Genecological Responses in Western Conifers to Climate Changes Over the Past Two Millennia[1]

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Vegetation changes in western North American mountains are assumed to shift up and down in elevation in response to climate change. In addition, local populations are assumed to be optimally adapted to their environments. We review these assumptions in light of recent analyses of forest tree responses to climate changes over the past two millennia.

First, we analyzed well-preserved downed deadwood at 3000 m on Whitewing Mountain in the eastern Sierra Nevada. These were dated to 800-1350 CE and comprised whitebark, western white, sugar, Jeffery, and lodgepole pines, and western hemlock, identified by wood anatomical characteristics. Excepting whitebark pine, which is now largely in krummholz form, these species are currently 200 m or more lower in elevation; sugar pine is not locally native and is 600 m lower in elevation. Moreover, the lower elevation limit of whitebark is 100 m above the upper limit of sugar pine. Using the joint overlap of the climate spaces by discriminant analysis and based on downscaled PRISM data for these species, we estimated the climate for the period of sympatry to be warmer (+3.2^{o}C annual minimum temperature) and slightly drier (-24 mm annual precipitation) than present (Millar et al. 2006a); <http://www.fs.fed.us/psw/publications/millar/psw_2006_millar027.pdf>. This was a period of century-long droughts in the region (Stine 1994).

We next examine results from (Rehfeldt et al. 1999), who analyzed growth relationships in 120 lodgepole pine seed sources with the climate at 60 common garden locations in British Columbia, Canada. They found that the fastest-growing seed source at a location was from a warmer location and that growth of most seed sources was greater at a warmer location than the local one. In both cases, the difference between the local population's location and that for maximum growth increased with increasing latitude. This suggests that the populations not only lag current climate changes, but they did not fully adapt to the Little Ice Age climate (Westfall and Millar 2004); <http://www.fs.fed.us/psw/publications/westfall/psw_2004_westfall001.pdf>. However, because temperature changes have increased with increasing latitude, this will decrease the adaptational gradient (Cf. García-Ramos and Rodríguez 2002).

Next, we compared tree-ring growth between living trees with those that died in three eastern Sierran limber pine stands following a persistent drought during the 1980s. Both the mean and GARCH-modeled interannual variance in growth was greater in the dead tress than the living during the 18th and 19th centuries, but mean growth was greater in the living during the 20th

[1] A copy of the powerpoint presented at the 2007 SFTIC/WFGA meeting will be available at the senior author's web site (http://www.fs.fed.us/psw/programs/snrc/staff/westfall/)

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century Moreover, based on a second-order response surface model of station composites of maximum and minimum temperatures and precipitation versus tree ring widths, the dead trees were less responsive than the living to increasing winter precipitation under high minimum temperatures. This the dead trees were less water-use efficient, implying that these populations have undergone adaptation to current climate changes (Millar et al. In press); <http://www.fs.fed.us/psw/publications/millar/pub_limber_pine.pdf>.

Finally, we studied recruitment of limber and bristlecone pines in the White Mountains, in eastern California. Limber pine is recruiting in much greater numbers than bristlecone above current treeline, which is dominated by bristlecone, and about 300 m above current limber pine treeline and about 100 m above the bristlecone treeline. Recruitment peaked during the 1980s and was associated with higher minimum temperatures and a low phase of the Atlantic Multidecadal Oscillation (Millar et al. 2006b); <http://www.fs.fed.us/psw/publications/ millar/posters/millar_etal_poster_agu2006.pdf>. In addition, recruitment was insensitive to minimum temperature under low winter precipitation, but increased with increasing minimum temperature under high precipitation. Additional analyses in correlations of recruitment with the NCEP/NCAR reanalysis 700 hPa data (http://www.cdc.noaa.gov/Correlation/) indicated that recruitment was enhanced by increased precipitation the September prior to the recruitment, a warm, relatively dry June in the current year, and relatively wet late summer, early fall, influenced by monsoonal moisture flow in the current and following two years.

Thus we find that episodic, threshold, and reversible changes are more common responses to late Quaternary climate changes in mountain ecosystems than are linear or gradual changes. These have resulted in non-analogous vegetation assemblages, like those at Whitewing Mt. Because species appear to respond to individualistic tragectories, such responses will complicate conservation planning. An additional complication is that populations will lag genetic (or adaptational) responses to not only current, but to past climatic changes.

Acknowledgements: In addition to the contributions of our coauthors and to the acknowledgements noted in our papers listed below, we give special thanks to Dan Cayan and Mike Dettinger for helpful discussions and assistance with the NCEP/NCAR data.

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