The Hardwood Ecosystem Experiment: Functional Diversity

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The HEE and Functional Diversity: Outline

- HEE project overview and experimental design
- Functional diversity and its applications
- Some preliminary results
- Future directions and discussion
HEE Objectives

1. Develop silvicultural systems that maintain oak dominated forests

2. Determine the impacts of these systems on ecological communities

3. Determine the impacts of these systems on human communities

4. Develop tools to engage the public regarding forest management and ecosystem health

Source: Kalb and Mycroft 2013
Nine experimental units located in Morgan-Monroe and Yellowwood State Forests
- Research core: 190-270 ac
- Buffer area: 540-975 ac

20 miles between northernmost and southernmost units

Three management systems:
- Even-aged
- Uneven-aged
- Control (no harvest)

Buffer areas managed by single-tree selection
Even-aged units:
- Clear-cuts (10 ac; 4 ha)
- Shelterwood (10 ac)
- “No harvest” matrix

Uneven-aged units:
- Patch-cuts (1-5 ac; 0.4-2.0 ha)
- Single-tree selection matrix

Control units:
- No harvesting in research core
- Single-tree selection buffer
Patch-cut: 3 ac

Spring 2008 (pre-harvest)

Fall 2008 (post-harvest)

Spring 2009 (0.5 years)

Spring 2010 (1.5 years)

Spring 2011 (2.5 years)

Photos by John Maxwell, Indiana DNR
The Many Taxa of the HEE

Breeding Birds
- Sampled in all 9 units
- 9 surveys since 2006
- 91 species (2006-2012)
- 47,471 observations ('06-'12)

Moths
- Sampled in 3 units (MMSF)
- 7 surveys since 2007
- 318 species (2007-2013)
- 38,453 captures ('07-'13)

Bats
- Sampled in all 9 units
- 8 surveys since 2006
- 7 species

Wood-boring Beetles
- Sampled in all 9 units
- 7 surveys since 2006
- 120 species

Trees
- Sampled in all 9 units
- 2 surveys (pre- & post-harv.)
- 144 species (incl. shrubs)
- ~ 50,000 records

Note: there are many others! My work so far has focused on these five due to their trait diversity and availability of trait data.

Photos: Keith Summerville (moth), Ashley Kissick (beetle)
Disturbance in Forest Ecosystems

- Historic disturbance regimes
  - Wind
  - Fire

- Functional traits of trees that are linked to succession
  - Seed size
  - Wood density
  - Nutrient uptake rate

- Resource pulses are associated with disturbance
Stacked Ecological Disturbances

Planned

Unplanned

Source: National Climatic Data Center, NOAA
Species Diversity

Species Richness: number of species

Species Evenness: distribution of species among individuals

Species Diversity: Richness x Evenness
## Functional Diversity

<table>
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<th>Species</th>
<th>Body mass (g)</th>
<th>Generation length (y)</th>
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<tbody>
<tr>
<td>Cerulean warbler</td>
<td>9.04</td>
<td>3.6</td>
</tr>
<tr>
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<td>42.6</td>
<td>4.9</td>
</tr>
<tr>
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<td>286.6</td>
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<td>1101.2</td>
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![Graph showing body mass vs. generation length](chart.png)
**Functional Diversity**

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**Functional richness**: area of trait space filled by the community

**Functional evenness**: how evenly do species fill the trait space?

**Functional divergence**: how similar in trait values are the most abundant species?
## Functional Traits: Birds

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<th>Trait Category</th>
<th>Taxa-specific Trait</th>
<th>Northern Cardinal</th>
<th>Scarlet Tanager</th>
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<tbody>
<tr>
<td>Body size</td>
<td>Body mass</td>
<td>42.6 g</td>
<td>28.2 g</td>
</tr>
<tr>
<td>Diet</td>
<td>Diet</td>
<td>70% plants &amp; seeds</td>
<td>80% invertebrates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20% invertebrates</td>
<td>10% fruit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10% fruit</td>
<td>10% plants &amp; seeds</td>
</tr>
<tr>
<td>Food acquisition</td>
<td>Foraging strata</td>
<td>40% ground</td>
<td>40% mid-story</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20% understory</td>
<td>40% canopy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20% mid-story</td>
<td>10% understory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20% canopy</td>
<td>10% ground</td>
</tr>
<tr>
<td>Overwintering strategy</td>
<td>Migration</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Life history</td>
<td>Generation length</td>
<td>4.9 years</td>
<td>4.4 years</td>
</tr>
</tbody>
</table>

Photos: www.allaboutbirds.org
Functional Traits of the HEE

**Birds**
- Body Mass
- Diet
- Foraging Strata
- Migrant
- Generation Length

**Moths**
- Wingspan
- Diet Breadth
- Feeding Guild
- Overwintering Stage
- Voltinism

**Beetles**
- Body Size
- Diet Breadth
- Feeding Guild
- Overwintering stage
- Voltinism

**Bats**
- Body Mass
- Diet
- Foraging Strata
- Maximum Lifespan

**Trees**
- Maximum Height
- Seed Size
- Wood Density
- Shade Tolerance
- Drought Tolerance

Photos: Keith Summerville (moth), Ashley Kissick (beetle)
Functional Linkages

Birds
- Body Mass
- Diet
- Foraging Strata
- Migrant
- Generation Length

Moths
- Wingspan
- Diet Breadth
- Feeding Guild
- Overwintering Stage
- Voltinism

Beetles
- Body Size
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Trees
- Maximum Height
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- Shade Tolerance
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Photos: Keith Summerville (moth), Ashley Kissick (beetle)
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<tr>
<th>Trait Category</th>
<th>Taxa-specific Trait</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body size</td>
<td>Wingspan</td>
<td>1.1 – 13 cm</td>
</tr>
<tr>
<td>Diet</td>
<td>Diet breadth</td>
<td>Generalist, Specialist, Oligophagous(^a)</td>
</tr>
<tr>
<td>Food acquisition</td>
<td>Feeding guild</td>
<td>Generalist, Herbivore, Woody plant feeder, Detritivore</td>
</tr>
<tr>
<td>Overwintering strategy</td>
<td>Overwintering stage</td>
<td>Egg, Larva, Pupa</td>
</tr>
<tr>
<td>Life history</td>
<td>Voltinism(^b)</td>
<td>1, 2, or 3 generations/year</td>
</tr>
</tbody>
</table>

\(^a\) Feeds on genera within a single family
\(^b\) Generations per year

Trait sources: Keith Summerville
Moths: Species Richness

No. species/sample

Year

2007 2008 2009 2010 2011 2012 2013

Pre-harvest Post-harvest

Clear-cut  Shelterwood  No harvest: Even-aged
Patch-cut  Single-tree  No harvest: Control
Moths: Species Richness

![Graph showing species richness of moths over years, with different harvest management strategies.]
Moths: Richness, Evenness, Diversity

Species Richness

Species Evenness

Species Diversity
Moths: Functional Diversity

Functional Richness

Year

Functional Evenness

Year

Functional Divergence

Year

Clear-cut  Shelterwood  No harvest: Even-aged
Patch-cut  Single-tree  No harvest: Control
## Birds: Landscape Example

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<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body size</td>
<td>Body mass(^a)</td>
<td>3.09 - 5790 g</td>
</tr>
<tr>
<td>Diet</td>
<td>Diet(^a)</td>
<td>% Invertebrates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Birds &amp; Mammals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Reptiles &amp; Amphibians</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Fish</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Fruit</td>
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<tr>
<td></td>
<td></td>
<td>% Nectar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Seed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Plants</td>
</tr>
<tr>
<td>Food acquisition</td>
<td>Foraging strata(^a)</td>
<td>% Water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Ground</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Understory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Midstory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Canopy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Aerial</td>
</tr>
<tr>
<td>Overwintering strategy</td>
<td>Migration(^b)</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Life history</td>
<td>Generation length(^b)</td>
<td>3.4 – 10.6 years</td>
</tr>
</tbody>
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Trait sources: \(^a\) Wilman et al. 2014. Ecological Archives. \(^b\) Birdlife.org
Birds: Richness, Evenness, Diversity

Species Richness

Pre-harvest | Post-harvest | Dr
---|---|---
Even-aged | Uneven-aged | No harvest

Species Evenness

Species Diversity

Photos: Rick Bowers
Birds: Functional Diversity

Functional Richness

- Pre-harvest
- Post-harvest
- Dr

Even-aged
Uneven-aged
No harvest

Functional Evenness

Pre-harvest
Post-harvest
Dr

Functional Divergence

Pre-harvest
Post-harvest
Dr

Photos: Rick Bowers
Ongoing Research Questions

• What are the advantages and disadvantages of using species or functional diversity in assessing species change after disturbance?

• Which traits drive functional linkages among trophic levels?

• Are there thresholds of functional diversity from which the community will not return to its pre-disturbance state?

• Do stacked disturbances increase or decrease functional diversity?
Acknowledgements

• Collaborators
  • Mike Jenkins (Purdue)
  • Barny Dunning (Purdue)
  • Jeff Holland (Purdue)
  • Mike Saunders (Purdue)
  • Keith Summerville (Drake)
  • Joy O’Keefe (Indiana State)
  • Andy Meier (HEE Project Coordinator)

• Indiana DNR, Division of Forestry
• Forestry and Natural Resources, Purdue University
Questions?

- More HEE info: http://www.heeforeststudy.org/
- Bryan Murray: bdmurray@purdue.edu