SPECIAL SESSION: Northern Hardwoods Silviculture Experiment to Enhance Diversity (NH-SEED)

Introducing the NH-SEED: A Holistic Experiment to Revisit Classical and Test Novel Silvicultural Systems in a Changing World

Christopher R. Webster, Yvette L. Dickinson, and Robert E. Froese[1]

Abstract.—Forest stewards aim to ensure forest sustainability through the application of the best available science. However, current silvicultural guidelines were developed under historical social, economic, and ecological conditions. When applied under novel conditions, these guidelines may have unpredictable or undesirable outcomes. Furthermore, silviculturists increasingly aim to manage ecosystems as complex adaptive systems, which requires a holistic understanding of ecosystem processes and functions. We established the Northern Hardwood Silviculture Experiment (NH-SEED) to develop alternative silvicultural systems for the management of Great Lakes northern hardwoods through identifying critical, process-limiting dynamics. This before-after, control-impact experiment uses a replicated split-plot design to investigate the influence of harvest intensity, site preparation, deer exclusion, and direct seeding. We are assessing: (1) logging productivity and impacts, (2) stand composition, structure and development, (3) financial returns, (4) understory plant community dynamics, (5) changes in wildlife populations, and (6) social impacts in response to the experimental treatments.

INTRODUCTION

Forest stewards aim to "ensure the continued health, integrity, and use of forests to benefit society in perpetuity" through the use of "our knowledge, skills and conservation ethic" (SAF 2000). This requires the application of the best available science to resolve ecological, social, and economic challenges. Nevertheless, while current silvicultural recommendations may represent the best available science, the outcomes of disturbances, such as silvicultural treatments, are influenced by ecological memories of initial or historical states (Johnstone et al. 2016, Webster et al. 2018), which were formed under often different social, economic, and ecological conditions than exist today and into the future. Therefore, when applied under novel conditions they may result in unpredictable, or worse still, undesirable outcomes. For example, many of the pre-existing, long-term, silvicultural studies initially focused on the issues that were important at the time, primarily wood production, quality development, and regeneration (Lugo et al. 2006). In the maple-beech-birch (*Acer-Fagus-Betula*) dominated northern hardwoods of North America, silvicultural research began in 1923 with the establishment of the Dukes Experimental Forest (Kern et al. 2014), and work undertaken by Eyre and Zillgitt (1953). In spite of applying the best available science at the time (Arbogast 1957), a potential negative result for biodiversity and forest resilience in the face of climate change (Elmqvist et al. 2003, Mori et al. 2013) has been "maple-ization" of northern hardwood stands over time (Angers et al. 2005, Crow et al. 2002, Doyon et al. 2005, Neuendorff et al. 2007, Schulte et al. 2007).

[1] Professor of Quantitative Ecology (CRW), College of Forest Resources and Environmental Science, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931; Silvicultural Scientist (YLD), Scion (New Zealand Forest Research Institute Ltd), Rotorua, New Zealand; and Professor of Biometrics (REF), College of Forest Resources and Environmental Science, Michigan Technological University, Houghton, MI 49931. CRW is corresponding author: to contact, call 906-487-3618 or email cwebster@mtu.edu.

In light of these challenges, we established a novel, long-term silvicultural study at Michigan Technological University's Ford Forest in the Upper Peninsula of Michigan. The overall goal of the Northern Hardwood Silviculture Experiment to Enhance Diversity (NH-SEED) is "to develop a sustainable plant production system for the production of timber from northern hardwood forests in the north central region which maintains a diversity of tree species for timber production, wildlife habitat, and ecological resilience" through identifying critical, process-limiting dynamics and potential management solutions. The experiment uses a before-after, control-impact (BACI) design, with a replicated split-plot design to investigate potential impacts of light limitation, seedbed limitations, deer browse, and seed limitation on diversity of forest regeneration and recruitment through the application of gradients of harvest intensity, site preparation, deer exclusion, and direct seeding. In addition, this experimental design provides opportunities for a variety of research topics that together provide a holistic framework for investigation including: (1) logging productivity and impacts, (2) stand composition, structure, and development, (3) financial returns, (4) understory plant community dynamics, (5) changes in wildlife assemblages and population viability of vulnerable wildlife populations, and (6) landowner willingness to implement the various silvicultural treatments.

Specific outcomes from each of these research topics are addressed separately by presenters in this organized session, with an extended abstract or manuscript for each.

DESIGN AND IMPLEMENTATION OF NH-SEED

Study Site

NH-SEED occupies 111 acres within Michigan Technological University's Ford Forest near Alberta, MI. At the time of European settlement, this area of the Ford Forest was dominated by sugar maple (*Acer saccharum*)/yellow birch (*Betula alleghaniensis*) forest; however, harvesting shortly after European settlement removed many large white pines (*Pinus strobus*), with scattered remnant well decayed stumps still present. In the mid-20th century, the forest was managed by Ford Motor Company primarily for hardwood timber. Since the 1950s, the forest has been managed by Michigan Technological University and is utilized for research and teaching. The NH-SEED site has been actively managed during Michigan Technological University's tenure using single-tree selection on a 10- to 15-year cutting cycle, until the establishment of the experiment in 2017.

The topography is rolling, and the mesic, moderately rich soils are dominated by well drained Champion cobbly silt loams with inclusions of poorly drained very stony Witbeck, and Carbondale and Tacoosh mucks (NRCS 2019). The habitat type is *Acer saccharum-Tsuga canadensis/Dryopteris spinulosa* (ATD), with a predominantly windthrow disturbance regime and relatively long return intervals (Burger and Kotar 2003). Prior to establishing the experiment, the stand had a basal area of 86.1 ft^2/acre, of which 68.6 ft^2/acre was sugar maple. The stand was fully stocked with a stand density index of 158, relative density of 93 percent (Tubbs 1977), and a broadly reversed-J size-class distribution, with few trees larger than 22 inches.

Experimental Design

Foundational work to establish NH-SEED began in mid 2015, with the initial pretreatment vegetation data collected during 2016. The experiment uses a replicated split-plot design, with every combination of levels within four factors represented in three replicate blocks. While laying out the experiment, efforts were made to ensure each replicate block was contiguous and as homogeneous as possible, using topographic breaks and roads as boundaries wherever possible.

Each of the three replicate blocks is divided into six silvicultural systems (six levels): clearcut (CC), single-tree selection (STS), shelterwood with high canopy cover (SW-H), shelterwood with low canopy cover (SW-L), irregular shelterwood with high canopy cover (ISW-H), and irregular shelterwood with low canopy cover (ISW-L). Each silvicultural system treatment unit occupies approximately 6 acres. The STS silvicultural system represents the business-as-usual approach and is therefore considered to be a control treatment for this factor. Three levels of site preparation are applied to each of the six silvicultural systems, including: untreated control, scarification, and artificial tip-up mounds. Each site preparation treatment unit occupies approximately 2 acres. Further, each site preparation treatment includes a deer exclosure (two levels, i.e., inside and outside exclosure), with seed addition plots both inside and outside the exclosure (two levels, i.e., with and without seed addition). Each deer exclosure was 400 ft^2, and each seed addition plot was 200 ft^2. In total there are 72 factorial treatment combinations represented on each of the three replicates.

The silvicultural systems included in the experiment encompass a wide gradient of management approaches. The CC silvicultural system removed all trees >4.5 feet tall in a single harvest with an estimated rotation length of 120 years. In contrast, STS silvicultural system aims to regularly harvest a sustainable volume on a 15-year cycle by maintaining a reverse-J shaped size class distribution using regulation with 75 ft^2/acre basal area in trees ≥5 inches d.b.h., Q-factor of 1.3 and maximum diameter at breast height (d.b.h.) of 20 inches. Both SW-H and SW-L aim to regenerate the stand through two harvests. The first harvest removes small trees to release growing resources and promote the establishment of regeneration. SW-H aimed to leave 60 percent residual canopy cover by removing all trees less than 10 inches. In contrast, SW-L aimed to leave just 30 percent canopy cover by removing all trees less than 14 inches. The second harvest is planned for approximately 2024 and will remove the remaining overstory of predominantly large diameter trees to promote the growth of the established regeneration. Currently, the shelterwood (SW-H and SW-L) and irregular shelterwood (ISW-H and ISW-L) silvicultural systems are identical; however, the overstory will not be removed in the irregular shelterwoods resulting in a two-aged stand for an extended period. The silvicultural systems were established with an initial commercial harvest during February and March 2017. All harvesting aimed to remove sugar maple, while preferentially retaining minor species. Furthermore, all conifers were retained.

This harvest was followed up by a silvicultural cleaning to remove all nonmerchantable small diameter trees (>4.5 ft tall and <4 inches d.b.h.) from all shelterwood, irregular shelterwood, and clearcut treatment units in August 2017. In contrast, these small trees were not removed from STS as they are intended as advance regeneration and their presence is fundamental to this management approach.

The artificial tip-up mound site preparation treatment was applied during the initial commercial harvest. Approximately 30 trees/acre were designated to be tipped-up while harvested by wrenching the tree from the ground with the mechanical felling head before cutting the trunk into logs. While we originally aimed to tip up the largest harvested trees, concern for damaging machines that are not designed for such use compelled us to target somewhat smaller diameter trees. Post-harvest inventory indicated that on average 34 mounds/acre (± 1.9, 1 SE) were created, with a mean mound width of 53.9 inches (± 3.8, 1 SE), and pit depth of 5.7 inches (± 1.1, 1 SE) and width of 59.3 inches (± 4.3, 1 SE). The scarification treatment was applied using a small dozer with salmon blade in October 2017, with the aim of disturbing the soil surface and removing competition vegetation on approximately 50 percent of the treatment unit. Fifty-four deer exclosures were erected during the summer of 2017 and spring 2018. Finally, a mix of native tree seeds were broadcast seeded on subplots between June and November of 2018, according to the natural dispersal timing of each species. Seed was added at the prescribed rate suggested by silvicultural recommendations if available, or at the high end of natural dispersal rates reported in the literature.

CONCLUSION

Modern, long-term silvicultural experiments are necessary to understand how silvicultural systems applied within the context of current forest and environmental conditions affect ecological, social, and economic outcomes and processes through time. While this experiment has and continues to yield important insights, the greatest value of this study likely rests on subsequent inquires that leverage its solid conceptual and experimental foundation.

ACKNOWLEDGMENTS

This project would not have been possible without the valuable contributions of the following individuals: Claudia Bartlick, Jim Schmierer, Matt Kelly, Curtis Edson, Tara Bal, Kristen Bretzski, Joesph Bump, Amy Schrank, Jared Wolfe, Amber Oja, Stefan Hupperts, Alexander Helman, Rafia Rahman, and numerous undergraduate field assistants. The following organizations assisted with various aspects of treatment implementation: Michigan Technological University's Ford Forest, the College of Forest Resources and Environmental Science at Michigan Tech University, J.M. Longyear LLC, and the USDA Forest Service. Funding for this project was provided by a grant from the USDA National Institute of Food and Agriculture AFRI program (grant no. 2017-67013-26261, project accession no. 1011796).

LITERATURE CITED

Angers, V.A.; Messier, C.; Beaudet, M.; Leduc, A. 2005. **Comparing composition and structure in old-growth and harvested (selection and diameter-limit cuts) northern hardwood stands in Quebec.** Forest Ecology and Management. 217(2-3): 275–293. https://doi.org/10.1016/j.foreco.2005.06.008.

Arbogast, C. 1957. **Marking guides for northern hardwoods under the selection system.** Stn. Pap. 56. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 20 p.

Burger, T.L.; Kotar, J. 2003. **A guide to forest communities and habitat types of Michigan.** Madison, WI: University of Wisconsin--Madison, Department of Forest Ecology and Management.

Crow, T.R.; Buckley, D.S.; Nauertz, E.A.; Zasada, J.C. 2002. **Effects of management on the composition and structure of northern hardwood forests in Upper Michigan.** Forest Science. 48: 129–145.

Doyon, F.; Gagnon, D.; Giroux, J.F. 2005. **Effects of strip and single-tree selection cutting on birds and their habitat in a southwestern Quebec northern hardwood forest.** Forest Ecology and Management. 209(1-2): 101–116. https://doi.org/10.1016/j.foreco.2005.01.005.

Elmqvist, T.; Folke, C.; Nystrom, M.; Peterson, G.; Bengtsson, J.; Walker, B.; Norberg, J. 2003. **Response diversity, ecosystem change, and resilience.** Frontiers in Ecology and the Environment. 1(9): 488–494. https://doi.org/10.1890/1540-9295(2003)001[0488:rdecar]2.0.co;2.

Eyre, F.H.; Zillgitt, W.M. 1953. **Partial cuttings in northern hardwoods of the Lake States: twenty-year experimental results.** Tech. Bull. LS-1076. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. 124 p.

Johnstone, J.F.; Allen, C.D.; Franklin, J.F.; Frelich, L.E. Harvey, B.J. [et al.]. 2016. **Changing disturbance regimes, ecological memory, and forest resilience.** Frontiers in Ecology and the Environment. 14(7): 369–378. https://doi.org/10.1002/fee.1311.

Kern, C.; Erdmann, G.; Kenefic, L.; Palik, B.; Strong, T. 2014. **Development of the selection system in northern hardwood forests of the Lake States: an 80-year silviculture research legacy.** In: Hayes, D.C. [et al.], eds. USDA Forest Service experimental forests and ranges. New York, NY: Springer: 201–223.

Lugo, A.E.; Swanson, F.J.; González, O.R.; Adams, M.B.; Palik, B. [et al.]. 2006. **Long-term research at the USDA Forest Service's experimental forests and ranges.** BioScience. 56(1): 39–48. 3568(2006)056[0039:LRATUF]2.0.CO;2.

Mori, A.S.; Furukawa, T.; Sasaki, T. 2013. **Response diversity determines the resilience of ecosystems to environmental change.** Biological Reviews. 88(2): 349–364. https://doi.org/10.1111/brv.12004.

Neuendorff, J.K.; Nagel, L.M.; Webster, C.R.; Janowiak, M.K. 2007. **Stand structure and composition in a northern hardwood forest after 40 years of single-tree selection.** Northern Journal of Applied Forestry. 24(3): 197–202. https://doi.org/10.1093/njaf/24.3.197.

Schulte, L.A.; Mladenoff, D.J.; Crow, T.R.; Merrick, L.C.; Cleland, D.T. 2007. **Homogenization of northern U.S. Great Lakes forests due to land use.** Landscape Ecology. 22(7): 1089–1103. https://doi.org/10.1007/s10980-007-9095-5.

Society of American Foresters [SAF]. 2000. **SAF code of ethics.** https://www.eforester.org/SESAF/CodeofEthics.aspx (accessed January 14, 2020).

Natural Resources Conservation Service [NRCS]. 2019. **Web soil survey.** Washington, DC: U.S Department of Agriculture, Natural Resources Conservation Service, Soil Survey Staff. https://websoilsurvey.sc.egov.usda.gov/ (accessed May 27, 2021).

Tubbs, C.H. 1977. **Manager's handbook for northern hardwoods in the north-central states.** Gen. Tech. Rep. NC-39. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 29 p.

Webster, C.R.; Dickinson, Y.L.; Burton, J.I.; Frelich, L.E.; Jenkins, M.A. [et al.]. 2018. **Promoting and maintaining diversity in contemporary hardwood forests: confronting contemporary drivers of change and the loss of ecological memory.** Forest Ecology and Management. 421: 98–108. https://doi.org/10.1016/j.foreco.2018.01.010.

CITATION: Webster, Christopher R.; Dickinson, Yvette L.; Froese, Robert E. 2023. **Introducing the NH-SEED: A Holistic Experiment to Revisit Classical and Test Novel Silvicultural Systems in a Changing World.** In: Kern, Christel C.; Dickinson, Yvette L., eds. Proceedings of the first biennial Northern Hardwood Conference 2021: Bridging science and management for the future. Gen. Tech. Rep. NRS-P-211. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station: 131–135. https://doi.org/10.2737/NRS-GTR-P-211-paper27.