Family Forest Network

Ecological Forestry Pilot Project

Technical Note #4

Harvest Prescription Protocols

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Project Overview

Under the general guidance of ecological forestry recommendations contained in *An Independent Review of Forest Practices in Nova Scotia* (Lahey 2018), the Family Forest Network (FFN) is working with partners, landowners, and contractors to plan and conduct a series of harvest and silviculture treatments on small private woodlands across Nova Scotia. The objective of these treatments is to demonstrate and document the costs and benefits of implementing ecologically sensitive management on small private woodlands across a wide range of forest conditions. Results will be used to refine or develop management guidelines and tools, and to inform provincial policies related to silviculture funding. For the purposes of this project, ecological forestry aims to:

Manage forests in a manner that promotes the development and/or restoration of stands to climax vegetation types appropriate to local landscape, ecosite, and soil conditions, and with consideration of climate change adaptation needs and objectives.

Earlier Technical Notes in the series outlined (i) how target vegetation types (VTs) were selected, (ii) the protocols for trial site selection and follow up surveys, and (iii) details on pre-treatment data collection forms developed for this project (Appendix 3). This Technical Note outlines the approach taken to develop harvest treatment prescriptions.

Harvest Prescriptions

As a starting point for developing harvest prescriptions, ecological classification and mapping of sites is undertaken based on detailed pre-treatment assessment (Keys et al. 2023; Neily et al. 2023) and protocols developed for delineating ecological planning units (EPUs) on the ground (see Appendix 1 for more details). Pre-treatment assessments also provide information on biodiversity features that can be integrated into harvest prescriptions. This allows for site-specific, ecologically sensitive harvest planning at a scale appropriate for woodlot management.

From here, a baseline prescription is generated using the *Nova Scotia Silvicultural Guide for the Ecological Matrix* (SGEM) (McGrath et al. 2021). The SGEM was developed to aid ecological forestry planning on Nova Scotia Crown land (outside of designated protected and high production forest areas) and provides a consistent framework for harvest plan development. This baseline prescription is then reviewed by FFN forest professionals and adjusted as needed to accommodate site-specific objectives related to natural disturbance regime adaptation, climate change adaptation, restoration and biodiversity objectives, and soil health objectives. Details on each of these topics is provided below.

Natural Disturbance Regime Adaptation

A fundamental component of ecological forestry is integrating natural disturbance regimes (NDRs) into management decision-making. This recognizes that forest ecosystems have evolved and adapted over time to dominant natural disturbance patterns (type/severity/frequency), so that emulating these NDRs is the best way to maintain ecosystem function and biodiversity when conducting forest management activities (Kuuluvainen et al. 2021). In Nova Scotia, dominant NDRs affecting forest ecosystems are fire, wind/hurricanes, and spruce budworm (Taylor et al. 2020). However, these NDRs have variable impacts and do not affect all forest types and/or geographic regions in the same way.

In a recent analysis of NDRs and related forest management in Nova Scotia, MacLean et al. (2022) suggested that stand-level age class distribution would typically be all-aged for Tolerant Hardwood, Tolerant Mixedwood, and Tolerant Softwood vegetation types; and multi-aged (with some trees surviving disturbance) for Spruce-Pine vegetation types.[1] In addition, the percentage of area "killed" after disturbance events would typically be 100% Low for Tolerant Hardwood and Tolerant Mixedwood, 50% Low and 50% Moderate for Tolerant Softwood, and 60% Moderate and 40% High for Spruce-Pine vegetation types.[2] These results can be used to guide harvest intensity levels for different vegetation and site types included in the FFN project.

Emulation of NDRs using the area and mortality (harvest intensity) percentages above is most appropriately applied to late-successional (climax) vegetation types. However, many sites included in the FFN project will have early or mid-successional forest cover dominated by red maple, white birch, aspen, and/or balsam fir. Since the goal is to promote development of site-appropriate climax vegetation types, this may require adjustments to initial harvest levels to facilitate this transition. For example, stands currently with high balsam fir cover on a site that would normally support Tolerant Mixedwood would typically see this fir die-out over a short period of time due to insects (e.g., spruce budworm or tussock moth) or natural senescence. In this case, a larger removal of fir (i.e., > 30% mortality) would better mimic natural disturbance in this stand, while also promoting a more desirable post-harvest species mix. In addition, natural disturbances vary in their extent, so a mix of gap sizes would be more appropriate than a uniform cookie-cutter approach to size and distribution of harvest patches.

[1] Tolerant here means shade-tolerant and is associated with climax vegetation types that include sugar maple, yellow birch, beech, white ash, red spruce, eastern hemlock, and white pine. Spruce-Pine vegetation types are associated with nutrient and/or moisture limited sites and include black spruce, pine (white/red/jack), red oak, and red maple.

[2] Low = < 30% mortality, Moderate = 30-60% mortality, High = > 60% mortality.

Climate Change Adaptation

Nova Scotia is part of the Acadian Forest Region (Rowe 1972), a mixedwood forest that bridges conifer-dominated boreal forests to the north with temperate deciduous forests to the south. Although a small province, Nova Scotia supports a diverse range of tree species and over 100 recognized forest vegetation types (Neily et al. 2023). According to species distribution maps compiled by Fryer (2018), several boreal tree species found in Nova Scotia are near the southern limits of their ranges (e.g., white spruce, balsam fir, black spruce, white birch), while other temperate species are nearer their northern limits (e.g., red oak, yellow birch, white ash, eastern white pine). This has led to projections of several "winners and losers" as climate change leads to shifts in optimal climate conditions and habitat suitability for some species (e.g., Bourque et al. 2008; Taylor et al. 2017). These projected changes will affect both forest ecosystems and forest management across the province.

Given that Nova Scotia is a small, peninsular province, it is likely that some boreal species like black spruce, balsam fir, and white spruce will become severely maladapted and reduced under changing climate conditions, except perhaps in certain habitats like treed swamps (black spruce) and cooler coastal and high elevation forests (balsam fir and white spruce). In contrast, some temperate species like white pine, red oak, and red maple may thrive under new climate conditions (as already suggested by Taylor et al. 2017). An example of how these trends could impact local forest ecosystems and forest management is provided below.

Black spruce / Feathermoss (SP5) is a vegetation type commonly found on dry, poor sites across Nova Scotia and is considered an edaphic (site-constrained) climax community on these sites (Neily et al. 2023). White pine is also adapted to these conditions and is commonly an associate species in these black spruce-dominated stands. With climate change, white pine could become the dominant species replacing black spruce on these sites, possibly in association with red maple and/or red oak. This would mean a potential natural shift towards one of three other vegetation types currently recognized in the province: *White pine / Blueberry / Bracken* (SP4); *White pine – Red maple / Velvet-leaf blueberry / Bracken* (MW12); and *Red oak – White pine / Teaberry* (MW11) (Neily et al. 2023).

Given this scenario, woodland owners may decide that proactively shifting upland black spruce stands towards one of these other three vegetation types is a reasonable and ecologically desirable adaptation option. Mixedwood conditions (MW11 and MW12) would also promote resilience in these stands by enhancing biodiversity and structure (Seidl et al. 2016).

Climate change will also impact NDRs (MacLean et al. 2022), so that current management must account for the possibility of more frequent and/or intense wind events, as well as increased fire hazard. Harvest treatments should therefore try to also enhance wind-firmness of residual trees (e.g., by harvesting patches of variable size and distribution rather than conducting more uniform single-tree treatments), and reduce fire risk (e.g., by maintaining existing hardwood cover and managing ericaceous shrub build-up in softwood dominated stands).

Restoration and Biodiversity Objectives

Along with emulation of NDRs, another fundamental component of ecological forestry is maintenance or enhancement of biodiversity and related ecosystem function. Resilience to stressors like climate change is enhanced by species and structural diversity (Seidl et al. 2016) and restoring Acadian forest ecosystems to their climax condition promotes these features.

Through past management and land-use practices, many forest stands in Nova Scotia are currently young or have a high percentage of boreal and/or pioneer species (e.g., balsam fir, white birch, trembling aspen). Actively managing and steering development of these stands towards site-appropriate climax forests is one of the main objectives of the FFN project. This means accurately characterizing ecological stand conditions before treatment, determining ecologically possible (and desirable) successional options based on these conditions, and adjusting SGEM prescriptions to promote these transitions while also actively managing for biodiversity objectives (e.g., Neily and Parsons 2017). For stands that are already in a climax condition, harvest prescriptions would be designed to maintain and perpetuate these conditions while also promoting stand quality, resilience, and health.(3)

An example of how biodiversity is integrated into harvest prescriptions is the identification and retention of what we call ecological growing stock (EGS). EGS trees are those that enhance diversity (e.g., super-canopy trees, uncommon trees, seed trees) and/or wildlife habitat (e.g., cavity/den trees, mast trees) within a stand. In addition, pre- and post-treatment stand structure and coarse woody material (CWM) data are being collected to assess treatment impacts on these biodiversity components. If CWM volumes are currently low, purposeful additions of CWM may also be part of treatment prescriptions (based on values reported in Neily and Parsons 2017).

Soil Health Objectives

Forest soil health is fundamental to forest ecosystem health and sustainable forest management. Through promotion of soil health, private woodland owners can maintain or

[3] NDR and climate adaptation objectives would also be integrated into final prescription plans as needed.

enhance forest productivity, carbon sequestration, biodiversity, and climate change resilience (e.g., Raison and Khanna 2011; Bakker et al. 2019; Page-Dumroese et al. 2021).

Many forest soils in Nova Scotia have been negatively impacted by acid deposition and are currently low in base cation nutrients, especially calcium (Keys at al. 2016). These impacts have likely been exacerbated in some cases by previous clearcut harvesting or fire that removed additional base cation nutrients as well as nitrogen. It is therefore imperative that current harvesting not remove more nutrients than sites can naturally supply through soil weathering and atmospheric deposition, and that soils are not physically damaged by harvesting operations (e.g., through compaction, rutting, and erosion).

To this end, all harvests in the FFN project will meet nutrient sustainability guidelines recently developed by the Nova Scotia Department of Natural Resources and Renewables for Acadian forest types (Keys and Bockstette 2023) and will explicitly outline mitigation measures to reduce site-specific soil damage (see Appendix 2 for more details).

In addition, liming treatments may be applied on some sites to promote restoration of Tolerant Hardwood and Tolerant Mixedwood vegetation types that are more calcium-demanding than Tolerant Softwood and Spruce-Pine vegetation types.

Research Requirements

As the FFN pilot project is an operational research project, replication of treatment prescriptions is needed for statistical analysis. This means similar vegetation types on similar ecosites will generally have the same treatment prescription applied. Some variation can be accommodated for site-specific conditions (e.g., biodiversity features) and/or landowner objectives, but the main treatment must be the same across related sites. Target replicate numbers range from 5 to 15 depending on how common the vegetation type is across the province (Keys and Dickie 2023). Untreated controls approximately 1 ha in size will also be established at each site for comparison purposes.

Sample Prescription

To illustrate the harvest prescription process, a sample prescription summary for a site in central Nova Scotia is outlined below. An EPU map would normally accompany this summary but is excluded here for privacy reasons. All harvest sites in the FFN pilot project will have a similar prescription summary produced.

Treatment Objectives: To proactively transition hemlock (eH) dominated SH1 (*Hemlock / Needle carpet*) and SH3 (*Red spruce – Hemlock / Wild lily-of-the-valley*)[4] stands to a more mixedwood condition to mitigate anticipated future damage from hemlock woolly adelgid (HWA).

To increase biodiversity and climate change resilience by promoting greater tree species and ground vegetation diversity, by enhancing vertical and horizontal structure, and by adding coarse woody material (CWM) to levels more in keeping with recorded averages for the Spruce-Hemlock (SH) Forest Group.

To generate income from the sale of predominantly sawlog-size eH and red spruce (rS).

SGEM Baseline Prescription: High-Retention Gap Irregular Shelterwood (HG-IR) on finer soils (ST5/6) and High-Retention Continuous-Cover Irregular Shelterwood (HC-IR) on coarser soils (ST2/2-L, ST3/3-L) with 67% basal area (BA) retention.

Climate Adaptation: Focus on variable size gap harvesting instead of continuous cover for the whole site to promote mixedwood cover, to mitigate windthrow hazard, and to better mimic natural disturbance regime (NDR) impacts.

NDR Adaptation: Add some additional micro-gaps between larger gaps to better mimic natural disturbance impacts and promote release of advanced rS regeneration. Minimum overall retention after harvest should be no less than 60% which is in keeping with the NDR range for the SH forest group.

Restoration Adaptation: Promote white pine (wP) and yellow birch (yB) establishment by using target gap sizes of 0.13-0.15 ha (20-22 m radius). It is ok and desirable for some gaps to be larger or smaller with a range of 0.10-0.20 ha (18-25 m radius), but these should not be the dominant condition. Leave between 10-20% live trees in gaps (depending on gap size – trees to be marked). Some light scarification at the time of harvest is also desirable to promote germination of wP and yB. Gap distribution should not be uniform, but mainly dictated by stand conditions.

Biodiversity Adaptation: Add large-diameter CWM as needed (target about 30 m^3/ha of trees 20+ cm DBH). Target low quality trees for CWM and distribute as evenly as possible (could be part of micro-gap establishment).

[4] Forest Ecosystem Classification (FEC) units are described in Neily et al. 2023: 2023-002-biodiversity-tech-report.pdf (novascotia.ca)

	Retain all ecological growing stock (EGS)[5] trees and standing dead trees (snags) if possible.
	Avoid harvesting MW4 (*Hemlock – Red maple / Wood fern – Starflower*) inclusions.
	Plant yB and possibly maple and wP in gaps to supplement natural regeneration if necessary (based on a follow-up survey).
	Consider later HWA inoculation of select trees in and/or between gaps. If considering this, healthy co-dominant trees should be selected – not necessarily the largest trees.
<u>Development Trajectory</u>:	Shift from a dominant SH1 (*Hemlock / Needle carpet*) vegetation type to a more resilient mix of late-successional SH3 (*Red spruce – Hemlock / Wild lily-of-the-valley*), MW1 (*Red spruce – Yellow birch / Evergreen wood fern*), and MW3 (*Hemlock – Yellow birch / Evergreen wood fern*) vegetation types over time, with a possible mid-successional MW2 (*Red spruce – Red maple – White birch / Goldthread*) or MW4 *(Hemlock – Red maple / Wood fern – Starflower*) transition period in larger gaps.
<u>Soil Health Considerations</u>:	The dominant sustainable mean annual increment (SusMAI) value for harvest areas is 6.9 m^3/ha/yr for the SH1/ST5-ST6 combination. The lowest SusMAI value is 2.6 m^3/ha/yr for the SH3/ST2 inclusion. The estimated harvest mean annual increment (HarMAI) is 1.5 m^3/ha/yr (based on a maximum 40% BA removal), well under the minimum SusMAI. The proposed harvest is nutrient sustainable.
	Given dominant fine to loamy soils (ST5/6/2-L) at this site and expected seasonal wetness; compaction, rutting, and erosion hazards will be High-Very High during harvest operations. Mitigation measures are required to limit soil damage to a maximum of 5% by EPU.
<u>Soil Damage Mitigation</u>:	- Stay on high ground and avoid travel in depressions. - Minimize trail coverage and avoid unnecessary travel. - Reinforce trails with slash and/or corduroy to prolong use (count on main trails being damaged but covering minimal area). - Allow for some harvesting outside of trails when slash is needed. - Minimize travel on slopes and use pulp for water bars as needed. - Minimize mineral soil exposure, especially on slopes. - Shut down operations when needed or stockpile harvested wood adjacent to trails until conditions allow for extraction.

[5] EGS are trees with ecological importance regardless of their current or potential economic value. This includes uncommon species for the stand, large legacy trees, seed trees, climate adapted trees, and wildlife trees (cavities/dens, mast, nests).

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Appendix 1: EPU Development and Mapping

Based on detailed pre-treatment assessment (PTA) data, an ecological planning unit (EPU) map is developed for each harvest area that delineates ecosystem units associated with the same ecosite, forest group, and relative species mix. These EPUs would generally have the same treatment applied throughout each unit and would be expected to respond in the same way to this treatment. EPUs are not exactly synonymous with the traditional definition of a forest stand because EPUs can use vegetation and/or soils as differentiating factors, and they can accommodate complexes of similarly related vegetation types and/or soil types. Where any EPU is at least 0.5 ha in size, it is mapped as a separate unit. EPUs may also contain smaller inclusions with different vegetation or soil conditions that are identifiable on the ground and that may require a different treatment from the main EPU, including the possibility of no treatment.

In addition to detailed PTA data, other digital data layers are used to help delineate EPU boundaries. These include:

- 1:10,000 scale provincial orthophoto images.
- LiDAR digital elevation model (DEM) data and related hill shade mapping.
- Provincial hydrology maps.
- Wet areas mapping (WAM) that predicts water flows and pooling in the landscape.
- Provincial wind exposure mapping.

The result is a comprehensive and spatially referenced map that greatly enhances the planning, execution, and potential success of ecologically based forest management at the woodlot scale.

Appendix 2: Soil Damage Criteria and Thresholds

Recommended machine wheel track depth and mineral soil exposure damage criteria for FEC soil types – based on research conducted by K. Keys and review of related literature (e.g., McNabb et al. 2001; Keys 2005; Powers et al. 2005; Startsev and McNabb, 2009). A maximum of 5% soil damage by ecological planning unit (EPU) is the target for FFN treatments.

FEC Soil Type	Maximum Allowable Wheel Track Depth (cm)	Exposed Mineral Soil Counts as Damage*
1	25	Yes
2	20	No
2-C	20	Yes
2-L	15	No
3	10	No
3-C	15	Yes
3-L	10	No
4	5	Yes
5	10	No
5-C	15	No
6	5	No
6-C	10	No
7	5	Yes
8	15	No
8-C	20	No
9	10	No
9-C	15	No
10	5	No
11	10	No
12	5	No
13	5	No
14	25	-
15	5	Yes
16	5	Yes
17	5	Yes
18	5	Yes

*** Exposed mineral soil counts as damage on all stony (S-phase) soils.**

Appendix 3: FFN Technical Report Series Documents

FFN Technical Report 1: Vegetation Type Selection (May 2023)

FFN Technical Report 2: Site Selection and Survey Protocols (June 2023)

FFN Technical Report 3: PTA Data Collection Forms (August 2023)

FFN Technical Report 4: Harvest Prescription Protocols (November 2023)