Forest Health Monitoring in California, Oregon, and Washington: Results and Interpretation

Richard T. Busing

Abstract.—From 1992 to 1997, standardized plots were established at about 500 sites in California, Oregon, and Washington as part of the national Forest Health Monitoring program. In California, 197 plots were established from 1992 to 1995; in Oregon and Washington, a total of 304 plots were established in 1997. Summarization of baseline data by state reveals similarities and differences among states. Trend analysis of the California data reveals few changes in forest structure variables, but substantial changes in certain crown indicator variables. For example, foliage transparency and crown dieback variables indicated improved crown condition since the 1992 drought. Additional trend data will allow further assessment of changes in tree condition in relation to environmental changes.

The detection monitoring component of the national Forest Health Monitoring Program includes plot data collection from a network of forested sites across the United States. Measurements of forest condition are made periodically at each site for monitoring and assessment of trends. California was the first Pacific Coast state in which Forest Health Monitoring plots were established. A grid of 197 forested sites was initiated there in 1992 and completed in 1995. Plots were established at most of the forested grid sites in Oregon and Washington in 1997. A comparison of baseline data among these Pacific Coast states is presented here. In addition, California data for certain indicator variables are examined for trends in forest condition from 1992 to 1996.

METHODS

Sampling Design

Sampling methods for Forest Health Monitoring are based on a rotating panel design with approximately 4,200 sites located on a triangular grid across the mainland U.S. (Palmer *et al.* 1991; fig. 1). In the western United States, data are collected every summer from one plot per site. Only a subset of sites is sampled each year; any given site is sampled at least once every 4 years. Baseline measurements are complete for sites in California, Oregon, and Washington. Eventually, sites in Alaska and Hawaii will be added to cover forest lands for all Pacific Coast states. I present baseline data from 1992 to 1995 in California and from 1997 in Oregon and Washington. I also present trend data from 1992 to 1996 in California.

Baseline Data

Using the Forest Health Monitoring grid (fig. 1), 197 sites were measured in California from 1992 to 1996. In 1997, 168 sites were measured in Oregon and 134 sites were measured in Washington. At each site, a cluster of four circular subplots totaling 0.067 ha in area was sampled. A combination of conventional stand mensuration techniques (e.g., stem density and basal area) and more recently developed indicators of health (e.g., sapling vigor, tree live crown ratio, crown dieback, and foliage transparency) were used within the plots. See Liegel and Busing (1996) for further information on the specific measurements applied in Pacific Coast states. Data were summarized by state in one of two ways depending on the parameter: (1) as a collection of site values averaged across all individuals in a plot, or (2) as a collection of tree values pooled across all trees in a region or state.

Trend Data

In California, the 52 permanent plots established in 1992 were revisited in 1996. During 1996, 10 additional plots on the grid network were measured. Thus, more sites were measured in 1996 than in 1992. Various forest health indicator measurements were made at each site (Liegel and Busing 1996). Of these variables, certain measures of tree crown condition were selected for trend analyses. Three crown condition variables (live crown ratio, crown dieback, and foliage transparency) showed high repeatability of estimation in comparisons between trainers and field crews in the Pacific Coast states. A cumulative distribution of site means for selected indicator variables was plotted for each sampling year, allowing comparison over time.

Research Ecologist, USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR 97331 USA.

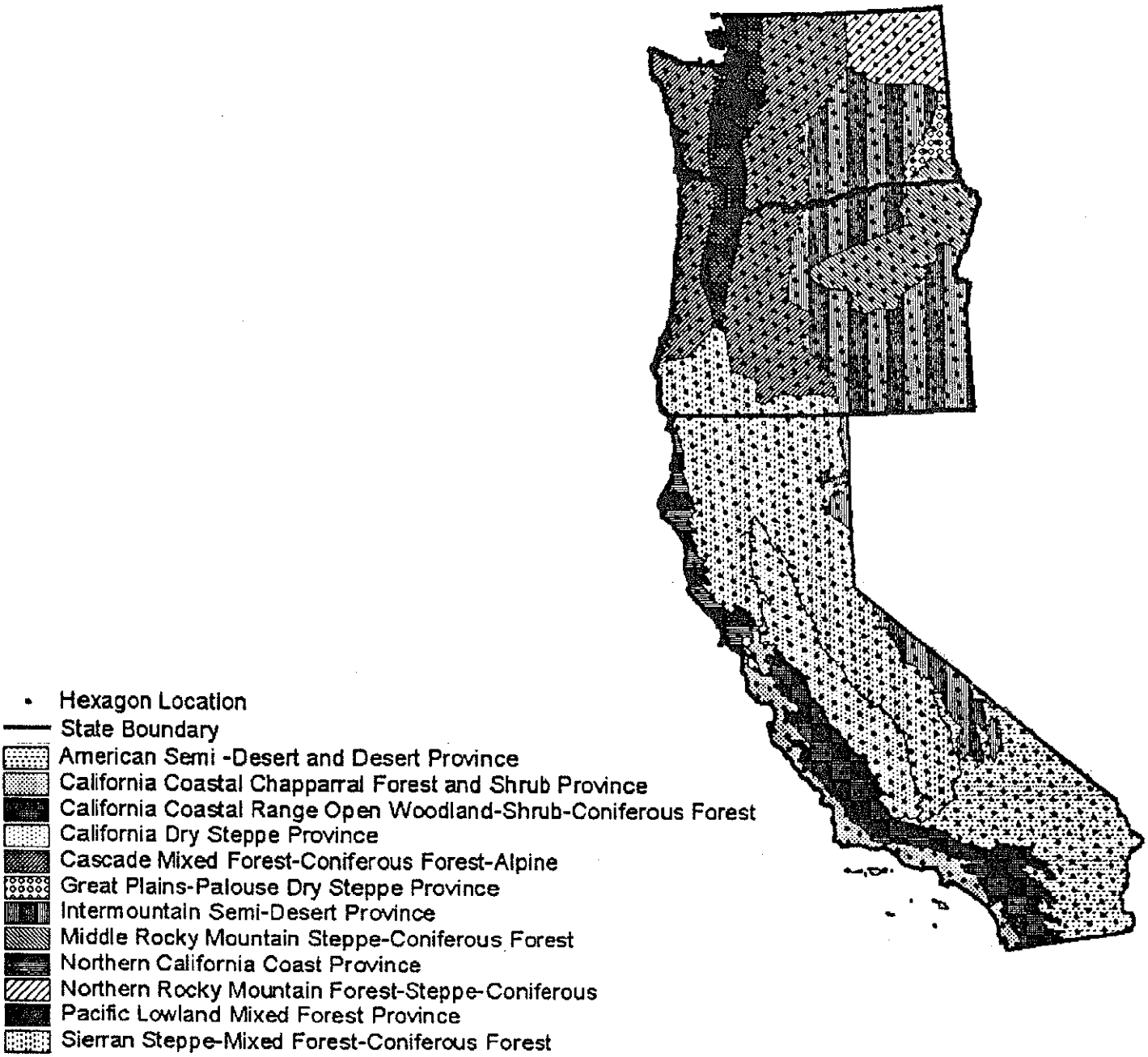

Figure 1.—*The triangular grid of sites in California, Oregon, and Washington with Bailey's (1995) ecoregions.*

RESULTS

Baseline Data

The proportion of forested grid sites ranged from 31 percent in California to 51 percent in Washington (table 1). California and Oregon had a small percentage of woodland sites, and Washington had no woodland sites. Inaccessible forest sites made up less than 6 percent of the entire grid in each state.

The types of forests encountered differed strongly by state (table 1). For example, Douglas-Fir dominated about a third of the sites in Oregon and in Washington, but only 5 percent of the California sites. Sites with Hemlock-Spruce were common only in Washington. Hardwood-dominated sites were common only in California.

Stand structure showed several similarities among states (table 1). The mean densities of live seedlings and tree stems were similar among states. Mean live basal area values did not differ more than 6 m^2/ha among states.

Table 1.—*Forest attributes by state*

Attribute	California	Oregon	Washington
Land Cover (Percent of sites)			
Timberland	25	37	47
Woodland	3	5	0
Inaccessible forest	3	3	5
Non-forest	69	56	49
Forest Type (Percent of forested sites)			
Douglas-Fir	5	31	39
Pine	16	21	14
Fir-Spruce	14	4	7
Hemlock-Spruce	1	5	25
Redwood	1	0	0
Mixed Conifer	17	21	11
Hardwoods	30	5	2
Other	16	13	2
Stand Structure (Mean and standard deviation)			
Seedling density (n/ha)	1,914±349	1,905±305	2,073±381
Stem density	913±27	887±76	956±148
Snag density	25±3	32±4	59±7
Basal area (m^2/ha)	27±2	27±2	33±2
Tree Species Diversity (Mean and standard deviation)			
Species richness	2.9±0.1	3.0±0.1	3.0±0.1
Simpson diversity	0.29±0.02	0.32±0.02	0.32±0.02
Shannon diversity	0.47±0.03	0.52±0.03	0.55±0.03

However, snag density was noticeably high in Washington. Live tree diameter distributions for each state were log-linear in form (fig. 2). Similarity in the percent frequency of stems in each size class was evident.

Mean tree species diversity of sites did not differ strongly among states (table 1). Species richness (species counts) means ranged from 2.9 in California to 3.0 in Oregon and Washington. Although mean species richness values were quite similar among states, richness as well as the Simpson and Shannon diversity indices were lowest in California.

Baseline values for certain forest health indicator variables differed by state. In Washington, for example, good sapling crown vigor ratings were infrequent and average ratings were frequent in comparison to California and Oregon (fig. 3). In California, mean foliage transparency of tree crowns was relatively low (fig. 4).

Several forest health indicator variables were similar across states. Distributions of mean live crown ratio differed only slightly among states (fig. 5). The same was true for mean crown dieback (fig. 6). The frequency of trees lacking damage was also similar among states (fig. 7).

Trend Data

Distributions of mean live crown ratio in California were similar between 1992 and 1996 (fig. 8a), suggesting little change in live crown ratio across the State. However, distributions of mean crown dieback (fig. 8b) and foliage transparency (fig. 8c) suggested poorer crown condition in 1992 than in 1996.

DISCUSSION

Several similarities in baseline data are evident among the three states studied. Mean tree species diversity, quantified by richness, does not differ greatly among states.

Figure 2.—*Diameter distributions of live trees by state.*

Figure 3.—*Sapling crown vigor ratings by state.*

Figure 4.—*Cumulative distributions of foliage transparency by state.*

Figure 5.—*Cumulative distributions of live crown ratio by state.*

Figure 6.—*Cumulative distributions of crown dieback by state.*

Figure 7.—*Tree damage by state.*

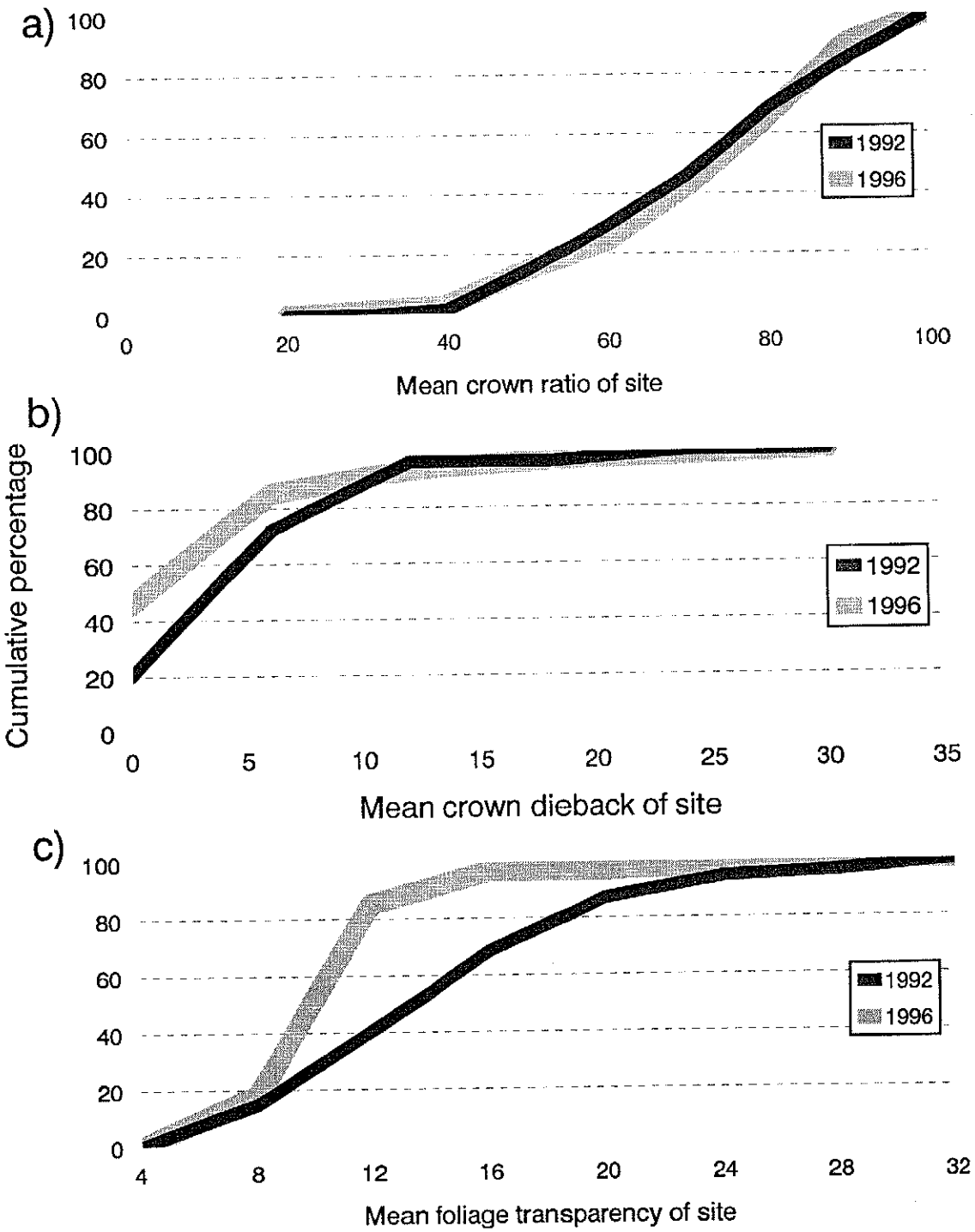

Figure 8.—*Cumulative distributions of indicator variables in California for 1992 and 1996: (a) live crown ratio, (b) foliage transparency, and (c) crown dieback.*

Although tree species composition differs among states, the mean number of tree species encountered per site is similar. In addition, total stand density and basal area of live stems do not differ greatly among states. Tree diameter distributions are log-linear in form and similar among states. The log-linear diameter distribution, common in uneven-size forest stands (Leak 1965), also occurs across these large regions that have a mixture of stands with contrasting structures and disturbance histories. Of the forest health indicators examined, distributions of site mean live crown ratio and site mean crown dieback are similar among states. In each state, approximately 20 percent of live trees had at least one type of damage recorded.

There are several notable differences in baseline data among the three states. For obvious biogeographic reasons, the proportion of forested land and the species composition of forests differed among states. The reasons for other differences such as the high snag density in Washington are less clear and require examination of other data or further study. Differences in forest health indicators among states require careful examination. Of the indicators examined here, sapling crown vigor and foliage transparencies showed differences among states. The reasons for these differences must be studied for effective long-term monitoring and assessment. It is critical that the sources of these differences are elucidated. Whether they are the result of human error, or biological or environmental differences has bearing on their interpretation.

The observed changes in crown dieback and foliage transparency from 1992 to 1996 in California indicate improved crown condition of live trees over the period. This improvement is correlated with increased rainfall since late 1992, the end of a multiple-year drought. Thus, these indicators may respond to drought stress. Their ability to detect effects of droughts and other environmental stresses can be assessed as further trend data become available.

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