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Reversal of multicentury tree growth improvements and loss of synchrony at mountain tree lines point to changes in key drivers

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Summary

1. Altitudinal tree line ecotones (ATE) are among the most sensitive plant formations facing global warming as the altitudinal decrease in temperature is considered the driver controlling the upper elevation limit of tree lines world-wide. In this study, we attempted to answer the following questions: (i) how have the conditions during the last 2–3 centuries affected ATE tree growth (physiology) and recruitment (demography)? and (ii) how strong is synchrony between these two processes at the ATEs?

2. We used spatial sampling grids at different ATEs in two ecosystems on two subcontinents: *Nothofagus pumilio* in the Andes of Chilean Patagonia (46° SL) and *Pinus albicaulis* in the Rockies of Western Montana, USA (46° NL). Basal increment cores were extracted from trees to estimate the growth and recruitment date. An annual detrended basal area increment was estimated for each tree and was modelled against elevation and time.

3. Tree growth improved over multiple centuries at all tree lines. Recently (*c*. 50 years), however, improvements are disappearing or reversing. The uppermost tree line trees showed moderate declines in Montana and incipient declines in Patagonia. The declines are most dramatic slightly below current tree line (*c*. 200 m). Tree recruitment patterns showed that tree lines have been moving uphill in both regions until at least 40–70 years ago. These movements occurred primarily through abrupt pulses upward with infilling occurring concurrently (Patagonia) or at some time thereafter (Montana).

4. Synchrony between growth and recruitment occurred in the 18th and 19th centuries in both regions. This synchrony was negative in Patagonia and positive in Montana, with varying lag periods. During the 20th century, these patterns of synchrony were lost at all sites. This loss of synchrony suggests that we could be entering a global period in which temperature is no longer the dominant driver of key features of tree lines.

5. *Synthesis*. Our study shows that at two structurally different tree lines, recent and initial declines in growth and losses of long-term synchrony are occurring in the latter part of the 20th century. These findings are opposite to simplistic expectations of global warming effects on tree line dynamics and call for a model reformulation that uncouples drivers of growth and recruitment.

Key-words: altitudinal gradients, Chile, climate change, *Nothofagus pumilio*, Patagonia, *Pinus albicaulis*, plant–climate interactions, tree line ecotone

Introduction

There is extensive evidence that global temperatures have increased during the last century, particularly at high elevation (Díaz & Bradley 1997), with average reported increases of about 0.6 °C (Houghton *et al*. 2001; Jones, Osborn & Briffa 2001; Villalba *et al*. 2003). The ongoing global warming has been described as an important factor altering the range of species and performance, and its population-level effects are thought to be more readily detected or predicted in boundary areas of species distributions (MacArthur 1972; Innes 1991; Loehle 2000; Gamache & Payette 2004; Messaoud, Bergeron

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