Limber Pine Forest Mortality Event in Response to a Late-20th-Century Low Precipitation/High Temperature Period

Millar, C.I., Westfall, R.D., and Delany, D.L.
Sierra Nevada Research Center, Pacific Southwest Research Station
USDA Forest Service, Albany, CA, USA

Fig. 2

INTRODUCTION

Limber pine (*Pinus flexilis*) is a wide-ranging, high-elevation conifer of western North America (Fig. 1a). It reaches a range limit along the eastern escarpment of the Sierra Nevada, California (Fig 1b), where it occurs in small, widely disjunct stands confined to decomposed granitic soils and steep, northeastern exposures. Whereas most stands are sparse with scattered slow-growing, relict trees 500-1500 yrs old (Fig 2), a few are closed-canopy, with straight-stemmed, fast-growing trees, mostly <200 yrs old. These stands experienced rapid mortality (>50%) in the late 1980-1990s (Fig. 3) during a low-precipitation period.

Our previous analyses of limber pine in the region revealed major colonization and extirpation events related to centennial-scale droughts during the last 3700 years. To better understand limber pine response, we analyzed 20th-century climate relations associated with growth and mortality in stands that experienced extreme mortality. We report preliminary results and conclusions.

STUDY GOALS

Determine growth rates, ages of live and dead trees, and death dates of dead trees in 3 eastern Sierra fast-growing, closed-canopy limber pine stands where mortality was extreme.

Evaluate relationships of regional 20th-century instrumental climate to annual growth and dates of mortality.

METHODS

Field & Lab

Three disjunct limber pine stands were studied, Deschambeau (DES), Clot Cyn (CLO), and Laurel Cyn (LAU) (Fig. 1b), each of which had visible mortality >50%.

35-74 dead trees and 10 live trees per stand were cored to the pith using standard dendrochronological methods. We report preliminary results from a total of 80 trees, comprising 26 live trees and 54 dead trees from the three stands. Pith (birth) and death dates were determined by cross-dating with standardized local limber pine tree-ring chronologies and annual growth was measured.

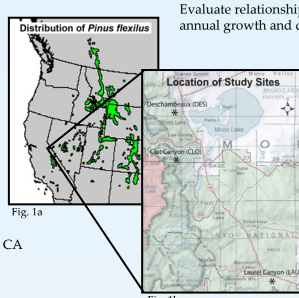


Fig. 1a

Fig. 1b

Fig. 3

Statistical Analyses (SAS, 2004)

Regional instrumental climate records for the 20th century were compiled from Lake Tahoe, Yosemite Valley, and Sacramento, CA (WRCC, 2005), and a composite record was developed following the approach in Millar et al., 2004.

Moving Average Variance Analysis (10-year window; JMP) was conducted on standard deviations of precipitation to assess interannual variability in precipitation.

Lag Correlation Analysis (Mathematica) was performed on annual limber-pine growth in live and dead trees to evaluate growth in any single year relative to precipitation in current and previous years.

Response Surface Analysis (JMP) was run using mean minimum and maximum temperatures, mean precipitation, and annual growth in live and dead trees to evaluate association of growth with climate.

Heterogeneity of variance (PROC AUTOREG) was tested on annual growth in live and dead trees to evaluate changes in variances over time.

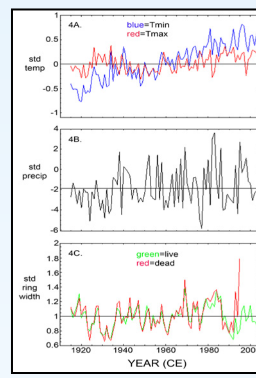


Fig. 4

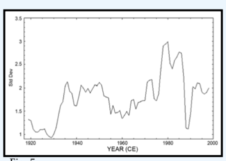


Fig. 5

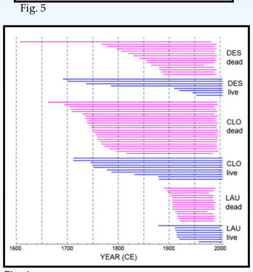


Fig. 6a

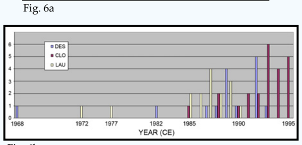


Fig. 6b

RESULTS

20th Century Regional Climate

A composite instrumental record showed increasing mean minimum temperatures over the 20th century, with an average increase of 1.0°C from 1910 to 2005; maximum temperature did not show a trend (Fig. 4a).

Precipitation showed trends in multi-year variability (Fig. 4b). Whereas several years in the late 1970s had the lowest annual precipitation of the century, 1984-1994 was the longest period of sustained below-average precipitation. Another low precipitation period occurred during 1920-1930.

Low variability in precipitation during the late 1980s-early 1990s is apparent in the 10-year-window analysis (Fig. 5). Similar low variability in precipitation occurred during the 1920-1930 period of low mean precipitation. The highest variability in 20th-century precipitation occurred in the early-mid 1980s.

Tree Growth, Death, & Climate Relations

Sampled live and dead trees within stands did not differ significantly in period of establishment, although stand ages did differ (Fig. 6a); Clot Cyn, 200-300 yrs; Deschambeau, 100-250 yrs (a single tree was 400 yrs); and Laurel Cyn, <100 yrs.

Death dates of trees ranged from 1968-1995; all but 4 trees died during 1985-1995 (Fig 6b). Death dates were similar among stands, but earlier at Laurel Cyn. Mortality paralleled low precipitation in this period.

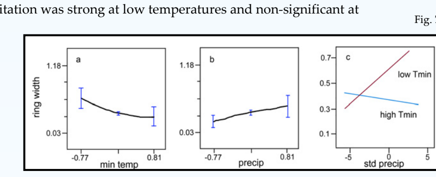
Annual growth was significantly negatively correlated with minimum temperature (r^2= -0.06; p<0.001, Fig. 7a) and positively correlated with precipitation (r^2 = 0.10; p<0.001; Fig. 7b). Decline in growth is observable during low precipitation periods of 1920-1930s and late 1980-early 1990s, and increase in growth occurred in years of high precipitation in the early 1940s and early 1980s (Fig 4c).

The highest correlation between precipitation and growth was the current year; lower correlations occurred with 1, 2, and ~8 yrs prior precipitation. This lag is evident during 1984-1986, when growth remained high despite low precipitation (Fig. 4c).

Interactions of growth were significant for temperature and precipitation. Tree response to changes in precipitation was strong at low temperatures and non-significant at high temperatures (Fig. 7c).

Variances in growth were significantly higher during the 20th century than during the 19th century (p<0.001).

Fig. 7



CONCLUSIONS

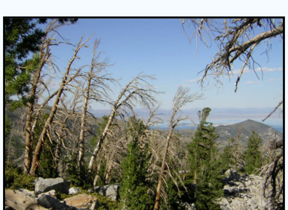
An extreme mortality event occurred during 1985-1995 in young limber pine stands at the species range margin in the eastern Sierra Nevada.

The event coincided with a period of below-average 20th-century precipitation during 1984-1995, and high minimum temperature relative to the early-and mid-20th century.

Limber pine growth during the 20th century in live and dead trees declined during conditions of lower precipitation and increased during conditions of higher precipitation.

Interactions of growth with temperature and precipitation suggest that as temperatures increased through the 20th century, growth not only decreased, but trees were less able to respond resiliently to favorable precipitation periods. This made drought periods more stressful, and mortality more likely. If temperatures continue to increase in the future, mortality events may occur even when drought is not severe.

Periods of high variability in precipitation (oscillating wet/dry), as expressed from the 1980s through late 1990s, appear also to decrease resilience of limber pine.



Clot Canyon site

Laurel Canyon site

REFERENCES

Millar, C.I., Westfall, R.D., Delany, D.L., King, J.C., Graumlich, L.C., 2004. Response of subalpine conifers in the Sierra Nevada, California, U.S.A., to 20th-century warming and decadal climate variability. Arctic, Antarctic, and Alpine Research 36, 181-200.

SAS Institute Inc., 2004. SAS OnlineDoc® 9.1.2.Cary, NC: SAS Institute Inc. JMP Statistics and Graphics Guide, version 5. SAS Institute Inc., Cary, NC.

WRCC (Western Regional Climate Center), 2005. Instrumental weather databases archived at: http://wrcc.dri.edu.