CLIMATE CHANGE WINNERS AND LOSERS

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Science is imperfect. It is, after all, a human endeavor. But the *scientific process* confronts biases and aims to correct errors. Science benefits by having assumptions, hypotheses, and related questions explicitly stated and by submitting data-driven manuscripts for peer-review. One of the strengths of the scientific process is the transparency and eagerness many scientists show in pointing out errors of other scientists; dogma and rhetoric are always in the crosshairs of science and competition is strong.

Through the scientific process our understanding of the natural world occurs in spurts. COVID-19 is a good example of the uneven and irregular growth in knowledge and its application (management). Two steps forward, one step back. Three steps forward, one step back. Mistakes in application of science may be made because societal actions are required even when the data necessary to guide such actions are still being collected, analyzed, or their analyses peer reviewed.

The description and explanation for the dynamic distribution of species is one of the longer running scientific explorations. Knowing where different species exist, and why, is the basis of our understanding of the interactions of species in communities and ecosystems and their sustainable management. For instance, the 19th century explorer Alfred Russel Wallace (a Charles Darwin contemporary) described the biogeographical differences between Asian and Australia. The thoroughness of his work encouraged the English biologist Thomas Henry Huxley to coin the term "Wallace Line" to describe the transition zone between these continents. To this day, Wallace's influence on biogeography is introduced to undergraduate students across the world as an example of the world's variability driven by evolution.

Closer to home, species distributions continue to change. Theoretically, competition occurs when multiple species have nearly the same habitat needs within a community. At some point one species will tend to be the winner of the limited "niche space" and become relatively more abundant.

As an example, in a 2009 paper in the journal *Climate Change Biology* scientists used trapping and museum data to document late 20th century distribution changes for small mammal species in Michigan. According to the authors, "Changes consistently reflect increases in species of primarily southern distribution (white-footed mice, eastern chipmunks, southern flying squirrels, common opossums) and declines by northern species (woodland deer mice, southern red-backed voles, woodland jumping mice, least chipmunks, northern flying squirrels)."

Scientific models also offer insights regarding the shifts of species distributions, including tree species. According to the US Forest Service's *Tree Atlas* (www.fs.fed.us/nrs/atlas/tree/) different models considering different levels of CO_2 emissions and temperature and drought factors suggest that our forests in northern Lower Michigan will likely see species shifts in upcoming decades (Table 1). Tree species for which habitat is projected to decrease include trembling and bigtooth aspen (or "popple"), balsam fir, black spruce, paper birch, and jack and red pine. Tree species for which habitat may increase include white and black oak, black cherry, black walnut, shagbark hickory, and American elm.

Follow-up work in 2014 in the journal *Ecosphere* suggested adaptation to climate change may depend on a mix of tree species capable of providing different ecosystem services. More landscape-level tree diversity increases adaptation capability of forests overall. And cooler sites (those closer to the Great Lakes) may be important refugia for tree diversity. Under current conditions, models also suggested landscapes in the northern Lower Michigan may see substantial increases in white pine, northern hardwoods, and some oak species. However, whether or not these species will increase in abundance will be dependent on other factors as well, including seed and seedling mortality due to disease or predation (browse) and other environmental factors that drive seedling establishment and growth.

Private landowners would benefit by thinking ahead for an uncertain future. Most models suggest the future will be warmer and pulses of precipitation different than what we now experience. Diverse forests dominated by native vegetation offer some degree of adaptability for the future. Promoting species better adapted for a warmer climate is possible. Planning and management should focus on retaining plant species diversity in stands or restoring species that are suited to the site but have been extirpated. These restored species should be those that are well positioned for a future climate as described above and elsewhere.

The effects of climate change are often intermingled with land use change, invasive species, deer browse, and landscape fragmentation. Larger, wilder landscapes managed more extensively (but less intensively) within a more ecological context are needed. For more about forests, climate change, about programs for private landowners see the US Forest Service's *Climate Change Resource Center*: www.fs.usda.gov/ccrc/topics/forest-stewardship

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Table 1. Projected climate change "winners" and "losers" based on habitat suitability for a given tree species in neLP. Browsing and other factors that limit reproduction are not considered (from Prasad et al. 2007 and ongoing). Species are listed in decreasing order (i.e., species listed first either are expected to decline or increase more).

Habitat Suitability Decreases	**Habitat Suitability Increases**
Quaking aspen	White oak
Northern white-cedar	Eastern red-cedar
Balsam fir	Black oak
Sugar maple	American elm
Jack pine	Black cherry
Red pine	Silver maple
Paper birch	Black walnut
Black spruce	Shagbark hickory
Bigtooth aspen	Hackberry
Balsam poplar	Slippery elm