Restoring American Chestnut:

HOW ASSISTED MIGRATION IS BEING USED TO [RE]INTRODUCE A KEYSTONE SPECIES UNDER CLIMATE CHANGE

By Pete Clark[1], Tony D'Amato[1], Paul Schaberg[2]

Climate change is expected to alter many aspects of forest ecosystems. Among these changes, tree species ranges are projected to shift northward and upslope in response to warming temperatures and altered precipitation patterns. Unfortunately, natural seed dispersal and plant migration rates dramatically lag behind the pace of climate change.

Figure 1 Example of seedlings established in a one-acre harvest gap in a northern hardwood forest after being planted five years prior. Nine species were planted to test different forms of assisted migration, including assisted population enrichment (PE) and assisted range expansion (RE). Photo by Tony D'Amato.

[1]Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, VT
[2]US Department of Agriculture, Forest Service, Northern Research Station, Burlington, VT

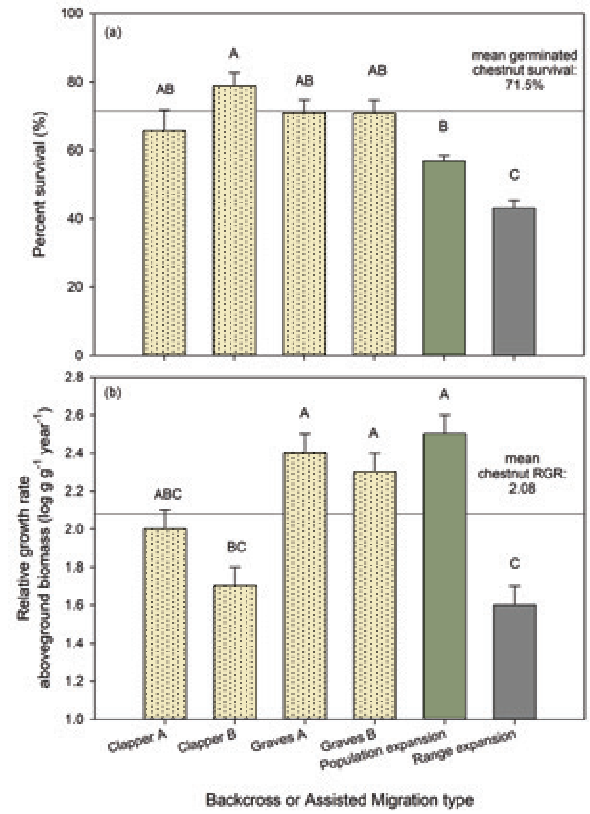
For instance, tree migration rates in the eastern U.S. after the last glaciation were approximately 300-1500 feet per year (100-500 meters). Compared to the rate of climate change, approximately 3-6 miles per year (5-10 kilometers), trees are greatly outpaced in this race. An outcome of losing this race is that by the end of the century, climate may shift so far outside the historic range that forested communities could ultimately become maladapted to new and novel conditions. This is problematic because it will lead to issues with forest health, greater ecological vulnerability, and potentially high levels of mortality with fewer offspring to replace overstory trees in decline.

In anticipation of these changes, various forest adaptation strategies have been proposed, including intentionally modifying species composition via "assisted migration" to incorporate tree species and genotypes expected to be better adapted to future climate regimes. With respect to assisted migration, the devil is in the details. For instance, *assisted population expansion* refers to the movement of species or genotypes over relatively short distances, such that movements occur within a species' historic range and often aim to augment already existing populations at northern latitudes with seed sources from southern seed zones. Pushing the envelope, *assisted range expansion* refers to "modest" movement of species to environments outside of historic ranges, but to areas forecasted to be better suited to track the pace of climate change. This movement is intended to move species to places they would reach if they could only migrate as fast as the climate is changing.

Foresters have a rich legacy of using tree planting to achieve various outcomes, namely for timber production. Historically, the long-term conservation paradigm has been to prioritize locally adapted species and genotypes with only modest movements away from parent seed sources. Considering dramatic changes to many forested landscapes that we have already observed (extreme forest fires, repeated "one-in-a-century" droughts, more invasive pests and pathogens) coupled with the forecasted increases in these events, there is a pressing need to assess how forest adaptation measures that include assisted migration may be used to support forest conservation strategies aimed at meeting diverse cultural and ecological objectives. Among these objectives is to examine how assisted migration may be incorporated into restoration efforts of degraded foundation species, like the American chestnut.

In 2017, a partnership formed between the University of Vermont, Dartmouth College, the U.S. Forest Service Northern Research Station, the Northern Institute of Applied Climate Science, and The American Chestnut Foundation to assess forest adaptation strategies in the northeastern United States. This work was part of an international effort, *Adaptive Silviculture for Climate Change*, and the project by this team involved a 400-acre (161 hectare) "operational scale" experiment in a northern hardwood forest in northern New Hampshire to test various forest management strategies that confer ecological adaptation, termed resistance, resilience, or transition (learn more at adaptivesilviculture.org). This experiment is the largest of its kind in the region, and

Figure 2

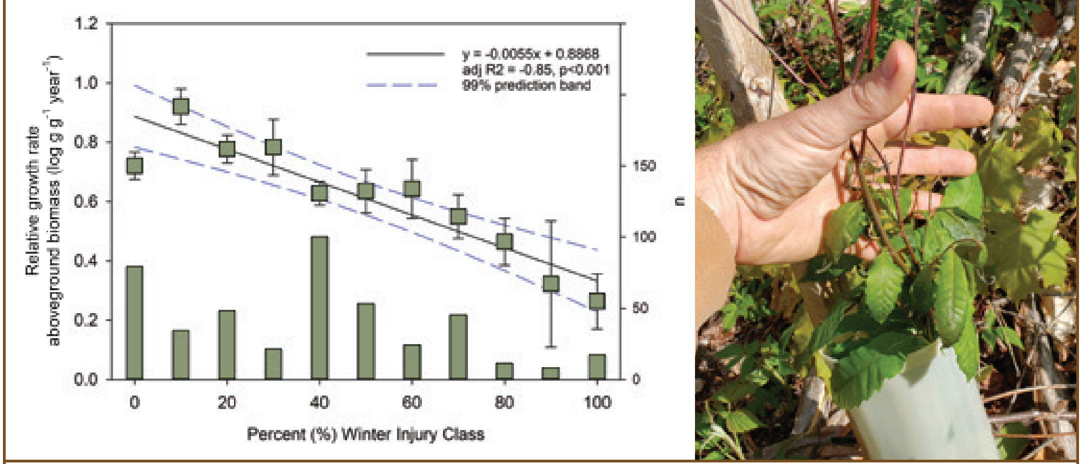


Five-year survival (top) and relative growth rate (bottom) in terms of aboveground biomass of American chestnut seedling backcrosses (Clapper and Graves) relative to other species tested, grouped by assisted migration type (assisted population expansion, assisted range expansion). Species classified as assisted population expansion are northern red oak, red spruce, eastern hemlock, bigtooth aspen, white pine, and black cherry. Those classified as assisted range expansion are bitternut hickory, black birch, and American chestnut (the latter presented separately in the figure). Letters denote groups that are significantly different ($p<0.05$).

the second of now twelve replicate installations in North America that apply a common climate-smart forest management framework across various ecosystems.

To test the efficacy of assisted migration as a tool to adapt and diversify forest species composition, in 2018 our team planted nearly 5,000 seedlings from nine species expected to fare better under a changing climate (**Figure 1**). In addition to selecting species forecasted to increase in abundance under a warming climate, emphasis was placed on planting diverse species that may confer important ecological traits and cultural values for a future forest, not just for future timber value. For example, conifers like red spruce and eastern hemlock were included to help provide a more mesic, deep shade environment; species with nutrient rich seeds such as red oak and bitternut hickory were incorporated to provide future seed sources for wildlife and traditional uses. Other species included black cherry, bigtooth aspen, white pine, black birch, and of course, American chestnut (four families of Clapper and Graves B_3F_3 hybrid backcrosses). Some of these species are locally present on the site but only comprise a small part of the forest. In the assisted migration nomenclature, these species would be examples of assisted population enrichment. Other species, like chestnut, have never been part of these ecosystems but can be found growing within 100 miles (160 kilometers) to the south and are expected to have favorable species habitat in the future. These are considered assisted range expansion plantings.

Figure 3



The effect of percent shoot winter injury (three-year mean) on American chestnut seedlings in terms of relative growth rate in aboveground biomass (boxplots and linear regression) and the number of individuals affected (n; bars). RIGHT: Picture depicting winter shoot injury and associated dieback on an American chestnut seedling. Figure reference: Clark et al. 2022

Being a seedling is no easy task and establishing roots outside of your element can be even harder. Pressures on seedlings from nursery transplant shock, moose browse, competition from other vegetation, or the increasing occurrence of extreme weather events (drought, spring frost) are just a few examples that make the seedling stage a bottleneck for survival. To track performance over a five-year period, our planted seedlings were monitored twice annually to assess various measures of growth, survival, and capacity to grow at or beyond their range limits. Among the many exciting findings from our study was the ability for American chestnut to not only persist but maintain high levels of growth and survival during this critical life stage (**Figure 2**). This is impressive given the parent seed source for chestnuts was nowhere close to being local (more on this below). Remarkably, American chestnut outperformed all other assisted range expansion plantings that we tested and has performed as well as the more locally adapted assisted population enrichment plantings.

Nevertheless, the American chestnut seedlings in our experiment have faced many challenges growing far north of the species' historic range. One of the biggest limitations has been extreme low temperatures which led to frost damage to sensitive shoots (**Figure 3**). This produced considerable die-back on seedlings resulting in more bush-like growth forms and challenging its ability to maintain sustained growth. Still, our results indicate that the species has a strong capacity to tolerate shade from competition and maintain high growth rates, which should give these seedlings an advantage to help shape future forest demography.

There is a growing interest in using tree planting to achieve various benefits for climate change, such as restoration of degraded species and ecosystems, reforesting understocked forests or afforesting non-forest areas to elevate the greenhouse gas and carbon mitigation potential, or adaptively responding to climate change via assisted migration. Despite this interest, the capacity of forest nurseries to supply sufficiently diverse species and seed from climate-adapted seed zones falls seriously short of the need. Nowhere is this problem more apparent than with the American chestnut. While many factors contribute to the lack of seed of availability, there are simply few reproductively viable seed sources left to be relied upon for broadscale chestnut restoration. One of the outcomes of our work was a demonstration that American chestnut has the capacity to be incorporated into northern forests settings, far from the parent seed source. This finding has important implications for species restoration given that these sites may ultimately become more favorable for this species as climate continues to change. Provided they can hang on, these chestnut plantings may become a valuable seed source to help restore this species into the future.

Read the full story and learn more about this research at doi.org/10.1016/j.foreco.2022.120505.

Clark, P. W., A. Freeman, A. D'Amato, P. Schaberg, G. Hawley, K. Evans, C. Woodall. 2022. Restoring a keystone tree species for the future: American chestnut assisted migration plantings in an adaptive silviculture experiment. *Forest Ecology and Management*. 523. doi.org/10.1016/j.foreco.2022.120505