

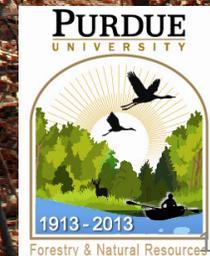
# The Hardwood Ecosystem Experiment: Functional Diversity

Bryan Murray

Postdoctoral Research Associate

Department of Forestry & Natural Resources

Purdue University



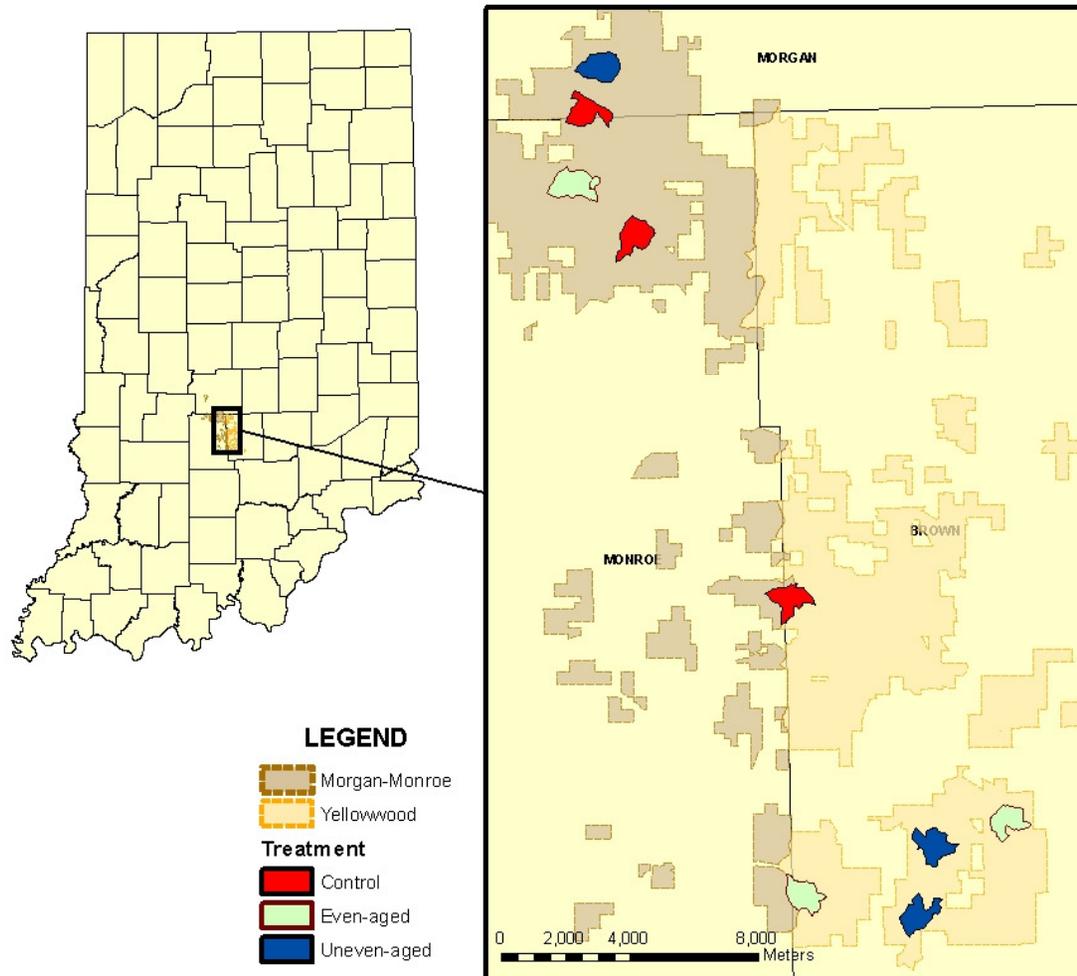
# The HEE and Functional Diversity: Outline

- 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

# HEE Experimental Design



Nine experimental units located in Morgan-Monroe and Yellowwood State Forests

- Research core: 190-270 ac
- Buffer area: 540-975 ac

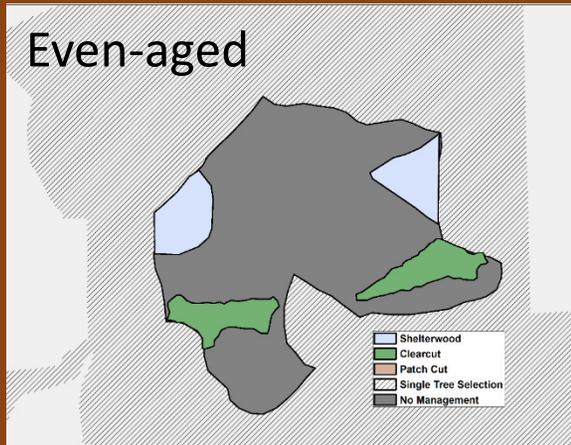
20 miles between northernmost and southernmost units

Three management systems:

- Even-aged
- Uneven-aged
- Control (no harvest)

Buffer areas managed by single-tree selection

## Even-aged



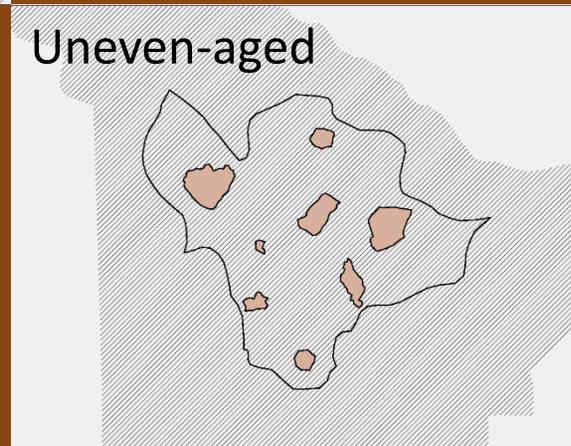
## Even-aged units:

- Clear-cuts (10 ac; 4 ha)
- Shelterwood (10 ac)
- “No harvest” matrix

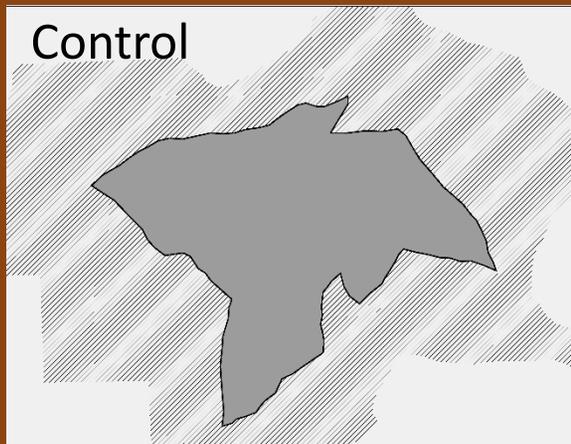
## Uneven-aged units:

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

## Uneven-aged



## Control



## 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

Clear-cut: 10 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)

## Bats

Sampled in all 9 units  
8 surveys since 2006  
7 species



## Moths

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

## Wood-boring Beetles

Sampled in all 9 units  
7 surveys since 2006  
120 species



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

## Trees

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



# Disturbance in Forest Ecosystems



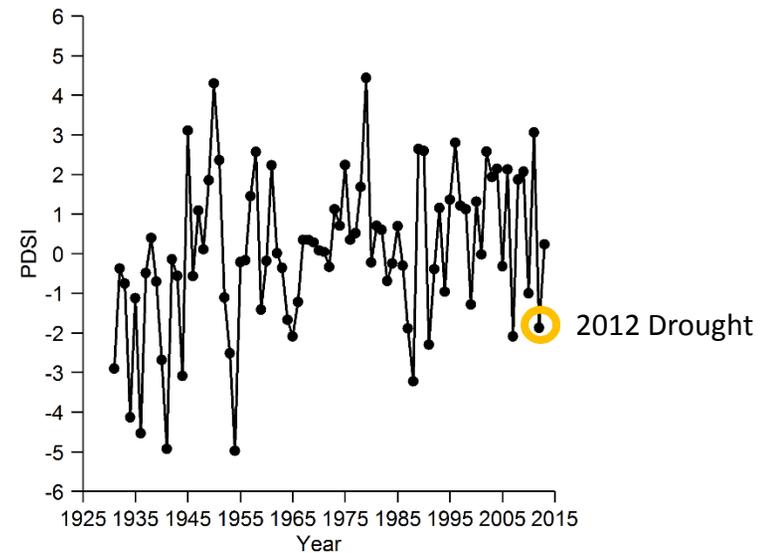
- Historic disturbance regimes
  - Wind
  - Fire
- *Functional traits* of trees that are linked to succession
  - Seed size
  - Wood density
  - Nutrient uptake rate
- Resource pulses are associated with disturbance

# Stacked Ecological Disturbances

## Planned

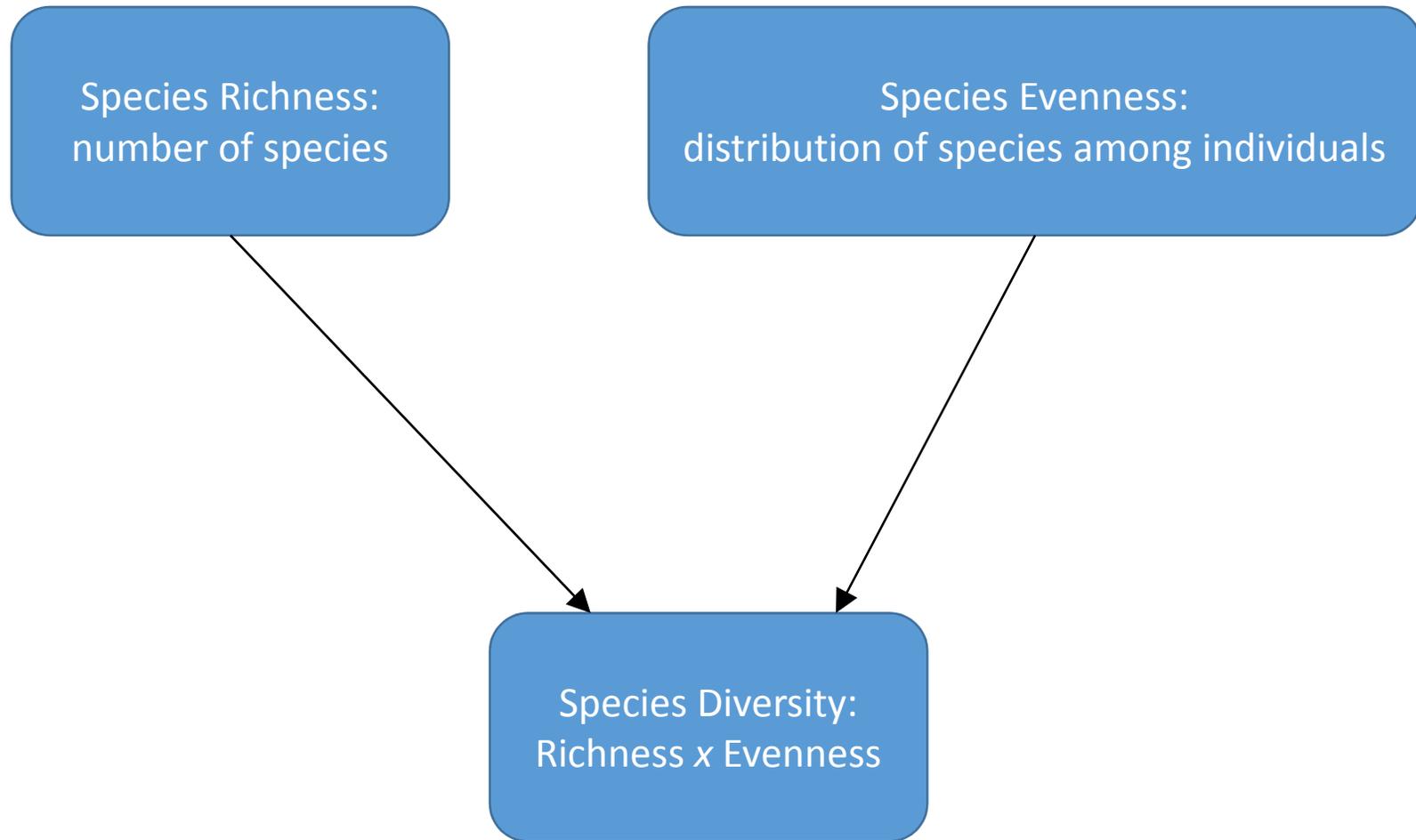


## Unplanned



Source: National Climatic Data Center, NOAA

# Species Diversity

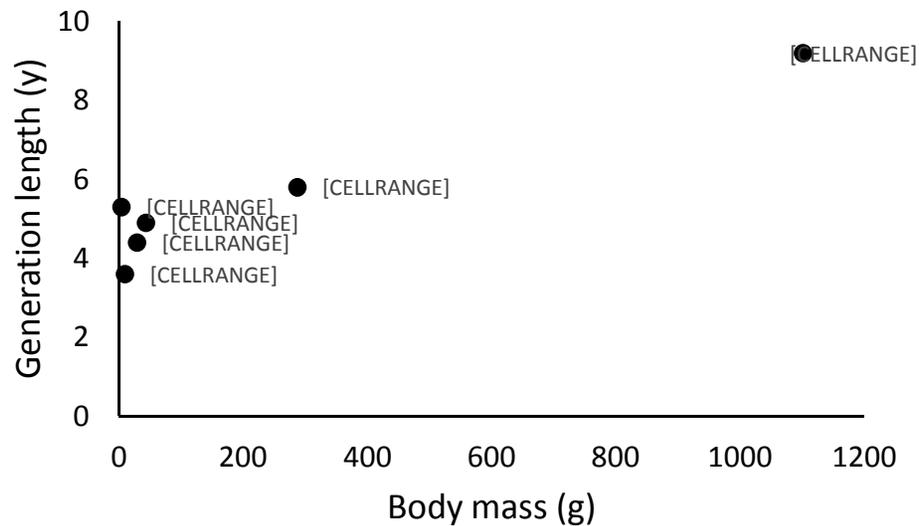


# Functional Diversity

Species	Body mass (g)	Generation length (y)
Cerulean warbler	9.04	3.6
Northern cardinal	42.6	4.9
Pileated woodpecker	286.6	5.8
Red-tailed hawk	1101.2	9.2
Ruby-throated hummingbird	3.1	5.3
Scarlet tanager	28.2	4.4

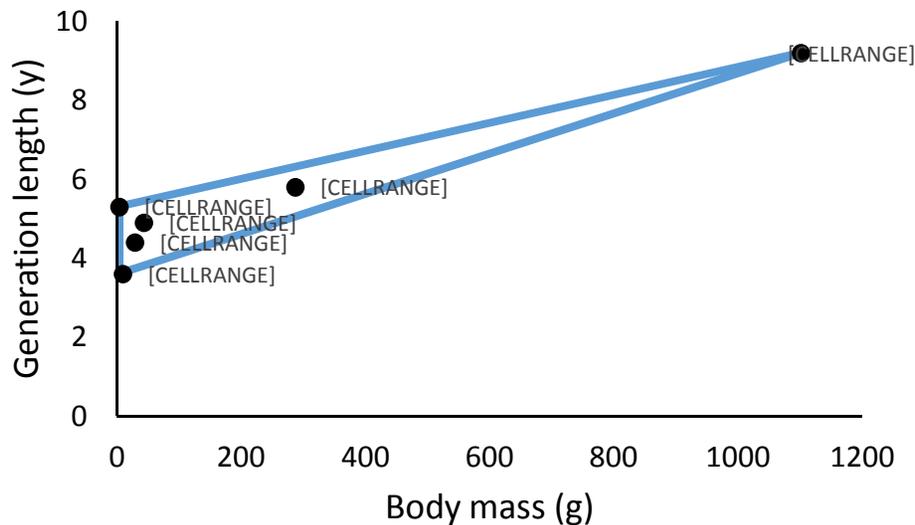
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Functional richness: area of trait space filled by the community

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

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



# Functional Traits of the HEE



## Birds

Body Mass  
Diet  
Foraging Strata  
Migrant  
Generation Length

## Bats

Body Mass  
Diet  
Foraging Strata  
Maximum Lifespan



## Moths

Wingspan  
Diet Breadth  
Feeding Guild  
Overwintering Stage  
Voltinism

## Beetles

Body Size  
Diet Breadth  
Feeding Guild  
Overwintering stage  
Voltinism

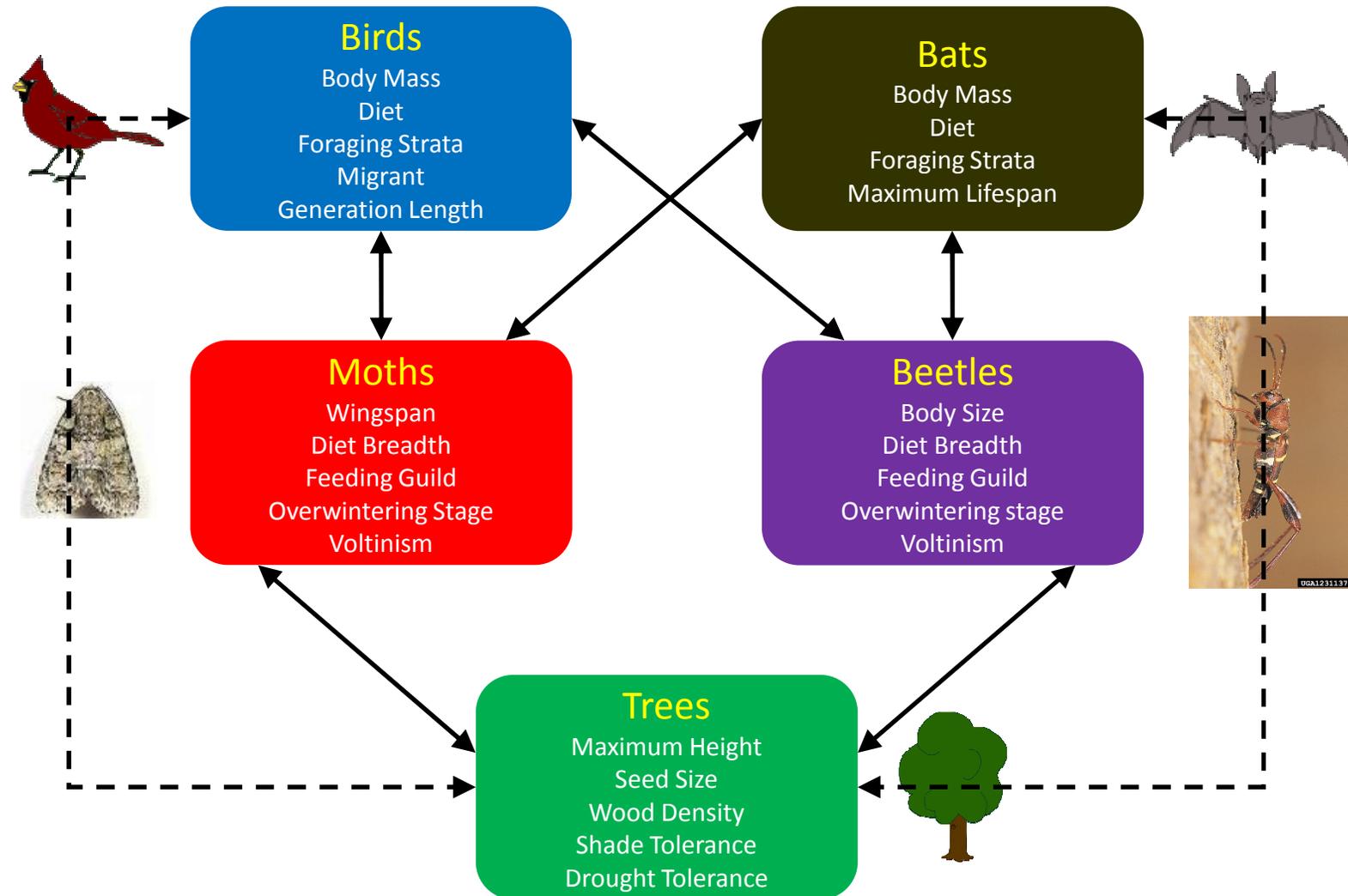


## Trees

Maximum Height  
Seed Size  
Wood Density  
Shade Tolerance  
Drought Tolerance



# Functional Linkages



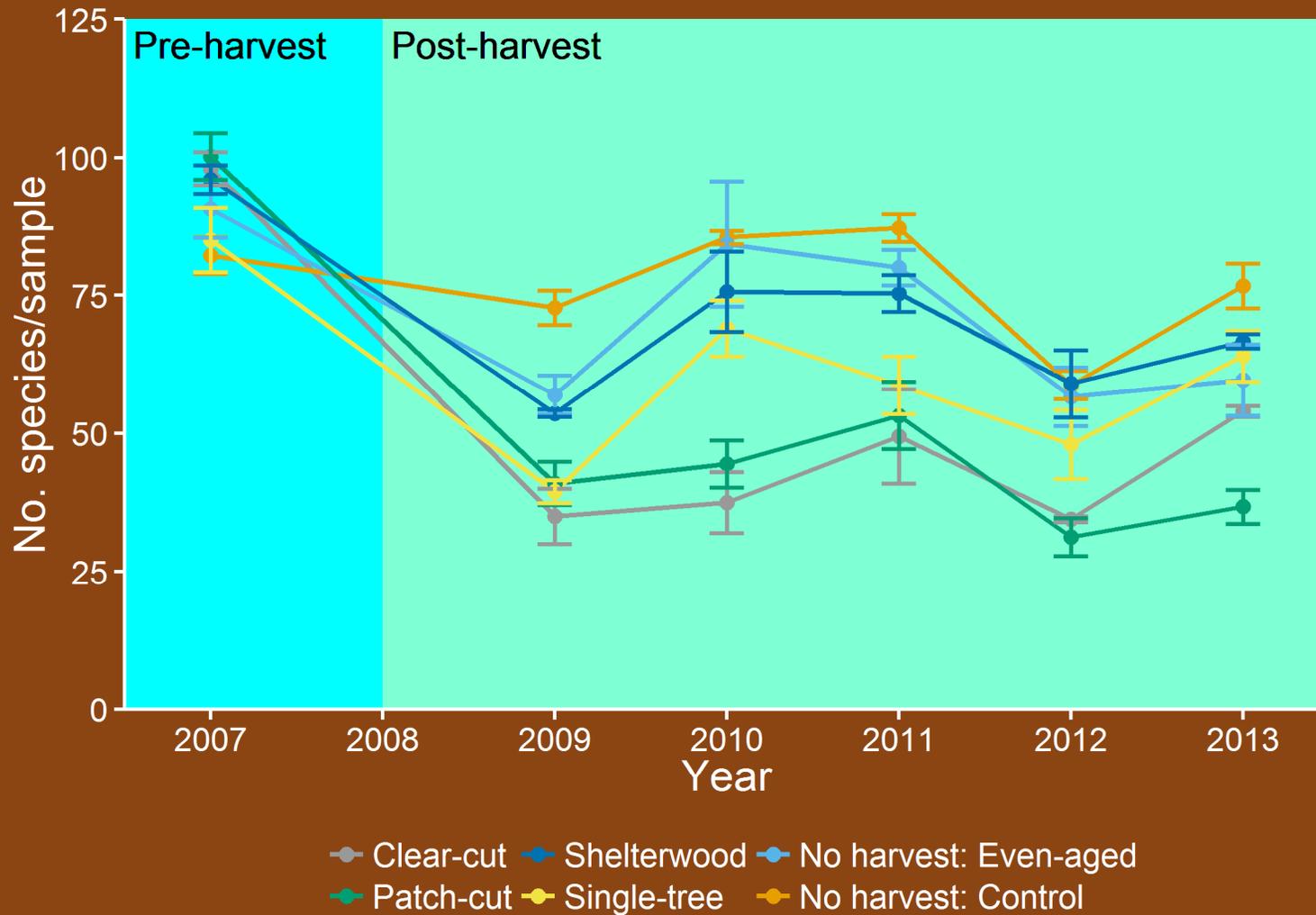
# Moths: Harvest Level Example

Trait Category	Taxa-specific Trait	Range
Body size	Wingspan	1.1 – 13 cm
Diet	Diet breadth	Generalist Specialist Oligophagous <sup>a</sup>
Food acquisition	Feeding guild	Generalist Herbivore Woody plant feeder Detritivore
Overwintering strategy	Overwintering stage	Egg Larva Pupa
Life history	Voltinism <sup>b</sup>	1, 2, or 3 generations/year

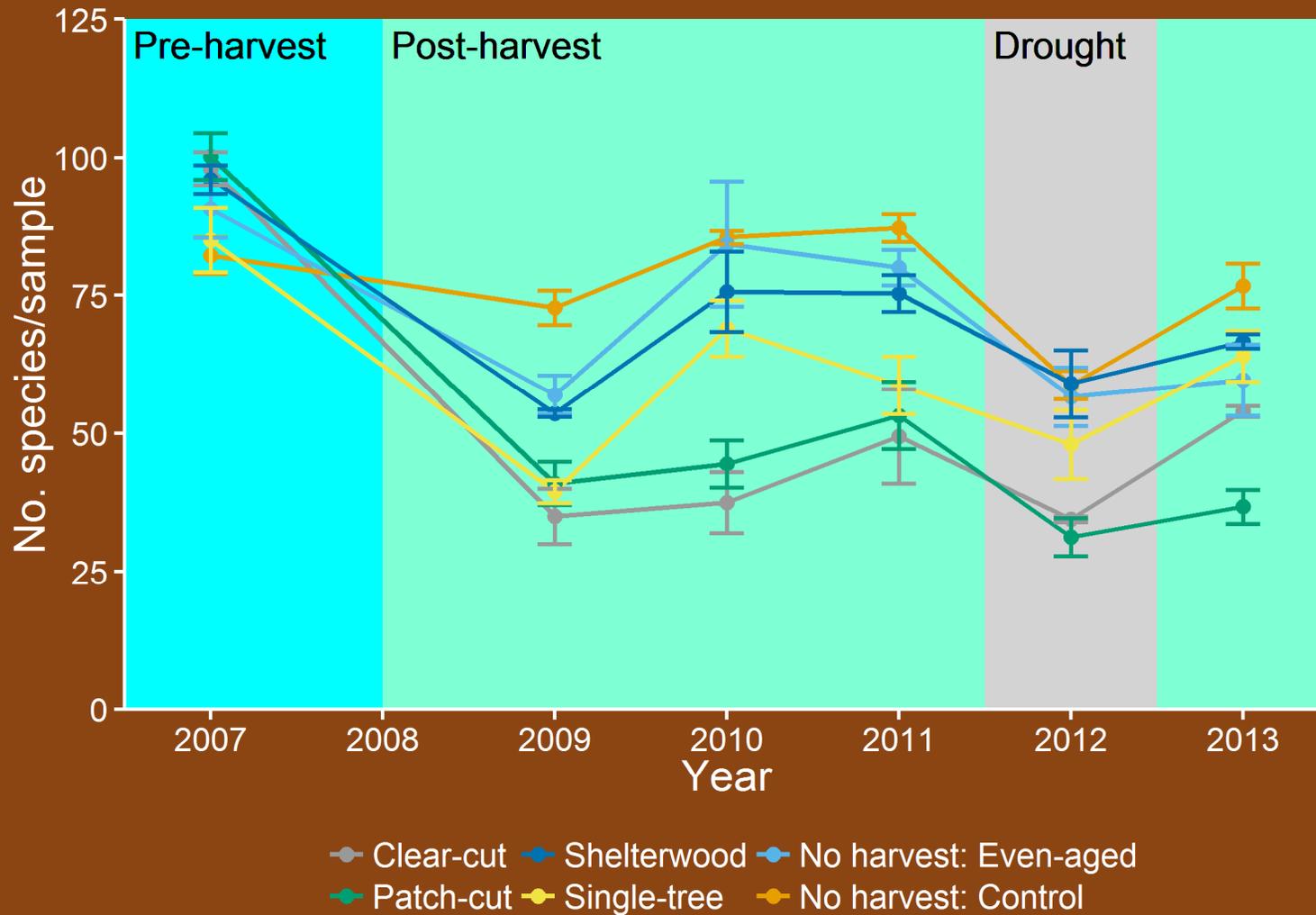
<sup>a</sup>Feeds on genera within a single family

<sup>b</sup>Generations per year

# Moths: Species Richness

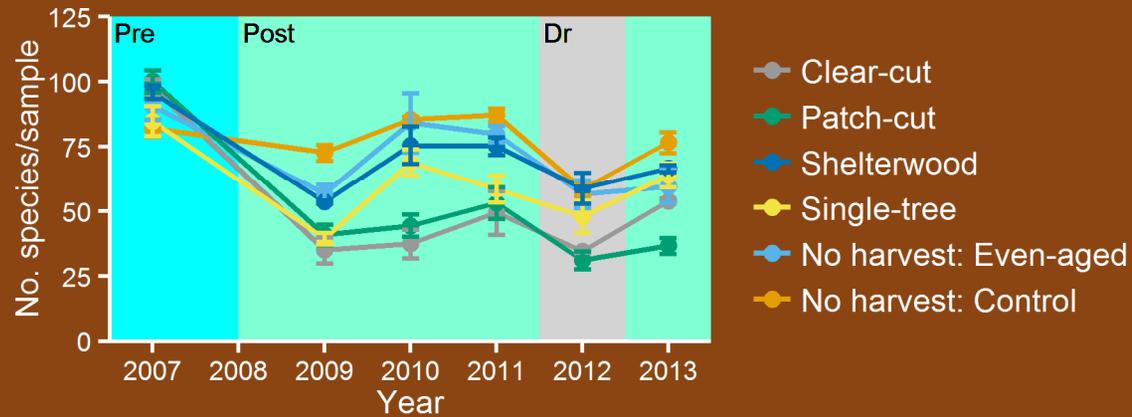


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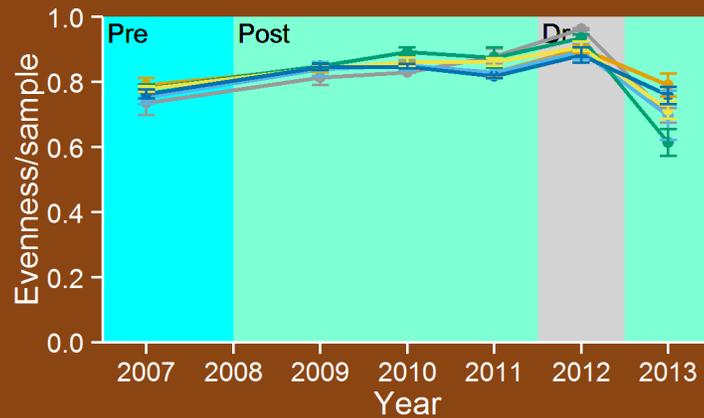


# Moths: Richness, Evenness, Diversity

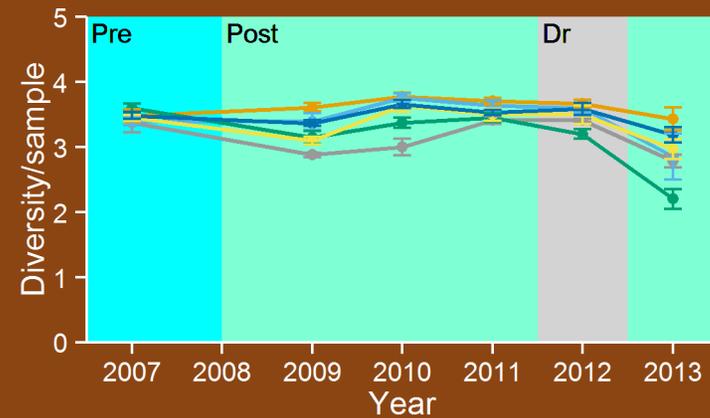
## Species Richness



## Species Evenness

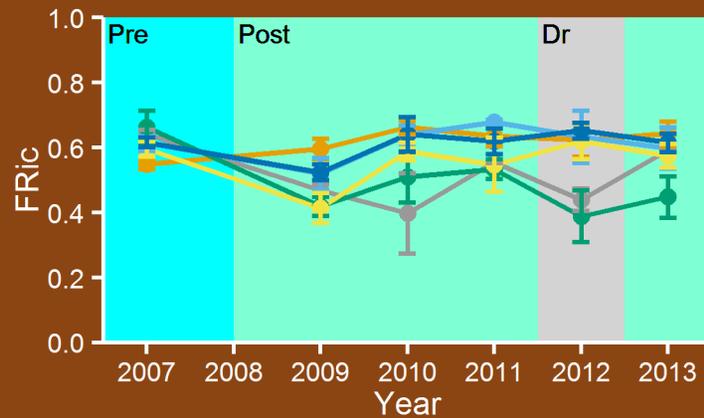


## Species Diversity

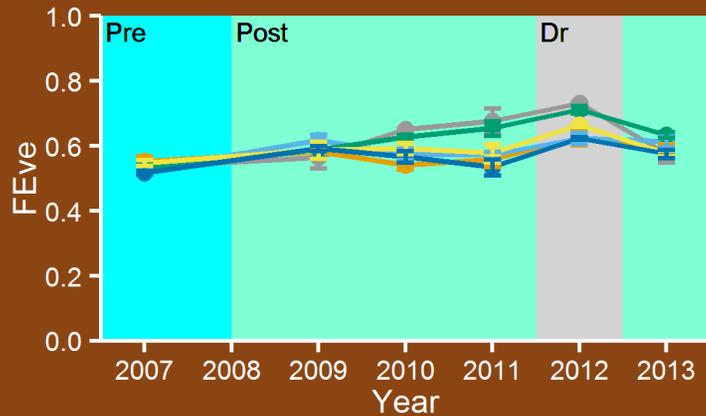


# Moths: Functional Diversity

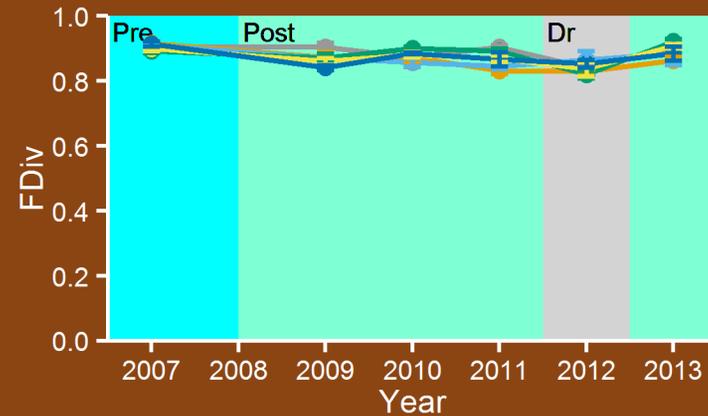
Functional Richness



Functional Evenness



Functional Divergence



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

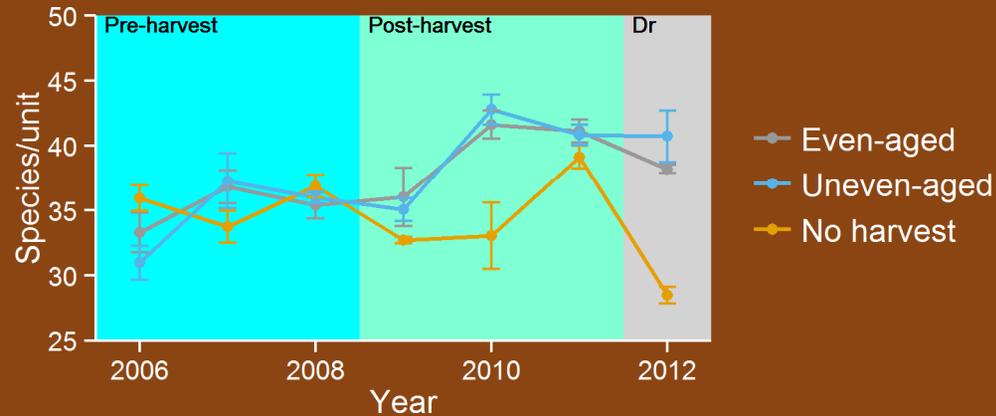
# Birds: Landscape Example

Trait Category	Taxa-specific Trait	Range
Body size	Body mass <sup>a</sup>	3.09 - 5790 g
Diet	Diet <sup>a</sup>	% Invertebrates % Birds & Mammals % Reptiles & Amphibians % Fish % Fruit % Nectar % Seed % Plants
Food acquisition	Foraging strata <sup>a</sup>	% Water % Ground % Understory % Midstory % Canopy % Aerial
Overwintering strategy	Migration <sup>b</sup>	Yes/No
Life history	Generation length <sup>b</sup>	3.4 – 10.6 years

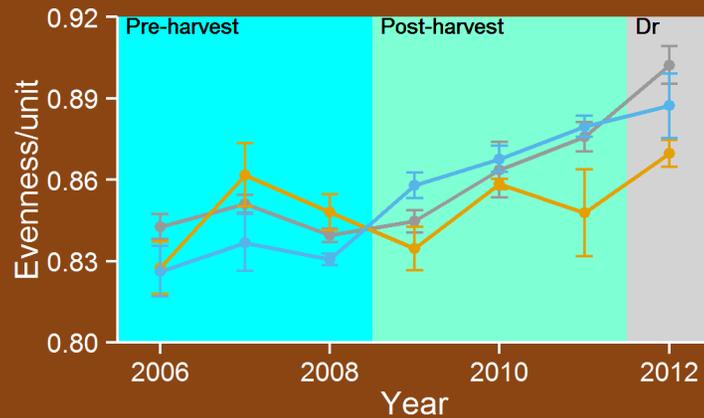
Trait sources: <sup>a</sup>Wilman et al. 2014. Ecological Archives. <sup>b</sup>Birdlife.org

# Birds: Richness, Evenness, Diversity

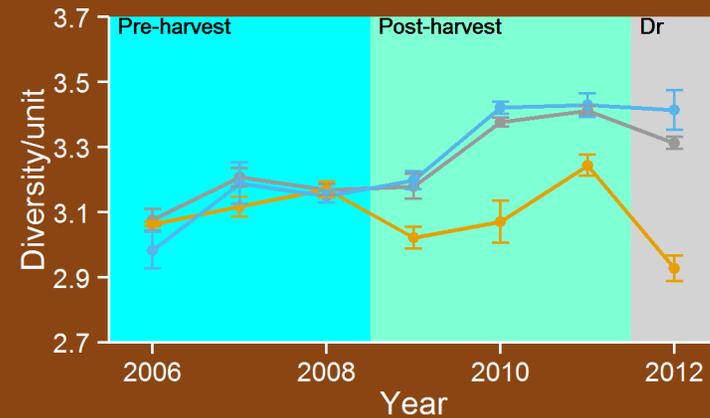
## Species Richness



## Species Evenness

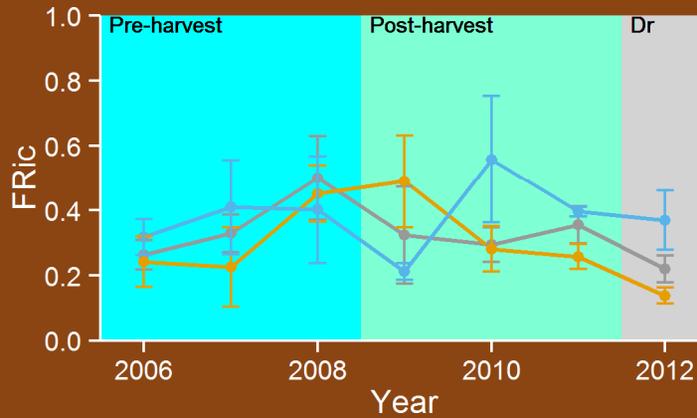


## Species Diversity

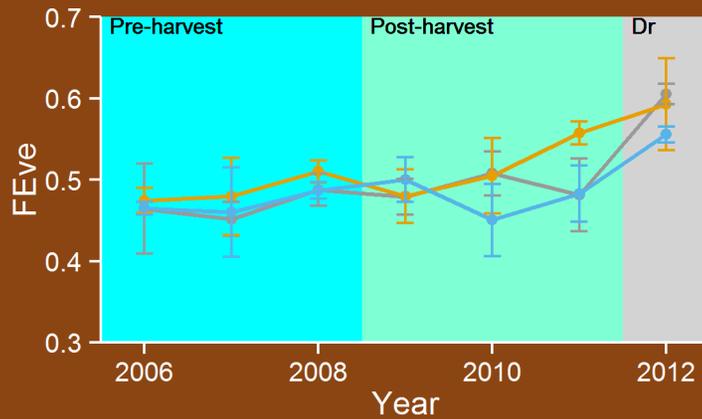


# Birds: Functional Diversity

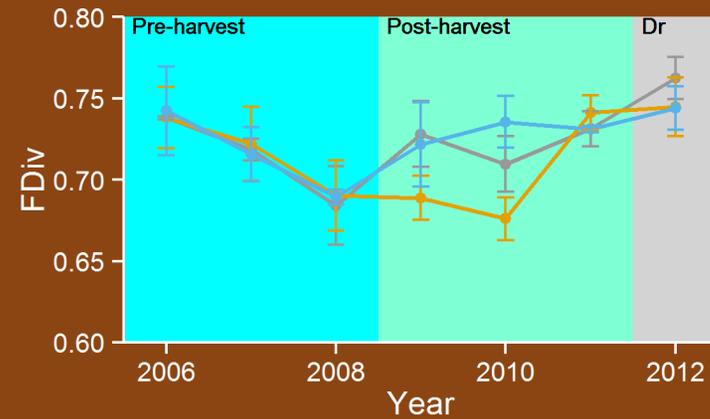
## Functional Richness



## Functional Evenness



## Functional Divergence



# 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

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  - Mike Jenkins (Purdue)
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  - Mike Saunders (Purdue)
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  - 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](mailto:bdmurray@purdue.edu)