Restoration Monitoring of Indiana Riparian Hardwood Ecosystems

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U.S. Department of the Interior
U.S. Geological Survey

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Natural Resource Damage Assessment & Restoration Program

Restoration Program

U.S. Fish & Wildlife Service

Balancing Ecosystem Characterization Intensity with Level-of-Effort to Design Restoration Monitoring

U.S. Department of the Interior
U.S. Geological Survey

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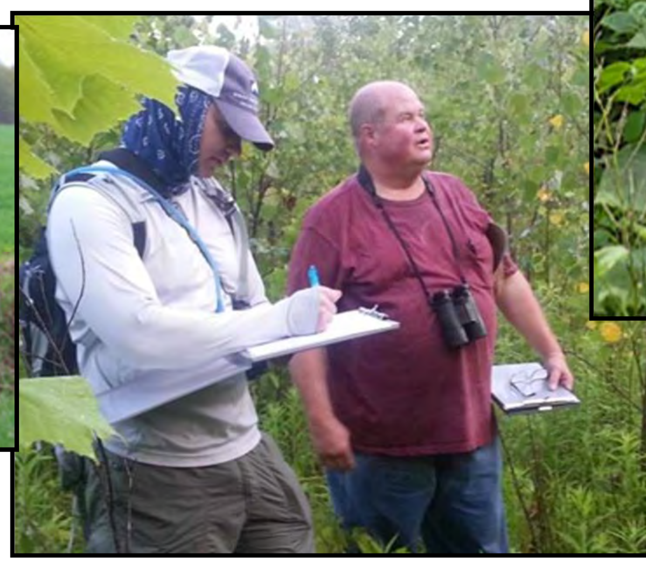
Presentation Outline

Restoration Monitoring - Needs and Realities

Field sites and focal study areas

Riparian hardwood restoration study - assessing acquired information with varying levels-of-effort

Examples of Results - Vegetation and Mammal Communities



Designing and Implementing a Monitoring Plan

What should be monitored?

1. **Baseline Monitoring**

   "But for contamination" (NRDAR)

   Pre-restoration and Reference

2. **Implementation / Compliance Monitoring**

   Performance Standards

   Rarely proceeds further than here

3. **Effectiveness Monitoring**

   Performance Criteria w/ Adaptive Management

4. **Validation Monitoring**

   Causal Relationships

How can we increase post-implementation monitoring to better assess progress and increase learning?

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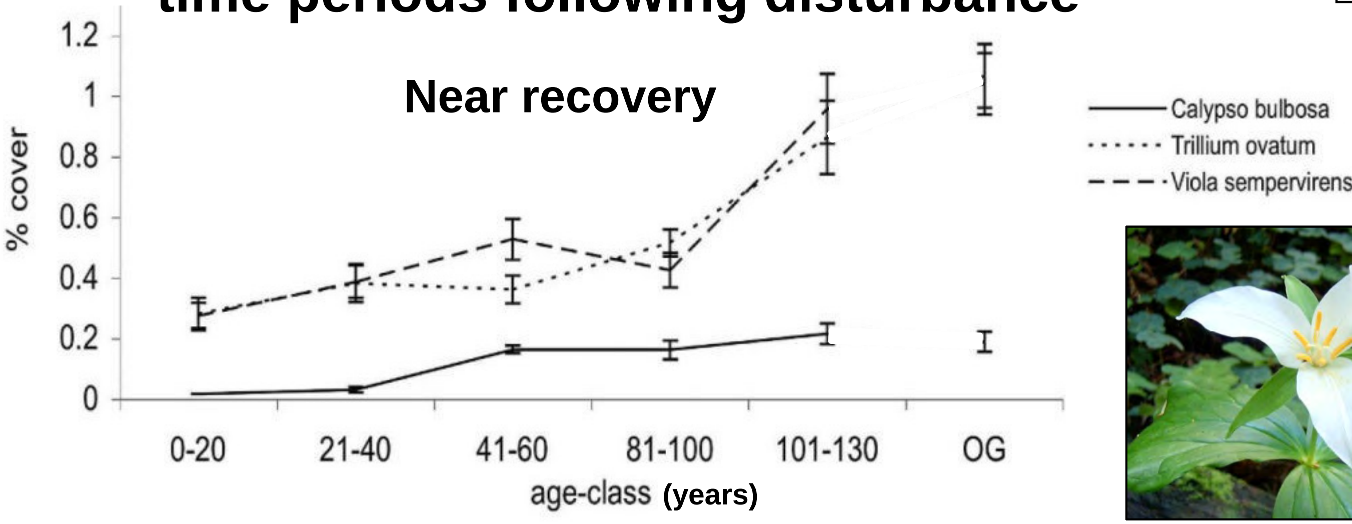
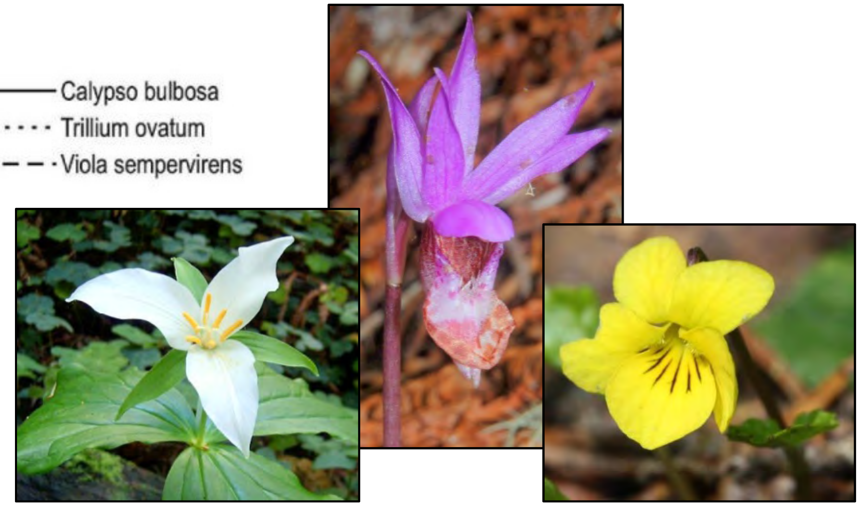
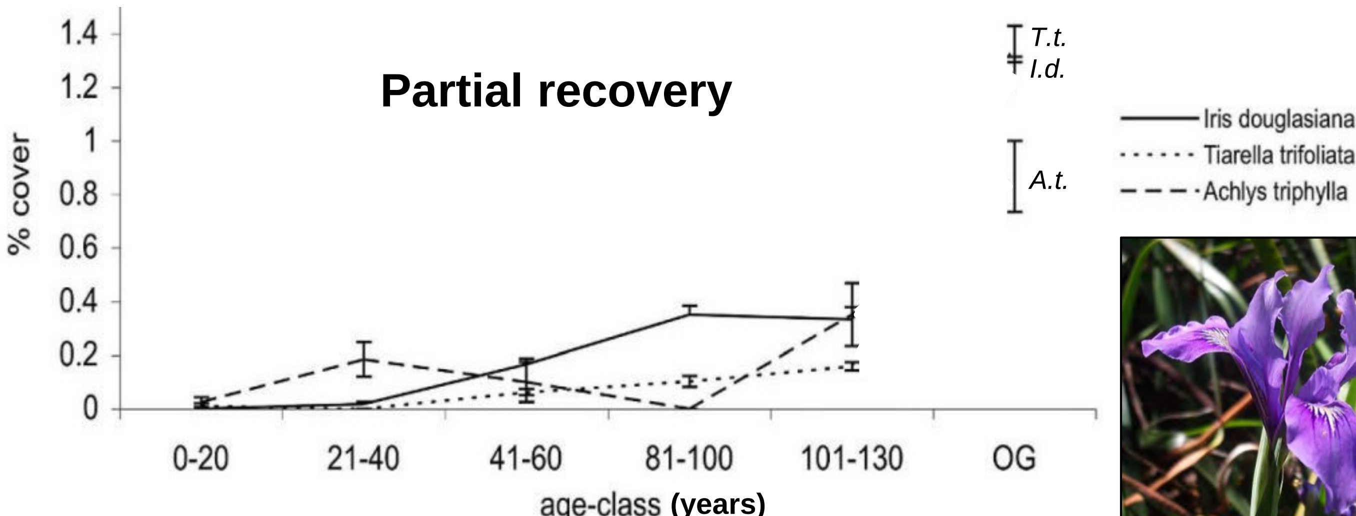
Designing and Implementing a Monitoring Plan

Monitoring Duration - Chronosequences show ecosystem recovery can require long time periods following disturbance

Redwood Forest Recovery







Russell & Hageseth Michels 2010 - MADROÑO, Vol. 57, pp. 229–241

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Hardwood Forest Restoration Monitoring

Overall Project Goals:

- **Assess the progress of afforestation in NRDA restorations**
  - **A range of ecological elements - Soils, vegetation, trees, wildlife**
  - **Methods from thorough (expensive) to rapid (not expensive)**
  - **Evaluate information gained vs. level-of-effort to determine detail required to assess restoration progress and management needs**
- **Relate biotic and abiotic elements to ecological function and ecosystem services**
- **Assess post-restoration recovery in the context of restoration goals and baseline and reference ecosystems in the region**
- **Provide site managers with data necessary to inform additional management options to achieve restoration goals**

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***Focus of this presentation*: Can we optimize sampling effort at lower levels to encourage increased monitoring?**

NE Indiana Watersheds

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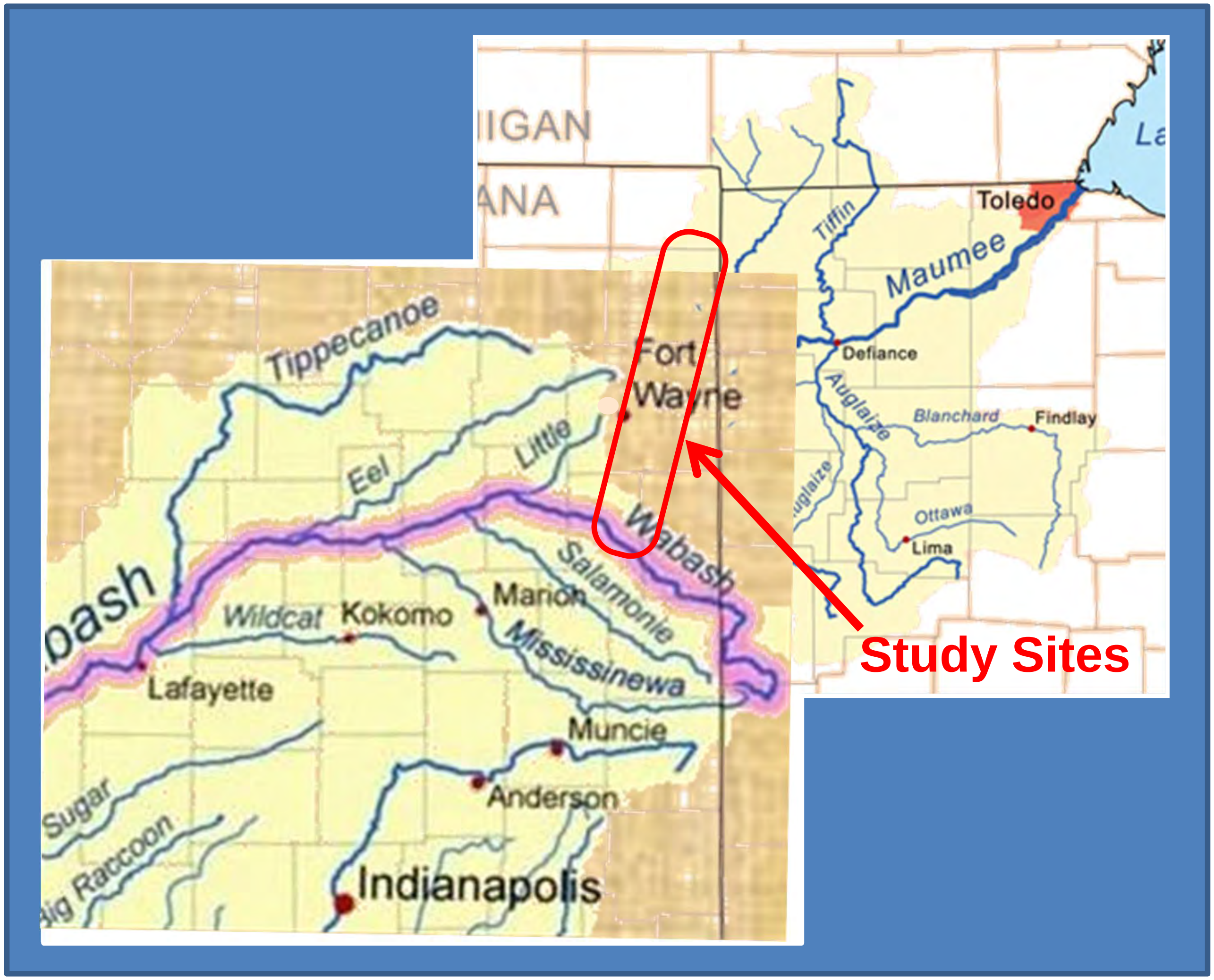
NE Indiana Watersheds

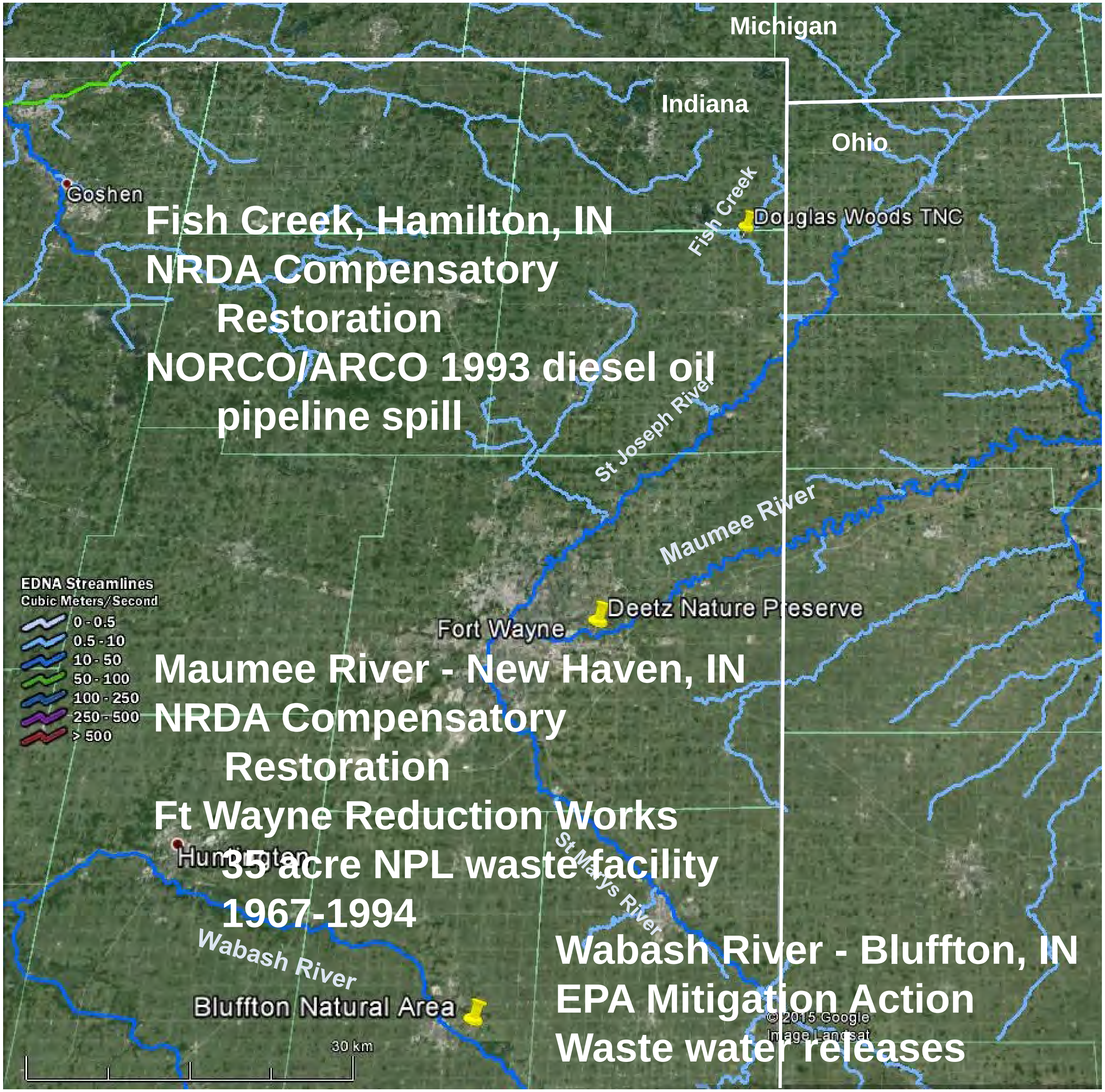


Three Riparian Study Sites Of Interest

Douglas Woods / Fish Creek (The Nature Conservancy)

Deetz Nature Preserve (New Haven Parks & Recreation)

Bluffton Native Habitat Waterway (City of Bluffton)



NRDA Restoration Goals for Riparian Hardwood Reforestation Sites
(Based on Consent Decrees and Restoration Plans)

- Broad, general and focused on recovery of injured resources
- Regeneration of lost forest habitat
- Recovery of fish and wildlife resources associated with sites
- Restoration of migratory bird habitat
- Reduction of sediment and nutrient run-off to protect aquatic resources in adjacent water bodies.

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Fish Creek Restorations

The Nature Conservancy

Restoration Objectives:

- Flood storage
- Forest habitat
- Improve water quality:
  - + infiltration
  - + retention
  - – soil runoff
  - + nutrient processing

700 acres reforested along the fish creek riparian corridor

T&E Species:

Copper belly water snake

Clubshell, Northern riffleshell &

White cat's paw pearly mussels

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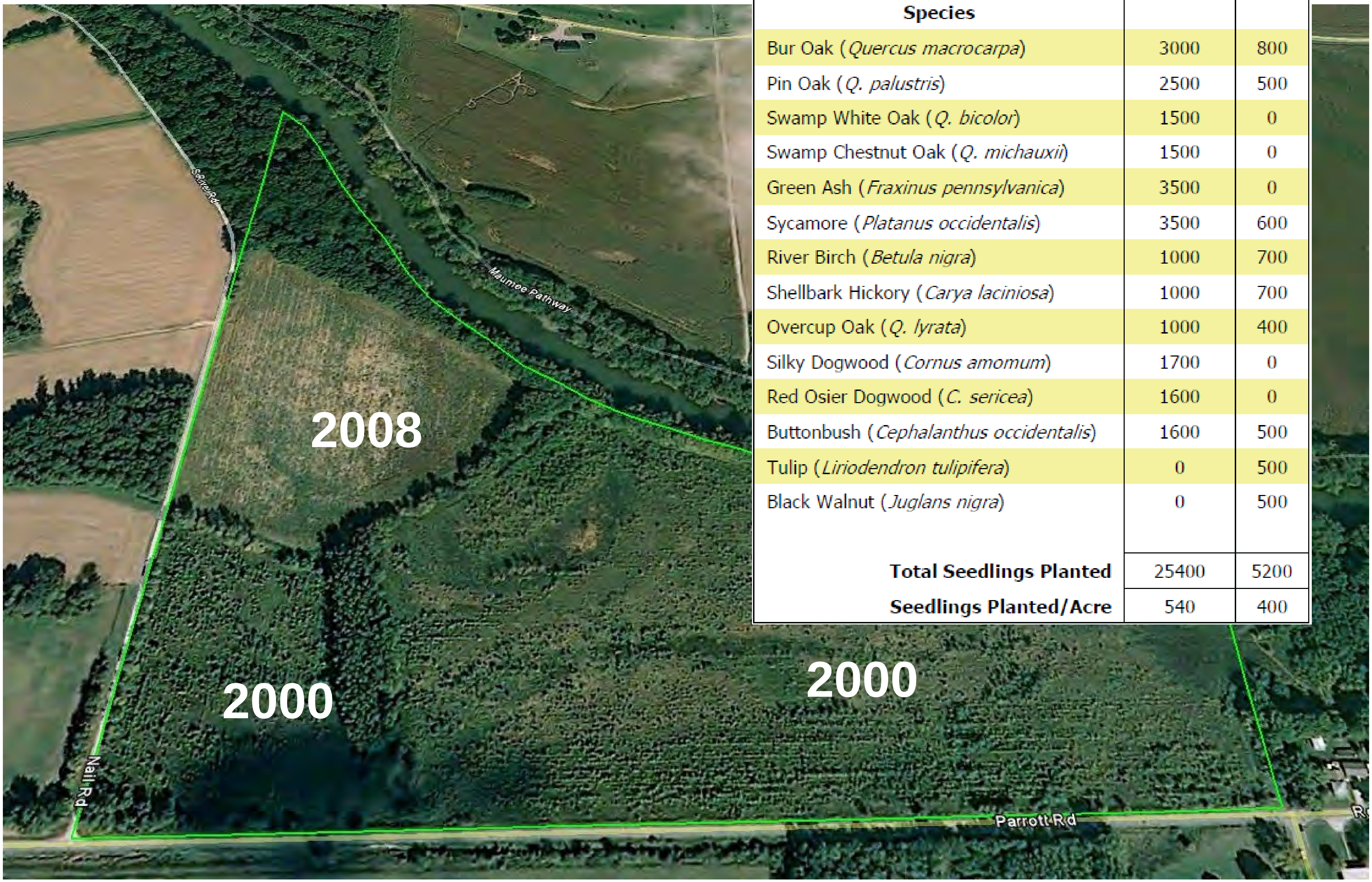
Deetz Nature Preserve - Maumee River

Deetz Nature Preserve
Maumee River



Year Planted	2000	2008
Acres Planted	~47	~13
Species		
Bur Oak (*Quercus macrocarpa*)	3000	800
Pin Oak (*Q. palustris*)	2500	500
Swamp White Oak (*Q. bicolor*)	1500	0
Swamp Chestnut Oak (*Q. michauxii*)	1500	0
Green Ash (*Fraxinus pennsylvanica*)	3500	0
Sycamore (*Platanus occidentalis*)	3500	600
River Birch (*Betula nigra*)	1000	700
Shellbark Hickory (*Carya laciniosa*)	1000	700
Overcup Oak (*Q. lyrata*)	1000	400
Silky Dogwood (*Cornus amomum*)	1700	0
Red Osier Dogwood (*C. sericea*)	1600	0
Buttonbush (*Cephalanthus occidentalis*)	1600	500
Tulip (*Liriodendron tulipifera*)	0	500
Black Walnut (*Juglans nigra*)	0	500
Total Seedlings Planted	25400	5200
Seedlings Planted/Acre	540	400

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75 acres total
60 acres restored

2000 planting - 47 acres, 540 seedlings/acre
2008 planting - 13 acres, 400 seedlings/acre

Deetz Nature Preserve - Maumee River

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Riparian buffering effect reduces sediment/nutrient load to adjacent Maumee River, improving habitat for beneficial aquatic plants, insects, and bottom-dwelling fish.

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Bluffton Native Habitat Waterway - Wabash River

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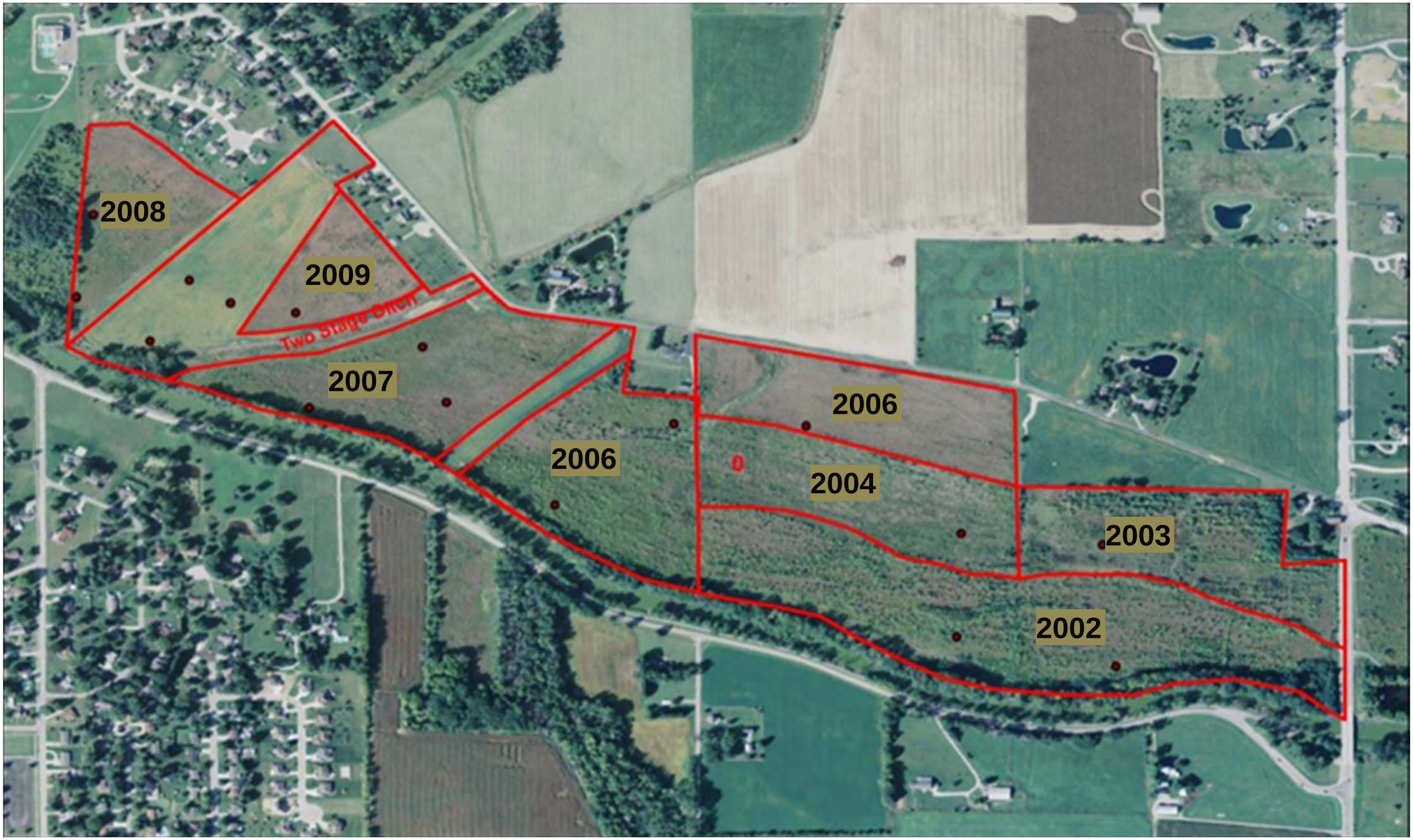
Bluffton Restoration Implementation Dates



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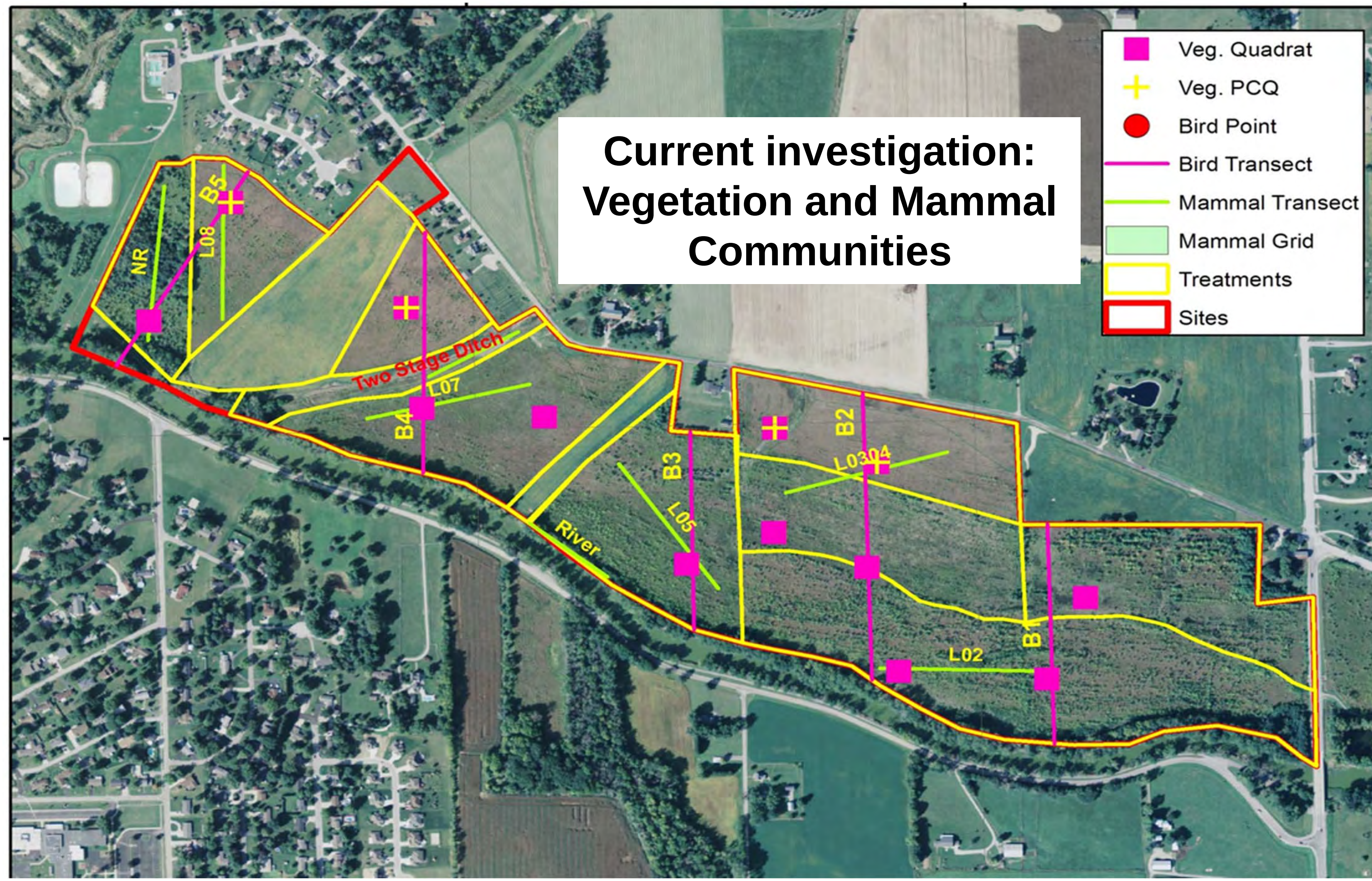
Bluffton Monitoring Locations



Similar monitoring strategies were used on all three sites

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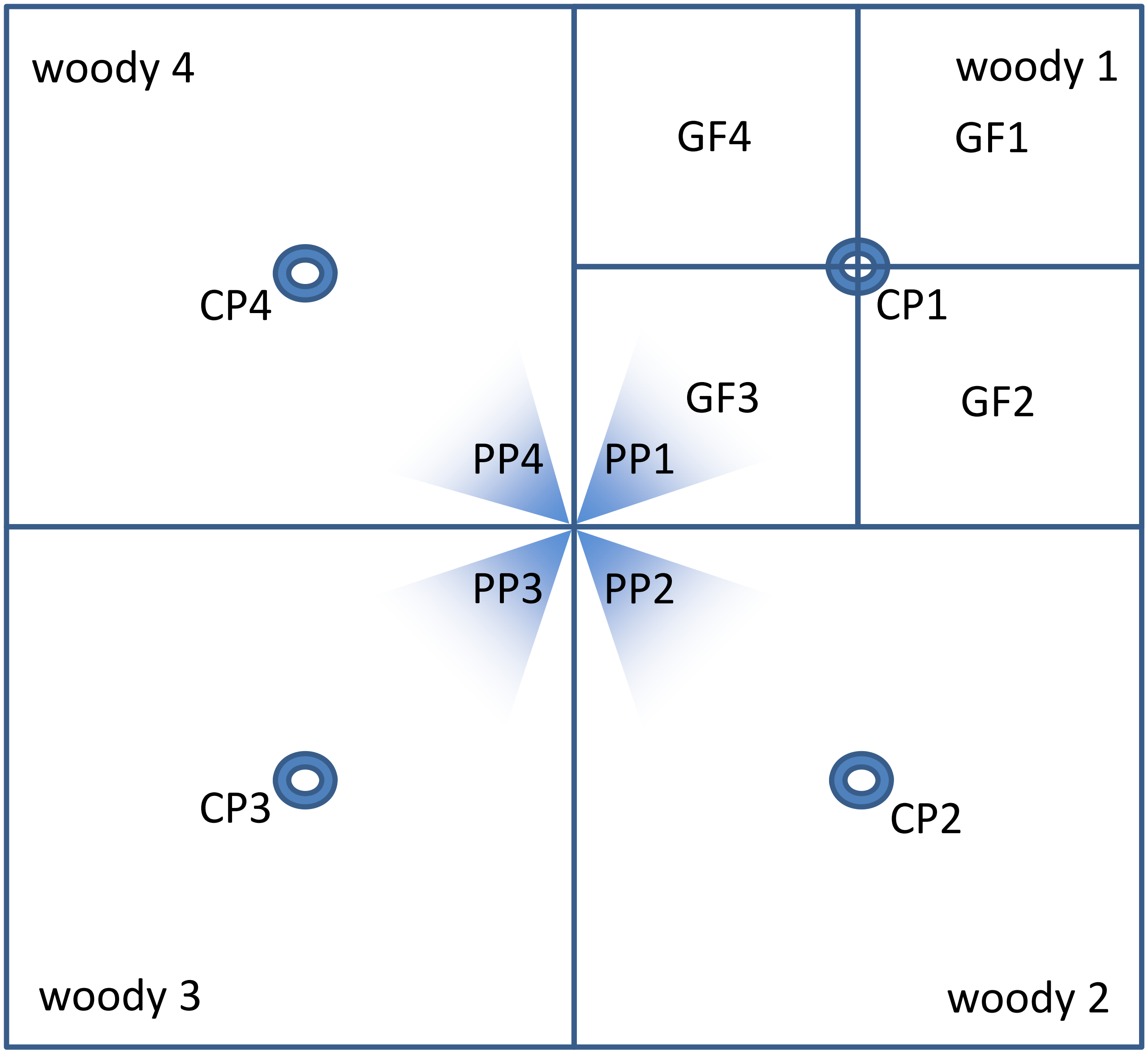
Vegetation Sampling - 20x20 m Quadrat Plots



- **Plots:**
1) Soils, cover, slope, aspect
2) Plot photos (PP) at 45°, 135°, 225° and 315°
3) Canopy photos (CP) at center of woody quarters
- **Woody stems (woody):**
1) 4, 10 m X 10 m quarters
2) dbh of shrubs (dbh<10 cm) measured in NE quarter and height estimated
3) dbh of trees (dbh>=10 cm) measured and height estimated
- **Ground flora (GF):**
1) 4, 5m X 5m quarters of shrub plot sampled as numbered
2) Only new species recorded in each quarter
3) Estimate of cover for 100 m^2

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Species	Bluffton (richness = 98)			Deetz (richness = 68)			TNC (richness = 129)			Means		
	Relative cover	Relative frequency	Importance value	Relative cover	Relative frequency	Importance value	Relative cover	Relative frequency	Importance value	Relative cover	Relative frequency	Importance value
Solidago altissima	0.123	0.037	0.080	0.051	0.034	0.042	0.189	0.021	0.105	0.121	0.031	0.076
Elymus virginicus	0.056	0.018	0.037**	0.195	0.045	0.120	0.014	0.021	0.018	0.088	0.028	0.058
Toxicodendron radicans				0.118	0.045	0.082	0.116	0.018	0.067	0.078	0.021	0.049
Symphyotrichum lateriflorum	0.029	0.025	0.027	0.155	0.045	0.100				0.061	0.023	0.042
*Phalaris arundinacea**	0.062	0.018	0.040	0.054	0.017	0.035	0.059	0.015	0.037	0.058	0.017	0.038
Andropogon gerardii	0.129	0.028	0.078**							0.043	0.009	0.026
Geum laciniatum	0.060	0.031	0.046	0.010	0.028	0.019				0.023	0.020	0.021
Carex normalis	0.051	0.025	0.038	0.019	0.028	0.024				0.023	0.018	0.020
Fraxinus americana	0.030	0.034	0.032	0.013	0.034	0.023				0.014	0.023	0.018
Acer saccharinum	0.036	0.037	0.037	0.008	0.028	0.018				0.015	0.022	0.018
Carex davisii	0.034	0.031	0.032	0.013	0.022	0.018				0.016	0.018	0.017
Rumex crispus	0.014	0.034	0.024	0.019	0.028	0.024				0.011	0.021	0.016
Verbesina alternifolia							0.073	0.018	0.046	0.024	0.006	0.015
Vitis vulpina				0.012	0.028	0.020	0.016	0.021	0.018	0.009	0.016	0.013
Carex annectens	0.043	0.031	0.037							0.014	0.010	0.012
Panicum virgatum	0.044	0.028	0.036**							0.015	0.009	0.012
Schizachyrium scoparium	0.046	0.022	0.034**							0.015	0.007	0.011
Acer negundo				0.005	0.028	0.017	0.012	0.021	0.017	0.006	0.016	0.011
*Pyrus calleryana** ← **Callery pear**				0.022	0.039	0.030				0.007	0.013	0.010
Polygonum spp.				0.037	0.017	0.027				0.012	0.006	0.009
Anemone canadensis							0.044	0.009	0.027	0.015	0.003	0.009
Phleum pretense							0.035	0.018	0.026	0.012	0.006	0.009
Poa pratensis							0.043	0.006	0.025	0.014	0.002	0.008
Poa compressa	0.031	0.015	0.023							0.010	0.005	0.008
Cornus racemosa				0.035	0.011	0.023				0.012	0.004	0.008
Laportea canadensis							0.043	0.003	0.023	0.014	0.001	0.008
Ulmus americana				0.009	0.034	0.021				0.003	0.011	0.007
Platanus occidentalis				0.012	0.028	0.020				0.004	0.009	0.007
Quercus bicolor	0.020	0.018	0.019							0.007	0.006	0.006
Populus deltoides				0.025	0.011	0.018				0.008	0.004	0.006
Grand Total	**0.809**	**0.431**	**0.620**	**0.810**	**0.551**	**0.680**	**0.645**	**0.171**	**0.408**	**0.754**	**0.384**	**0.569**

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Dominant species in order of decreasing mean importance value

Red shading = top 10 importance values at each site

*** Exotic Species of Concern ** Known Planted Ground Flora**

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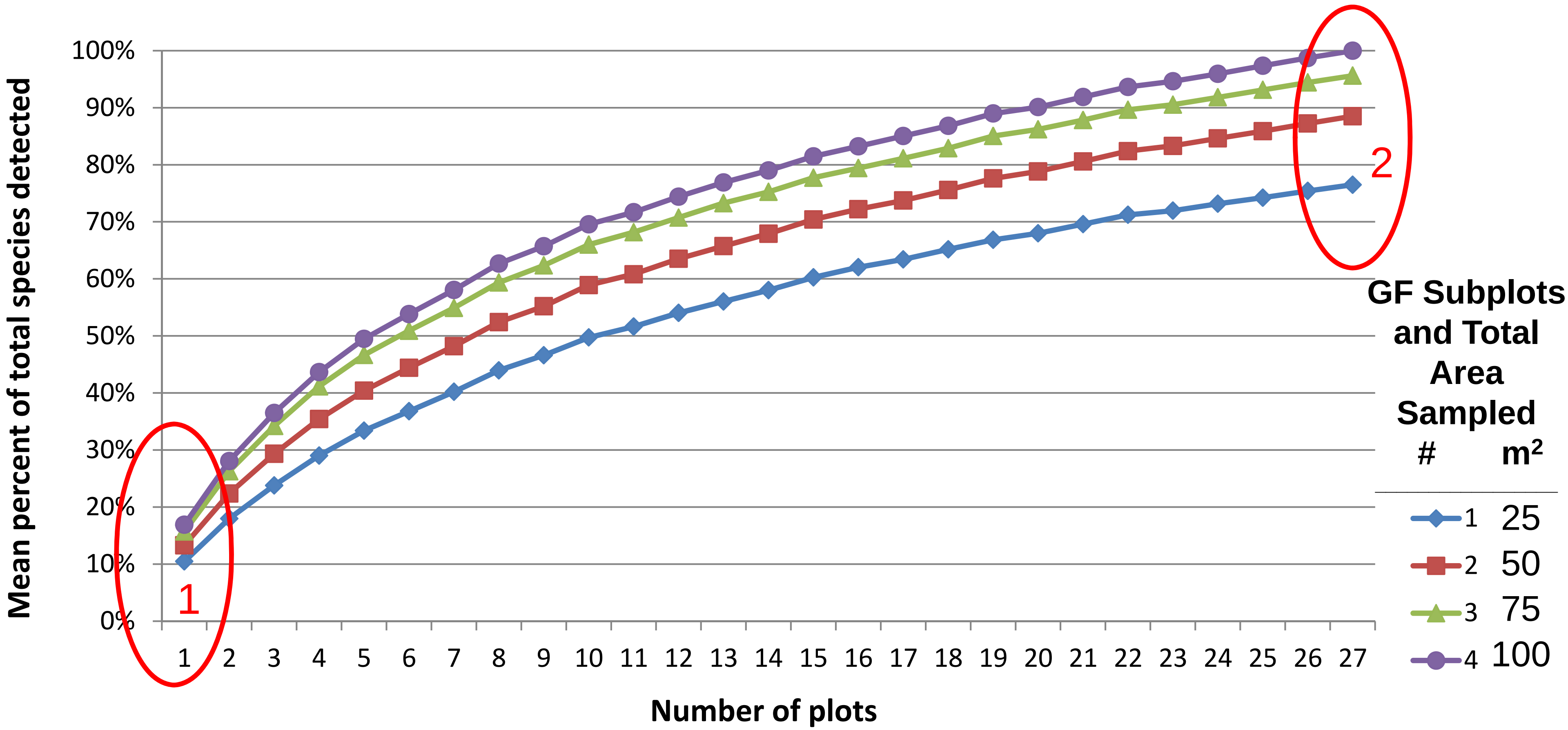
Effort vs Information: Species-Area Relationship

The greatest proportion of data arises from the initial sampling effort



1 - On average, the first 25 m^2 ground flora (GF) subplot yielded 62% of the species detected in the combined area of the four subplots (100 m^2).

2 - Collectively, the first subplots included 78% of species detected during the entire study.

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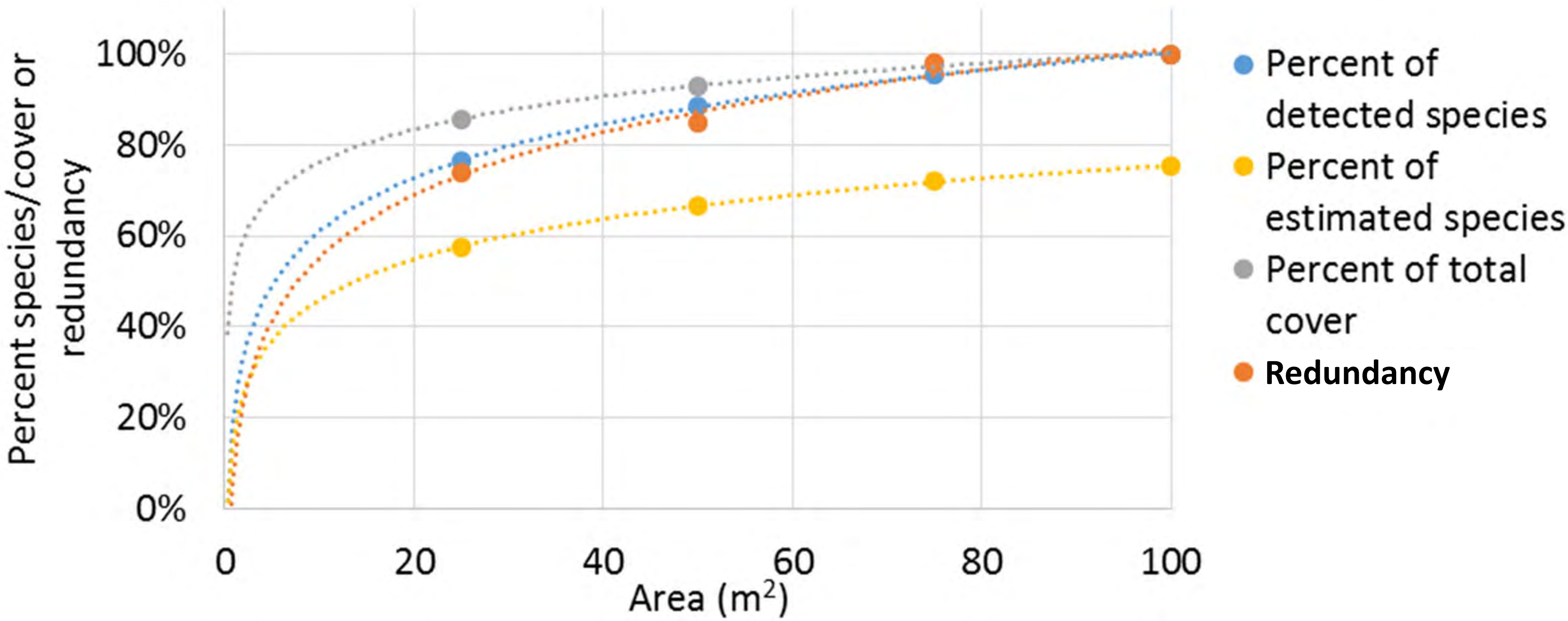
***Notes*: See Slide 19 for quadrat and GF configurations. Data developed using a jackknife resampling (500X) procedure of the 27 study quadrats from the 2015 field season**

Relationships - Information Content and Sampling Area



Data from the 25 m^2 plots:

- accounted for more than 80% of vegetative cover at the sites

- were ~75% redundant with data from the full 100 m^2 plots

Smaller plots are able to detect the dominant species at restored sites.

Next steps - examine relationship to baseline and reference sites to assess recovery trajectory

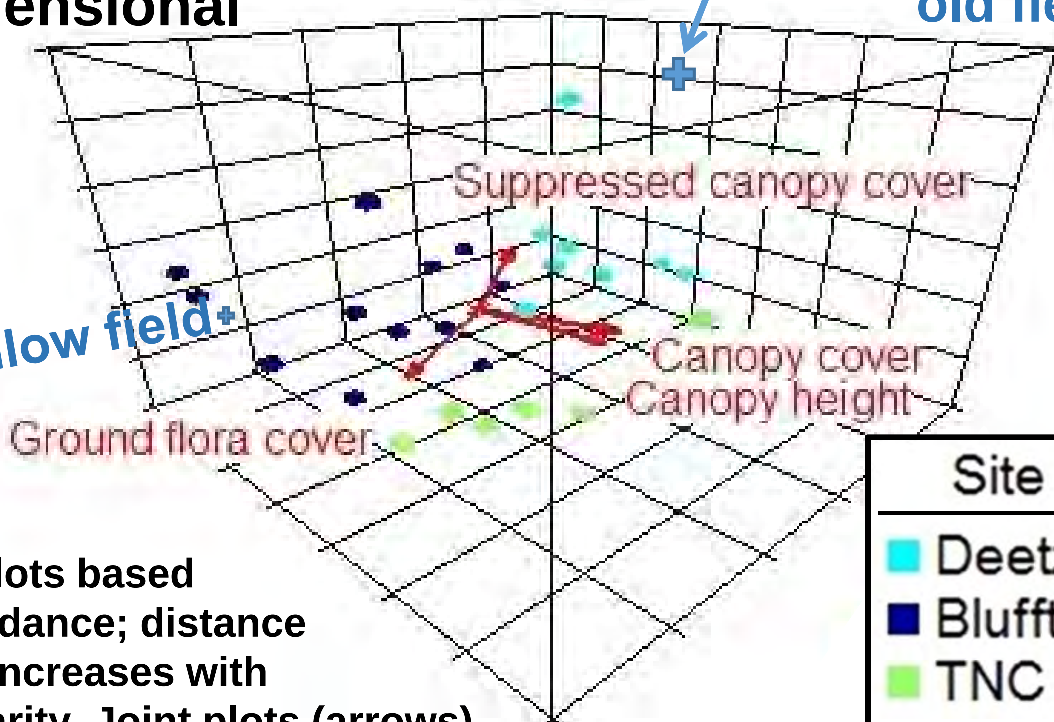
Quantifying Community Development

Non-Metric Multi-Dimensional Scaling (NMS)

Callery pear (invasive)-dominated old field Undesired condition

Loamy floodplain forest
ESD# F109XY030MO
(NRCS Ecological Site Description)
Desired target/reference condition

Pre-restoration condition **Fallow field**



Site	
Deetz	
Bluffton	
TNC	
	Hypothetical potential states against which restoration condition can be compared

NMS output of plots based on species abundance; distance between points increases with relative dissimilarity. Joint plots (arrows) indicate direction of increase for environmental parameters (red labels) correlated subsequent to NMS

Study sites were evaluated relative to other restored sites or as trajectory through time
- **Away from pre-restoration conditions (Fallow field),**
- **Toward target or reference conditions (e.g. NRCS Ecological Site Type), or**
- **Toward undesired alternative state where corrective action may be necessary (e.g., where a non-native invasive species may have adverse effects).**

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Method Background: McCune & Grace. 2002. Analysis of Ecological Communities. 304p. (www.pcord.com) ISBN: 0-9721290-0-6

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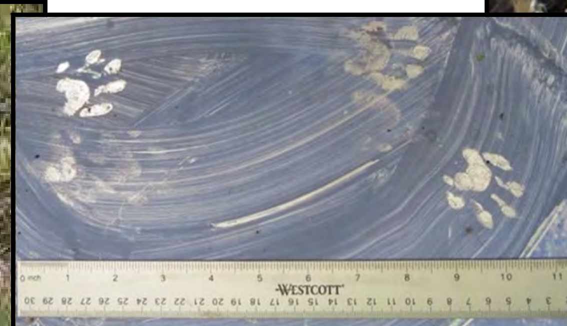
Mammal Sampling Methods

- **Mammal fauna sampled at all three restored sites during May and August sessions in 2015**
  - **5 consecutive nights/session (small mammals)**
  - **4 consecutive nights/session (other taxa)**
- **Used taxon-appropriate methods**
  - **Sherman small mammal live trap transects**
    (6 or 7 transects/site, 25 stations/transect, 2 traps/station)
  - **Anabat ultrasonic detectors**
    (6 detectors/site)
  - **Trail cameras, track plates**
    (10 co-located cameras and plates/site)



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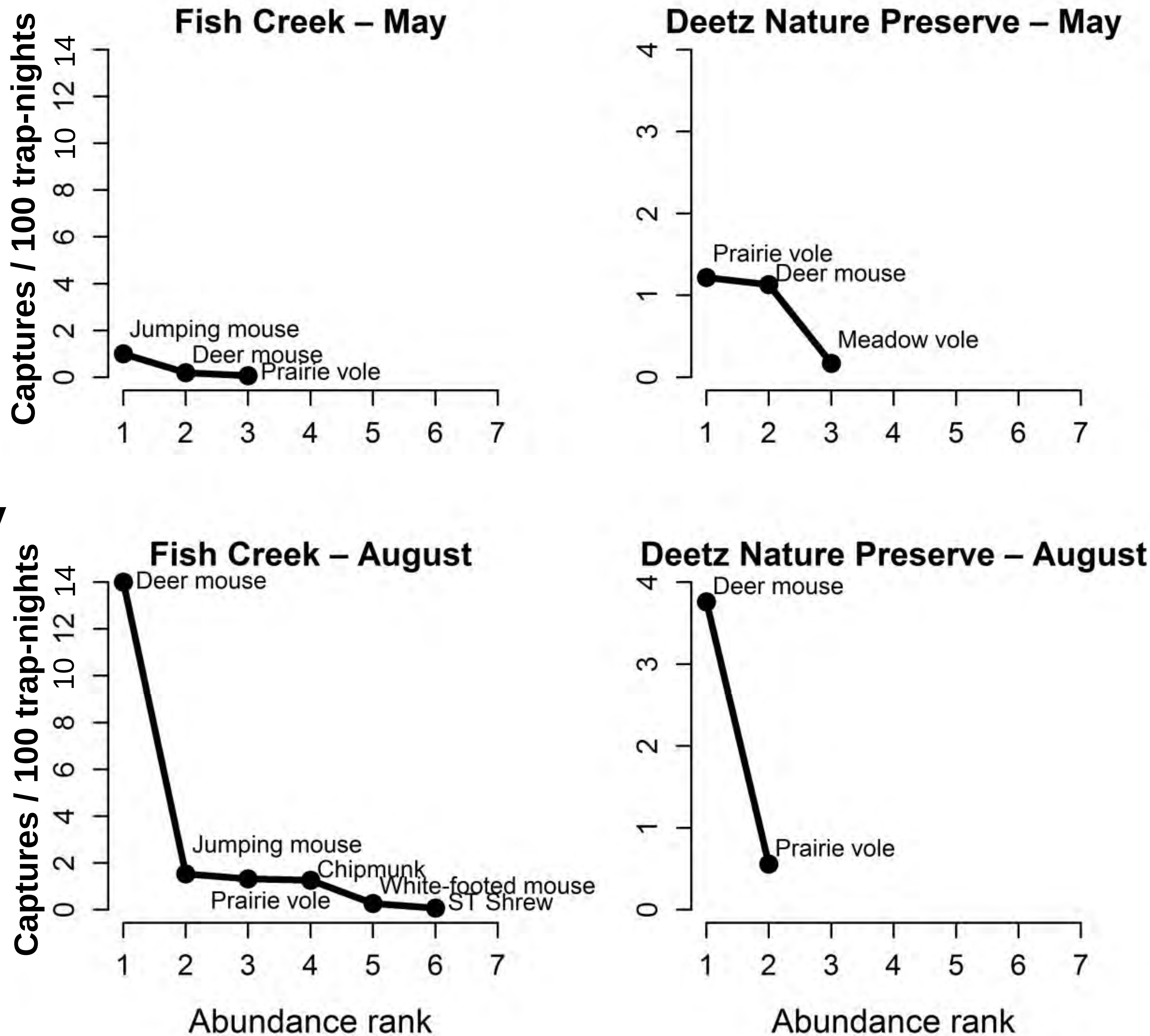
Small Mammal Community Diversity

Note: Each seasonal trapping session = 1500 trap nights



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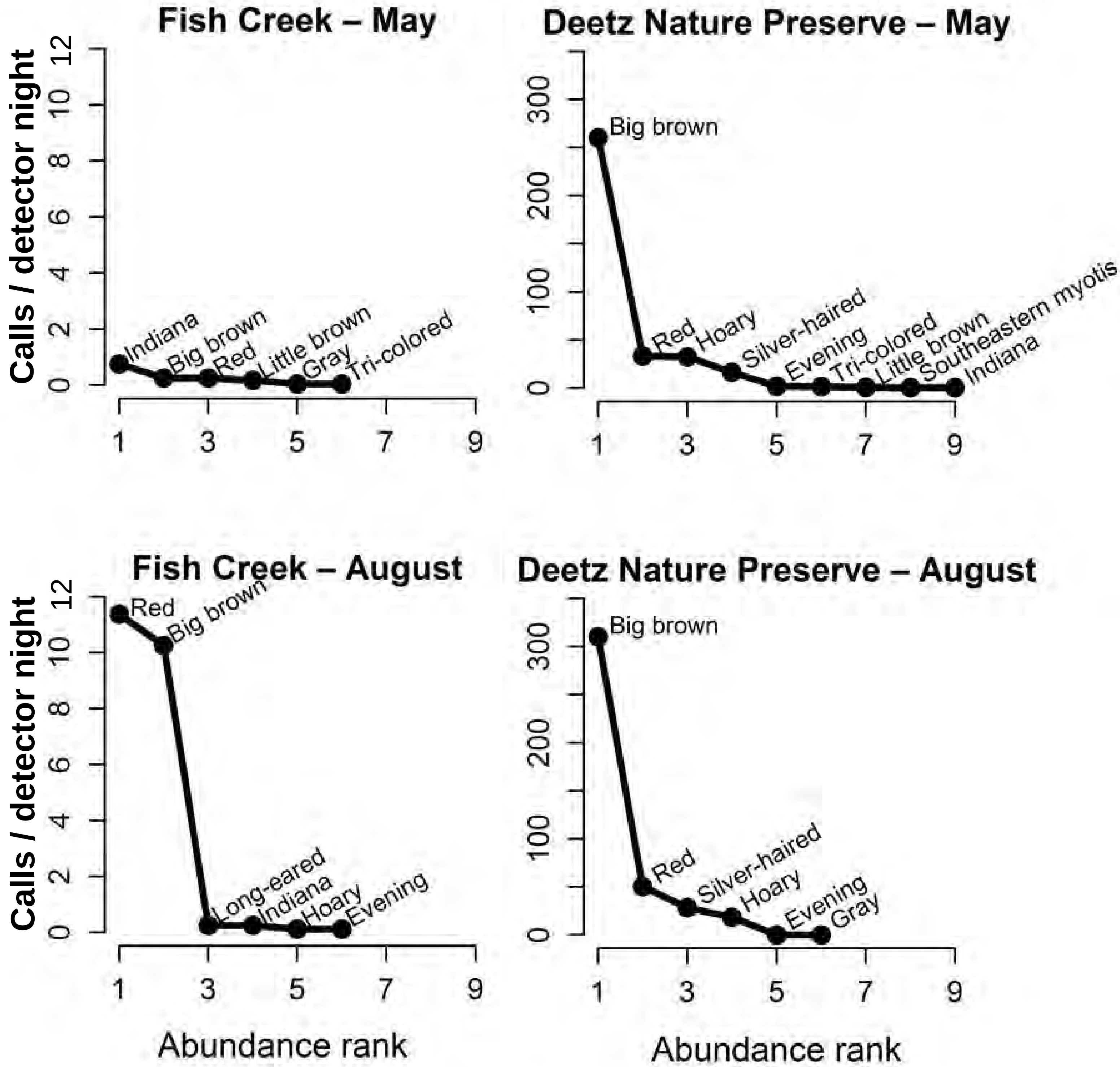
Bat Community Diversity

Note: Each seasonal monitoring session = 10 detector nights



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Modelling the Effect of Level-of-Effort

Subsamples of data are being used to model how sampling effort affects:

1. **Species richness: detection of biodiversity (Presented here)**
2. **Abundance: estimates of species abundances and their precision**
3. **Occupancy: patterns of occurrence and probability of detecting species of interest**

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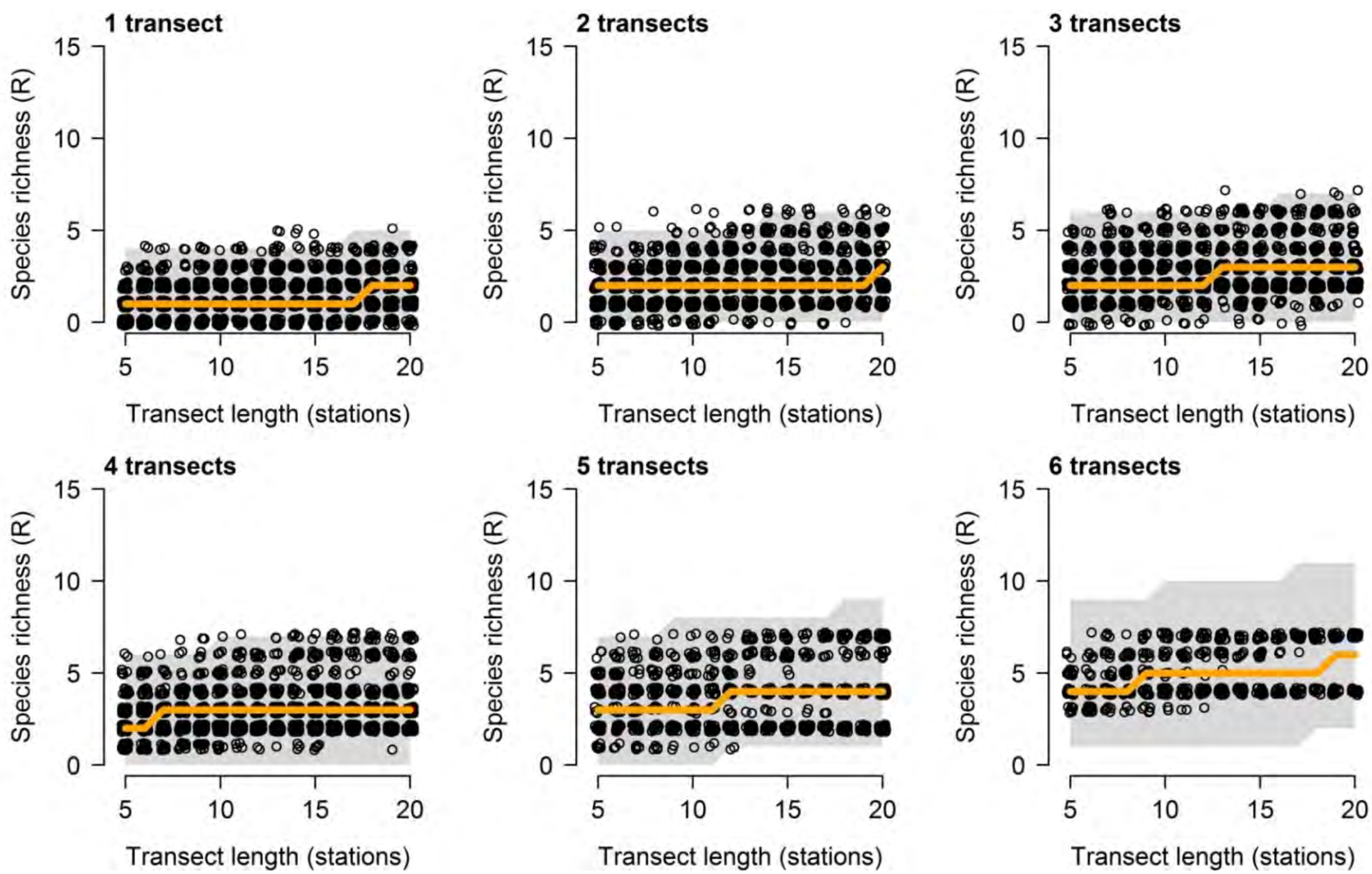
Modelling Approach

- **Hierarchical models of species richness were fit using Bayesian inference**
- **Resampling approaches examined the effects of:**
  - **Number of samples (transects or detectors)**
  - **Intensity of samples (transect length or deployment length)**
- **Species Richness: Poisson distribution with linear or non-linear fixed or mixed effects of sampling effort**

Small Mammal Species Richness



$$\text{Richness} \sim \text{Poisson}(\lambda);\ \boldsymbol{log(\lambda) = \beta_0 + \beta_1 N_{traps};\ \beta_0, \beta_1 | N_{transects}}$$

- **With more and longer transects, more species were detected**
- **Shorter transects detected equivalent diversity, but more transects were required**

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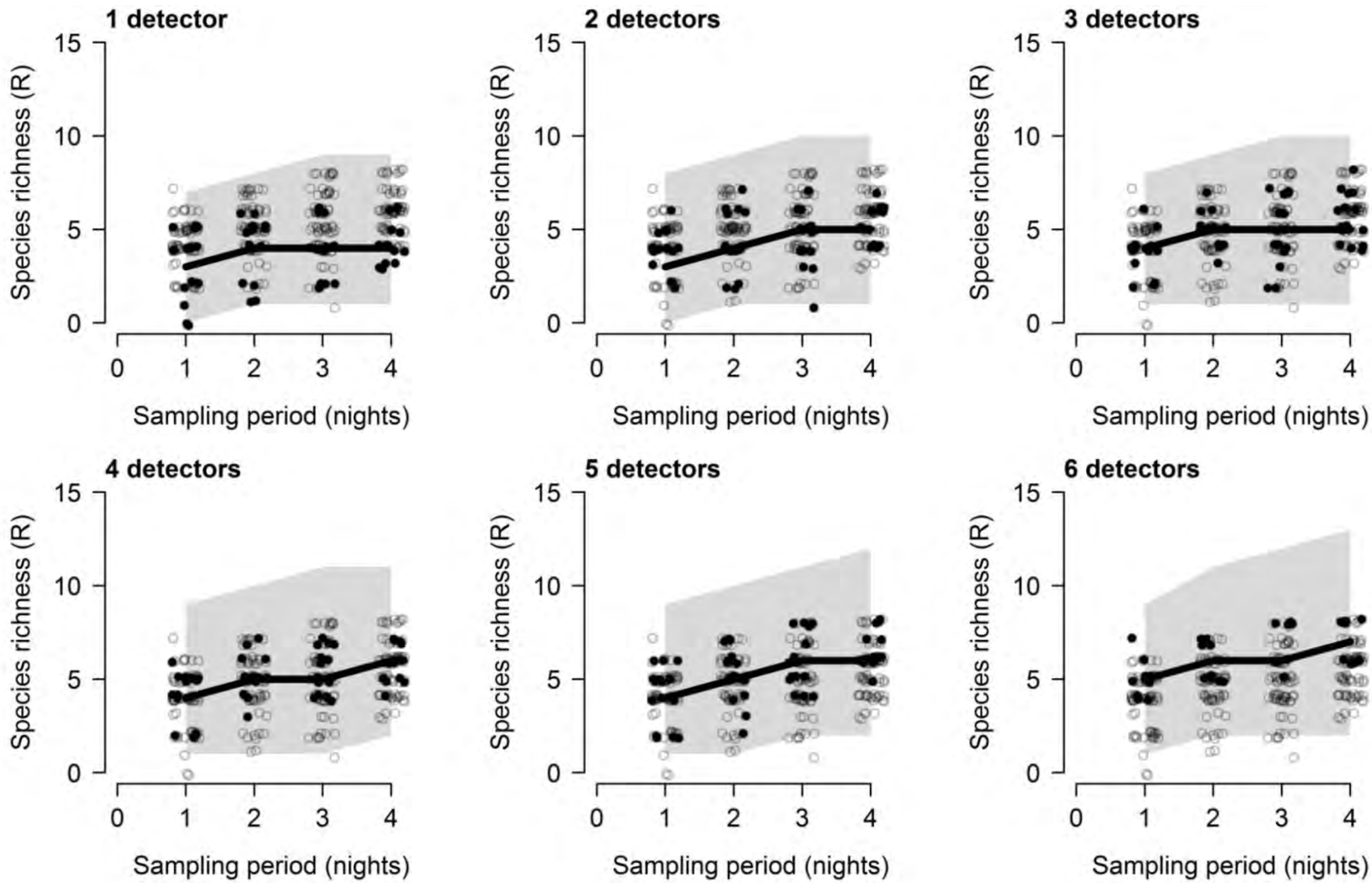
Bat Species Richness



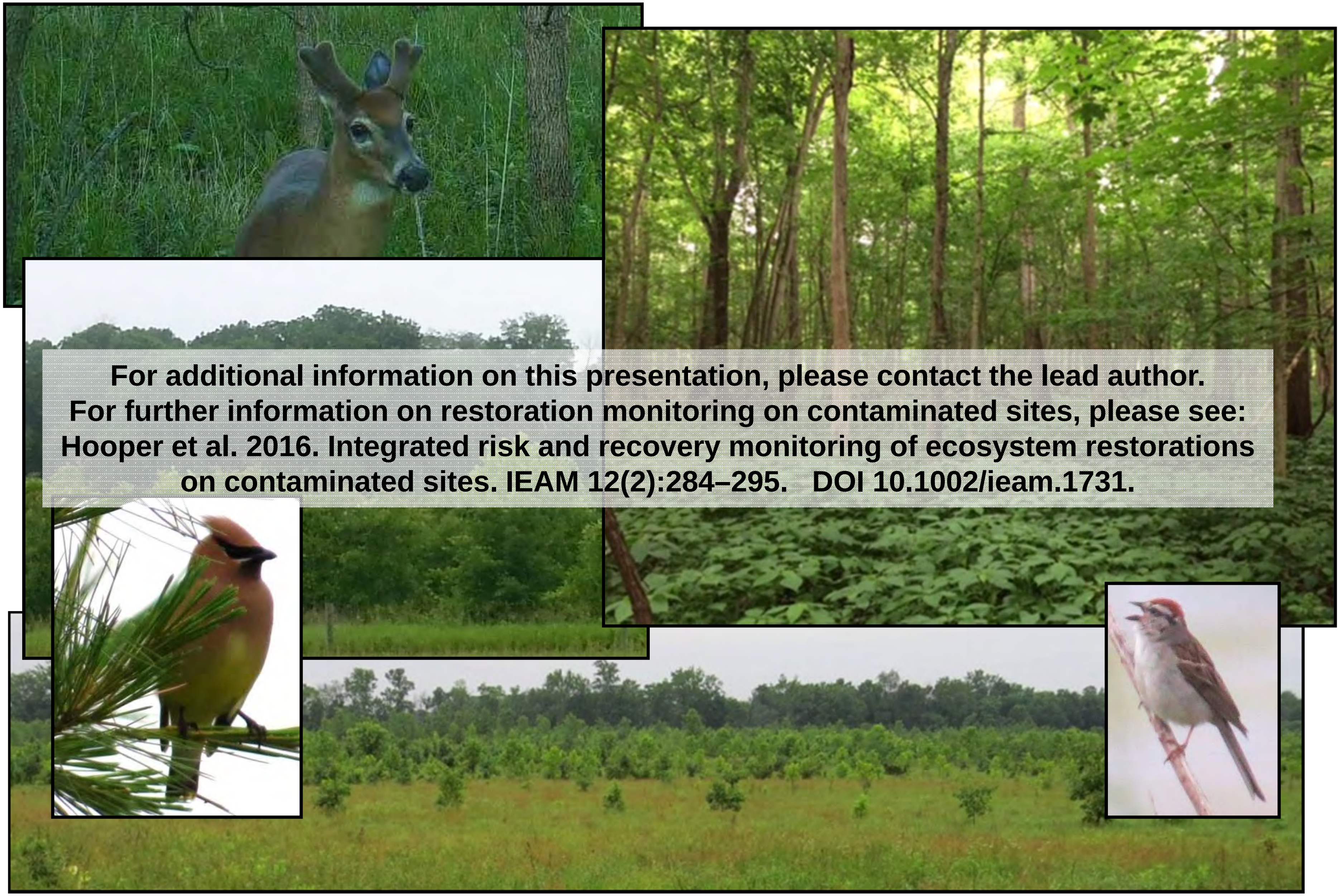
$$\text{Richness} \sim Poisson(\lambda);\ log(\lambda) = \frac{\alpha N_{nights}}{\beta + N_{nights}};\ \alpha | N_{detectors}$$

- **Similar findings with small mammals - asymptote suggested**
- **Sampling in 2016 will increase duration to test for asymptote**

Information vs Level-of-Effort

Overall Preliminary Findings

- **Intensive field sampling provided data sets that documented species diversity, abundance and community relationships.**
- **Resampling approaches modeled vegetation and mammal findings and demonstrated substantial data acquisition potential using reduced sampling effort.**
- **Upcoming field season will continue to build the base data sets while testing the findings of the models.**



For additional information on this presentation, please contact the lead author.
For further information on restoration monitoring on contaminated sites, please see:
Hooper et al. 2016. Integrated risk and recovery monitoring of ecosystem restorations on contaminated sites. IEAM 12(2):284–295. DOI 10.1002/ieam.1731.