# Growth Rates in a Southern California Population of Knobcone Pine ( *Pinus attenuata* )

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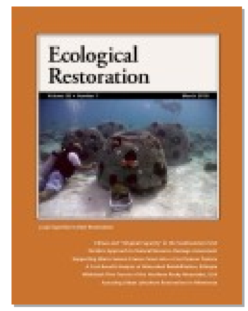


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# Restoration Notes

Restoration Notes have been a distinguishing feature of *Ecological Restoration* for more than 25 years. This section is geared toward introducing innovative research, tools, technologies, programs, and ideas, as well as providing short-term research results and updates on ongoing efforts. Please direct submissions and inquiries to the editorial staff (mingram@wisc.edu and cmreyes@wisc.edu).

## Growth Rates in a Southern California Population of Knobcone Pine (*Pinus attenuata*)

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Data on growth rates of commercially valuable conifers are widely available, but less information has been published on other conifers. Nonetheless, such noncommercial species are sometimes included in revegetation plans, and the success criteria or performance standards often stipulate satisfactory growth rates. This report, while based on a small sample, details growth rates in one such species, knobcone pine (*Pinus attenuata*), in hopes that this information will be useful to researchers and land managers.

This thin-barked, fire-dependent pine occurs at elevations of a few hundred to about 1,900 meters above sea level in scattered populations from Baja California to southern Oregon. It tolerates serpentine and other poor soils, is quite drought resistant, and typically grows in chaparral and conifer forest communities. The closed seed cones accumulate on the parent tree, sometimes for decades, until fire melts the resin that seals the cones. The first seeds are released within hours of the fire, but additional seeds may be released as long as four years afterward (Howard 1992). Fire usually kills the parent trees, but the seeds germinate in great abundance, "as thickly as stalks in a cornfield" (W.L. Jepson, cited in Peattie 1950). Knobcone pine is occasionally used for erosion control and watershed rehabilitation projects (Howard 1992). Restorationists do plant knobcone pine occasionally, but it has potential to be used more often in restoration projects on dry sites with poor soils.

In October 2000, a previously unknown population of about 50 knobcone pine seedlings and saplings was discovered on a granodioritic, chaparral-covered ridge informally known as "Chamise Ridge" above the west shore of Silverwood Lake, San Bernardino County, California. Jeffrey pine (*Pinus jeffreyi*), big-cone Douglas-fir (*Pseudotsuga macrocarpa*), and California black oak (*Quercus kelloggii*) dominate the south shore of the lake; the north shore, little more than 2 km away, is almost at the edge of the Mojave Desert. In between lies a band of chaparral; dominant species include chamise (*Adenostoma fasciculatum*), manzanita (*Arctostaphylos* spp.), California lilac (*Ceanothus* spp.), and skunkbrush (*Rhus trilobata*). The California Department of Water Resources (DWR) maintains a rain gauge near the southwestern arm of the lake; average precipitation is 54.9 cm/y, mostly falling as winter rain, a small amount as snow. However, Chamise Ridge is drier.

Wildfire swept across Chamise Ridge in 1993, but by 2000, dense chaparral, 1–3 m tall, covered the ridge again. Most of the young knobcone pines formed a single doghair thicket (ca. 34°17'39.9" N, 117°19'43.7" W, elevation 1,080 m) on the north-facing slope near a tangle of charred, cone-studded knobcone pine branches; several additional seedlings were scattered among burnt knobcone snags, together with seedlings and saplings of an unidentified species of cypress (*Cupressus*). No evidence of knobcone pine was found on the south-facing slope despite the uniform soil type on the ridge.

In December 2000, 35 saplings in the doghair thicket and 5 scattered seedlings were numbered, and their height was measured on the uphill side from the base of the trunk to the top of the apical bud using a flexible steel construction tape. The trees were remeasured four times over the next two years. They could be measured accurately to a height of about 375 cm by folding the steel tape back on itself and threading it vertically through the branches, then lowering the still folded tape and recording the height at the fold. The knobcone data were collected incidental to an ultimately unsuccessful Coulter pine (*P. coulteri*) planting project on Chamise Ridge, which used survival rate and annual increase in tree height as the only success criteria; therefore, no other growth data were collected. In late October 2003, a few days before the next site visit, another wildfire burned the site, consuming all new growth as well as the charred remains from the 1993 fire.

Five of the 40 trees lost their numbered tags during the study period or could not be relocated in the dense chaparral. Of the remaining 35 trees, six died during the study period, two of them because their bark was stripped, presumably by rodents. Four additional trees suffered some bark damage by October 2002 and might not have survived much longer. Thus about 30% of the trees were dead or dying within ten years of their establishment. The tallest tree in the area (about 3 m tall in October 2000) had

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**Table 1. Growth of knobcone pine (*Pinus attenuata*) trees near Silverwood Lake in San Bernardino County, California after a 1993 wildfire.**

| | Date (month/day/year) | | | | |
|---|---|---|---|---|---|
| Variable | 12/7/00 | 4/17/01 | 10/16/01 | 4/16/02 | 10/16/02 |
| **Total** (*n* = 29) | | | | | |
| Height (cm) | | | | | |
| Mean ± SD | 200.2 ± 64.9 | 210.9 ± 68.1 | 239.6 ± 72.6 | 245.8 ± 75.3 | 252.0 ± 74.9 |
| Minimum | 66.0 | 66.0 | 78.7 | 78.7 | 81.3 |
| Maximum | 304.8 | 307.3 | 337.8 | 348.0 | 353.1 |
| **Quartile 1** (*n* = 8) | | | | | |
| Mean height (cm) ± SD | 113.0 ± 20.4 | 118.8 ± 22.4 | 141.6 ± 28.2 | 145.1 ± 29.1 | 150.5 ± 30.9 |
| Growth since 2000 (cm) | — | 5.8 | 28.6 | 32.1 | 37.5 |
| % increase since 2000 | — | 5.1 | 25.3 | 28.4 | 33.4 |
| **Quartile 2** (*n* = 7) | | | | | |
| Mean height (cm) ± SD | 189.4 ± 27.0 | 200.7 ± 27.2 | 229.3 ± 31.6 | 233.0 ± 33.9 | 242.8 ± 34.0 |
| Growth since 2000 (cm) | — | 11.3 | 39.9 | 43.6 | 53.4 |
| % increase since 2000 | — | 5.9 | 21.1 | 23.0 | 28.2 |
| **Quartile 3** (*n* = 7) | | | | | |
| Mean height (cm) ± SD | 240.2 ± 5.1 | 251.8 ± 10.1 | 283.0 ± 9.5 | 290.6 ± 8.2 | 296.1 ± 7.5 |
| Growth since 2000 (cm) | — | 11.6 | 42.8 | 50.4 | 55.9 |
| % increase since 2000 | — | 4.8 | 17.8 | 21.0 | 23.3 |
| **Quartile 4** (*n* = 7) | | | | | |
| Mean height (cm) ± SD | 270.7 ± 22.4 | 285.6 ± 18.0 | 318.2 ± 16.2 | 328.8 ± 14.3 | 332.7 ± 15.4 |
| Growth since 2000 (cm) | — | 14.9 | 47.5 | 58.1 | 62.0 |
| % increase since 2000 | — | 5.5 | 17.6 | 21.4 | 22.9 |

**Table 2. Cumulative annual precipitation (cm) from the beginning of the water year near the south shore of Silverwood Lake. Each water year starts on October 1 of the preceding calendar year and continues through September 30 (DWR, unpub. data).**

| **Water Year** | **2000** | **2001** | | | **2002** | | | **2003** |
|---|---|---|---|---|---|---|---|---|
| **Date** | **9/30/00** | **12/7/00** | **4/17/01** | **9/30/01** | **10/16/01** | **4/16/02** | **9/30/02** | **10/23/02** |
| **Current** | 54.7 | 4.0 | 50.2 | 50.8 | 0.0 | 19.3 | 19.3 | N/A |
| **Historical (mean)** | 54.9 | 16.3 | 50.6 | 54.9 | 2.8 | 50.6 | 54.9 | 2.8 |

grown to well over 3.75 m tall by October 2002; it is not included in the data analysis because it was inadvertently excluded in December 2000. Eight of the 29 measured survivors, however, attained heights of 300 cm or more during the study period (Table 1), and several immature seed cones were observed on one of them in October 2002. The smallest surviving tree, on the other hand, only grew from 66 cm to 81 cm during the study period.

The beginning of the 2001 water year (October 1, 2000, to September 30, 2001) was fairly dry; by December, only 4.0 cm of rain had fallen at DWR's weather station, compared to a historical cumulative average of 16.3 cm (Table 2). By April 2001, cumulative precipitation for the water year was near the historical cumulative average; the trees grew an average of 10 cm during that time. Another 0.5 cm of rain fell in mid-May 2001, with hardly any further rain until mid-November, when a storm dropped the first 1.6 cm of the 2002 water year. Surprisingly, the trees grew an average of nearly 29 cm between April and October, despite the summer drought.

The 2002 water year was much drier; by mid-April 2002, the area had received only 19.3 cm of precipitation, a fraction of the historical cumulative average. Nonetheless, the trees grew an average of 6 cm between October 2001 and April 2002. No further measurable rain fell during the remainder of the water year, and between April and October the trees grew only another 6 cm on average, much less than during the preceding summer.

To determine whether the tallest trees skewed the average, the data were analyzed separately for each quartile (Table 1). The tallest quartile had roughly twice the growth rate (cm/y) of the shortest quartile. In terms of percent increase in height since October 2000, however, the smaller trees actually seemed to have a somewhat higher growth rate.

Based on photos of Chamise Ridge taken shortly after the 1993 fire, it seems unlikely that any of the knobcone seedlings and saplings predate the fire. Although it is unknown exactly when the seedlings became established on Chamise Ridge, if we assume that the seeds germinated in fall 1993, the trees' mean annual increase in height would be 28.0 cm/y over a period of nine growing seasons, fairly close to their mean annual increase in height of 25.9 cm/y during the study period. This growth rate is roughly comparable to rates reported for knobcone pines in the Santa Ana Mountains (Vogl 1973) and near San Luis Obispo (Keeley et al. 1999) but less than half that reported for a Mendocino County site receiving an average of 94 cm of rain per year (McCreary 2001).

For the Chamise Ridge stand, the ten-year fire return interval was too short to sustain its continued existence in that only one tree had produced even a few immature seed cones, which take two years to mature, by the end of the ninth growing season; and the fire at the end of the tenth growing season obliterated all signs of the stand. Nonetheless, others have reported that a fire return interval of as little as 14 years does not hamper recovery of knobcone stands (Minnich and Everett 2001), even though knobcone pines in the Santa Ana Mountains typically begin bearing seed cones only between 10 and 12 years of age (Vogl 1973). In other knobcone populations, trees as young as five or six years (Peattie 1950) or even two years (Keeley et al. 1999) may already produce seed cones. Nonetheless, given this species' great tolerance of harsh site conditions, good resistance to disease and insect attack, and rapid growth rate, it may be worth including in revegetation projects on harsh sites in its native range.

### Acknowledgment

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## Rehabilitation of Red Mud Bauxite Wasteland in India (Belgaum, Karnataka)

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Red mud is an insoluble waste material from the production of high-grade aluminum from bauxite. It is a highly alkaline mixture of fine metal oxides, and therefore the deposits of red mud pose number of environmental and health risks. The most common method for its disposal is storage in impounded dike deposits. The ecological rehabilitation of red mud residue deposits is complicated by many factors, including its hazardous nature, extremely high pH and salinity, poor water-holding capacity, and extremely low microbial activity (Krishna et al. 2005). Establishment of vegetation cover has rehabilitated the red mud residue in rare successful cases; however, the nutrient concentrations in vegetation tend to be low, which can be improved to some extent by addition of ameliorants such as gypsum and sewage sludge (Barrow 1982, Wong and Ho 1991). Gypsum is a calcium sulfate ($CaSO_4 \cdot 2H_2O$), and it reduces alkalinity via calcium carbonate ($CaCO_3$) formation and improves the structure of the substrate through the exchange of sodium for calcium, which help reduce pH as the calcium absorbs hydroxide ions. Red mud closely resembles alkali soil in its high pH and exchangeable sodium percentage and the associated physicochemical properties, and hence it is likely to react in a similar way to gypsum. Here, we present a pilot study at the aluminum refineries of Hindustan Aluminum Company Ltd. (HINDALCO), located in Belgaum, Karnataka, in southern India, which generate about 400,000 metric tons of bauxite waste per annum. The goal was to initiate a process of rehabilitation by establishing and sustaining vegetation growth and improving the physicochemical properties of the bauxite residue.

The rehabilitation attempt was preceded by nursery experiments from January to December 2002 involving 13 treatment combinations of soil amendments and inoculants and five tree and four grass or legume species. The selection of tree and grass species was driven by some of their favorable properties such as high tolerance of alkaline and saline soils, relatively fast growth rates, soil-binding properties, and ability to supply biomass to local people in the form of fuel wood and fodder (Sharma et al. 2004). The soil amendments were gypsum, farmyard manure (FYM), and vegetative dry dust in three different proportions. The FYM was used to enrich nutrient supply and to partially make up for the deficiency of zinc, while the vegetative dust, a mixed dry biomass of grasses, herbs, and trees, improved water retention and moisture-holding capacity and also provided micronutrients to the plants.