Can Trees Move North? Reproductive Potential of Forest Expansion in the Circumpolar North

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As climate warms, it is anticipated that some species will expand their ranges northwards (and upwards, in alpine ecosystems) as environmental constraints on establishment lessen. Modelling and experimental evidence have shown a time lag between periods of climatic warming and range shifts in treeline, or forest-tundra ecotone, vegetation. One of the leading explanations for this time lag is seed limitation, caused by a low productivity or poor dispersal of seeds. Adverse environmental conditions at the forest-tundra ecotone may limit seed production and dispersal, seed viability, and/or tree growth and survival, thereby limiting forest expansion. Our objective was to measure seed production and viability of the dominant tree species across the circumpolar forest-tundra transition. We hypothesized that the reproductive ability of individuals would be lower at the margin of tree occurrence than within continuous boreal forest. Study sites were established within the forest-tundra transition in northern Canada, Sweden, Norway, and Russia. Cones or catkins were collected from the dominant tree species (black and white spruce, tamarack, balsam fir, mountain birch, Scots pine, and Siberian spruce) in each study site for one to three years from 2007-2009. Germination tests were carried out to determine seed viability. Although the dominant species at each study site differed, the overall patterns in reproduction remained the same: 1) trees in continuous forest produced more seed than individuals in sparsely-treed tundra during the sampling period; and 2) seed production and viability were variable across sampling years. As a consequence, the overall pattern was a reduction in reproductive potential across the forest-tundra ecotone in circumpolar boreal forests. The factors driving the observed gradient in reproductive potential were primarily the change in forest density, and secondarily, variations in seed viability and productivity per tree. For these reasons, spatial gradients in stand density are likely to be a key factor determining seed availability beyond the forest limit. Stand infilling (i.e., increases in density) within the forest-tundra ecotone may thus be an important precursor to the development of sufficient seed inputs to support treeline advance in response to climate. High annual variability in seed production and viability suggests that individual years of high seed production may contribute disproportionately to tree recruitment at the forest-tundra ecotone, making annual variability in climate conditions a key control of treeline movement. Seed availability is not the only factor influencing treeline movement, however. Safe sites for seed germination and establishment are critical for recruitment. Local processes, such as seed predation, herbivory, and fire, may affect the amount of viable seed for dispersal, the survival of seedlings, or the availability seedbeds. In conclusion, our synthesis of data suggests that, where there is sufficient viable seed and optimal seedbed, treeline responses to climate change will be a) initially driven by stand infilling near the forest limit, and b) strongly influenced by stochastic processes of annual variability in climate and seed production.