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

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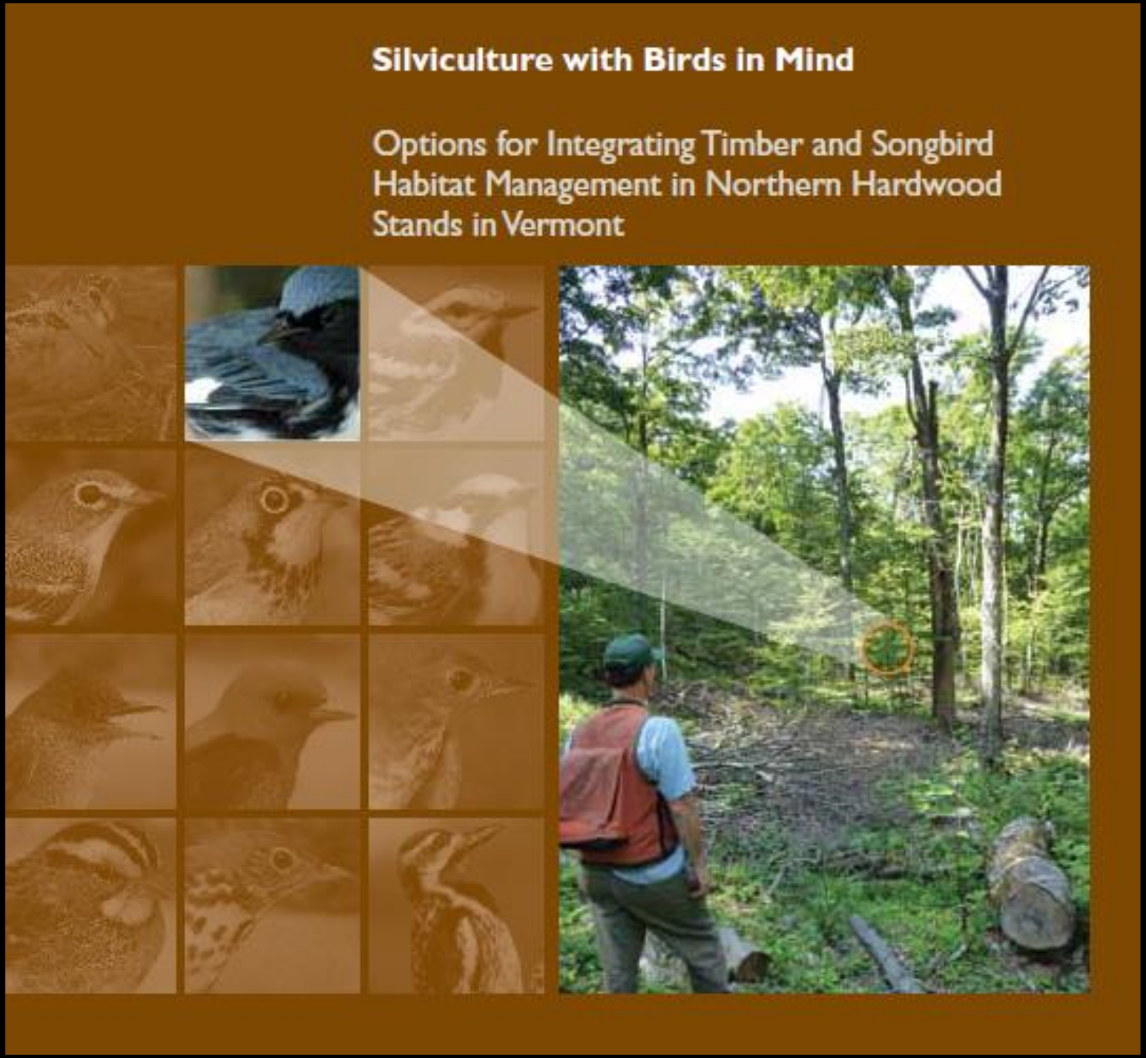


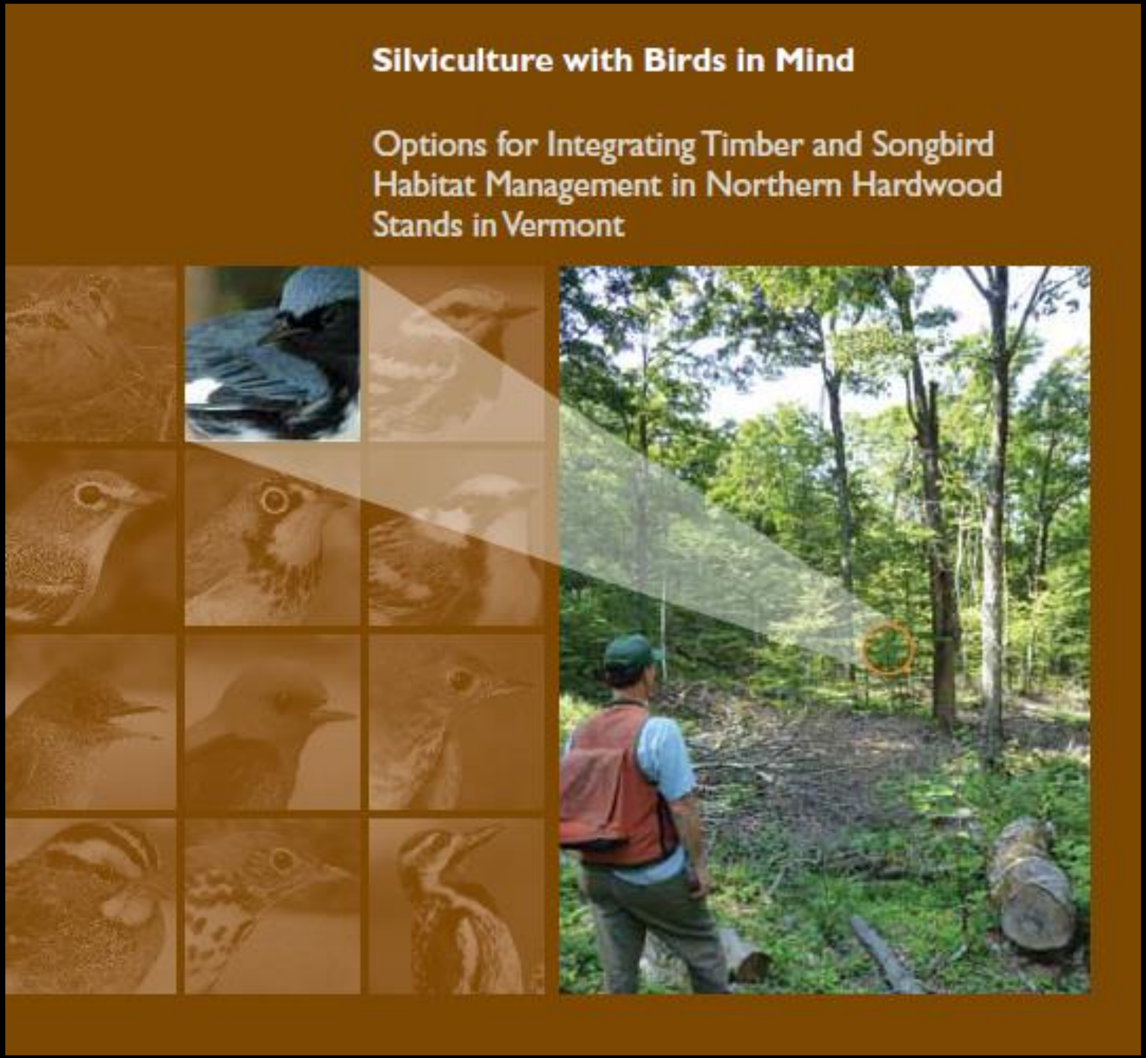
Vermont Adubon's Silviculture with Birds in Mind (SBM)

- 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?



Principles of Disturbance-Based Forest Management at the Stand Scale

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

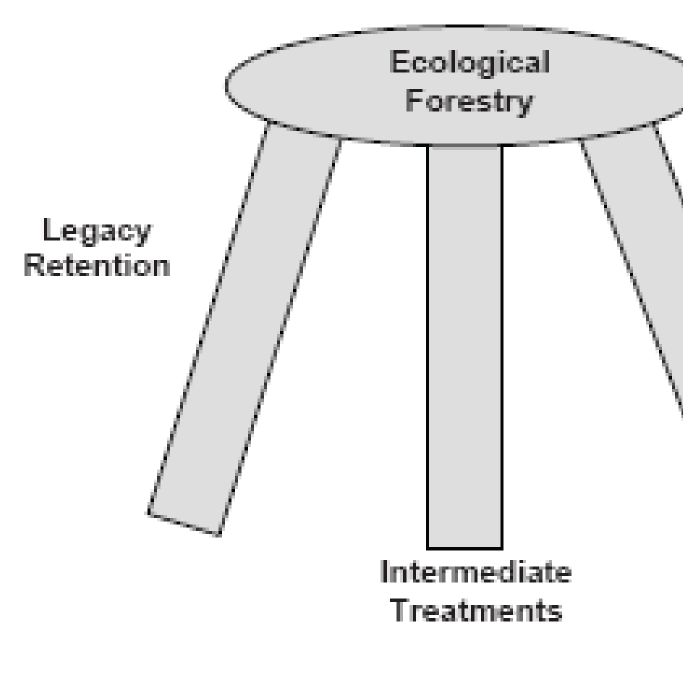


Figure 1.—The three-legged stool of ecological forestry.

Fig. from Franklin et al. (2007).

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

Williams Woods, VT

Ampersand old-growth forest, Adirondack State Park, NY

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

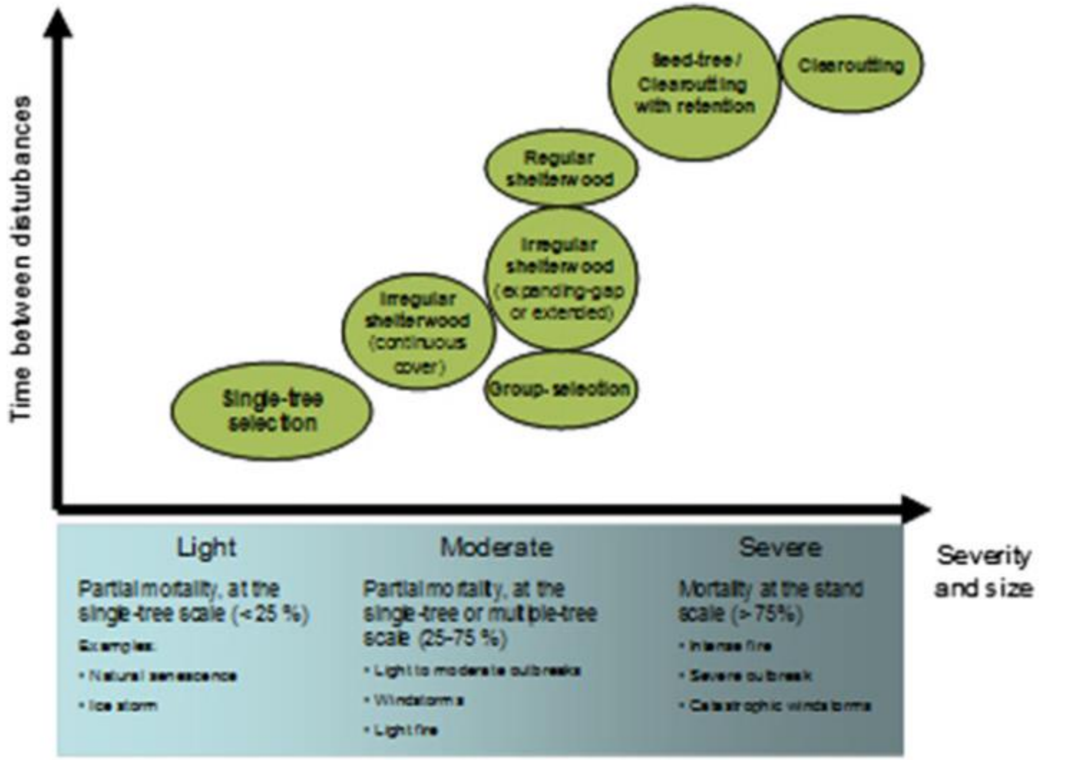


Figure 2 Conceptual framework situating silvicultural systems according to a gradient of severity, size and frequency of disturbances at the stand scale (adapted from Raymond *et al.*, 2013).

Kern et al. 2016. Forestry

Emulating natural disturbances through modified gap-based silviculture

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

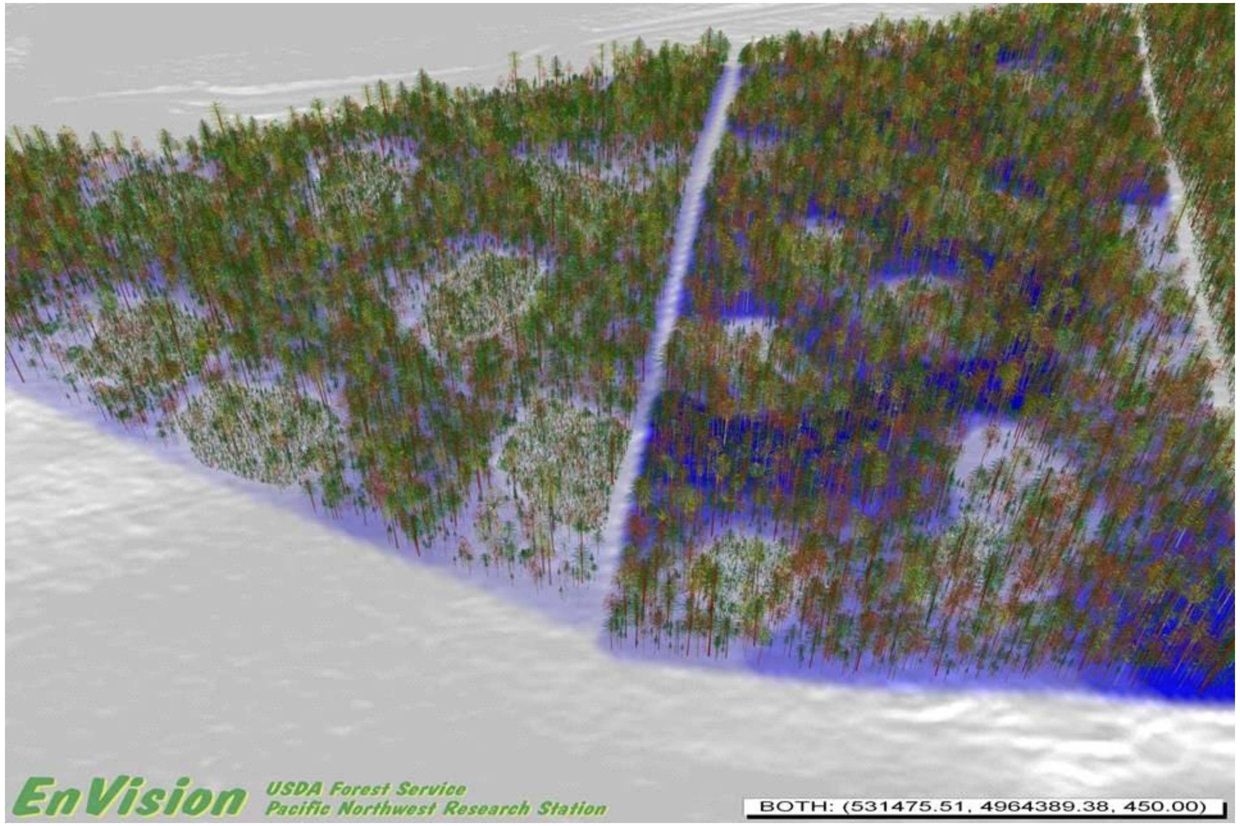
Mt. Mansfield State Forest, VT

- 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.

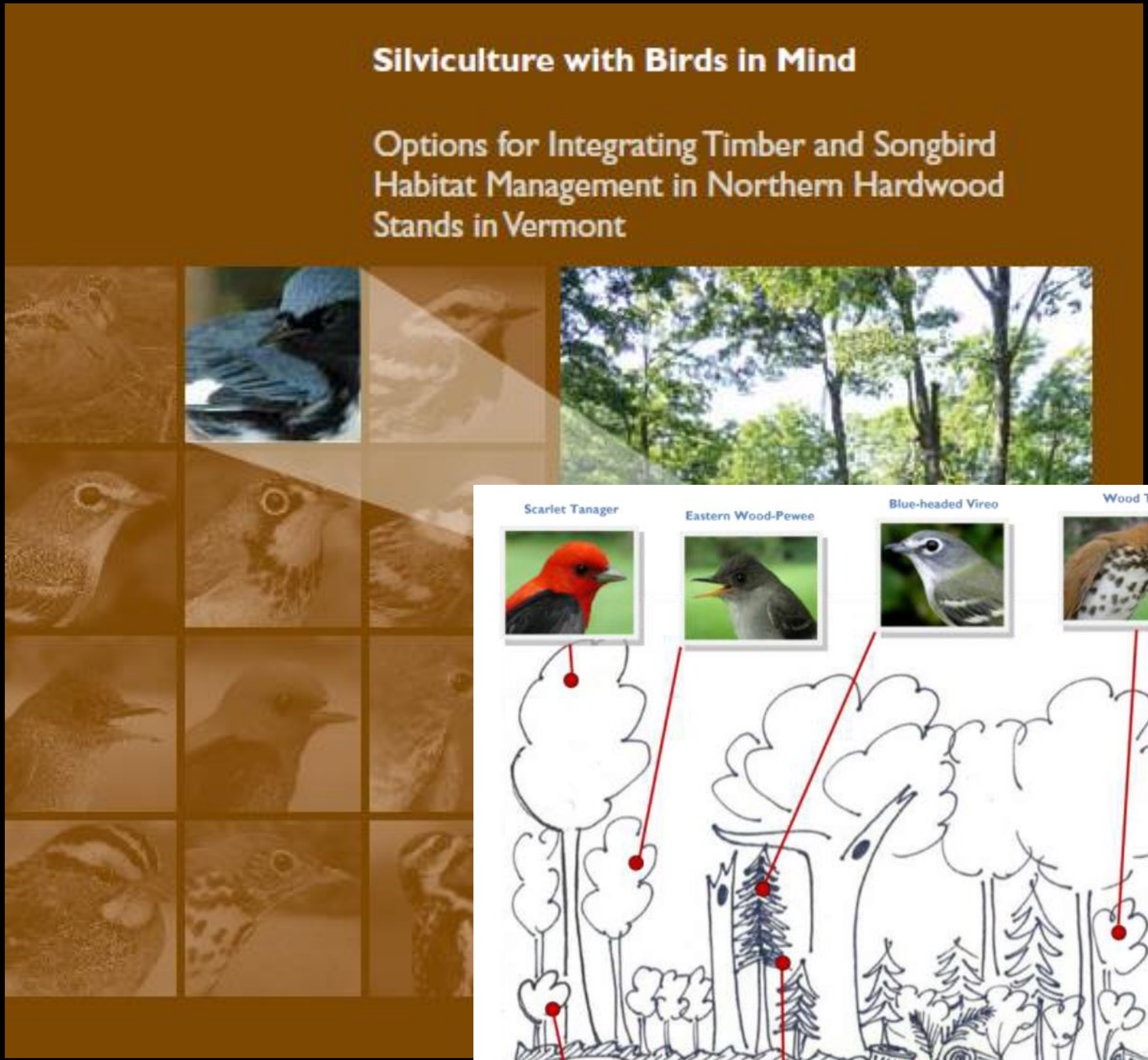
- Expanding group selection with retention
- Entry cycle and area in openings mimic disturbance frequency and intensity
- Emulates 1% annual disturbance rate, but with LEGACY TREES!

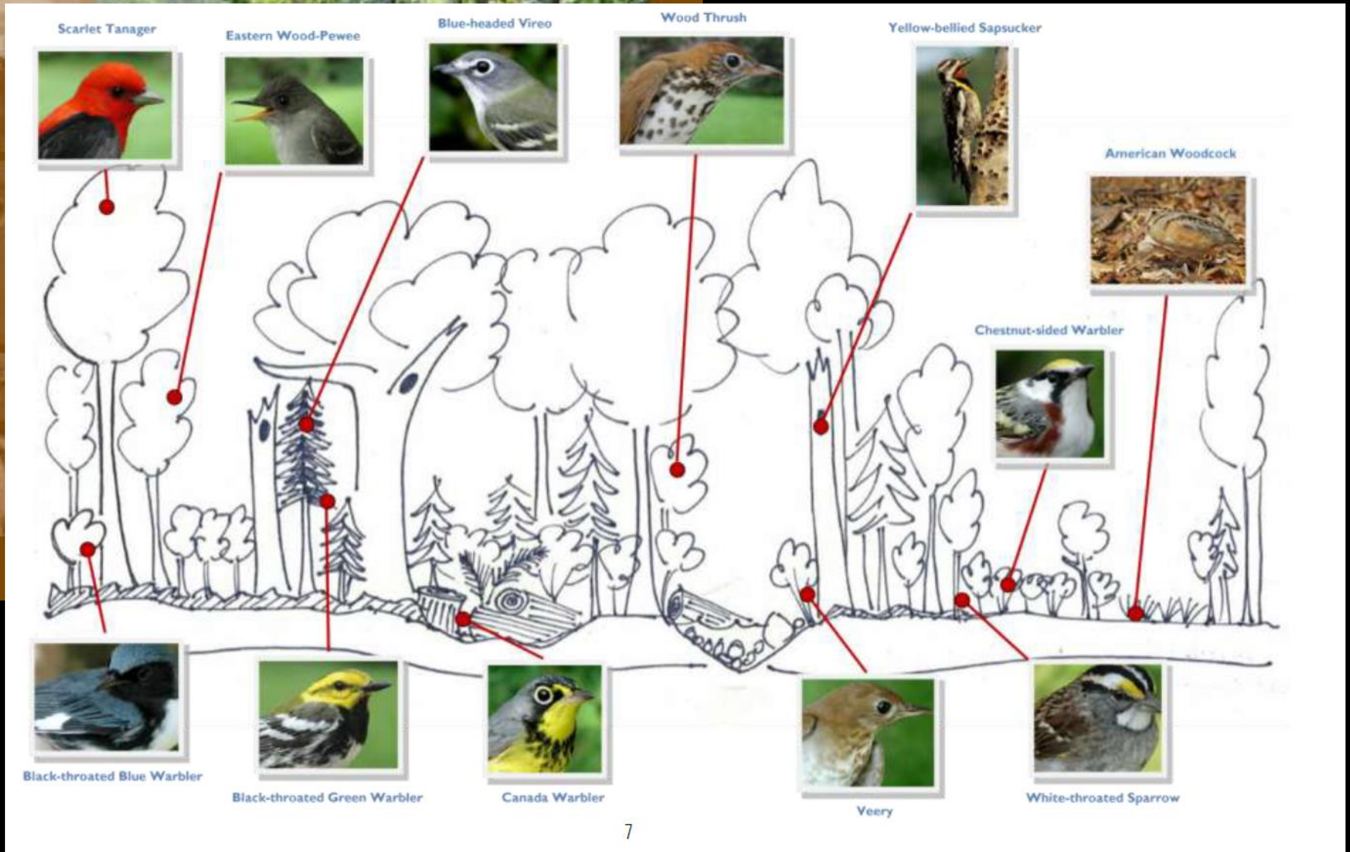


(Seymour 2005, Saunders and Wagner 2005)

Variable Retention Harvesting/ Irregular Shelterwood method in red pine (*Pinus resinosa*), Minnesota, USA

Irregular Shelterwood method in mixed white pine (*Pinus strobus*) – northern hardwoods, Vermont, USA





- 12 indicator species
- 40 priority songbird species

Forest Type

Hardwood Forest	Mixedwood Forest	Softwood Forest
		
≥75% *hardwood species such as maple, birch, beech, and ash*	*25-75% softwood species with the rest being hardwoods*	≥75% *softwood species such as eastern hemlock, spruce, fir, or pine*
Swamp	**Boreal Forest**	**Riparian Forest**
		
Forested wetland such as a hemlock, red maple, or cedar swamp.	*Circumpolar band of forest characterized by species that are adapted to the extreme cold of this region.*	*Forest along a stream or river that may be regularly disturbed or affected by flooding.*

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Stand Condition

Stand Condition I **Northern Hardwood (or Mixedwood) Poletimber Stands with Small Sawtimber and High Stem Quality and High Stocking**

AGS > 40ft^2/acre (hardwood) or 60ft^2/acre (mixedwood)

But, AGS 12"+ < 25ft^2/acre AGS (hardwood) or 40ft^2/acre (mixedwood)

Total BA > 100ft^2/acre (hardwood) or 130ft^2/acre (mixedwood)

Example Stand Data
Mean Stand Diameter: 8.5"
Trees Per Acre: 240
Total Basal Area/Acre (BA): 115 ft^2
AGS Basal Area/Acre: 72 ft^2
Overstocked, above B-line
Site Class: I-II
Current Age Class Distribution: even-aged or two-aged

Example Stand Notes
Stem exclusion stage. Lacking significant regeneration; 0-5-foot layer minimally occupied and where present it is heavily browsed and/or of non-commercial species. Minor and scattered softwood component. Minimal recent disturbance. Generally a closed canopy exists and large-diameter (>20" DBH) trees are lacking. Coarse woody material is lacking. Snags exist but in low densities and typically of small diameter (<16" DBH).

Example Silvicultural Objectives
integrating timber and forest bird habitat:

Increase sawtimber quantity, quality, and volume increment.

Maintain a diversity of plant species in all forest layers, with particular attention toward both commercial tree species (e.g. yellow birch, red oak) and non-commercial species (e.g. hobblebush, striped maple) valuable to wildlife.

Manage seed-producing trees and shrubs for a continuous source of wildlife food and high-quality seed for regeneration.

Maintain 70-85% canopy cover, using openings to enhance horizontal structure and understory development.

Maintain or create inclusions of early- to mid-successional tree species and partially open midstories.

Increase softwood component where viable.

Increase abundance of large-diameter (>16" DBH) snags, cavity trees, and downed woody material.

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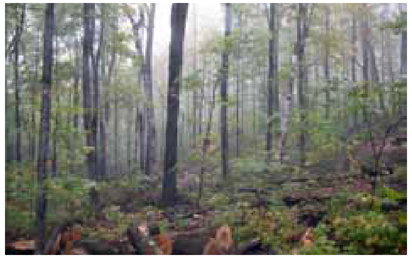
Bird Species of Interest

Black-throated blue warbler

Choice of 6 Silvicultural Options

Variable-Retention Thinning

Thin throughout the stand with variable retention by removing trees of low-vigor and poor quality, reducing crown cover to 70-75% in small poles and 75-85% in larger poles and small sawtimber. Remove most overtopped individuals, 50-60% of intermediate crown class and 10-25% of co-dominant crown class.



AFTER HARVEST, CLUSTERS OF LOW-RISK, HIGH VIGOR TREES REMAIN INTACT WITH MIXED-SIZED OPENINGS SCATTERED THROUGHOUT.

Notes & Considerations

Focus removals on suppressed, intermediate, and the poorest quality co-dominant trees (least desirable competitors, high risk, low vigor).

Retain some senescent paper birch, aspen, or dry hardwood cavity trees >9" DBH in which yellow-bellied sapsuckers and/or northern flickers may excavate nesting cavities.

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

Identify and retain trees heart rot in the bole or w than 4" in diameter as po

Strive for relatively even trees; most cavity users a

When faced with two ca leave the one that will ha the development of the r

Consider pre-treatment f native, invasive species.

Caution: thinning in onl reduce vertical structure, mixed species stands.

Forest Bird Species that Might Benefit

Condition	Duration Post-treatment	Benefitin
Enhanced foraging in open midstory and gaps	1-30 years	Eastern
Increased understory density	3-15 years	Wood T
Enhanced softwood component	5+ years	Black-th Blue-hea
Increased growth and vigor in canopy trees	5+ years	Scarlet T Wood T
Enhanced cavity tree nest sites	5+ years	Yellow-b
Increased midstory density	15+ years	Wood T

Mixed Intermediate Treatments

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

FREE THINNING OF HIGH QUALITY DOMINANTS AND CO-DOMINANTS WITH LIBERATION CUTTING TO RELEASE ADVANCE REGENERATION.

Notes & Considerations

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

Expand croptree criteria to include specis of particular value for foraging birds (eg. yellow birch), or condition (eg. large crowns for perching, nesting, foraging), overstory inclusions of softwoods in 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 ant individuals.

Benefiting Bird Species
Eastern Wood-Pewee
Black-throated Blue Warbler Canada Warbler Veery Wood Thrush
Canada Warbler Black-throated Green Warbler Blue-headed Vireo
Scarlet Tanager Wood Thrush
Wood Thrush Canada Warbler

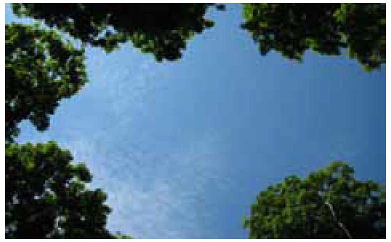
Crop Tree Release with Canopy Gap Formation

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-sided, 5-10-foot crown release.
- Sawtimber-sized crop trees should receive a 1-3-sided 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.



CANOPY GAPS BETWEEN CROP TREES SHOULD RANGE IN DIAMETER FROM 30-75 FEET.

Notes & Considerations

Expand crop tree definition to include:

- tree species of particular value for foraging birds (e.g. yellow birch).
- tree conditions of particular value for forest birds (e.g. large crowns for perching, nesting, foraging).
- under-represented species (especially soft-mast producers) in more pure hardwood stands.

Manage to increase the production of seed and wood volume increment; favor a diversity of seed-producing native tree and shrub species and free them from overtopping and less-productive individuals.

Give consideration to potential for stem sprouting on best-quality sawtimber and veneer stems, adjust extent of release accordingly.

Trees with cavities or dens should only be cut to release high-quality crop trees. Consider girdling to release the crop trees without removing cavity or den trees.

Locate gaps to release advance regeneration, to remove clusters of high-risk, low-vigor, or low-value trees, and to avoid easily disturbed, sensitive sites.

SBM treatment	Disturbance emulation
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

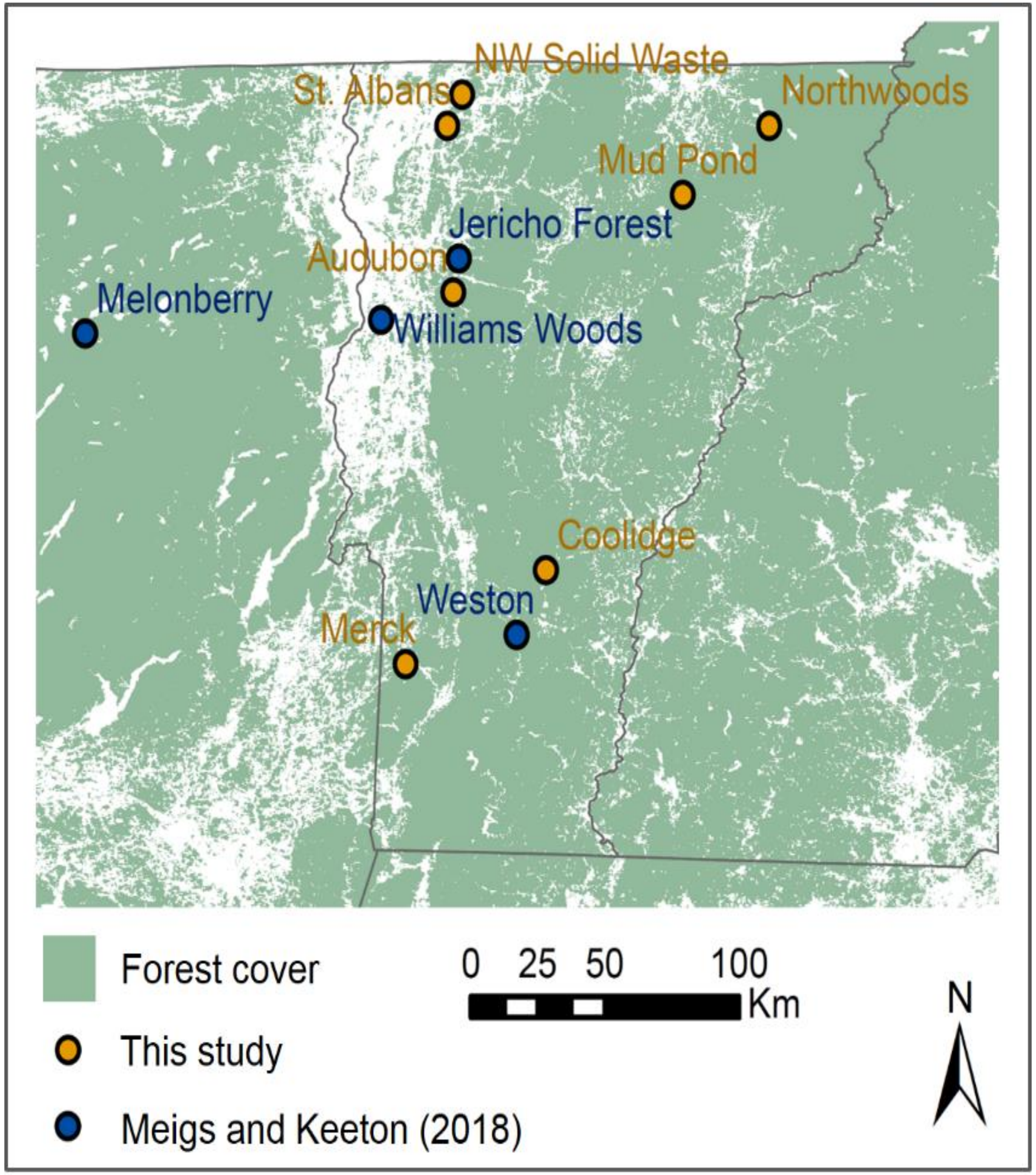
(i) analyze the co-benefits of multiple habitat indicators and carbon storage within four years of treatment.

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



Data Analysis

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

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

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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

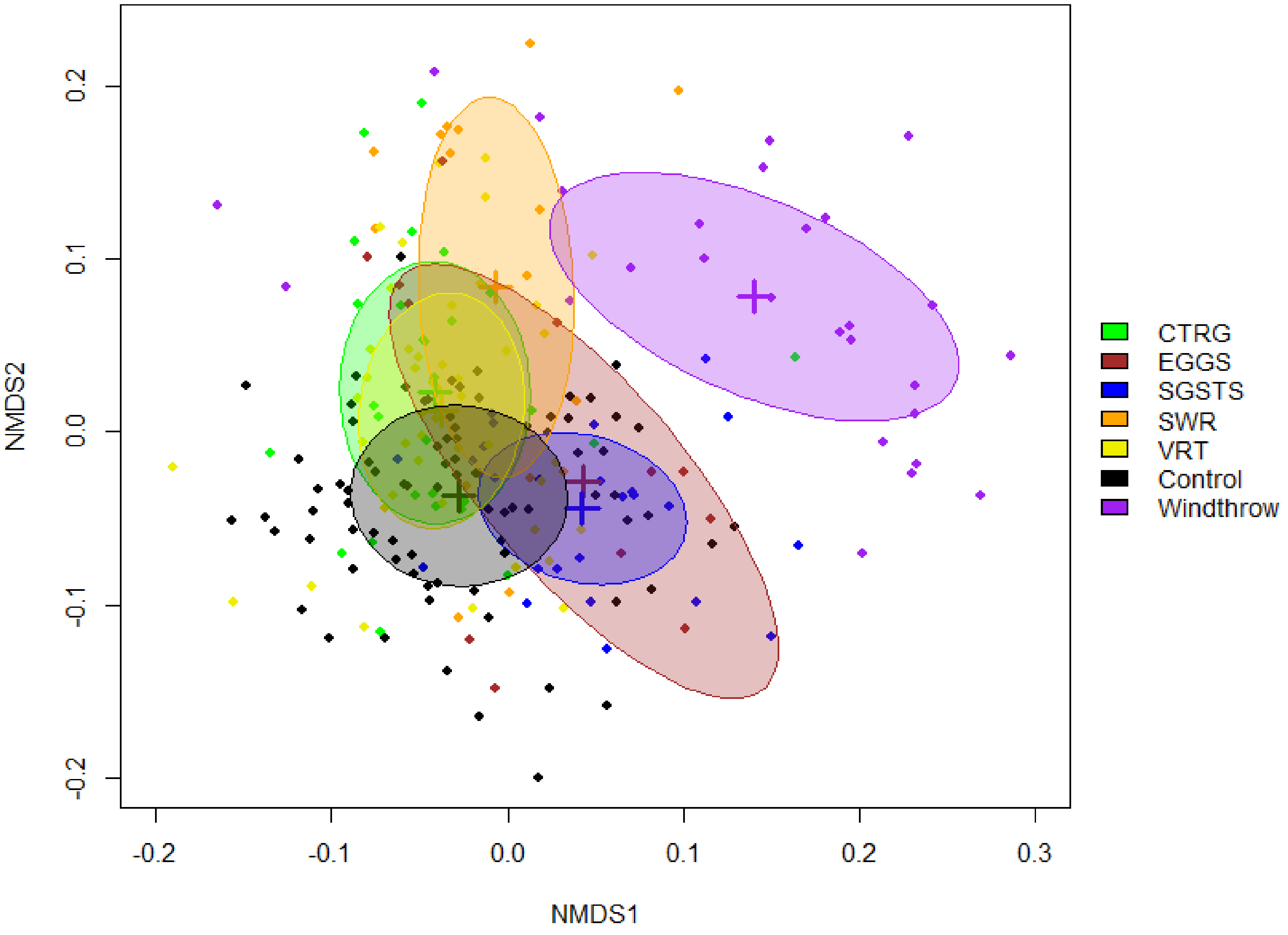
Statistical Analyses:

- 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

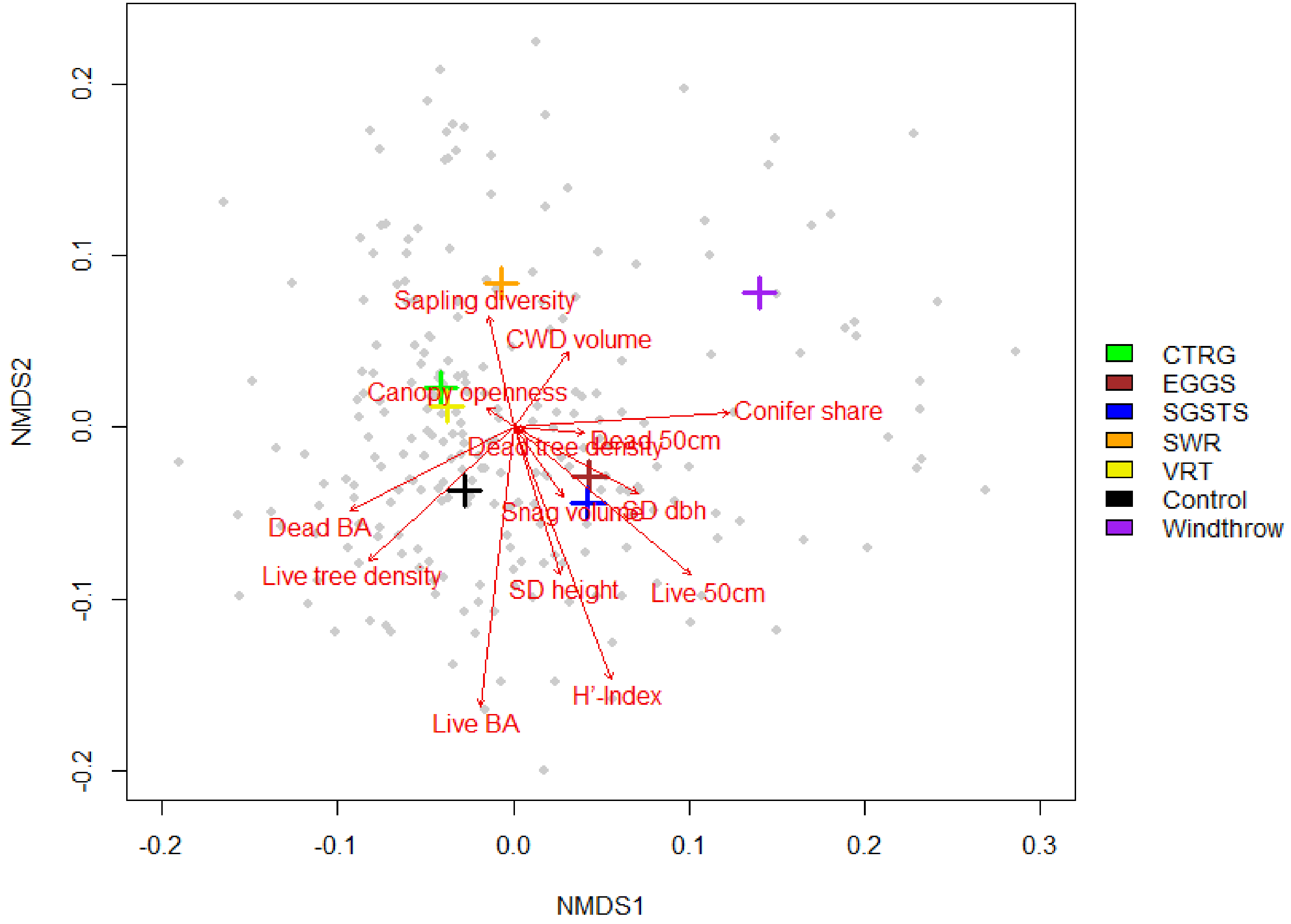
Ellipses present the standard deviation of points around the centroids (crosses).

- 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



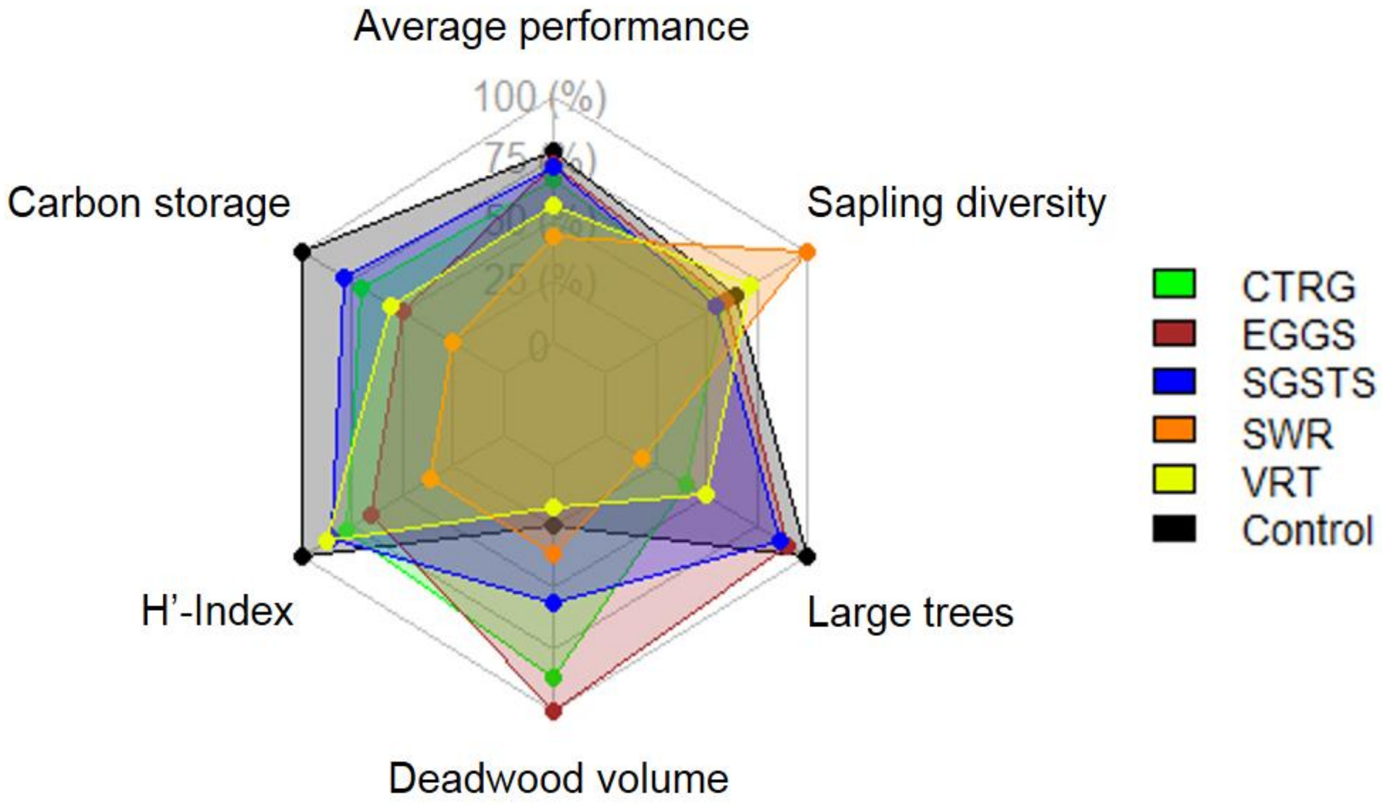
Crosses represent the centroids of treatments.

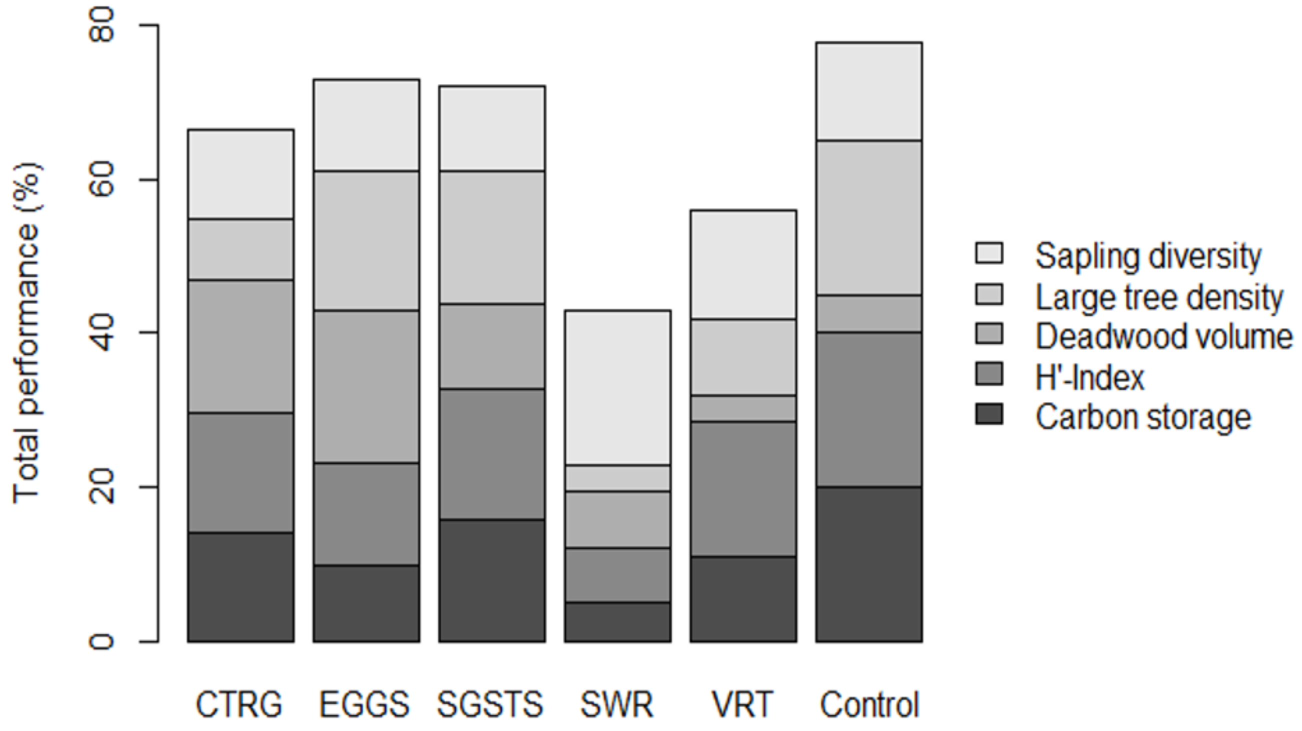
- Variation in structural effects
- Not always immediate enhancement over controls
- But increased sapling diversity suggest long-term effects

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



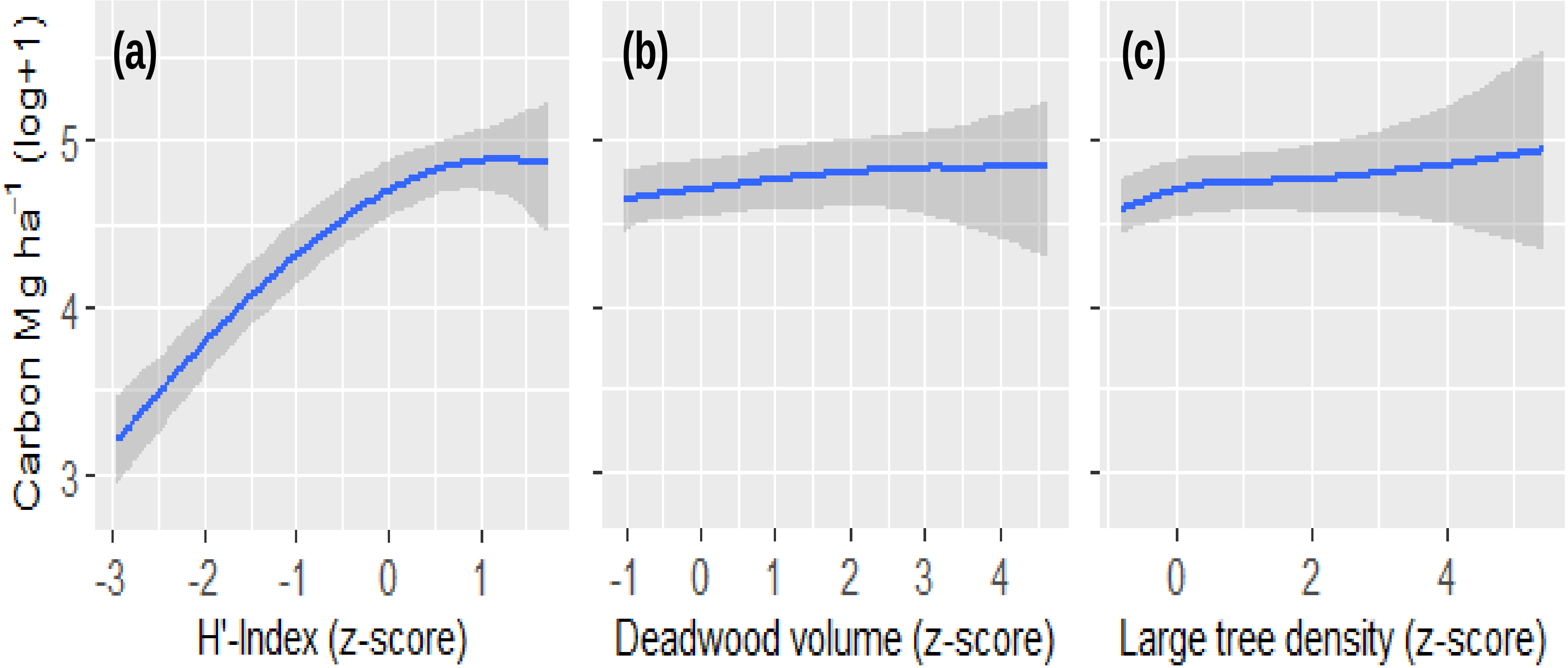


Combined relative performance of each response variable across the treatments

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.

Audubon Center, VRT Unit

Summary of Findings

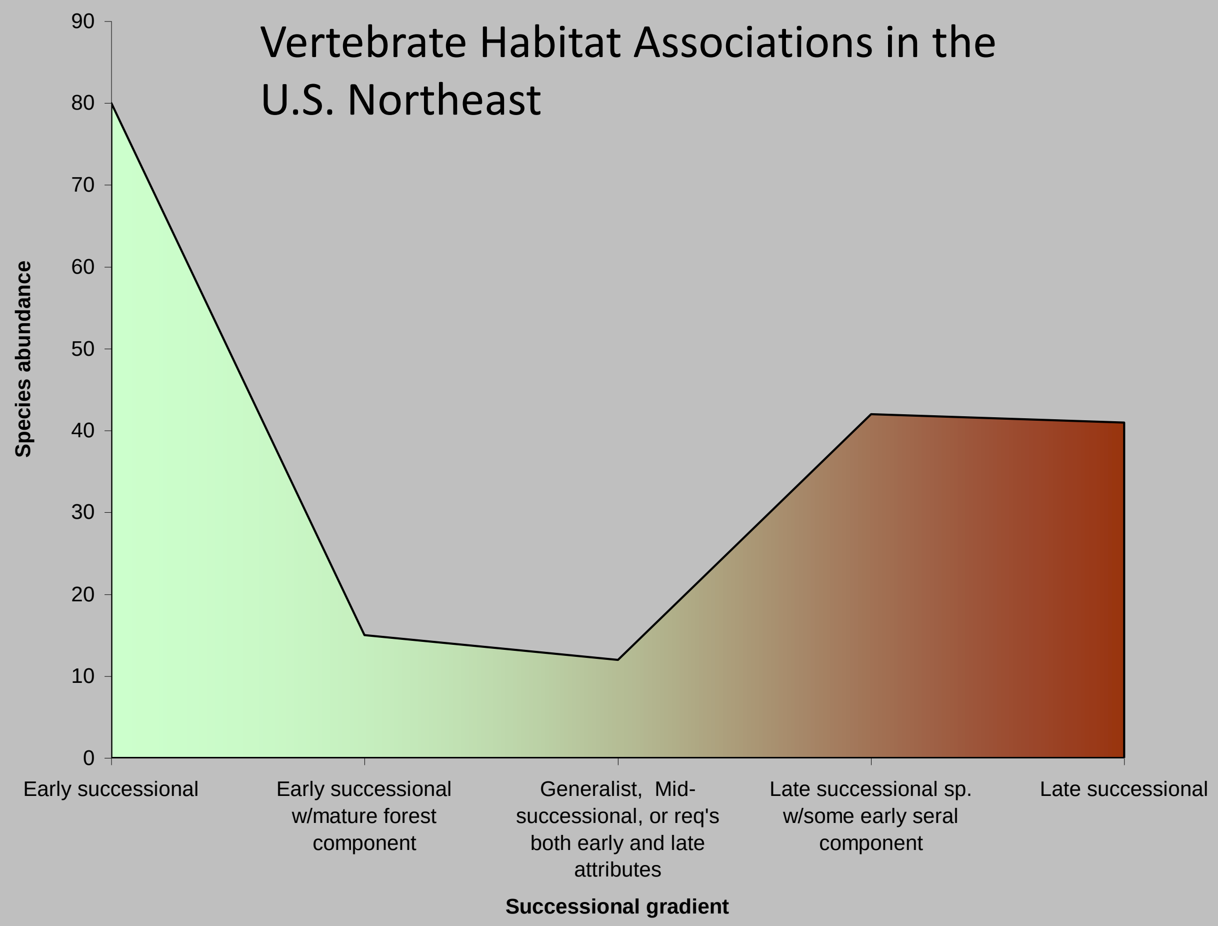
- SBM/disturbance-based silvicultural treatments created higher amounts of standing and downed deadwood and increased sapling diversity
- Long-term effects on stand dynamics look promising but need to be tracked
- SBM treatments significantly enhanced the variation of structural elements required by 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



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