Reply to the comment on “Long-term decline of sugar maple following forest harvest, Hubbard Brook Experimental Forest, New Hampshire.”

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Reply to the comment on “Long-term decline of sugar maple following forest harvest, Hubbard Brook Experimental Forest, New Hampshire.”

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Abstract

Sugar maple decline in eastern North America is caused by a complex combination of factors with soil nutrition being one of several important determinants. Given the complexity of sugar maple population dynamics and the geographic extent of the species, we support Bailey et al.'s (2018) argument to interpret results from Cleavitt et al. (2018) with due caution. The experiment at Hubbard Brook Experimental Forest represents an atypical application of contemporary forest practice in the White Mountain National Forest. However, some comments in Bailey et al. (2018) missed the point; others inaccurately characterized our paper. Cleavitt et al.'s (2018) 30-year record of vegetation recovery following whole-tree harvest documented a worrisome inability of a sugar maple population that successfully established post-harvest to maintain its position in the understory. This lack of persistence on base-poor soils like those in the mid and upper elevations of Hubbard Brook Experimental Forest suggests that the successful recruitment of sugar maple is not guaranteed.

Key words: forest recovery, northern hardwood forest, whole tree harvest, sustainable management, community assembly
The sustainability of sugar maple (*Acer saccharum*) trees in the forests of eastern North America is a major concern (Horsley et al. 2002). Thus, we acknowledge the comments by Bailey et al. (2018) on our recent efforts to understand sugar maple regeneration following an experimental whole-tree harvest in New Hampshire (Cleavitt et al. 2018). In particular, we agree with their caution about drawing management guidelines from experimental forest manipulations. Several aspects of the whole-tree harvest of Watershed 5 at Hubbard Brook Experimental Forest (HBEF) were indeed atypical in comparison with standard forestry practices in the region. In general, whole-tree harvests result in more biomass removal and greater disturbance intensity than other even-aged management techniques (Ranius et al. 2018). As Bailey et al. (2018) noted, the requirements of the research design using the small watershed approach constrained the implementation of best forest practices. Thus, typical management techniques used to limit soil erosion and nutrient losses were not fully employed in the Watershed 5 experiment. Any assessment of our study for management or policy evaluation should therefore consider the differences between this experiment and current forest practice in the White Mountain National Forest.

However, our detailed 30-year study of vegetation recovery documented a surprising trajectory in sugar maple population dynamics, a trajectory that we believe has both ecological and management implications. Our current understanding of community assembly in northern hardwoods is that long-lived, understory-tolerant species like sugar maple typically get established soon after disturbance and then persist for decades in the understory. When the shorter-lived, understory-intolerant tree species die (e.g., *Prunus pensylvanica*, *Populus* and *Betula* spp), sugar maple ascend to the forest overstory (Botkin et al. 1972, Marks 1974). Thus,
the key bottleneck to sugar maple recovery is establishment immediately post-harvest. Bailey et al. (2018) criticized the lack of information regarding seed supply and light availability in our study, presumably relating these factors to establishment success. However, our data (Fig. 2b in Cleavitt et al. 2018) and associated research (Mou et al. 1993) empirically demonstrated the successful re-establishment of sugar maple following this whole-tree harvest. Furthermore, Mou and Fahey’s (1993) model of regrowth following whole-tree harvest at HBEF, a model that simulated the effects of competition and resource availability, projected a steady increase in the fractional importance of sugar maple over the first 13 years of recovery. Our data support this prediction (Fig 2b) – the decline in sugar maple importance was not apparent until after 1994, 11 years post-harvest. Thus there were enough seeds and light available for sugar maple recruitment immediately post-harvest. The surprising and potentially worrisome aspect of our results was that sugar maple was not able to maintain its position in the understory. Moreover, its displacement was not entirely due to competition with the other understory-tolerant species, American beech (Fagus grandifolia); as we reported, 31% of the 1 x 1 m plots from which sugar maple disappeared during 30 years of stand development were simply unoccupied by any trees in 2014, suggesting that competition from any neighboring beech was weak.

Bailey et al. (2018) argued that the relevance of conclusions drawn from Cleavitt et al. (2018) about sugar maple regeneration was limited because alternative treatments or controls were not included in the study and region-wide issues related to sugar maple regeneration and soil chemistry were ignored (Comment, second paragraph). These criticisms do not accurately characterize our paper. In the Introduction, we not only noted sugar maple regeneration failure in the adjacent uncut reference watershed at HBEF but also provided an overview of sugar maple ecology and management in the region. Furthermore, we explicitly compared vegetation
dynamics after the whole-tree harvest in Watershed 5 to an earlier strip-cutting harvest in the adjacent watershed (Watershed 4). While our conclusions focused on the results from one unique, long-term experiment, we placed these conclusions within the broader context with appropriate care to identify their limitations. For example, Cleavitt et al. (2018) explained in the Discussion that the pre-harvest abundance of sugar maple on the site was anomalously high. We did not suggest, as Bailey et al. (2018) contend (Comment, third paragraph), that the standard for decline was sugar maple recovery to pre-harvest abundance. Rather, it was the lack of sugar maple persistence through time following whole-tree harvest that we defined as indicative of decline.

In retrospect, Cleavitt et al. (2018) could have expanded the review of sugar maple management to include more details on the local perspective. According to the silvicultural guide for New England and New York (Leak et al. 2014), clear cutting and similar even-aged techniques applied to northern hardwood forests are expected to produce adequate sugar maple regeneration. For example, Leak et al. (2014) reported an equal abundance of beech and sugar maple (11% of relative basal area, Table 12) in a 25-year old clear-cut at Bartlett Experimental Forest (BEF), a research forest in the White Mountain National Forest near HBEF (38 km northeast). Earlier research at BEF found that any sufficiently intense logging disturbances (e.g., selection and patch cutting) should promote sugar maple regeneration more than beech (Leak and Wilson 1958, Leak 2005). Nevertheless this additional context reinforces our central contention that the results from the whole-tree harvest experiment run counter to expectations.

We concur with Bailey et al. (2018) that the evidence for soil calcium (Ca) depletion being a result of forest harvest on Watershed 5 is not conclusive. Cleavitt et al. (2018) did not claim to have established a cause and effect relationship between sugar maple regeneration
failure and soil Ca status. Our observations, as we explained in the Discussion of our paper, relied on correlations between sugar maple persistence and Ca supply. The further discussions offered in their Comment on this point constructively add to the debate on the drivers of sugar maple regeneration and point towards the need for further studies on this subject.

Clearly sugar maple decline is caused by a complex combination of factors, with Ca supply being one of several important determinants (Leak et al. 1987, Horsley et al. 2002, Bannon et al. 2015). Given the complexity of sugar maple population dynamics, we agree with the admonition in Bailey et al. (2018) to interpret the results from Cleavitt et al. (2018) with due caution. But our 30-year record of forest recovery following whole-tree harvest does suggest that on base-poor soils like those in the mid and upper elevations of HBEF, even if sugar maple is abundant in the regeneration layer post-harvest, the successful recruitment of sugar maple is not guaranteed. In this regard, we echo Horsley et al.'s (2002) recommendation to managers that they "can take positive steps to maintain the health of sugar maple by choosing appropriate sites for its culture, monitoring stress events, and examining soil nutrition."
Literature Cited


