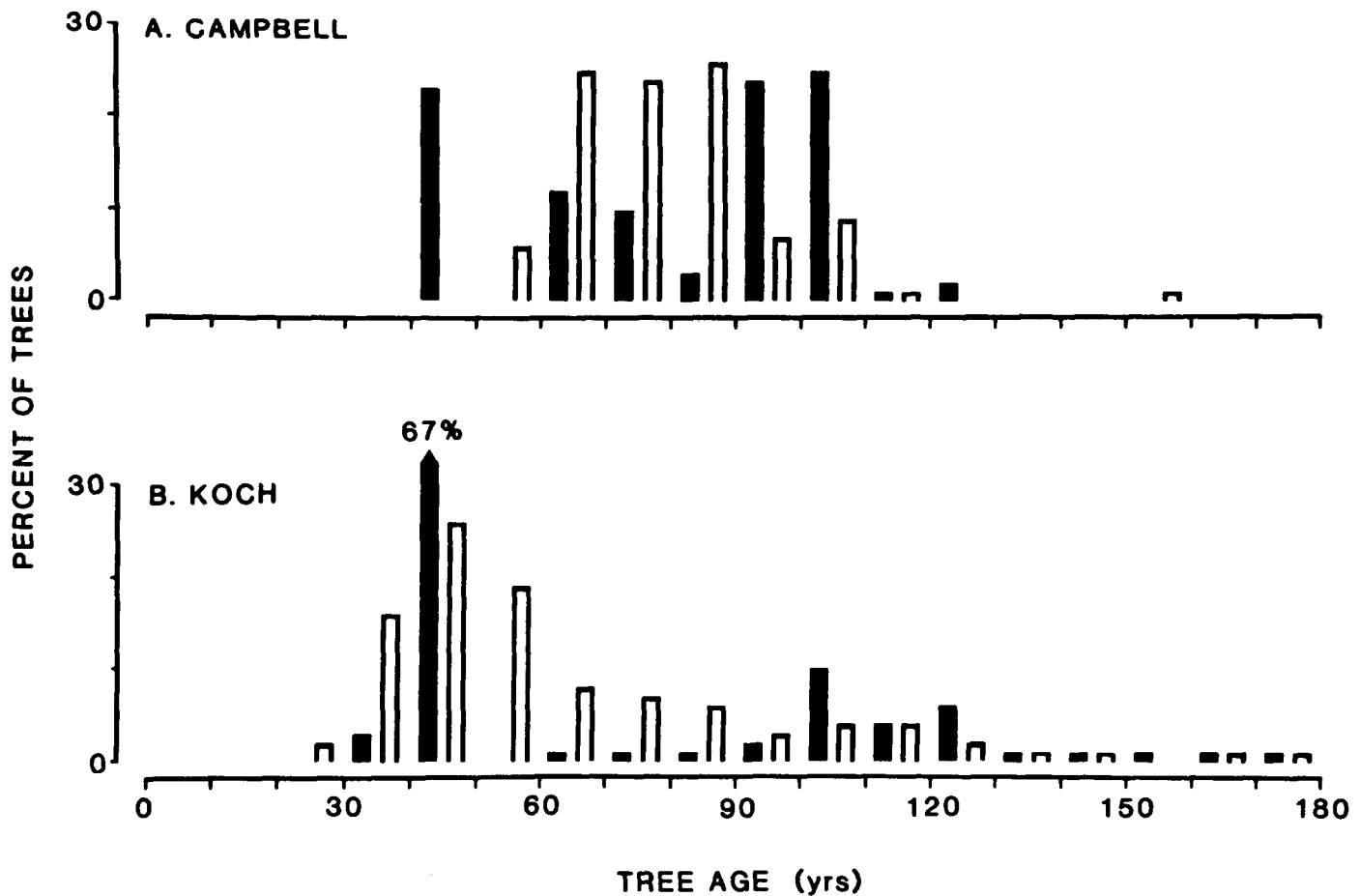


Fig. 1. Actual (solid bar) and predicted (open bar) age structures at both sites as a measure of goodness-of-fit for the linear regression equation with diameter at breast height as the independent variable. Actual and predicted distributions are different for both sites (Table 1).

natural events occurring throughout that 40-yr period, such as increased livestock grazing, decreased fire frequency, or deer population decline were considered to have affected that age structure (White 1966, Vankat and Major 1978). We found that blue oak age structures generated from predictive equations depict a more continuous and broadly uneven age structure than actually occurred. This result suggests that the search for coincident management and natural events should instead focus on events of shorter duration and more sporadic recurrence than previously considered.

We conclude that accurate estimates of blue oak age structure cannot be based on predictive age and diameter relationships. Therefore we suggest that future studies of blue oak age structure should be based only on direct measure of tree age from increment cores or tree cutting.

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