Chamise Chaparral Dead Fuel Fraction Is Not Reliably Predicted by Age

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ABSTRACT. Fire managers of southern California chaparral often assume that the amount of dead material in chaparral shrubs is closely related to canopy age. Analysis of chamise (Adenostoma fasciculatum), *sampled from southern California shrublands, indicates that the ratio of dead to live components is not related reliably to age of shrub canopy. Further statistical description of the data indicates that fractions of dead material greater than 0.40 are rare. The results provide grounds for seriously questioning current assumptions about the strong relationship between age and fraction dead in southern California chaparral fuels.*

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Natural resource managers of southern California shrublands (chaparral) address the planning aspects of wildland fire by using the concept of age class management. Wildland fire managers assume that the dead vegetative fuel is the most important characteristic that influences fire intensity. And, they assume that the older the vegetative canopy, the greater is the fraction of dead fuel. These two assumptions form the basis for management of chaparral fuel by age class (Hunter and Philpot 1982). The goal of management by age class is to keep chaparral stands young enough to prevent accumulations of dead fuel that result in unmanageable, highly destructive wildland fires (Rogers 1982).

Chaparral fire managers have been using a mathematical model that provides various fuel descriptors, including the fraction of fuel that is dead, as a function of canopy age (Rothermel and Philpot 1973, Philpot 1974). Although this model is largely based on chamise chaparral (*Adenostoma fasciculatum*) data, it is generally applied to chaparral stands composed of other species. This age-dynamic chaparral fuel model has been distributed to field personnel through classes on prescribed burning and fire behavior in California. Also, the southern California chaparral fuel model option (SCAL) in the FIRECAST (Cohen 1986) computer program is based on the dynamic fuel model. FIRECAST is a fire behavior predictor generally available to fire managers from various fire agencies through the computer system of the California Office of Emergency Services.

Although the concept of a relationship between age of chaparral and fraction of dead fuel has been widely accepted by fire managers, contradictory observations during prescribed burns and wildfires compelled us to question it. Our initial field observations of the fraction dead in various age classes of chaparral indicated a high degree of variability and generally less total dead fuel than predicted. We initially turned our attention to the literature for guidance in determining whether a relationship between age and fraction dead exists.

Past studies have extensively characterized chamise and other chaparral species. Several studies examined fuel characteristics of one or more chaparral species (Countryman and Philpot 1970, Nord and Countryman 1972, Wakimoto 1977, Rundel and Parsons 1979), but none of these studies quantitatively described a relation of age to fraction dead. Other chaparral studies provide age-related information concerning the dynamics of the stand species composition (Hanes 1971, Patric and Hanes 1964, Stohlgren et al. 1984), but the fraction of the dead vegetative fuel was not described. Several authors believe that the fraction of dead vegetation increases with age, but did not present quantitative studies (Philpot 1974, Green 1981, Hanes 1974).

The literature did not contain the information needed to resolve our question about age and fraction dead, so we conducted a field study that sampled the dead vegetative fraction of chamise chaparral with regard to canopy age. This article reports the results of that field study.

METHODS

Chamise was chosen for this study on the basis of three considerations: (1) chamise chaparral data strongly influenced the age/fraction dead relationship believed to exist; (2) Hanes (1971) indicated that chamise was the most common chaparral species in southern California, and (3) Countryman and Philpot (1970) quantified fuel information, including the fraction dead, for a 33-year-old stand of chamise that could serve as one point for comparison.

Two types of sampling procedures were followed. The first was a multi-

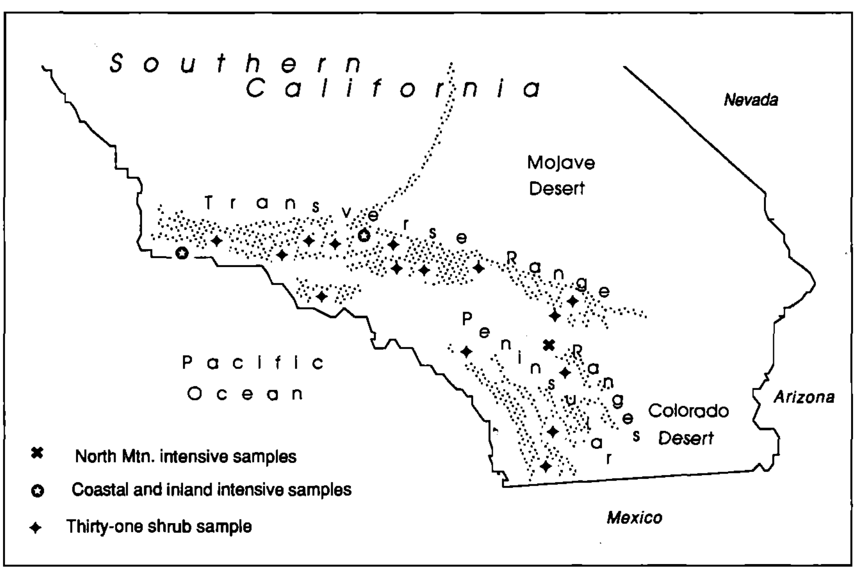

Figure 1. Symbols indicate the locations of sample sites of chamise fraction dead.

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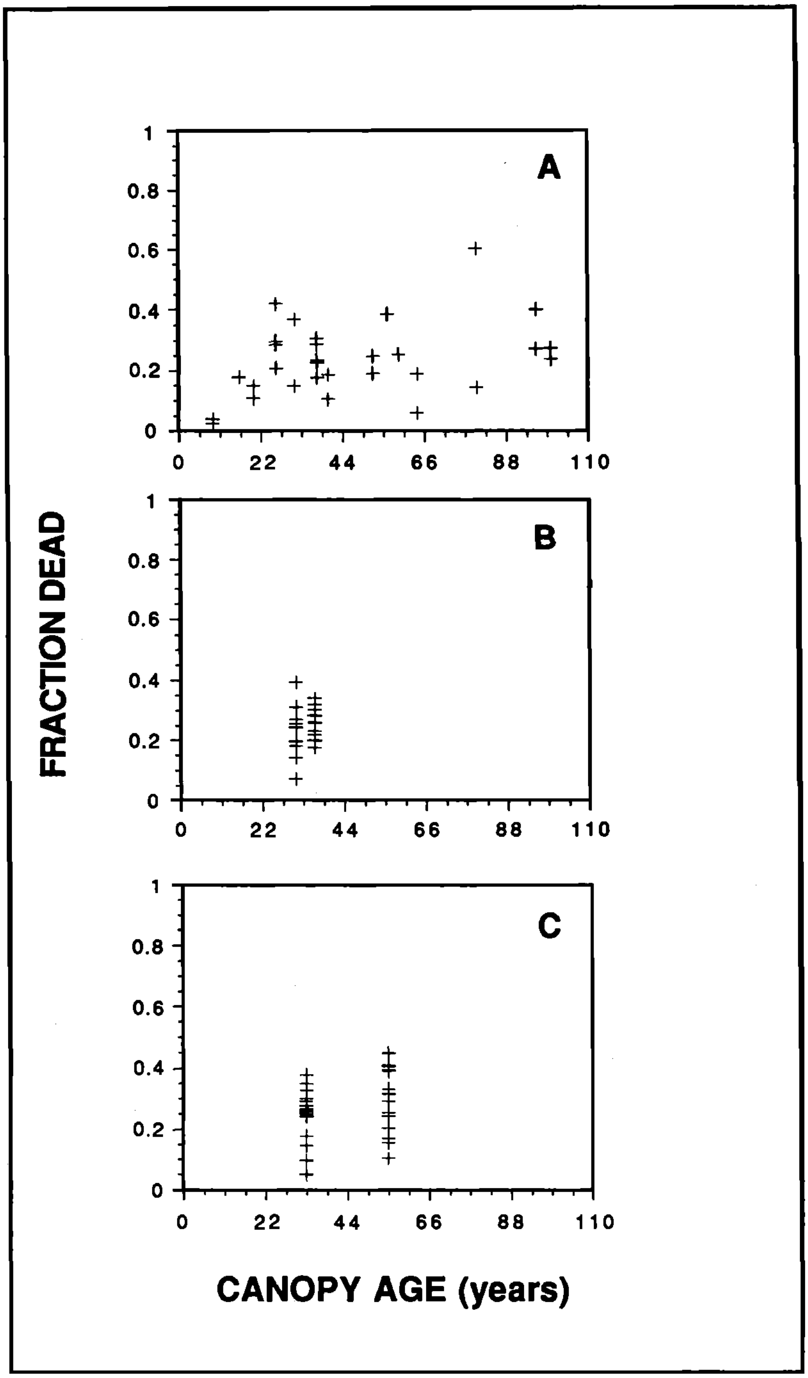

Figure 2. Scatter plots of the 31-shrub sample (A) and intensive sample plots at the coastal and interior mountains (B) and North Mountain (C) display sample results for chamise fraction dead by canopy age.

site procedure that sampled individual chamise shrubs extensively across southern California. The second procedure sampled three specific southern California sites intensively, with a greater number of shrubs taken from each site than was the case for the first procedure. The intensive samples were used to provide insight into the kind of within-site variability that might be found in southern California stands of chamise, and to provide a comparison for evaluating the multi-site data. Figure 1 identifies locations where shrub samples were taken.

The multisite procedure sampled 31 chamise shrubs from 15 different southern California locations within areas vegetated by chaparral community series (Paysen et al. 1980, 1982). Canopy ages, for the sites sampled, ranged from 9 to 100 years. The sampling locations were chosen arbitrarily with respect to several factors: (1) the availability of chamise as the dominant shrub species in the area, (2) our ability to identify canopy age from age class maps, (3) the representation of the range of known canopy ages (current fire history maps limit this to 1–100 years), (4) the representation of the geographic and ecological (based mostly on climate at this stage of the procedure) range of southern California chamise sites, and (5) our ability to access the site for shrub collection. With the use of vegetation maps, fire history maps (for age class), climate zone maps, and road maps for accessibility, a general location was chosen through an iterative process until all of the above criteria were met. General locations were never chosen from on-site inspections.

Using the intensive, site-specific, sampling procedure, a sample of size ten was taken from each of two different southern California chaparral sites. The general locations were arbitrarily selected as in the multisite procedure, but with two major exceptions: (1) the chamise-dominated sites represented canopy ages of 30–39 years since the last fire, and (2) the general locations represented a general climatic contrast between the coastal zones and the interior mountains. Within the selected general locations, specific sites were randomly selected.

Individual shrubs, the sampling units for both sampling procedures, were randomly selected. The random shrub was selected by choosing a random direction and distance (within 100 m) from an access point. If the resulting vector did not locate an appropriate chamise site and shrub, the process was repeated from the location of the unusable sample location. The sampled shrub was cut, bagged, and removed from the site for analysis at the USDA Forest Service Fire Laboratory, in Riverside, CA.

The shrub analysis followed the procedures used by Countryman and Philpot (1970). Shrub material, foliage, and stems less than 76 mm, was separated into living and dead categories. The material was then put into containers for oven-drying over a 24-hour

Table 1. Summary statistics for all chamise sample data sets of fraction dead.

	Data set				
Statistic	31-shrub sample	Coastal mtns. age 31 yr	Interior mtns. age 36 yr	North Mtn. age 33 yr	North Mtn. age 55 yr
Median	0.228	0.249	0.259	0.259	0.303
Mean	0.223	0.237	0.259	0.244	0.286
S.D.	0.120	0.092	0.053	0.088	0.107
Sample size	31	10	10	16	16

Table 2. Sample estimates and bootstrap summary statistics for the mean, standard deviation, and median, for the 31-shrub data set. The summary statistics were run on 500 bootstrap estimates (θ*) of each statistic.

	Summary statistics		
Statistic estimates	Mean	S.D.	Median
θ[1]	0.233	0.118	0.228
Mean (θ*)[2]	0.230	0.117	0.220
S.E. (θ*)	0.021	0.020	0.022
Bias (mean (θ*) − θ)′	−0.003	−0.001	−0.008

[1] θ indicates the sample estimate of the statistic of interest.
[b] θ* represents a bootstrap estimate of the statistic of interest.

period at 95°C. The dried vegetation was then weighed to determine its mass.

As a complement to the two sample sets described above, data were included from the original Countryman and Philpot (1970) chamise fuels study, and from our resampling of their site. Countryman and Philpot sampled 16 chamise shrubs from a single site whose vegetative canopy age was 33 years old. Twenty-two years later, we sampled 16 chamise shrubs from their original site (the North Mountain samples in Figure 1) whose canopy age was then 55 years old.

To establish a quantitative measure of the relationship between fraction dead and age in our multisite sample, we used a nonparametric coefficient, Kendall's tau, as a measure of correlation. We chose not to use the usual correlation and regression techniques because there was no reason to believe that the restrictions imposed by these techniques (for example, linearity in the case of the linear correlation coefficient, *r*) were appropriate. Kendall's tau responds only to monotonicity, and therefore does not demand specific functional relationships (such as linearity) of the data.

Because of the small sample size, we performed a bootstrap resampling procedure (Efron 1982, Efron and Gong 1983) on the 31-shrub sample to check the internal consistency of the data as it might affect the measure of correlation. The resampling comprised 500 iterations of resampling with replacement from the 31 pairs of fraction dead/age values. The size of each sample was 31. For each iteration, an estimate of Kendall's tau was calculated; to summarize these estimates, mean and standard errors of the tau estimates were then calculated.

For the same multisite sample, we calculated summary statistics on the fraction dead data to generally describe the occurrence of the dead fuel component for southern California chamise chaparral. The fraction dead was described using the bootstrap procedure on the sample mean, median, standard deviation, and quantiles (10th through 90th percentile).

RESULTS

The plot of the 31-shrub, multisite data reveals little, if any, relationship between the fraction dead and age (Figure 2). Inspection of the site-specific data sets shows that the variability found on a specific site is similar to that found in the multisite data, and the range of the specific site data is comparable to that of the multisite data.

The results of the bootstrap procedure suggest that unevenness and outlying values in the 31-shrub, multisite sample do not significantly influence the estimates of the mean, median, and the standard deviation. Table 1 presents summary statistics of the actual data, and Table 2 presents summary statistics of the bootstrap estimates. The small values for the standard errors of the mean, median, and the standard deviation for the bootstrap sample, as well as the low bias values, imply that the actual 31-shrub sample is not significantly influenced by outliers or unevenness in the data.

Similarly, the bootstrap results suggest that the Kendall's tau measure of correlation provides a reasonable estimate of the relationship between the fraction dead and the age. Figure 3 summarizes the actual and the bootstrap estimate of Kendall's tau. A positive tau between 0.0 and 1.0 indicates a positive relationship between the fraction dead and age. The resulting tau of 0.225, while statistically different from zero (with a two-tailed probability of 0.078), indicates a very weak association. The values for the bias and the standard error of tau indicate that the Kendall's tau estimate is reasonable for the 31-shrub sample.

Further description of the multisite shrub sample, without regard to age, indicates a strong clustering of the data. Figure 4, a histogram of the frequency of occurrence of the fraction dead, shows the 31-shrub sample data

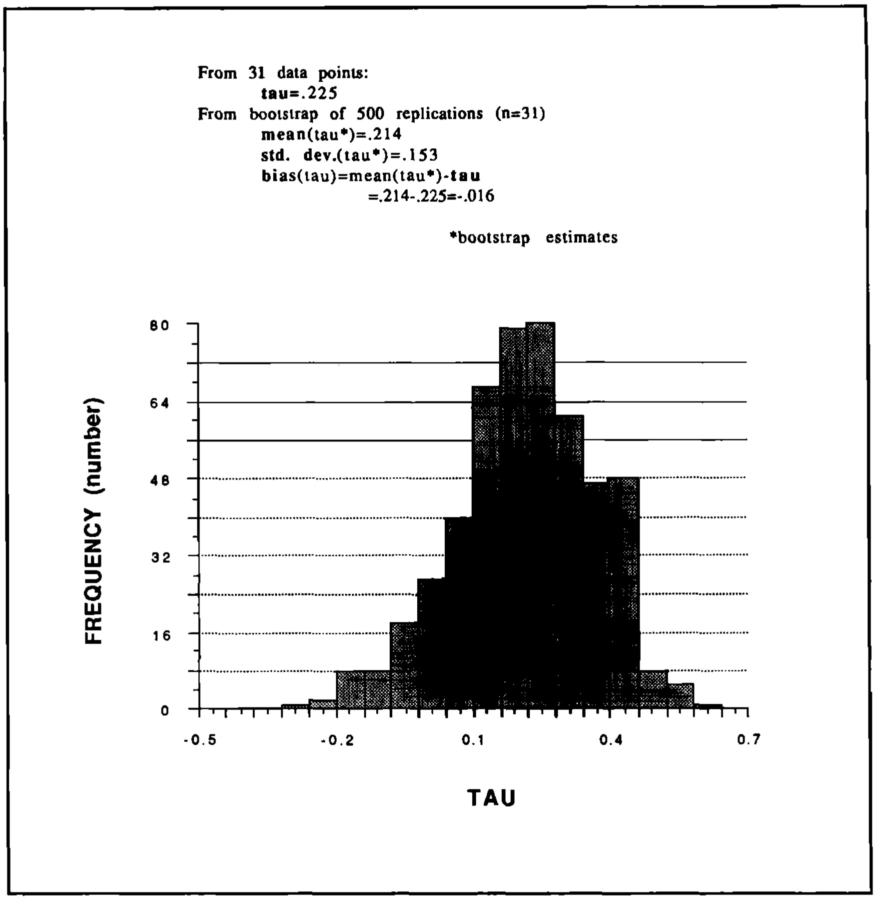

Figure 3. A histogram of the 500 bootstrap estimates of Kendall's tau. The value of tau calculated from the actual field data (n = 31) is 0.225. From bootstrap estimates of 500 replications, mean (tau*) = 0.214; S.D. (tau*) = 0.153; bias (tau) = mean (tau*) − tau = 0.214 − 0.225 = −.011. (Tau* indicates the bootstrap estimate of tau.)

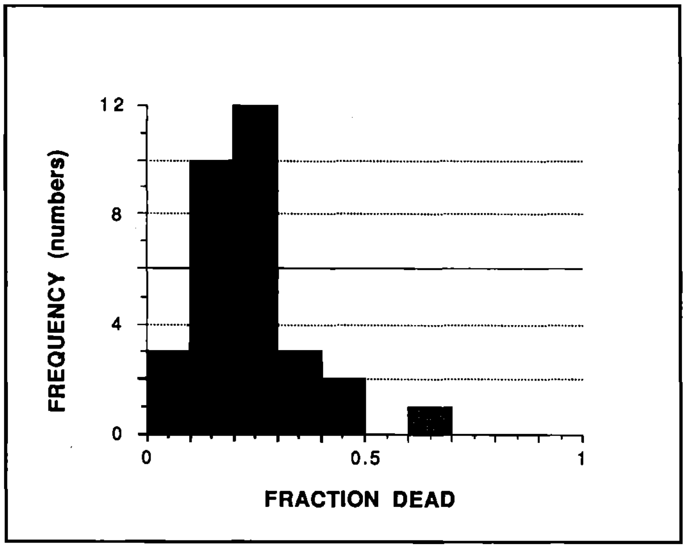

Figure 4. Histogram showing the frequency distribution of the actual 31 chamise fraction dead data.

distributed around a central value. For this distribution, the mean is 0.233 and the median is 0.228 (from Table 1). The closeness of the mean and median values indicates that the data distribution is somewhat symmetrical. This concurs with the low measure of fraction dead/age correlation provided by Kendall's tau.

Mean percentiles, developed from the bootstrap procedure, were used to establish a cumulative frequency distribution for fraction dead, which allows estimation of the frequencies of fractions dead relative to particular values. For example, as seen in Figure 5, 50% of the fractions dead fall below approximately 0.22, and 80% of the fractions dead fall below approximately 0.31. Fractions dead approaching 0.50 and greater are rare.

An inspection of all data sets, summarized in Table 1, using box and whisker plots (Figure 6) indicates a prevailing tendency of the fraction dead data to cluster around a central value. With box and whisker plots we can compare the sample sets with regard to dispersion, central tendency, and skewness (Emerson and Strenio 1983). Inspection reveals that the median value for each data set is central to the range values, and central to the values that delimit the central 50% of the data. The overlap of values within the central 50% of the data for each data set, and containment of all data set medians within the 95% confidence limits for the North Mountain (age 55 years) median, gives the impression that all samples were from a single population. This overlap also suggests that site, at the stand level (as opposed to the shrub level), is not a dominant factor in the development of fraction dead.

CONCLUSIONS

Our data indicate that a general fraction dead/age relationship is very weak for southern California chamise chaparral (*Adenostoma fasciculatum*)—at least within the age range (9 to 100 years) sampled. Thus, age of chamise canopy does not provide a reliable estimate of the fraction dead of vegetative fuel. Since the current method of using age to estimate the fraction dead is based on chamise characteristics, no reliable age estimate exists for other chaparral species.

Our results show a symmetric distribution of chamise fraction dead values around a relatively low value in the fraction dead scale. This distribution suggests that 80% of the time we will find stands of chamise with fraction dead values less than or equal to 0.31—regardless of canopy age.

RECOMMENDATIONS

Southern California vegetation managers requiring an estimate of the fraction dead of chamise and other chaparral species should obtain an average fraction dead estimate from on-site sampling. The use of a canopy age map (e.g., a fire history map) as a tool for predicting fraction dead in chamise and other chaparral stands is not recommended. Further, the results of this study bring into serious question the efficacy of age class management in chamise chaparral if that management is based on an expected age-fraction dead relationship as a predictor of potential fire behavior or other effects.

The lack of an age/fraction dead relationship for chamise chaparral does not negate the fact that a fraction dead exists. The lack of an age relationship indicates that other interacting factors such as yearly climate variability, insects, and disease could be responsible for the fraction of dead fuel. Because we sampled over a relatively

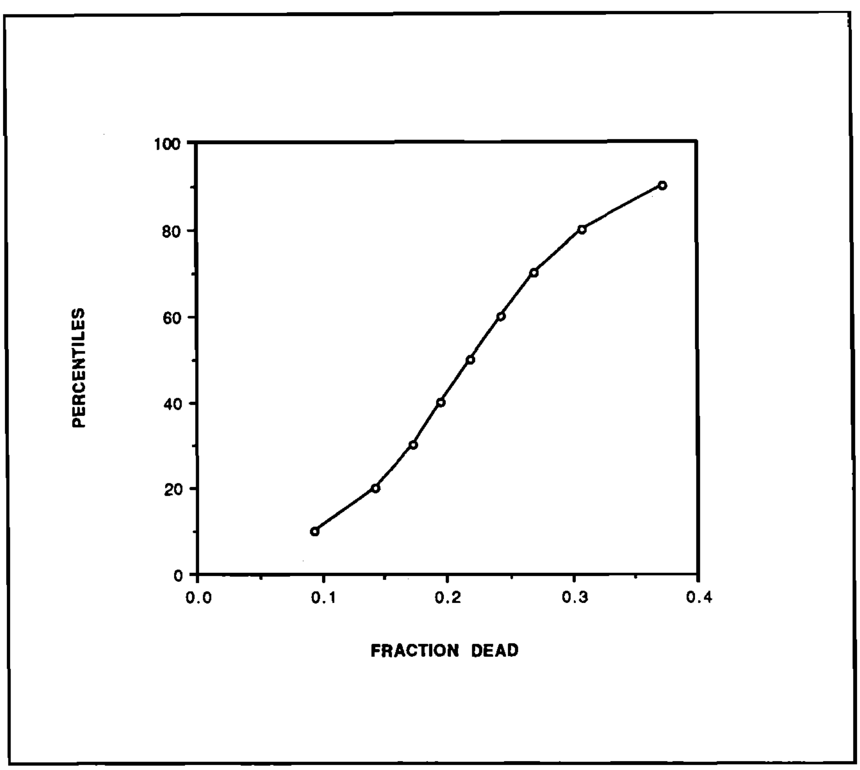

Figure 5. Bootstrap estimate of the cumulative frequency distribution of chamise fraction dead for the 31-shrub sample.

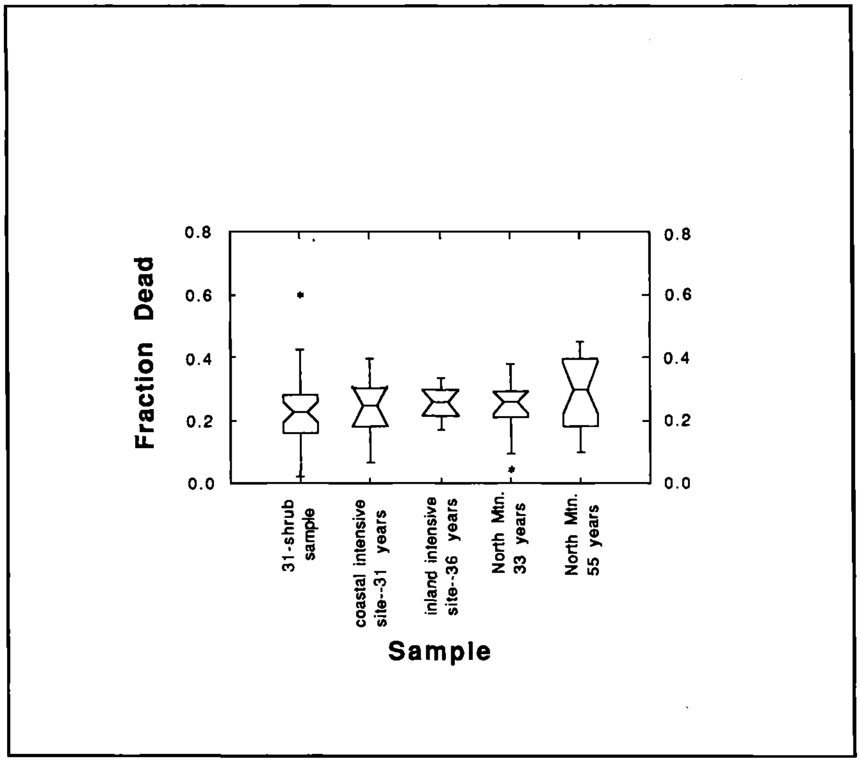

Figure 6. Box and whiskers plots for all data on chamise fraction dead discussed in this paper. The length of the box approximates the interquartile range of the data. The cross bar shows the median, with notches approximating 95% confidence limits for the median. Ninety-nine percent of the data points fall within the range indicated by the "whiskers." Outliers are indicated by asterisks.

short time period (1984–85), we cannot be certain as to how persistent the value of central clustering and the distribution of fraction dead are. Our descriptions of the fraction dead should be viewed as the sampled condition and subject to change.

Important new understanding about southern California chaparral would include how the fraction dead is produced and how long it takes for significant fractions dead to accumulate. This information would indicate for how long sample estimates of fraction dead would be viable.

Given the lack of any consistent relationship between age and fraction dead in chamise, we as fire professionals need to reexamine our perceptions of the way fraction dead affects fire behavior in these stands—especially if that understanding is based on field observation of fire behavior. If, for example, we assume a level of fraction dead (based upon a canopy age map) and that assumption is not correct, then observed fire behavior should not fit our expectations—if there is a necessary relationship between fire behavior and fraction dead. If, however, the fire behavior does fit our expectations under these circumstances, then perhaps fire behavior is not as heavily dependent on the fraction dead as we have been led to believe. We are forced to conclude that fire behavior variations in chamise chaparral are more complex than can be described by a single fuel characteristic like the fraction of dead vegetation. □

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