Disturbance-based silviculture for bird habitat diversification: effects on forest structure, dynamics, and carbon storage

Bill Keeton and Dominik Thom

Carbon Dynamics Lab, Rubenstein School and Gund Institute, University of Vermont
Vermont Audubon’s Silviculture with Birds in Mind (SBM)

- Collaborative effort involving >100 stakeholders
- Overwhelming support for bird conservation on private lands
- Objective is to diversify bird habitats
- Silvicultural guide
- Program is expanding across the eastern U.S.
- Incorporates principles of natural disturbance-based forestry

Research Questions:

What are the outcomes in forest structure and dynamics?

Can we use SBM and disturbance-based practices to also enhance ecosystems services, like carbon storage?
From Franklin, Mitchell, and Palik (2007):

- Incorporating biological legacies into harvest prescriptions
  → e.g. Variable retention harvesting

- Incorporating natural stand development processes, including small-scale disturbances, into intermediate treatments
  → e.g. Variable density thinning

- Allowing for appropriate recovery periods between regeneration harvests
  → e.g. Extended rotations

---

**Figure 1.**—The three-legged stool of ecological forestry.
Role of Intermediate Intensity Disturbances:

*For example:*

- Microbursts
- Tornados
- Ice Storms
- Localized insect and pathogen outbreaks

*They create:*

- Variably sized gaps
- Multi-aged, irregular structure
- Landscape heterogeneity
- Habitat diversity
Emulating natural disturbances through modified gap-based silviculture

- There are a range of options
- No “one-size-fits-all” approach
- Forest type, disturbance regime, and site-specific
- Shade tolerance of desired regeneration a key consideration
- Experimentation all over the world
- Growing use in practice

Figure 2 Conceptual framework situating silvicultural systems according to a gradient of severity, size and frequency of disturbances at the stand scale (adapted from Raymond et al., 2013).
Emulating natural disturbances through modified gap-based silviculture

- Structural Complexity Enhancement: Variable density with small gaps (0.02 ha mean)

- Modified Group Selection: Irregular sized gaps (0.05 ha mean) with light retention in gaps

Mt. Mansfield State Forest, VT
“Expanding Gap” Study. Univ. of Maine.

• Expanding group selection with retention
• Entry cycle and area in openings mimic disturbance frequency and intensity
• Emulates 1% annual disturbance rate, but with LEGACY TREES!

(Seymour 2005, Saunders and Wagner 2005)
Irregular Shelterwood method in mixed white pine (Pinus strobus) – northern hardwoods, Vermont, USA

Variable Retention Harvesting/ Irregular Shelterwood method in red pine (Pinus resinosa), Minnesota, USA
Silviculture with Birds in Mind

Options for Integrating Timber and Songbird Habitat Management in Northern Hardwood Stands in Vermont

- 12 indicator species
- 40 priority songbird species
**Forest Type**

- Hardwood Forest
- Mixedwood Forest
- Softwood Forest

**Stand Condition**

**Example Stand Data**
- Mean Diameter: 4.5" (11.4 cm)
- Total Basal Area/acre (BA): 115 ft²
- AGB Basal Area/acre: 72.0 ft²
- Site Class: 1-B
- Current Age Class Distribution: even-aged or two-aged

**Example Stand Notes**
- Stem exclusion stage. Lacking significant regeneration; 6-5 foot layer minimally occupied and often present is heavily browsed and/or non-commercial species. Mixed and scattered softwood component. Minimal non-court disturbance. Generally a closed canopy exists and large diameter (G19") DBH trees are lacking. Crotch woody material is lacking. Stumps exist but in low densities and typically of small diameter (≤4") DBH.

**Bird Species of Interest**

- Black-throated blue warbler
Choice of 6 Silvicultural Options

Variable-Retention Thinning

Notes & Considerations
Focus removals on suppressed, intermediate, and the poorest quality co-dominant trees (fast growing competitors, high risk, low vigor).

Retain some scattered paper birches, oaks, or dry hardwood cavities 60-70 DBH in which yellow-bellied flycatchers and/or northern flickers may excavate nesting cavities.

Recruit snags by girdling some poor quality dominants; leave worst-quality cut stems in woods as drowned woody material.

Identify and retain trees heart rot in thebole or with heart rot in diameter at breast height.

Strive for relatively even trees; most cavity users are small. When faced with a cavity, leave the one that will have the development of the cavity.

Consider pre-treatment mortality, native, invasive species.

Cautions: thinning in order to reduce vertical structure in mixed species stands.

Forest Bird Species that Might Benefit

<table>
<thead>
<tr>
<th>Condition</th>
<th>Duration Post-treatment</th>
<th>Beneficiary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced foraging in open midstory and gaps</td>
<td>1-40 years</td>
<td>Eastern Wood-Pewee</td>
</tr>
<tr>
<td>Increased understory density</td>
<td>5-15 years</td>
<td>Black-throated Bluebird</td>
</tr>
<tr>
<td>Enhanced softwood component</td>
<td>5+ years</td>
<td>Wood Thrush</td>
</tr>
<tr>
<td>Increased growth and vigor in canopy trees</td>
<td>5+ years</td>
<td>Scarlet Tanager</td>
</tr>
<tr>
<td>Enhanced cavity tree nest sites</td>
<td>5+ years</td>
<td>Yellow-bellied Flycatcher</td>
</tr>
<tr>
<td>Increased midstory density</td>
<td>15+ years</td>
<td>Wood Thrush</td>
</tr>
</tbody>
</table>

Crop Tree Release with Canopy Gap Formation

Identify 30-70 crop trees per acre with particular value for timber and wildlife.

Release crop trees from competing vegetation:
- Pole-sized crop trees should receive a 2-3-in.-diameter, 10-foot crown release.
- Suitability-sized crop trees should receive a 1-3-in.-diameter crown release.

Between crop trees, create circular canopy gaps ranging from 30-75 feet in diameter on 5-15% of the area at each entry. Within gaps, all poor-quality stems >1 inch DBH should be cut.

Benefits Bird Species

<table>
<thead>
<tr>
<th>Benefiting Bird Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Wood-Pewee</td>
</tr>
<tr>
<td>Black-throated Bluebird</td>
</tr>
<tr>
<td>Canada Warbler</td>
</tr>
<tr>
<td>Veery</td>
</tr>
<tr>
<td>Wood Thrush</td>
</tr>
<tr>
<td>Canada Warbler</td>
</tr>
<tr>
<td>Black-throated Green Warbler</td>
</tr>
<tr>
<td>Blue-headed Vireo</td>
</tr>
<tr>
<td>Scarlet Tanager</td>
</tr>
<tr>
<td>Wood Thrush</td>
</tr>
<tr>
<td>Wood Thrush</td>
</tr>
<tr>
<td>Canada Warbler</td>
</tr>
</tbody>
</table>

Mixed Intermediate Treatments

Use a combination of free thinning with liberation cuttings, cleanings, and seedings to treat groups of trees within the stand, as dictated by existing stand conditions.

Notes & Considerations
Particularly applicable in highly variable stands with high proportion of unacceptable growing stock and scattered occurrences of desirable species.

Expand canopy criteria to include species of particular value for foraging birds (e.g., yellow birch), or condition (e.g., large crowns for perching, nesting, foraging), or species often eluded to hardwood-dominated stands or under-represented species (especially soft- mast producers such as black cherry) in more pure hardwood stands.

Focus removals on defective, high-risk, and low-value trees especially to release an understory of more desirable species.

Favor most vigorous, best-formed dominant and subdominant individuals.
<table>
<thead>
<tr>
<th>SBM treatment</th>
<th>Disturbance emulation</th>
</tr>
</thead>
</table>
| Crop Tree Release and Canopy Gap Formation (CTRG) | • Emulate crown release processes  
• Emulate fine-scaled disturbances               |
| Expanding-Gap Group Shelterwood (EGGS)            | • Emulate expanding natural gap dynamics, including legacy tree retention  
• Create two- or multi-aged structures          |
| Small-group and Single-tree-selection (SGSTS)     | • Emulate range of density-dependent and density-independent mortality processes  
• Create uneven-aged structures                  |
| Shelterwood with Reserves (SWR)  
  “Irregular Shelterwood”                         | • Emulate the biological legacies associated with natural disturbances  
• Retaining live trees over multiple rotations  
• Create two- or multi-aged stands               |
| Variable Retention Thinning (VRT)  
  “Variable Density Thinning”                     | • Emulate mortality processes leading to enhanced growth on residual trees  
• Enhance horizontal variation in stand structure |
Objectives:

(i) Describe the outcome of SBM treatments and compare them with natural disturbances typical for the region; and

(ii) analyze the co-benefits of multiple habitat indicators and carbon storage within four years of treatment.

Hypothesis:

SBM treatments have varying effects on individual structural indicators of habitat, and as a suite of techniques emulate a range of low to intermediate severity natural disturbance influences on forest structure.
Study Design:

- 7 SBM demonstration sites
- 5 of the 6 SBM treatments
- 1 to 4 stands per site
  - Uncut reference stands (controls)
  - Treated stands
- 6-41 randomly distributed inventory plots per site
  - Nested plot design
  - Overstory and understory structure and composition
- 217 SBM plots in total
- Comparison with 4 intermediate intensity windthrow sites from Meigs and Keeton (2018) – 27 plots
How do the treatments compare to the controls?

How do the treatments compare to each other?

How do the treatments compare to intermediate wind disturbance?

What are the effects of key indicators of structural complexity and habitat, including H index, large tree density, coarse woody debris?

How do structural indicators co-vary with carbon storage (aboveground biomass)?

What are the implications for stand development dynamics?
Data Analysis

Dr. Dominik Thom, Gund Post-Doctoral Researcher, UVM

Calculations:
• 14 indicators of structural and compositional diversity
• Carbon densities
  - volumetric approach w/species specific coefficients
  - specific gravities by tree parts
  - density reduction factors for dead and downed
• $H$ index of structural complexity
  – combines tree dbh, height, and species diversity

Statistical Analyses:
• Pairwise independence tests with a Benjamini-Hochberg p-value adjustment
• Non-metric Multi-Dimensional Scaling (NMDS)
• Gower distance matrix before fitting the NMDS
• Multilevel permutation-based analysis of similarities (ANOSIM), controlling for location and stand conditions
• Correlation of key variables assessed using a variance inflation factor (VIF) and Pearson correlation matrix
• Multi-hierarchical Bayesian modeling of fixed and random effects
• Bayesian models used in combination with Markov Chain Monte Carlo (MCMC) sampling
• Goodness-of-fit analyzed with Bayesian R^2 and posterior predictive checks
NMDS of forest structural and compositional variables

Ellipses present the standard deviation of points around the centroids (crosses).

- High degree of dissimilarity among treatments
- Also some overlap in enhancement of key structural attributes, such as CWD and relative density of large trees
- Shelterwood with Reserves (Irregular Shelterwood) most similar to intermediate windthrow

From: Thom and Keeton, For. Ecol. and Mgt. in review
Associations between treatments and forest structural and compositional variables

Crosses represent the centroids of treatments.

- Variation in structural effects
- Not always immediate enhancement over controls
- But increased sapling diversity suggest long-term effects
Treatment effect on key variables for habitat conditions and aboveground carbon storage

Based on multi-hierarchical Bayesian models with location and stand as random effects.

Model outputs were back-transformed to original values and scaled by predicted maximum values.
Combined relative performance of each response variable across the treatments

The theoretical maximum is 100% if all variables were at their maximum values in one of the groups.

- No treatments had higher combined performance compared to the control
- But lagged effects likely from regeneration, release, and growth!!
Relationships btw forest structure and total aboveground carbon storage

Notes: Variables are ordered according to their effect size on carbon. Note that x-axes denote the z-scores (scaled and centered) of predictors while carbon storage on the y-axes is log+1-transformed.
Summary of Findings

• SBM/disturbance-based silvicultural treatments created higher amounts of standing and downed deadwood and increased sapling diversity

• Long-term effects on stand dynamics look promising but need to be tracked

• SBM treatments significantly enhanced the variation of structural elements required by different groups of birds and other wildlife

• Where structural complexity is also enhanced there will be carbon storage co-benefits
**Management Implications**

- Promoting structural complexity, such as canopy heterogeneity, likely to increase carbon services (sequestration and storage)

- SBM and disturbance-based practices provide additional options for foresters to diversity habitats and manage for a range of ecosystem services

- May need additional silvicultural approaches to fully emulate intermediate wind and other natural disturbances
Funding from -
McIntire-Stennis Forest Research Program

Assistance from -
Kathryn Wrigley
Andrea Urbano
UVM Field Crews
Nancy Patch
Graham Leitner
Steve Hagenbuch
Jim Shallow
Vermont Audubon !!