Climate Change and the Future of Seed Zones

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Abstract: The use of native plants in wildland restoration is critical to the recovery and health of ecosystems. Information from genecological and reciprocal transplant common garden studies can be used to develop seed transfer guidelines and to predict how plants will respond to future climate change. Tools developed from these data, such as universal response functions and trait shift maps, can help managers make informed decisions regarding restoration strategies, such as assisted migration, in the face of climate change.

Keywords: seed transfer guidelines, seed zones, assisted migration, common garden studies

Introduction

The use of native plants in wildland restoration is critical to the recovery and health of ecosystems and to ecosystem resilience in the face of climate change. Seed zones and seed transfer guidelines help ensure that adapted plant material is reintroduced after disturbances, such as fire or grazing, and may be particularly important for the long-term resilience of re-established native plant populations (Ying and Yanchuk 2006; see also Table 1 for a definition of adaptation). Seed transfer guidelines can also help land managers select plant material that is most likely to be adapted to future climates (Thomson and others 2010). Thus, the development of seed transfer guidelines forms an integral piece of the native plant restoration infrastructure.

Table 1. Definitions.

Adaptation: An adaptation is a trait with a functional role in the life history of an organism that is maintained and evolved by means of natural selection. An adaptation refers to both the current state of being adapted and to the dynamic evolutionary process that leads to the adaptation. Adaptations contribute to the fitness and survival of individuals.
Universal Response Function: Combines individual response functions - the expected change in a trait value due to climate differences across a set of seed sources - and individual transfer functions - the expected change in a trait value for a given seed source due to climate differences across a set of possible transfer locations - into a single equation. Universal response functions can be used to model expected changes in trait values for any given seed source due to transfers to new locations or due to changes in climate.

Development of Seed Transfer Guidelines

Information from genecological studies, in which multiple populations are grown in one or a few common gardens, has been successfully used to develop seed zones for a number of tree species (Sorenson 1992, St. Clair and others 2005). Work is now being performed to develop seed zones for native grasses and forbs (Horning and others 2010; Johnson and others 2010). Genecological studies have both benefits and limitations in developing seed transfer guidelines. The primary benefit of genecological studies is that a large number of populations are sampled, such that adaptive differences can be determined across large areas of a species' range. However, because gardens represent only a small portion of the climatic variation experienced by the study populations, interpretation of genecological data must assume that plant populations are adapted to local conditions at their source and that demonstrated differences are due to those adaptations. This is generally a safe assumption for native plant species; however, it may not always be the case.

Seed Transfer Guidelines and Climate Change

Reciprocal transplant studies, where plants from several populations are planted in a set of sites that represent local and non-local climates, are effective at testing whether and how plants from specific populations are adapted to their local environments (Kawecki and Ebert 2004). When sites represent extreme environments, these studies have been used effectively to predict how plants will respond to future climate change as climates shift towards new extremes, particularly in cases with a large number of both populations and garden sites. For example, a long term study on lodgepole pine (*Pinus contorta*) in British Columbia, which tested 140 provenances at 60 sites, used a universal response function (defined in Table 1) to determine expected growth rates under future climate conditions (Wang and others 2010). This study found that growth rates of lodgepole pine were likely to increase in much of the northern range, primarily because marginal habitats in that region would become more hospitable due to warming.

When large reciprocal transplant studies are not feasible, data from genecological studies can be used to estimate the impact of future climate change on seed transfer guidelines. For example, a study on white spruce (*Picea glauca*) in Ontario determined future seed zones under three different climate change scenarios (Thomson and others 2010). Interestingly, this study found that two out of the three climate change scenarios predicted little change from current seed zones, but the third scenario predicted substantial shifts from current seed zones, indicating inherent uncertainty.

We performed a genecological study to determine seed zones for bluebunch wheatgrass (*Pseudoroegneria spicata*) throughout the intermountain west (St. Clair and others in press). As a follow-up study we are developing models to determine how optimal trait values will shift under future climate change scenarios. To do this we use regression models to link population level differences in adaptive traits, determined from common garden data, with the local climates at each source population. These regression models are then used within a geographical information system (GIS) to map expected optimal trait values across the landscape for both current and future climates. For example, we found that optimal heading date values for bluebunch will shift toward both earlier and later dates in 2050, depending on location (Figure 1).

Assisted Migration

Assisted migration is a strategy for helping ecosystems to adapt to climate change by moving species from locations with suboptimal climates to more optimal climates. While this strategy is controversial, due mostly to the possibility of introducing species which subsequently

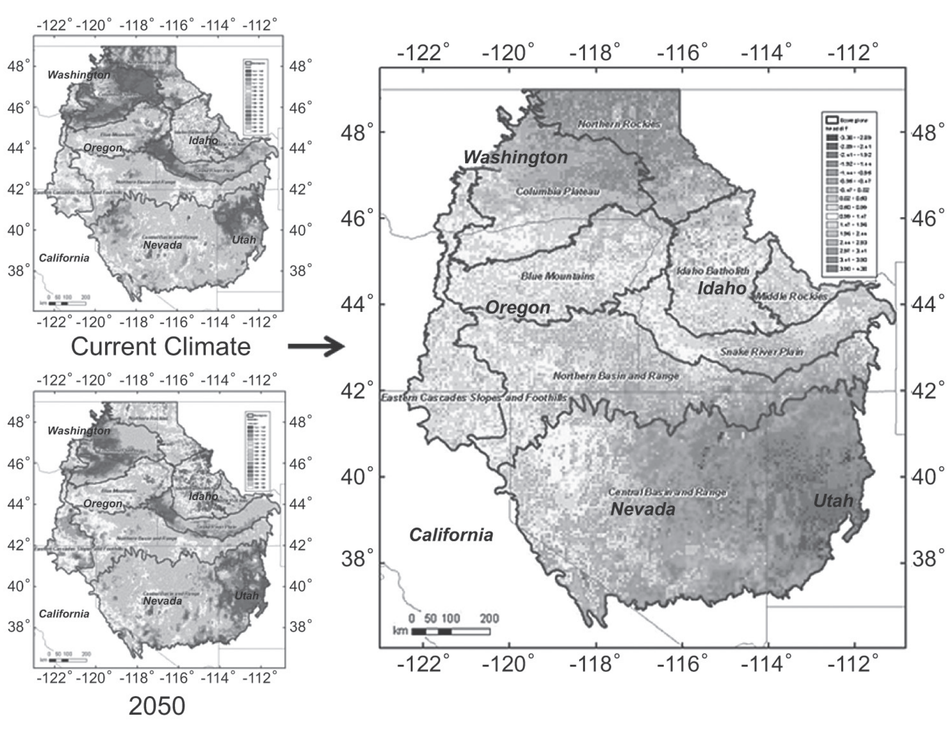

Figure 1. Map of predicted trait values for heading date of bluebunch wheatgrass (*Pseudoroegneria spicata*) in the intermountain west under current and future climate scenarios, and the difference between the maps indicating the expected shift in optimal heading date values under climate change.

become invasive, it may become necessary if climate change continues to accelerate. Estimates of natural species migration rates during past periods of climate change range from 100-400 m (328-1312 ft) per year (Davis and Shaw 2001; Aitken and others 2008). However, current rates of climate change may require migration rates of 3000-5000 m (9843-16404 ft) per year, well beyond the movement capacity of many native species. Species that are long-lived, have low dispersal potential, and/or have low genetic variation will be particularly threatened by this rate of climate change.

Genecological and reciprocal transplant studies can help inform both the necessity and expected efficacy of management decisions related to assisted migration. Trait shift maps such as the one presented in Figure 1 can show areas where current trait values of a species are out of synch with predicted future optimums, which will help determine areas where populations may be at risk of local extinction. Universal response functions can also help determine the expected outcomes of proposed transfers. For example, the British Columbia lodgepole pine study found that using population specific transfer guidelines to move seed to locations with optimal future climates could increase lodgepole pine growth rates beyond the predicted rates if no transfers occurred (Wang and others 2010).

Conclusion

Genecological and reciprocal transplant common garden studies are critical to the development of seed zones and seed transfer guidelines. Current modeling techniques using data from these studies can help determine how seed transfer guidelines will shift due to future climate change and will be particularly useful in making decisions regarding assisted migration. Design of future common garden studies, and the models developed from them, will need to take into account the inherent uncertainty of climate models predicting future change in order to help managers determine the best strategies for future native plant restoration.

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