Title
Narrowing the estimates of species migration rates

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How fast can species migrate? This continues to be a difficult question to answer, in part due to a gap between answers provided by paleoecology versus modern life history studies (Clark et al. 2004). Paleoecological studies indicate a capacity for rapid migration (but see McLachlan et al. 2005), but inferences are typically made across broad spatial and temporal scales, and for long-lived species such as trees (e.g., Davis 1981). Studies in present-day systems suggest the capacity for rapid migration is much lower, but the short duration of most studies is not ideal for capturing the rare events that might be most important for long-distance dispersal, especially when viewed over the lifetime of a long-lived species (Nathan 2006).

A series of recent papers by Lesser and Jackson combine dendroecological and molecular approaches to quantify the contribution of long-distance dispersal to patterns of population establishment and expansion over the past several hundred years (Lesser and Jackson 2012, 2013). Lesser and Jackson analyzed individual trees within four populations at the range margin of *Pinus ponderosa* in northern Wyoming, USA. All four populations are separated from the main distribution of the species by 15 km to over 100 km and were probably established via dispersal events from the main population. Lesser and Jackson estimated recruitment dates for at least 84% of the total number of individuals in each population by sampling and dating multiple tree cores from each individual (Lesser and Jackson 2012).

Analyzing the pattern of recruitment dates across individuals in each population allowed the authors to estimate population growth rates for each population since establishment. The four populations were established from 1531-1655 cal yr CE. Subsequently, populations followed a logistic growth pattern, but initial growth was probably slower than predicted due to Allee effects in small populations (decreases in fitness caused by small population size). Climate may have also played a role in slowing initial growth, since particularly favorable climates didn't occur until one to two centuries after establishment.

Having reconstructed a detailed population growth framework, the authors then used molecular tools to estimate the contribution of long-distance dispersal to population establishment and growth (Lesser and Jackson 2013). They genotyped each individual and performed parentage analysis, which allowed them to infer the relative contributions of local vs long-distance dispersal across the growth trajectory of each population. Following establishment, the lag time to within-population establishment was 290 to 300 years for two populations, and never occurred for the other two populations. Thus, for over 100 years, population growth occurred via long-distance dispersal alone; even after within-population establishments started to occur, long-distance dispersal continued to significantly contribute to population growth. The authors also found that the population closest to the range edge (15 km) served as an important source for long-distance dispersal into the three more-distant populations.

Lesser and Jackson focus on long-distance dispersal and so don't explicitly translate their data into estimates of population migration, but back-of-the envelope calculations based on their data[1] show that the rate of population spread is between 125–280 m/yr for one population (slightly higher than molecular-based estimates from McLachlan et al. 2005) but between 350–3300 m/yr for the other three populations (more in line with estimates from fossil pollen data). While these estimates are very rough, most rates of population migration are less than 500 m/yr, with one fast outlier.

A nice complement to these estimates comes from a recent paper by Ordonez and Williams (2013), analyzing shifts in the 'core distribu-

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[1] The spread in the estimates comes from calculating the rates of migration based on time of first establishment (faster estimate), time of first population growth, and time of first within-population establishment (slowest estimate). The nearby contiguous population was established by 1500 CE at the latest, so estimates of rates of migration are upper (faster) estimates. Minimum distance from each population to the primary estimated source population was estimated from ImageJ and is thus approximate.

tion' of a species based on fossil pollen data in eastern North America. These analyses of the spread of the core distribution place rates of migration around 170–270 m/yr for the period from 16 kyr BP to 1 kyr BP (Ordonez and Williams 2013). Thus, while substantial uncertainty and variability remains in these estimates, these recent studies both support a middle ground view: rates of migration generally aren't as fast as inferred from some paleoecological studies, but are faster than rates inferred from phylogeography. Given the intermediate time scales of Lesser and Jackson's studies (Lesser and Jackson 2012, 2013) and the increasing sophistication of paleoecological approaches (e.g., Ordonez and Williams 2013), we are on the verge of being able to link rates of dispersal and population growth observed in modern life history studies with those rates of growth and migration observed in paleoecological studies. This is an increasingly important task, given discussions about species capacity for the rapid migration rates needed to respond to future climate change (e.g., Ohlemüller 2011).

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