Effects of Multi-scale Environmental Characteristics on Agricultural Stream Biota in the Midwestern USA

5th National Monitoring Conference

May 9, 2006 San Jose, California

Julie A. H. Berkman, Barbara C. Scudder, Michelle A. Lutz, Mitchell A. Harris
U.S. Geological Survey

Outline

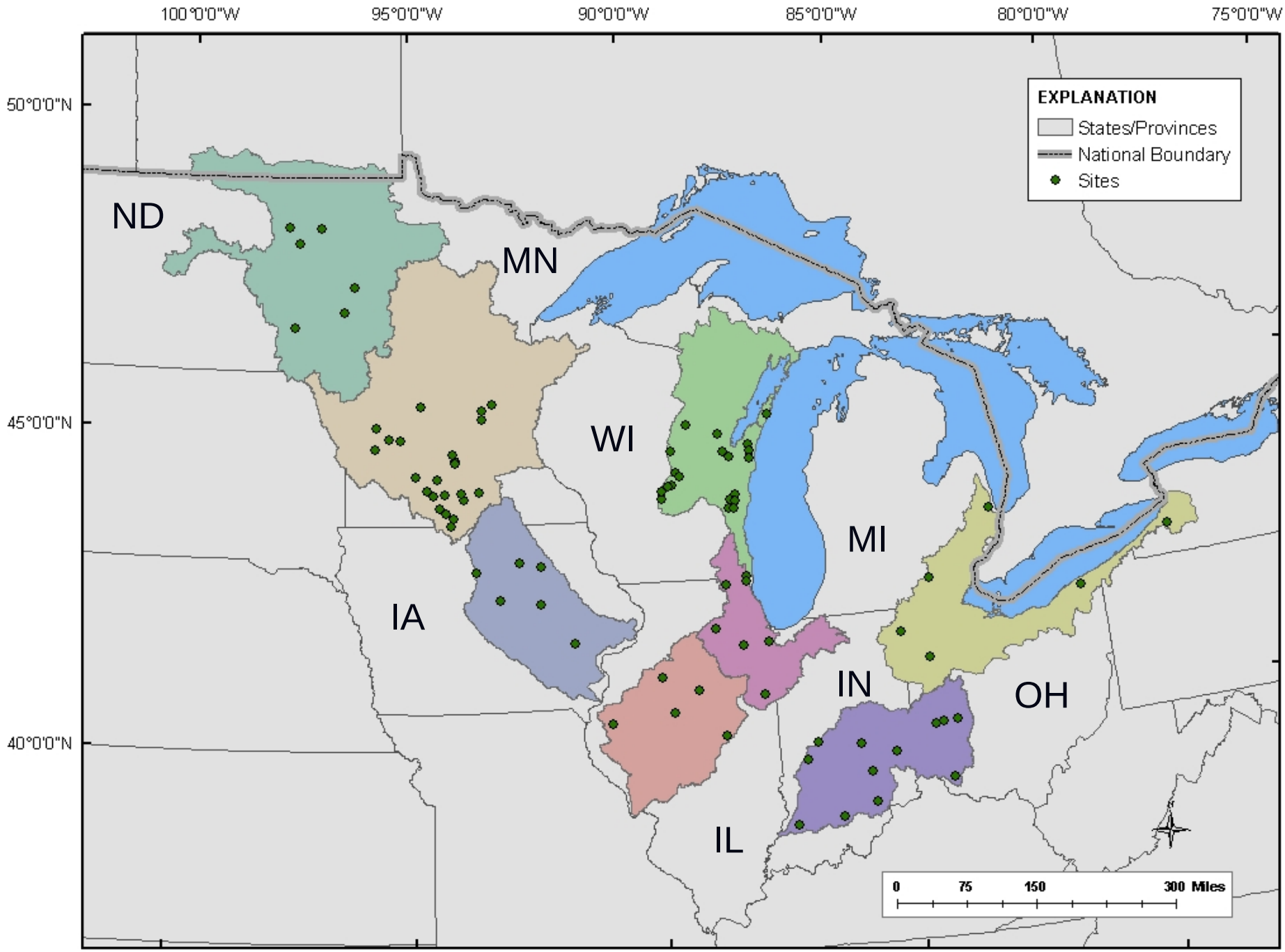
- Purpose
- Overall approach
- Geographical setting and site selection
- Data collection and analysis:
  - What is meant by multiple scales?
  - Which environmental characteristics were used as variables?
  - What aspects of the biological assemblages were used?
  - How were environmental and biological data brought together?
  - What are our results **at multiple spatial scales?**
- Relating BMPs and biological-assemblage responses

USGS

Purpose

- Evaluate responses of stream biological assemblages to environmental variables across multiple-scales in agricultural watersheds
- Identify the strongest relations between biological and environmental data that can be applied to assessing water-quality improvements in agricultural watersheds throughout the Midwest
- Assess which physical variables are the best focus for improvements in water quality through agricultural BMPs, for which we spend about $4,000,000,000 per year nationally (Shields *et al.*, 2006)

USGS

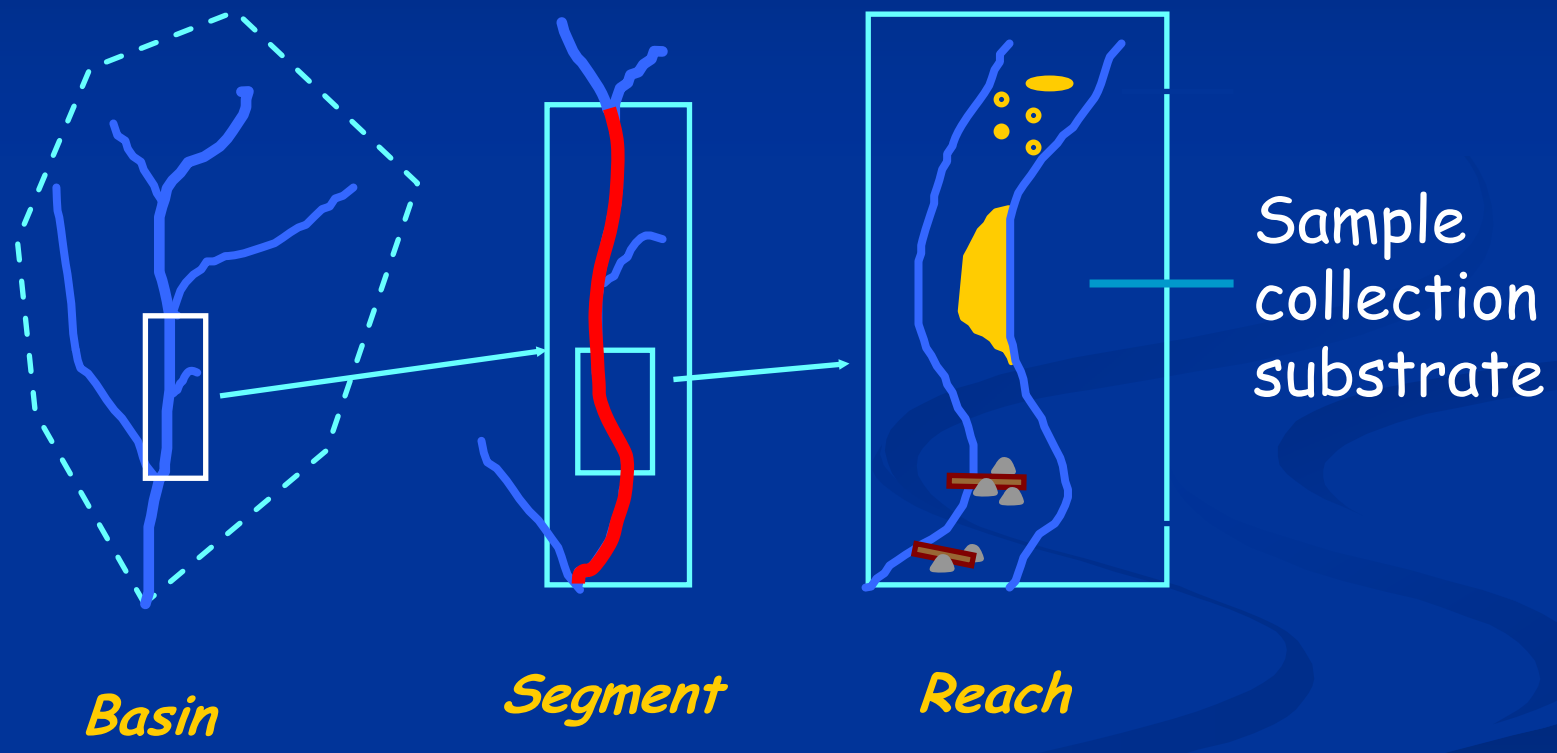

100°0'0"W
95°0'0"W
90°0'0"W
85°0'0"W
80°0'0"W
75°0'0"W
50°0'0"N
45°0'0"N
40°0'0"N
EXPLANATION
States/Provinces
National Boundary
Sites
ND
MN
WI
MI
IA
IN
OH
IL
0
75
150
300 Miles

Steps in Assessment

1. **Organize assessment approach**
   a. Identify agricultural practices for improvement of water quality
   b. Develop assessment endpoints
   c. Define geographic scope
2. **Build scientific foundation for assessment**
   a. Evaluate biological assemblages in relation to environmental variables **at multiple spatial scales**
   b. Identify relations between biota and agricultural BMPs
   c. Develop a conceptual model or index for measuring improvement due to specific agricultural BMPs
3. **Verify**
4. **Calibrate and validate**
5. **Publicize—Outreach and implementation**

USGS

What is meant by scale?
Why does scale matter in monitoring streams?



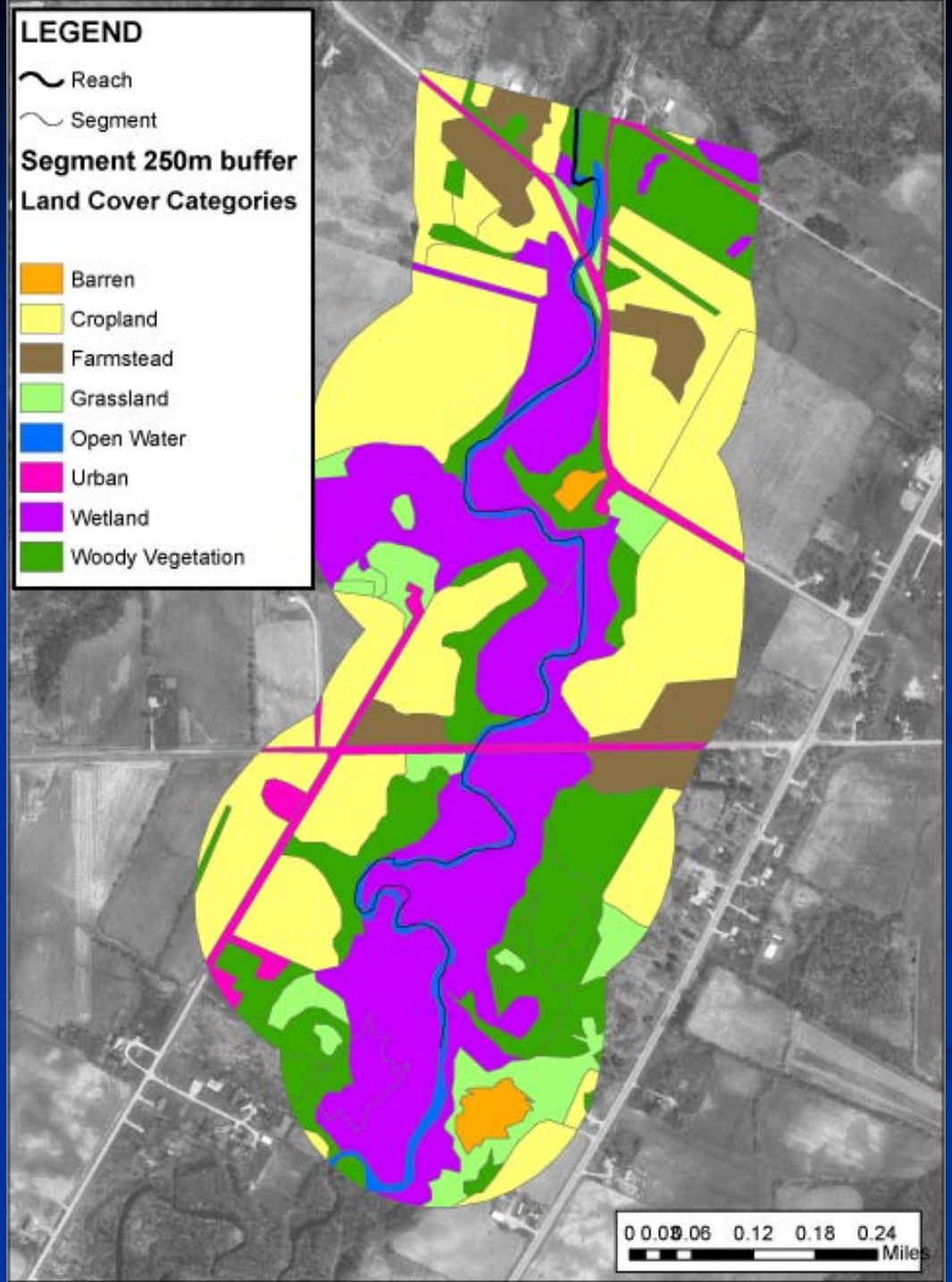
Reach

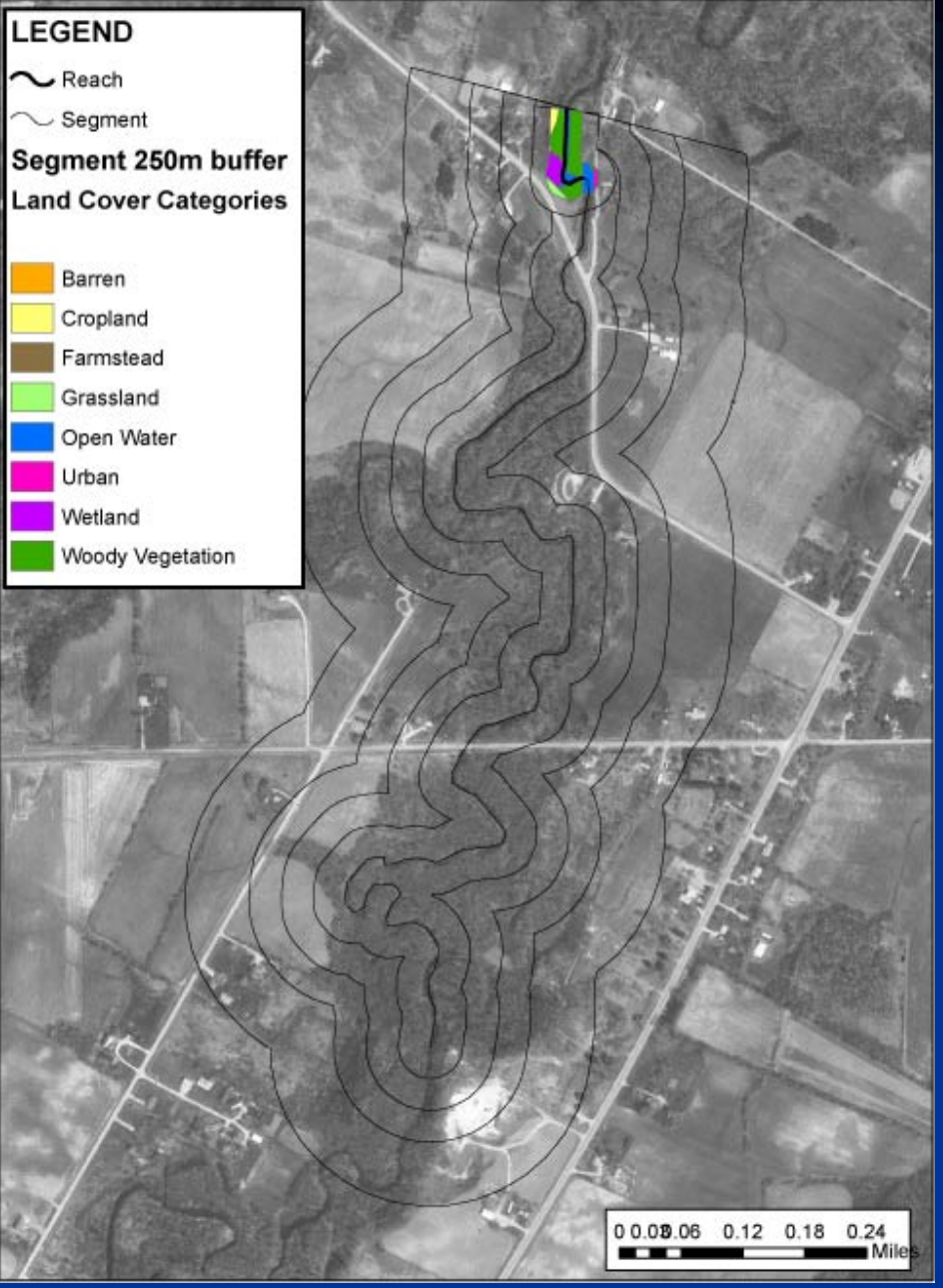
Segment

Watershed

Photo of watershed by Mitch Harris

Land cover characterization




LEGEND
Reach
Segment
Segment 250m buffer
Land Cover Categories
Barren
Cropland
Farmstead
Grassland
Open Water
Urban
Wetland
Woody Vegetation
0 0.06 0.12 0.18 0.24
Miles

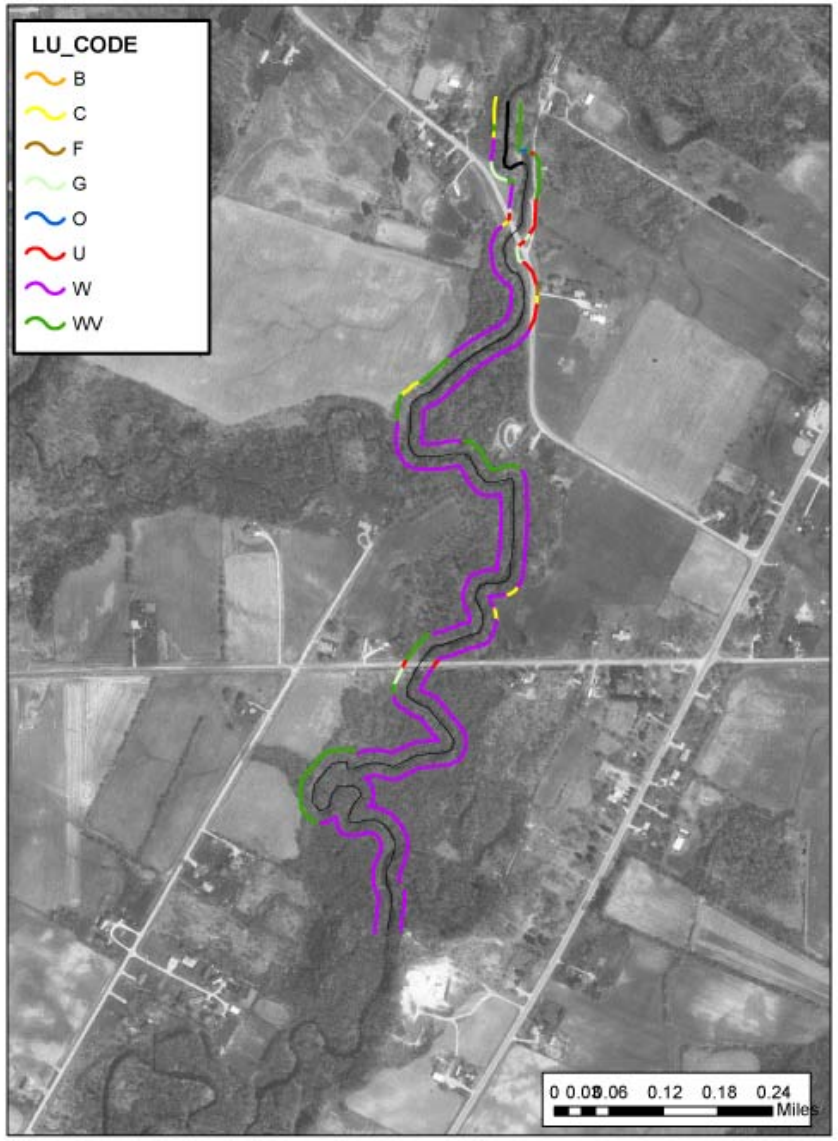
USGS

Segment margin

"Riparian buffer"

15 m from bankfull

- Percent land cover length
- Average land cover length
- Percent disturbed vs. natural
- Number of fragments



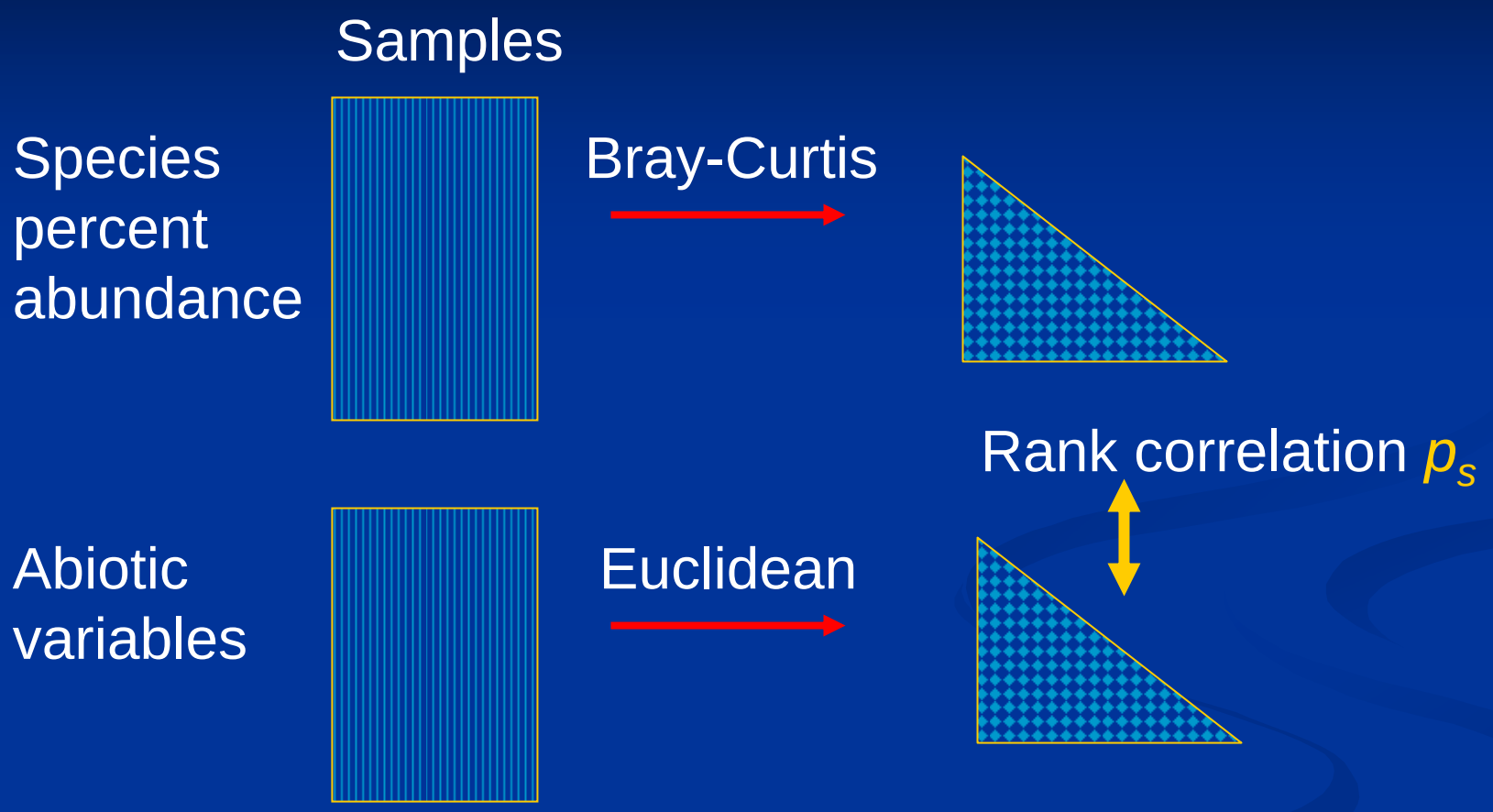
Algae

USGS

Invertebrates

Fish

PRIMER BioEnv analysis



p_s = An index of agreement of the two triangular matrices

An example of the results of reach variables & algae assemblages

Best results out of 28 reach variables

rank correlation p_s = 0.232 - 0.240

- **Average stream velocity**
- **Percent riffles**
- **Percent fine silty substrate**
- **Percent stream bank erosion**
- **Percent 50-m buffer in woody vegetation**
- **Percent bank covered by vegetation**

Summary of correlations between biological assemblages and environmental variables at each physical scale

	Reach	Segment	Watershed	Combined
Algae	0.240	0.269	0.441	0.477
Invertebrates	0.244	0.205	0.488	0.492
Fish	0.193	0.219	0.615	0.615

With n=86, the 5% two-tailed significance level occurs when >0.210

1% two-tailed significance level occurs when >0.275

USGS

Reach variables

Best reach variables	Algae	Inverts	Fish
Average stream velocity	+	+	
Percent riffles	+	+	+
Percent fine silty substrate	-*		
Percent bank covered by vegetation	+	+	+
Percent stream bank erosion	+	-	
Percent 50-m buffer in woody vegetation	+	+	
Average wetted channel width			+/-

USGS

Segment variables

Best segment variables	Algae	Inverts	Fish
Percent woody vegetation in margin		+	+
Stream sinuosity	-		
Segment gradient	+		
No. of fragments/km in margin	-	-	-
Avg. length of undisturbed buffer/km			+
Percent 150-m buffer in woody vegetation	+	+	+
Percent 250-m buffer in cropland	-	-	-

USGS

Watershed variables

Best watershed variables	Algae	Inverts	Fish
Latitude	+	-	-
Percent low-permeable soils	+	-	+
Drainage area	-	+	+
Percent total forest land cover	+	+	+
Percent mixed forest land cover		+	+
Average watershed slope	+		+

Combination of the Best selected variables

Best watershed variables	Algae	Inverts	Fish
Latitude	+	-	-
Percent low-permeable soils	+		+
Drainage area	-	+	+
Percent total forest land cover	+	+	+
Percent fine silty substrate	-		
Average watershed slope	+		
Percent bank covered by vegetation		+	+

USGS

Summary of correlations between biological assemblages and environmental variables at each physical scale

	Reach	Segment	Watershed	Combined
Algae	0.240	0.269	0.445	0.477
Invertebrates	0.244	0.205	0.488	0.492
Fish	0.193	0.219	0.615	0.615

Steps in Assessment

1. **Organize the assessment approach**
   a. Identify agricultural practices for improvement of water quality
   b. Develop assessment endpoints
   c. Define geographic scope

2. **Build a scientific foundation for the assessment**
   a. Evaluate biological assemblages in relation to environmental variables **at multiple spatial scales**
   b. Identify relations between biota and agricultural BMPs
   c. Develop a conceptual model or index for measuring improvement due to specific agricultural BMPs

3. **Verify**
4. **Calibrate and validate**
5. **Publicize—Outreach and implementation**

USGS

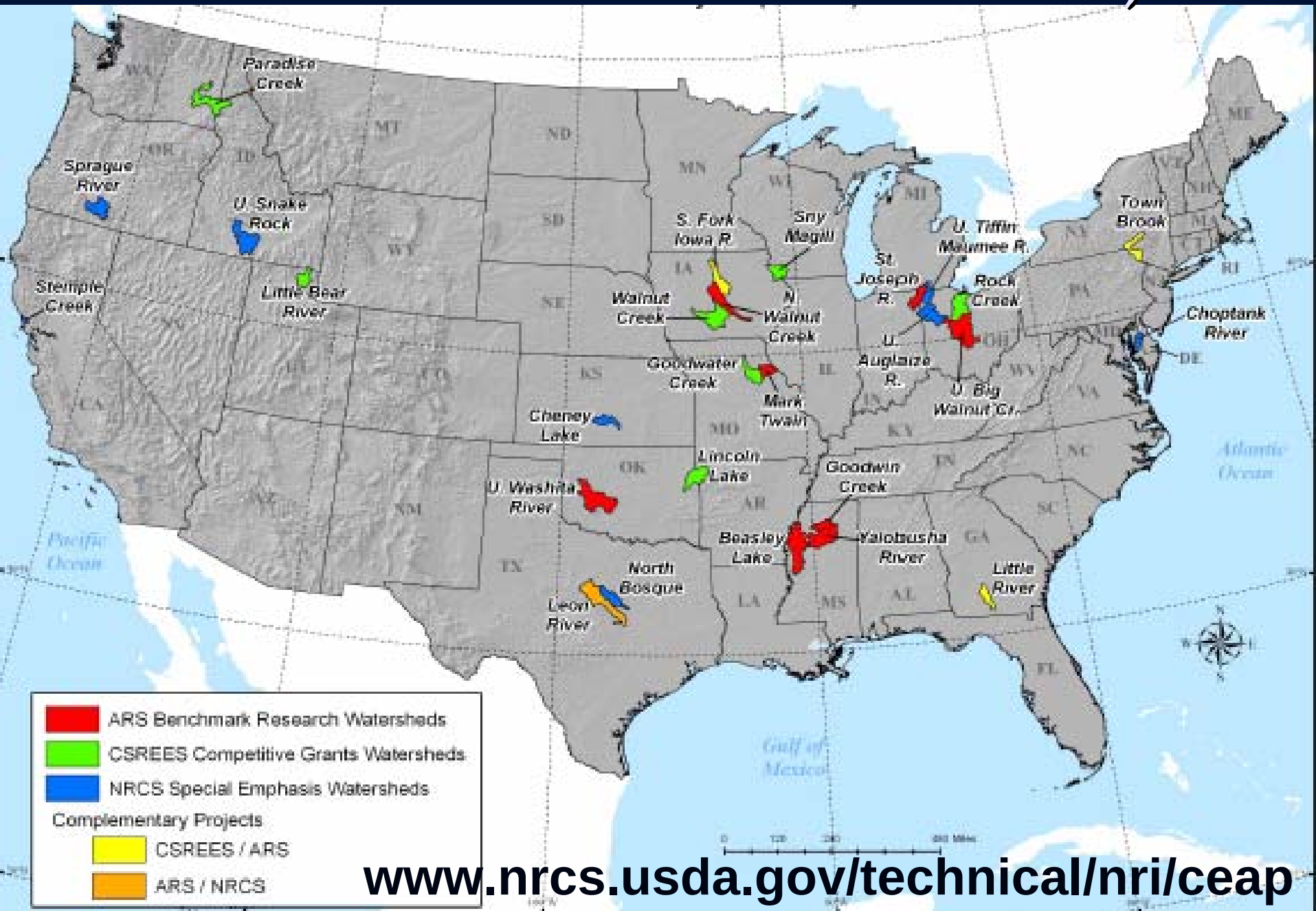
At which scale are the BMPs being applied?

At which scale should the effects be assessed?

Agricultural BMP	Biological response
Bank stabilization (percent bank erosion)	Algae and Invertebrates
Bank vegetative cover	Algae, Invert., and Fish
Riparian buffer (avg. length of undisturbed buffer/km)	Fish
Woody vegetation, 50 m	Algae and Invertebrates
Reduce sediment runoff (percent fine substrate)	Algae* (from rock substrates)

USGS

Conservation Effects Assessment Project



www.nrcs.usda.gov/technical/nri/ceap

Summary

- The responses of stream biological assemblages to environmental characteristics across multiple scales revealed the importance of the larger scale watershed variables for all three groups, but especially the fish.

- The strongest relations between biological and environmental data were identified and whether the biological assemblage had positive or negative response. For example sensitive fish, cobble fish, and the alga ***Achnanthidium minutissimum*** (Kützing) Czarnecki were all positively associated with stream velocity, percent riffles, and bank vegetative cover while tolerant algae and invertebtrates, as well as omnivorous fish were negatively correlated with these features.

- Physical variables that can be managed through Best Management Practices such as bank vegetative cover and woody vegetation in riparian buffer at the reach scale and undisturbed buffer at the segment scale, were matched with biota that could be used to assess improvements in water quality.

Next steps are to identify

1. Relations between biota and agricultural BMPs
2. Scale at which the BMPs are applied, and
3. Which biologic endpoints would be best for assessing water-quality improvements in agricultural watersheds throughout the Midwest.

Thank you

Coauthors:

Barbara Scudder, Michelle Lutz, and Mitchell Harris

Others who have provided valued assistance:

USGS Wisconsin WSC

Amanda Bell

Faith Fitzpatrick

James Kennedy

Jana Stewart

USGS National Research Program, Menlo Park, CA

James L. Carter

USGS Nebraska Water Science Center

Michaela Johnson

For more information on this study contact:

Julie A. Hambrook Berkman, Ph.D.
U.S. Geological Survey
6480 Doubletree Ave.
Columbus, OH 43229-1111
jberkman@usgs.gov
614-430-7730

Barbara C. Scudder
U.S. Geological Survey
8505 Research Way
Middleton, WI
53562-3581
bscudder@usgs.gov
608-821-3832