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Age structure of forests on Soldiers Delight, a Maryland serpentine area[1]

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KNOX, R. G. (Dept. Biol., Univ. of North Carolina, Chapel Hill, NC 27514). Age structure of forests on Soldiers Delight, a Maryland serpentine area. Bull. Torrey Bot. Club 111: 498–501. 1984.—The age structures of four wooded stands, representing a range of pine and oak forests on a Maryland serpentine area, were sampled. Ring counts from increment borings showed distinct age clusters in three of the stands. These indicated past episodes of recruitment, which may reflect disturbance of the stands by fire or drought.

Key words: age structure, disturbance, forest, Maryland, recruitment, serpentine.

Plant communities of serpentine areas are often floristically and physiognomically distinct from nearby communities on other substrates. Many ecologists have emphasized the importance of soil characteristics to the structure of serpentine vegetation. Proctor and Woodell (1975) stressed that "the total environment provided by serpentine is uniquely unfavorable." Nevertheless, the deeper soils on serpentine can support vegetation similar to that supported by soils derived from felsic parent materials (Shreve 1910, Rune 1953, Dearden 1979). In Maryland, Delaware, and southeastern Pennsylvania, the vegetation on many serpentine areas has been altered by residential or commercial development. The remaining undeveloped large serpentine area support mosaics of plant communities that range from prairie-like openings and pine scrub or greenbrier (*Smilax*) thickets to pine forests and mixed deciduous forests.

Preliminary observations on a number of serpentine "barrens" in this region suggested that substantial portions of the forests consisted of single-aged cohorts of trees. If confirmed, this suggestion ought to prompt a reassessment of the relative importance of disturbance to the maintenance of serpentine vegetation. The object of this investigation was to determine whether recruitment of trees had been episodic or continuous in the forests of one serpentine area.

Methods. A large (800 ha) serpentine area in Baltimore County, near Baltimore, Maryland, known as Soldiers Delight, was chosen for study. It supports a mosaic of plant communities, including grassy openings with small pines (*Pinus virginiana*), dense stands of pines, mixed oak (*Quercus* spp.) and pine woods, and some stands of larger oaks. Although parts of the outcrop were mined for chromium in the early to mid-19th century, most of the area is now in the Soldiers Delight State Park (Forest, Park, and Wildlife Service, Maryland Department of Natural Resources). There was little evidence of mining disturbance in the stands described below.

Four forested areas were selected for comparison. In each, I measured soil depth in several holes made with a hand auger. Tree basal-area estimates were made at 25 m intervals along 200 to 350 m transects using the Bitterlich variable radius method (Mueller-Dombois and Ellenberg 1974) and averaged along each transect. This method was not suitable for stand 2. Stand heights were estimated from the average height of a sample of canopy trees. The four stands were:

1. A pine stand (*P. virginiana*) of 7.5 m mean height, in 30–40 cm of soil. Basal area, 25 m^2 ha^{-1}.

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2. A stand of pines and oaks (*Quercus* spp.) of 12 m mean height, in 20–40 cm of soil. Evidence of recent pine mortality.

3. A stand of oaks and pines of 10 m mean height, in more than 1 m of soil. Basal area, 20.5 m^2 ha^{-1}.

4. A stand of oaks of 20 m mean height, in 60–100 cm of soil. Basal area 24.5 m^2 ha^{-1}.

Stands 1, 2 and 4 were upland stands in shallow soils having well-defined horizons, whereas stand 3 was next to a small permanent stream and had a deep soil with poorly differentiated horizons. The serpentine parent material was apparent at the bottom of soil cores in the upland stands, and it was visible in the stream bed and banks in stand 3 and the shallower soils nearby.

In spring of 1978, I collected increment borings from the major tree species in each stand. The species sampled were: Virginia pine (*Pinus virginiana*), blackjack oak (*Quercus marilandica*), post oak (*Q. stellata*), black oak (*Q. velutina*), and sassafras (*Sassafras albidum*). Nomenclature follows Fernald (1950). Some hybrids of black oak and blackjack oak in stand 4 (James C. Hull, Towson State University, personal communication) may have been included as black oaks.

To test for prominent cohorts in the age structure, sampling included a nonrandom cross-section of sizes. Trees were cored at breast height (1.3 m) in all but stand 1, where coring was at waist height and 2 years were subtracted from the resulting ages.

Even though none of the sample diameter distributions were significantly different from normal distributions (Kolmogorov-Smirnov, $p > 0.20$), sampling bias could produce an irregular observed distribution of ages. Therefore, age distributions were compared with a null hypothesis based on age predictions from diameter, rather than a theoretical distribution. For the null hypothesis, age and size data were pooled across all four stands and log age/log diameter regressions were developed for each species. These regression models were then applied to the diameter data for each stand to produce a predicted age distribution for that stand. The observed age distribution for each stand was then compared to this predicted distribution with the Kolmogorov-Smirnov statistic (Sokal and Rohlf 1981). If present, distinct major age cohorts should appear as significant deviations between the observed and predicted frequency distributions.

Results. Table 1 shows the results of log age/log diameter regressions for the five species sampled. Models were significant at the 0.05 level for Virginia pine, blackjack oak, and black oak. Sample sizes (n) were quite small for post oak and sassafras, so significant models were less likely. Nonetheless, their models would be accepted at the 0.10 level.

Observed age distributions in stands 1, 2, and 4 were significantly different from predicted distributions (Kolmogorov-Smirnov, alpha = 0.05) (see Fig. 1). These findings did not change when the outlying points were deleted, nor were they affected when only the species with models significant at the 0.05 level were included. The points in the distributions where the Kolmogorov-Smirnov statistic, D_{max}, was highest corresponded to age cohorts at 23 years in stand 1, 37 and 45 years in stand 2, and about 160 years in stand 4 (ages at breast height). Virginia pine formed the major

Table 1. Coefficients and significance by species for the model: Age = a(Diameter)^b; fit by linear regression of log age on log diameter. The letters a and b refer to the model; the others have their usual statistical meanings; n = sample size, R^2 = proportion of the variance attributable to the model, p = probability of obtaining a result at least this extreme by chance.

Species	a	b	n	R^2	p
Virginia pine	4.92	0.63	39	0.63	0.0001
Blackjack oak	4.50	0.83	16	0.70	0.0001
Post oak	1.03	1.28	6	0.56	0.088
Black oak	3.76	0.85	16	0.83	0.0001
Sassafras	0.41	1.58	5	0.66	0.096

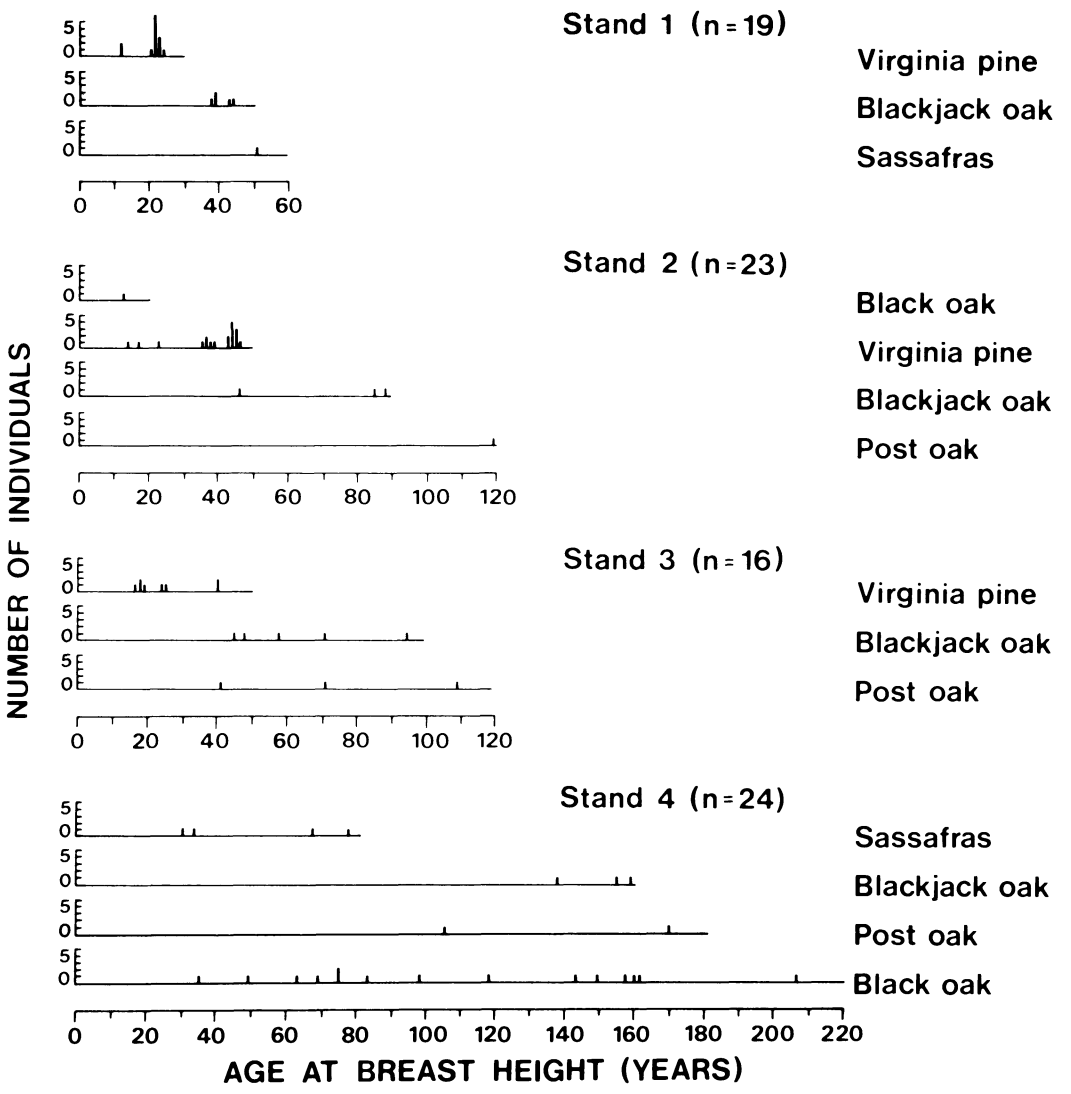

Fig. 1. Age distribution of sample individuals by stand and species. The height of the bar indicates the number of individuals in each one-year age group.

age clusters in stands 1 and 2. Although differences in potential growth rates among sites could have influenced the fit of the regression models, averages of annual diameter increments were nearly identical in the samples from the stands with the deepest and shallowest soils (stand 3: 0.471 cm yr^{-1}, stand 2: 0.476 cm yr^{-1}). In addition to sampled individuals shown for stand 4 in Fig. 1, four hollow blackjack oaks were cored and estimated to be about 160 years old. These would have added to the significant cohort, if complete ring counts were available. Also one old post oak had 232 rings in the best core, but the center was not reached.

Discussion. A few recruitment episodes strongly influenced the age structure of three of the four stands. The finding of episodic recruitment is unremarkable from the perspective of modern, population-based, vegetation ecology. However, past work has emphasized the roles of climate and parent material in determining the structure of this vegetation (Robinson *et al.* 1935, Shreve 1910). Disturbance affected the present structure of forest stands on

Soldiers Delight, and may have contributed to differences between stands as well. The test employed was statistically conservative because the pooled data themselves were used to produce the predicted distributions. The results were consistent with the finding that even-aged stands of *Cupressus sargentii* occupy the more chemically extreme sites in a California serpentine vegetation (Koenigs *et al.* 1982). The possible role of disturbance in maintaining the open vegetation and arrested soil development of the habitat of many rare serpentine plants has implications for the long-term management of these areas.

Several factors could have caused episodes of recruitment. Fire scars were visible on a number of oak and sassafras trunks, and cross-sections cut from downed black oaks near stand 4 showed patterns of damage and regrowth, suggesting fires at 8 to 40 year intervals since about 1850. Climatic fluctuations like those that disturb some granite outcrops in Georgia (Phillips 1981) may cause drought mortality and subsequent recruitment in shallow soils on Soldiers Delight. As stands 1 and 2 were nearly even-aged, it seems unlikely that factors intrinsic to the stands caused the recruitment episodes. In addition, I could not rule out forest clearing for grazing, for crops, or associated with mining as a past disturbance, despite the well-known low agricultural value of serpentine soils.

Further, Shreve (1910) did not include Virginia pine in his descriptions of Soldiers Delight, nor are pines present in his published photographs. Virginia pine is now a dominant species. An aerial photograph taken in 1971 (provided by the Maryland Geological Survey) showed open vegetation in many areas that had developed closed canopy pine stands by 1984. As the vegetation of Soldiers Delight has changed greatly within the history of the older forest stands, the pre-settlement disturbance regime is difficult to reconstruct from present patterns. Nevertheless, recent changes and stand age structures show that woody species can rapidly establish dense stands on shallow serpentine soils. This implies that, unless current conditions are radically different from those controlling woody plant establishment in the past, some form of regular disturbance would have been necessary to maintain the open habitat of characteristic serpentine plants.

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