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Failure to migrate: lack of tree range expansion in response to climate change

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Abstract

Tree species are expected to track warming climate by shifting their ranges to higher latitudes or elevations, but current evidence of latitudinal range shifts for suites of species is largely indirect. In response to global warming, offspring of trees are predicted to have ranges extend beyond adults at leading edges and the opposite relationship at trailing edges. Large-scale forest inventory data provide an opportunity to compare present latitudes of seedlings and adult trees at their range limits. Using the USDA Forest Service's Forest Inventory and Analysis data, we directly compared seedling and tree 5th and 95th percentile latitudes for 92 species in 30 longitudinal bands for 43 334 plots across the eastern United States. We further compared these latitudes with 20th century temperature and precipitation change and functional traits, including seed size and seed spread rate. Results suggest that 58.7% of the tree species examined show the pattern expected for a population undergoing range contraction, rather than expansion, at both northern and southern boundaries. Fewer species show a pattern consistent with a northward shift (20.7%) and fewer still with a southward shift (16.3%). Only 4.3% are consistent with expansion at both range limits. When compared with the 20th century climate changes that have occurred at the range boundaries themselves, there is no consistent evidence that population spread is greatest in areas where climate has changed most; nor are patterns related to seed size or dispersal characteristics. The fact that the majority of seedling extreme latitudes are less than those for adult trees may emphasize the lack of evidence for climate-mediated migration, and should increase concerns for the risks posed by climate change.

Keywords: biogeography, climate change, Forest Inventory and Analysis, latitude, presence/absence, range shift, seedling, tree migration

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Introduction

Anticipating whether or not species range limits can track climate change is a goal of global change research (Clark *et al.*, 2001; Davis & Shaw, 2001; Jackson *et al.*, 2009; Loarie *et al.*, 2009; Dawson *et al.*, 2011). Across the globe, mounting evidence confirms widespread temperature increases, particularly at high northern latitudes (IPCC, 2007). In the eastern United States, mean annual temperatures increased during the 20th century in the Midwest and Northeast, but not in the Southeast, where warming summers were balanced by cooling winters (Fig. 1a). When viewed in terms of a velocity, as has been advocated recently (Loarie *et al.*, 2009), regions in the Northeast and Upper Midwest have seen climate shifts of more than 100 km during the 20th century (Fig. 1b). As the climate warms, new regions that become available for occupation may be colonized as those no longer suitable are abandoned. Inevitable time lags involved in plant dispersal, colonization, establishment, and maturation threaten not only rare species but also many that are abundant and provide vital ecosystem functions and services. Numerous datasets and models suggest a variety of species' responses to changing climate, but robust empirical evaluation remains challenging.

Previous studies generally agree that plants will respond to climate warming by shifting their ranges to higher elevations and latitudes (Hughes, 2000; McCarty, 2001; Walther *et al.*, 2002; Parmesan & Yohe, 2003; Parmesan, 2006; Chen *et al.*, 2011), but only elevation responses are thus far readily apparent in data (Beckage *et al.*, 2008; Holzinger *et al.*, 2008; Kelly & Goulden, 2008; Lenoir *et al.*, 2008; le Roux & McGeoch, 2008; Bergamini *et al.*, 2009; Crimmins *et al.*, 2011; Van Bogaert *et al.*, 2011). The most recent comprehensive meta-analysis by Chen *et al.* (2011) does not include latitudinal range shifts of plants. In fact, studies of plant latitudinal range boundaries rely heavily on models at global (Thomas *et al.*, 2004), continental (Bakkenes *et al.*, 2002; Thuiller *et al.*, 2005; Meier *et al.*, 2011), and

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