Watching the forest: "sentry" surveys at Hubbard Brook

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Seedlings are the future of the forest. Seedlings are a means both of population recruitment and migration of trees. That is why we have been paying very close attention to the tree seedlings at Hubbard Brook. Some of the patterns that our work has uncovered over the last decade include: 1) American beech regeneration from seedlings (Cleavitt et al 2008); 2) sensitivity of sugar maple seedlings to soil Ca and litter depth (Juice et al. 2006; Cleavitt et al. 2011); 3) critical role of non-growing season factors in sugar maple seedling survival throughout the Hubbard Brook Valley (Cleavitt et al. 2014); and, most recently 4) patterns of colonization by seedlings of two more southerly species, northern red oak (*Quercus rubra*) and eastern white pine (*Pinus strobus*) that were absent from the Hubbard Brook Valley until recently (Cleavitt et al. unpubl.). This research highlight will focus on our "sentry surveys" started in 2011 for these two climate immigrants, northern red oak and eastern white pine.

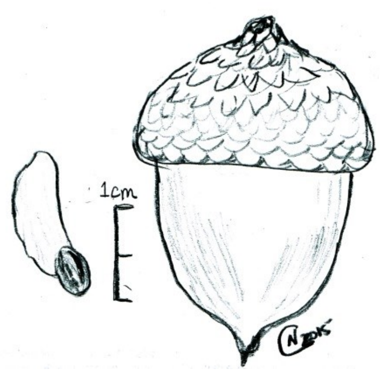

Figure 1. Relative sizes of eastern white pine and northern red oak seeds. Note that the size difference is even more pronounced (that is the resources available to the new seedling) when the "wing" of the pine is not included.

Northern red oak and eastern white pine have occurred at the mouth of the Valley for hundreds of years, but these species are not present as canopy trees beyond the mouth of the Valley. Although both species are predicted to shift northward in response to climate change, their pattern of migration will differ because these trees have contrasting seed sizes and related seed dispersal mechanisms. Pine has a small winged seeds that are wind dispersed while oak has large seeds that are mainly animal dispersed (particularly rodents and blue jays) (**Fig. 1**). This difference is already evident in the distribution pattern of seedlings in the Valley (**Fig. 2**).

While the density of oak and pine in the Valley is greater near the mouth of the Valley in the East (**Fig. 2**), pine seedlings have been found much farther into the Valley than oak. In addition, pine seeds may have come in on logging equipment as the largest subcanopy individuals are at the top and bottom of Watershed 5, and those at the top have matured to cone producing individuals (30 years post-clearcut).

In Hubbard Brook Valley, pine and oak seedlings show a wide range of ages suggestive of ability to persist in the understory conditions for up to 15 years (**Fig. 3**). Two acorn mast years have occurred since we started following oak seedlings, the first in 2010 and the second in 2014, which are evident in the large spikes in seedlings born in 2011 and 2015, respectively.

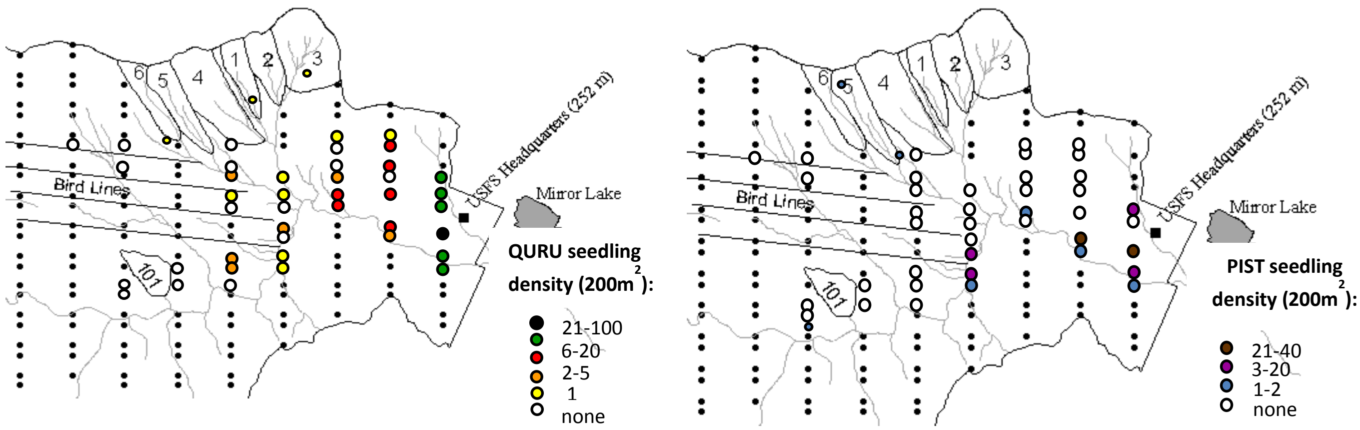

Figure 2. The distribution and density of northern red oak (QURU) and eastern white pine (PIST) in the eastern portion of the Hubbard Brook Valley. There are several white pine seedlings to the west of the area shown here and white pine are more widely distributed in the Valley.

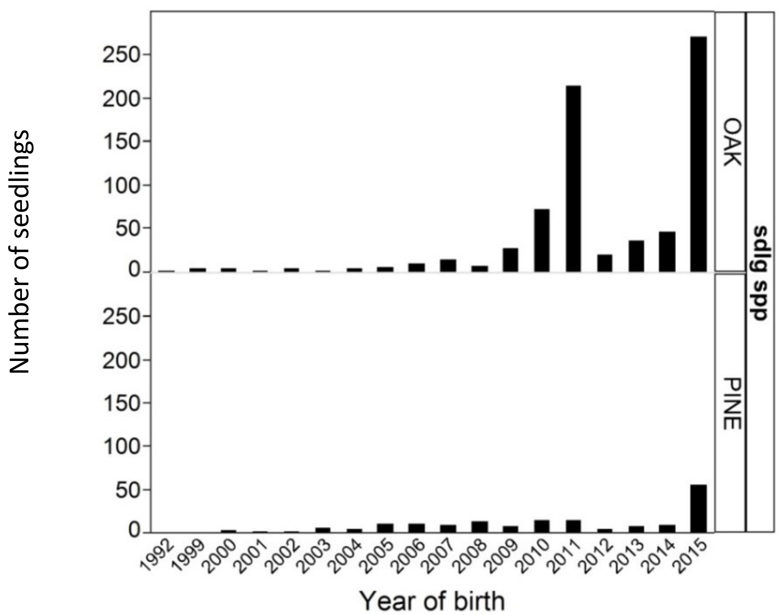

Figure 3. Age distribution of currently marked seedlings at 40 200m^2 plots in the Valley. The 2011 and 2015 mast cohorts for red oak are much clearer than the flatter age distribution for white pine. Both species have seedlings that have survived in the northern hardwood forest understory for 15 or more.

For seedlings born in the 2011 mast year, the survival rate of marked seedlings of oak and pine has been surprisingly high (average of 60%; **Fig. 4**) about twice that of sugar maple seedling survival (average 30%; Cleavitt et al. 2014). Survival has also been 20% higher for seedlings in the more westerly transects (**Fig. 4**), possibly because of their larger initial size (**Fig. 5**) or fewer pathogens. Both differences in initial seedling height and leaf number suggest that larger seeds were dispersed further into the Valley.

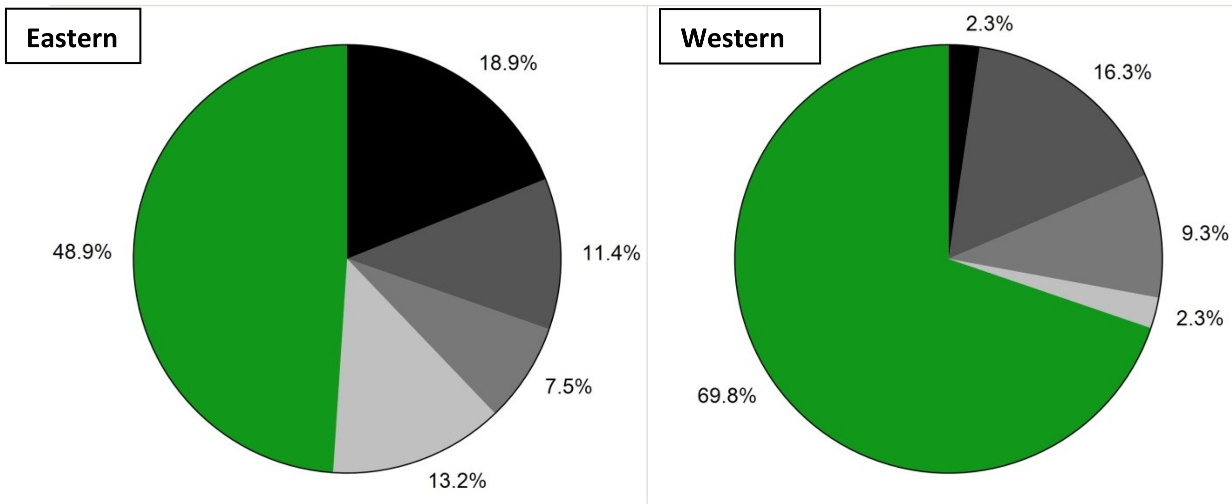

Figure 4. Comparison of survival and mortality (% of all seedling marked) for oak and pine seedlings of the 2011 cohort for the easternmost (closest to adults of the species) and westernmost transects. Green represents the percent of the seedlings marked that remained alive in 2015 and the black and gray represent the percent of seedlings that have died from 2012 (black) to 2015 (lightest gray).

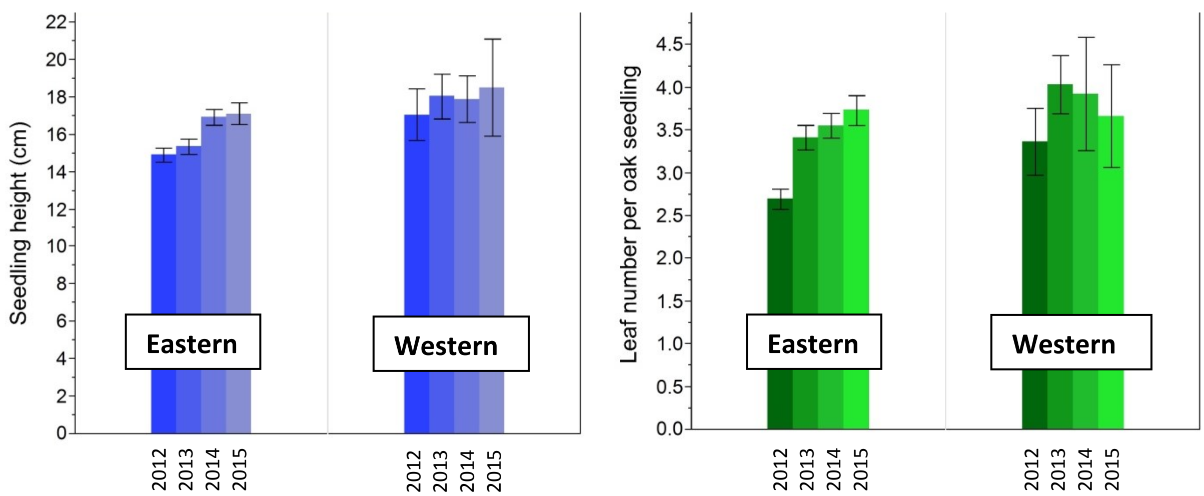

Figure 5. Comparison of seedling height growth (blue bars) and leaf number (green bars) (mean ± 1SE) for 2011 oak cohort for the first four years (2012-2015) growing in the easternmost (closest to adults of the species) and westernmost transects.

Two major factors may be changing the playing field and allowing the immigration of these species: 1) lengthening of the growing season (Richardson et al. 2006) and 2) current and future opening of the canopy (e.g., van Doorn et al. 2011; van Doorn 2014) by a number of factors including: decline of sugar maple (acid rain impacts on soils) and American beech (beech bark disease), legacy of 1998 ice storm (canopy breakage; loss of paper birch), the 2013 microburst, and the impending arrival of hemlock woolly adelgid and the emerald ash borer. There is no denying that the forest is facing a time of accelerated change, but how *much* change will be required to tip the centuries of stalemate for red oak and white pine advancing into the northern hardwood forest? Stay tuned!

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