ABSTRACT: Boreal Forest Warming at an Ecotone in Danger (B4Warmed) is a manipulative open-air experiment begun in 2009 in northern Minnesota exploring key mechanisms related to terrestrial ecosystem response to future climate warming and precipitation shifts. In doing so it simultaneously addresses the potential for projected climate change to alter tree function, species composition, and ecosystem processes at the boreal-temperate forest ecotone. The experiment includes a total of 72 7.1m² circular plots in two forested sites, in open and closed canopy habitats, and focuses on responses of juveniles of 11 local tree species, the soil community, and related biogeochemical processes. In 2012, we installed and deployed event-based rain exclosures on 18 plots in the open canopy replicates of the warming experiment begun in 2009, to remove approximately 40% of rain events during the summer. The design is thus now an incomplete factorial, with 3 levels of warming x 2 levels of rain x 2 sites (only in open, total of 36 plots) and with 3 levels of warming x 2 sites x 2 habitats (total of 54 plots), with 18 of the 72 plots included in both experimental contrasts. Treatments include three target levels of simultaneous plant and soil warming (ambient, + 1.7 °C, + 3.4 °C) and either ambient or reduced rainfall.

Some patterns for 2012 (and across the 2008-2012 period) were consistent with hypotheses about responses of species co-occurring in southern boreal forest but with contrasting boreal versus temperate distributions. Boreal species, especially conifers, showed negative responses to warming of photosynthesis, survival and growth. Temperate broadleaves (oak and maples) by contrast tended to have neutral or positive photosynthesis, growth and survival responses. Other responses to warming though were similar across species- these included consistent shifts (acclimation) in the temperature response functions of photosynthesis and respiration, as well as an extended phenological growing season due to earlier leaf-out and later leaf-drop. These responses were generally similar across years, rather than being amplified or minimized over time. Current emphasis includes developing generalized temperature acclimation response functions (e.g., for photosynthesis, respiration, and phenology) to incorporate into ecosystem and land surface models, as such processes are currently inadequately addressed in such work.

At the ecosystem scale, we observed that warming (both levels) increased soil respiration in both sites in all years, for example by 18% in 2009, 25% in 2010, 17% in 2011, and 9% in 2012 in the +3.4 °C treatment. Soil CO₂ flux decreased significantly in the rain removal treatments in 2012, but rain removal did not decrease the magnitude of the stimulation of soil CO₂ flux by warming. Additionally, rising temperatures can affect plant performance indirectly by increasing nutrient availability in soil via accelerating microbial activities. To address this issue in isolation, we assayed the growth of three indicator plant species in soils removed from our experimental plots. Biomass was significantly increased in soils from the +3.4 °C warmed soils compared to the ambient plots, providing a clear indication that warming treatment modified soil processes in significant ways. Ongoing assays of soil microbial and microfaunal communities, and of related carbon and nitrogen cycling processes, will provide insights into the mechanisms underlying these belowground responses.