Project Completion Report
Rocky Mountains Cooperative Ecosystem Studies Unit (RM-CESU)

Project Title: "How Does Disturbance Interact with Climate to Shape Vegetation Patterns in Rocky Mountain National Park?"

Project Code (such as UMT-72 and/or the "P" number): CSURM 261, P12AC10682

Type of Project: Research

Funding Agency: National Park Service

Partner University: Colorado State University

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Start Date of Project: July 1st, 2012

End Date of Project: December 31st, 2014

Funding Amount: $12,000

Project Summary

Climate change is expected to alter species distributions as ranges shift to track favorable temperature and precipitation regimes. Range shifts are already being observed across a wide range of taxa, but many species are not keeping pace with the rate of recent climate warming. This is particularly true for tree species, which often experience significant migration lags due to a variety of non-climatic factors that can hinder range expansion or delay range retreats. Because many other species depend on trees for food or habitat, migration lags in tree species may have cascading impacts on a wide range of taxa that would otherwise face few barriers to migration.

The importance of understanding how climate change will affect tree species distributions prompted several related research questions: 1) What factors contribute to the observed lags in tree species distributions? 2) Can biotic disturbances accelerate climate-driven shifts at the range margins of trees species? 3) How important is climate in determining landscape-scale vegetation patterns? Our research addressed these questions using an integrated approach drawing on exiting literature, field sampling, and statistical models to inform our understanding of potential climate change impacts on the distribution of seven common tree species in Rocky Mountain National Park.

Fieldwork for this project involved resampling 14 ecotone transects located in Rocky Mountain National Park at the range margins of lodgepole pine. These transects were initially established and sampled between 1992-1995 by Dr. Thomas Stohlgren, but had not been resampled since. Many of the transects were subsequently affected by a widespread mountain pine beetle outbreak, presenting a unique opportunity to study the effects of a biotic disturbance on the range margins of common tree species. We focused on understanding how climate change and mountain pine beetle (*Dendroctonus ponderosae*) disturbance interact to affect the range margins of lodgepole pine (*Pinus contorta*). We found that lodgepole pine range margins have shifted very little in Rocky Mountain National Park, despite a warming climate and a widespread disturbance event that reduced competition. We expected that mountain pine beetle disturbance would facilitate recruitment of species better adapted to the current climate, but the impact on patterns of seedling dispersion turned out to be minimal. Individual species may vary in their ability to take advantage of new recruitment opportunities presented by the interaction between insect outbreaks and a warming climate, and fire-adapted species such as lodgepole and ponderosa pine may not respond as strongly to biological disturbances.

The impact of non-climatic constraints on current tree species distributions was also evident at the landscape scale, and climatic variables alone proved insufficient to explain patterns of co-occurrence among tree species. Together, these findings suggest that Rocky Mountain tree species will not uniformly shift upward in elevation as the climate continues to warm. Range shifts will likely be episodic and idiosyncratic, and forecasts based solely on climate data may over-estimate the rate and under-estimate the landscape-scale heterogeneity of potential distribution changes.

This project has resulted in three papers (one published, one in review, one in preparation). It also resulted in a PhD dissertation. We also replaced missing plot markers and constructed new tree maps for all of the transects to ensure that these sites can continue to be used for climate change monitoring in the future.

References:

Renwick, K. M., and M. E. Rocca. 2015. Temporal context affects the observed rate of climate-driven range shifts in tree species. *Global Ecology and Biogeography* 24:44–51.

Renwick, K.M., Rocca, M.E., and Stohlgren, T.J. In Press. Biotic disturbance facilitates range shift at the trailing but not leading edge of lodgepole pine's altitudinal distribution. *Journal of Vegetation Science*

Renwick, K.M., and Rocca, M.E. In Preparation. Assessing the vulnerability of forest plants to climate change using multivariate species distribution models.

Number of students participating in this project:

1 Graduate Student: PhD conferred Dec. 2014

4 Undergraduate Students

Lessons Learned from this project:

Mountain pine beetle disturbance accelerated a range retreat at the lower range margin of lodgepole pine by killing mature trees in areas no longer suitable for recruitment. The upper range margin of lodgepole pine remained stable, with competition from spruce and fir trees limiting the establishment of lodgepole pine. Tree species distributions will not uniformly shift upslope as the climate warms, and non-climatic factors such as biotic processes and disturbance legacies should be incorporated into models that seek to forecast future tree species distributions.

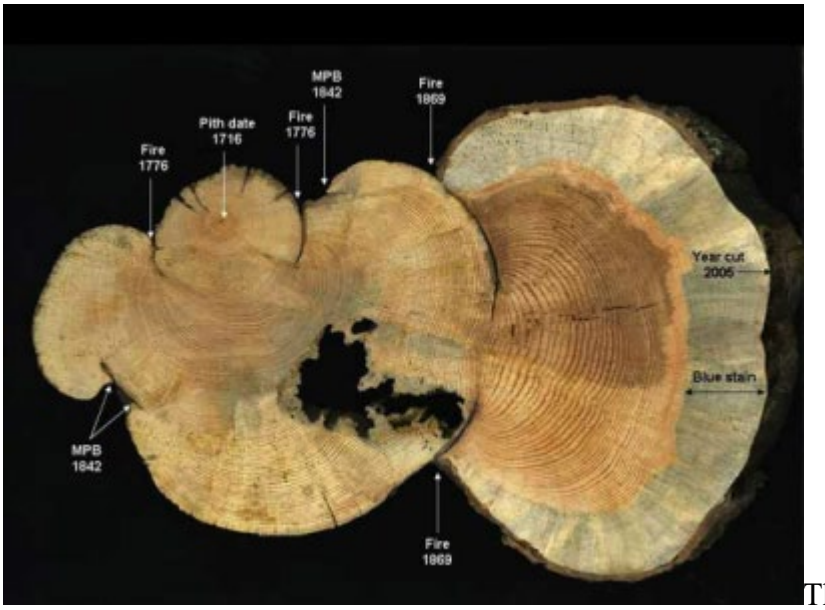
Early Career Climate Forum Brief:

Of trees and beetles: Research at the intersection of climate change and disturbance dynamics

Apr 11, 2016 Katie Renwick, North Central Climate Science Center, Montana State University

Many trees in the Rocky Mountains were alive long before I was born- before my grandparents were born. These trees bore witness to an unprecedented rise in CO_2 concentrations, and have weathered the associated changes in climate. In the past decade, however, many trees that survived two centuries of climate change have been killed by a tiny insect: the mountain pine beetle.

The mountain pine beetle is a native insect roughly the size of a grain of rice. These tiny insects have co-evolved with native pines, and mountain pine beetle outbreaks tend to occur cyclically every few decades. The recent outbreak, however, is the largest ever observed, and part of the reason for this may be related to climate change.



This 290 year old lodgepole pine survived two fires and one previous mountain pine beetle outbreak before being killed by beetles in 2005. The outer rings show the characteristic bluish tint cause by the blue stain fungus that beetles carry. Photo credit: Natural Resources Canada

Rising temperatures can favor the mountain pine beetle in two ways: by inhibiting the defensive mechanism of trees and by increasing overwinter survival of beetles. Trees defend themselves against beetle attacks by producing a sticky substance called pitch, with oozes out of the holes produced by beetles and can block their entry. When a tree is stressed due to drought, however, it cannot produce enough pitch to keep out all of the attacking beetles. Warmer winters also favor the mountain pine beetle because beetle larvae cannot survive particularly cold winters, which usually help to keep their population in check. Increases in beetle outbreaks can be considered an indirect consequence of climate change, and this disturbance is having a far greater impact on forests than the direct effects of climate change alone.

In addition to the large and immediate impact the beetle outbreaks have on forest structure and ecosystem dynamics, this disturbance may also drive a rapid period of species turnover that serves to facilitate climate–driven range shifts. Because trees are long-lived and can tolerate a wide range of climatic conditions, they often persist in areas that are no longer suitable for seedling establishment. Disturbances like fire or insect outbreaks that kill mature trees can usher in a period of rapid change by reducing competition, which allows new species to establish that are better adapted to the current climate.


Measuring seedlings with my PhD advisor, Dr. Monique Rocca, in a lodgepole pine stand where many trees were killed in the mountain pine beetle outbreak.

My dissertation research investigated the potential for mountain pine beetle disturbance to accelerate shifts at the range margins of lodgepole pine (*Pinus contorta*), a species common throughout the intermountain west. With support from the land managers at Rocky Mountain National Park, I was able to re-sample a large number of vegetation transects that were established twenty years ago. Roughly half of these transects had been impacted by the mountain pine beetle outbreak. This allowed me to compare how species composition had changed over a 20-year warm period both with and without disturbance.

We found that lodgepole pine seedling densities were higher at the upper (cooler) range margin, which suggests a moderate climate change response independent of disturbance. At lodgepole pine's lower range margin, changes were much more dramatic. Mountain pine beetle disturbance removed most of the mature lodgepole pine trees, and yet few new lodgepole seedlings were found. Instead, the disturbance was associated with a pulse of new Douglas-fir seedlings. This suggests that the current climate may no longer be suitable for lodgepole pine recruitment. The new Douglas-fir seedlings will eventually grow to replace the mature lodgepole pines that died in the beetle outbreak, perhaps weathering another century of rising temperatures.

More information on the research can be found in two related publications:

Renwick, K.M. & Rocca, M.E. 2015. Temporal context affects the observed rate of climate-driven range shifts in tree species. Global Ecology and Biogeography, 24:44-51.

Renwick, K.M., Rocca, M.E., and Stohlgren, T.J. In Press. Biotic disturbance facilitates range shift at the trailing but not leading edge of lodgepole pine's altitudinal distribution. Journal of Vegetation Science

Katie Renwick is a postdoctoral researcher with the North Central CSC.

A mountain pine beetle (Dendroctonus ponderosae) perched atop a match stick for scale. Photo credit: US Forest Service