USGS
science for a changing world

Sources and Ecology of *E. coli* in the North Shore Channel and North Branch of the Chicago River

Murulee Byappanahalli and Richard Whitman
U.S. Geological Survey
Porter, Indiana

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

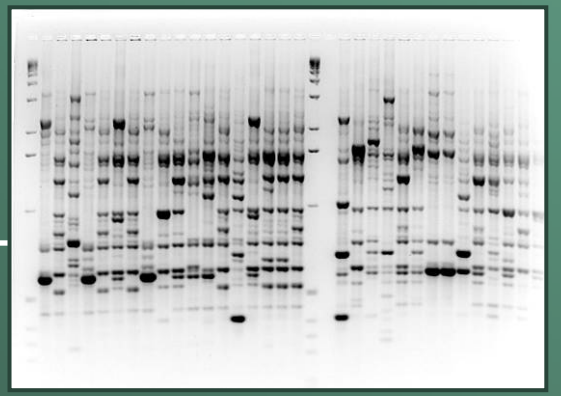
USGS Great Lakes Science Center, Lake Michigan Ecological Research Station (LMERS)

USGS

Microbial Research at LMERS

Recreational Water Quality

- Ecology of fecal indicator bacteria
- Predictive modeling
- Microbial source tracking



USGS

Sources of FIB Determine the Relative Risk to Swimming-Related Illnesses

Source	Relative risk
Human feces/sewage	High
Non-human (e.g., animal feces)	Moderate
Environmental (e.g., plants, soil, sand)	Low (unknown?)

USGS

Examples of Human Pathogens Potentially Present in Raw Domestic Wastewater

Organism	Disease	Symptoms
Bacteria		
E. coli (enteropathogenic)	Gastroenteritis	Diarrhea
Salmonella typhi	Typhoid fever	High fever, diarrhea
Other *Salmonella spp.*	Salmonellosis	Food poisoning
Vibrio cholerae	Cholera	Severe diarrhea and dehydration
Protozoa		
Cryptosporidium	Cryptosporidiosis	Diarrhea
Entamoeba histolytica	Amebiasis	Prolonged diarrhea
Giardia lamblia	Giardiasis	Mild to severe diarrhea
Viruses		
Adenovirus	Respiratory disease	Diarrhea, vomiting
Enteroviruses	Gastroenteritis	
Norwalk agent	Gastroenteritis	
Rotavirus	Gastroenteritis	

USGS

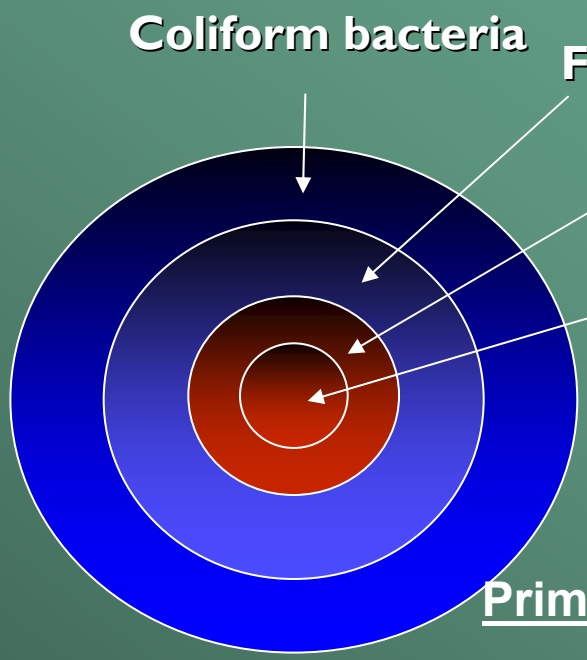
FIB Sources: Animals and the Environment

Animals (Moderate Risk)	Environment (Risk???)
E. coli O157:H7	Beach sand
Salmonella	Soil/sediment
Campylobacter	Plants (e.g., *Cladophora*)
Cryptosporidium	

USGS

Development of Recreational Water Quality Standards: Fecal Indicator Bacterial Concept

- 1900-1970: Total coliform bacteria (50-2400 colony-forming units, CFU/100 mL)
- 1972-1986: Fecal coliforms (200 CFU/100 mL)
  - Epidemiological and water quality studies were conducted
- 1986-Present: *E. coli* or enterococci (freshwater); enterococci (marine water)
- New Epidemiological and water quality studies: 2003-2007
  - New water quality guidelines by 2012



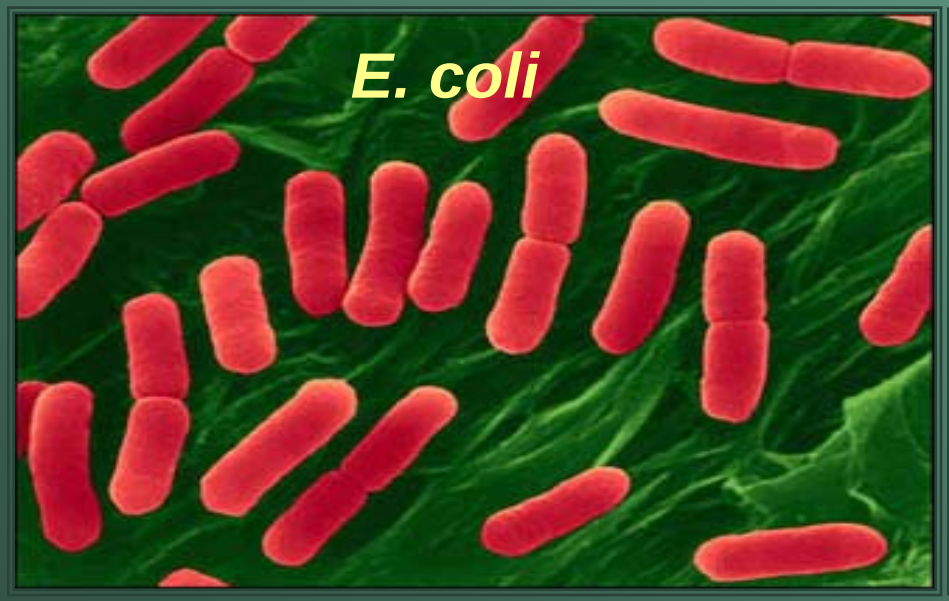
Primary Body Contact (e.g., swimming)

126 *E. coli* or 33 enterococci/100 CFU mL*

*Geometric Mean

USGS

E. coli and Enterococci are Used as Indicators of Water Quality in Great Lakes



USGS

Presentation Objectives

To determine:

- **spatial-temporal distribution of *E. coli* in surface water and sediments along selected locations above and below the Northside Wastewater Reclamation Plant (NSWRP),**
- **potential *E. coli* contributions from soil/sediment from wooded (forest), grassy, erosional/stream bank, and depositional areas to the river,**

USGS

Presentation Objectives (cont.)

- discuss the results of the USGS-MWRD project in light of the USGS research findings on ambient *E. coli* occurrences in the watersheds of Lake Michigan.

USGS

Sampling Locations

- Above outfall
  - Bridge Street (UPS-1): N42°03’21.96’, W87°42’03.29’
  - Oakton Street (UPS-2; WW-102): N41°59.820’, W87°42.610’
- NSWRP Outfall: NSOUT
- East River at Carmen/Albany: N41°58’16.69”, W87°50’47.70”
- Below Outfall
  - Foster Avenue (DNS-1; WW-101): N42°01.570’, W87°42.580’
  - Wilson Avenue (DNS-2; WW-37): N41°57.860’, W87°41.800’

USGS

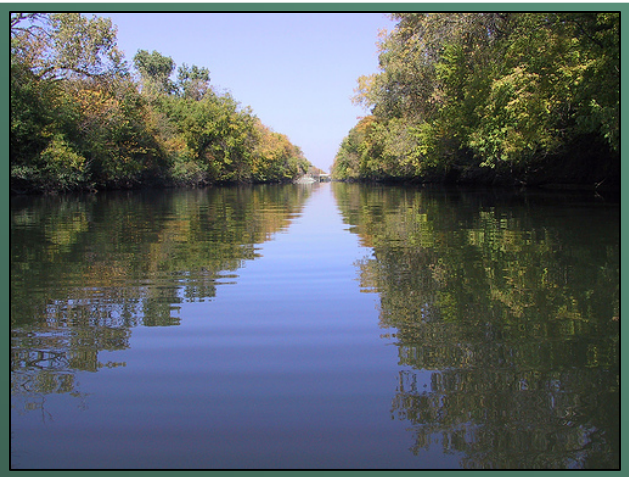
Bridge Street (UPS-1)

USGS

Oakton Street (UPS-2)

USGS

Foster Avenue (DNS-1)

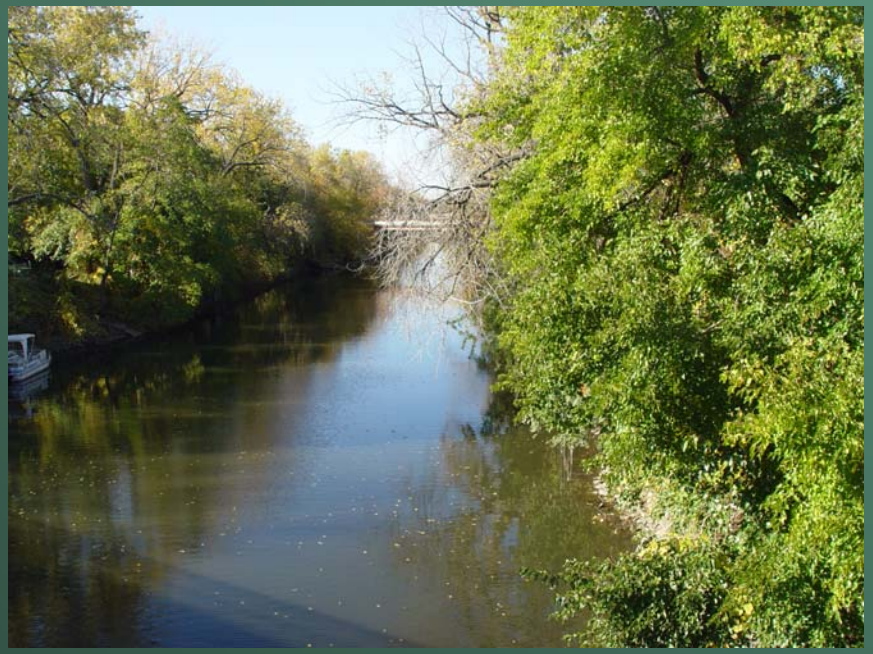


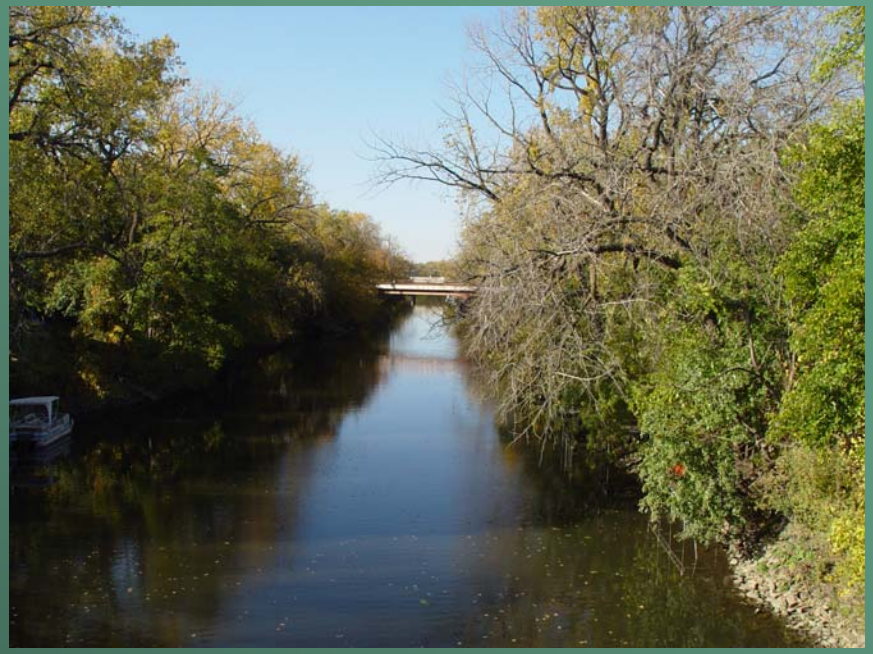
USGS

East River at Carmen/Albany

USGS

Wilson Avenue (DNS-2)





USGS

Map of Sampling Locations

Sampling Design

- North Shore Channel Segment
  - Triplicate samples of water and sediments were collected at upstream (UPS-1 and UPS-2), downstream (DNS-1 and DNS-2), and East River (at Carmen/Albany) locations
- NSWRP plant outfall (triplicate water)
- Five sampling events in 2008:
  - August 26
  - September 9
  - September 23
  - October 7
  - October 21

USGS

Sampling Design (cont.)

- Soil/sediment samples from two recreational parks: Channelside Park Canoe Launch by Oakton St. and East River Park by Albany/Carmen Ave.:
  - wooded
  - grassy
  - erosional/stream bank
  - depositional areas
- Three sampling events:
  - September 23
  - October 21
  - October 31

USGS


Wooded


Grassy


Depositional

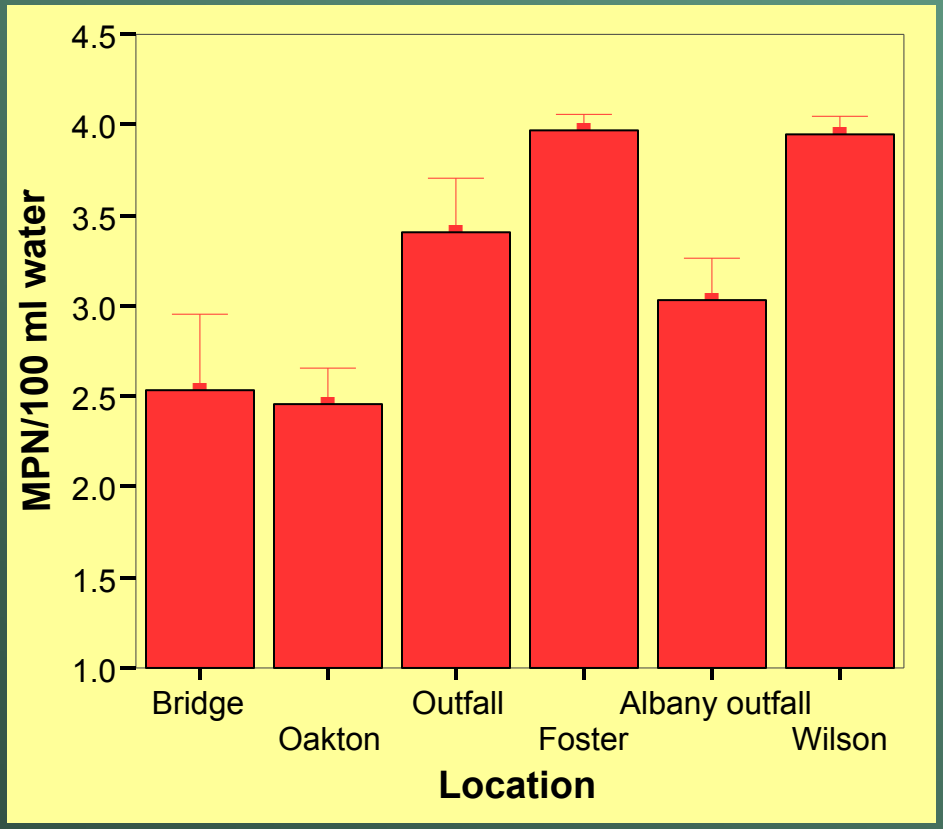

Erosional/Stream Bank

Sample Analysis

- **Microbiology**
  - All water, soil, and sediment samples were analyzed for *E. coli* by the DST technique (IDEXX Colilert-18)
  - Composited water and sediment samples were analyzed for enterococci
- **Soil and sediment samples**
  - Textural composition and organic carbon

USGS

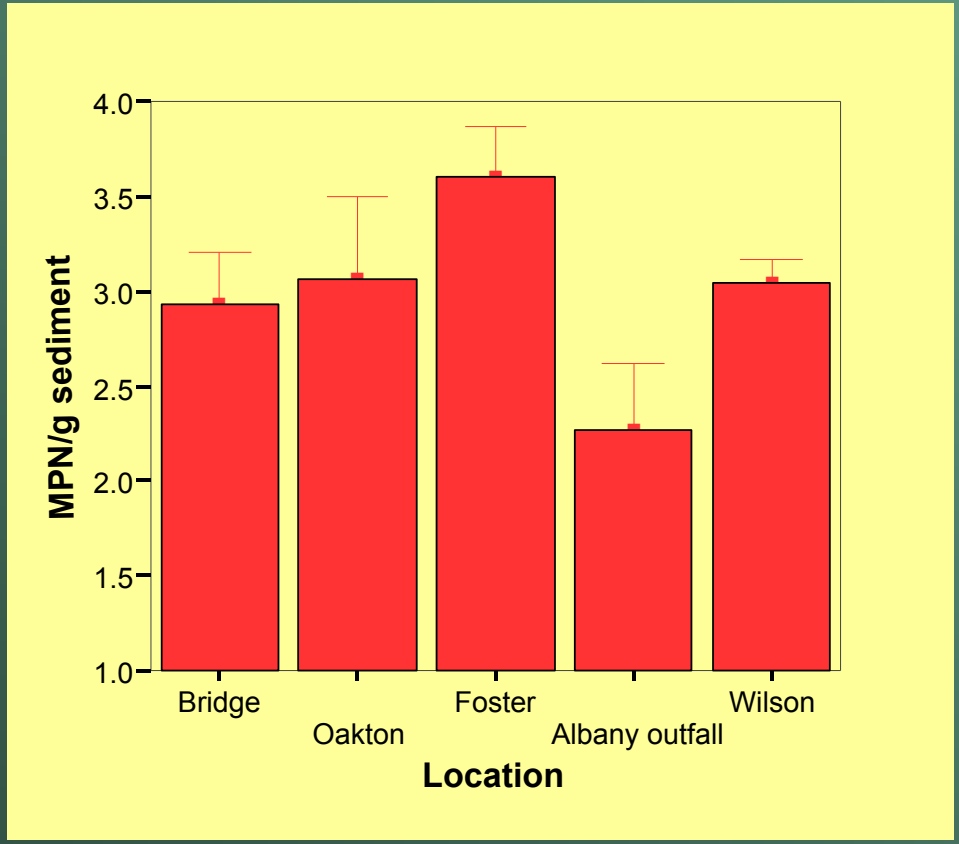
Log Mean *E. coli* Densities in Water



- *E. coli* densities in water of both downstream locations (Foster Ave. and Wilson Ave.) were significantly higher than at the upstream locations (Bridge St. and Oakton St.).

USGS

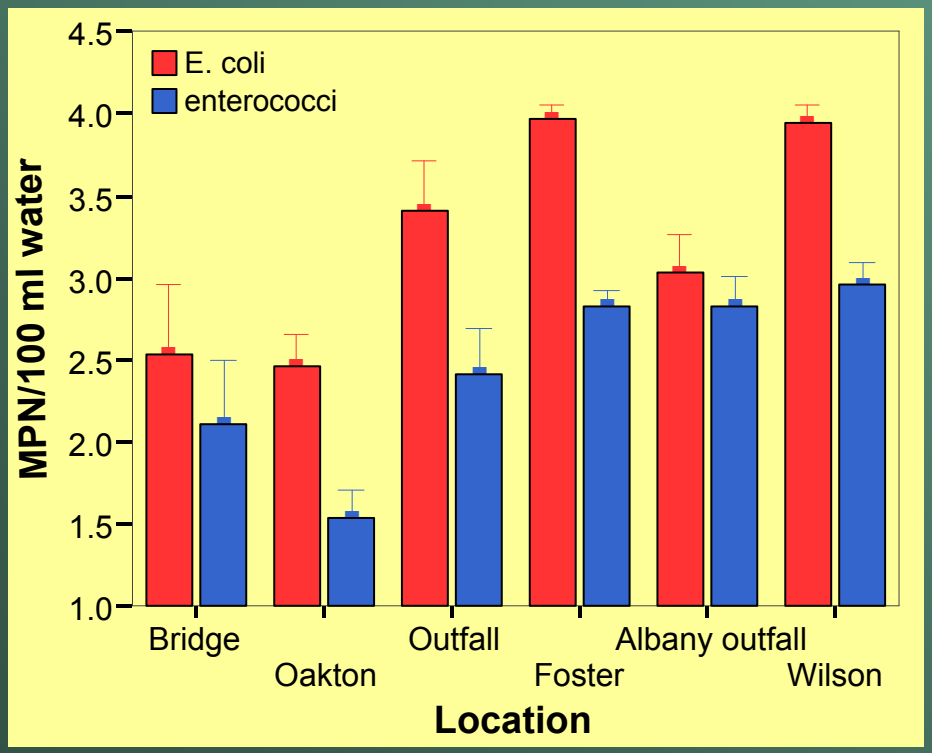
Log Mean *E. coli* Densities in Sediment

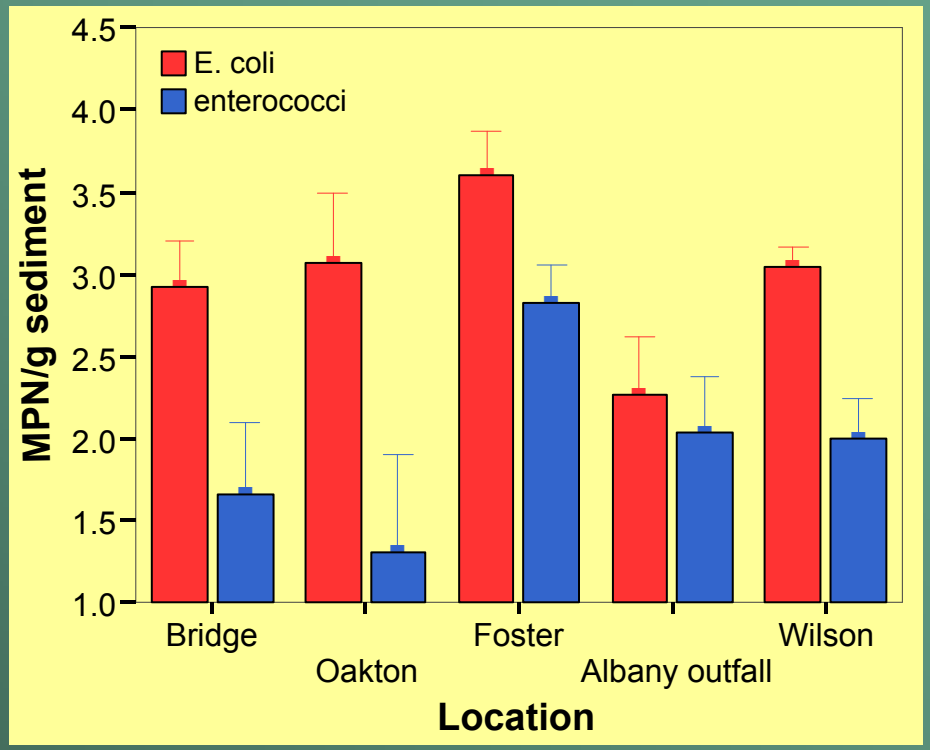


- *E. coli* densities in sediments collected from Foster Ave. were significantly higher than at Albany Ave., but not from any other location.
- There were no correlations in *E. coli* densities among locations.

USGS

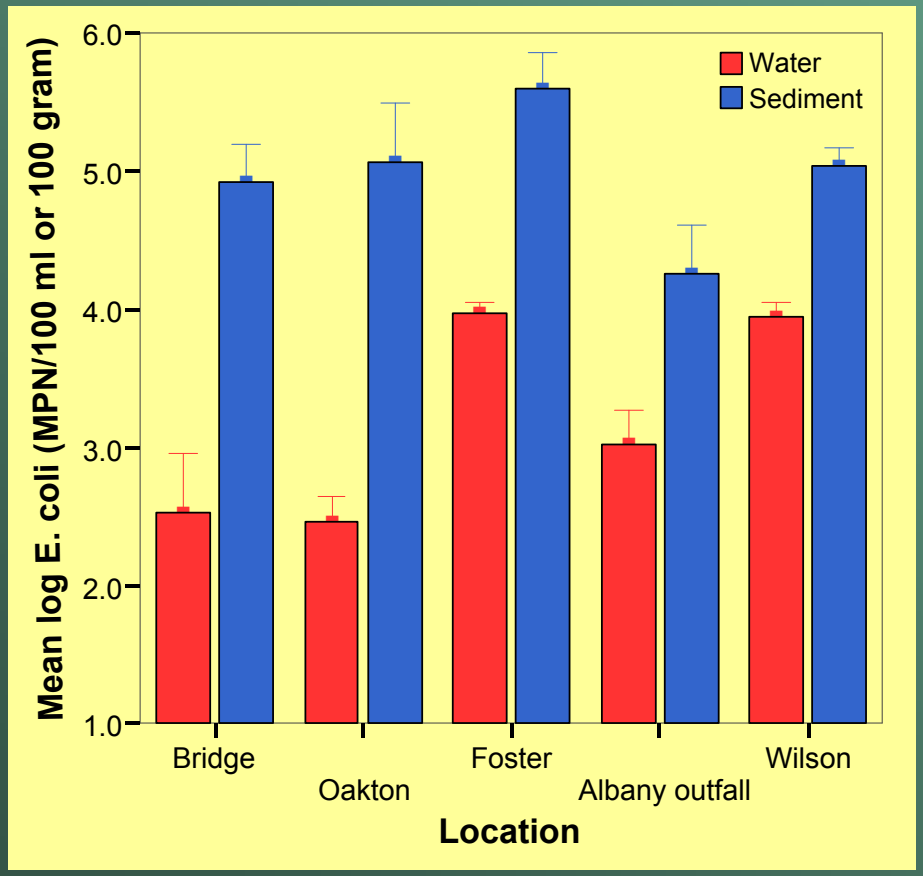
Log Mean *E. coli* and Enterococci in Water and Sediment





USGS

Sediments may Impact Overlying Water



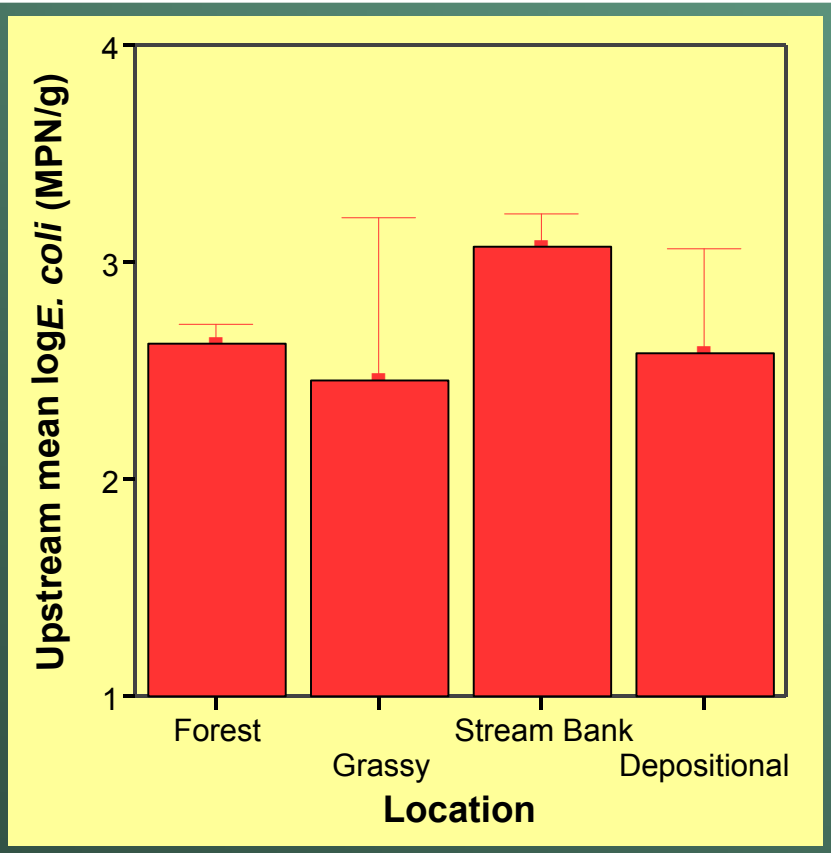
- When comparing 100 ml of water to 100 g of sediment, *E. coli* densities in the sediment were significantly higher than in water at each location.

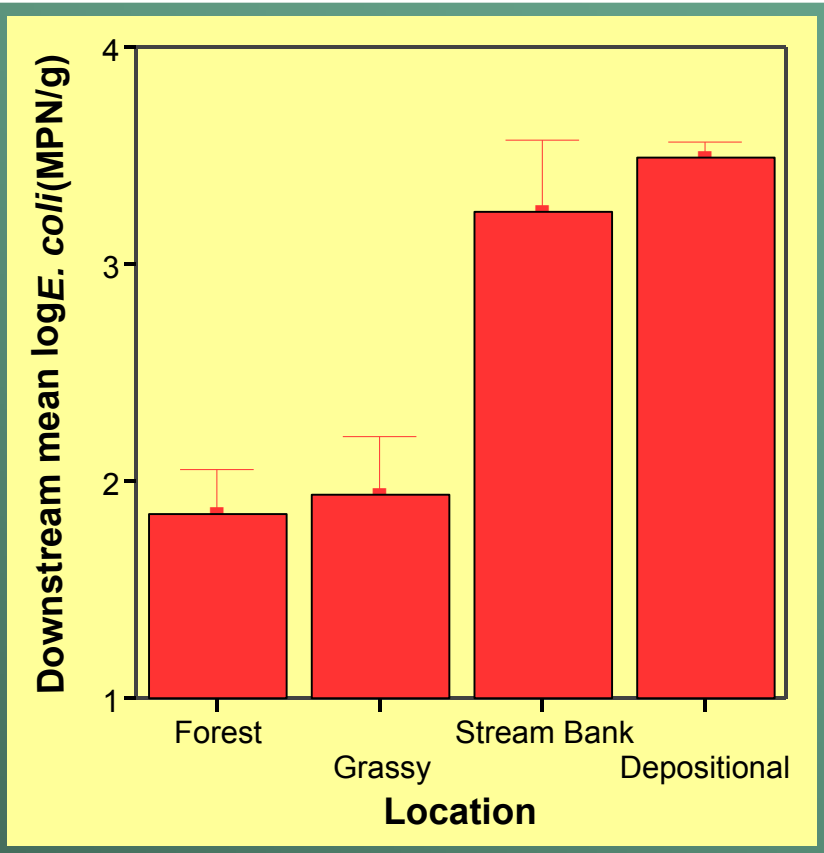
USGS

Other *E. coli* Sources and Their Potential Impact on River Water

USGS

Recreational Parks: Run-off from Upland Soils and Stream Margins may Affect *E. coli* Densities in the River

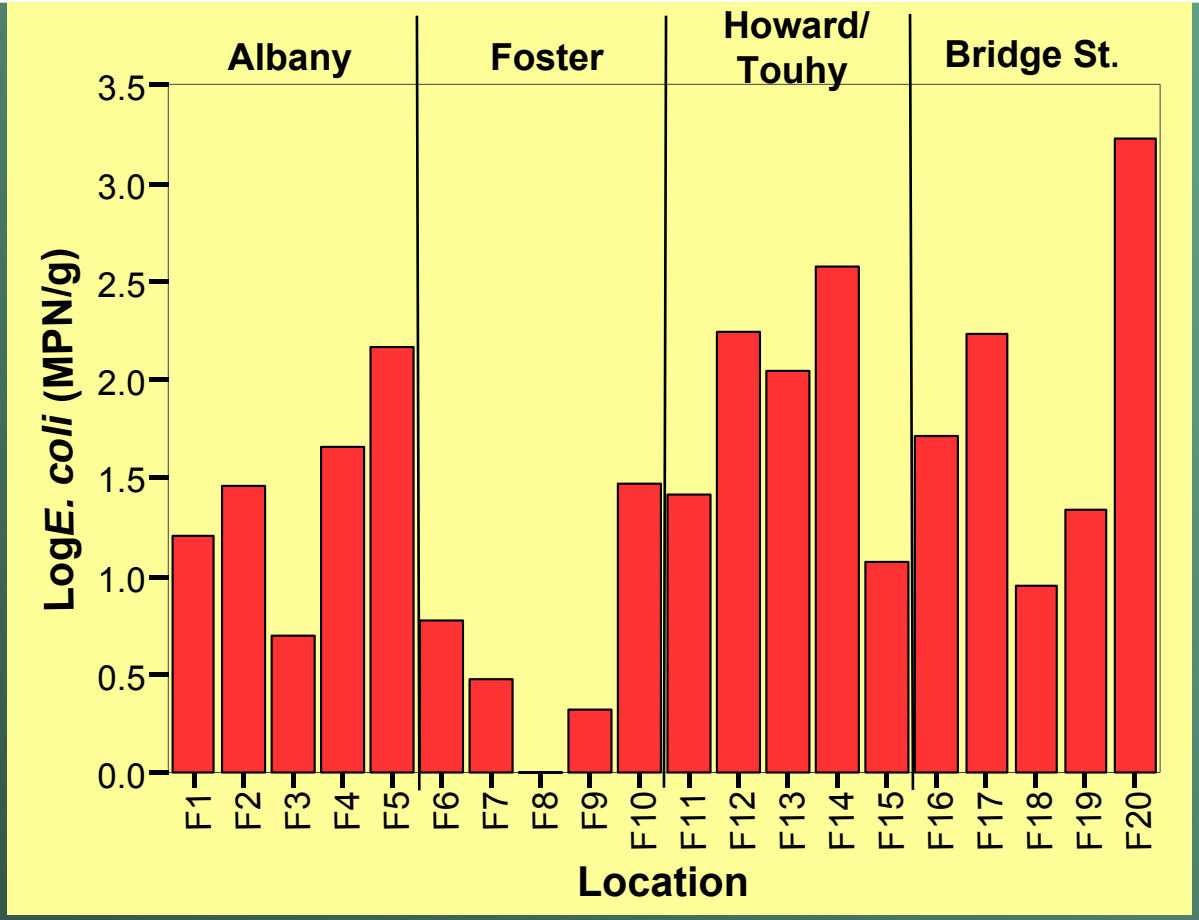




Channel-side Park Canoe Launch (near Oakton St.) **East River Park**

USGS **September 23, October 21, and October 31; *n*=120**

Distribution of *E. coli* in Soils from Four Recreational Parks: Bridge St. to Albany Ave.



USGS

Storm Sewer Outfalls

USGS

E. coli from Storm Sewer Outfalls

Date/24-hr Cumulative Rainfall (in)	Storm Sewer *E. coli* (mean log MPN/100 ml)	
	Evanston	Lincolnwood
09/04/08 (2.69)	4.86	4.77
09/29/08 (0.60)	4.43	5.93
10/08/08 (1.20)	4.74	3.46
10/20/08 (0.46)	3.07	5.32

USGS

Fecal Indicator Bacteria are Commonly Found in the Watersheds of Lake Michigan

Creeks and streams (water, sediments)

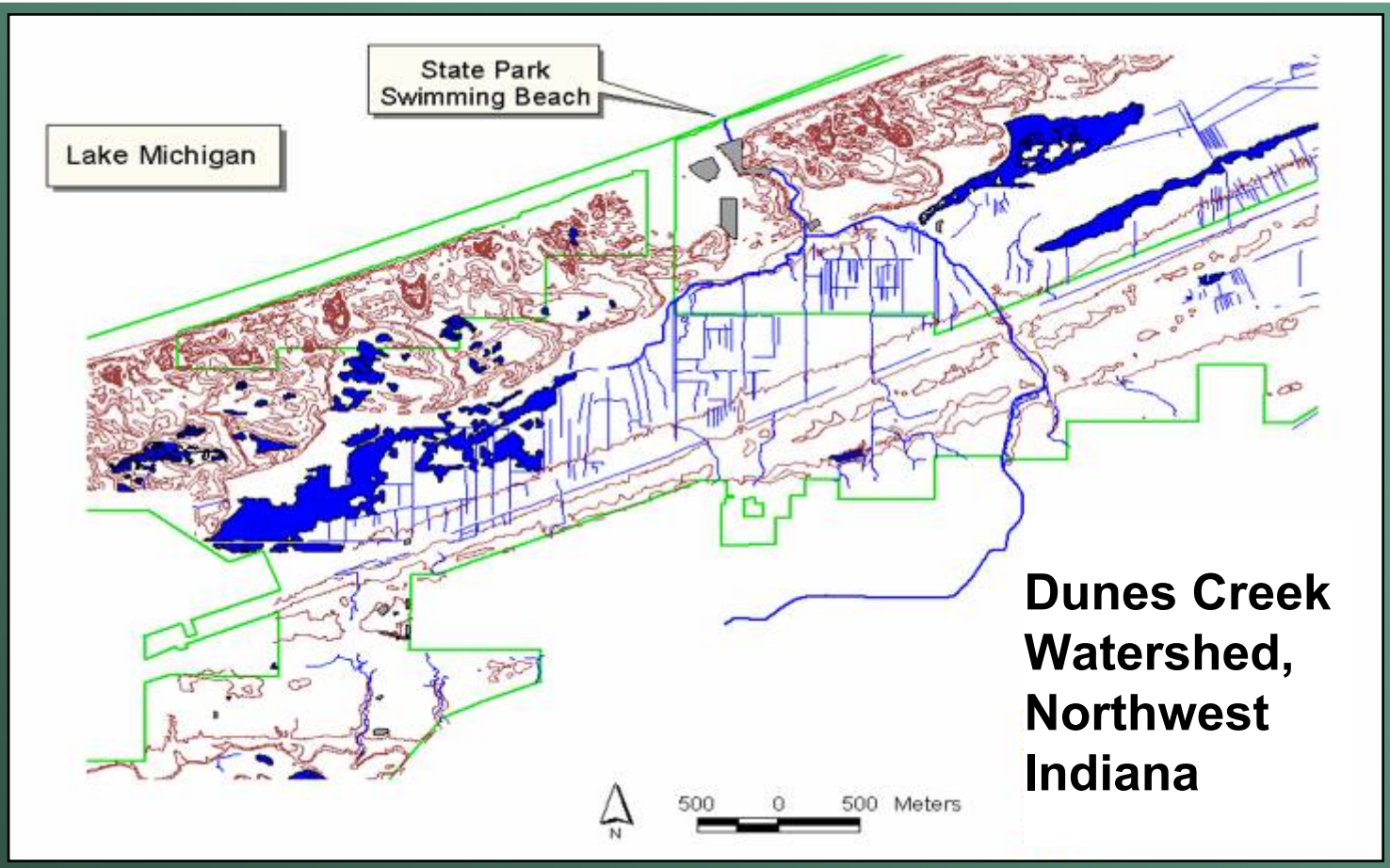
Riparian soils

Beach sand

Green alga *Cladophora*

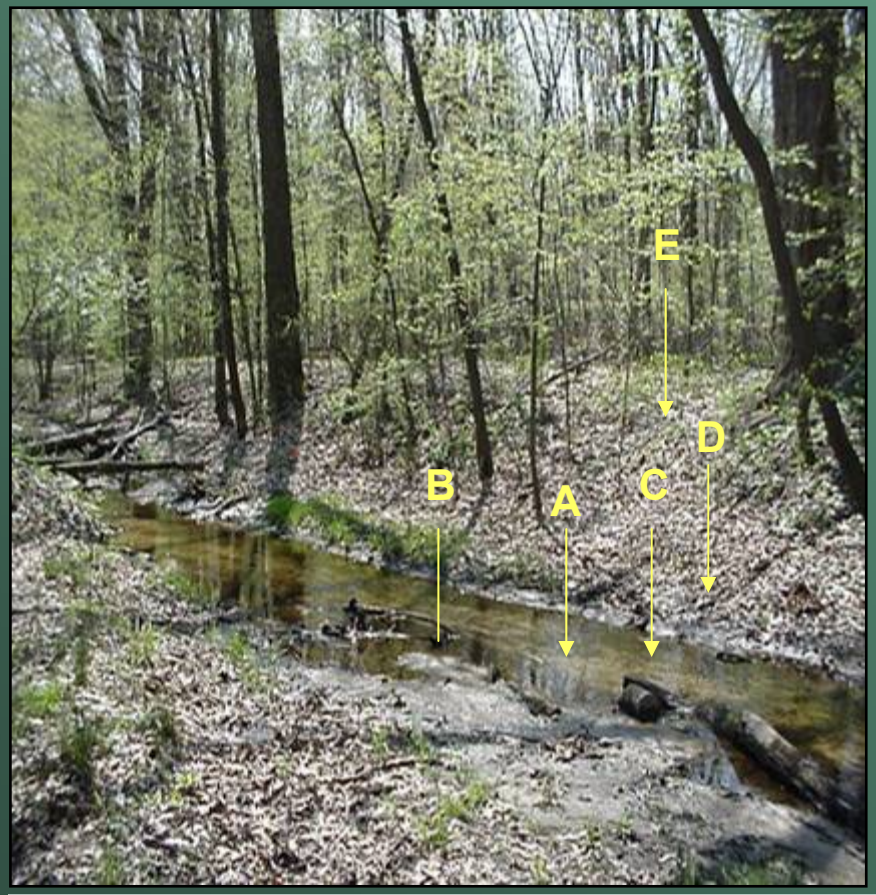
USGS

Linking Watershed Components: Riparian Soils with Creek and Sediments



USGS

Dunes Creek Watershed: *E. coli* of Stream Water and Sediments are Correlated



Stream Water-A
Stream Sand-B
Margin Sand-C
Sand @ 1 m from margin-D
Soil @ 4 m from margin-E

Connected Lines Indicate Significant Correlation (Spearman rho, p=0.05, n=15)

USGS

Whitman, R.W., M. Fowler, D.A. Shively and M.N. Byappanahalli. 2002. Distribution and characterization of E. coli within the dunes creek watershed, Indiana Dunes State Park. Report for: Indiana Department of Natural Resources, Indiana Dunes State Park.

Colonization Potential and Survivability of *E. coli* in Forest Soil

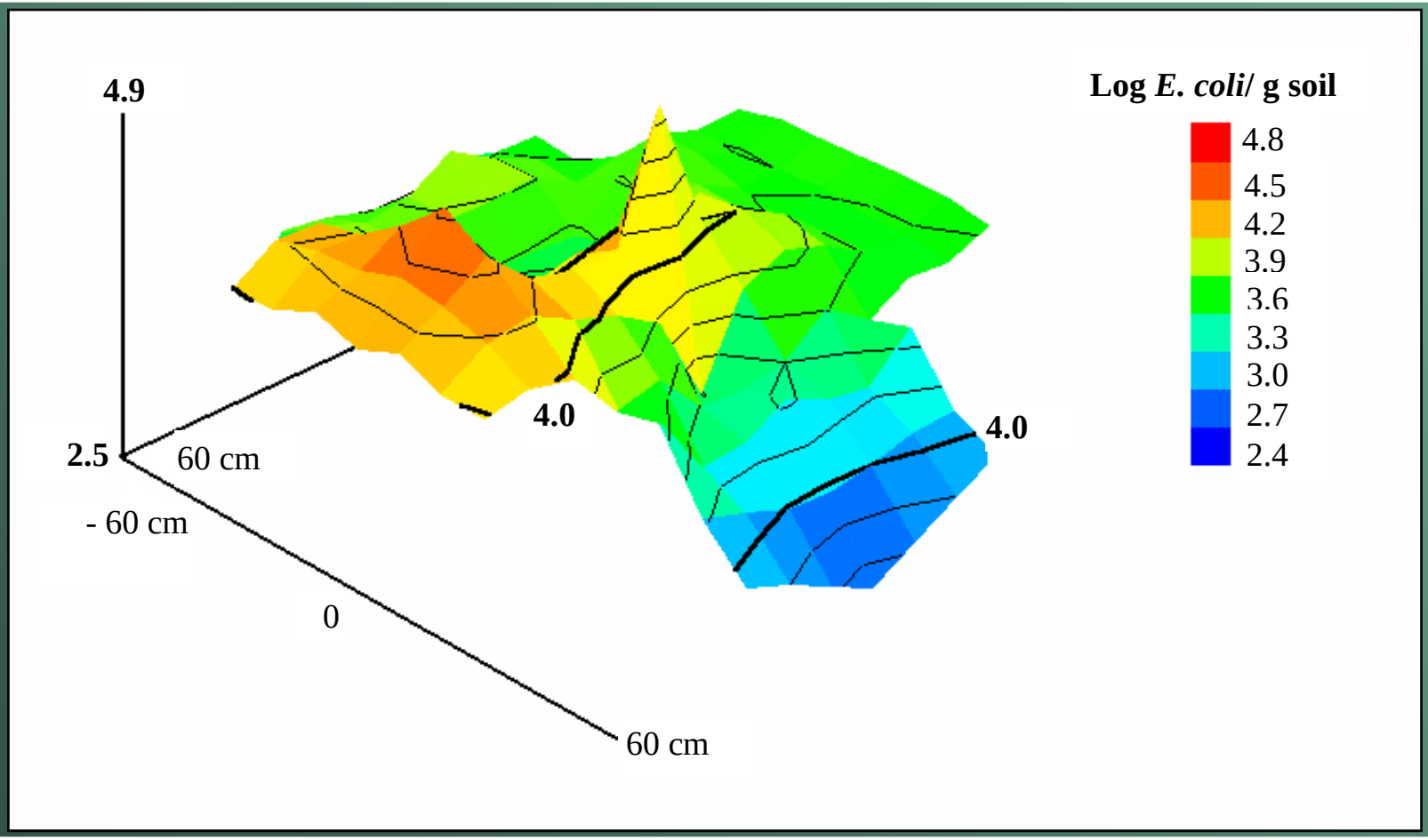
Days after sterilization	*E. coli* counts (MPN g^{-1})
-1	1.54×10^2
0	< 1
5	1.11×10^3
20	9.5×10^1
28	1.34×10^2
81	$> 2.42 \times 10^3$
160	1.66×10^2
216	1.71×10^2
250	1.40×10^2
369	2.50×10^5

***E. coli* recolonization of forest soil in a 0.05 m^2 area**

USGS

Whitman, R. L., M. B. Nevers, and M. N. Byappanahalli 2006. Examination of the Watershed-Wide Distribution of *Escherichia coli* along Southern Lake Michigan: an Integrated Approach. Applied and Environmental Microbiology. 72(11), 7301-7310

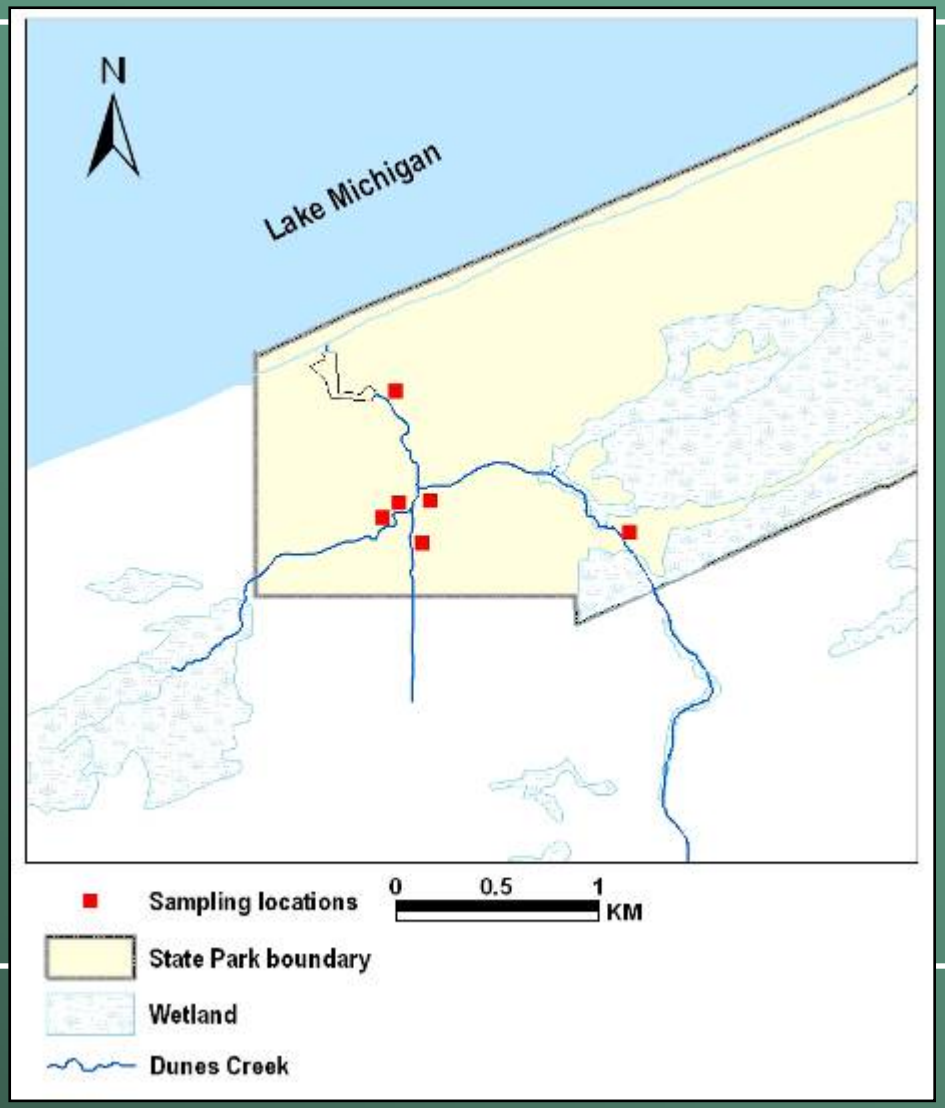
Spatial Distribution of *E. coli* in Soil Five Months After Hot Water Treatment



USGS

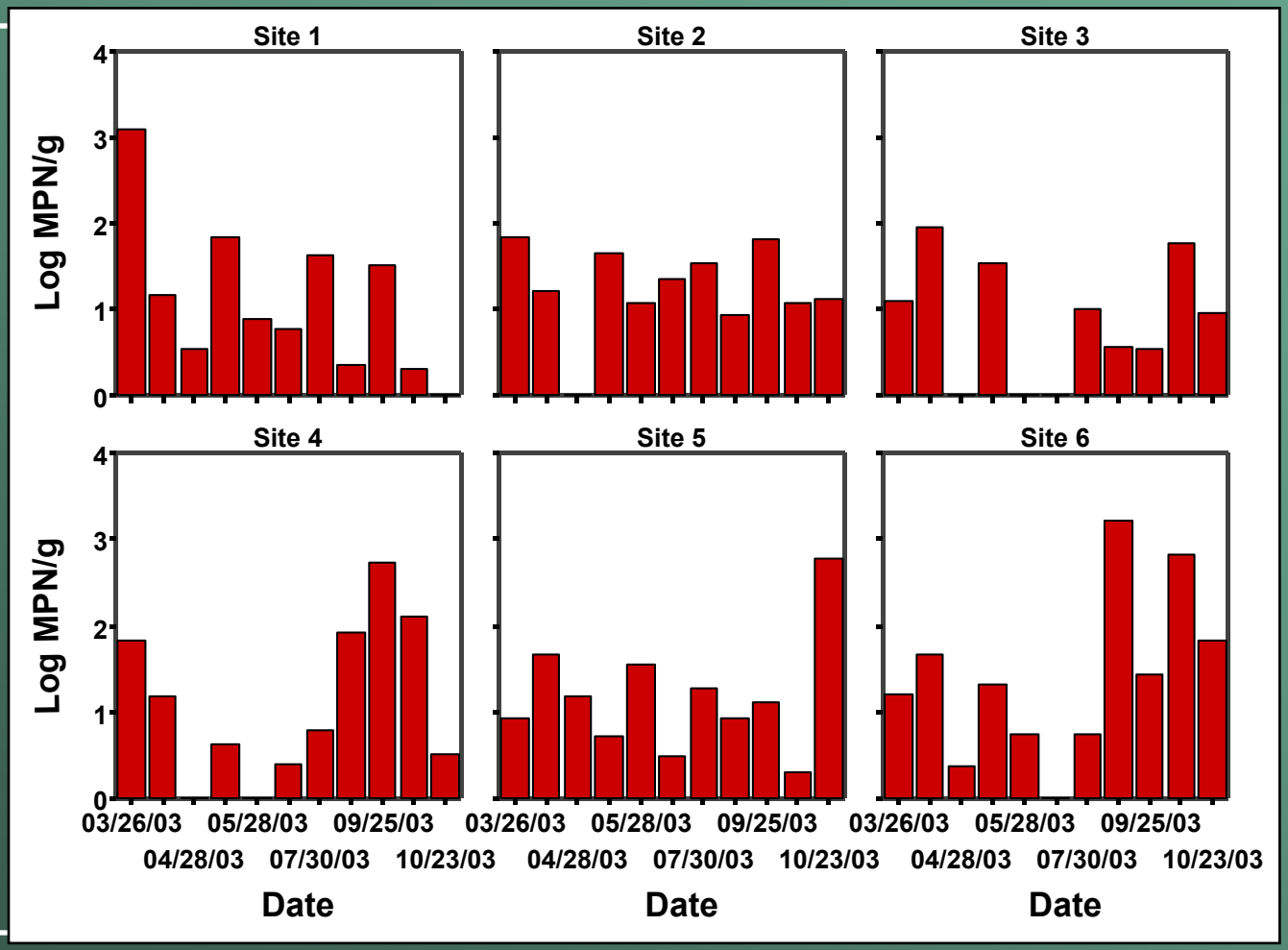
Whitman, R. L., M. B. Nevers, and M. N. Byappanahalli 2006. Examination of the Watershed-Wide Distribution of *Escherichia coli* along Southern Lake Michigan: an Integrated Approach. Applied and Environmental Microbiology. 72(11), 7301-7310.

E. coli is Commonly Found in Riparian Forest Soils of Dunes Creek



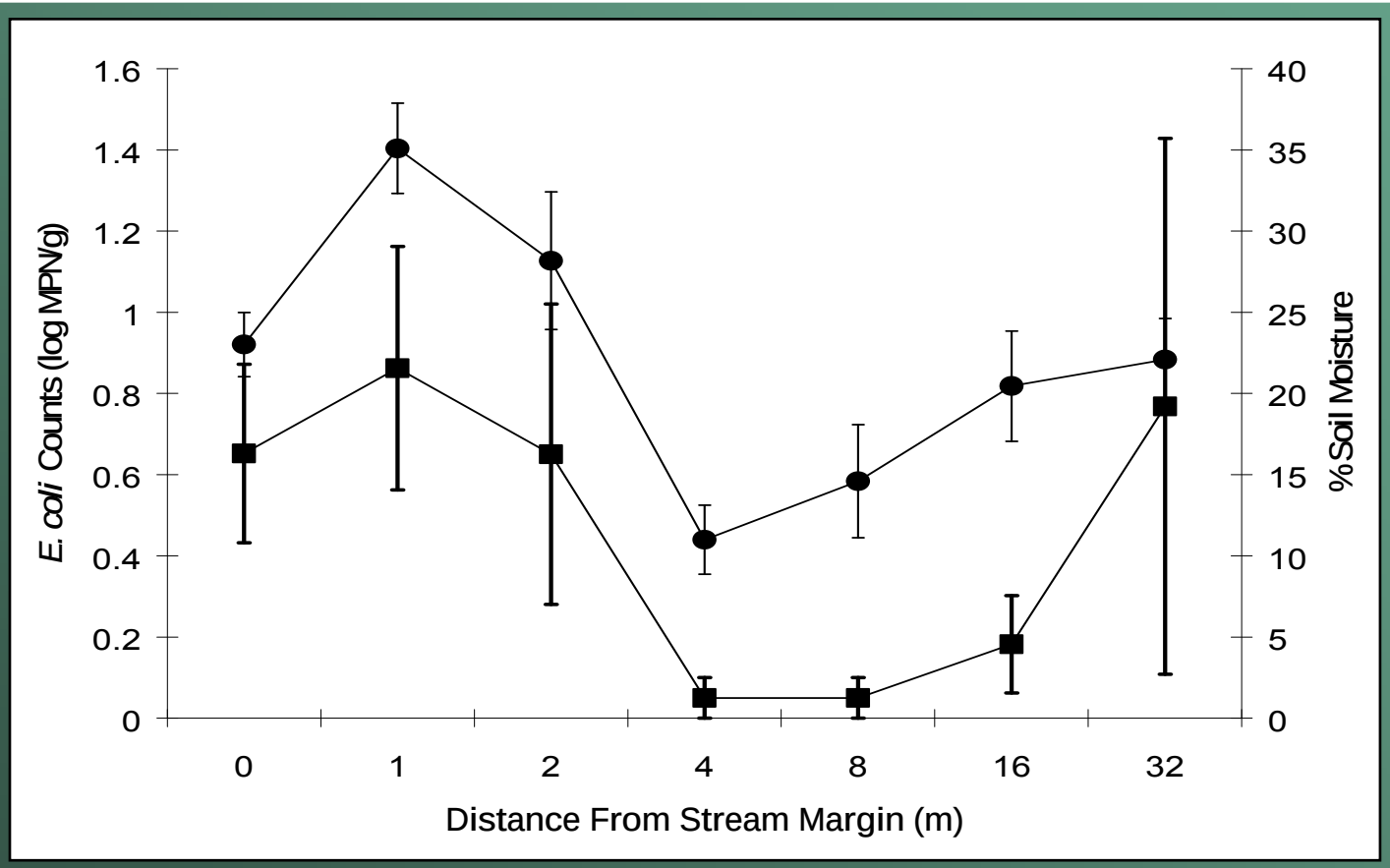
USGS

E. coli was Recovered in Riparian Forest Soils in All Seasons



Byappanahalli M. N., R. W. Whitman, D. A. Shively, M. J. Sadowsky and S. Ishii. 2006. Population structure, persistence, and seasonality of autochthonous *Escherichia coli* in temperate, coastal forest soil from a Great Lakes watershed. Environmental Microbiology 8 (3), 504–513.

E. coli Counts in Sediment and Soil Vary With Moisture Content

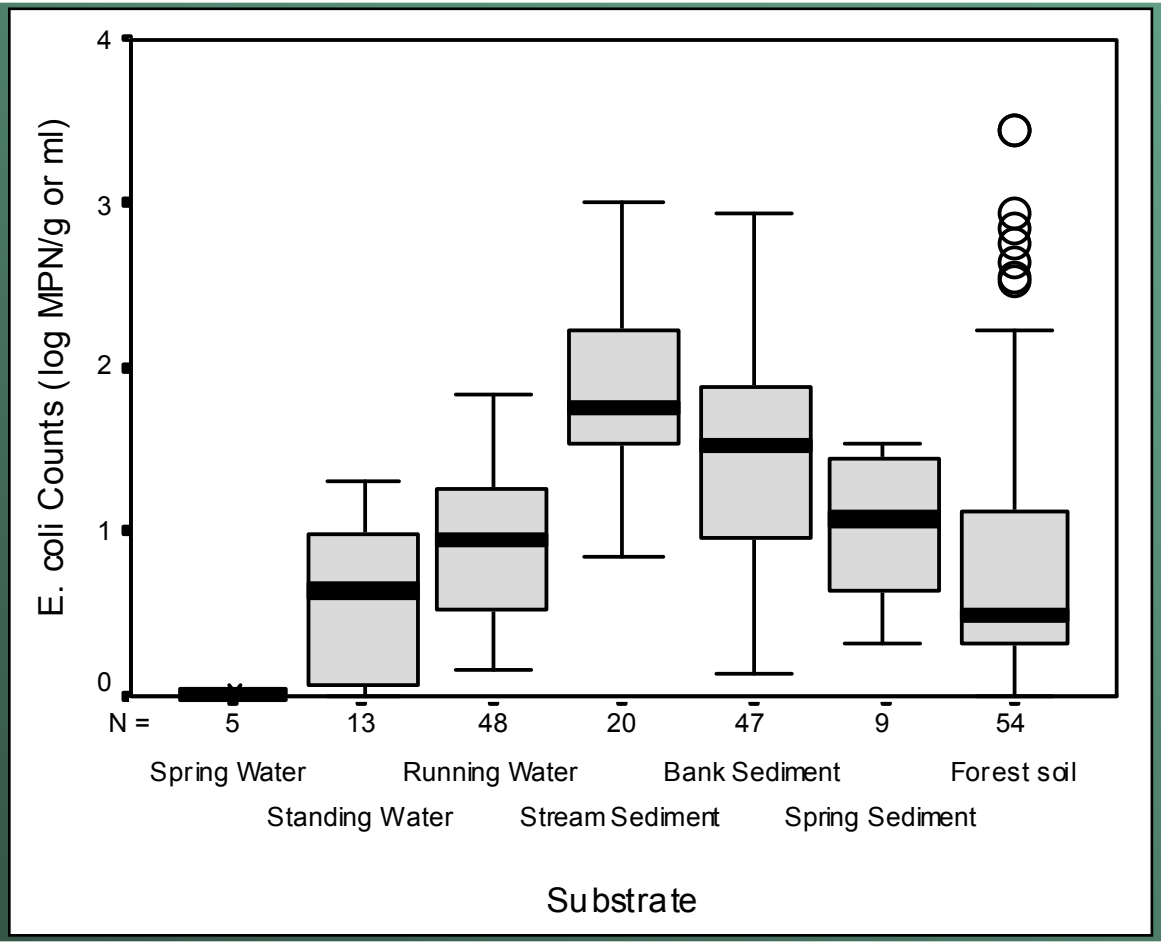


Mean *E. coli* (■) and percent soil moisture (●)

USGS

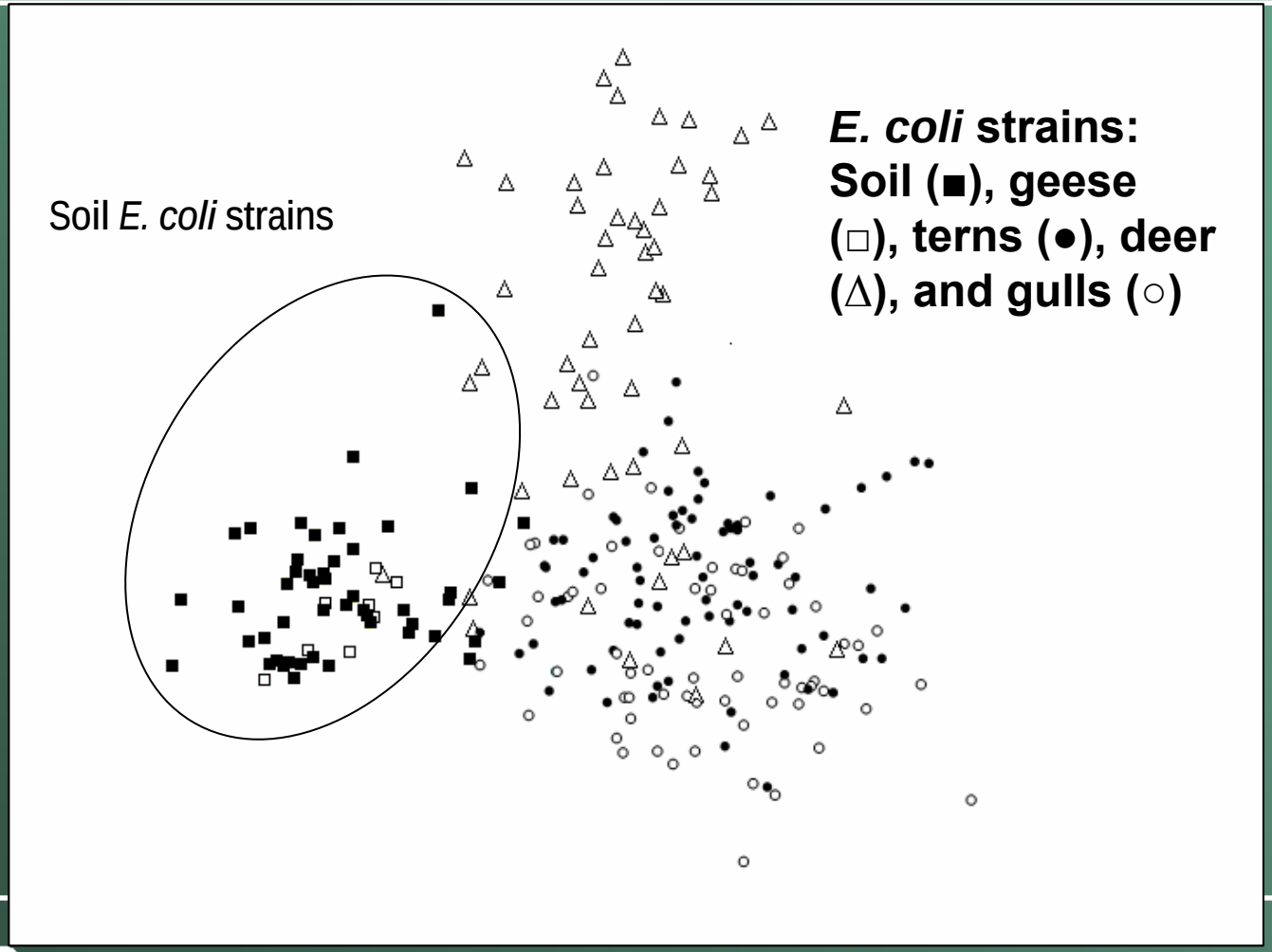
Byappanahalli, M., M. Fowler, D. Shively, and R. Whitman. 2003. Ubiquity and persistence of *Escherichia coli* within a midwestern stream. Applied and Environmental Microbiology 69:4549-4555.

E. coli is Ubiquitous in Dunes Creek and Other Similar Watersheds



Whitman, R.W., M. Fowler, D.A. Shively and M.N. Byappanahalli. 2002. Distribution and characterization of E. coli within the dunes creek watershed, Indiana Dunes State Park. Report for: Indiana Department of Natural Resources, Indiana Dunes State Park.

Soil-borne *E. coli* Strains were Genetically Distinct



USGS

Byappanahalli M. N., R. W. Whitman, D. A. Shively, M. J. Sadowsky and S. Ishii. 2006. Population structure, persistence, and seasonality of autochthonous *Escherichia coli* in temperate, coastal forest soil from a Great Lakes watershed. Environmental Microbiology 8 (3), 504–513.

E. coli Ubiquity in the Watersheds of Southern Lake Michigan: USGS Findings

- *E. coli* is commonly found in forest soils throughout the year, making soil a significant non-point source.
  - *E. coli* may grow in the soil under certain conditions.
- Stream sediments are a source of *E. coli* to stream water during resuspension.
- Stream outfalls are a source of FIB to beach water.
- When examining indicator bacterial source, flux, and context, the entire lake and stream watershed as a dynamic interacting system should be considered.

USGS

Summary

- *E. coli* densities in water at downstream locations (Foster Ave. and Wilson Ave.) were significantly higher than at upstream locations (Bridge St. and Oakton St.).
- High *E. coli* densities were found in sediments in both upstream and downstream locations.
- *E. coli* was consistently found in soils from the wooded, grassy, erosional/stream bank, and depositional areas of the two recreational parks (Oakton St. and Albany Ave.) studied.

USGS

Summary (cont.)

- *E. coli* recovery in soils from other public parks along the North Branch of the Chicago River suggests its widespread occurrence in this environment.

- Other *E. coli* contributions to the Chicago River include outfalls (e.g., East Park River) and storm drains, especially under high flow conditions.

USGS

Acknowledgments

MWRDGC R&D

Dr. Thomas Granato

Analytical Microbiology and Monitoring Section

- Dr. Geeta Rijal
- Auralene (Toni) Glymph
- Richard Gore
- James Kaehn

IWD Staff

Robert Renaud

Sharon Sopcak Phelan

Kenneth Johnson

Alexander Wilczak

North Side Wastewater Reclamation Plant

James Kaminski

USGS

Katarzyna (Kasia) Przybyla-Kelly

Dawn Shively

Ashley Lukasik

USGS

Thank You