Silvicultural Principles for Northern Forest Restoration based on Financial Productivity and Avian Functional Diversity

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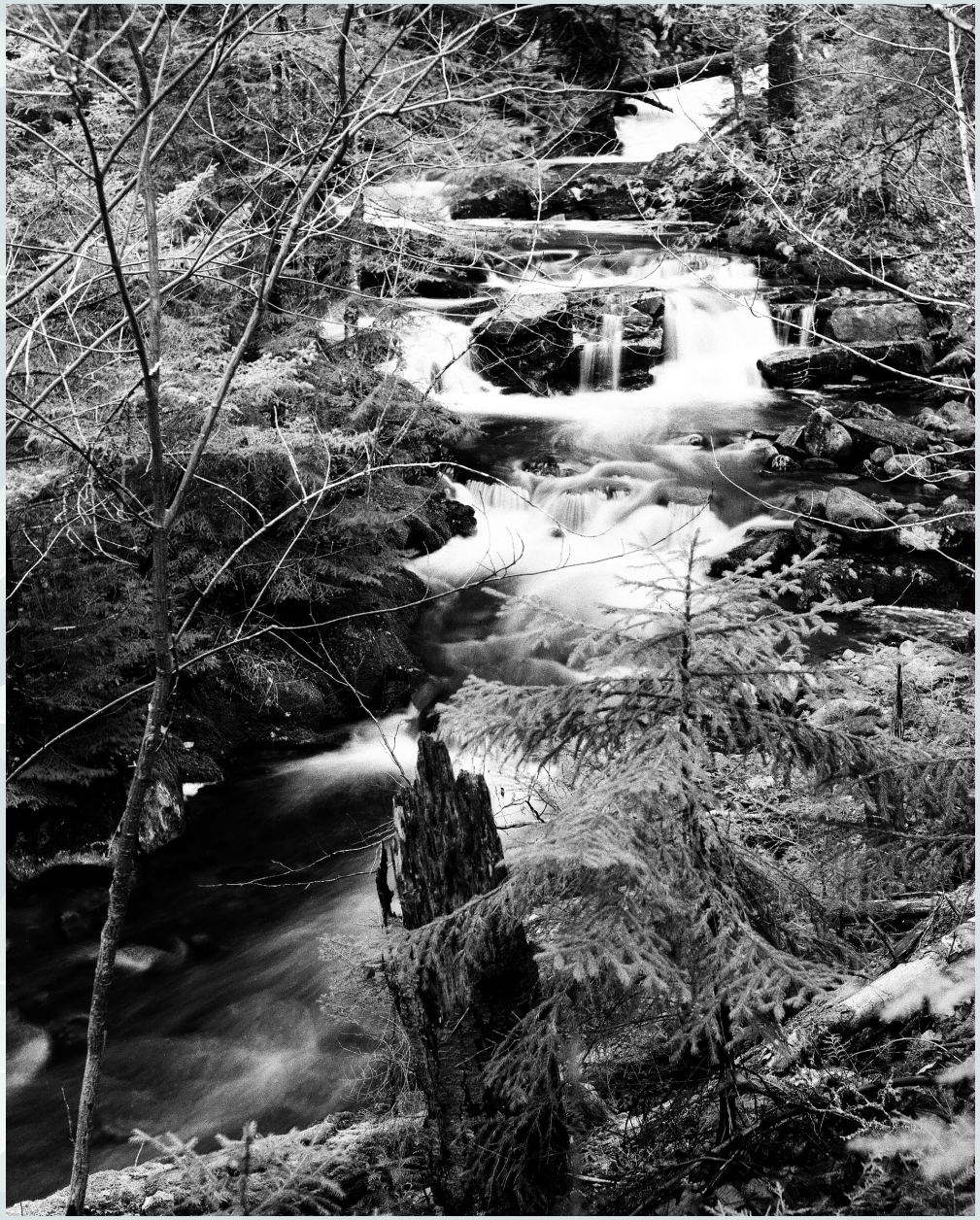


The Northern Forest (NY, VT, NH, ME)

- Dramatic changes in land ownership starting in the mid-1980s
- High-grading and diameter limit cutting have been frequent (Nyland 1992, Belair and Ducey 2018)
- Nearly 40% of forest land base has stocking that impairs delivery of ecosystem services ("degraded;" Gunn et al. 2019)
- Can we restore ecosystem functions and services, functional diversity, and resiliency?

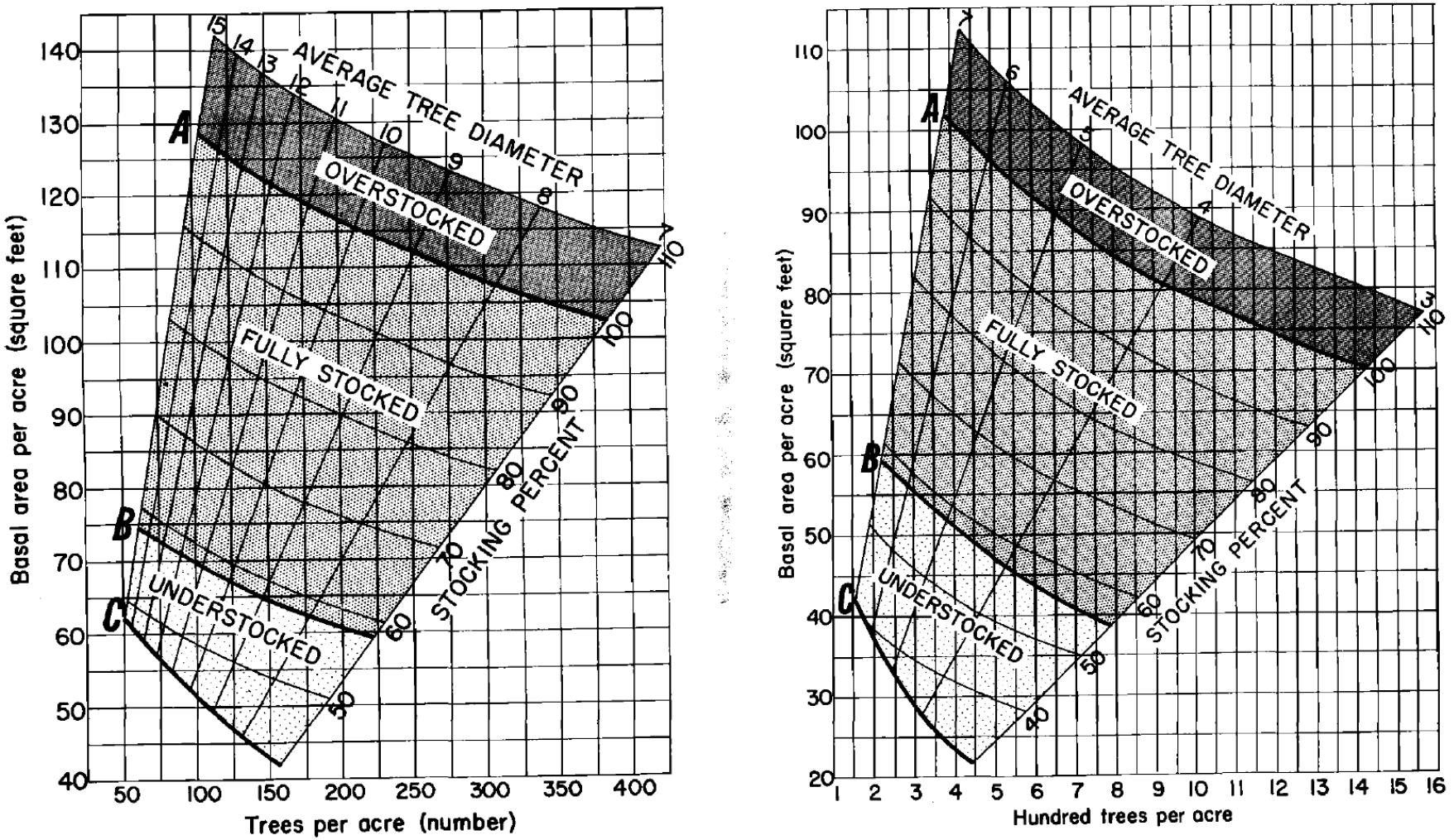


FIGURE 4. *Relation of basal area, number of trees, and average tree diameter to stocking percent for upland hardwood forests of average uniformity. Tree-diameter range 7–15 (left), 3–7 (right). The area between curves A and B indicates the range of stocking where trees can fully utilize the growing space. Curve C shows the lower limit of stocking necessary to reach the B level in 10 years on average sites. (Average tree diameter is the diameter of the tree of average basal area.)*

Using Ducey-Knapp (2010) Relative Density...

Economically Degraded

Category 1:	Meets density cutoff only counting acceptable growing stock of primary species
Category 2:	Meets density cutoff only counting acceptable growing stock of primary and secondary species
Category 3:	Meets density cutoff only counting acceptable growing stock of primary, secondary, and tertiary species
Category 4:	Requires all trees of all species and quality to meet density cutoff
Category 5:	Does not meet minimum density cutoff despite sufficient stand age

Questions

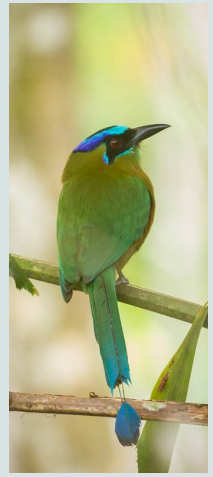
How does avian community functional diversity relate to degradation?

Is this relationship consistent across trait groups that support specific ecosystem functions and services?

What does that mean for silviculture and management?

Why Birds?

- Sensitive to rapid habitat change
- Diverse and abundant
- Easy to survey
- Provide critical ecosystem functions



Functional Diversity

Functional Traits

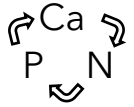
- Foraging stratum

- Percent diet seeds

- Wing length

Ecosystem Functions

- Nutrient cycling



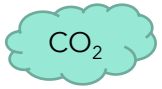
- Seed dispersal

- Pest control

Ecosystem Services

- Timber

- GHG mitigation



- Wildlife recreation

Study System

Nulhegan Basin

- NE Kingdom VT
- 26,000 acres softwood, hardwood and mixed forest
- 15 Stands

Bartlett Experimental Forest

- White Mountain NF
- 2,343 acres of softwood, hardwood and mixed forest
- 17 stands

Surveys

Bird point counts

50m, 10min

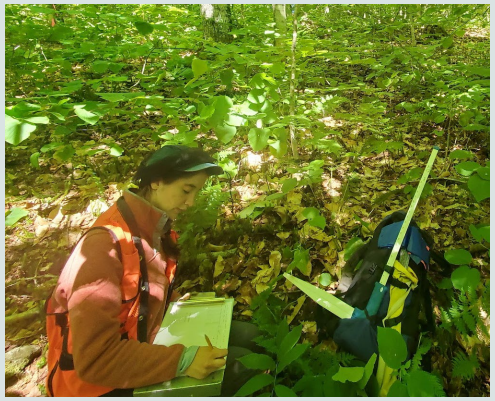
Heard or seen

Species & abundance

Vegetation surveys

Prism plots

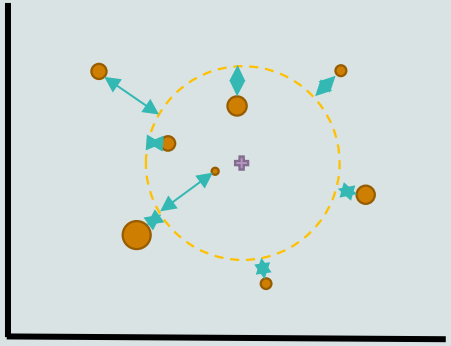
- Species
- DBH
- Tree Quality



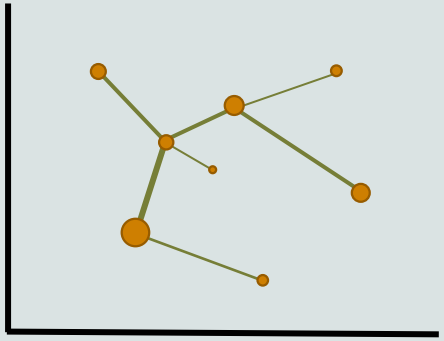
Functional Diversity Analysis

Functional Dispersion
Low FDis = underutilized resources in community

Functional Divergence
Low FDiv = poor niche differentiation; high resource competition



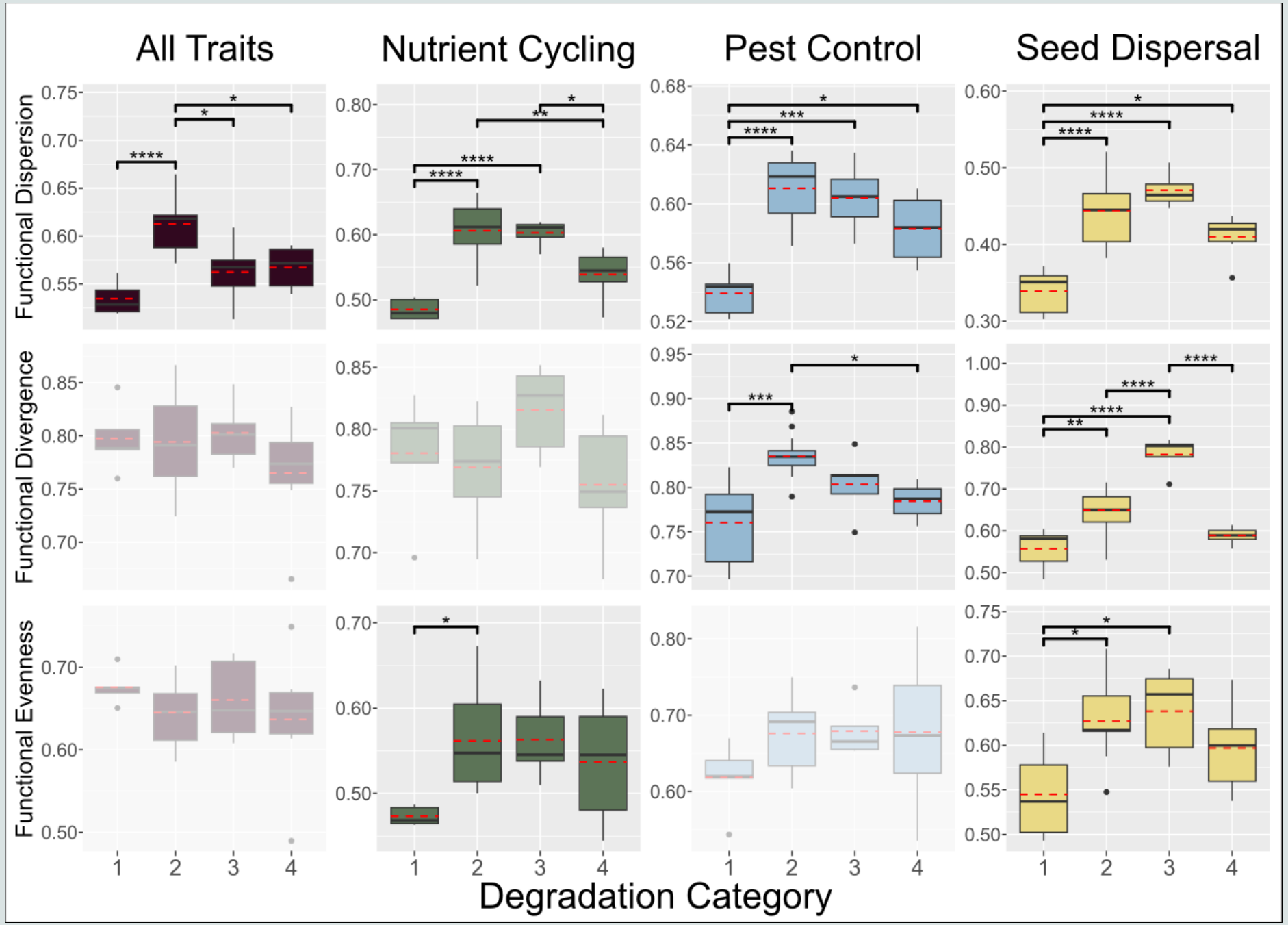
Functional Evenness
Low FEve = poor resilience to stochastic events

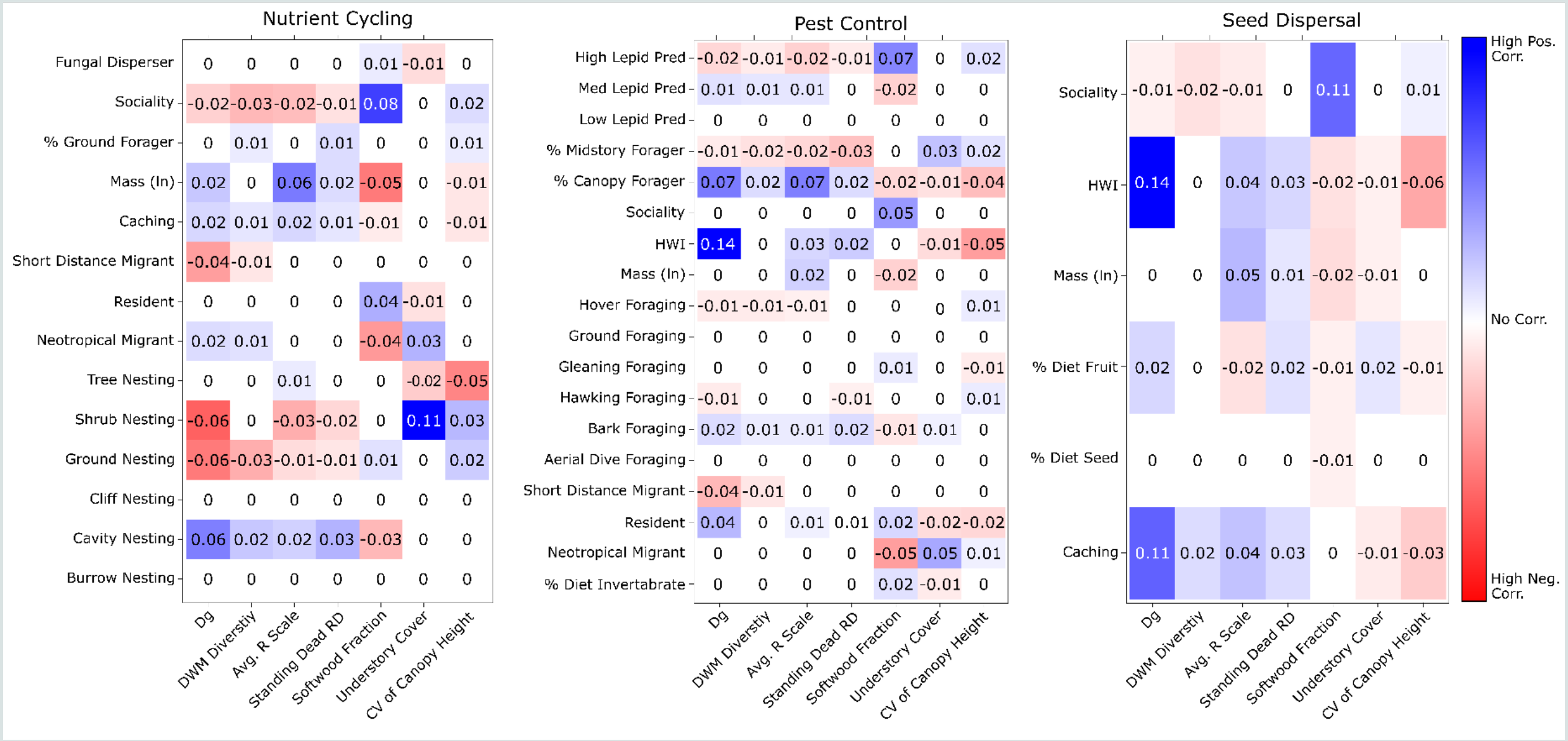


(modified from Mouillot et al. 2013

Functional Traits

Traits Matrix	
Total Traits	**Gathered From**
27	AVONET, Elton Traits, BOW, ADW
Functional Axis	**Specific Traits**
Seed Dispersal	HWI, body mass, caching , sociality, % diet fruit, % diet seed
Nutrient Cycling	HWI, body mass, % ground foraging, migrant, nest location, caching, fungal disperser, sociality
Pest Control	HWI, body mass, % diet invertebrate, % mid-story foraging, % canopy foraging, migrant, foraging strategy, lepidopteran, sociality


All Traits
Nutrient Cycling
Pest Control
Seed Dispersal
Functional Dispersion
Functional Divergence
Functional Evenness
Degradation Category


Nutrient Cycling
Fungal Disperser 0 0 0 0 0.01 -0.01 0
Sociality -0.02 -0.03 -0.02 -0.01 0.08 0 0.02
% Ground Forager 0 0.01 0 0.01 0 0 0.01
Mass (ln) 0.02 0 0.06 0.02 -0.05 0 -0.01
Caching 0.02 0.01 0.02 0.01 -0.01 0 -0.01
Short Distance Migrant -0.04 -0.01 0 0 0 0 0
Resident 0 0 0 0 0.04 -0.01 0
Neotropical Migrant 0.02 0.01 0 0 -0.04 0.03 0
Tree Nesting 0 0 0.01 0 0 -0.02 -0.05
Shrub Nesting -0.06 0 -0.03 -0.02 0 0.11 0.03
Ground Nesting -0.06 -0.03 -0.01 -0.01 0.01 0 0.02
Cliff Nesting 0 0 0 0 0 0 0
Cavity Nesting 0.06 0.02 0.02 0.03 -0.03 0 0
Burrow Nesting 0 0 0 0 0 0 0
Dg
DWM Diverstiy
Avg. R Scale
Standing Dead RD
Softwood Fraction
Understory Cover
CV of Canopy Height
Pest Control
High Lepid Pred -0.02 -0.01 -0.02 -0.01 0.07 0 0.02
Med Lepid Pred 0.01 0.01 0.01 0 -0.02 0 0
Low Lepid Pred 0 0 0 0 0 0 0
% Midstory Forager -0.01 -0.02 -0.02 -0.03 0 0.03 0.02
% Canopy Forager 0.07 0.02 0.07 0.02 -0.02 -0.01 -0.04
Sociality 0 0 0 0 0.05 0 0
HWI 0.14 0 0.03 0.02 0 -0.01 -0.05
Mass (ln) 0 0 0.02 0 -0.02 0 0
Hover Foraging -0.01 -0.01 -0.01 0 0 0 0.01
Ground Foraging 0 0 0 0 0 0 0
Gleaning Foraging 0 0 0 0 0.01 0 -0.01
Hawking Foraging -0.01 0 0 -0.01 0 0 0.01
Bark Foraging 0.02 0.01 0.01 0.02 -0.01 0.01 0
Aerial Dive Foraging 0 0 0 0 0 0 0
Short Distance Migrant -0.04 -0.01 0 0 0 0 0
Resident 0.04 0 0.01 0.01 0.02 -0.02 -0.02
Neotropical Migrant 0 0 0 0 -0.05 0.05 0.01
% Diet Invertabrate 0 0 0 0 0.02 -0.01 0
Dg
DWM Diverstiy
Avg. R Scale
Standing Dead RD
Softwood Fraction
Understory Cover
CV of Canopy Height
Seed Dispersal
Sociality -0.01 -0.02 -0.01 0 0.11 0 0.01
HWI 0.14 0 0.04 0.03 -0.02 -0.01 -0.06
Mass (ln) 0 0 0.05 0.01 -0.02 -0.01 0
% Diet Fruit 0.02 0 -0.02 0.02 -0.01 0.02 -0.01
% Diet Seed 0 0 0 0 -0.01 0 0
Caching 0.11 0.02 0.04 0.03 0 -0.01 -0.03
Dg
DWM Diverstiy
Avg. R Scale
Standing Dead RD
Softwood Fraction
Understory Cover
CV of Canopy Height
High Pos. Corr.
No Corr.
High Neg. Corr.

Forest Structure and Silviculture…

- Degradation Category 2, not Category 1, is the “sweet spot”
- High vertical heterogeneity is important at the stand scale
- Conifer cover elevates functional diversity within hardwood stands
- Relationships with standing and downed dead wood are weaker

To promote financial productivity *and* avian functional diversity…

- Don’t try to force stands up to Category 1 (canopy fully occupied by primary species)
- Huge gains from moving Category 3 and Category 4 stands to Category 2 via improvement thinning and regrowth
- Consider whether Category 5 stands have species and desirability to move to Category 2/3; if not, consider regeneration

Highest avian functional diversity is in hardwood/softwood mixtures

- Retain quality softwoods of desirable species (e.g. white pine, red spruce) when thinning hardwood stands
- This can help move toward Category 2 *and* provide habitat features that support functional diversity
- Don’t overdo it! A diversity of stands *across* the landscape is important… don’t wreck good-quality hardwood or softwood stands trying to achieve mixture at fine scales

Vertical structure matters, but…

- Across most sites in this landscape, single-tree selection promotes beech, which is generally undesirable and now under forest health threat
- Indiscriminate “selective” harvesting is what got us here to start with
- Stratified, single-cohort mixtures work well in this region – and provide key early-successional habitat at young stages
- Cumulative effects of beech leaf disease, hemlock wooly adelgid, spruce budworm are of serious concern

What about dead wood?

- Many studies show a strong influence of standing and downed dead wood on avian communities
- Dead wood *diversity*, not just quantity, may be important
- Fostering dead wood diversity requires maintaining stocks of large-diameter dead wood
- You can’t have large-diameter dead wood without large-diameter live trees

Yes, we can have timber *and* functionally-diverse avian communities

- Avian functional diversity supports key ecosystem functions, that in turn lead to services
- Sound silviculture with attention to structural habitat variables can also restore degraded stands

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