Members

Sen. Carlin Yoder, Chairperson
Sen. Ryan Mishler
Sen. Lindel Hume
Sen. Richard Young
Rep. Sean Eberhart
Rep. Michael Karickhoff
Rep. Kreg Battles
Rep. David Niezgodski

NATURAL RESOURCES STUDY COMMITTEE

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MEETING MINUTES[1]

Meeting Date/Time: **August 28, 2012 (10:00 A.M.) & August 29, 2012 (9:30 A.M.)**
Meeting Place: **Dean's Auditorium (Room 241) Pfendler Hall, 715 W. State St.**
Meeting City: **West Lafayette, Indiana**
Meeting Number: **1**

Members Present: **Sen. Carlin Yoder, Chairperson; Sen. Ryan Mishler; Sen. Lindel Hume; Sen. Richard Young; Rep. Sean Eberhart; Rep. David Niezgodski.**

Members Absent: **Rep. Michael Karickhoff; Rep. Kreg Battles.**

The Natural Resources Study Committee (Committee) and the Water Resources Study Committee (WRC) joined to conduct this meeting. The WRC Chairman, Representative William Friend, presided over the morning's agenda. The meeting was called to order at 10:15 a.m. Chairman Friend asked members and staff of both committees to introduce themselves.

Steve Yaninek, Department Head, Department of Entomology, Purdue University (Purdue), and Council Secretariat, Indiana Invasive Species Council (IISC)
Phil Marshal, Division of Entomology and Plant Pathology Department of Natural Resources' (DNR) and IISC Member

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[1] These minutes, exhibits, and other materials referenced in the minutes can be viewed electronically at http://www.in.gov/legislative Hard copies can be obtained in the Legislative Information Center in Room 230 of the State House in Indianapolis, Indiana. Requests for hard copies may be mailed to the Legislative Information Center, Legislative Services Agency, West Washington Street, Indianapolis, IN 46204-2789. A fee of $0.15 per page and mailing costs will be charged for hard copies.

Mr. Yaninek and Mr. Marshall reported on IISC's objectives, organizational structure, and strategic plan. (Exhibit 1) The report also identified the following invasive species management efforts: 1) gypsy moth, 2) tulip tree scale insect, 3) thousand cankers disease, 4) emerald ash borer, and 5) brown marmorated stink bug. Mr. Marshall explained that the IISC has no regulatory powers and work with existing state agencies.

Responding to committee questions, Mr. Marshall stated that the Asian carp invasion has not reached the Wabash River, but is close to the Logansport area.

Ron Turco, Ph.D., Director of the Indiana Water Resources Research Center and the Purdue University Water Community

Dr. Turco provided information and data on the role and use of water in agriculture, watershed systems, and water quality and quantity. (Exhibit 2) Answering a question regarding how salmonella can contaminate cantaloupes, Dr. Turco responded that the skin of the fruit is resistant to organisms, thus, the skin must break to become contaminated.

Tomas Höök, Department of Forestry and Natural Resources, Purdue University, and Purdue University Water Community Member

Mr. Höök discussed the Illinois-Indiana Sea Grant Program and the importance of the Great Lakes as the world's largest surface fresh water supply. (Exhibits 3, 4, 5, & 6)

The meeting recessed for lunch at 12:00 p.m. Senator Carlin Yoder, Chairman, Natural Resources Study Committee, presided over the afternoon proceedings and reconvened the meeting at 1:15 p.m.

Mark Basch, Section Head, Department of Natural Resources (DNR), Water Rights Section

Mr. Basch reported on DNR's water resources management programs. (Exhibit 7) In response to members' questions, Mr. Basch stated that:

- DNR can restrict water pumping but has done so only once (1988).
- The state can sell water from reservoirs but contracts cannot be longer than 50 years. There are, currently,9 contracts for the sale of water.
- There are about 1,300 licensed well drillers and pump installers. They are required to complete 6 hours of continuing education every 2 years.
- Abandoned wells must be plugged within 5 years of being abandoned. Active wells must submit records to DNR.

John Davis, Deputy Director, DNR

Mr. Davis provided an update of the effect of the drought on state owned properties. He noted the following effects:

- Lower lake levels have exposed submerged towns, like Monument City, leading to an increased number of people visiting these sites.
- Water front concessionaires have had a loss in business.
- The number of fish kills has increased.
- Certain fire hydrants that connect directly to lakes for a water source have become unusable because of the lower lake levels.

Chris Hurt, Agricultural Economist, Purdue Extension Service

Professor Hurt provided information on the 2012 drought and its effect on Indiana's agricultural economy. (Exhibit 8) Professor Hurt also reported as follows:

- The 2012 drought will be one of the most expensive natural disasters since 1980. Yield losses in Indiana are estimated to be much higher than the national average. For example, estimated corn crop losses in Indiana are 40% but nationally losses are 25%; soy bean losses are 24% in the state, however, nationally the crop is down 18%.
- Forward pricing crops will hurt farmers this drought year. Livestock farmers will also be greatly impacted due to the higher cost of feed.
- While this year the net loss is high, over the long term the federal crop insurance program is actuarially sound because for many years crop insurance brought in more premium income than what was paid out.
- Indiana produces 8% of the ethanol in the nation. Because this year will not yield enough corn crop, the U.S. Environmental Protection Agency is considering a renewable fuel standard waiver that would reduce the amount of ethanol that it requires to be produced next year.

Ron Turco, Ph.D., Director, Indiana Water Resources Research Center and the Purdue University Water Community

Dr. Turco reported on Purdue's water resources programs and discussed data on pharmaceuticals in freshwater. (Exhibits 9; 10 & 11) Dr. Turco stated the following:

- Human pharmaceuticals are found twice as often as agricultural pharmaceuticals. Levels are higher in Lake Michigan. While pharmaceuticals can be extracted from water using ultraviolet and other aggressive chemical treatments, it is expensive and would add to the cost of water. The best strategy is to prevent pharmaceuticals from entering water systems.
- Indiana needs a water assessment program similar to the Illinois Water Survey to evaluate the impact of water resources on Indiana's interests (e.g., quality, floods, irrigation, and business development) over the next 30 years.

Jack Wittman, Ph.D., Director, Layne Hydro Division, Layne Christensen Company

Dr. Wittman presented information pertaining to the effects of users' competition for water on natural resources, municipalities' growth, and agricultural uses. (Exhibit 12) Dr. Wittman, answering a member's question, reiterated the importance of addressing the state's need for a sound water supply plan, to rethink the water grid, and to modernize the regulatory infrastructure. Dr. Wittman contrasted Indiana's water resources to New Mexico's, where the state will spend over $100 million to pipe water.

The Senator Yoder, Chair, recessed the meeting at 3:30 p.m.

Officials from Purdue invited the Committee members and others in attendance to join a tour of the Hardwood Tree Improvement and Regeneration Center and the Wood Processing and Industrial Engineering facility.

Senator Yoder reconvened the Committee at 9:40 a.m. on August 29, 2012.

Chris Smith, Legislative Director, Department of Natural Resources (DNR)

Mr. Smith updated the Committee on various natural resource matters from the previous year. His presentation included the following information:

- The overall gate revenues at the state parks have been slightly up from 2011.
- The number of campers has risen and fallen with the weather (i.e. early warm; mid-summer heat and drought).
- Indiana State Park Inns lead the nation in occupancy with a 61.35% occupancy rate. For the fiscal year, the Inns made $3.4 million in profit.
- The Indiana Heritage Corps program, an AmeriCorps program run by the Indiana State Parks and Reservoirs Division, is currently in its inaugural program year. As of July 2012, the 22 members serving in the Indiana Heritage Corps program have completed 42.61 miles of trail work - an achievement that far exceeds the program's goal.
- Heat and low water levels resulted in lower sales of fishing licenses this season.
- On March 2, 2012, a tornado destroyed an area three miles long and ¾ mile wide in Clark State Forest. The Division of Forestry worked with private businesses to conduct a salvage operation to recover 4 million board feet of timber. The area was divided into five sections and the timber in each section was sold in a lump sale, a shared sale, or a price per board foot.
- The Healthy Rivers INitiative is Indiana's largest land conservation initiative. It is conducted in partnership with other resource agencies and organizations that work with willing landowners to permanently protect over 43,000 acres located in the floodplain of the Wabash River and Sugar Creek and over 26,000 acres of the Muscatatuck River bottomlands. The wetlands are protected through a combination of fee simple acquisitions from willing sellers, conservation easements, and Wetlands Reserve Program enrollments.
- The third annual Hoosier Outdoor Experience will take place at Ft. Harrison State Park on Sept 15 & 16. The free event will have over 50 hands-on events for visitors to participate in, including shooting sports, bird watching, camping, and fishing. Last year 21,300 people attended.
- As of June 2012, Indiana has a trail within 7.5 miles of 97.5% of all Indiana residents. This represents over 3,000 miles of trails.
- Outdoor Indiana magazine has increased its paid subscriptions for three consecutive years after a 14 year decline.
- DNR has added video to its various communications tools and launched a YouTube channel: www.youtube.com/user/idnrvideos

Mr. Smith concluded with a review of recently enacted legislation and adopted rules.

In response to Committee questions, Mr. Smith stated the following:

- A special antlerless deer season at the end of the year will allow hunters to use their unused hunting licenses in certain counties.
- DNR has been teaching people to differentiate between minnows and small Asian carp to make sure the invasive species is not transferred into Indiana lakes.
- Outdoor Indiana magazine does not accept advertisements. This allows the magazine to have a lower postage rate. However, the hunting guide accepts advertising which helps off-set the printing cost.

Rob Swihart, Ph.D., Head, Department of Forestry and Natural Resources, Purdue University

Dr. Swihart presented an overview of the Department of Forestry and Natural Resources (DFNR) at Purdue University. (Exhibits 13 & 14) Information presented to the Committee included the following:

- DFNR has over 300 undergraduate and 86 graduate students enrolled in the program.
- There has been a steady rise in the number of grants received and publications made by the DFNR staff.
- The DFNR's research programs are highly ranked among the other national programs.
- DFNR extension and research activities include the Hardwood Tree Improvement and Regeneration Center, hardwood ecosystem experiment programs, forest tax advice for landowners, and developmental genetics.

Mike R. Saunders, Assistant Professor of Hardwood Silviculture, Department of Forestry and Natural Resources, Purdue University

Mr. Saunders provided a summary of the Hardwood Ecosystem Experiment (HEE). (Exhibit 15) Mr. Saunders highlighted the following information:

- There are numerous obstacles that face forest management, including potential major shifts in the composition of the forest.
- HEE has several primary objectives including developing systems that maintain oak dominated forests and determining the impact of silvicultural systems on various species groups and economic ramifications on local communities.
- HEE will study various forest management practices for the next 100 years.

Mr. Saunders concluded with a summary of the many specific research activities that are included within HEE.

In response to Committee questions, Mr. Saunders stated that certain conditions (e.g. lack of ground fires) help maple trees survive. Once maple trees are established it is difficult for oak trees to propagate.

Dan Cassens, Ph.D., Professor and Extension Wood Products Specialist, Department of Forestry and Natural Resources, Purdue University

Dr. Cassens stated that wood is a common material and timber is a common resource but neither is understood as a resource and emotions often overshadow the science in timber harvesting. He provided the following information on the Woody Biomass Project (Exhibit 16) to the Committee:

- About 3.8 times more wood is grown than harvested.
- About 20% of Indiana is forested.
- Nearly 50% of dry wood is carbon. When wood is burned the carbon dioxide is released but other trees recapture carbon dioxide. Young trees capture more carbon dioxide than mature trees.
- Wood does not release carbon dioxide into the atmosphere if it remains in the soil (e.g. roots) or is permanently sequestered (e.g. furniture).
- Biomass from wood can be used as a crop to generate renewable energy.

Barney Dunning, Ph.D., Associate Professor, Department of Forestry and Natural Resources, Purdue University

Dr. Dunning stated that there are several biological unknowns concerning the effects of biomass harvest. (Exhibit 17) His presentation included the following information:

- A new study has begun to examine the harvest of hardwoods and the use of the of the downed woody debris.
- Harvesting the downed woody debris may have various biological impacts (e.g. forest nutrient cycling, habitat for animals).
- A conference on woody biomass in Indiana will be co-sponsored by Purdue University this fall. The conference will bring together information from the university, foresters, wildlife groups, and renewable energy organizations.

Linda Stalker Prokopy, Ph.D., Useful to Usable (U2U) Project Coordinator, Associate Professor, Department of Forestry and Natural Resources, Purdue University

Dr. Prokopy presented an overview of a new project concerning climate variability and change information for crop producers. (Exhibit 18) Dr. Prokopy's testimony included the following information:

- The corn yields for Indiana and the nation are predicted to be down this year. Researchers are trying to determine if the change in temperature and precipitation patterns are an abnormality or part of a climate change.
- Climate variability limits season-to-season predictability and lessens the ability to maintain viable farm operations.
- The U2U Project is a five year project to transform existing climate information into usable knowledge for agriculture decision making.
- The project uses an interdisciplinary team that is represented through various universities and organizations.
- A key issue for the project is to examine the financial, production, and environmental outcomes of short-term management decisions and long-term investment planning under different climate scenarios.

The Chair adjourned the meeting at 11:35 a.m.

NRSC
Aug. 28 & 29, 2012
Exhibit # 1

NATURAL RESOURCES STUDY COMMITTEE
Indiana Invasive Species Council (IISC) Report Briefin
August 28, 2012

Council Chairman John Jachetta, Dow AgroSciences LLC
Council Secretariat Steve Yaninek, Purdue University
Amy Cornell, Indiana State Department of Agriculture
Bill Fielding, Indiana Department of Transportation
Philip Gramelspacher, Indiana Forestry and Woodland Owners Association
Eric Fischer, Indiana Department of Natural Resources' Division of Fish and Wildlife
Kristopher Krouse, Shirley Heinze Land Trust, representing land trusts, conservation and/or parks and recreation organizations
John Williams, Indy Parks
Phil Marshall, Department of Natural Resources' Division of Entomology and Plant Pathology
Dr. Sandi Norman, Indiana State Board of Animal Health
Open position, representing industry

Indiana Invasive Species Council Objectives:
The IISC continues to focus on addressing the duties set forth by the Indiana General Assembly. In 2009, the Indiana General Assembly established the Indiana Invasive Species Council (IISC) within the Purdue University College of Agriculture to enhance the ability of state agencies to detect, prevent, monitor and manage new and long established invasive species. This action was based on the recommendation of a task force established by a joint House and Senate committee. Invasive species are exotic insects, plants, fish, birds, mammals and other organisms that are a serious threat to Hoosier homes, environment and economy. The goal of the IISC is to work with responsible agencies and partners to effectively and efficiently slow the spread and thwart the impact of invasive species in Indiana. The council's most important function is to give citizens and industries a way to voice concerns and opinions about management of invasive species in Indiana while providing science-based, relevant information about current or emerging issues.

Open positions on IISC:
Filling this council is critically important to its mission and as elements of IISC working groups. The IISC forwarded several candidates to Governor Daniels for consideration and appointment. While we are still short one member (the Industry representative), the IISC appreciates the Governor's action in replacing a retiring member and reappointing several current IISC associates.

IISC Strategic Plan completed:
A formal strategic plan is critical to the functioning of the IISC and necessary for progress on tactical issues; this plan was completed in the second quarter, 2012 and includes seven key elements:

1. **Recommend project priorities, funding, rules, and laws**
   1) Few governmental agencies and partners have adequate staff and/or funding to fully address invasive species threats and infestations. Therefore, setting priorities will assist agencies and their partners in implementing the most cost-effective long-term control and/or eradication program.
   2) IISC will identify and prioritize funding needs. Funding needs may include research, management and education and outreach programs.

3) IISC will review the regulatory framework of invasive species in Indiana and make recommendations on the regulatory structure needed to successfully implement invasive species goals and objectives.
   a) Guidelines for Prioritization:
      i) Identify significant and important resources to protect.
      ii) Inventory properties to identify invasive species population sizes and locations.
      iii) Prioritize populations for management based on the significance of the resource, the existence of effective control methods, the invasiveness of the species, and the potential for long-term control.
      iv) Implement control and document our successes/failures.
      v) Reevaluate priorities based on our experiences with control and as we learn about new information and control methods.

2. Recommend a lead state agency to develop an invasive species inventory for each invasive species taxon (plants, insects and plant diseases, aquatics, animal diseases) and maintain a data management system

1) In Indiana, jurisdiction over invasive species is divided between the Department of Natural Resources (DNR), Board of Animal Health (BOAH), Office of Indiana State Chemist (OISC), County Weed Boards, and township trustees. Currently, there is no agency charged with gathering and maintaining data on invasive species in Indiana. This information is crucial for agencies and land managers to determine which new invasive species threaten which parts of Indiana, whether eradication of new infestations is feasible, and what are appropriate control strategies.

3. Communicate with other states, federal agencies, and state and regional organizations to enhance consistency and effectiveness in preventing the spread of, early detection of, response to; and management of invasive species

1) Invasive species know no boarders and can move in ways that negate political boundaries. Where appropriate, IISC will seek to coordinate with other state and federal agencies and organizations to leverage their experiences and approaches to invasive species management and funding.

4. Coordinate education and outreach activities

1) The IISC must identify key audiences, determine what educational materials are needed, tailor messages for each audience and determine the appropriate agency or partner to disseminate the information. The council has a duty to plan and conduct a public informational meeting every 2 years.

5. Assist governmental agencies in reviewing current invasive species policies and procedures, addressing any deficiencies or inconsistencies in such policies and procedures and reviewing the agencies' performance measures for accountability concerning the agencies' invasive species actions

1) Given the many state agencies and their varied missions in Indiana, it is not surprising that there are inconsistencies in policies and practices on invasive species between them. In some cases, one state agency is actively working to eradicate or control an invasive species that another agency may be deliberately introducing into Indiana.
2) IISC needs to identify the roles, responsibilities and lines of authority between state agencies and partners to assist governmental agencies in reviewing current invasive species policies and procedures. Information exchange between programs is critical to support regulatory coordination and facilitate invasive species management.

3) The IISC provides a regular forum for reviewing state agency policies and practices to identify ways to improve consistency and address any deficiencies.

6. Receive and manage reports from all governmental agencies that act on the council's recommendations

1) The science and economic impacts and management of invasive species are more than one person or agency can expertly know or expertly implement as policy. As a representative council, the IISC can address the science and policy issues in a way that results in an outcome that is fair and practical. This activity may include a formal request for reports on government agency actions resulting from this council's recommendations

7. Apply for and provide grants for education and management of invasive species

1) Additional funding may be needed to improve prevention, early detection and control and management of invasive species in Indiana in a cost-effective manner. The IISC can identify alternative funding sources that may be available and position Indiana to take advantage of them.

IISC Advisory committees

To address these opportunities and responsibilities, the IISC has established two advisory committees, including:

1. The Invasive Plants Advisory Committee and
2. The Aquatic Invasive Advisory Committee.

Invasive Plant Advisory Committee:

1. Best Management Practices (BMPs) Project
   a) This advisory committee has identified useful BMPs for forestry, transportation and utilities, and urban forestry and is in the process of adapting them for use in Indiana.
      a. A "Top Ten" list of BMPs has been drafted to cover all audiences at once rather than addressing separate work areas, the IISC is in the process of obtaining feedback on usability and will soon incorporate feedback from agencies. Following this step the IISC will meet to endorse and implement.
2. Invasive species list project
   a) The Invasive Plant Advisory Committee is developing an invasive terrestrial plant list based on a new assessment of approximately 100 species using a transparent, science-based process prioritized by potential impacts and availability of information. Assessed species will be reviewed for potential regulatory implications.
      (1) Standard formats have been created for species that are in trade and those that are not in trade, and assessments are proceeding rapidly with completion for the majority targeted for the end of September, 2012. Copies of the assessments will be posted on the IISC website and used for action prioritization.

Aquatic Invasive Advisory Committee:

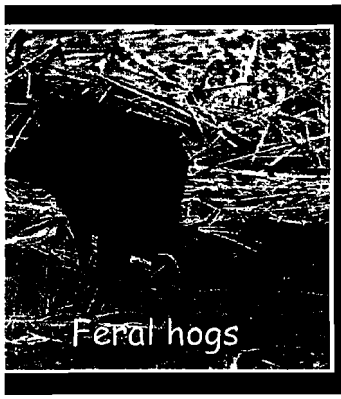
1. Supported preliminary adoption of the Aquatic Nuisance Plant Species Proposed Rule (LSA #12-50):
   a. Rule prohibits sale of 28 spp. of aquatic plants, 17 of the 28 are federal noxious weeds.
   b. Will seek to work with Notre Dame and The Nature Conservancy to approach other taxa in a similar manner.

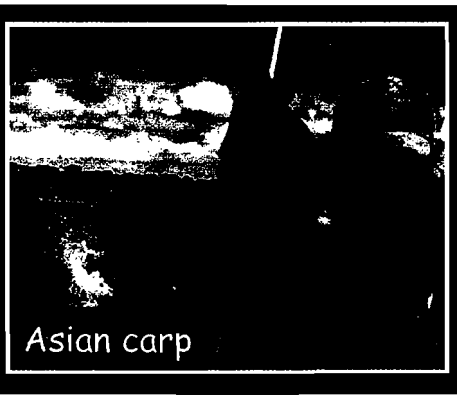
Emerging invasive species issues in Indiana:

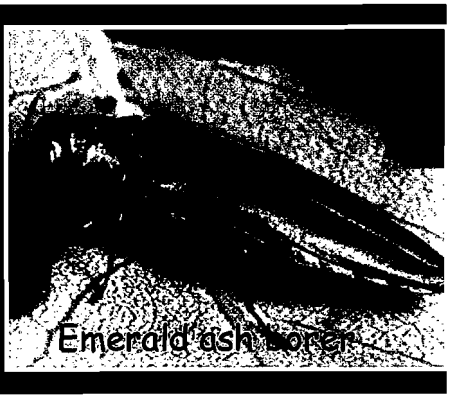
1. Gypsy moth - a successful management program
2. Tulip tree (*Liriodendron tulipifera*) at risk of dying on a widespread basis from a scale insect.
3. Thousand Cankers Disease management plan/ state import ban
4. Emerald ash borer quarantine
5. Brown Marmorated Stink Bug

Indiana Invasive Species Council

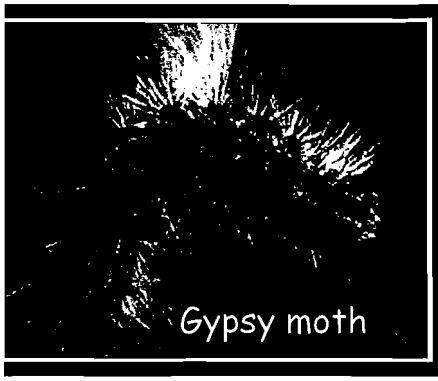
Invasive species – exotic insects, plants, fish, birds, mammals, pathogens, and many other organisms – are a serious threat to Indiana's **homes, environment and economy**.

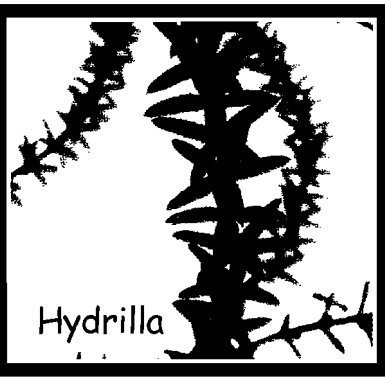


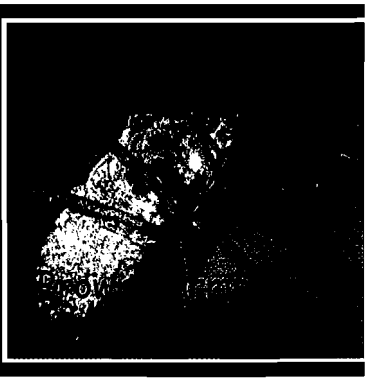




The **Indiana Invasive Species Council (IISC)** was established to enhance the ability of government agencies to **detect, prevent, monitor, and manage** invasive species, as well as **increase public awareness** about these growing threats.







The **IISC** is here to work on the invasive species threat on behalf of all of Indiana citizens. Visit the **IISC Website** for updates on invasive species issues in Indiana where you can:

- *Become a member of an **IISC Work Group**.*
- *Find notices of upcoming public meetings.*
- *Contact the IISC with comments and suggestions.*

IISC
Indiana Invasive Species Council

http://www.entm.purdue.edu/iisc/

Working together, we can slow the spread and lessen the impact of invasive species in Indiana and beyond.

Water and Indiana

Ronald Turco
Professor, Environmental Microbiology & Agronomy

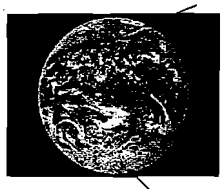
Director, Indiana Water Resources Research Center
& The Purdue Water Community

You are 55 to 78% water and it is a major part of everything you do!

Water per day per person	
Drinking	2-4 L
Domestic	40-400 L
Food (the hidden water)	1000-5000 L (and more)

The average American uses about 378 L water per day not accounting for water embedded in food and other products.

The 71% of the earth's surface is covered in water however, of this volume only 1 % is useable !



Antarctic and Greenland ice sheets, contains 99% of all fresh water on earth

Five Oceans 97.5%

Glaciers, Snow & Ice 1.75%

Groundwater 0.075%

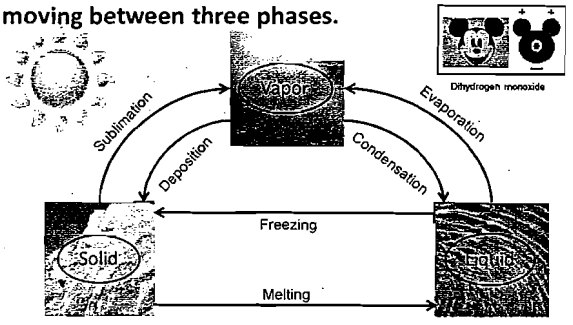
Lakes, swamps & rivers 0.025%

The world's water resources are finite !

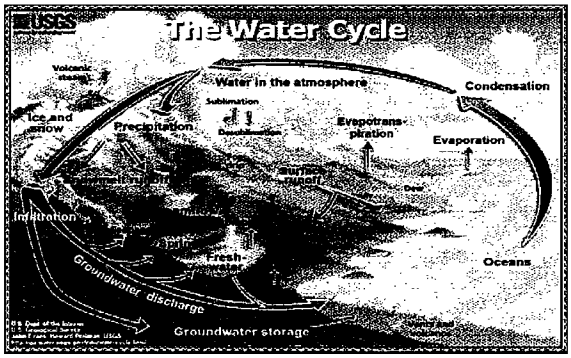
The world's water demands are expanding and unmet !

3

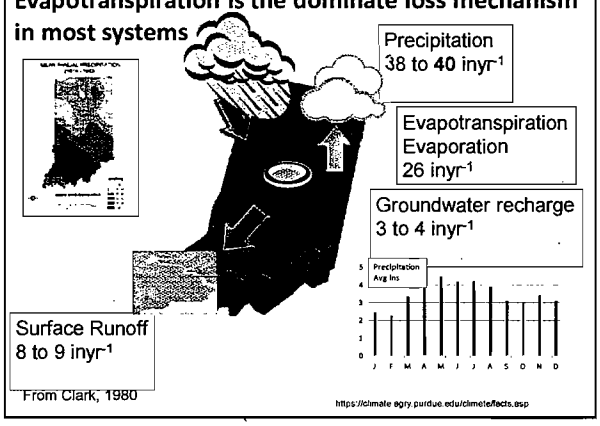
The total amount of water on earth is fixed at about 1.36×10^{20} liters (3.6×10^{19} gal) – it is constantly moving between three phases.



The three phases control the world's available water supply as part of a global Water Cycle.



Evapotranspiration is the dominate loss mechanism in most systems



Rainfall is the best source of water for agriculture as it provides vast amounts of green water!

Area	Rainfall Amount (in)	Gallons
1 Ac	1	27,154 (113 tons)
"	3	81,462
"	5	135,770
1 sq mile	1	17×10^6

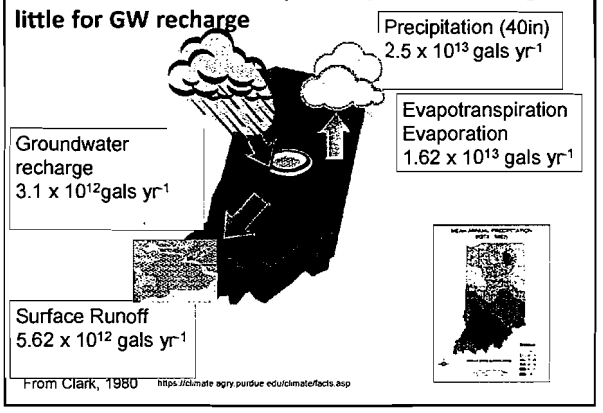
http://ga.water.usgs.gov/edu/earthrain.html

Rainfall over Indiana generates vast amounts of water

Area	Rainfall Amount (in)	Gallons
23,307,520 ac Indiana	1	6.3×10^{11} (2.6×10^9 tons)
"	3	1.89×10^{12}
"	5	3.16×10^{12}
372 sq mile Indianapolis	1	6.46×10^9

http://ga.water.usgs.gov/edu/earthrain.html

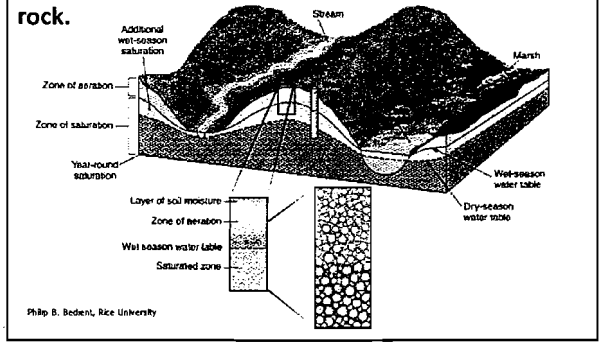
Most water is lost to evapotranspiration leaving little for GW recharge

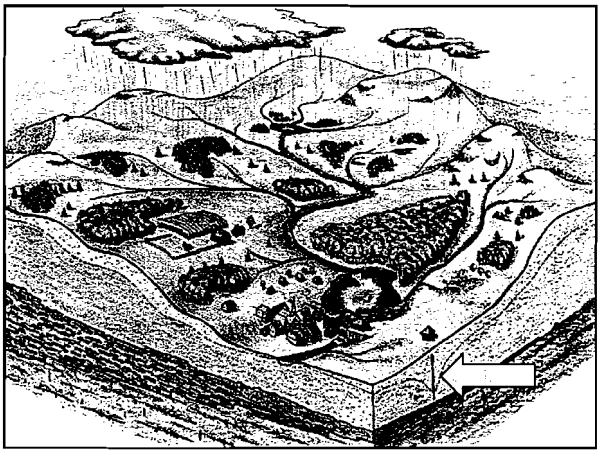


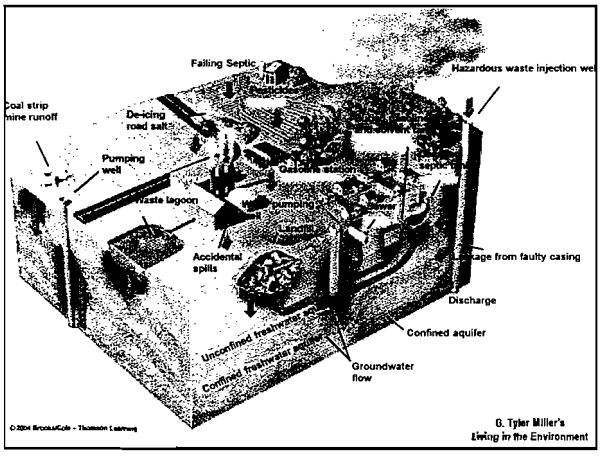
From Clark, 1980 https://climate.agry.purdue.edu/climate/facts.asp

Water for agriculture (food) is controlled by the soils ability to hold and then deliver a supply.

Groundwater and surface water are connected. Ground water occurs when water recharges the subsurface through cracks and pores in soil and rock.





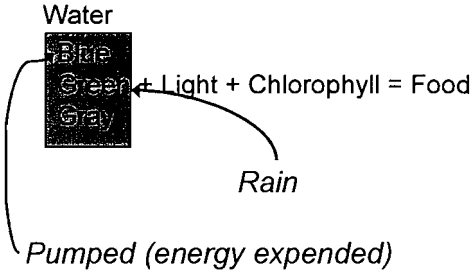


Agriculture uses three types of water: green, blue and gray water – two are free and one is not.

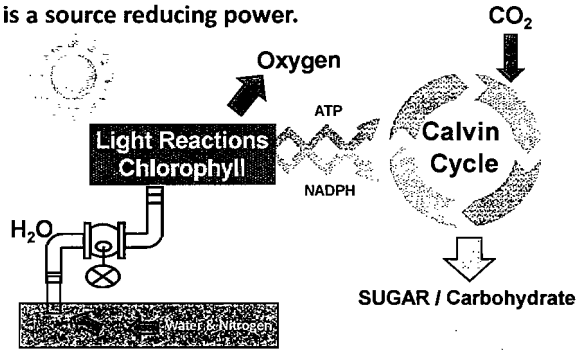
Green water = precipitation

Blue water = irrigation removed from other fresh water sources

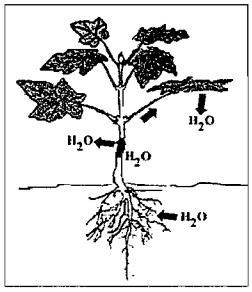
Gray water = irrigation from high grade waste water



Water's role in plant growth is critical as it holds up the plant, moves nutrients and waste materials and is a source reducing power.



To be clear, about 95% of the plant's biomass is from photosynthesis reaction (5% from soil minerals)- photosynthesis is linked to water



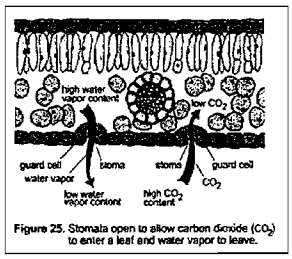


Figure 25. Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave.

From J. Volenec

The ability to supply water to a plant is significant for production.
How much water does it take to produce a 1.5 lb. bag of alfalfa?

- A) 10 lbs. (1.2 gallons)
- B) 50 lbs. (6 gallons)
- C) 100 lbs. (12 gallons)
- D) 1000 lbs. (121 gallons)
- E) 2000 lbs. (241 gallons)

A 1.5 lb. Bag of Alfalfa requires a lot of water – its water use efficiency (WUE) is not great.

E) 2000 lbs. (241 gallons)

WUE is expressed as kg H_2O/kg DM

WUE=350 means that 350 kg H_2O is needed to produce 1 kg of plant biomass a low number is preferred

Ranges from 250 >1000
Factors that improve yield also tend to improve WUE

The majority of agriculture is rain fed. Irrigated agriculture provides 40% of the world's food and consumes 75% of world's freshwater resources; up to 95% in some developing countries.

Today

14 plants and 8 terrestrial animals provide 90% of the worlds calories from some 30,000 eatable plant species

Wheat, rice, and corn provide ½ world's calories

Four primary forms of animals: fish, beef, pork, and chicken

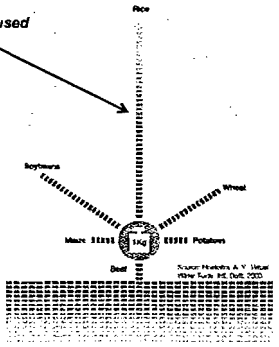
Food is water!

Water for food
Volume of water required to produce one kilogram of...

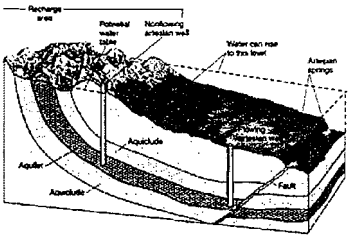
Total water used

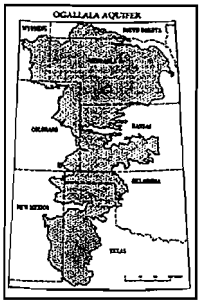
Water Footprint consists of three components:
BLUE + GREEN + GREY water usage!

The "water use impact" reflects removal of blue water

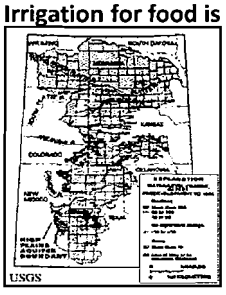


Groundwater for well water is a tricky trade as nature can't keep up with removal rates.



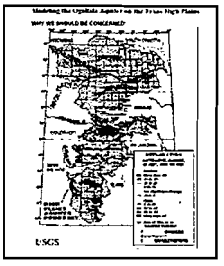


Groundwater recharge is critical for long-term stability of a regions water supplies. Not all areas allow for recharge that is equal to the use. Irrigation for food is a resource trade.



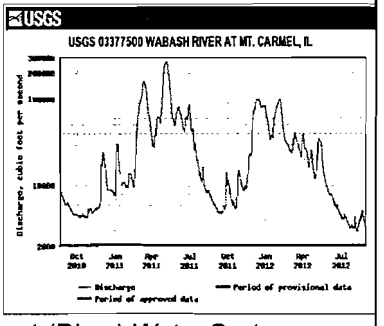
Ogallala Aquifer

170,000 wells
3.3 B AcFt



Draw down 2-3 feet per year – recharge is 10% by rainfall

(1 acre foot = 326,000 gallons)

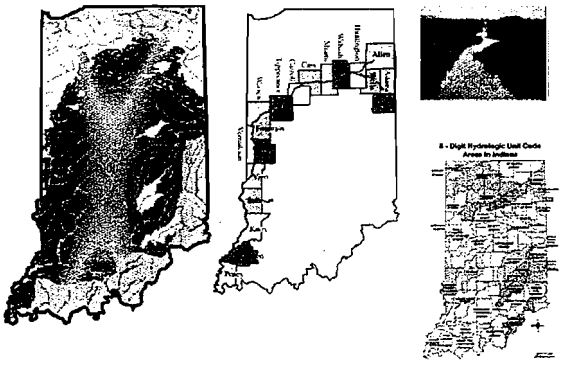


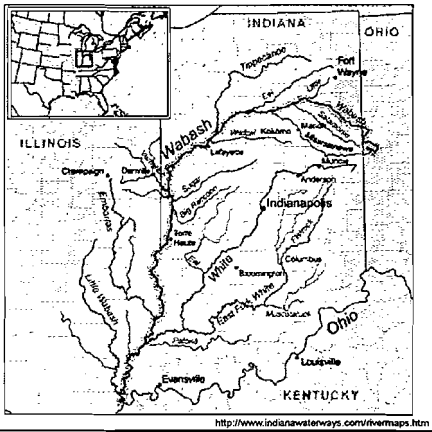
Major Midwest (River) Water Systems

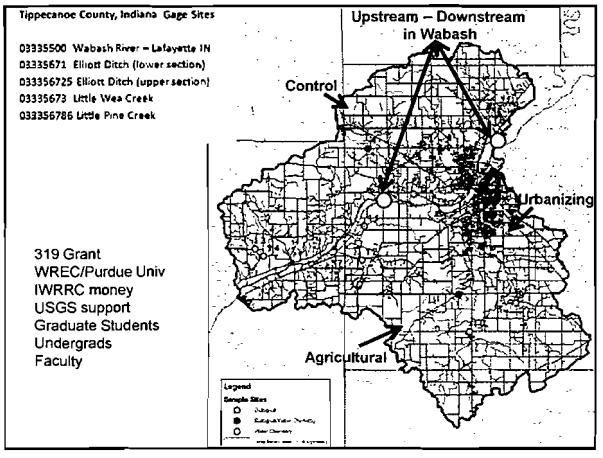
Goal: To guide effective management that shows change to create the baseline information for implementation practices !

THE WATER THAT GETS AWAY MONITORING ON WABASH RIVER AND 3 SMALLER SUBWATERSHED SYSTEMS

In Indiana, the Wabash Watershed is a major catchment area







Data collection is extensive

Every 15 minutes

Flow
- One gauge site / Watershed (3)
- Wabash River Two Sample Sites
  - One gauge site

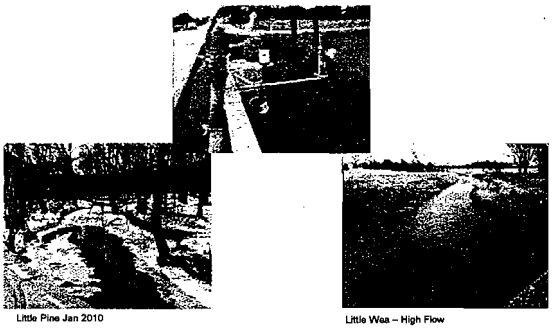
Sondes
- Temperature
- Conductivity
- pH
- Dissolved Oxygen
- Turbidity

Every Week (Rain, Sun, Snow)

Biological
- Bacteria – *E. coli*
- Total Coliforms
- Enterococci
- Algae

Chemical
- Nitrate + Nitrite
- Ammonia (no longer collected)
- Organic Carbon
- Total Phosphorus
- Total Suspended Solids

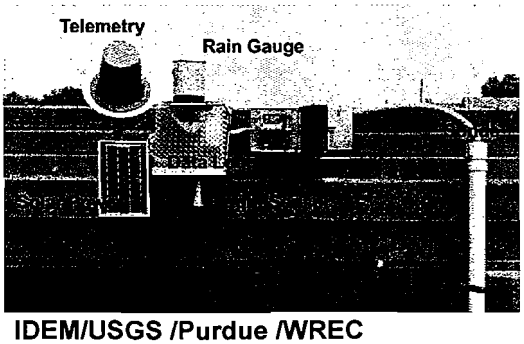
Sampling takes place 52 times a year



Little Pine Jan 2010

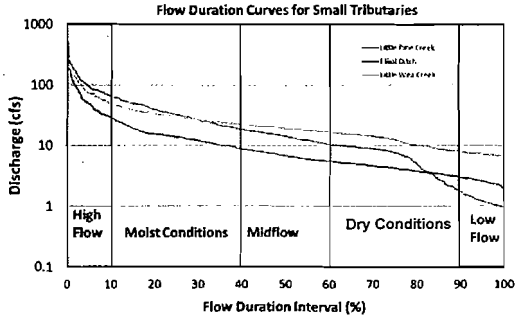
Little Wea – High Flow

Gauging Station with Sonde



IDEM/USGS /Purdue /WREC

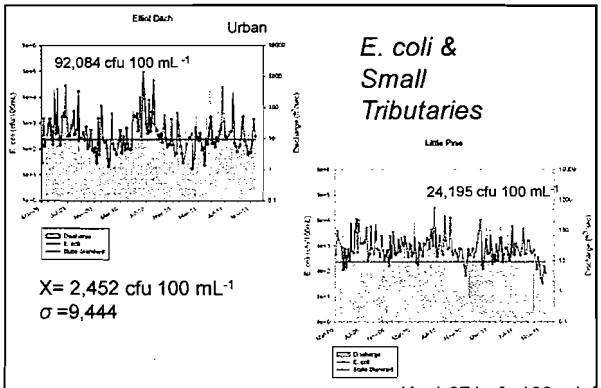
Our gauging and sampling plans have allowed us to develop a hydrology based framework



Water Quantity

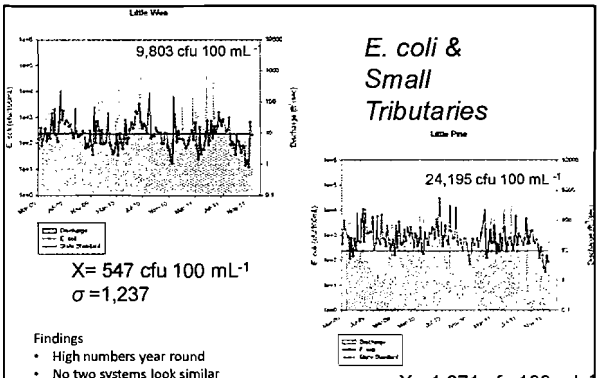
Water System	Mean (x) cfs	SD (σ)	Min Flow cfs	Max Flow cfs	Total Area acre	Total AG %	Total Dev %	Total For %
Wabash R. Up	7,837	9,053	1,056	58,646				
Wabash R. Down	8,147	9,411	1,098	60,967				
Little Pine	25.7	55	0.02	800	13,855	89.6	7.3	2.6
Little Wea	24.9	50	0.41	1,413	11,067	93.8	4.3	1.2
Elliott Ditch	19.6	58	0.3	1,748	11,451	47.2	48	1.8

Water System	Mean (x) gpd
Wabash R. Up	5.0×10^9
Wabash R. Down	5.2×10^9
Little Pine	1.6×10^7
Little Wea	1.6×10^7
Elliott Ditch	1.2×10^7



X= 2,452 cfu 100 mL^{-1}
σ =9,444

X= 1,671 cfu 100 mL^{-1}
σ =1,237

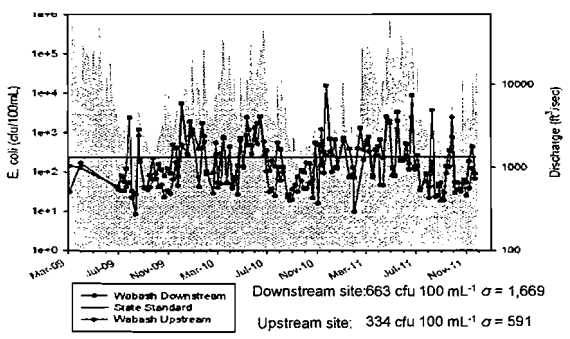


X= 547 cfu 100 mL^{-1}
σ =1,237

Findings
- High numbers year round
- No two systems look similar
- High variation in the number

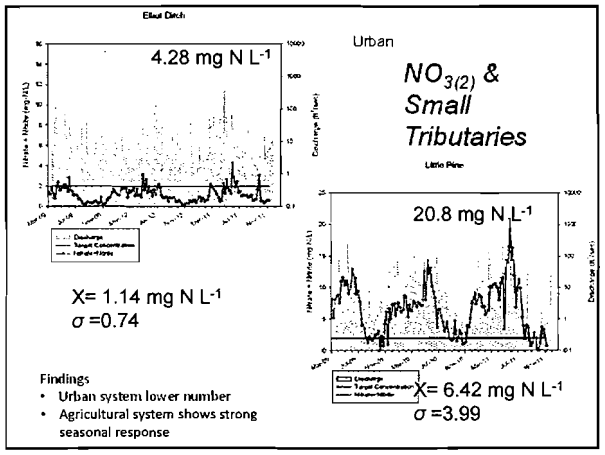
X= 1,671 cfu 100 mL^{-1}
σ =3,081

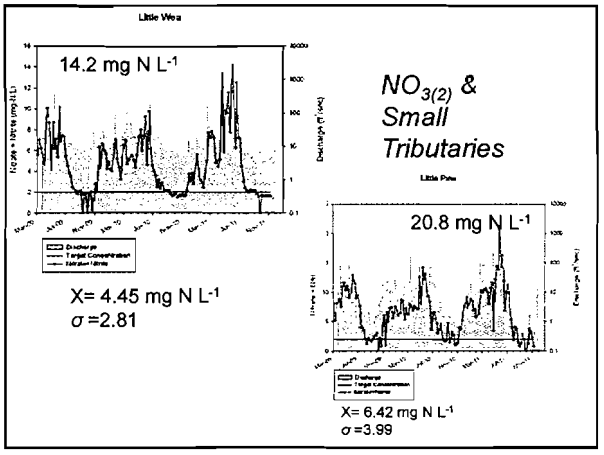
E. coli in the Wabash

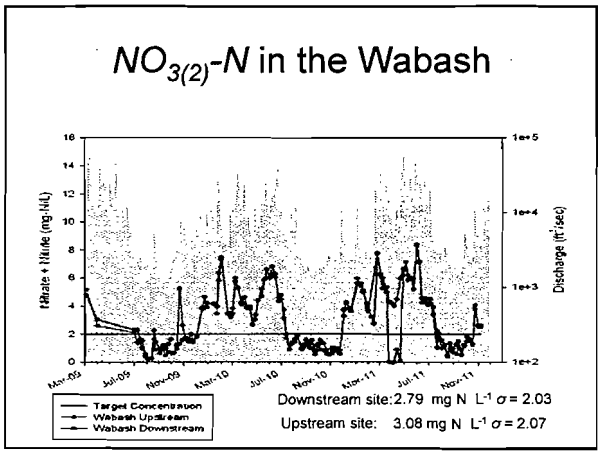


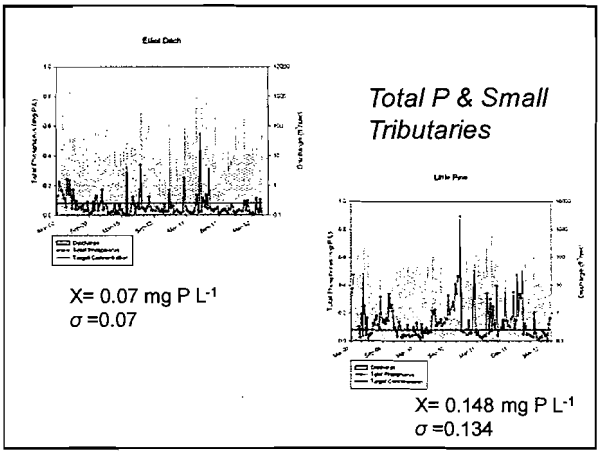
Downstream site:663 cfu 100 mL^{-1} σ = 1,669

Upstream site: 334 cfu 100 mL^{-1} σ = 591

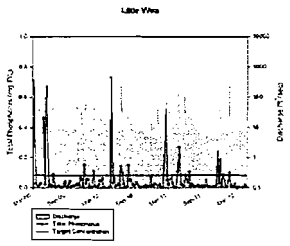

Urban
4.28 mg N L-1
NO3(2) & Small Tributaries
20.8 mg N L-1
X= 1.14 mg N L-1
σ =0.74
X= 6.42 mg N L-1
σ =3.99
Findings
• Urban system lower number
• Agricultural system shows strong seasonal response


14.2 mg N L-1
NO3(2) & Small Tributaries
20.8 mg N L-1
X= 4.45 mg N L-1
σ =2.81
X= 6.42 mg N L-1
σ =3.99

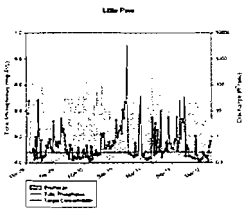

NO3(2)-N in the Wabash
Nitrate + Nitrite (mg/L)
Discharge (ft³/sec)
Target Concentration
Wabash Upstream
Wabash Downstream
Downstream site:2.79 mg N L-1 σ = 2.03
Upstream site: 3.08 mg N L-1 σ = 2.07


Total P & Small Tributaries
X= 0.07 mg P L-1
σ =0.07
X= 0.148 mg P L-1
σ =0.134

Total P & Small Tributaries

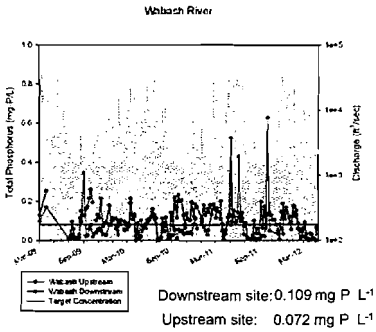


X= 0.051 mg P L^{-1}
σ =0.116



X= 0.148 mg P L^{-1}
σ =0.134

Total P in the Wabash



Downstream site: 0.109 mg P L^{-1} σ = 0.069
Upstream site: 0.072 mg P L^{-1} σ = 0.079

Variation rules the response!
% Coefficient of Variation

System % CV	*E. coli*	$NO_{3(2)}$ N	P	NH_4
Wabash R. Up	177	67	114	429
Wabash R. Down	252	73	70	333
Little Pine	184	62	87	300
Little Wea	226	63	235	711
Elliott Ditch	384	65	566	425

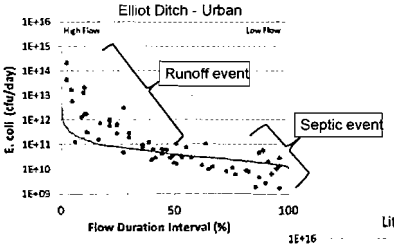
%CV = 100* (σ/X)

Load Estimations
Total (lb/year)

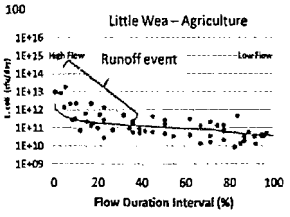
	Total (lb/year)				
	Elliot Ditch	Little Pine	Little Wea	Wabash Up	Wabash Down
Nitrate + Nitrite	38,920	373,829	284,531	67,575,726	67,434,702
Total Phosphorus	6,885	5,990	7,723	2,151,176	2,061,052
Total Suspended Solids	3,730,722	1,757,364	2,518,072	1,510,678,862	1,157,912,855
Dissolved Organic Carbon	142,668	233,104	198,782	85,996,966	95,633,802
	Total (cfu/year)				
	Elliot Ditch	Little Pine	Little Wea	Wabash Up	Wabash Down
E. coli	1.95E+17	4.74E+14	1.89E+14	4.09E+16	5.44E+16

Load Estimations
Total (lb/acre/year)

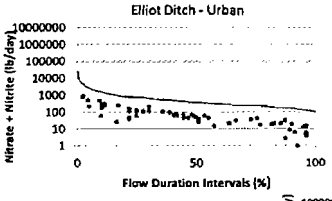
	Total (lb/acre/year)				
	Elliot Ditch	Little Pine	Little Wea	Wabash Up	Wabash Down
Nitrate + Nitrite	3.42	27.04	25.55	14.57	14.05
Total Phosphorus	0.60	0.43	0.69	0.46	0.43
Total Suspended Solids	327.49	127.12	226.12	325.78	241.20
Dissolved Organic Carbon	12.52	16.86	17.85	18.55	19.92
	Total (cfu/acre/year)				
	Elliot Ditch	Little Pine	Little Wea	Wabash Up	Wabash Down
E. coli	1.71E+13	3.429E+10	1.70E+10	8.83E+09	1.13E+10



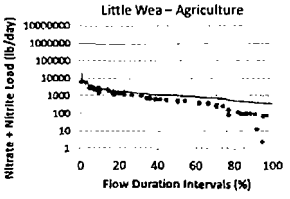
E. coli & Small Tributaries



Findings
- Sources are variable/BMP should meet this need
- Data suggests practices for mitigation (implementation)
  - Erosion control
  - Riparian buffers



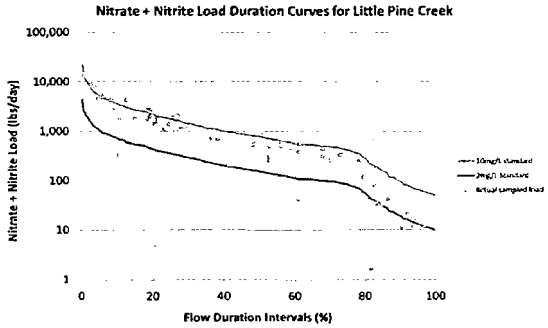
Nitrate - Nitrite & Small Tributaries

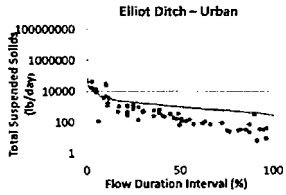


Findings
- At the present "standard" level the urban & Ag systems are at load limits
- Data suggests mitigation (implementation) needs extend beyond erosion control as system is less high flow driven
  - Riparian buffers
  - Cover Crops
  - Biological Barriers

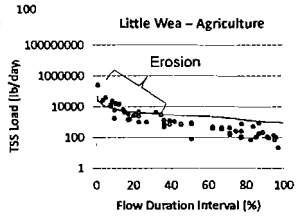
Drinking water standard shown for Nitrate = 10mg/L

Target for Great Bend watershed: 2 mg/L, which would be lower





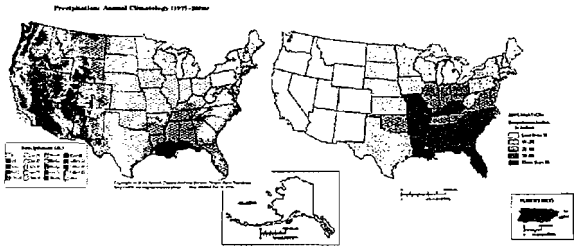
Total Suspended Solids & Small Tributaries



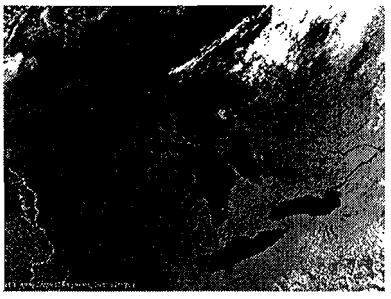
Findings

- Sources are similar
- Common BMP should meet this need
- Data suggests practices for mitigation (implementation)
  - Erosion control
  - Riparian buffers

The input of precipitation starts the reaction: net evapotranspiration is a function of soil and plant type, we can drink the rest.

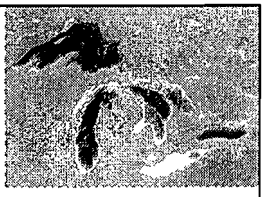


Tomas Höök
Illinois-Indiana Sea Grant Program
Dept of Forestry and Natural Resources
Purdue Water Community



PURDUE

Great Lakes Facts

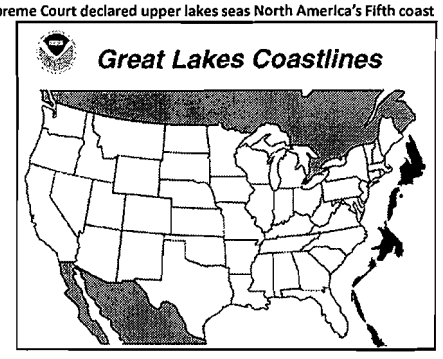


- From NOAA-GLERL
- 95,000 Square miles of water
- 11,000 miles of coastline
- 250 Species of fish
- Drinking Water for 40 Million People
- >$4 Billion Sports Fishery
- 1/3 of U.S. registered boaters
- Commercial Shipping—200 Million Tons—1270 Mile Transportation Route
- Largest (20%) surface freshwater supply in the world (90% of surface U.S. supply)
- 56 Billion Gallons per day for
  Municipal, Agricultural, Industrial
- 1,000 mile international border
- 33 Million People (8 states and 1 Province)

PURDUE

Important Coastline

1871 Supreme Court declared upper lakes seas North America's Fifth coast



PURDUE

Illinois-Indiana Sea Grant

Two great states caring for one Great Lake

- One of 32 programs across the country.
- Funded by the National Oceanic and Atmospheric Administration (NOAA).
- We conduct outreach, educational and research that empowers southern Lake Michigan communities to achieve a healthy environment and economy.

Sea Grant
ILLINOIS - INDIANA

IISG Research Program

- 2008-2011—almost $2 million in development, omnibus, and external grant funds—was spent funding 40 peer-reviewed research projects.
- www.iisgcp.org

Sea Grant
ILLINOIS - INDIANA

Steps to a healthier Lake Michigan

1. Aquatic invasive species pathways
2. Preventing pharmaceuticals from reaching waterways
3. Sustainable community decision-making
4. Building aquaculture markets
5. Helping communities remove contaminated sediments and restore habitats
6. Educating elementary and high school students
7. Sustainable water supply and inter-regional planning
8. Transferring Great Lakes monitoring data to end users
9. Helping families eat fish wisely
10. Helping people get rid of stuff sensibly
11. Lake Michigan recreation
12. Climate Change adaptation
13. Sustaining the Lake Michigan foodweb

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12. Climate Change adaptation
13. Sustaining the Lake Michigan foodweb

Step 1: IISG helps reduce the spread of aquatic invasive species through key pathways.

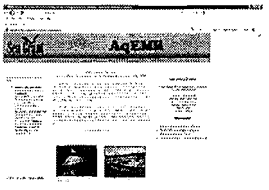
- Pet stores and hobbyist societies
- Research informed City of Chicago invasive species ordinance.
- We are working with IN DNR and water garden suppliers to develop plans to stop invasive plants.
- We are on the federal work group for the Asian Carp National Management and Control Plan.
- We are conducting Asian Carp cut-n-cook demos.

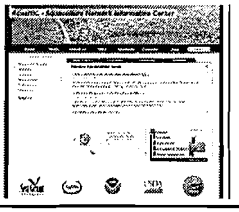
Step 2: IISG helps reduce the amount of pharmaceuticals entering our waterways.

- We are the go-to source for drug take back program information.
- We have developed the tool kit and workshops for communities who want to conduct take back programs.
- The program is expanding to other Great Lakes states and nationally with 25 collection events around the Great Lakes over a 10 day period this spring, collected over 4 million pills.

Step 4: IISG helps producers build aquaculture markets.

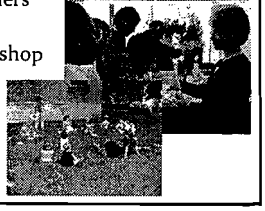
- **Growing Aquaculture in Indiana** - IISG, Indiana Soybean Alliance, Purdue University, and the Indiana Aquaculture Association, Inc. have launched a strategic initiative to grow the Indiana aquaculture industry. The initiative is designed to integrate and coordinate Indiana's aquaculture policies, research, and outreach to advance aquaculture production in the state.
- **Aquaculture Economics and Marketing Resources**
- **AquaNIC**





Step 6: IISG is helping teachers meet state and national science education standards.

- Online and in person teacher workshops and student resources
- The *Greatest of the Great Lakes* curriculum collection gives teachers access to the best resources.
- Lake Michigan Exploration workshop build new relationships between scientists and educators.

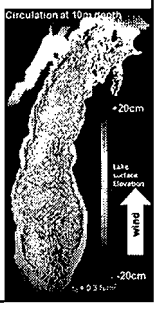


Step 11: Lake Michigan recreation

- Real-time buoy
  - Michigan City, IN
  - Currently: wind, temperature (air and water), rel. humidity, solar radiation, barometric pressure, wave height and direction, webcam
- Improve boating/swimming safety
- Enhance fishing, swimming, boating experiences

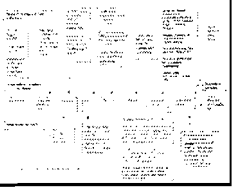
Step 12: Community adaptation to climate change

- NOAA Regional Team Project – Climate adaptation planning
- Future climate projections
- Impacts on fish habitat and information needs for managers



Step 13: Sustaining the Lake Michigan Foodweb

- IISG-led Great Lakes Regional Research Information Network
  - Define lake-wide research priorities
- Funding research projects



Illinois-Indiana Sea Grant

Two great states caring for one Great Lake

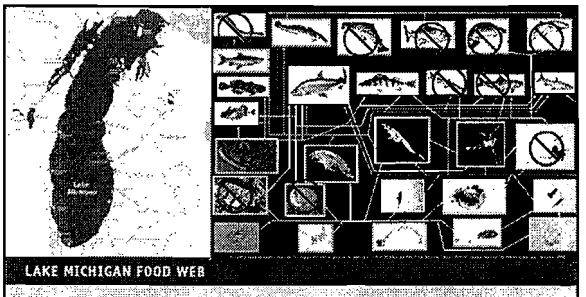
- One of 32 programs across the country.
- Funded by the National Oceanic and Atmospheric Administration (NOAA).
- We conduct outreach, educational and **research** that empowers southern Lake Michigan communities to achieve a healthy environment and economy.

Sea Grant
ILLINOIS - INDIANA

Tomas Höök
Illinois-Indiana Sea Grant Program
Dept of Forestry and Natural Resources, Purdue University

Research focus:
Threats to Great Lakes Foodwebs and Fisheries

Invasive species
Over-fishing
Nutrient run-off
Habitat loss
Climate change

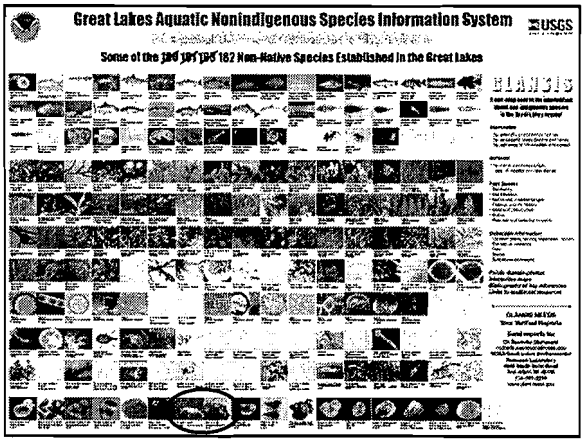


LAKE MICHIGAN FOOD WEB

An "unnatural" Lake Michigan Ecosystem

Over-fished/Stocked/Invaders

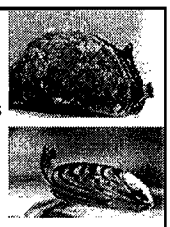
Non-native species ⊘

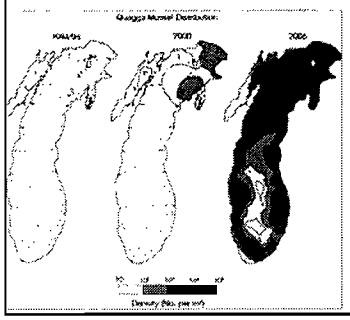


Dreissenid mussels

1990: Zebra mussels present in all Great Lakes

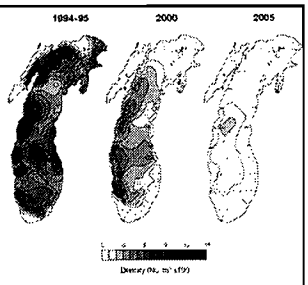
2005: Quagga mussels present in all Great Lakes

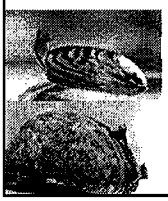


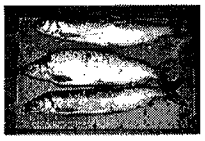


99% of dreissenid biomass is quagga mussel

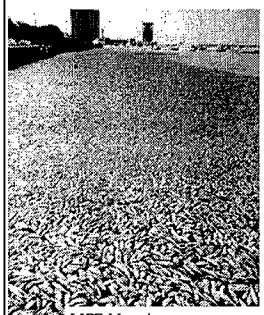
Impacts on Diporeia







History of alewives in Great Lakes



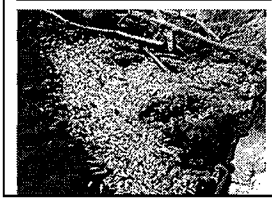
LIFE Magazine
Chicago Lake Michigan, 1967

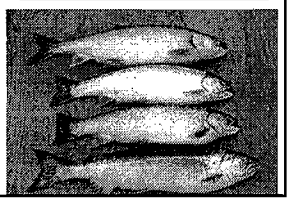
Muskegon Chronicle, 1968
Muskegon, Lake Michigan

History of alewives in Great Lakes

Past:
- Altered zooplankton assemblages
- Displaced some native fishes
- Massive die-offs

Present:
- Alewife population size reduced
- Forage base of economically important salmonine fisheries





Alewives in Lake Michigan

Salmon and trout
(% of diet alewives)

Chinook salmon (90%)
Coho salmon (75%)
Lake trout (58%)
Steelhead (66%)
Brown trout (64%)

↑

Alewives

- ~$1 billion annual fishery for salmon and trout
- Dependent on alewife forage base
- Alewife population abundance has varied tremendously over time
- Recently crashed in Lake Huron
- Reduced in Lake Michigan

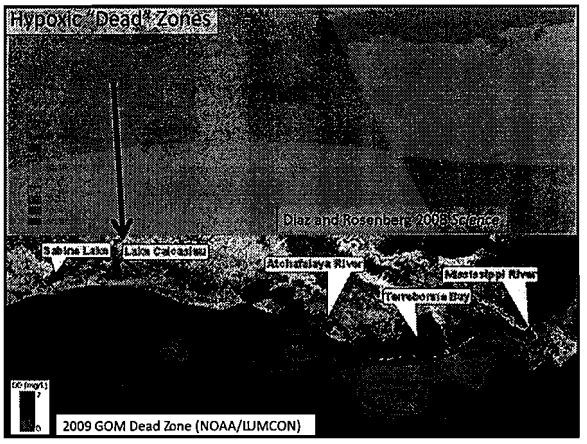
News Release August 27, 2012

PROPOSED SALMON STOCKING REDUCTIONS ANNOUNCED FOR LAKE MICHIGAN

ANN ARBOR, MI—Following more than a year of consultation with angler groups and other stakeholders, the Lake Michigan Committee (LMC) has proposed a new management strategy for Lake Michigan salmon. Beginning in spring of 2013, the LMC recommends that Chinook salmon stocking in Lake Michigan be **reduced to one-half of current stocking levels**. With salmon egg collections to begin in September, 2012, fisheries management agencies are now developing plans to decrease fingerling production targets to levels supporting reduced stocking, for a minimum of three years. The LMC comprises representatives from each of the state fisheries management agencies in Indiana, Illinois, Michigan, Wisconsin, and the Chippewa Ottawa Resource Authority (CORA). The Great Lakes Fishery Commission (GLFC) facilitates the committee's activities.

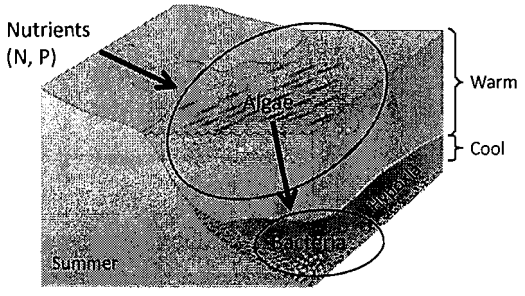
Alewife production in altered Lake Michigan

- What habitats produce alewife?
- What are main prey for young alewife?
- What are impacts of other invasive species?



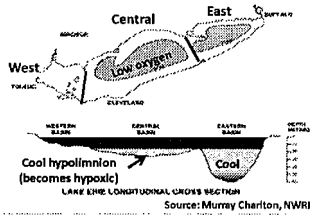
Hypoxia (<2-4 mg/l) in Aquatic Systems

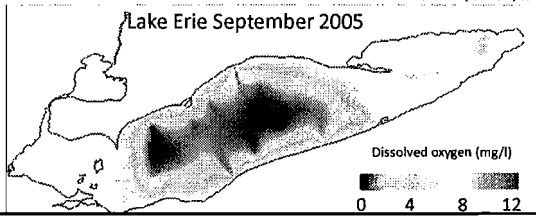
- Cultural eutrophication as a cause of hypoxia



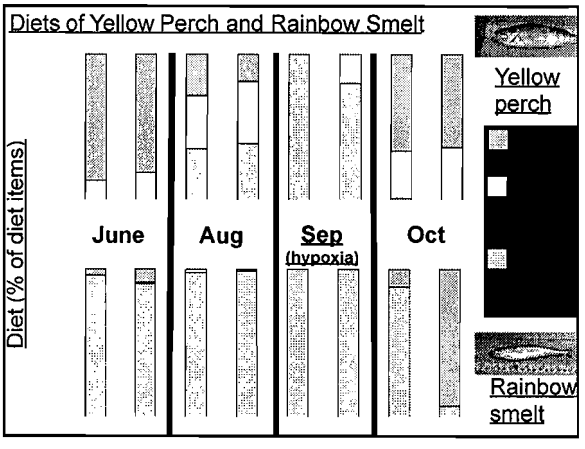
PURDUE

Lake Erie hypoxia

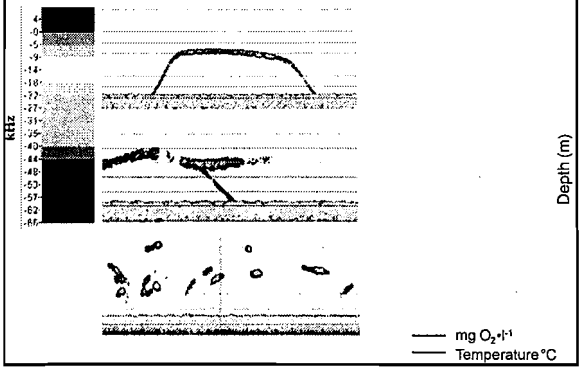


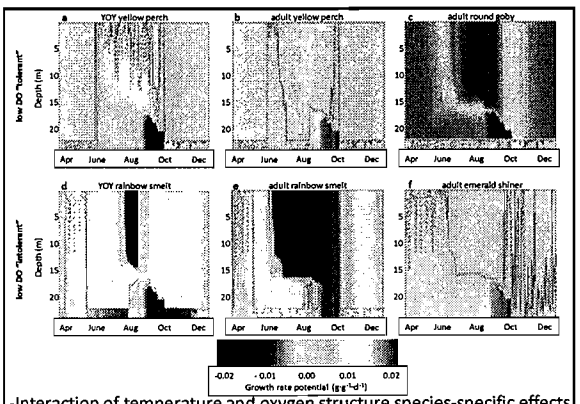


Diets of Yellow Perch and Rainbow Smelt



Yellow perch behavior under hypoxia



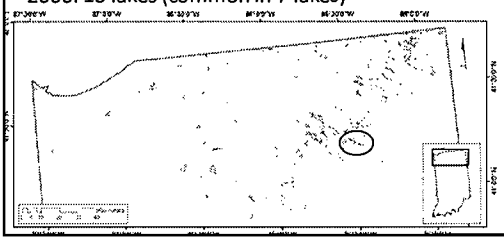


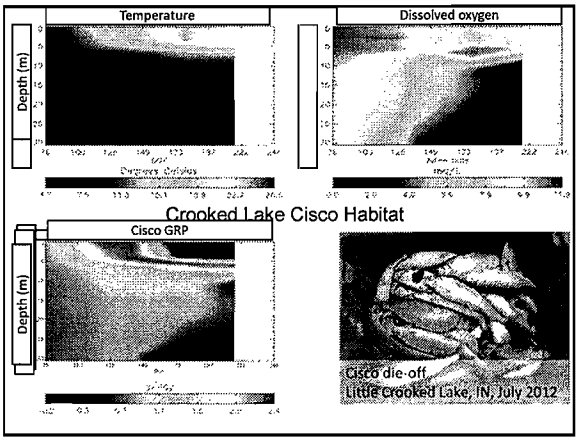
-Interaction of temperature and oxygen structure species-specific effects
-Climate change may exacerbate problem

Cisco in Indiana Glacial Lakes

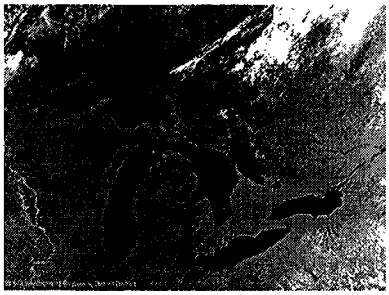
Species of special concern

- 1950: 42 lakes
- 1975: 26 lakes
- 2000: 13 lakes (common in 7 lakes)





Tomas Höök
Illinois-Indiana Sea Grant Program
Dept of Forestry and Natural Resources
Purdue Water Community



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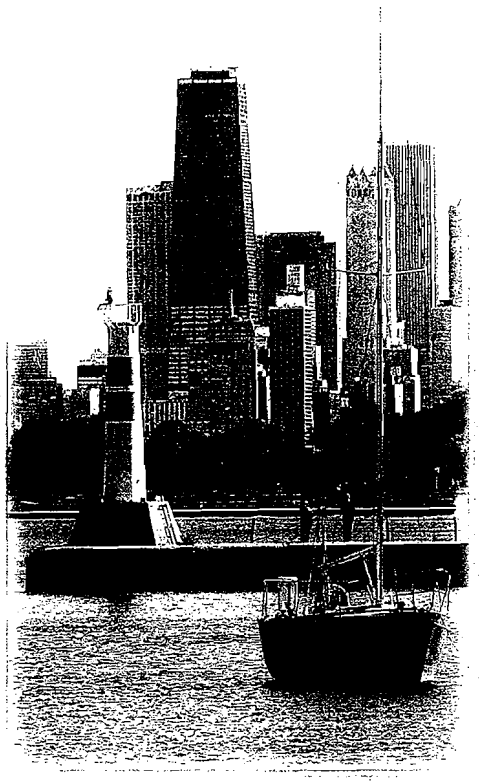


Sea Grant
ILLINOIS - INDIANA

NRSC
Aug. 28 & 29, 2012
Exhibit # 4

Illinois-Indiana Sea Grant

Discovery Grant Projects

Just as a gardener hopes that their scattered seeds will eventually bloom into a lush garden, Illinois-Indiana Sea Grant awards Discovery Grants, or "seed" grants, to a number of projects in the hopes that the initiatives will grow into something larger. This publication highlights some results from recently funded projects.

IISG has funded 35 projects that relate closely to key concerns the program is committed to address.

For example, several researchers studied how fish are impacted by changes in their environment. Zachary Blevins and Cory Suski at the University of Illinois examined how land use patterns affect the physiology of stream fish while Yang Cao, also at the U of I, modeled 10-year changes in juvenile fish populations in Lake Michigan nearshore waters.

Contaminants were also a focus. Antony Acushia at Purdue University was funded to develop a web-based tool to measure environmental quality standards for phosphorus, one of the most troublesome pollutants in the Great Lakes. Purdue's Maria Sepulveda experimented with a new method for assessing toxicity and the need for remediation in contaminated waters.

Brian Deal at the U of I studied a new way for addressing another key concern, land use planning in Illinois to be more sustainable by incorporating the value of ecosystem services into the process.

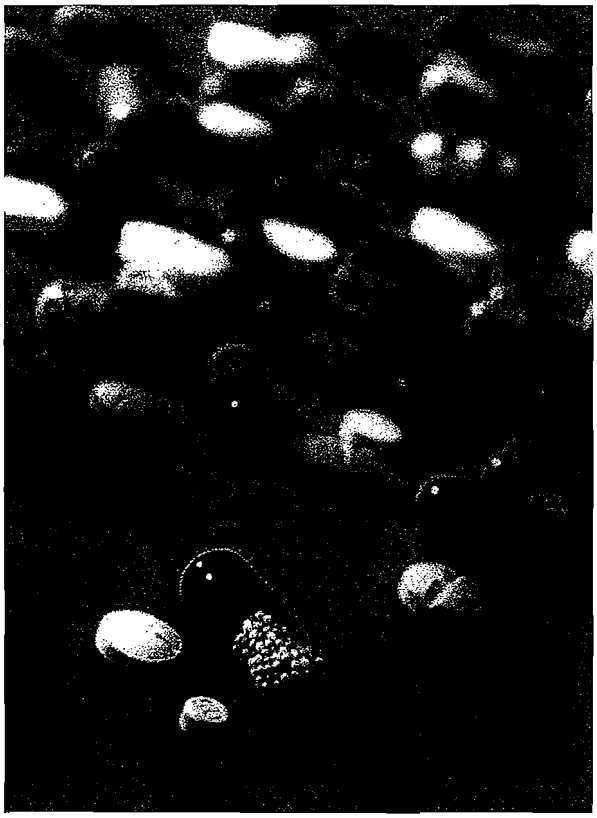
Turn the page to read results and implications of featured Discovery Grant projects.

Lake Michigan shoreline water is a medicine cocktail

During his research to measure pharmaceutical abundance along the shorelines of Lake Michigan, Ball State University biologist Thomas Lauer said he and his fellow researchers found chemical compounds "practically everywhere."

Lauer and Melody Bernot, also from Ball State, repeatedly sampled four southern Lake Michigan sites and found antibiotics, mood-stabilizing drugs, pain-relievers, antibacterials, and more. "To get large, measurable numbers, consistently, in all those places was a bit surprising to us," Lauer said. "It is an intimidating thought, considering how big the lake is."

While the observed chemical concentrations are not toxic to humans, they can be a concern if these medications enter our drinking water. A 2008 Associated Press investigation found pharmaceuticals in the drinking water supplies of at least 41 million Americans. In addition, there is a long list of negative effects these chemicals can have on aquatic organisms. For example, medicines have been shown to disrupt reproductive development in frogs, cause irreversible masculinization in fish, and impair predator avoidance in minnow and shrimp.



The Lake Michigan study focused on Michigan City and East Chicago, Indiana; St. Joseph, Michigan; and Chicago. At each site, surface and bottom water samples were taken near drinking water intake points, and at the mouth of incoming rivers.

Bernot and Lauer have applied for larger grants to further understand the fate of these chemicals in the environment and ultimately how humans may be affected.

Recreation reduces Karner blue butterfly reproduction

Patrick Zollner, a Purdue University ecologist, studied the impact that people walking on nature trails have on the reproduction habits of the Karner blue butterfly, a federally endangered species found in the Indiana Dunes National Lakeshore.

The study shows that human recreation can disrupt the breeding patterns of this butterfly, as well as other species.

Using data of actual butterfly behavior in a simulation model, Zollner's team found that Karner blue butterflies lay significantly fewer eggs on their host plant, wild lupine, when the plants are 10-15 meters from the trail. They laid more eggs on plants that were farther away.

"Depending on the circumstances, about 17 percent of females are only laying half of their potential eggs because of human disturbance," Zollner said. To minimize negative effects on this endangered species, Zollner suggests that wild lupine plots be at least 25 meters from the trail.

This information can be useful for resource managers who are under increasing pressure to implement strategies that address the negative effects of outdoor recreational activities on wildlife.

Zollner and his team have now submitted a proposal to study how the Huron-Manistee National Forest equestrian population impacts Karner blue butterflies across their range.

X-ray chemical turns toxic in disinfected drinking water

University of Illinois geneticist Michael Plewa's study revealed that a non-toxic medical diagnostic chemical that accumulates in drinking water sources can become a toxic chemical during the disinfection process. These results led the National Science Foundation to award Plewa and his collaborators at the Federal Institute of Hydrology in Germany and the University of Akron $495,000, with $217,000 of that going directly to Plewa, to study this further.

"We would not have been able to get this award if it wasn't for the discovery grant," Plewa said. "We were very happy to have that opportunity, and we feel this success shows the investment was not misplaced."

The study found that water near hospitals can contain disinfection by-products due to iodinated x-ray contrast media (ICM) that is found in wastewaters from hospitals. ICM is a substance people consume to enhance medical imaging. It is usually excreted within 24 hours, but treatment plants are unable to completely remove it from drinking water.

"These drugs serve as a catalyst for chemical reactions when you use disinfectants, such as chlorine," Plewa said, adding that he hopes there is a way to modify the ICM chemistry to eliminate the problem.

"This is one of very few examples where a nontoxic material that is put into a drinking water supply is converted to toxic material due to disinfection. The environment is so complex it boggles the mind."

New use for ethanol —feeding Hybrid striped bass

Recently, fish meal has become economically and environmentally unsustainable as a primary protein source for fish farming. Jesse Trushenski, an aquaculture nutritionist at Southern Illinois University Carbondale, studied the use of ethanol yeast as a fish meal replacement in feeds for hybrid striped bass.

The yeast is left over from bio-ethanol production, so Trushenski sees the idea as a "win-win" solution.

"From an aquaculture perspective, we are always protein hungry. However, traditional protein sources are not going to meet the industry's growing demand," she said. "We are always looking for protein-dense ingredients that we can use in feeds."

Trushenski found that ethanol yeast will not completely replace fish meal, but it can significantly reduce the amount needed. The study showed that fish meal can be reduced as low as 7.5–15 percent in ethanol yeast-based feeds without having negative side effects.

The project was done in collaboration with Archer Daniels Midland, which is funding further research on the topic.

"In Illinois, we raise more than 100,000 pounds of hybrid striped bass each year. More cost-effective feeds can help our aquaculture industry grow. So in a sense, these seed dollars are transitioning into economic development for our region," Trushenski said, adding that saving money on fish food would greatly cut down on expenses. "Feed can represent 50 percent or more of the cost of production, so anything we can do to help our growers use regional resources to reduce costs is a move in the right direction."

Alum can reduce phosphorus after manure spill

Accidental manure spills in the United States have been occurring more frequently in the past 20 years due to increases in the number of livestock hogs. First responders have ways to adequately remove phosphorus and ammonia directly from the water column, but they do not focus on nutrients that may have become bound in sediment.

Graduate student Shalamar Armstrong of Purdue University (now at Illinois State University), and his advisor, soil scientist Phillip Owens studied the fate of sediment after a spill and potential treatment options, namely using aluminum sulfate as a barrier to nutrient deposition.

"We wanted to see if the response was effective, and if phosphorous and nitrogen were being treated," said Armstrong. Under laboratory conditions, they documented that, after a spill, phosphorous is stored temporarily in the sediment and then released back into the water. In samples taken, phosphorous concentrations in the water columns well exceeded EPA water quality criteria.

Their solution, to apply aluminum sulfate to sediment in the remediation process, seems to reduce the release of phosphorus into the water column by 70-90 percent as compared to control treatments. Armstrong and Owens believe that this could be a useful step in treating some areas affected by manure spills.

This research has been published in several peer-reviewed journals and helped Armstrong receive the Purdue University Agronomy Department's 2010 Outstanding Graduate Student Ph.D. Research Award.

Storm tracking takes flight over Lake Michigan

University of Illinois atmospheric scientist David Kristovich tested a mobile sounding system that might help predict the fate of storms that move across Lake Michigan. This system measures temperature, humidity, and atmospheric pressure.

"The Great Lakes make it difficult to predict summer weather. One problem weather forecasters face is determining what will happen when massive storms reach one side of the lake. It is hard to figure out if those storms will make it across to the other side and cause severe weather," Kristovich said. "We don't have a lot of information; on the lake, we don't have people taking observations all over the place like we do on land."

The device they used is called a rawinsonde, which is attached to a weather balloon with a parachute. Because the system is connected to a balloon, researchers were also able to record the wind direction and speed.

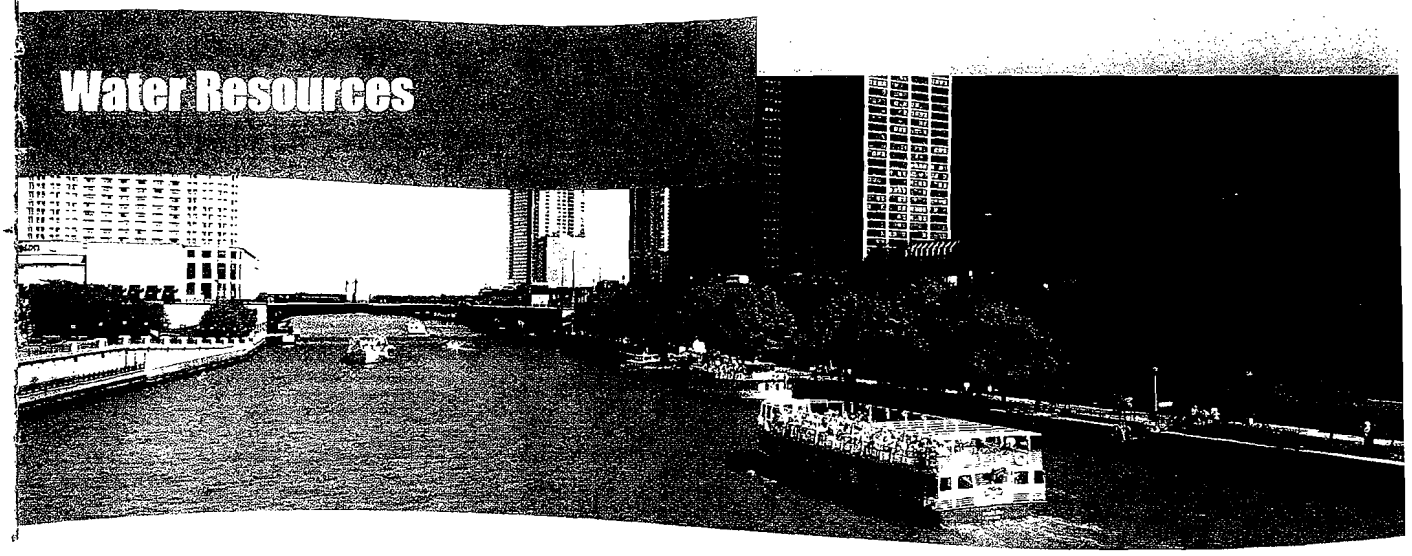
Kristovich said having a test run for the device was critical for ironing out issues for future projects, which will include larger collaborative efforts with groups like the Ontario Winter Lake-effect Snow project and the AgI Seeding Cloud Impact Investigation.

NRSC
Aug. 28 & 29, 2012
Exhibit # 5

Illinois-Indiana Sea Grant

IMPACTS: Today and Tomorrow

Water Resources



The PROBLEM: Future water concerns loom large today

Water, of course, is key to life. To flourish, we need water present in sustainable quantities and sufficiently clean to promote the health of people, of ecosystems, and more.

In the Chicago region, water may seems like a given since the population sits on the shores of Lake Michigan, a bountiful freshwater resource. But it is not, by any means, a sure thing. Illinois has legal limits to how much water can be taken from Lake Michigan and as communities continue to grow and spread out away from the lake, available aquifers are being tapped at unsustainable rates. A predicted population growth of up to 64 percent by 2050 in northeastern Illinois could create water shortages as demand outpaces supply. The impacts of climate change may compound this concern.

Population increases and climate change can put pressure on water resources in other ways. For example, as large rain events become more frequent, managing stormwater and predicting flood levels will be more challenging. Water quality in some locations has suffered over the years due to industry and urbanization, impacting local economies and natural habitats. More people, buildings, and parking lots threaten to compound that.

By planning for the future today, we can ensure the sustainability and health of our water resources for tomorrow.

ACTION and RESULTS:

Illinois-Indiana Sea Grant (IISG) has been proactive in efforts to plan for a future water supply in the Chicago region—informing conservation pricing, providing on the ground support to municipalities, and addressing potential climate change impacts. IISG is also helping communities and regional planners manage stormwater by providing critical information on flooding potentials, green infrastructure, and smart growth. And, IISG is striving to reduce or help managers smartly address contaminants in Lake Michigan, as well as local streams and wetlands.

Strategies for water conservation: Is the price right?

A regional water supply plan for northeastern Illinois was unanimously approved by the Regional Water Supply Planning Group in 2010. The planning effort was led by the Chicago Metropolitan Agency for Planning (CMAP) with IISG Environmental Planning Specialist Marty Jaffe as a member of the group and IISG Water Resource Economist Margaret Schneemann providing critical data on a key component of the plan—water pricing.

Schneemann led a study of current residential rate structures to examine conservation pricing methods promoting sound regional water management. Her research is based on a review of almost 300 water systems that serve a population of 8.2 million in the region.

She concluded that a primary aim of conservation-oriented pricing is to cover the full cost of water, which sends correct signals to users. For example, if the full cost of deep bedrock aquifer water is incorporated into pricing, it may become more cost-effective for suppliers to draw from inland rivers or Lake Michigan, allowing the aquifer to recover. In turn, Lake Michigan water users would be prompted to continue the trend toward more efficient use. Full cost recovery also provides the means to pay for necessary repairs or improvements to the region's aging infrastructure.

Conservation pricing can create incentives for users to curb consumption without affecting prices on water necessary to survive. One strategy, seasonal pricing, is to increase rates during the summer, when water use is at its peak, in an effort to discourage excessive use. A decrease in consumption during peak periods will delay or prevent costly water system expansions.

Schneemann found that the most important component of conservation pricing, however, is to improve water billing and education. If people do not understand their bills and do not monitor their use and water rates, the effectiveness of conservation programs will be compromised.

Illinois is required to comply with Great Lakes water conservation provisions, so state funding and regional coordination will be critical. Without that coordination, hundreds of separate water systems make decisions based on their own interests. Regional water supply planning and conservation-oriented pricing provide incentives for sustainable water management that is both locally preferred and regionally optimal.

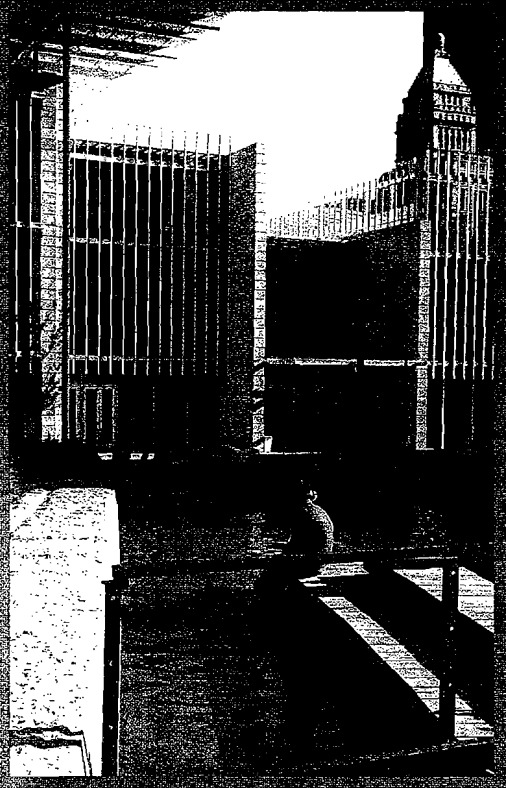
Schneemann will continue to assist CMAP in implementation of the water supply plan through outreach programs targeted to municipalities. These programs will provide water utilities assistance in successfully moving into the 21st century, working with them to build necessary capacities to meet community needs, such as economic development, dependable infrastructure, climate variation adaptation, and water conservation objectives.

IISG helps municipalities set rates, inform public

Northeast Illinois water suppliers are faced with a challenge: demand is increasing in the midst of growing limits on supply. Add to that, water supply infrastructure is aging in many towns and repair dollars are drying up. To help address these issues, IISG's Margaret Schneemann is providing on the ground assistance for communities as they design water rates.

Setting rates for drinking water and wastewater is a multistage process and communities can benefit from assistance in a range of areas—from identifying revenue needs and accurately accounting for costs to identifying community-appropriate rate setting policy objectives and designing the rate schedule to address these objectives.

Municipalities can also benefit from outreach and public education help during the rate design process to ensure stakeholder input that addresses the communities' unique needs. Public outreach also helps build community support for water and wastewater services and the revenue necessary to sustain these services. Schneemann can assist in facilitating an informed dialogue by serving as a liaison between utilities and the public, ensuring that everyone considers the full cost of water now and for future generations.



Proactive planning may ease climate impacts on water resources

Climate change predictions for the Chicago region include the increased likelihood of storms, but as precipitation variability increases, also drought. The net effect may be a drier climate that can stress the region's shallow aquifer water supplies, deteriorate water quality, and also impact water use by impairing navigability, recreational, and biological integrity.

CMAP predicts an increase of about 12 percent in water demand over present use due to climate change. In the face of these increases, CMAP's Water 2050 water supply plan proposes a suite of more stringent water conservation measures and water rate structures for full-cost pricing to better manage water demand within the region.

To better manage drought impacts, IISG will work with CMAP to develop a suite of proactive management options beyond water conservation and use restrictions. These options may include reservoirs managed by multi-jurisdictional water wholesalers, the use of stormwater or treated reused water to recharge shallow aquifers, or revised drought-resistant landscaping standards. IISG will also examine the financing of drought management options, including the role of water pricing, so that the economic implications and true costs of drought management policies can be better assessed by water utilities and municipal officials.

Green infrastructure provides financial and environmental benefits

In an Illinois EPA-funded study, IISG's Martin Jaffe found that green infrastructure is just as effective as conventional stormwater infrastructure, and is less expensive.

In light of climate change predictions, which include bigger storm events and more flooding, managing urban stormwater will become even more critical in northeastern Illinois and throughout the state.

The purpose of the study, required by the 2009 Illinois Green Infrastructure for Clean Water Act, was to examine the standards and costs of green infrastructure as a possible replacement for or supplement to conventional urban stormwater infrastructure (e.g. sewers and on-site detention and retention ponds).

Green infrastructure is a sustainable, environmentally-friendly approach to land use planning. Its practices—such as rain gardens, permeable pavements, and green roofs—naturally manage stormwater to improve water quality, reduce flood risk, and increase biodiversity.

Jaffe found that, on average, many of the green infrastructure methods are about as effective as conventional detention ponds in removing total nitrogen and total suspended solids from stormwater runoff, while also reducing the rate and volume of the stormwater discharged to nearby lakes and streams.

Green infrastructure also provides valuable community benefits—more groundwater recharge, increased open space for recreation and habitat, and energy savings by reducing ambient temperatures—not provided by conventional stormwater facilities. Moreover, economic models show that most green infrastructure is cheaper to install and maintain than conventional stormwater infrastructure over their respective useful lives.

In 2010, Jaffe presented his final recommendations to the Illinois General Assembly. As a result of this study, scientists from the University of Illinois-Chicago will develop a model to help planners determine which methods are effective for specific areas.

Next, Jaffe and IISG Director Brian Miller will develop a distribution and training plan to recommend educational materials needed to train local officials in the best green infrastructure practices for urban stormwater management and to determine which local officials ought to be trained.

Lakefront counties establish buffer zones

Indiana's Porter and LaPorte counties sit along sand dunes and beach ecosystems of Lake Michigan. As these counties face population growth, protecting natural areas and water resources is critical to the region.

Through Planning with POWER workshops and data from the *Local Decision Maker* (LDM) web tool, IISG's Robert McCormick has worked closely with local officials as they update their comprehensive land use plans. Using LDM, LaPorte County planners identified critical natural resources in the Lake Michigan watershed and established protections for these resources. As part of recently incorporated smart growth principles, Porter County commissioners adopted a watershed overlay ordinance establishing riparian buffer zones on all primary, secondary, and tertiary streams and rivers in the county. Vegetative buffer zones will reduce runoff and erosion and help protect Lake Michigan water quality because all these tributaries ultimately flow into it. This ordinance is the first of its kind in Indiana.

High-tech beach monitoring

Beach managers need reliable methods to determine the origins of contaminants to reduce those sources and maintain a healthy beach. Two Purdue University Calumet scientists, Ben Chin and Charles Tseng, will develop a new, accurate, rapid, and easy-to-use laser bio-imaging technology to identify sources of bacterial contaminants for numerous beaches along the Great Lakes as well as for other water systems in the nation. This project is funded through the Great Lakes Restoration Initiative.

Leslie Dorworth, IISG aquatic ecology specialist, and Sonia Joseph of Michigan Sea Grant will develop an outreach program for this new technology. They will provide the researchers with key contacts in the respective state environmental agencies to facilitate sample collection and will develop training workshops to demonstrate the new technique to beach managers.

Promoting natural lawn and landscape care

Urbanization includes more than buildings and parking lots—lush green parks and lawns help beautify the landscape. But maintaining this greenery often includes the use of a considerable amount of fertilizers and pesticides.

With funding through the Great Lakes Restoration Initiative, IISG's Margaret Schneemann and Leslie Dorworth are set to begin project to reduce pesticides and fertilizer inputs to the Great Lakes basin by promoting and implementing sustainable lawn and landscape practices at the community and household level.

Working with the University of Illinois Extension, the Safer Pest Control Project, and Lake Champlain Sea Grant, IISG will develop outreach materials, programs, and training to educate professional landscapers, master gardeners, relevant retailers, and municipal personnel regarding natural lawn and landscaping care options.

Flood potential in Chicago region is higher than expected

Flood peaks in the Chicago metropolitan area are higher than they used to be, and they are also 25 percent higher than estimates currently used by water managers, according to an IISG study. Estimating future flood peaks accurately is critical in terms of allocating resources to minimize damage from these events.

Momcilo Markus, a researcher at the Illinois State Water Survey studied Chicago area flood trends using data from the U.S. Geological Survey and NOAA. He found that the steady increase in flood discharges in small streams over the past 100 years is due to increases in urbanization and precipitation, with urbanization playing the major role. Between 1954 and 1999, urbanization, on average, increased from about 11 percent to 62 percent in the 12 Chicago area watersheds. If you account for ongoing urbanization, flood peaks will become even higher.

Precipitation has also increased. At the Aurora College rain gauging station, the 10 largest historical storms recorded have been since 1950, and these storms were much larger than any in the previous 50 years.

Flood flow estimates are reviewed by the Illinois Department of Natural Resources and are published by the Federal Emergency Management Agency. The extent of flooding shown on Flood Insurance Rate Maps guides development and insurance purchases. Flooding estimates are used to design bridges and culverts as well as plan development.

Living near waterways can be a plus or a minus

Decades of industry in the Great Lakes region have left many polluted lakes and rivers, which have also taken an economic toll on the communities along these waterways.

John Braden, a University of Illinois economist, found that property values for homes near contaminated waterways can be significantly depressed. With funding, from IISG, Braden's team looked at houses near the Sheboygan River in Sheboygan County, Wisconsin. This study was complemented by a similar one in Buffalo, New York.

Photo courtesy of John Braden

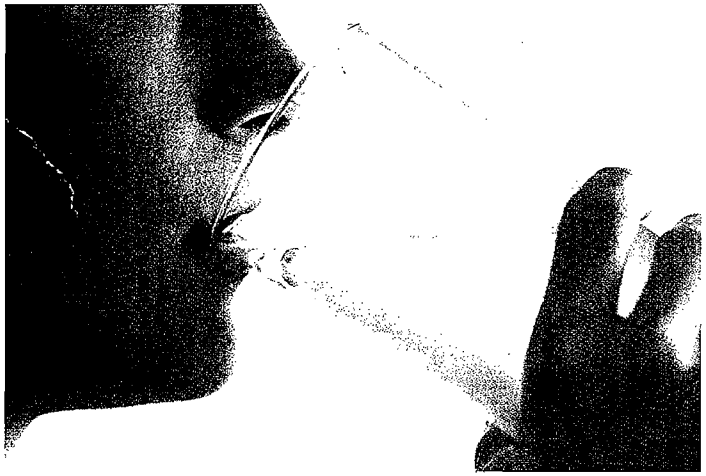
About 14 miles of the Sheboygan River has been designated an Area of Concern by the U.S. EPA, which means that the waters have been significantly impaired by pollutants such as nitrogen, PCBs, and heavy metals. While upper sections of the river have been restored, Braden's study focused on residents living in the lower sections of the river, which have not yet been cleaned up. In survey results, less than 20 percent of respondents viewed the river as environmentally safe.

Braden found that for owner-occupied homes within a five-mile radius of the Sheboygan River Area of Concern, the overall estimated loss of value is $158 million, which translates into an 8 percent discount, on average.

Disinfecting drinking water can create toxic bi-products

Safe drinking water is something we've all come to take for granted in this country and in much of the world. By eliminating infectious diseases from drinking water, we have made much of the world a dramatically safer place.

However, the process of disinfecting drinking water has led to its own set of concerns. Some disinfectant by-products, or DBPs, which result from the reaction of organic matter with disinfectants, can have long-term health impacts, including several types of cancer. Some DBPs have been linked to fetal development problems.



Approximately 600 DBPs have been identified, which represents only a fraction of the total number. The U.S. EPA regulates a small number of known DBPs and the agency is in a six-year period of evaluation of present guidelines.

In a project partially funded by IISG, Michael Plewa, a University of Illinois genetic toxicologist, has developed a comprehensive in vitro database of toxicity levels of DBPs considered a priority by the U.S. EPA. Plewa's team, which included scientists at EPA, tested DBPs to assess their impacts on mammal cells and their genetic material.

Plewa's database will provide the foundation for the EPA's assessment of present regulations. The database can also serve as a much-needed practical resource for the water treatment community as they make decisions regarding local disinfection practices.

The bottom line ...

- The northeastern Illinois regional water supply plan includes data on conservation pricing, which promotes sustainable regional water management.
- Municipalities have access to assistance as they develop water rates that support much needed infrastructure improvements and repairs.
- Research reveals that green infrastructure is just as effective as conventional stormwater infrastructure, and is less expensive.
- Porter County commissioners adopted a watershed overlay ordinance establishing riparian buffer zones on streams and rivers in the county, which will help protect Lake Michigan water quality.
- Flood peaks in the Chicago metropolitan area are higher than they used to be, and they are also 25 percent higher than estimates currently used by water managers.
- A new method for measuring methylmercury levels in freshwater has proved to be more accurate than standard methods.

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Margaret Schneemann, Water Resource Economist
MSchneemann@cmap.illinois.gov; 312-676-7456

Leslie Dorworth, Aquatic Ecology Specialist
dorworth@calumet.purdue.edu; 219-989-2726

Illinois-Indiana Sea Grant is one of more than 32 programs of the National Sea Grant College Program created by Congress in 1966. Sea Grant is a partnership of universities, government, business, and industry that addresses marine and Great Lakes needs to enhance sustainable coastal economic development. Funding is provided by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA Grant #NA10OAR4170068), Office of Sea Grant, University of Illinois at Urbana-Champaign, and Purdue University. The University of Illinois and Purdue University offer equal opportunities in programs and employment.

Sea Grant
ILLINOIS - INDIANA

IISG-10-10

Photo courtesy of John Braden

NRSC
Aug. 28 & 29, 2012
Exhibit # 6

DON'T "P" ON YOUR LAWN!

Algae blooms or clear water? You can make a difference!

Phosphorus (P) is a nutrient found in many fertilizers that feeds algae blooms in lakes. Switch to "P-free" fertilizers and follow these easy tips for healthy lawns and lakes...

HEALTHY LAWN TIPS
for green lawns not green lakes!

- **TAKE A SOIL TEST...** if you are seeding a new lawn, or want to learn more about your lawn's nutrient content, pH level, and organic content.
- **FERTILIZE...** only with **phosphorus-free fertilizers**. Most Indiana and Illinois lawns have enough P and only need nitrogen (N). The best time to fertilize is spring and fall. Your soil test results will determine your fertilizer needs. Sweep up fertilizer from sidewalks and driveways, and don't fertilize before heavy rain.
- **WATER...** if desired, in early morning, when there is less than one inch of rain per week. During droughts, grass will survive without watering by going dormant.
- **PLANT GRASS SEED...** on existing lawns at least once a year with a mix of grass seed and compost. Use a grass mixture that does well in the setting (soil, light, activity). Leave legumes, such as common white clover, in the grass to add nitrogen, which will naturally fertilize your lawn.
- **MOW...** to maintain a height of 3 to 4 inches and cut off no more than 1/3 of grassblade. Leave clippings on lawn to add nutrients and organic matter, but be sure to sweep the clippings off pavement.
- **WEEDS...** will be discouraged by using these tips. Pull by hand any weeds that grow.

LOOK FOR THE ZERO!

The three numbers on fertilizer bags show the N-P-K nutrient analysis. The middle number is the phosphate (phosphorus) content. A "zero" in the middle means it is phosphorus-free.

Lawns rarely need extra potassium (K), but adding some does not affect water quality.

Visit WWW.LAWNTOGREATLAKES.ORG to learn more and find local stores that carry "P-free" fertilizer

The Lawn to Lake Partners: Illinois-Indiana Sea Grant, University of Illinois Extension, Safer Pest Control, Northwestern Indiana Regional Planning Commission, Chicago Metropolitan Agency for Planning, Lake Champlain Sea Grant

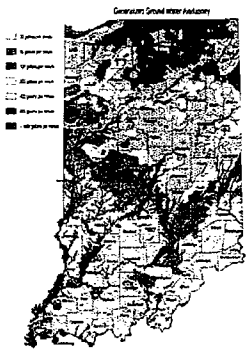
LAWN TO LAKE

NRSC
Aug. 28 & 29, 2012
Exhibit # 7

Update of Water Resource Availability, Management and Distribution in Indiana

INDIANA DEPARTMENT OF NATURAL RESOURCES

Statewide Ground Water Availability
(1980 Governor's Study)



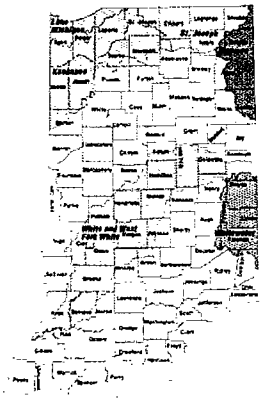
Indiana Department of Natural Resources
Division of Water

The Division of Water studies and maintains information on surface and ground water availability:

- USGS Gaging Network: 165 Stream Gages; 36 Monitoring Wells; 10 Lake Gages; 1 Reservoir Gage
- 6 Basin Studies completed during 1987 -2002
- County Bedrock/Unconsolidated Aquifer Systems Maps completed in 2011

Water Resource Assessments
(Basin Studies)

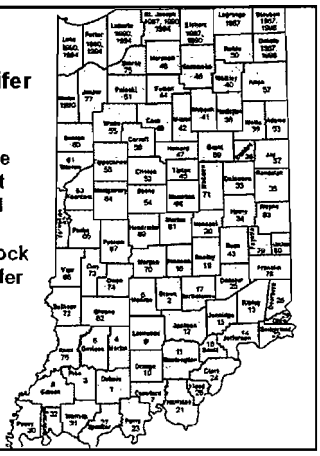
Six Completed 1987-2002



Division of Water Aquifer Systems Mapping

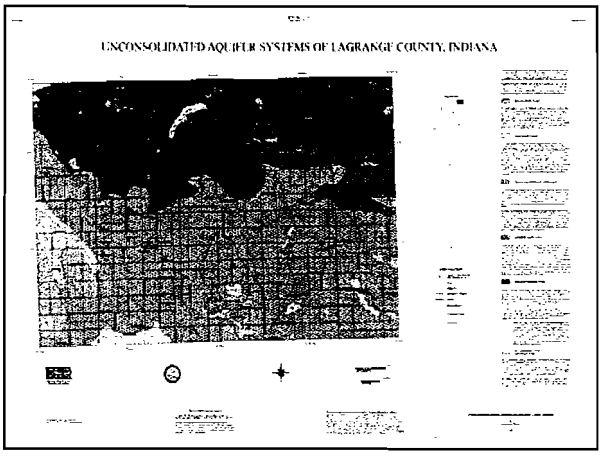
County-based statewide aquifer systems project completed August 2011

Maps completed for bedrock and unconsolidated aquifer systems



Indiana Code 14-25-7-15: Water Resource Management

- Every person who has a SWWF shall register it with the Natural Resources Commission
- All SWWF completed after July 1, 1984, must be registered within 3 months after installation
- The owner of the SWWF shall report water use within three months after the end of each calendar year on forms provided by the commission



Significant Water Withdrawal Facility (SWWF)

- The water withdrawal facilities of a person that, in the aggregate from all sources and by all methods, has the capability of withdrawing more than 100,000 gallons of ground water, surface water, or ground and surface water combined in one day.

Indiana Department of Natural Resources / Division of Water

Water Use System

Water Use Information For 2011

Registration : 76-02726-M

Owner :
Indiana Department of Natural Resources
Division of Parks & Reservoirs
402 W. Washington St. W298
Indianapolis IN 46204
Phone: (317) 232-4124

Contact :
Pokagon State Park
Ted Bohman, Property Manager
450 Lane 100 Lake James
Angola IN 46703-9501
Phone: (260) 833-2012

Total Time of Pump Operation: 365 Days Measurement Method:

Ground Water Withdrawal Information In Millions Gallons

Number	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	.22	.20	.17	.18	.20	.53	.42	.30	.20	.34	.16	.28
2	.22	.20	.17	.18	.20	.53	.42	.30	.20	.34	.16	.26
3	.08	.09	.10	.04	.10	.17	.29	.18	.11	.09	.02	.02
4	.08	.06	.10	.04	.10	.17	.29	.18	.11	.09	.02	.02

Ground Water Source Information:

Number	Capacity, GPM	Depth FT	Diameter, IN	Aquifer Utilized	UTMN	UTME
1	90	80	6	SG	4618675	664500
2	150	87	8	SG	4618675	664575
3	100	150	8	GR	4619675	663650
4	100	130	8	GR	4619420	663760

Indiana Code 14-25-4: Water Rights: Emergency Regulation

- Provides for "Timely and Reasonable Compensation" to owners of domestic wells affected by high capacity ground-water pumpage
- Provides for restrictions on high capacity ground-water pumpage under certain conditions

2011 STATE TOTALS

	Withdrawals (BG)	*Capacity (MGD)*	*Withdrawals vs Capacity*	*Current Number*
Surface Intakes	2851	17963	43.5%	1361
Wells	226	5109	12.1%	6454
TOTAL	3077	23072	36.6%	7815
Facilities				3667

Timely and Reasonable Compensation

Timely and reasonable compensation consists of and is limited to the following:

1) The immediate temporary provision at the prior point of use of an adequate supply of potable water
2) Reimbursement of expenses reasonably incurred to obtain a temporary supply of water and/or provide timely and reasonable compensation as provided in (3)(A) and (3)(B).

(3) Either;

(A)The restoration of the affected well to its former relative capability;

(B) The permanent provision at the prior point of use of an alternative supply of potable water; or

(C) The permanent restriction or scheduling of the high capacity ground-water withdrawals so that the affected well continues to produce its normal supply of water.

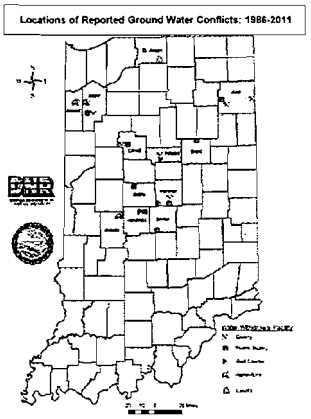
Restriction of Ground-Water Withdrawals

The director may restrict the quantity of ground water that may be extracted from a significant ground-water withdrawal facility upon the declaration of a ground water emergency if:

(1) The facility is reasonably believed to have caused the failure of the complainant's water well; and

(2) The immediate temporary provision of and adequate supply of water is not carried out; or

(3) There is reasonable belief that continued ground-water withdrawals from the facility will exceed the recharge capability of the ground-water resource of the area.



IC 14-25-5: Emergency Regulation of Surface Water Rights

- Provides protection for owners of freshwater lakes against impacts of significant water withdrawal facilities
- Significant lowering of lake level must be documented
- Water level lowering must result in *significant environmental harm*

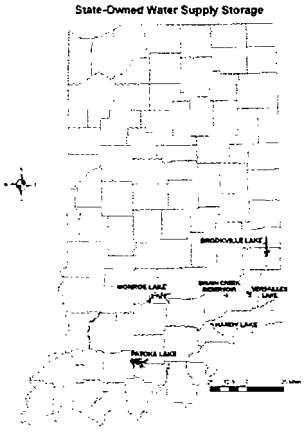
IC 14-25-2
Minimum Stream Flow and Sale of Water Contracts

- State of Indiana may sell water for water supply purposes from reservoir impoundments financed by the state.
- State of Indiana may contract for minimum stream flows or for the sale of water on a unit pricing basis for a period of no more than 50 years.
- After June 30, 1991, State of Indiana must be compensated at the rate of thirty-three dollars ($33) per one million (1,000,000) gallons of water.

Existing Water Supply Contracts: Dates, Terms, & Expirations

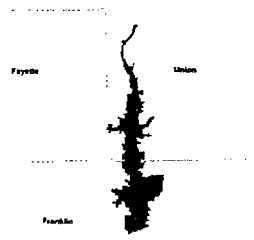
Lake	Client	Contract	Term (yrs)	Expires	Avg. Daily Limit	Annual Limit
					million gal.	million gal.
Brookville	Brook Hill GC	1/7/05	10	1/7/15	—	25.00
Brookville	Brookville Enhancement Partners (GC)	7/2/2011	10	7/2/2021	—	35.00
Hardy	Stucker Fork CD	2/17/97	40	12/31/38	no limit	no limit
Monroe	Bloomington	1/7/05	20	1/7/25	24.000	*8,760.00*
Monroe	Boy Scouts of Am.	5/15/90	25	8/31/15	0.200	20.00
Monroe	Eagle Pointe GC	3/17/2009	10	3/17/2019	—	85.00
Monroe	IPALCO	7/21/2009	20	7/21/2029	—	325.90
Monroe	Salt Creek Svcs.	2/9/68	50	2/9/18	0.025	*9.13*
Patoka	Patoka Lake Reg.	7/1/2009	50	6/30/2059	20.000	*7,300.00*

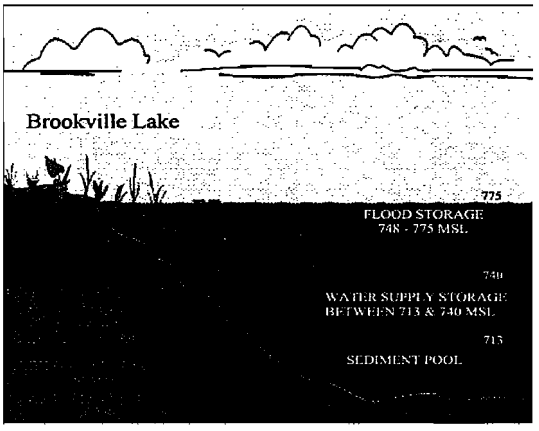
State-Owned Water Supply Storage



Brookville Lake

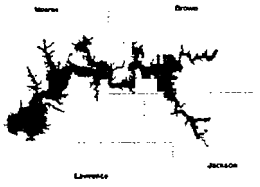
- **Water Supply Storage:**
  740 – 713 ft.
  89,300 acre feet
  (29,098 MG)
- **Supply Committed:**
  243 MG (0.8%)
- **Firm Yield:**
  82 MGD





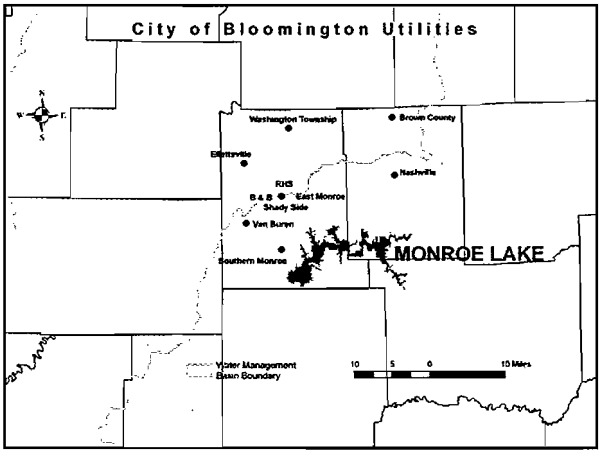
Monroe Lake

- **Water Supply Storage:**
  538 – 515 ft.
  (52,136 MG)
- **Supply Committed:**
  9,200 MG (17.6%)
- **Dependable Yield:**
  122 MGD



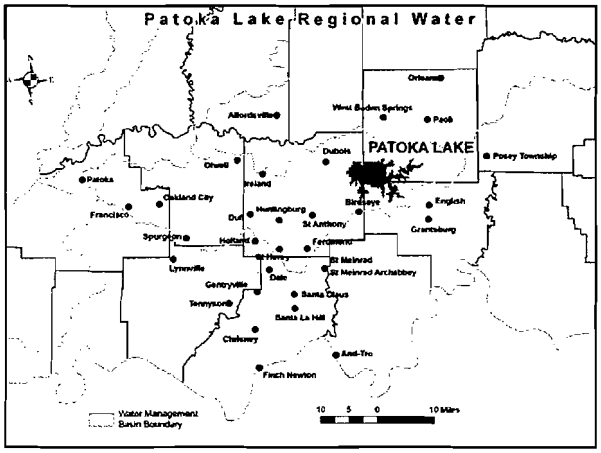
Brookville Lake
Current Water Supply Contracts

Client	Annual Use (5yr Ave.)	Annual Limit
Brook Hill GC	9.4 MG	25.0 MG
Buck Point GC	23.5 MG	35.0 MG
Franklin Co. Water (currently inactive)	66.9 MG	182.5 MG
Total:	99.8 MG	242.5 MG



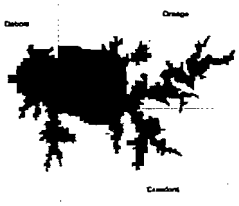
Monroe Lake
Current Water Supply Contracts

Client	Annual Use (5yr Ave.)	Annual Limit
City of Bloomington	5,352.3 MG	8,760.0 MG
Eagle Pointe Golf	41.5 MG	85.0 MG
IPALCO	0 MG	325.9 MG
Salt Creek Services	1.2 MG	9.1 MG
Boy Scouts (inactive)	0 MG	20.0 MG
Total:	5,394.9 MG	9,200.0 MG



Patoka Lake

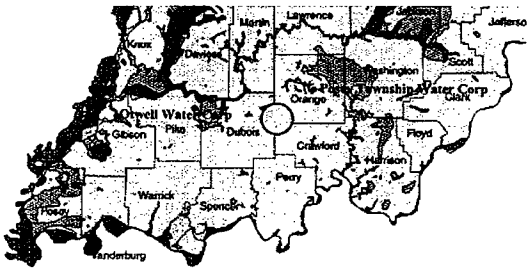
- Water Supply Storage:
  536 – 506 ft.
  (34,949 MG)
- Supply Committed:
  7,300 MG (20.8%)
- Firm Yield:
  78 MGD



Patoka Lake
Current Water Supply Contracts

Client	Annual Use (5yr Ave.)	Annual Limit
Patoka Lake Reg. Water & Sewer District	2,250.5 MG	7,300.0 MG
Total:	2,250.5 MG	7,300.0 MG

Patoka Area Groundwater Availability



Pump Installer Licensing: Effective January 1, 2011

- Initial Pump Installer Licenses—500 issued since effective date;
- License Holding Well Drillers Adding the Pump Installer Endorsement—400+
- Approximately 1300 total licensed WD and PI
- Regulation well received, supported, & promoted by local Plumbers, Heating, and Cooling Association (IPHCC), Indiana Rural Water Association (IRWA), & Indiana Ground Water Association (IGWA)

Ground Water Supply Potential of Charlestown State Park

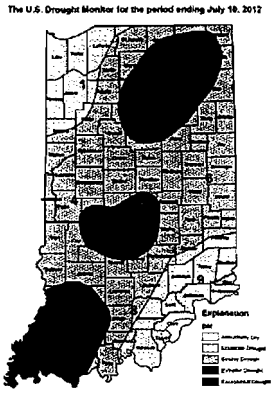
- 2011 report of ground water supply potential completed in two phases:
  1) Field investigation
  2) Ground water flow model
- Estimated sustainable yield of approximately 75 MGD
- Recharge of aquifer by Ohio River provides protection against drought
- Current capacity of treatment plant is 2 MGD (can be increased to 4 MGD)

Continuing Education for Water Well Drillers and Water Well Pump Installers

- 6 hours per cycle for each endorsement
- Established continuing education in two year cycles as condition of license renewal
- Pre-approval required for all courses
- 54 Opportunities Approved since program began; including Online course availability
- Over half of license holders have completed minimum requirements

Effect of 2012 Drought on Water Resources

"Water Shortage Warning"
Issued on July 17th, 2012, for entire State under Criteria Established in *Indiana's Water Shortage Plan*



2012 Ground Water Rights Investigations under IC 14-25-4

- Approximately 150 investigations conducted during months of June and July, 2012
  1) Jasper Co. – AG Irrigation
  2) Hendricks Co. – GC Irrigation/PWS
  3) Putnam Co. – AG Irrigation
  4) Benton/Warren Co. – AG Irrigation
  5) Allen Co. – PWS/GC Irrigation/Quarry
  6) Hamilton Co. – GC Irrigation/PWS
- Timely and Reasonable Compensation to be determined by IDNR, Division of Water

Water Shortage Plan Advisory Phases and Recommended Conservation:

- *Watch Phase* - 5% voluntary conservation
- *Warning Phase* - 10 to 15% voluntary conservation
- *Emergency Phase* – >15% conservation (Governor Declaration under IC 10-14-3)

Objectives of Water Shortage Plan:

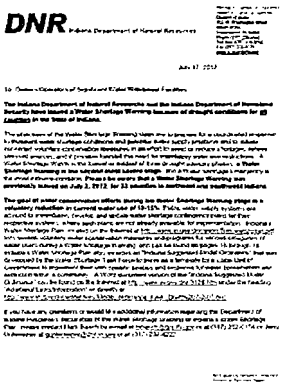
1) Coordinated Response to Water Shortage conditions

2) Voluntary Conservation to avoid or reduce shortages

INDIANA'S WATER SHORTAGE PLAN

INDIANA DEPARTMENT OF NATURAL RESOURCES DIVISION OF WATER

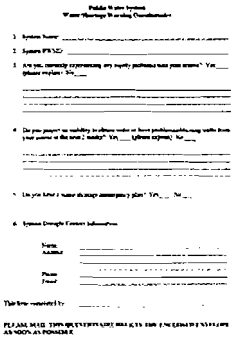
2012 Declaration of *"Water Shortage Warning"* sent to owners of 3650 SWWFs


DNR Indiana Department of Natural Resources

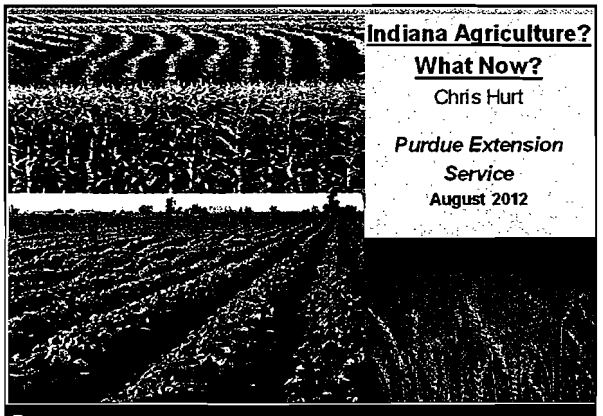
Drought Indicators

- 1-month Standardized Precipitation Index (SPI)
- U.S. Drought Monitor
- Below normal percentiles of regionalized monthly average streamflow

IDEM *"Water Shortage Warning Questionnaire"* sent to all PWS Systems in State



Purdue Extension 2012



Indiana Agriculture?
What Now?
Chris Hurt

Purdue Extension Service
August 2012

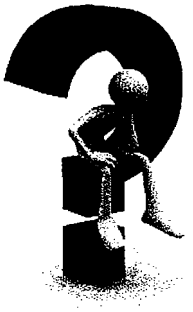
PURDUE

2005 Katrina -$146.3 billion

1988 Drought -$77.6 Billion

2012 Drought -$????

What do we do now???



Source: National Drought Mitigation Center

PURDUE

U.S. Down 25%

Trend	Aug.'12	Bu. from trend	% of Trend	
165.0	100	-65	60.6%	*State Avg.*
173.6	117	-57	67.4%	North West
168.1	105	-63	62.5%	North Central
152.1	100	-52	65.8%	North East
174.0	96	-78	55.2%	West Central
166.2	99	-67	59.6%	Central
158.4	102	-56	64.4%	East Central
164.6	83	-82	50.4%	South West
142.6	85	-58	59.6%	South Central
142.2	92	-50	64.7%	South East

PURDUE

U.S. Down 18%

Soybeans				
Trend 12	Aug 2012	Bu from Trend	% of Trend	
48.3	37.0	-11.3	76.6%	STATE
49.4	40.0	-9.4	81.0%	North West
49.3	39.0	-10.3	79.0%	North Central
45.6	37.0	-8.6	81.2%	North East
51.1	35.5	-15.6	69.5%	West Central
51.9	39.0	-12.9	75.2%	Central
49.1	38.5	-10.6	78.4%	East Central
46.0	31.5	-14.5	68.5%	South West
40.4	31.0	-9.4	76.7%	South Central
41.7	35.0	-6.7	83.8%	South East

PURDUE

But NOT the Worst Financial Year

Natural Hedge

Crop Insurance

PURDUE

Average Indiana Revenues Per Acre

		Corn Yield Bu./Acre	Corn Price	Revenue Per Acre	SoyYield Bu./Acre	Soybean Price	Revenue Per Acre	Revenue 50/50
	2009	171.0	$3.66	$626	49.0	$9.80	$480	$553
	2010	157.0	$5.38	$845	48.5	$11.50	$558	$701
	2011	146.0	$6.20	$905	45.0	$12.40	$558	$732
May 15 Expected	2012	165.8	$5.10	$846	48.6	$13.10	$637	$741
Aug 10th Update	2012	100.0	$8.30	$830	37.0	$16.10	$596	$713
% Change From May 15 Expectation		-40%	63%	-2%	-24%	23%	-6%	-4%
Assume 25% forward priced at May levels				$693			$559	$626
% Change assuming 25% forward contracted				-18%			-12%	-16%

PURDUE

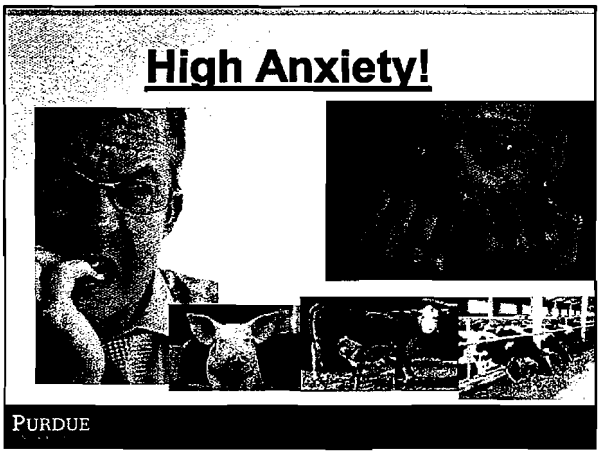
Difference Makers: Crop Farm Families

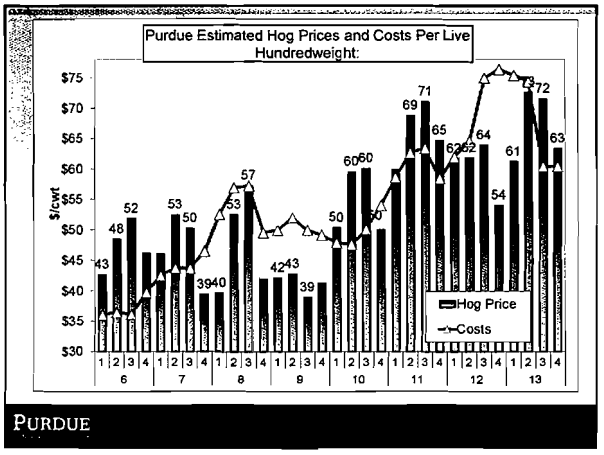
- Final Level of yields
- How much forward contracted
- Crop Insurance Program
- Harvest Option Price
- Does farm family have livestock

PURDUE

	Normal Crop	60%Corn 75% Beans No forward contract No insurance	60%Corn 75% Beans 35% Forward Contract No Insurance	60%Corn 75% Beans No forward contract 75% RA Harvest Option
Corn Forward contracted			144,375	
Beans Forward contracted			113,750	
Corn sold harvest	412,500	396,000	165,000	396,000
Beans sold harvest	325,000	300,000	160,000	300,000
Crop Insurance corn				79,200
Crop Insurance beans				
Corn Expenses	-375,000	-375,000	-375,000	-380,000
Bean Expenses	-300,000	-300,000	-300,000	-304,000
	$62,500	**$21,000**	**-$91,875**	**$91,200**

PURDUE


High Anxiety!
PURDUE


Purdue Estimated Hog Prices and Costs Per Live Hundredweight:
$/cwt
$75
$70
$65
$60
$55
$50
$45
$40
$35
$30
Hog Price
Costs
6
7
8
9
10
11
12
13
PURDUE

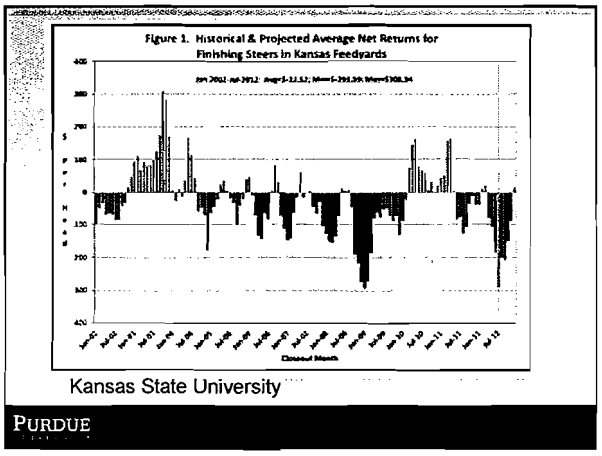
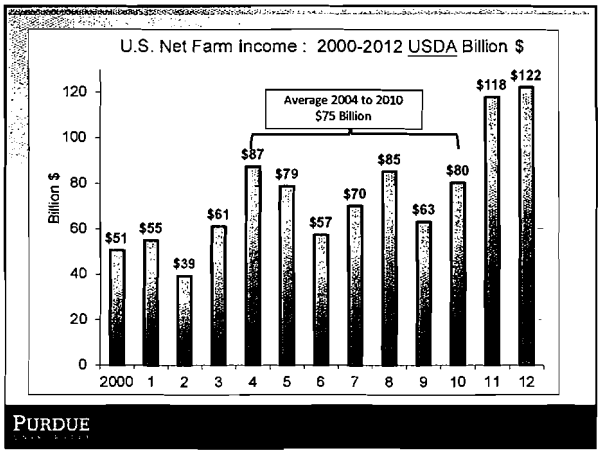


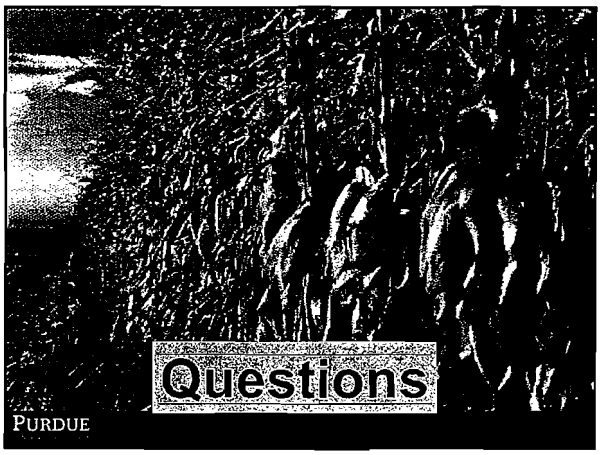
Figure 1. Historical & Projected Average Net Returns for Finishing Steers in Kansas Feedyards
Kansas State University
PURDUE

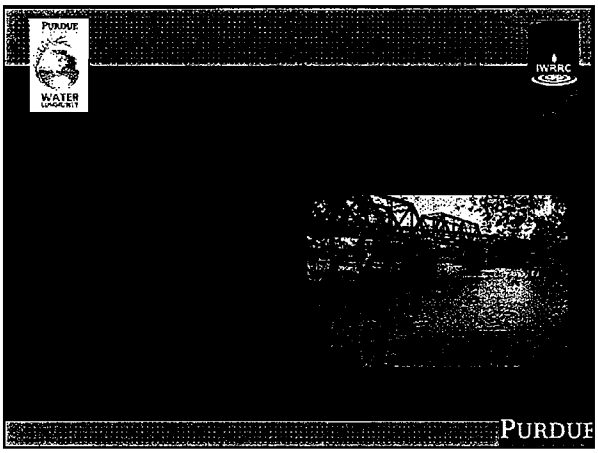

U.S. Net Farm Income : 2000-2012 USDA Billion $
Average 2004 to 2010
$75 Billion
Billion $
120
100
80
60
40
20
0
$51
$55
$39
$61
$87
$79
$57
$70
$85
$63
$80
$118
$122
2000
1
2
3
4
5
6
7
8
9
10
11
12
PURDUE

Crop Income Protection

- Your Crop Insurance Program
- Government Farm Program
- Your Marketing Program
- Your GREAT Management

PURDUE





Purdue University

...Purdue University will be the preeminent institution, leading the world in discovery to advance agriculture, food and natural resources ...

The Purdue Water Community is a vibrant, interconnected academic group that has created a collaborative environment for the discovery and delivery of critical information focused on solving global and regional water problems.

Working at the Nexus of Water, Food, Climate and Energy

Water for the future

Water Community

College of Engineering	College of Agriculture	College of Science	College of Health & Human Sciences
Agricultural & Biological Engineering	Agricultural & Biological Engineering	Earth & Atmospheric Science	Health Sciences
Civil Engineering	Agronomy		
Ecological & Environmental Engineering	Agricultural Economics		
	Forestry & Natural Resources		
	Food Science		

PWC Key Program Areas

Great Lakes and Inland Lakes
Wabash River Ecology
Climate Change and Water Supply
The intersection of Agricultural and Water
Engineering Sustainable Water Systems
Water Infrastructure Management
Public Health Impacts

IWRRC a National Program

We are one of the 54 Water Centers in the National Water Research Institute (NWRI) program established by the "water resources research act of 1964."

In 48 years, we have funded more than 200 water projects for Indiana.

Mission

The mission of IWRRC is to serve the citizens of Indiana through:

Discovery that expands the realm of knowledge and develops solutions to problems relevant to Indiana.

Mission

We conduct basic and applied research, host an outreach program and support students in answering questions about Indiana's water.

Research – Outreach – Student Training

How does the IWRRC function?

Coordinates:

- The intellectual and physical resources of all Indiana's Universities, state agencies, and industries to resolve technical, economic, on problems associated with water resources management, use and preservation of water contamination.

IWRRC

Total 104 (b) in 2011: **$92,524**

~$18,000 per project

~$8,000 operations costs

Proposals will be due: 11-16-2012

Outside review of proposals

IWRRC (104 B)

Specifically, federal authorization (funding):

- Provides the base for each institute to establish cooperative programs with local governments, state agencies, and industry.
- Supporting and promoting multidisciplinary problem solving research.

IWRRC (104 B)

Funding for the institutes program requires a 2:1 non-federal:federal match and projects must meet the criteria as specified by USGS

IWRRC (104 B)

As required by federal law, none of the federal funding appropriated directly for the institutes is used to pay overhead costs, and each institute matches every dollar of its base appropriation with at least two dollars from non-federal sources.

IWRRC (104 B)

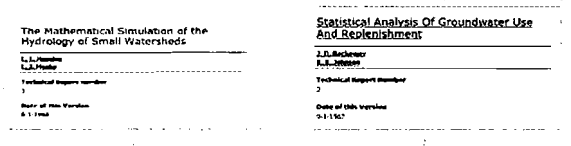
In Indiana no direct state funds are provided to the IWRRC.

- Each PI matches the federal dollar with "creative approaches" .. PI time

This contrasts many other states were federal funds are matched (2NF:1F) by the state creating a larger pool of resources

Older Reports

http://docs.lib.purdue.edu/iwrrc/



Current Projects 2011-12

Transport and retention of atrazine, metolachlor, carbaryl, and chlorothalonil in agricultural streams (Bernot, Ball State)

Monitoring and modeling of hydrodynamic processes at the Wabash-Tippecanoe Confluence (Merwade, Purdue)

Niche breadth variation of fish assemblages for the entire Wabash River (Pyron, Ball State)

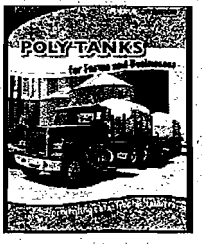
Current Projects 2011-12

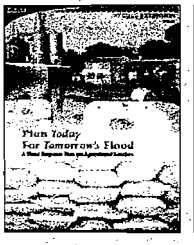
Connectivity & Functioning of Wetlandscapes: A Complex Network Modeling Analysis (Rao, Purdue)

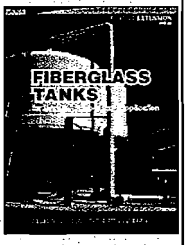
Identifying Opportunities for Soil and Water Conservation With Indiana's County Surveyors and Drainage Boards (Prokopy, Purdue)

Current Outreach Projects 2011-12

Pollution Prevention Strategies for Farmers and Commercial Input Applicator Businesses

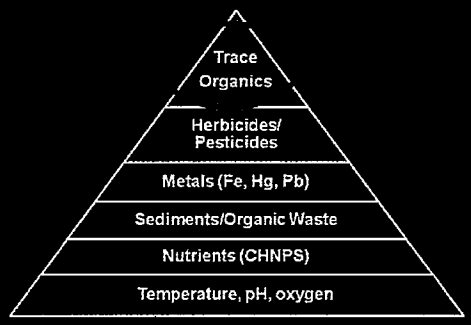






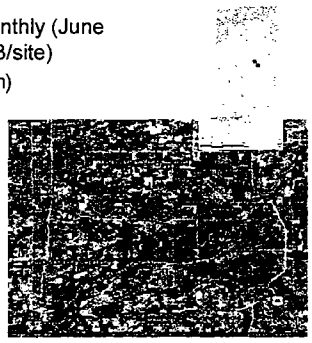
Veach, A, **MJ Bernot**. *In Press*. Temporal variation of pharmaceuticals in an urban and agriculturally influenced stream. Science of the Total Environment.

Bunch, AR, **MJ Bernot**. 2011. Pharmaceutical abundance in central Indiana streams and effects on microbial activity. *EcoToxicology* 20:97-109



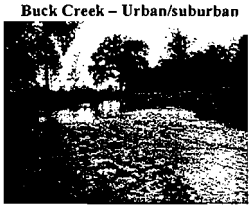
Temporal variation in pharmaceuticals - UWR

- Two sites sampled monthly (June 2009-June 2010; N=13/site)
  - Buck (suburban/urban)
  - Killbuck (agricultural)
- Pharmaceuticals
- Physiochemical characteristics
- Sediment composition
- Isotopic signatures



Temporal variation in pharmaceuticals - UWR

Buck Creek – Urban/suburban



Killbuck Creek –Agricultural

Table 1 Study site characteristics. Values reported are means (standard deviation) of 19 sampling events

	Land Use	Source	Discharge (m^3/s)	pH	Temp. (°C)	DO (mg/L)	NO_3 (mg/L)	PO_4 (mg/L)
Buck Creek	Urban/ suburban	CSO	2.0 (1.3)	7.7 (1)	10.4 (7.3)	15.7 (2.7)	3.6 (4.4)	0.4 (0.4)
Killbuck Creek	Agricultural	Septic	0.3 (0.4)	7.6 (1)	11.6 (9.3)	12.1 (4)	2.7 (0.8)	0.7 (0.9)

Veach and Bernot, 2011, Science of the Total Environment

Compound	Chemical Structure	Primary Use	Frequency (%)	Ranges (ng/L)
Gemfibrozil		Lipid regulating agent	100	1.2-11
Caffeine		Mild stimulant	96	11-400
Cotinine		Nicotine by-product	92	2.1-37
Acetaminophen		Analgesic/fever reducer	84	1.6-460
Sulfamethoxazole		Antibiotic used with trimethoprim	84	1.2-16
Ibuprofen		NSAID, pain reliever	68	1.8-42
DEET		Insect repellant	64	8-290
Carbamazepine		Anticonvulsant	28	1.1-2.7
Trimethoprim		Antibiotic used with sulfamethoxazole	28	3-58
Sulfamethazine		Veterinary antibiotic	20	1.2-22
Triclosan		Antiseptic, disinfectant	12	9.1-22
Sulfadimethoxine		Veterinary antibiotic	4	2.2

Veach and Bernot, 2011, Science of the Total Environment

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Veach and Bernot, 2011, Science of the Total Environment

- Detected in >90% samples:
  - Gemfibrozil, caffeine, cotinine

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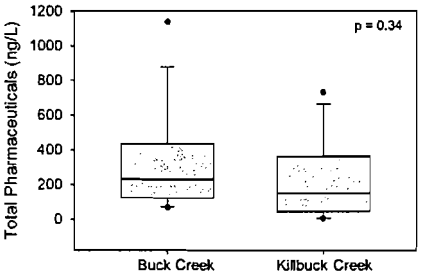
Veach and Bernot, 2011, Science of the Total Environment

Concentrations measured ranged over an order of magnitude for most compounds

Spatial variation in pharmaceuticals - UWR

H_2: Pharmaceutical concentrations would be comparable in the urban and rural streams

Temporal variation in pharmaceuticals - UWR



Total pharmaceutical concentrations did not differ between sites

Sites had comparable pharmaceutical concentrations

Temporal variation in pharmaceuticals - UWR

Data suggest microbial activity may drive pharmaceutical persistence in the environment

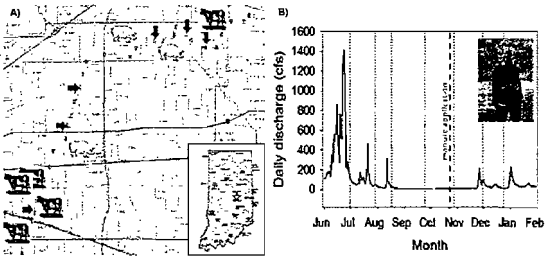
- Previous studies indicate flow and CSO input
- High frequency compounds:
  - oxygen, temperature, depth
- Low frequency compounds:
  - pH, turbidity

Previous studies focus on assessments during periods of high microbial activity (late spring/summer)

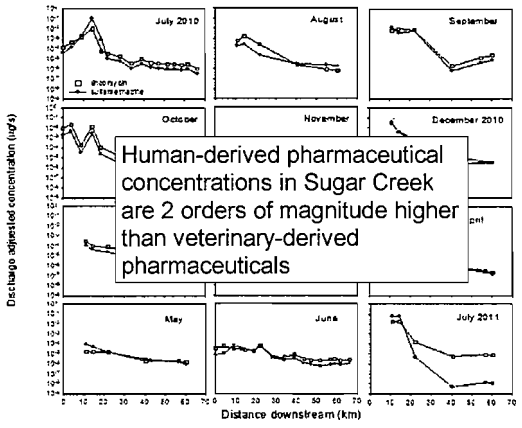
- *Pharmaceutical concentrations high in winter/early spring*

Veach and Bernot, 2011, Science of the Total Environment

Longitudinal transport of veterinary pharmaceuticals - Sugar Creek

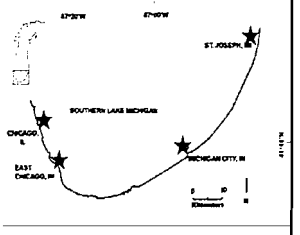


Monthly sampling at multiple sites along a 9 mile reach influence by CAFOs



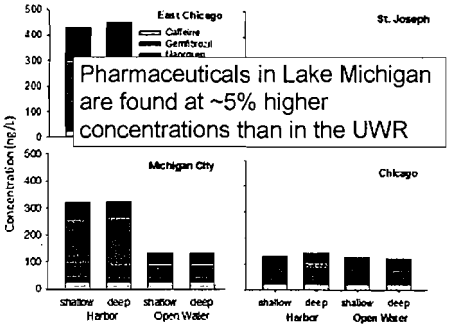
Human-derived pharmaceutical concentrations in Sugar Creek are 2 orders of magnitude higher than veterinary-derived pharmaceuticals

Pharmaceuticals in near-shore habitats of Lake Michigan



Seasonal sampling at tributaries and open water sites

Pharmaceuticals in near-shore habitats of Lake Michigan



Pharmaceuticals in Lake Michigan are found at ~5% higher concentrations than in the UWR

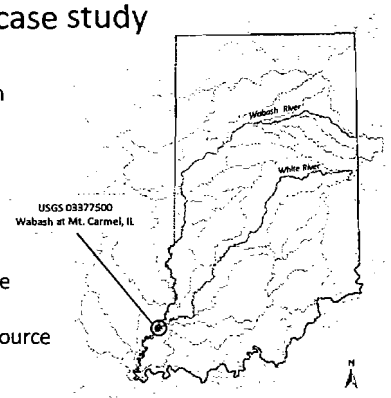
Conclusions (*What we know*):

- Pharmaceuticals are ubiquitous in freshwaters
- Controls vary with compound and site
- Trace concentrations can affect organisms
- Effects vary with compound and organism
- Preliminary work has highlighted compounds and periods of greatest concern
  - Acetaminophen, carbamazepine, DEET, triclosan
- Continued work will allow for greater predictive power and regulatory need assessments

UNIVERSITY

Preliminary case study

- Water Balance on Wabash Basin
- Objectives:
  - Develop a methodology
  - Demonstrate the significance of an holistic water resource analysis

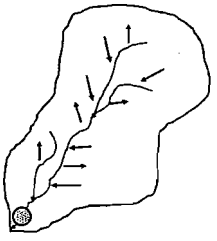


Human Water Cycle...

- Human activity alters the natural water cycle
- When you withdraw water downstream, was it previously used upstream? If so, how much are we reusing the water of the rivers?
- Literature review: EPA's Wastewater in receiving waters at water supply abstraction points, 1980
- Relevance in terms of water resources planning, water quality, public health, inter-jurisdiction regulations/ collaboration/ research.

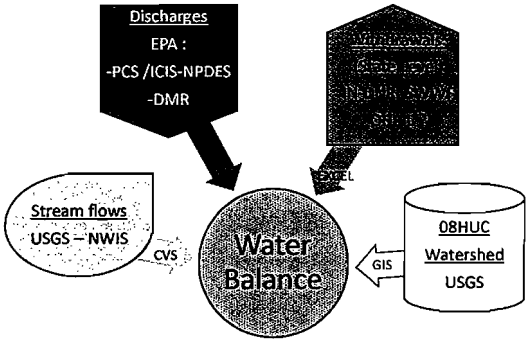
Theoretical Basis

- Assess water reuse by:
  - Determining volume of water DISCHARGED into streams
  - Take US Geological Survey (USGS) gauging station STREAM FLOW measures as reference
  - Evaluate the relationship between discharges and surface waters stream flow



- Compare with volume of surface water WITHDRAWN
- Analysis at different Hydrologic Unit Code (HUC) Levels

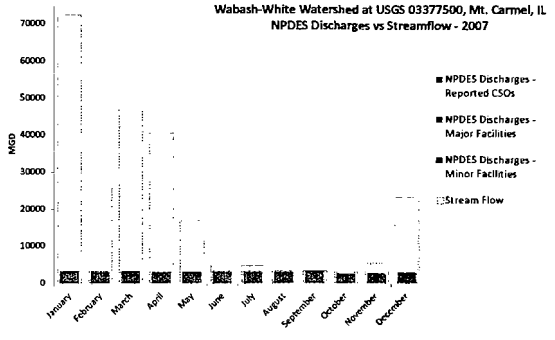
Preliminary datasets



Results

- Integrated geospatial + temporal water use database for Wabash Watershed
  - Quantitative data:
    - Stream flows (time-series)
    - Volume of water withdrawals / discharges
  - Qualitative data:
    - Discharges / withdrawals characterization
    - Watersheds water use and reuse profiles
- Key element: Watershed Hydrologic Unit Code (HUC) – Natural Boundaries vs Political Boundaries

Results



Significance

- During low flow months:
  - "Used" water ranges between 5 – 98%
  - We are essentially withdrawing, using, treating and discharging the entire volume of the river
- Relevance of holistic approach – Extent of unplanned water reuse + withdrawals situation => discussion about managing our water resources
- Coordinated data acquisition, data organization and data management would facilitate this type of research

We Need: *An Indiana Water Assessment Program*

To answer the questions:

How will water, (*e.g.,* water quality, floods, irrigation climate change, business and development) Impact our state's interest over the next "30 years."

IWRRC The Next 10 Years

- We need a "larger" Indiana water community ....
- We need to fully support IWRRC and expand water research in the state!
- The Illinois Water Survey is a good example..

Papers

2007IN219B Pyron, M. , J. S. Beugly, J. M. Pritchett, S. J. Jacquemin, T. E. Lauer, and J. R. Gammon. 2011. Long-term fish assemblages of inner bends in a large river. River Research and Applications 27:684-692

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Distribution of nonprescription pharmaceuticals in central Indiana streams and effects on sediment microbial activity

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Abstract Since the discovery of trace concentrations of pharmaceuticals in streams and treated drinking water around the world, a call has been made by both the scientific community and the general public to increase understanding of the potential effects these compounds may have on freshwater integrity. We measured abundance and distribution of pharmaceuticals in headwater streams across the Upper White River Watershed of central Indiana. Four nonprescription pharmaceuticals (1,7-dimethylxanthine, caffeine metabolite; acetaminophen; caffeine; cotinine, nicotine metabolite) were found at one or more sites with mean concentrations of 0.038, 0.109, 0.057 and 0.041 μg/l, respectively. Caffeine was measured at trace concentrations at all sites sampled. Higher pharmaceutical concentrations were associated with streams having >90% agricultural land use in the sub watershed, suggesting that nonpoint sources, such as septic tanks, may contribute to stream pharmaceutical contamination. To assess the influence of these pharmaceuticals on stream microbial activity, we measured changes in sediment respiration and nutrient uptake in response to pharmaceuticals using both in vitro and in situ techniques. For in vitro experiments, respiration rates were not significantly different from controls with pharmaceutical exposure. However, net NO_3^--N uptake increased significantly with nicotine concentrations. Net NH_4^+-N uptake was reduced in response to caffeine and nicotine exposure. In situ experiments indicated nicotine exposure increased microbial respiration. Our data show pharmaceuticals are ubiquitous in headwater streams of central Indiana and likely influence stream microbial activity depending on the pharmaceutical compound and history of exposure.

Keywords Pharmaceuticals streams · Freshwater · Land use · Microbial activity

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Introduction

Pharmaceuticals have been found at trace concentrations in streams throughout the United States (Kolpin et al. 2002; Cahill et al. 2004; Glassmeyer et al. 2005; Focazio et al. 2008) and around the world (Lissemore et al. 2006; Roberts and Thomas 2006; Gómez et al. 2007). Pharmaceuticals have also been found in groundwater (Barnes et al. 2008) and treated drinking water (Ternes et al. 2002). Since these discoveries, a call has been made by both the scientific community and the general public to increase understanding of the potential effects these compounds may have on freshwater integrity. If these compounds are influencing the structure or function of aquatic ecosystems, and potentially human health through exposure in drinking water, proactive strategies to reduce environmental contamination are needed.

The primary pathway for pharmaceuticals to enter aquatic ecosystems is through human consumption followed by excretion of un-metabolized pharmaceuticals (Halling-Sørensen et al. 1998; Cain et al. 2004). Only a fraction of pharmaceuticals ingested are metabolized and remaining compounds are excreted in waste either in the parent form or as a metabolite. These compounds then enter the aquatic environment after passing through wastewater treatment facilities, as most current wastewater treatment methods are not designed to remove trace organic pollutants, such as pharmaceuticals (Halling-Sørensen et al.

1998; Ternes 1998; Daughton and Ternes 1999; Roberts and Thomas 2006). Higher pharmaceutical concentrations have been linked to streams receiving effluents from areas draining larger population densities (Buerge et al. 2003). Because of this link between pharmaceutical concentrations in freshwater and human waste, most studies have focused on waterways directly receiving point source pollution from wastewater treatment effluents.

Recent studies have noted pharmaceuticals are not only in wastewater effluent, but also are ubiquitous in streams not receiving effluent (Kolpin et al. 2002; Cahill et al. 2004; Glassmeyer et al. 2005; Lissemore et al. 2006; Roberts and Thomas 2006; Gómez et al. 2007; Focazio et al. 2008). However, data regarding the abundance and distribution of these compounds is still lacking as many studies have limited geographical ranges focused on areas with higher human populations (Kolpin et al. 2002; Glassmeyer et al. 2005; Focazio et al. 2008). Before the potential environmental effects of these contaminants can be assessed, factors that influence the distribution and concentration of pharmaceuticals in the aquatic environment must be further examined.

Pharmaceutical compounds are designed to have a physiological effect on organisms and thus it is likely that they may also alter function of aquatic microbial organisms (Halling-Sørensen et al. 1998). Studies assessing the potential environmental risk of pharmaceuticals in aquatic ecosystems have primarily focused on acute toxicity tests for higher organisms (e.g., invertebrates and fish; Smith and Burgett 2005; Crane et al. 2006; Heckmann et al. 2007) with limited data assessing effects on microbial organisms (Lawrence et al. 2005). Microbial processes (respiration, nutrient uptake) are a holistic measure of ecosystem function as they are essential to nutrient flow and the transformation of organic matter (Hall and Meyer 1998; Hill et al. 2000; Balser et al. 2006; Nweke et al. 2007). Thus, microbial communities are commonly used to examine the influence of contaminants on aquatic ecosystems (Balser et al. 2006) and can provide vital information about the influence of pharmaceuticals to both ecosystems and organisms. Further, processes at lower levels of organization (i.e., microbial respiration, nutrient uptake) may be influenced by contaminants more rapidly than effects on higher organisms (Clements 2000). Therefore, changes in microbial activity may be an early indicator of stress before a compound affects invertebrates or vertebrates.

We examined pharmaceutical abundance and distribution in the Upper White River Watershed (UWRW) of central Indiana. Additionally, the potential influence of nonprescription pharmaceuticals on stream ecosystem function was examined via changes in sediment microbial activity. The objectives were to: (1) quantify the distribution of pharmaceuticals in the UWRW and relate to land use and physiochemical factors; and, (2) assess the influence of four commonly found pharmaceuticals (acetaminophen, caffeine, ibuprofen, nicotine) on microbial respiration and nutrient uptake using both in vitro and in situ experiments.

Materials and methods

Study area

Sampling was conducted in the UWRW of central Indiana (Fig. 1). The UWRW supplies 85% of the surface water needed for human use in Indianapolis and central Indiana (Crawford 1995). The UWRW covers 7040 km^2 across 16 counties with a gradient of urban activities (Upper White River Watershed (UWRW) Alliance 2007). Because of anthropogenic activities, the UWRW is one of the most degraded watersheds in the country. Ten headwater streams within the watershed were selected for sampling to represent a range of urbanization (Fig. 1). Percent land use was calculated using a topographic method with a 1:24,000 USGS topographic map.

Water samples

Water samples were collected from ten sites within 12 h on 23 July 2008 during baseflow conditions. Two modified grab samples were collected from three verticals, at approximately the one-quarter, one-half, and three-quarter points of the transect that extended from the left edge to the right edge of water at each site. The first sample was analyzed for dissolved pharmaceuticals and was collected from the stream into a 1 l baked amber glass bottle. Immediately after sample collection, water was filtered from the glass collection container into another baked amber glass bottle using a Geopump© connected to a syringe filter with an ashed 25 mm Whatman© glass fiber filter (GF/F; 0.7 μm pore size). Samples were packed on ice and shipped overnight to the USGS National Water Quality Laboratory in Denver, CO for analysis of 14 commonly used pharmaceuticals: 1,7-dimethylxanthine, acetaminophen, albuterol, caffeine, carbamazepine, codeine, cotinine, dehydronifedipine, diltiazem, diphenhydramine, sulfamethoxazole, thiabendazole, trimethoprim, and warfarin, using mass spectrometry (USGS schedule 2080). Descriptions of the analytical methods for detection of pharmaceuticals have been detailed elsewhere (Kolpin et al. 2002; Cahill et al. 2004). Water quality parameters were also measured at three points for each site using a Hydrolab© minisonde equipped with an LDO oxygen sensor, turbidity meter, temperature probe, and pH sensor. Mean ($N = 3$) values for each site were used in data analyses.

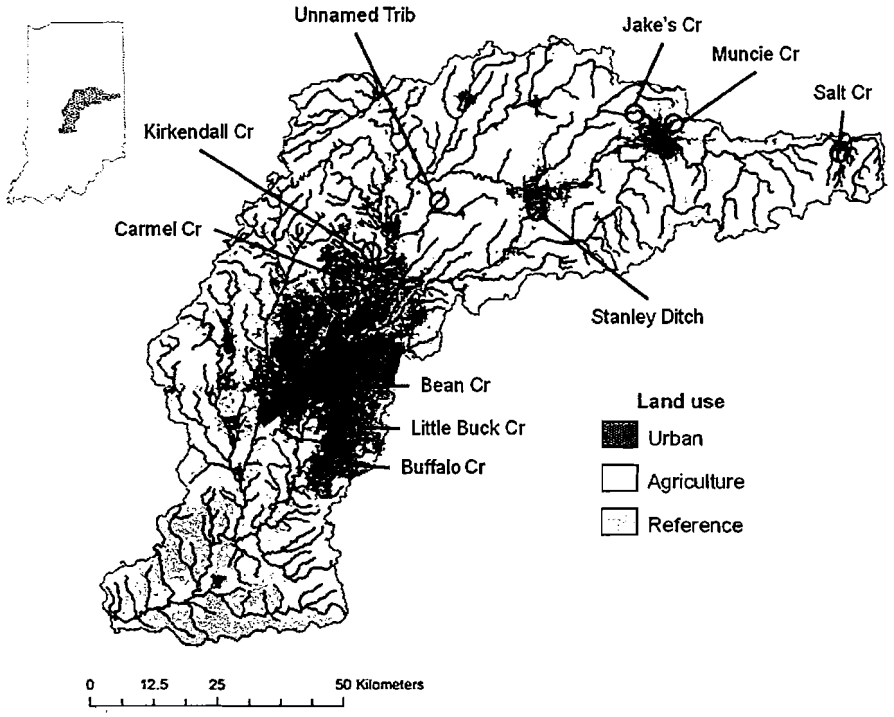

Fig. 1 Sample site locations in the Upper White River Watershed of central Indiana. *Map* depicts dominant land-use types. Reference *land use* refers to forest and wetland

The second water sample was collected into a 1 l acid-washed Nalgene© bottle and placed on ice for return to the laboratory. These samples were filtered in the laboratory within 24 h of collection, using a Geopump© connected to a syringe filter with an ashed 25 mm Whatman© glass fiber filter (GF/F; 0.7 μm pore size), into another acid washed Nalgene© bottle. Samples were then frozen for subsequent analysis of cations (ammonium, calcium, lithium, magnesium, potassium, sodium) and anions (bromide, chloride, nitrate, nitrite, phosphate, sulfate) using ion chromatography (Dionex ICS-3000; Dionex Corporation, Sunnyvale, CA).

Microbial response to pharmaceuticals: in vitro experiments

Sediment and water collection

Stream sediment and water were collected from a headwater stream in Delaware County of east central, IN for two in vitro experiments conducted simultaneously. The stream where collection took place had no point source inputs from wastewater treatment effluents and was a sampling site for measurement of pharmaceuticals as described above. Sediment from the top 5 cm of the stream bottom was collected from the stream thalweg as a natural microbial inoculum (sensu Kemp and Dodds 2002; Inwood et al. 2005). Sediment and water were brought back to the laboratory where sediment was homogenized and invertebrates were removed using a USGS no. 14 sieve; stream water was filtered using a Geopump© connected to a syringe filter with an ashed 25 mm Whatman© glass fiber filter (GF/F; 0.7 μm pore size) as above. Collected sediment and filtered water were stored in acid-washed Nalgene© bottles and refrigerated until experiments began (<24 h). Sediment and water were used for two simultaneous mesocosm experiments assessing microbial response to pharmaceutical treatments: (1) measurement of microbial respiration via dehydrogenase activity (DHA); and, (2) measurement of net nitrate (NO_3^--N) and ammonium (NH_4^+-N) uptake via change in concentrations over time.

Experimental mesocosms

Sieved, homogenized sediment was separated into subsamples by placing 2 ml into acid-washed 12 ml falcon tubes for DHA analyses ($N = 68$) and 30 ml into 120 ml HDPE specimen cups for net nitrogen uptake analyses ($N = 68$). After sediment separation, 2.5 ml of filtered stream water was added to falcon tubes and 90 ml filtered stream water was added to specimen cups. The four treatment pharmaceuticals selected for this study (acetaminophen, ibuprofen, caffeine, nicotine) have been found at trace concentrations throughout US surface waters (Kolpin et al. 2002). These compounds have a range of human uses: acetaminophen is an antipyretic pain reliever; ibuprofen is an anti-inflammatory; caffeine is a stimulant; and, nicotine is a central nervous system stimulant. For both respiration and nutrient uptake experiments,

Table 1 Treatment concentrations for in vitro and in situ pharmaceutical experiments

Pharmaceutical	Treatment concentration (μg/l)			
	Low	Mean	Intermediate	Max
Ibuprofen	0.1	0.2	0.6	1
Acetaminophen	0.055	0.11	5.055	10
Caffeine	0.0405	0.081	3.0405	6
Nicotine	0.012	0.024	0.462	0.9

Treatment concentrations were selected to represent the range of concentrations measured in freshwater (Kolpin et al. 2002)

four concentrations of each pharmaceutical compound (Table 1) and a control (no pharmaceutical addition) were tested (17 treatments total) with four replicate mesocosms for each treatment. Treatment concentrations for each pharmaceutical were low, mean, intermediate, and maximum concentrations based on concentrations observed in U.S. surface waters (Kolpin et al. 2002).

Microbial respiration: dehydrogenase activity assay (DHA)

Dehydrogenases are oxidoreductase enzymes that oxidize organic compounds by transferring electron pairs during microbial respiration (Smith and McFeters 1997). The use of tetrazolium salts as an electron acceptor is a widely accepted method for measuring microbial respiration, as they form a deep red colored formazan when reduced and can be measured using spectrophotometry (sensu Hill et al. 2000). Pharmaceutical treatments (Table 1) were added to prepared mesocosms (2 ml sieved sediment and 2.5 ml filtered water) and vortexed for 1 min to ensure complete mixing. Next, 1 ml of 0.75% iodonitroetrazolium (INT) chloride was added to each tube and tubes were capped and vortexed followed by incubation for 3 h at 27°C. The reaction was then stopped with addition of 8 ml of methanol and again vortexed. Samples were subsequently centrifuged for 10 min and the supernatant collected for spectrophotometric analyses. INT-formazan absorbance was measured using a Schimadzu dual-beam spectrophotometer (UV-1700 Phermaspec) at 428 nm. Background absorbance was subtracted from samples based on mean absorbance of four samples with no INT-chloride added. Formazan concentrations were calculated using a standard curve prepared with INT-formazan and then converted to mg of dissolved oxygen (O_2) consumed. Remaining sediment in falcon tubes was dried at 350°C and sediment grams dry mass (gdm) was measured for each replicate. Sediment microbial respiration was expressed as mg O_2/gdm/h.

Net nitrate and ammonium uptake

Net nutrient uptake was measured as change in nutrient concentration over time in laboratory mesocosms (sensu Kemp and Dodds 2002). Initial nutrient concentrations were determined by removing 10 ml of filtered water from each replicate mesocosm. Pharmaceutical amendments were then added accordingly (Table 1). All mesocosms were then incubated for 48 h at 27°C followed by collection of 10 ml filtered water for measurement of final nutrient concentrations. Nitrate was analyzed using ion chromatography as above followed by calculation of concentrations based on a standard curve. Ammonium was analyzed using colorimetric phenol hypochlorite technique (Aminot et al. 1997) and concentrations were calculated based on a standard curve. After collection of water for nutrient analyses, remaining water was decanted from each replicate mesocosm and sediment was dried and weighed as above. Initial stream nutrient concentrations were 2.04 mg NO_3^--N/l and 90.5 μg NH_4^+-N/l. Nutrient uptake is expressed as change in mg NO_3^--N/gdm/h or change in μg NH_4^+-N/gdm/h. For replicates where final concentration was greater than initial concentration (net mineralization; $N = 30$ for NO_3^--N; $N = 9$ for NH_4^+-N), net uptake rate was estimated as zero.

Microbial response to pharmaceuticals: in situ experiment

Nutrient diffusing substrata (NDS)

NDS is a method to assess microbial colonization and respiration using cellulose sponge substrates over nutrient and pharmaceutical enriched agar. NDS procedures were modified from Tank et al. (2006). Nine agar treatments were prepared including a control (no pharmaceuticals) and low and high treatment concentrations for acetaminophen, ibuprofen, caffeine, and nicotine (Table 1). The treatment concentrations were the mean and maximum concentrations used in the in vitro experiment (Table 1). Agar was autoclaved to 50°C and allowed to cool before pharmaceutical treatments were added. Each treatment had eight replicate NDS prepared. Pharmaceutical-amended agar was poured into 90 ml polycon plastic cups with holes drilled into the hinged lids. After agar solidified, pre-weighed cellulose sponges were placed on top of agar-filled cups. Cellulose sponges were used to select for bacterial colonization once placed into the stream; algae prefer a hard inorganic surface so any changes in weight were attributed to bacterial growth. Agar treatments were randomly attached to L-bars using cable ties with one of each treatment per L-bar. NDS were placed into Muncie Creek in Muncie, IN. This stream was one of the ten sites sampled for pharmaceutical concentrations (Muncie Creek; Fig. 1).

At the time of incubation, stream temperature was 22°C, dissolved oxygen in the water column was 9.2 mg O_2/l, NO_3-N and NH_4-N concentrations were 3.2 and 0.12 mg N/l, respectively, and pH was 8.4. Conditions were comparable to experimental conditions during in vitro experiments. Plastic stakes were used to secure L-bars to the stream bottom and placed into a stream riffle at base-flow conditions. NDS were oriented so ~10 cm of stream water was flowing over sponges at ~0.5 m^3/s during incubation. To protect from animal destruction or tampering, chicken wire was used to enclose NDS during stream incubation. After a 2 week incubation period, L-bars and attached NDS were removed from the stream. In the laboratory, cellulose sponges were separated from the NDS, rinsed lightly with deionized water to remove unattached particles and placed in 50 ml falcon tubes with 10 ml of deionized water. Microbial respiration was analyzed using DHA (as described above). Sponges were then dried in a drying oven (2 days at 100°C) and weighed for measurement of change in grams dry mass (gdm).

Statistical analysis

Pearson's correlation analyses, with Bonferonni correction for multiple comparisons, were used to evaluate the relationship between pharmaceutical concentrations and stream physiochemical parameters or watershed land use. For in vitro experiments, dose response equations were developed using linear and non-linear regression analyses to model respiration and net nutrient uptake rates in response to pharmaceutical concentrations. Models were developed using SigmaPlot v. 10.0 dynamic fit wizard. Models were not forced through the origin as respiration or net nutrient uptake may occur in the absence of pharmaceuticals. For in situ experiments, a one-way analysis of variance (ANOVA) followed by Tukey's post-hoc pair wise comparisons was used to evaluate differences in respiration rates and microbial colonization among treatments with pharmaceutical treatment as the main effect ($N = 9$ treatments each with nine replicates). To normalize data, oxygen consumed was log transformed prior to statistical analyses. ANOVA and correlation statistical analyses were conducted using Minitab 15 (Minitab Inc. 2006). Data are presented as arithmetic means and standard error.

Results

Pharmaceutical concentrations

Of the 14 pharmaceuticals analyzed, four nonprescription pharmaceuticals (1,7-dimethylxanthine, caffeine metabolite; acetaminophen; caffeine; cotinine, nicotine metabolite) were found at one or more sites with mean concentrations of 0.038, 0.109, 0.057 and 0.041 μg/l, respectively (Table 2). Caffeine was ubiquitous with trace concentrations measured at all sites. Concentrations of 1,7-dimethylxanthine (caffeine metabolite), acetaminophen, caffeine, and cotinine (nicotine metabolite) ranged from 0.015 to 0.078, 0.025 to 0.318, 0.019 to 0.176, and 0.037 to 0.045 μg/l, respectively (Table 2). Other pharmaceuticals analyzed but not found in concentrations above detection limits (0.01 μg/l) in the UWRW were dehydronifedipine, diltiazem, diphenhydramine, sulfamethoxazole, thiabendazole, trimethoprim, and warfarin.

Table 2 Pharmaceutical concentrations quantified in study sites in the Upper White River Watershed of central, Indiana USA

Site	Pharmaceutical concentrations (μg/l)			
	1,7-Dimethylxanthine	Acetaminophen	Caffeine	Cotinine
Salt Cr	0.078	0.088	0.176	0.045
Muncie Cr	0.023	0.318	0.056	<DL
Jake's Cr	<DL	0.058	0.057	<DL
Stanley Ditch	0.015	0.056	0.039	<DL
Unnamed trib	<DL	<DL	0.019	<DL
Kirkendall Cr	<DL	<DL	0.047	<DL
Carmel Cr	<DL	<DL	0.043	<DL
Bean Cr	<DL	<DL	0.030	<DL
Little Buck Cr	<DL	<DL	0.021	<DL
Buffalo Cr	<DL	0.025	0.085	0.037

DL (detection limit) = 0.01 μg/l 1,7-dimethylxanthine; 0.02 μg/l acetaminophen; 0.02 μg/l caffeine; 0.02 μg/l cotinine

Physiochemical factors related to pharmaceutical concentrations

Physiochemical parameters varied among streams sampled (Table 3) indicating a range of different freshwater ecosystems were selected. Based on standard deviation, chloride (mean = 40.33 mg/l ± 22.44), sulfate (mean = 30.15 mg/l ± 50.08), and specific conductivity (mean = 775 μs/cm ± 267) varied the most across sites while pH (mean = 7.82 ± 0.46), nitrite (mean = 0.01 mg N/l ± 0.014), bromide (mean = 0.02 mg/l ± 0.007), ammonium (mean = 0.09 mg N/l ± 0.05) and potassium (mean = 1.95 mg/l ± 0.41) varied the least across sites. Water column dissolved oxygen ranged from 5.61 to 8.84 mg O_2/l (mean = 6.72 ± 0.96). Total pharmaceutical concentration (sum of all compounds measured) was correlated with lithium concentrations ($p < 0.01$, $r = 0.84$). As lithium was

Table 3 Physiochemical parameters measured at sites in the Upper White River Watershed of Central IN, USA

	Salt Cr	Muncie Cr	Jake's Cr	Stanley Ditch	Unnamed trib	Kirkendall Cr	Carmel Cr	Bean Cr	Little Buck Cr	Buffalo Cr	Mean ± SD	
Water column characteristics												
Temperature (°C)	21.7	22.2	22.4	17.6	15.2	21.1	20.6	20.0	22.3	22.0	20.5	±2.2
pH	8.6	8.4	8.4	7.5	7.3	7.7	8.0	7.5	7.5	7.3	7.8	±0.5
Specific conductivity (μS/cm)	829	1019	680	1019	1274	634	838	300	568	591	775	±266
Total dissolved solids (mg/l)	0.53	0.65	0.44	0.66	0.82	0.41	0.54	0.01	0.36	0.38	0.48	±0.21
Dissolved oxygen (mg/l)	8.84	6.31	5.88	5.94	8.00	6.35	6.89	6.90	6.43	5.61	6.72	±0.96
Salinity (mg/l)	0.43	0.53	0.35	0.53	0.67	0.32	0.44	0.30	0.29	0.30	0.42	±0.12
Turbidity	10.4	36.9	63.0	0.2	1.7	14.7	9.0	1.6	13.7	4.9	15.6	±18.8
Anions (mg/l)												
Chloride	40.3	36.4	33.0	72.3	95.6	35.9	90.5	58.2	44.3	63.2	40.3	±22.4
Nitrite	0.01	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	±0.01
Bromide	0.02	0.04	0.02	0.02	0.03	0.04	0.04	0.03	0.03	0.03	0.02	±0.01
Nitrate	1.96	1.13	0.39	1.20	0.23	0.89	0.40	1.35	0.88	0.79	1.96	±0.58
Phosphate	0.08	0.02	0.06	0.01	0.01	0.01	0.00	0.05	0.03	0.03	0.08	±0.03
Sulfate	30.2	181.8	27.8	52.4	119.4	42.0	47.7	45.3	20.1	18.	30.2	±50.1
Cations (mg/l)												
Lithium	0.002	0.004	0.001	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	±0.001
Sodium	16.2	13.5	13.2	27.9	31.1	12.9	35.4	28.2	19.7	27.1	22.5	±7.9
Ammonium	0.11	0.11	0.21	0.08	0.11	0.06	0.03	0.04	0.04	0.11	0.09	±0.05
Potassium	2.12	2.17	1.30	1.41	2.52	2.44	1.90	2.25	1.89	1.48	1.95	±0.41
Magnesium	26.6	35.6	18.2	24.3	29.5	17.0	17.3	17.83	12.4	11.3	21.0	±7.4
Calcium	33.0	52.8	31.7	37.7	52.6	32.1	32.3	35.2	26.5	19.1	35.3	±9.9

Mean and standard deviation (SD) of site characteristics across study streams provided

only present in streams with measurable pharmaceuticals, this pattern indicates potential co-occurrence of these compounds. Concentrations of individual pharmaceutical compound were variably correlated with stream physiochemical parameters (Table 4). Specifically, nitrate concentrations were correlated with 1,7-dimethylxanthine ($p < 0.05$) and caffeine ($p < 0.05$). Acetaminophen concentrations were correlated with sulfate ($p < 0.05$) and magnesium ($p < 0.05$). Caffeine was correlated with phosphate concentrations ($p < 0.05$).

Relationship of land use to pharmaceutical concentrations

Land use in the surrounding sub-watershed ranged from 2 to 99% urban across the ten study sites (Fig. 2). Agriculture land use was ≥90% of the sub-watershed at two sites, Muncie and Salt Creek. Urban land use correlated negatively with total pharmaceutical concentrations in streams ($p < 0.05$, $r = -0.65$), while agricultural land use correlated positively with total pharmaceutical concentrations ($p = 0.05$, $r = 0.64$) (Fig. 2). This correlation was driven by two sites (Muncie and Salt Creek) indicating that streams with large amounts of agricultural land use (>90%) are associated with higher pharmaceutical concentrations, where streams with moderate agricultural land use may be buffered from pharmaceutical inputs via some unknown mechanisms (potentially sewage treatment processes). Forest and wetland land-cover ("reference" land use) accounted for <10% of land in the sub-watershed for all streams and was not correlated with pharmaceutical concentrations. Concentrations of individual pharmaceutical compounds were not correlated with any measure of land use in the sub-watershed ($p > 0.05$).

In vitro microbial response

Pharmaceutical treatments did influence microbial respiration rates in vitro with all treatment compounds eliciting a concentration-dependent response (Fig. 3, Table 5). Microbial respiration increased at low concentrations of ibuprofen, caffeine, and acetaminophen but increased rates became saturated with higher concentrations of ibuprofen and caffeine and inhibited with higher concentrations of acetaminophen. In contrast, increasing concentrations of nicotine yielded an exponential decline in respiration rates. Nicotine yielded a stimulatory effect on net nitrate uptake at lower concentrations but the effect was saturated at

Table 4 Pearson correlation statistics assessing the relationship between stream physiochemical parameters and pharmaceutical concentrations in the Upper White River Watershed of central Indiana

	1,7-Dimethylxanthine		Acetaminophen		Cotinine		Caffeine	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value
Temperature (°C)	0.17	0.64	0.30	0.41	0.30	0.41	0.39	0.27
pH	**0.63**	**0.05**	0.61	0.06	0.20	0.58	0.59	0.07
Specific conductivity	0.22	0.55	0.35	0.33	−0.10	0.78	−0.01	0.97
TDS	0.22	0.54	0.34	0.34	−0.04	0.92	0.05	0.90
Dissolved oxygen	**0.65**	**0.04**	−0.07	0.85	0.35	0.33	0.47	0.18
Salinity	0.19	0.60	0.33	0.35	−0.18	0.61	−0.10	0.79
Turbidity	−0.03	0.93	0.46	0.19	−0.20	0.57	0.05	0.89
Chloride	−0.30	0.40	−0.41	0.24	−0.14	0.69	−0.35	0.32
Nitrite	0.15	0.68	0.45	0.19	−0.04	0.91	0.22	0.54
Bromide	−0.50	0.14	0.16	0.66	−0.33	0.36	-0.39	0.27
Nitrate	**0.78**	**0.01**	0.31	0.39	0.51	0.13	**0.64**	**0.04**
Phosphate	0.59	0.08	0.04	0.90	0.53	0.11	**0.67**	**0.03**
Sulfate	0.05	0.90	**0.73**	**0.02**	−0.34	0.34	−0.22	0.54
Lithium	0.58	0.08	**0.84**	**<0.01**	0.17	0.63	0.48	0.17
Sodium	−0.33	0.35	−0.48	0.16	−0.09	0.81	−0.34	0.34
Ammonium	0.16	0.65	0.30	0.39	0.20	0.59	0.30	0.40
Potassium	0.11	0.76	0.02	0.96	−0.14	0.69	−0.09	0.81
Magnesium	0.48	0.17	**0.72**	**0.02**	−0.09	0.81	0.15	0.68
Calcium	0.11	0.76	0.53	0.12	−0.43	0.22	−0.24	0.50
1,7-Dimethylxanthine	*	*	0.40	0.25	**0.66**	**0.04**	**0.88**	**<0.01**
Acetaminophen	*	*	*	*	0.03	0.94	0.24	0.51
Cotinine	*	*	*	*	*	*	**0.89**	**<0.01**

Bold values denote significant correlations ($p \leq 0.05$; $N = 10$)

* Indicates duplicate comparison in correlation matrix

higher concentrations (Fig. 4, Table 5). Acetaminophen also stimulated net nitrate uptake at lower treatment concentrations whereas caffeine inhibited net nitrate uptake in an exponential manner. Net nitrate uptake was not influenced by increasing ibuprofen concentrations (Fig. 4, Table 5). Similarly, net ammonium uptake was not influenced by increasing ibuprofen or increasing acetaminophen concentrations (Fig. 5, Table 5). Net ammonium uptake decreased linearly with caffeine concentrations but nicotine increased net ammonium uptake at lower concentrations (Fig. 5, Table 5). Overall, in vitro microbial activity response to pharmaceutical compounds varied with both the pharmaceutical compound tested and the measure of microbial activity.

In situ microbial response

In situ microbial respiration rates associated with pharmaceutical-amended substrates varied among pharmaceutical treatments ranging from 1.75 mg O_2/gdm/h in response to low acetaminophen treatments to 1.0 mg O_2/gdm/h in low caffeine treatments (Fig. 6). Control substrates (no pharmaceutical amendment) had mean respiration rates of 1.6 mg O_2/gdm/h. In contrast to in vitro experiments (Fig. 3), in situ pharmaceutical treatments found no effect of acetaminophen and ibuprofen on microbial respiration rates (Fig. 6). However, respiration in situ was significantly decreased relative to controls in the low nicotine treatment and all caffeine treatments (Fig. 6). Interestingly, microbial biomass on in situ substrates was significantly higher relative to controls in the nicotine and caffeine treatments indicating lower absolute rates of respiration and not simply decreased colonization by microbes (Fig. 6). In situ microbial colonization of pharmaceutical-amended substrates ranged from 0.052 to 0.105 gdm microbial biomass.

Discussion

Pharmaceutical concentrations in the UWRW are comparable to those found in other studies (Table 6) although acetaminophen and caffeine concentration are on the higher end of the ranges previously documented in US streams (Kolpin et al. 2002; Glassmeyer et al. 2005;

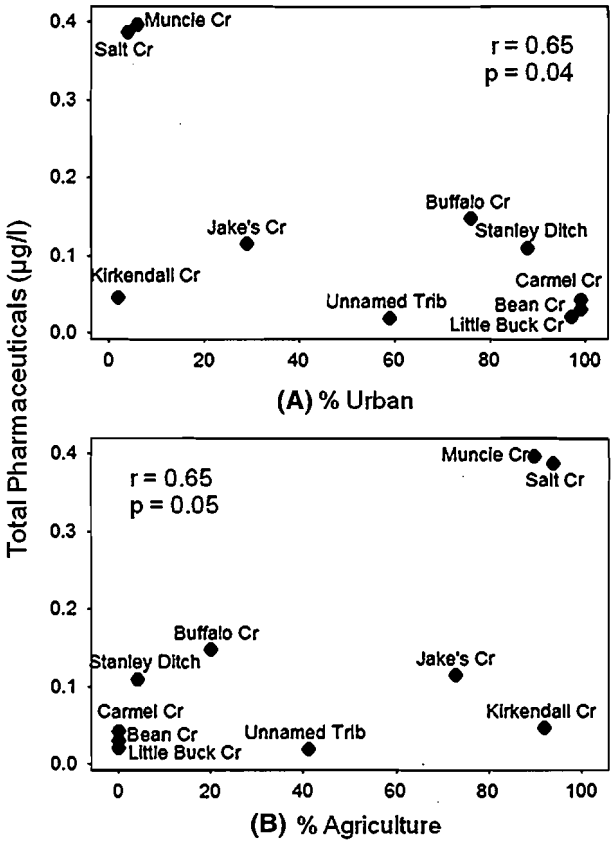

Fig. 2 Relationship between percent **a** urban and **b** agricultural land use in the sub-watershed and total pharmaceutical concentration for ten sites measured in the Upper White River watershed of central Indiana. Pearson correlation statistics noted

Focazio et al. 2008). The frequencies of detection for acetaminophen and caffeine were also higher in the UWRW relative to other studies in the US (Kolpin et al. 2002; Glassmeyer et al. 2005; Focazio et al. 2008). Sites in this study were smaller headwater streams compared to larger streams sampled in other studies. Kolpin et al. (2004) found that at higher flows pharmaceutical concentrations were likely diluted and detected less frequently. Thus, higher concentrations and more frequent detection in our study may be due to less dilution as our streams had lower discharge relative to sites assessed in previous studies.

Pharmaceutical concentrations in streams are thought to be associated with higher population densities and relative sewage input in urban areas (Ellis 2006). In this study, higher pharmaceutical concentrations were found in streams dominated by agricultural land use in the sub-watershed as opposed to more urban areas. Contrary to our hypothesis, a negative relationship between urban land use in the sub-watershed and total pharmaceutical concentrations was observed (Fig. 2). The main pathway for human pharmaceuticals to enter streams, sewage contamination, can be influenced by many factors including age and design of the sewer system (Walsh et al. 2005). Less urbanized areas tend to use more septic tanks and less advanced sewer systems that can leak untreated sewage into streams. This study suggests these nonpoint sources may be contributing to pharmaceutical contamination in freshwaters. Further, the negative correlation with urban land use suggests urban waste treatment processes may be removing pharmaceutical

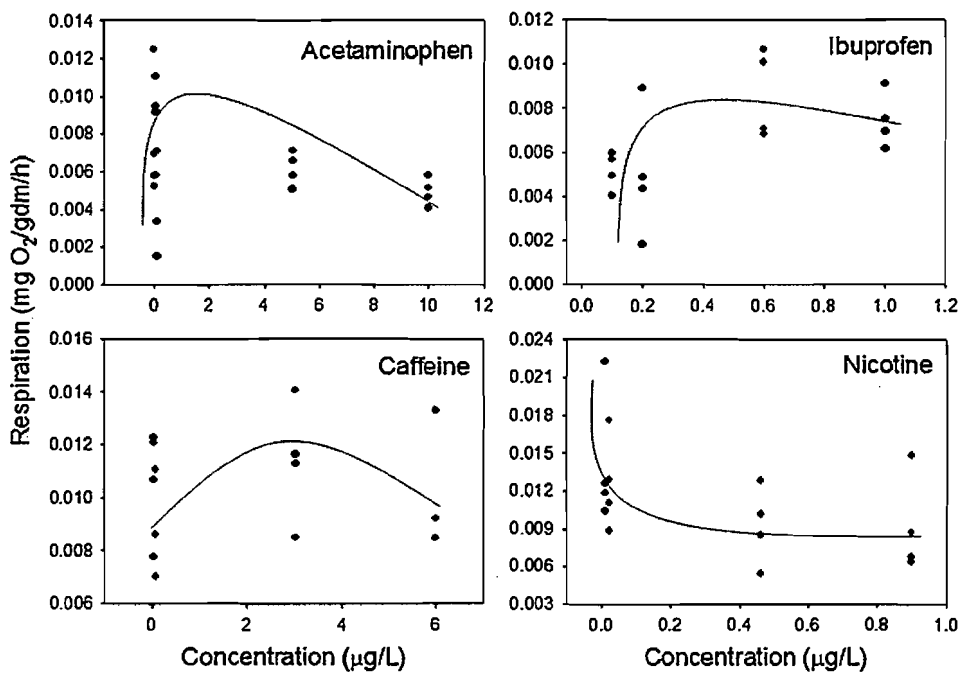

Fig. 3 In vitro sediment respiration response to pharmaceutical treatments. Four replicates shown for each treatment ($N = 4$ treatment concentrations) for each pharmaceutical compound. Significant linear and non-linear response patterns denoted by *lines*. Linear and non-linear equations and statistics provided in Table 5

Table 5 Predictive equations for respiration and nitrogen uptake with increasing pharmaceutical concentrations based on dose–response curves

Treatment	Equation	*p*-value	Type
Acetaminophen			
Respiration	$y = 0.01\ (\exp\ (-0.5\ (x - 2.4/7.3)^2))$	<0.0001	Peak
NO_3^--N uptake	$y = 0.007\ (\exp\ (-0.5\ (x - 0.4/0.1)^2))$	0.0015	Peak
NH_4^+-N uptake	*	*	*
Ibuprofen			
Respiration	$y = 0.0018\ (1 - \exp\ (-12.28x))$	0.007	Rise to max
NO_3^--N uptake	*	*	*
NH_4^+-N uptake	*	*	*
Caffeine			
Respiration	$y = 0.009\ (1 - \exp\ (-675x))$	<0.0001	Rise to max
NO_3^--N uptake	$y = 0.001\ (\exp\ (-0.092x))$	0.0015	Exponential decay
NH_4^+-N uptake	$y = 0.05 - 0.189x$	<0.01	Linear decay
Nicotine			
Respiration	$y = 0.009\ (\exp\ (-0.031x))$	<0.0001	Exponential decay
NO_3^--N uptake	$y = 0.0015\ (1 - \exp\ (-16x))$	<0.0001	Rise to max
NH_4^+-N uptake	$y = 0.17\ (1 - \exp\ (-135x))$	<0.0001	Rise to max

X pharmaceutical concentration (μg/l). For respiration, y = mg O_2/gdm/h; NO_3^--N uptake, y = mgNO_3^--N/gdm/h; NH_4^+-N uptake, y = mg NH_4^+-N/gdm/h. $N = 16$ for each model

* Indicates no significant relationship

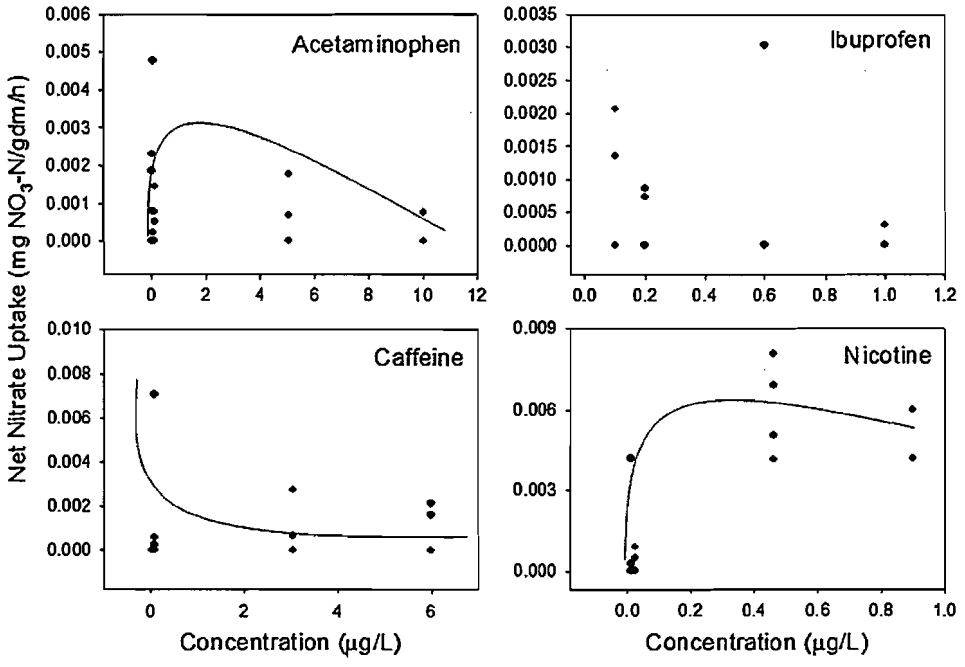

Fig. 4 In vitro sediment net nitrate uptake response to pharmaceutical treatments. Four replicates shown for each treatment ($N = 4$ treatment concentrations) for each pharmaceutical compound. Significant linear and non-linear response patterns denoted by *lines*. Linear and non-linear equations and statistics provided in Table 5

compounds prior to discharge into freshwaters. Urbanized areas tend to have updated sewage systems that carry waste to treatment facilities making contamination in streams not receiving wastewater treatment effluents less apparent, especially at base flow conditions when combined sewer overflows (CSOs) are not contributing to water flow, as in this study. Further, nitrate is normally associated with rural agricultural nonpoint pollution (Ribbe et al. 2008). Our data show concentrations of caffeine and 1,7-dimethylxane are correlated with nitrate concentrations further suggesting these compounds may be linked to rural, agricultural land use activities rather than urban activities in headwater streams. In contrast, urban waste is generally positively correlated with ammonium concentrations (Paul and Meyer

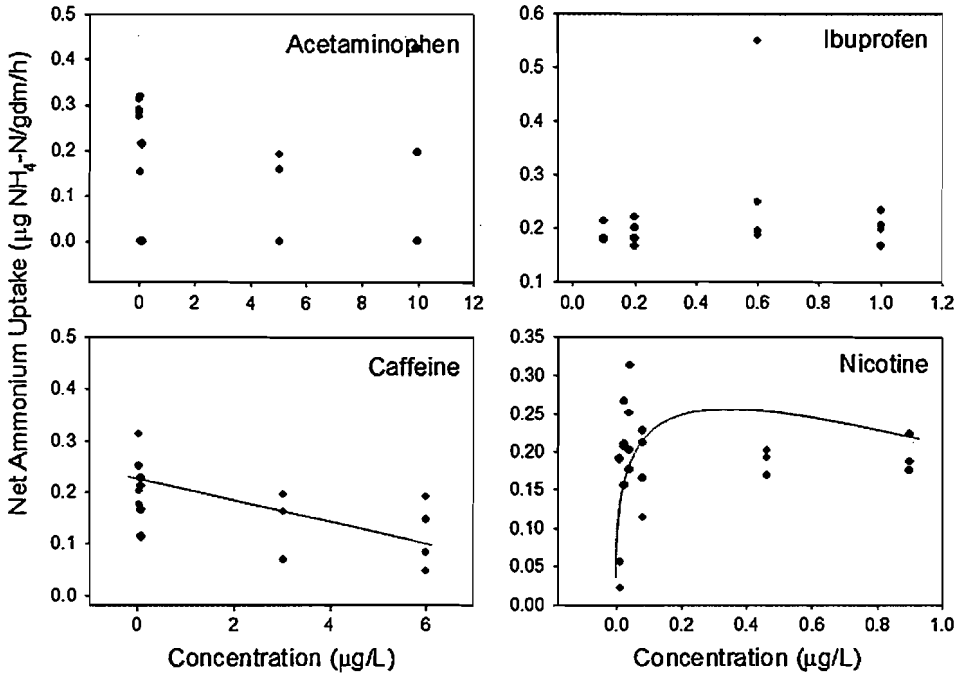

Fig. 5 In vitro sediment net ammonium uptake response to pharmaceutical treatments. Four replicates shown for each treatment ($N = 4$ treatment concentrations) for each pharmaceutical compound. Significant linear and non-linear response patterns denoted by *lines*. Linear and non-linear equations and statistics provided in Table 5

2001) although pharmaceuticals measured in this study were not correlated with NH_4^+-N concentrations either as total pharmaceutical concentration or concentrations of individual pharmaceutical compounds ($p > 0.10$, data not shown). The ubiquity of small nonpoint pollution sources may result in a larger cumulative effect on aquatic ecosystems (Duda et al. 1982), particularly during baseflow, which may be the case for pharmaceuticals in central Indiana.

Higher lithium concentrations were correlated with higher total pharmaceutical concentration across streams indicating pharmaceuticals may co-occur with lithium. Barber et al. (2006) found lithium to be a good indicator of anthropogenic waste inputs into streams, consistent with this study. Lithium is a drug used for the treatment of mood disorders (Price and Heninger 1994). Thus, the pathway lithium takes to enter freshwater is likely similar to other pharmaceutical compounds. Although more studies are needed, these results suggest that examining concentrations of this inorganic compound in streams may be a good indicator of the need for additional testing for organic pharmaceuticals. Lithium concentrations are significantly less expensive and labor intensive to quantify relative to pharmaceutical concentrations (ion chromatography techniques for lithium vs. mass spectrometry techniques for trace organics).

Data from the in vitro experiments suggest nonprescription pharmaceuticals can influence stream sediment respiration and net nitrogen uptake even at the trace concentrations currently found in US freshwaters. Microbes present a unique challenge in understanding the effects of contaminants, as compounds can be assimilated or degraded by microbes, in addition to their potential negative toxic effects. For example, Bradley et al. (2007) found that surface sediment microorganisms can alter the chemical structure of caffeine and nicotine yielding increases in microbial respiration in the presence of these compounds. Our data similarly indicate nicotine stimulated microbial activity as net nitrate and ammonium uptake (Figs. 4, 5) but inhibited overall microbial respiration (Fig. 3). Thus, it is likely that specific microbes can utilize nicotine as a nutritive source though the community overall may be inhibited. Lawrence et al. (2005) found some pharmaceutical compounds (including caffeine and ibuprofen) influenced microbial activity but stimulatory effects, potentially due to use of pharmaceuticals as a nutritive source, and inhibitory effects, potentially due to toxicity, depended on the specific pharmaceutical compound, consistent with our study. Identifying the mechanisms of microbial response in future studies is important to understanding how emerging contaminants could potentially alter nutrient cycling in stream ecosystems and thereby freshwater integrity.

If microbes are using pharmaceutical compounds as a nitrogen source, in place of dissolved NO_3^--N and NH_4^+-N, they may be removing less nitrogen from the water column potentially influencing nitrogen availability for other organisms or decreasing potential for mitigation of nitrogen pollution by microbes. If microbial nitrogen uptake from the water column is decreased, autotrophic production could be stimulated by increased nitrogen availability, potentially

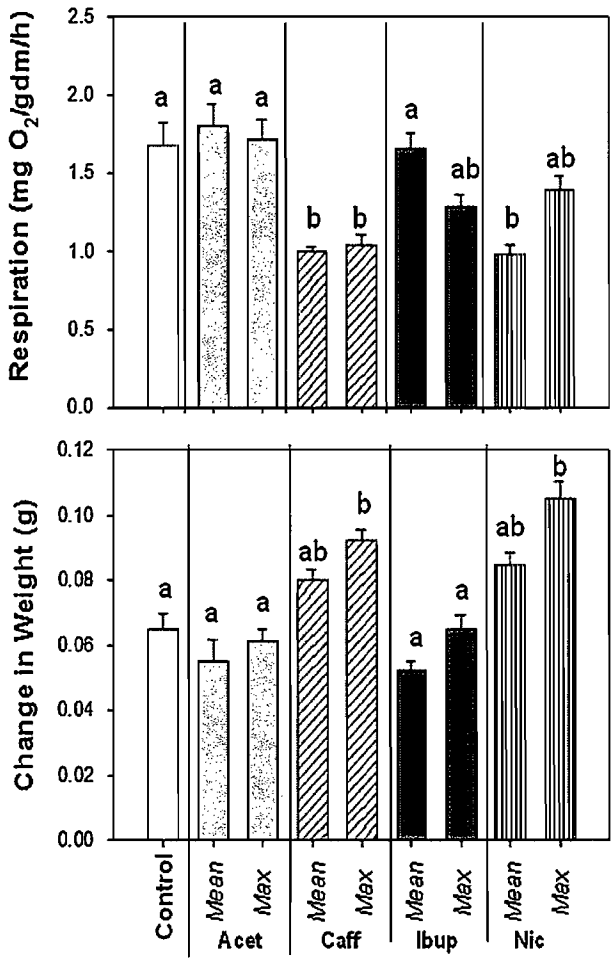

Fig. 6 Mean + SE microbial respiration rates and microbial biomass associated with pharmaceutical-amended nutrient diffusing substrates incubated in situ. *Control* no pharmaceuticals added, *Acet* acetaminophen amended substrate, *Caff* caffeine amended substrate, *Ibup* ibuprofen amended substrates, *Nic* nicotine amended substrates. Substrates were amended with two concentrations of each pharmaceutical compound (mean, max; Table 1). $N = 8$ for each *bar*. *Different letters* above *bars* indicate pair wise differences among treatments (ANOVA $p < 0.01$) when all treatments were considered. *Bars* with one or more of the same letters are not statistically different

resulting in unwanted algal blooms (Dodds and Welch 2000). Both ammonium and pharmaceutical contamination in streams have been linked to waste discharge from urban areas (Paul and Meyer 2001; Glassmeyer et al. 2005). This suggests that high concentrations of both nitrogen and pharmaceuticals are likely to co-occur in some systems. If NH_4^+-N is not removed from the water column because of decreased microbial uptake, due to either decreases in respiration or nutrient uptake, toxic concentrations of NH_4^+-N may occur at higher frequencies in streams affected by sewage. Alternatively, changes in nutrient uptake or respiration may be caused by shifts in the microbial community associated with pharmaceutical exposure. Lawrence et al. (2005) found pharmaceuticals (including caffeine and ibuprofen) alter microbial species in river biofilm communities potentially influencing nitrogen assimilated by the microbial communities. Regardless of the mechanism for changes in microbial activity, inhibited or stimulated microbial activity in response to trace concentrations of pharmaceuticals may alter ecosystem functioning.

In situ NDS experiments were conducted in the headwater stream with the highest concentrations of pharmaceuticals, Muncie Creek (Table 2). Although pharmaceutical sampling was conducted before the NDS experiment, we assume pharmaceutical concentrations detected in Muncie Creek were representative of typical conditions as NDS were incubated at base flow, consistent with timing of pharmaceutical measurements. In situ, caffeine and nicotine exposure significantly decreased microbial respiration (Fig. 6) consistent with the decreases in microbial activity observed in vitro. In contrast to in vitro experiments, there was not a significant microbial response to acetaminophen or ibuprofen exposure in situ. Biomass of microbial biofilms was similarly not influenced by acetaminophen or ibuprofen exposure in situ, though both nicotine and caffeine increased microbial biomass (Fig. 6). Ibuprofen has been shown to decrease biomass, whereas caffeine can increase biomass of aquatic microbial biofilms (Lawrence et al. 2005), consistent with this study. However,

Table 6 Comparison of maximum pharmaceutical concentration and frequency of detection measured in this study relative to previous studies

Reference	Sample type	Pharmaceutical concentration (μg/l)							
		1,7-Dimethylxanthine	%	Acetaminophen	%	Caffeine	%	Cotinine	%
This study	IN streams	0.04	30	0.11	50	0.06	100	0.04	20
Kolpin et al. 2002	US streams	0.11	29	0.11	24	0.08	62	0.02	32
Glassmeyer et al. 2005	US WWTP effluent	<DL	28	0.01	8	0.05	70	0.024	92
	Downstream from effluent	0.02	*	<DL	*	0.05	*	0.024	*
Focazio et al. 2008	US surface & groundwater	0.30	2	0.16	8	0.27	7.5	0.10	35

Frequency of detection is the percentage of samples collected pharmaceutical contamination was detected

% Frequency of detection, *WWTP* waste water treatment plant, *DL* detection limit

*Glassmeyer et al. (2005) averaged frequencies for both sample types

previous studies have not delineated effects of pharmaceuticals on growth or activity. Because microbial biomass increased when exposed to nicotine and caffeine, but respiration rates decreased, absolute microbial activity was altered as opposed to decreased microbial colonization.

Differences in microbial activity in vitro relative to in situ experiments with exposure to acetaminophen and ibuprofen may be because the incubation stream had a history of higher pharmaceutical exposure potentially yielding microbial adaptation and tolerance (Spain and Van Veld 1983; Liebert et al. 1991). Microbial activity in streams contaminated by pharmaceuticals may not be influenced if long-term exposure results in acclimation. An alternative explanation for variable microbial response to pharmaceuticals in the laboratory (in vitro) and field (in situ) experiments is that the microbial response is dependent on multiple factors including pH, organic matter, oxygen, and water chemistry as well as pharmaceutical concentration and history of pharmaceutical contamination in the stream. In vitro experiments were conducted at room temperature (27°C) whereas in situ experiments were conducted at a slightly lower temperature (22°C). Theoretically, the higher incubation temperatures during in vitro experiments would be expected to increase overall microbial respiration rates. However, in situ experiments yielded respiration rates an order of magnitude greater than respiration rates measured in vitro (Figs. 3, 6). Thus, the difference in incubation temperature likely had minimal influence associated with comparisons; rather, continuous supply of nutrients in situ likely was more conducive to higher microbial respiration. Further, water pH, oxygen concentrations, and nutrient concentrations were comparable in water used for in vitro experiments and in situ incubations, allowing for more robust comparisons on the effect of pharmaceuticals. Other factors not measured in this study such as light availability, organic matter, other trace contaminants, and shear stress may have also contributed to differences in observed results in vitro compared to in situ experiments. More comprehensive studies are needed to assess confounding factors on microbial response to pharmaceuticals.

This study demonstrates that pharmaceuticals are ubiquitous in headwater streams of central Indiana and depending on the compound and the concentration these pharmaceuticals may be influencing stream microbial activity. Contrary to our hypothesis, pharmaceutical concentrations were not associated with urban land use. Higher pharmaceutical concentrations were measured in streams with >90% agricultural land use in the sub-watershed and negatively correlated with urban land use in the sub-watershed. Because pharmaceuticals were associated with agricultural land use in streams not receiving direct wastewater treatment effluents, nonpoint sources such as septic tanks are likely contributing to pharmaceutical contamination in these ecosystems. Studies examining the frequency and distribution of pharmaceuticals in streams not receiving wastewater effluents will help in future management of these currently unregulated contaminates.

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Temporal variation of pharmaceuticals in an urban and agriculturally influenced stream

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ABSTRACT

Pharmaceuticals have become ubiquitous in the aquatic environment. Previous studies consistently demonstrate the prevalence of pharmaceuticals in freshwater but we do not yet know how concentrations vary over time within a given system. Two sites in central Indiana with varying land use in the surrounding watershed (suburban and agricultural) were sampled monthly for pharmaceutical concentrations and stream physiochemical parameters. Sediment samples were also collected at each sampling event for measurement of $\delta^{15}N$ natural abundance and sediment organic content. Across sites and sampling events, twelve pharmaceuticals were detected including acetaminophen, caffeine, carbamazepine, cotinine, N,N-diethyl-meta-toluamide (DEET), gemfibrozil, ibuprofen, sulfadimethoxine, sulfamethazine, sulfamethoxazole, triclosan, and trimethoprim. Sulfathiazole, lincomycin, and tylosin were not detected at either site at any time. The agriculturally-influenced site had comparable pharmaceutical concentrations to the urban-influenced site. In general, pharmaceutical concentrations increased during winter at both sites and decreased during spring and summer. Multiple regression analyses indicated that water column dissolved oxygen, the number of days since precipitation, and solar radiation influenced total pharmaceutical concentration in the urban-influenced site; whereas pH, chlorophyll *a* concentration, and total amount of rainfall in the previous 10 days influenced total pharmaceutical concentrations in the agriculturally-influenced site. Pharmaceutical concentrations were not correlated with sediment $\delta^{15}N$ across or within sites. However, sediment in the urban-influenced site had higher mean $\delta^{15}N$ signatures relative to sediment in the agriculturally-influenced site. These data indicate pharmaceuticals are persistent in aquatic ecosystems influenced by both agricultural and suburban activity. Pharmaceuticals are designed to have a physiological effect; therefore, it is likely that they may also influence aquatic organisms, potentially threatening freshwater ecosystem health.

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1. Introduction

Human populations have been increasing by approximately 78 million people per year (Jones, 2000). In addition, by the year 2025 almost two thirds of the world's population will live in urbanized locations (Pimentel et al., 2007). In conjunction with an increasing human population, contamination of freshwater resources due to human activities will also likely increase (Pimentel et al., 2007). Emerging contaminants in freshwater ecosystems is expected to increase with greater human populations including trace organics, such as pharmaceuticals.

Pharmaceuticals have been recognized as an environmental threat since the 1970s when compounds were first detected in freshwater (Kummerer, 2004; Tabak and Bunch, 1970). Not only have pharmaceutical contaminants been detected in aquatic environments throughout the United States (e.g., Barnes et al., 2008; Focazio et al., 2008; Glassmeyer et al., 2005; Kolpin et al., 2002; Kolpin et al., 2004), but these contaminants have also been detected in freshwater around the world (e.g., Camacho-Muñoz et al., 2010; Daneshvar et al., 2010; Sim et al., 2010; Vieno et al., 2005). Despite the ubiquity of pharmaceuticals in freshwater ecosystems, there has been limited quantification of environmental transport and fate of these compounds.

Pharmaceuticals and personal care products (PPCPs) can enter freshwater ecosystems via multiple sources including human excretion, drug disposal, and agricultural runoff associated with therapeutic treatment of livestock (Jorgensen, 2000). Higher concentrations of pharmaceuticals in freshwater are generally associated with inputs from wastewater treatment effluent (Phillips et al., 2005; Walraven and Laane, 2008) but concentrations vary with secondary waste treatment processes (Bartelt-Hunt et al., 2009; Phillips et al., 2005). Further, although effluent is thought to be a primary source of pharmaceutical pollutants, Kolpin et al. (2002) sampled 139 streams across the U.S. not influenced by wastewater and found >80 organic waste contaminants from residential, industrial, and agricultural sources. Additionally, Barnes et al. (2008) sampled 47 groundwater sites suspected to be contaminated from animal and human waste but not receiving effluent and also detected multiple pharmaceutical compounds. It is clear that PPCPs have become pervasive in freshwater, yet factors related to their persistence are still largely unknown.

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Pharmaceutical frequency of detection and concentrations detected in freshwater differ among individual compounds. For example, acetaminophen, caffeine, ibuprofen, and cotinine have been found at maximum concentrations of 10 μg/L (Kolpin et al., 2002), 8 μg/L (Glassmeyer et al., 2005), 25.4 μg/L (Camacho-Muñoz et al., 2010), and 1.03 μg/L (Glassmeyer et al., 2005), respectively. However, acetaminophen (50% detection frequency) and ibuprofen (36%) are not detected as frequently in freshwaters relative to caffeine (82.6%) and cotinine (92.5%) (Daneshvar et al., 2010; Glassmeyer et al., 2005; Kolpin et al., 2004). Compounds with the greatest detection frequencies across studies include caffeine, carbamazepine, cotinine, DEET, and sulfamethoxazole (>70% samples collected contain concentrations above detection limits) whereas, gemfibrozil, sulfamethazine, and sulfadimethoxine have been infrequently detected (<5% samples) (Glassmeyer et al., 2005; Kolpin et al., 2002; Kolpin et al., 2004). Similarly, acetaminophen, carbamazepine, DEET, and ibuprofen are detected at concentrations an order of magnitude greater than sulfamethazine, sulfadimethoxine, and trimethoprim (Barnes et al., 2008; Camacho-Muñoz et al., 2010; Kolpin et al., 2002). The variability in detection frequency and concentrations measured is likely due to usage rates, surrounding inputs and land use, as well as individual chemical properties (e.g., carbamazepine is more persistent than gemfibrozil). Further, variability may also be due to the

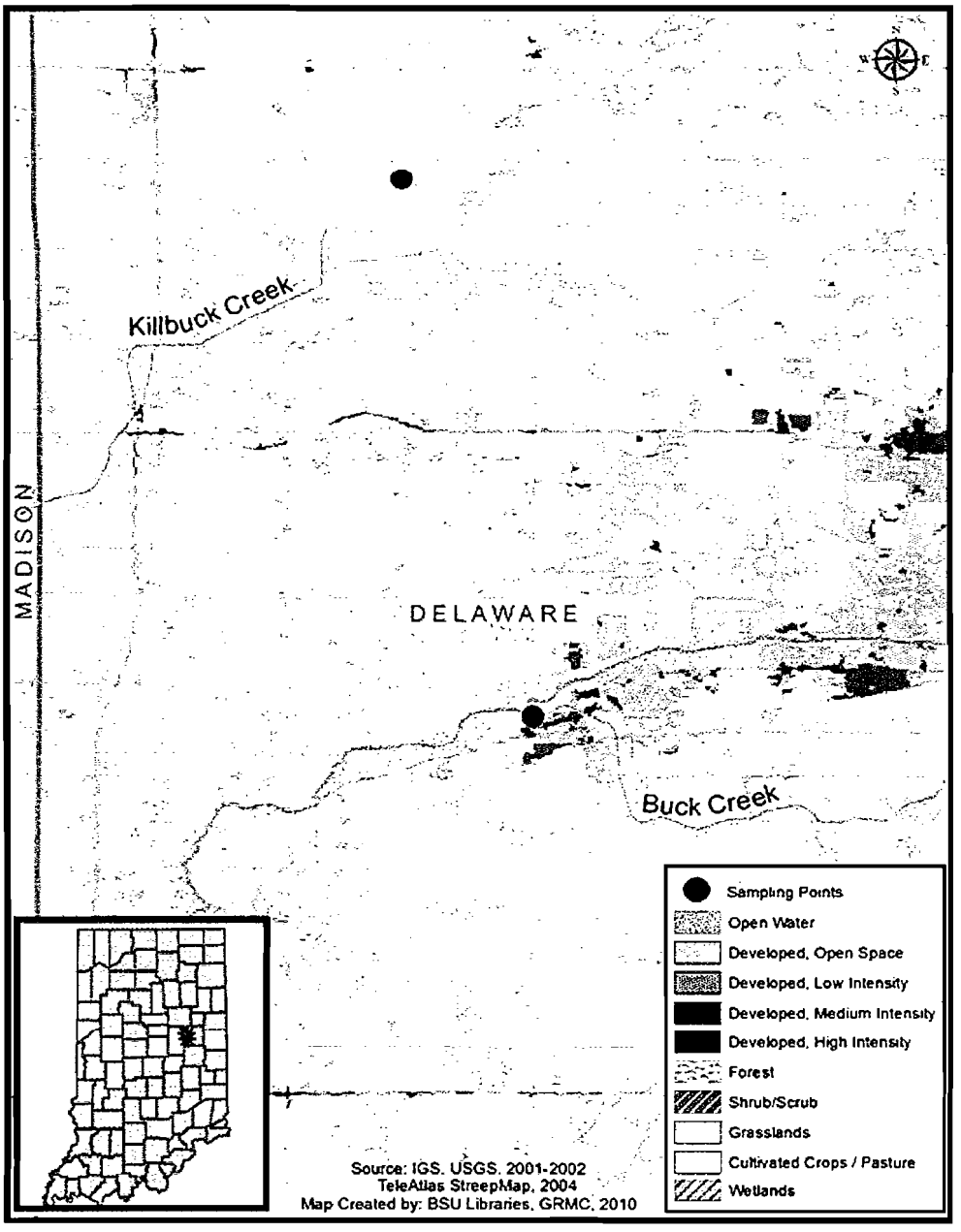


Fig. 1. Sampling locations in the Upper White River Watershed of central Indiana including an agricultural site (Buck) and an urban/suburban site (Killbuck). Surrounding land use denoted by shading.

Table 1
Study site characteristics. Values reported are means (ranges) of 24 sampling events. NO_3-N = dissolved nitrate; DO = dissolved oxygen in water column; PO_4-P = phosphate. * denotes parameters significantly higher in Buck Creek than Killbuck Creek ($p \leq 0.05$).

Study site	Land use	Discharge* (m^3/s)	pH	Temperature (°C)	DO* (mg/L)	NO_3-N (mgN/L)	PO_4-P (mgP/L)
Buck Creek	Suburban	2.4 (0.8–6.9)	7.8 (5.8–10.9)	10.8 (0.8–20.3)	15.1 (9.6–19.19.0)	3.5(0.01–15.3)	0.18 (0.001–1.1)
Killbuck Creek	Agricultural	0.43 (0.03–2.0)	7.1 (4.9–8.9)	11.7 (0.5–26.8)	11.8 (5.0–17.3)	4.7 (0.01–18.9)	0.28 (0.001–3.0)

timing of sample collection as temperature, and flow may influence abundance or persistence of pharmaceutical compounds. Few studies have quantified temporal variability within a given site to quantify the role of these influential factors (but see Daneshvar et al., 2010; Vieno et al., 2005).

The objective of this study was to quantify temporal variation in pharmaceutical concentrations in a suburban and agriculturally-influenced stream in central Indiana, as well as to identify environmental stream variables and sediment gradients related to the observed pharmaceutical concentrations. We hypothesized that pharmaceutical concentrations would be higher in the urban-influenced stream due to human waste contribution, as combined sewer overflows (CSO). We further hypothesized that both sites would have lower pharmaceutical concentrations in winter due to fewer overflow events and lower temperatures.

2. Material and methods

2.1. Study sites

Study streams were located in the Upper White River Watershed (UWRW) of central Indiana (Fig. 1). The UWRW encompasses a total of 174,830 acres with a gradient of both urban and agricultural land use. The two sites selected within the watershed (Buck and Killbuck Creek) were representative of differing land uses within corresponding sub-watersheds. Buck Creek is predominantly influenced by urban/suburban inputs whereas Killbuck Creek is influenced by agricultural inputs, specifically row-crop agriculture (Table 1). Buck Creek is located in the Buck Creek sub-watershed and drains 16,090 acres with silt loam soils compromising ~50% and loam comprising ~25% of the sub-watershed area. The present day land use within the sub-watershed is ~54% agriculture, primarily corn and soybeans; ~28.6% residential and greenspace, 11.6% commercial and transportation utilities, 2.9% industrial, and 0.4% government and institutional (White River Watershed Project, 2001). Killbuck Creek is located in the Killbuck/Mud Creek sub-watershed and drains 10,039 acres with silt loam soil compromising ~50% and silty clay loam comprising ~20% of the sub-watershed area. The present day land use in Killbuck Creek is 74.4% agricultural, 21.1% residential and greenspace, 4.1% commercial and transportation utilities, 0.4% industrial, and 0.4% government and institutional. *Escherichia coli* contamination has been found in Killbuck Creek due to septic system leakage (White River Watershed Project, 2001).

The Buck Creek sampling site was located ~9.7 km downstream of the last combined sewer overflow (CSO) in Muncie, Indiana and is influenced by a total of six CSO points upstream of the sampling site. Wastewater in the sub-watershed is treated via an aerobic activated sludge process unless discharged as raw sewage via CSO during high rainfall events. Killbuck Creek is influenced by residential septic tanks upstream of the sampling site. Due to the combined sewer overflow discharge solely present in Buck Creek, and septic tank leakage near Killbuck Creek, Buck Creek is considered the suburban site whereas Killbuck Creek is considered the agricultural site although other sources of waste may exist for both. Both sites are third order headwater streams with similar topography, geology and soils (White River Watershed Project, 2001).

2.2. Pharmaceutical collection

For this study, all compounds will be broadly defined as pharmaceuticals although certain compounds analyzed are considered medicinal drugs. Buck Creek and Killbuck Creek were sampled twice each month for a 12 month period (June 2009–May 2010). During the first sampling event each month, water samples for pharmaceutical analyses were collected during early to late morning in addition to measurement of physiochemical parameters and water column nutrient concentration measurements. The second sampling event each month consisted only of physiochemical parameter and nutrient concentration measurements. For the first sampling event each month, two filtered water samples (1000 mL; 150 mL) were collected and filtered on site using a 60 mm syringe connected to a syringe filter containing a 25 mm Whatman© glass fiber filter (GF/F; 0.7 μm pore size). Each water sample was collected from the middle of the water column in a well-mixed portion of the stream. The first water sample was filtered into a 1 L amber baked glass bottle containing the dechlorinating agent sodium thiosulfate as a preservative. After filtration, the water sample was placed on ice and shipped overnight to the State Hygienic Laboratory at the University of Iowa for analysis of 15 pharmaceutical analytes: acetaminophen, caffeine, carbamazepine, cotinine, DEET, gemfibrozil, ibuprofen, lincomycin, sulfadimethoxine, sulfamethazine, sulfamethoxazole, sulfathiazole, triclosan, trimethoprim, and tylosin using a Micromass Quattro tandem quadruple system equipped with a Waters 2995 high performance liquid chromatography (HPLC) autosampler with an electrospray interface to generate ions from the HPLC column flow (Table 2). Pharmaceutical measurements were

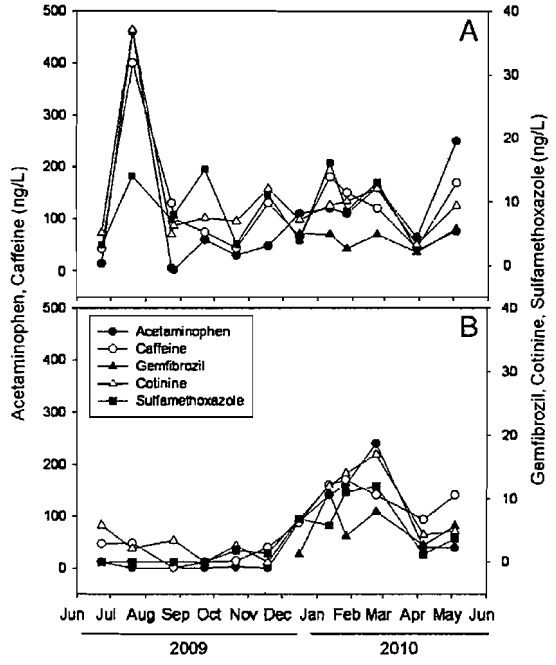
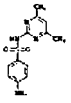
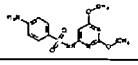


Fig. 2. Temporal patterns of pharmaceutical concentrations for high frequency compounds in A) Buck Creek and B) Killbuck Creek.

Table 2
Pharmaceutical frequency of detection (%) and concentration range for all analytes detected in Buck (N = 13) and Killbuck Creek (N = 12) combined. Analytes not detected: lincomycin, sulfathiazole, tylosin.

Compound	Chemical structure	Primary use	Frequency (%)	Ranges (ng/L)
Gemfibrozil		Lipid regulating agent	100	1.2–11
Caffeine		Stimulant	96	11–400
Cotinine		Nicotine by-product	92	2.1–37
Acetaminophen		Analgesic/fever reducer	84	1.6–460
Sulfamethoxazole		Human antibiotic	84	1.2–16
Ibuprofen		NSAID/pain reliever	68	1.8–42
DEET		Insect repellant	64	8–290
Carbamazepine		Anticonvulsant	28	1.1–2.7
Trimethoprim		Human Antibiotic	28	3–58
Sulfamethazine		Veterinary antibiotic	20	1.2–22
Triclosan		Antiseptic/ disinfectant	12	9.1–22
Sulfadimethoxine		Veterinary antibiotic	4	2.2

determined via a calibration curve with a quadratic curve fit using standards of ≥5 concentration levels including a range from 0.1 to 100 ng/mL. In addition, one laboratory blank was also analyzed for pharmaceuticals with each set of water samples each month in conjunction with QAQC assessments. If contamination was found, the reporting level was increased to 5 X the amount found in the blank. For most laboratory blanks, trace concentrations of caffeine and DEET were measured.

A total of 25 samples were analyzed for all pharmaceutical compounds except for gemfibrozil which was not included in the analyses until December 2009, yielding a total of 12 samples analyzed for gemfibrozil. All individuals assisting with pharmaceutical sample collection did not ingest or use any pharmaceuticals included in the analyte list for ≥24 h prior to collection and were required to wear neoprene gloves during water sample collection to prevent contamination.

2.3. Measurement of independent variables

The second water sample collected at all sampling events was filtered into a 150 ml acid washed Nalgene© bottle, placed on ice, returned to the laboratory, and immediately frozen for subsequent chemical analyses of anions and cations including: nitrate (NO_3-N), phosphate (PO_4-P), chloride (Cl^-), sulfate (SO_4^{2-}), bromide (Br^-), ammonium (NH_4-N), lithium (Li^+), potassium (K^+), magnesium (Mg^{2+}), and calcium (Ca^{2+}) using ion chromatography (DIONEX, ICS-3000). Stream physiochemical parameters were also measured at each sampling event using a Hydrolab© minisonde equipped with a Luminescent Dissolved Oxygen (LDO) sensor for measurement of water column dissolved oxygen (mg/L) as well as temperature (°C), pH, total dissolved solids (g/L), specific conductivity (mS/cm), and turbidity (NTU). The minisonde was placed in a well-mixed portion of the stream for measurements and allowed to equilibrate. Discharge (m^3/s) was estimated at each sampling event using a line transect with 5 equidistant points measured for depth and velocity using a Marsh-McBirney© flow meter. Chlorophyll *a* concentrations (μg/L) were measured using a hand-held Aquaflor© fluorometer. Precipitation data, the number of days since precipitation at the time of sampling, and the total amount of rainfall within 10 days of sampling, were provided from the National Weather Service (National Weather Service, 2010) using data for Muncie, Indiana and reported in millimeters. Solar irradiation measurements were measured in-stream using a Apogee© Basic Quantum meter Model BQM-S and reported as $\mu mol\ m^{-2}\ s^{-1}$. Combined sewer overflow data was provided by the town of Muncie, Indiana Waste Pollution Control Facility CSO Discharge Monitoring Reports.

2.4. Sediment collection

At each sampling event, three sediment samples were collected from the top 5 cm of the stream benthos at equidistant points across the reach. Sediment was transported to the laboratory and subsequently dried at 15.5 °C in a Model 30 GC Laboratory Oven. After drying, a sub-sample of all 3 sediment samples were combined and homogenized using a 2.38 mm USGS no. 5 sieve, crushed with a coffee grinder, and sent to the Marine Biological Laboratory (Woodshole, MA, USA) for analysis of $\delta^{15}N$ natural abundance and nitrogen content via mass spectrometry following combustion. The remaining sediment (≥3 g) was pre-weighed and placed in aluminum weighing boats, ashed in a Barnstead Thermolyne© FB 1400 muffle furnace for ≥2 h and then weighed to calculate percentage of organic matter content for each sediment sample.

2.5. Statistical analyses

Pharmaceutical concentrations were analyzed as both the concentration of individual pharmaceutical compounds as well as the total pharmaceutical concentration which was calculated as the sum of all pharmaceutical compounds detected. Bonferroni-corrected Pearson correlation coefficients were used to evaluate potential relationships between physiochemical parameters, sediment characteristics (i.e., sediment $\delta^{15}N$, % N, or % organic matter), precipitation measurements, and solar radiation with individual and total pharmaceutical concentrations both with sites combined (N = 25 sampling events) and within an individual site (Buck Creek N = 13; Killbuck Creek N = 12 sampling events). Bonferroni-corrected Pearson correlation statistics were also used to assess factors influencing sediment characteristics. All independent variables measured (N = 17) were included in correlation matrix analyses. Multiple regression with backward elimination analyses were used to develop predictive models describing factors influencing pharmaceutical concentrations both with sites combined (N = 25 sampling events) and within an individual site (Buck Creek N = 13; Killbuck Creek N = 12 sampling events). Independent variables included in multiple regression analyses were based on initial Pearson correlations and included discharge, temperature, pH, turbidity, water column dissolved oxygen, chlorophyll *a*, the number of days since precipitation at the time of sampling, the total amount of rainfall in the previous 10 days before the time of sampling, and solar irradiance. A

two sample *t*-test was used to identify differences in stream variables and total pharmaceutical concentrations among study sites. Pearson correlation coefficients were performed using SAS statistical software (SAS Institute® 9.2, 2002–2008 Cary, NC, U. S.). Multiple regression analyses and two sample t-tests were performed using Minitab 16 (Minitab® Inc. 2010, USA).

3. Results

3.1. Study site characteristics

Temperature, nitrate, and phosphate concentrations were similar between sites ($p>0.1$) (Table 1). However, mean pH (7.8) was greater in Buck Creek than Killbuck Creek (pH = 7.1) during the sampling period ($p=0.04$). Mean discharge (2.4 m^3/s), width (19 m), depth (0.22 m), and velocity (0.4 m/s) at Buck Creek was significantly greater relative to Killbuck Creek (0.43 m^3/s, 9.4 m, 0.3 m, 0.11 m/s, respectively; $p \leq 0.04$) and exhibited more variation over time during the sampling period. In addition, mean water column dissolved oxygen concentrations were greater in Buck Creek (15.1 mg/L) than Killbuck Creek (11.8 mg/L; $p<0.01$).

3.2. Pharmaceutical frequency of detection and concentration range

Across all sampling events, twelve pharmaceuticals were detected including acetaminophen, caffeine, carbamazepine, cotinine, DEET, gemfibrozil, ibuprofen, sulfadimethoxine, sulfamethazine, sulfamethoxazole, triclosan, and trimethoprim (Table 2). Three compounds were not detected in any sample including lincomycin, sulfathiazole, and tylosin. Gemfibrozil (100%), caffeine (96%), cotinine (92%), acetaminophen (84%), and sulfamethoxazole (84%) exhibited the highest frequencies of detection, whereas triclosan and sulfadimethoxine were detected in <10% of the samples analyzed. The concentrations measured for detected compounds varied over an order of magnitude across sampling events for most pharmaceuticals including acetaminophen (1.6–460 ng/L), caffeine (11–400 ng/L), and DEET (8–290 ng/L); compounds measured that exhibited less variability in concentrations included gemfibrozil (1.2–11 ng/L), cotinine (2.1–37 ng/L), sulfamethoxazole (1.2–16 ng/L), ibuprofen (1.8–42 ng/L), carbamazepine (1.1–2.7 ng/L), trimethoprim (3–58 ng/L), sulfamethazine (1.2–22 ng/L), and triclosan (9.1–22 ng/L). Sulfadimethoxine was only detected once during sampling efforts (2.2 ng/L) (Table 2).

In Buck Creek, acetaminophen, caffeine, cotinine, ibuprofen, triclosan, and carbamazepine were highest in July whereas sulfamethoxazole, sulfamethazine, DEET, and trimethoprim were highest in January (Figs. 2, 3). In addition, in Buck Creek, gemfibrozil was highest in May. In Killbuck Creek, acetaminophen, cotinine, ibuprofen, and sulfamethoxazole were highest in the February sampling whereas caffeine, DEET, gemfibrozil, triclosan, and trimethoprim were highest in the January sampling (Figs. 2, 3). In Killbuck Creek, sulfamethoxazine was highest in the November sampling. Further, in Killbuck Creek, carbamazepine and sulfadimethoxine were only detected in the January sampling.

3.3. Factors influencing pharmaceutical abundance

Across sites, pharmaceutical compounds detected in >65% of samples (gemfibrozil, caffeine, cotinine, acetaminophen, sulfamethoxazole, ibuprofen) were consistently correlated with water column dissolved oxygen ($p \leq 0.05$) (Fig. 4) except gemfibrozil which may be due to the fewer number of samples collected for this compound. In addition, cotinine, sulfamethoxazole, and DEET were negatively correlated with precipitation measurements ($p \leq 0.06$) (Fig. 5). No other physiochemical

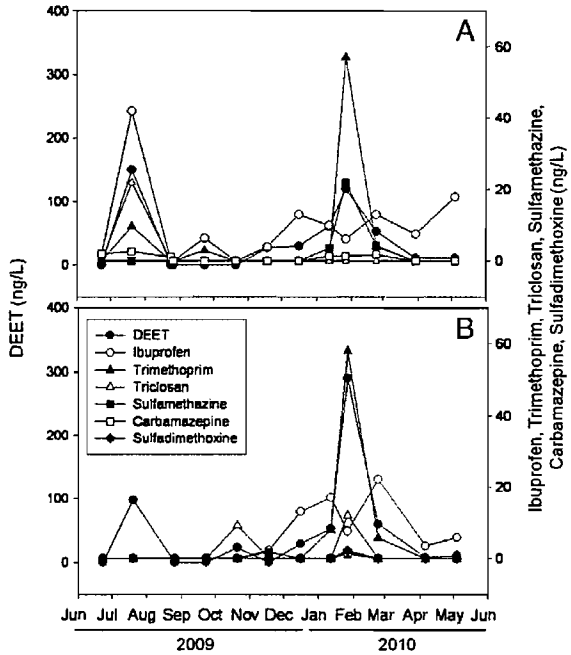


Fig. 3. Temporal patterns of pharmaceutical concentrations for low frequency compounds in A) Buck Creek and B) Killbuck Creek.

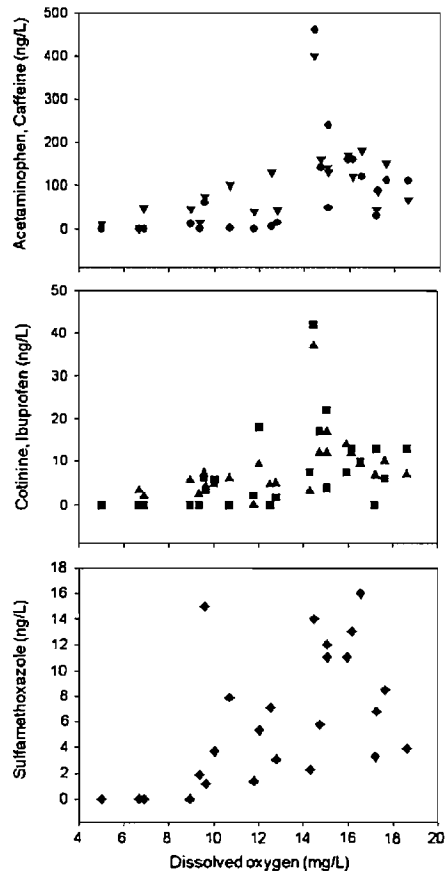


Fig. 4. Relationship between water column dissolved oxygen concentration and sulfamethoxazole, cotinine, acetaminophen, caffeine, and ibuprofen concentration across sites. Different symbols denote different pharmaceutical compounds: ● acetaminophen; ▼ caffeine; ▲ cotinine; ■ ibuprofen; ◆ sulfamethoxazole. See Table 3 for Pearson correlation statistics.

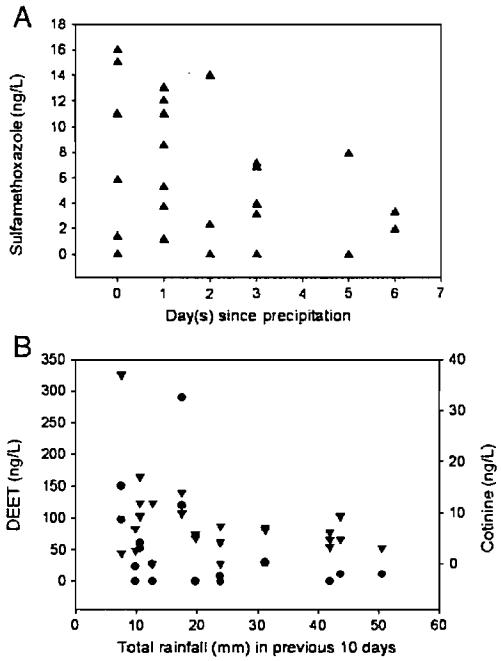


Fig. 5. Relationship between A) the number of days since precipitation and sulfamethoxazole concentration across sites; and, B) total rainfall in previous 10 days and DEET and cotinine concentration across sites. Different symbols denote different pharmaceutical compounds: ● DEET; ▼ cotinine; ▲ sulfamethoxazole. See Table 3 for Pearson correlation statistics.

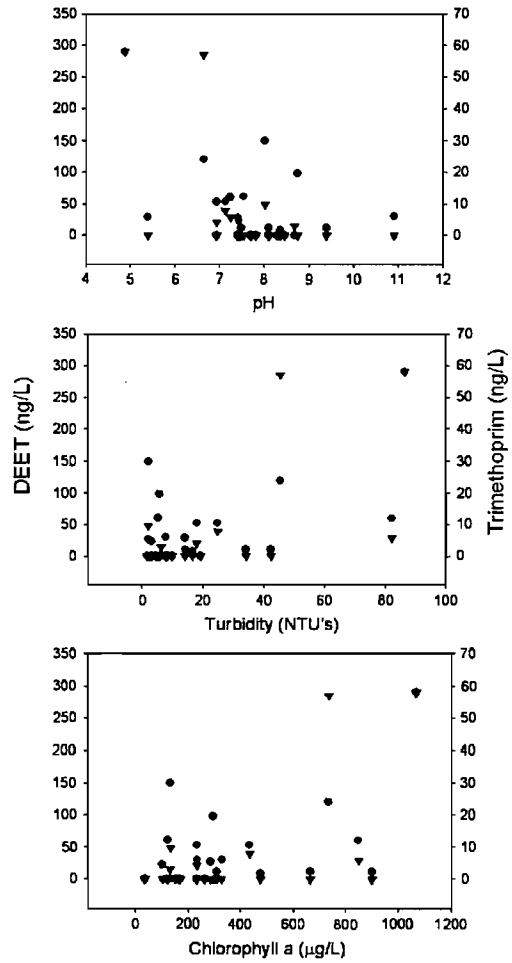


Fig. 6. Relationship between pH, turbidity, and chlorophyll *a* concentration and DEET and trimethoprim concentration across sites. Different symbols denote different pharmaceutical compounds: ● DEET; ▼ trimethoprim. See Table 3 for Pearson correlation statistics.

parameters measured were correlated with these high frequency compounds across sites.

Low frequency compounds (detected in <65% of sampling events) were not correlated with water column dissolved oxygen concentrations. Rather, DEET and trimethoprim were negatively correlated with pH ($p \leq 0.02$) and positively correlated with turbidity ($p \leq 0.01$) and chlorophyll *a* concentrations ($p \leq 0.01$) across sites (Fig. 6). Across sites, no pharmaceutical compounds were significantly correlated with any other stream variables measured (Table 3).

Within the suburban Buck Creek site, sulfamethoxazole was negatively correlated with days since precipitation at the time of sampling ($p = 0.02$). Within the agricultural Killbuck Creek site, caffeine, ibuprofen, and sulfamethoxazole were positively correlated with water column dissolved oxygen ($p \leq 0.02$). Caffeine and sulfamethoxazole were positively correlated with stream discharge ($p \leq 0.02$) at Killbuck Creek. Caffeine concentrations were also positively correlated with chlorophyll *a* concentrations at the Killbuck Creek (agricultural) site ($p < 0.01$). All high frequency compounds, excluding gemfibrozil, exhibited a negative correlation with water temperature ($p \leq 0.05$) within Killbuck Creek.

The sediment $\delta^{15}N$ content differed between sites ($p < 0.01$). Specifically, Buck Creek had significantly higher sediment $\delta^{15}N$ (mean = 7.13‰) relative to Killbuck Creek (mean = 68‰) ($p < 0.001$). In addition, Killbuck Creek had significantly higher N content in sediment (mean = 0.12% N) relative to Buck Creek (mean = 0.03% N) ($p < 0.01$) (Fig. 7). Within Killbuck Creek, $\delta^{15}N$ was negatively correlated with sulfamethazine ($p < 0.01$). Within Buck Creek, sediment $\delta^{15}N$ was negatively correlated with water column chloride concentration whereas sediment% OM was positively correlated with chloride concentrations ($\delta^{15}N$ $p = 0.03$;% OM $p = 0.01$). Sediment %N was also positively correlated with water column ammonium concentrations ($p = 0.04$) within Buck Creek (Table 3).

Across sites, sediment % N was negatively correlated with carbamazepine ($p = 0.05$). Sediment % N was also negatively correlated with stream width, mean velocity, discharge, water column dissolved oxygen, and chlorophyll *a* concentration ($p \leq 0.05$); and positively correlated with mean depth ($p = 0.04$) (Table 3). In contrast to pharmaceutical concentrations, sediment $\delta^{15}N$ was positively correlated with mean depth, mean velocity, and discharge across sites ($p \leq 0.02$), but negatively correlated with chloride ($p = 0.03$). Sediment organic matter (OM) content was negatively correlated with mean width ($p < 0.01$), and mean velocity ($p = 0.01$) and positively correlated with depth ($p = 0.02$). Measures of sediment quality were not significantly correlated with individual or total pharmaceutical concentrations when sites were combined ($p > 0.1$) (Table 3).

Independent variables measured but not significantly correlated to individual or total pharmaceutical concentrations across sites or within individual sites included total dissolved solids, nitrate, phosphate, solar irradiation, and CSO discharge in the previous 10 days before a sampling event ($p > 0.10$). Further, CSO discharge was not correlated with any measure of sediment quality (i.e., sediment $\delta^{15}N$, % N, or % organic matter; $p > 0.1$) (Table 3).

Multiple regression analyses indicated that water column dissolved oxygen controlled total pharmaceutical concentrations across sites (Table 4). When sites were analyzed independently, days since precipitation, dissolved oxygen concentrations, and solar radiation influenced total pharmaceutical concentrations in Buck Creek; whereas,

Table 3
Pearson correlation coefficient assessing relationships between pharmaceuticals in Buck and Killbuck Creek and physiochemical parameters. Bold values denote significant correlations ($p \leq 0.05$; $n = 25$; except gemfibrozil $n = 14$). Acronyms listed represent the following pharmaceuticals: ACE (acetaminophen), CAR (carbamazepine), CAF (caffeine), COT (cotinine), GEM (gemfibrozil), IBU (ibuprofen), SMX (sulfamethoxazole), SMZ (sulfamethazine), SDX (sulfadimethoxine), TRC (triclosan), TRP (trimethoprim), TP (total pharmaceuticals).

	ACE		CAR		CAF		COT		DEET		GEM		IBU	
	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
Discharge (m^3/s)	0.27	0.2	0.21	0.31	0.13	0.55	0.07	0.73	0.01	0.98	**0.86**	**0.01**	0.2	0.33
Temperature °C	−0.32	0.12	−0.14	0.51	−0.24	0.26	−0.23	0.28	−0.36	0.08	−0.04	0.88	−0.33	0.11
pH	−0.03	0.88	−0.24	0.25	−0.12	0.57	−0.14	0.52	**−0.47**	**0.02**	**−0.79**	**0.01**	0.02	0.94
TDS (g/L)	0.15	0.46	0.003	0.99	0.18	0.39	0.24	0.25	−0.04	0.84	**0.59**	**0.04**	0.2	0.32
Dissolved oxygen (mg/L)	**0.45**	**0.02**	0.37	0.07	**0.42**	**0.04**	**0.44**	**0.03**	0.35	0.09	−0.49	0.08	**0.44**	**0.03**
Turbidity (NTUs)	0.28	0.18	0.11	0.61	0.18	0.38	0.21	0.32	**0.58**	**0.01**	**0.55**	**0.04**	0.2	0.34
Chlorophyll *a* (mg/L)	0.18	0.38	−0.01	0.99	0.19	0.38	0.1	0.64	**0.52**	**0.01**	0.17	0.57	0.14	0.52
Nitrate (mg/L)	0.2	0.36	0.11	0.61	0.05	0.84	0.1	0.64	0.16	0.45	0.13	0.65	0.25	0.24
Day(s) since precipitation	−0.28	0.17	−0.12	0.56	−0.34	0.1	−0.17	0.42	−0.23	0.27	**0.56**	**0.04**	−0.29	0.16
Total rainfall (mm)	−0.23	0.27	−0.3	0.14	−0.2	0.34	−0.35	0.08	−0.38	0.06	0.27	0.36	−0.2	0.34
Solar radiation (MJ/m^2)	−0.17	0.43	−0.1	0.62	−0.12	0.55	−0.15	0.48	−0.29	0.16	−0.37	0.47	−0.22	0.3
$\delta^{15}N$	0.15	0.46	−0.06	0.77	0.16	0.45	0.17	0.43	−0.25	0.23	−0.43	0.17	0.14	0.51
Sediment% N	−0.19	0.36	**−0.4**	**0.05**	−0.34	0.1	−0.22	0.28	−0.01	0.96	0.16	0.62	−0.14	0.51
Sediment% organic matter	−0.1	0.64	−0.34	0.1	−0.29	0.16	−0.16	0.44	−0.12	0.58	0.26	0.42	−0.05	0.83

	SMX		SMZ		SDX		TRC		TRP		TP	
	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
Discharge (m^3/s)	0.17	0.43	0.33	0.1	−0.07	0.75	−0.14	0.51	0.15	0.49	0.18	0.39
Temperature °C	**−0.44**	**0.03**	−0.34	0.1	−0.27	0.18	0.01	0.98	**−0.4**	**0.05**	−0.36	0.07
pH	−0.26	0.21	−0.24	0.24	**−0.5**	**0.01**	−0.2	0.33	**−0.51**	**0.01**	−0.22	0.29
TDS (g/L)	0.29	0.16	−0.15	0.47	−0.09	0.66	0.02	0.92	−0.16	0.44	0.12	0.56
Dissolved oxygen (mg/L)	**0.53**	**0.01**	0.34	0.1	0.17	0.4	0.1	0.65	0.36	0.08	**0.48**	**0.01**
Turbidity (NTUs)	0.2	0.34	0.24	0.25	**0.61**	**0.01**	0.1	0.63	**0.64**	**0.01**	**0.39**	**0.05**
Chlorophyll *a* (mg/L)	0.07	0.73	0.27	0.2	**0.54**	**0.01**	0.05	0.82	**0.61**	**0.01**	0.33	0.11
Nitrate (mg/L)	0.09	0.66	−0.08	0.7	0.23	0.29	−0.03	0.9	0.14	0.53	0.16	0.45
Day(s) since precipitation	−0.38	0.06	−0.19	0.37	−0.11	0.6	0.1	0.62	−0.2	0.33	−0.32	0.11
Total rainfall (mm)	−0.28	0.18	−0.17	0.43	−0.08	0.69	−0.31	0.13	−0.19	0.36	−0.3	0.15
Solar radiation (MJ/m^2)	**−0.44**	**0.03**	−0.26	0.21	−0.16	0.45	0.05	0.82	−0.26	0.2	−0.23	0.27
$\delta^{15}N$	0.29	0.16	−0.05	0.81	−0.31	0.13	0.02	0.94	−0.21	0.32	0.05	0.82
Sediment% N	**−0.38**	**0.06**	−0.22	0.29	0.04	0.84	−0.01	0.96	−0.09	0.68	−0.22	0.29
Sediment% organic matter	−0.27	0.18	0.04	0.86	−0.16	0.44	−0.15	0.47	−0.07	0.75	−0.18	0.39

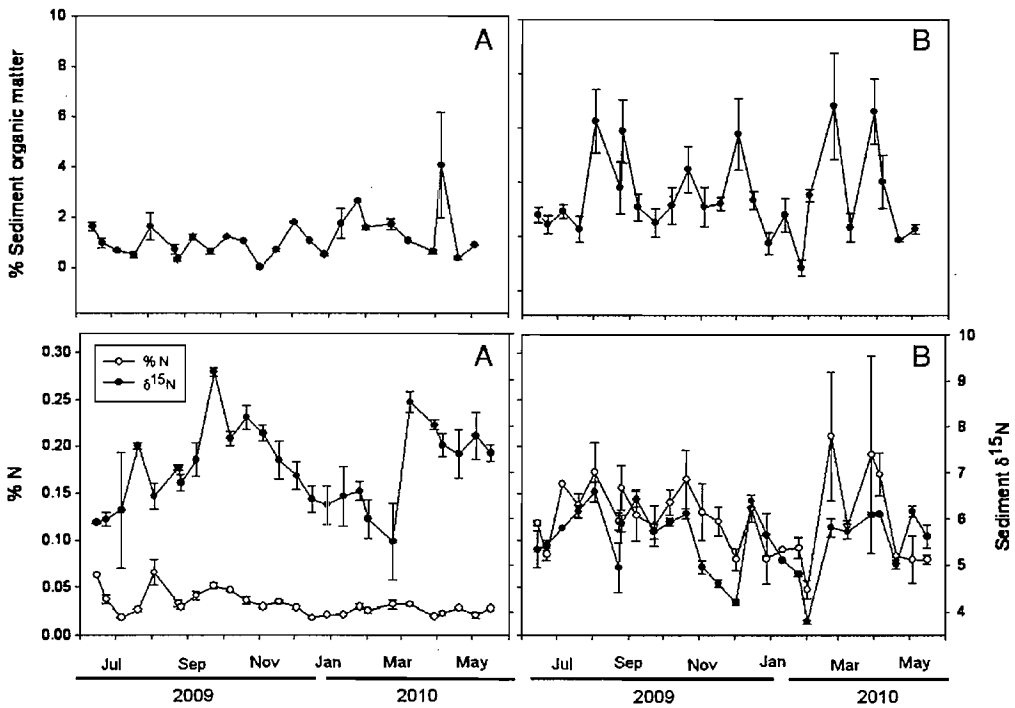


Fig. 7. Temporal patterns of sediment nitrogen content (as %N), isotopic natural abundance (as $\delta^{15}N$), and % sediment organic matter in A) Buck Creek, an agricultural stream; and B) Killbuck Creek, a suburban stream.

Table 4
Multiple linear regression equation and R^2 values for models developed across both sites (N = 25) and within each site (Buck Creek, N = 13; Killbuck Creek N = 12). Equations reference the following independent variables: DO = water column dissolved oxygen, days precipitation = days since precipitation at time of sampling, chlor A = chlorophyll *a* concentration, total rainfall = total amount of rainfall in previous 10 days prior to sampling. All models developed were significant at $p<0.05$.

Site	Regression equation	R^2
Buck Creek	= −1285 + 112 DO − 160 days precipitation + 41 solar irradiance	51.4
Killbuck Creek	= 694.8 − 79 pH + 0.52 chlor *a* − 167 total rainfall	93.6
Combined	= −156.9 + 33 DO	23.3

total rainfall in the previous 10 days, pH, and chlorophyll *a* concentrations were identified as factors influencing total pharmaceutical concentration in Killbuck Creek (Table 4).

4. Discussion

4.1. Range of pharmaceutical concentrations and frequency of detection

Pharmaceutical concentrations measured in this study were comparable to concentration ranges previously measured in U.S. streams and rivers (Camacho-Muñoz et al., 2010; Daneshvar et al., 2010; Glassmeyer et al., 2005; Kolpin et al., 2002; Kolpin et al., 2004; Vieno et al., 2005). However, concentrations measured in this study were lower than those previously measured in sewage treatment plant effluent (Glassmeyer et al., 2005; Godfrey et al., 2007) which may be due to dilution effects (Kolpin et al., 2004) (Table 5). In this study, pharmaceuticals found at highest concentrations detected were acetaminophen (460 ng/L), caffeine (400 ng/L), and DEET (290 ng/L); whereas, sulfadimethoxine (2.2 ng/L), triclosan (22 ng/L), and sulfamethazine (22 ng/L) were found in lower concentrations. Compounds detected most frequently in this study (i.e., gemfibrozil, caffeine, cotinine, acetaminophen, sulfamethoxazole, and ibuprofen) did not necessarily have the highest or most variable concentration ranges. Further, frequencies of detection for pharmaceuticals in this study are not consistent with previous studies for some compounds. For example, gemfibrozil has typically been found at lower frequencies (3.6%) (Kolpin et al., 2002) than observed in this study (100%, N = 12) (Table 5). In contrast, compounds not frequently detected in this study (carbamazepine, trimethoprim, and triclosan) have been more frequently detected in wastewater (carbamazepine 82.5%, triclosan 62.5%) (Glassmeyer et al., 2005) and some surface waters (Glassmeyer et al., 2005; Kolpin et al., 2004) suggesting pharmaceutical abundance in freshwaters is likely site-specific.

Variation in both detection frequency and concentrations measured across studies may indicate differential input, persistence, or sediment sorption characteristics. Pharmaceutical input into the aquatic ecosystem is a function of surrounding land use, usage rates, and wastewater treatment. In contrast, differential persistence and accumulation in sediment is predominantly a function of the properties of individual pharmaceutical compounds, sediment characteristics (i.e., sediment organic content), and degradation potential of the sediment microbial communities.

4.2. Spatial variation in pharmaceutical concentrations

All pharmaceutical compounds in this study were found at both sites with the exception of sulfadimethoxine which was found only once in Killbuck Creek. Due to wastewater effluent derived from a potentially larger contributing population, the suburban site was predicted to have higher pharmaceutical concentrations. However, contrary to this hypothesis, total pharmaceutical concentrations were not significantly different between the surburban and agriculturally influenced stream. Bunch and Bernot (2010) sampled ten sites within the UWRW and also consistently detected pharmaceuticals across a range of surrounding land uses although a negative correlation between urban land use in the sub-watershed and pharmaceutical concentrations was detected. These data suggest that the contributing population may be less predictive of pharmaceuticals in receiving waters than previously thought. Rather, wastewater treatment coupled with the contributing population may better predict pharmaceutical presence in receiving waters.

Studies measuring pharmaceuticals in the aquatic environment have primarily investigated urban sources such as sewage treatment plant effluent (Bartelt-Hunt et al., 2009; Glassmeyer et al., 2005; Phillips et al. 2008). However, advanced wastewater treatment (i.e., aerated activated sludge, trickling filter) associated with urban areas likely results in some removal of pharmaceuticals present before discharge to receiving waters (Phillips et al. 2008). Although the suburban site had a higher contributing population to wastewater effluent, wastewater was treated via activated sludge prior to discharge except during periods of combined sewer overflows (Fig. 8). Activated sludge as a secondary treatment has been documented to be an effective form of removal of some pharmaceuticals (Bartelt-Hunt et al., 2009; Buerge et al. 2003; Phillips et al. 2008); therefore, lower pharmaceutical concentrations are released into streams. In this study, the use of activated sludge treatment may account for lower pharmaceutical concentrations than expected due to higher removal efficiencies relative to the septic systems used in the agricultural site. Septic tanks commonly leak and result in large plumes of contaminated sewage (Carrara et al., 2008) potentially contributing to pharmaceuticals in receiving waters. Godfrey et al. (2007) sampled pharmaceuticals in septic tank effluent and groundwater below septic drainfields. Higher concentrations were generally seen in effluent, but certain pharmaceuticals (e.g., carbamazepine, sulfamethoxazole) persisted in groundwater (Godfrey et al., 2007). It has been suggested that increased persistence of pharmaceuticals from septic leakage may be influenced by oxidizing conditions and organic soil with high surface areas (Carrara et al., 2008). Although the surrounding landscape at the agricultural site consists of silt loam and silt clay loam, anoxic soil conditions may have allowed for compounds to persist.

Variable concentrations and detection frequencies across studies may also be due to differential sediment sorption. In this study, pharmaceuticals were measured only as dissolved compounds in the water column. However, some pharmaceuticals may persist in the environment sorbed

Table 5
Comparison of pharmaceutical concentrations detected in this study relative to previous studies investigating freshwater and wastewater effluent. Reported concentrations are median values. * = compound not included in study; ** = mean values reported; <DL = below detection limit.

Reference	Sample Type	Pharmaceutical concentration (μg/L)											
		Acetaminophen	%	Caffeine	%	DEET	%	Gemfibrozil	%	Carbamazepine	%	Triclosan	%
This Study	IN Streams	0.46	84	0.4	96	0.29	64	0.011	100	0.0027	28	0.022	12
Bunch and Bernot, 2010	IN Streams	0.109	50	0.057	100	*	*	*	*	*	*	*	*
Kolpin et al., 2002	U.S. Streams	0.11	24	0.081	62	0.06	74	0.048	4	*	*	0.14	58
Kolpin et al., 2004	Iowa Streams	0.67	21	0.05	74	0.064	3.6	<DL	0	0.091	26	0.046	3.3
Glassmeyer et al., 2005***	U.S. WWTP effluent	0.006	73	0.053	73	0.18	82	*	*	0.08	91	0.25	100
	Downstream from effluent	<DL	40	0.05	60	0.117	80	*	*	0.075	100	0.11	60

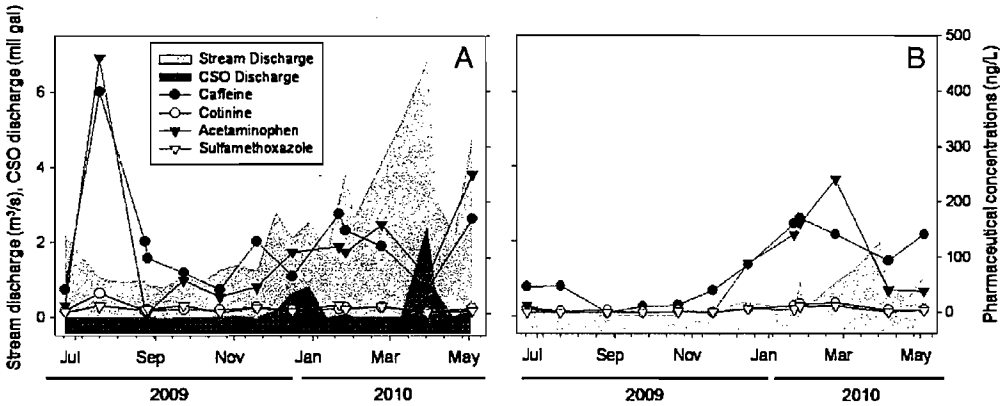


Fig. 8. Pharmaceutical concentrations, stream discharge and combined sewer overflow discharge (CSO) over the sampling period for A) Buck Creek, an agricultural stream; and, B) Killbuck Creek, an urban/suburban stream. See Table 1 for site descriptions. Pharmaceuticals plotted are high frequency compounds detected over the study period (Table 2).

to sediment and the rate of sorption is likely spatially and temporally variable depending on sediment type, pharmaceutical compound, and stream discharge. The ability of a compound to sorb to sediment is based on the organic carbon partitioning coefficients (K_{ow}), acid dissociation constant (pKa), and pH of the water (Jones et al., 2004; Lorphensri et al., 2007). Acetaminophen (log $K_{ow}=0.46$), caffeine (log $K_{ow}=0$), and sulfamethoxazole (log $K_{ow}=0.89$) have low K_{ow} yielding minimal potential for sediment sorption relative to ibuprofen (log $K_{ow}=3.5$), carbamazepine (log $K_{ow}=2.45$), or triclosan (log $K_{ow}=5.4$) potentially resulting in higher water column concentrations (Buerge et al. 2003; Jones et al., 2002; Radjenovic et al., 2008; Son et al., 2009). In this study, acetaminophen, caffeine, and sulfamethoxazole were more frequently found than ibuprofen, carbamazepine, and triclosan, consistent with reduced capability for sediment sorption. Although the K_{ow} is constant for a given pharmaceutical compound, water pH is variable yielding spatial and temporal variation in sorption potential. Further, during periods of high flow, pharmaceuticals may be transported via suspended particulates before settling. Cushing et al. (1993) suggested that surficial fine particulate organic matter is transported on average 4–8 km days^{-1} indicating that particulate matter is quickly exported downstream. If pharmaceuticals are attached to particulate matter, they may be transported downstream further than unattached compounds.

Alternatively, comparable pharmaceutical concentrations between the agricultural and urban site could result from differential usage rates per person in the sub-watershed. Pharmaceutical usage rates are not available for comparison among watersheds but we assume they are not significantly different. In addition, pharmaceuticals detected in both streams were primarily human pharmaceuticals. Although only four of the pharmaceuticals included in the analyte list (i.e., sulfamethazine, sulfadimethoxine, tylosin, lincomycin) are used in veterinary or livestock operations, these compounds were either never detected in sampling efforts or had frequencies of ≤20% indicating that agricultural operations are not likely the primary source of pharmaceutical input.

Previous studies have shown that higher $\delta^{15}N$ values in sediment can result from anthropogenic sources such as urban activities, notably wastewater input (Vander Zanden et al., 2005) whereas lower $\delta^{15}N$ values in sediment result from agricultural practices such as fertilizer application (Fogg et al., 1998). Thus, $\delta^{15}N$ signatures of primary consumers have been linked to sewage derived from populated areas (Cabana and Rasmussen, 1996). However, in this study, sediment $\delta^{15}N$ did not correlate with CSO discharge in Buck Creek although the site did have significantly higher sediment $\delta^{15}N$ content relative to Killbuck Creek indicating higher input of human and animal waste (Fogg et al., 1998; Steffy and Kilham, 2004) (Fig. 7). Further, Killbuck Creek had significantly higher sediment %N than Buck Creek (Fig. 7) indicating nitrogen input from sources other than sewage are potentially being discharged into Killbuck Creek.

4.3. Temporal variation in pharmaceutical concentrations

In this study, acetaminophen, carbamazepine, caffeine, cotinine, ibuprofen, and triclosan concentrations were highest during the July sampling in Buck Creek (Figs. 2, 3). During July, stream discharge (1.06 m^3/s) and CSO discharge (0.02 million gallons) were relatively low compared to discharge over the study period. Kolpin et al. (2004) found that pharmaceutical concentrations were lower during high flow conditions likely due to dilution. Lower dilution may partially explain the high concentrations seen in July in the urban site although CSO input in the previous 10 days before the sampling event was low. However, stream discharge was not correlated with pharmaceutical concentrations across or within sites indicating dilution alone did not dictate the observed pharmaceutical concentrations. Both nitrate and ammonium concentrations were highest two weeks prior to the July pharmaceutical sampling (Fig. 9) indicating another waste source other than CSO discharge may have emptied into Buck Creek. Therefore, other sources of waste may exist that are contributing to pharmaceutical abundance in the water.

Within Killbuck Creek, acetaminophen, caffeine, and cotinine were highest during winter months (December, January, February) (Fig. 8). Further, excluding the July sampling event, pharmaceutical concentrations in Buck Creek were also highest during winter months. Higher concentrations of pharmaceuticals during winter have previously been documented in Finnish and Swedish streams (Daneshvar et al., 2010; Vieno et al., 2005) and likely a function of lower temperature and irradiance as well as higher input relative to spring, summer, and fall. Seasonal variation of pharmaceuticals present in streams has only recently been documented (Daneshvar et al., 2010; Vieno et al., 2005). Thus, these data are consistent with other recent studies indicating pharmaceutical concentrations in freshwater are higher during winter. More compounds were detected during winter months (i.e., December, January, February) and more frequently than at other times of the year.

Several mechanisms are likely responsible for higher pharmaceutical abundance during winter including temperature, irradiance and input. Decreased water temperature not only within the stream itself, but also within the sewage treatment plant, likely reduces biodegrading activity yielding higher concentrations of pharmaceuticals to be transported downstream (Vieno et al., 2005). Yuan et al. (2004) examined biodegradation of nonylphenol (NP) in river sediment and found that between 20 °C and 50 °C, higher temperatures yielded greater biodegradation of NP. Further, increased biodegradation rates associated with

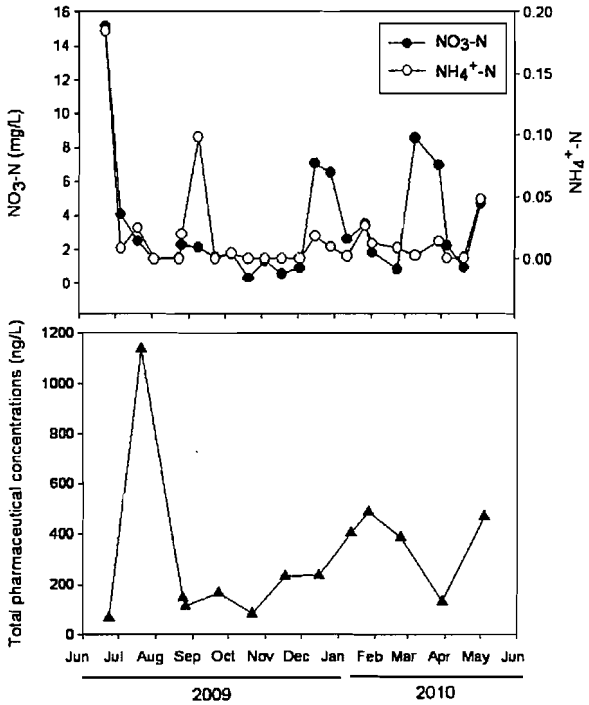


Fig. 9. Temporal patterns of nitrate (NO_3-N) and ammonium (NH_4-N) concentrations and total pharmaceutical concentrations in Buck Creek, a suburban stream.

higher temperatures may explain negative correlations identified between temperature and several of the high frequency compounds detected (i.e., caffeine, cotinine, acetaminophen, ibuprofen, sulfamethoxazole) in Killbuck Creek. Decreased solar irradiation in winter may also allow reduce abiotic degradation of pharmaceutical compounds (Daneshvar et al., 2010). During winter, snow and ice may reduce irradiation reaching surface water, in addition to shorter daylight periods, therefore reducing photodegradation of susceptible contaminants. Lam et al. (2004) found that certain pharmaceuticals (e.g., sulfamethoxazole) are transformed via photoreactions under sunlight whereas more recalcitrant compounds, such as carbamazepine, are more resistant to photodegradation. Thus, temporal variation in irradiance will likely only influence persistence of some pharmaceutical compounds.

4.4. Primary factors influencing pharmaceutical concentrations

Across sites, water column dissolved oxygen was positively correlated with concentrations of several individual pharmaceutical compounds (Fig. 4). In contrast to other studies, this may indicate that biota under low oxygen conditions may be better able to degrade frequently detected compounds (e.g., caffeine, cotinine, acetaminophen, sulfamethoxazole, ibuprofen) (Carrara et al., 2008). Within the agricultural site, dissolved oxygen correlated with only a few compounds (caffeine, ibuprofen, and sulfamethoxazole) and no relationships between dissolved oxygen and any pharmaceutical compounds were found within the suburban site. In addition, pH, turbidity, and chlorophyll *a* were significantly correlated with low frequency compounds (i.e., DEET and trimethoprim) (Fig. 6), but when examined across sites, no correlations were found. Different correlations identified across sites compared to within an individual site may suggest that only when sites are combined are strong predictors for pharmaceutical concentrations identified. Further, mechanistic explanations for persistence are likely more indicative within an individual site.

Discharge and precipitation have been proposed as a dominant predictor of pharmaceutical in freshwaters (Kolpin et al., 2004). However, our data indicate only weak relationships between pharmaceutical concentrations in streams and measures of water flow and precipitation (Table 3). Weakly significant correlations present between precipitation measurements and sulfamethoxazole, DEET, and cotinine (Fig. 5) are consistent with the concept of input and dilution playing a major part in the persistence of pharmaceutical contaminants. In older sewage infrastructures in the U.S., untreated sewage and storm water are released through sewers into waterways when the amount of influent exceeds a sewage plant carrying capacity (Benotti and Brownawell, 2007; Buerge et al., 2006; Musolff et al., 2010). Therefore, a major source of pharmaceuticals is likely through wastewater effluent. However, these weak associations found with precipitation measures and the high pharmaceutical concentrations measured in July (Fig. 8) suggest that there are other sources that contribute significantly to contaminants reaching the aquatic ecosystem.

5. Conclusions

Twelve pharmaceuticals were detected in two sites with differing land use in east central Indiana. More comprehensive studies are needed to develop a predictive understanding of pharmaceutical variation within aquatic ecosystems. Pharmaceuticals in freshwaters may not only alter biological processes, but also may enter human drinking water supplies leading to unintentional consumption of drug mixtures. Further investigation is essential to reduce anthropogenic contaminants from entering aquatic environments and assess regulatory need.

Acknowledgments

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NRSC
Aug. 28 & 29, 2012
Exhibit # 12

Effects of Drought on Water Use - 2012

COMPETITION AND IMPACTS ON MUNICIPAL USERS, AGRICULTURE AND INDUSTRY, SB132

Jack Wittman, PhD
Layne Christensen

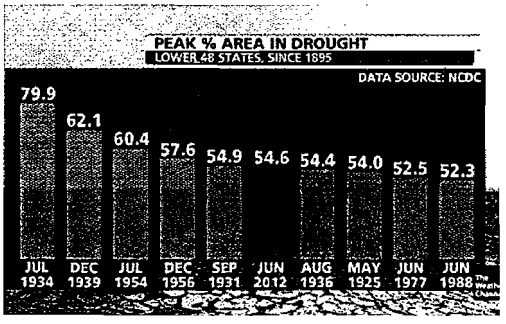
Economics, water use, impacts

HOW SERIOUS WAS THE DROUGHT?

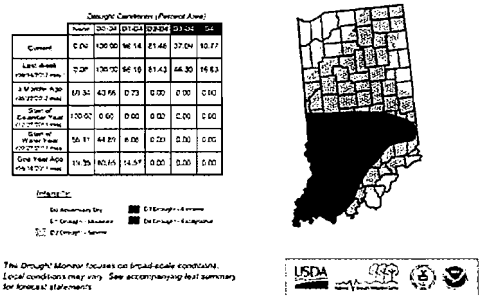
Questions

- How **serious** was the 2012 drought?
- Were the **utilities** in the state prepared?
- Was the **state** prepared?
- Where were the **problems**?
- Was there an "**upside**?"
- **SB 132** – a work in progress

How serious was the drought?



Indiana



August 21, 2012

Drought hit the most vulnerable part of the state

Observations – what happened?

- Losses in agriculture – crop insurance
- Peak use in many cities
- Low flows in rivers (lowest since 1941)
- Reservoir levels fell rapidly
- Water levels in aquifers dropped (locally)
- Power plants had to manage

We all got a wake up notice – drought effects are serious.

Observations – what happened?

- Losses in agriculture – crop insurance
- Peak use in many cities
- Low flows in rivers (lowest since 1941)
- Reservoir levels fell rapidly
- Water levels in aquifers dropped (locally)
- Power plants had to manage

Were utilities prepared?

- Generally, YES
- Peak use day were hit all over the state, mostly in the Southern half of state

Was the State prepared?

- IDNR – most action since 1988
- Utilities – infrastructure or resource
- Public – heard the conservation message
- IURC – what a year to begin SB132
- Homeland Security – got in the game

Upside of Drought

- Conservation

Problems? - Stress Tests

Basins	Streams	Aquifers
Lake Michigan	No	No
Wabash River	Yes	No
White River	Yes	Yes
Ohio River	No	no

Solutions encourage multiple-basin supplies and storage

RISKS ARE LOCAL AND TRANSIENT

Stabilizing Supplies

- Reuse
- Pricing signals
- Aquifer Storage and Recovery (ASR)
- Sustainable bank filtration systems

jack.wittman@layne.com

SB 132 – a work in progress

- Comparing use to capacity
- Mapping and evaluating problems
- Considering use with respect to the resource
- Perfect year to begin analysis

NRSC
Aug. 28 & 29, 2012
Exhibit # 13

Purdue University
Department of Forestry and Natural Resources
http://www.ag.purdue.edu/fnr

PURDUE UNIVERSITY

Learning

B.S. degrees in:

	# students
• Forestry	46
• Wildlife	217
• Fisheries and Aquatic Sciences	36
• Natural Resources Planning and Decision Making	13
• Wood Products Manufacturing Technology	4
	Total = 316

M.S. and Ph.D. students (n = 92) profile: average GPA = 3.68, GRE = 568 V (77), 691 Q (70)
Degrees awarded in the following areas:

- Ecology of Natural Systems
- Forest Biology
- Natural Resource Social Science
- Quantitative Ecology
- Fisheries and Aquatic Sciences
- Genetics
- Wildlife Science
- Wood Science

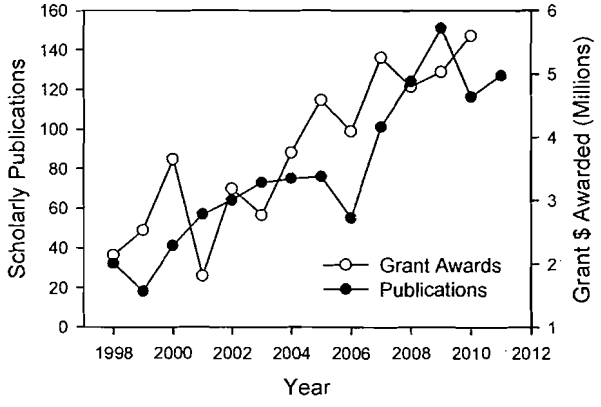
Discovery

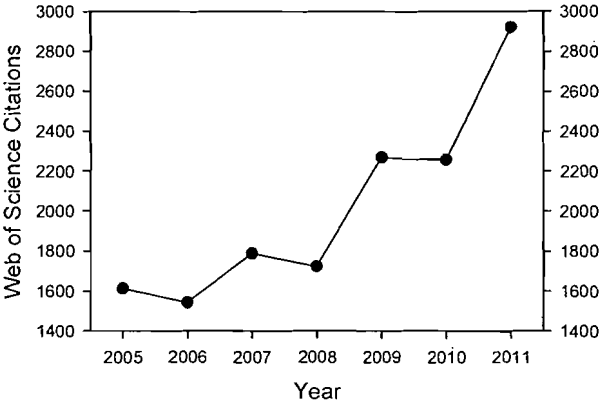
29 tenure-track faculty, 2 visiting faculty, 9 adjunct faculty, and 5 postdoctoral associates

Recognized areas of interdisciplinary excellence in:

1. Sustaining Hardwood Ecosystems
2. Genetics of Natural Resources
3. Applied Ecology
4. Land-Use Sustainability Science
5. Hardwood Improvement/Regeneration

Dramatic growth in scientific productivity and impact:





Indiana's Forest Resources: Opportunities and Threats

Current Status

5 million acres (21% of state land base): high productivity and timber quality

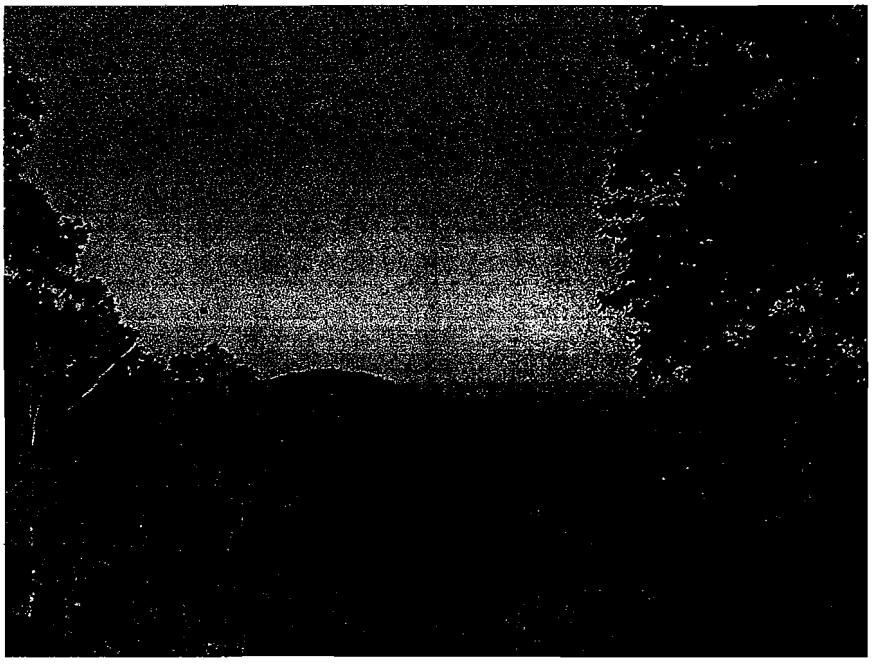
85% privately owned

Forest Benefits

- Greatly valued for recreation
- Critical reservoirs of biodiversity
- Important to rural economies: forestry and wood products manufacturing is a $7.5 billion industry employing >50,000 Hoosiers
- Premium Indiana Forest Products: rank in top 5 nationally in
    - Wood office furniture
    - Manufactured homes
    - Hardwood veneer and plywood
    - Wood kitchens and counter tops

Greatest Priorities

1. Minimizing fragmentation/conversion of forests to other land uses
2. Conserving soil and water resources
3. Controlling spread of invasive species
4. Conserving biodiversity



Clark State Forest

Synopsis of Research Rankings for FNR

The FNR doctoral program at Purdue ranked 5th nationally in a 2007 report published in *The Chronicle of Higher Education* from Academic Analytics.

The 2010 National Research Council rankings also reflect strengths in FNR. Overall rankings were derived from the survey-based (S) scheme, because it is data driven. FNR faculty were allocated to one of the following fields: (1) Forestry and Forest Science – 33 programs ranked; (2) Ecology and Evolutionary Biology – 94 programs ranked. Within the latter field, a separate comparison of rankings was made for fish, wildlife and natural resources programs.

In Forestry and Forest Science, FNR ranked (n = 33 programs):

- 7th overall
- 4th overall among land-grant universities
- 1st in percent of 1st-year students fully supported (tie)
- 2nd overall in terms of diversity of students and faculty
- 3rd in percent of interdisciplinary faculty
- 8th in average student GRE

In Ecology and Evolutionary Biology, FNR ranked (n = 94 programs):

- 13th overall
- 7th overall among public universities
- 4th in publication rate of faculty
- 1st in percent of 1st year students fully supported (tie)
- 5th in percent of 1st year students on external support
- 9th in percent of faculty with grants
- 14th in percent of Ph.D. students completing within 6 years
- 15th in percent of interdisciplinary faculty

In Fisheries and Wildlife, FNR ranked (n = 23 programs):

- 1st in publication rate of faculty
- 1st in percent of 1st year students fully supported (tie)
- 3rd in percent of 1st year students on external support
- 3rd in average GRE of students
- 6th in percent of interdisciplinary faculty

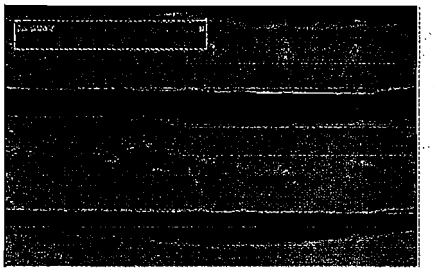
Forestry & Natural Resources

PURDUE UNIVERSITY

A Sampling of FNR Extension and Research Activities

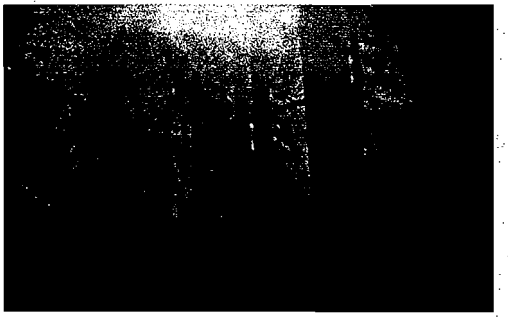
Sustaining Hardwood Ecosystems

- Hardwood Tree Improvement and Regeneration Center (HTIRC)
  - Fine hardwood tree improvement
  - Chestnut restoration
  - Butternut conservation
- Hardwood Ecosystem Experiment
- Climate Change and Eastern Forests
- Woody Biomass/Biofuels
- Forest Tax Advice for Landowners
- Log and Lumber Grading
- Hardwood Log Scanning
- Forest Products Web Community



Partnering for Land-Use Sustainability

- Illinois-Indiana Sea Grant College program
- Local Decision Maker
- Useful to Usable (U2U) integrated research/extension project
- Soundscape Science



zipTrips PURDUE

Natural Resources Genetics

- Wildlife and Plant Conservation
  - American chestnut
  - Butternut
  - *Acacia koa*
  - Eastern hellbenders
  - Eastern box turtles
  - Imperial eagles
  - Amphibians
- Aquatic Ecotoxicology
- Phytoremediation
- Developmental Genetics

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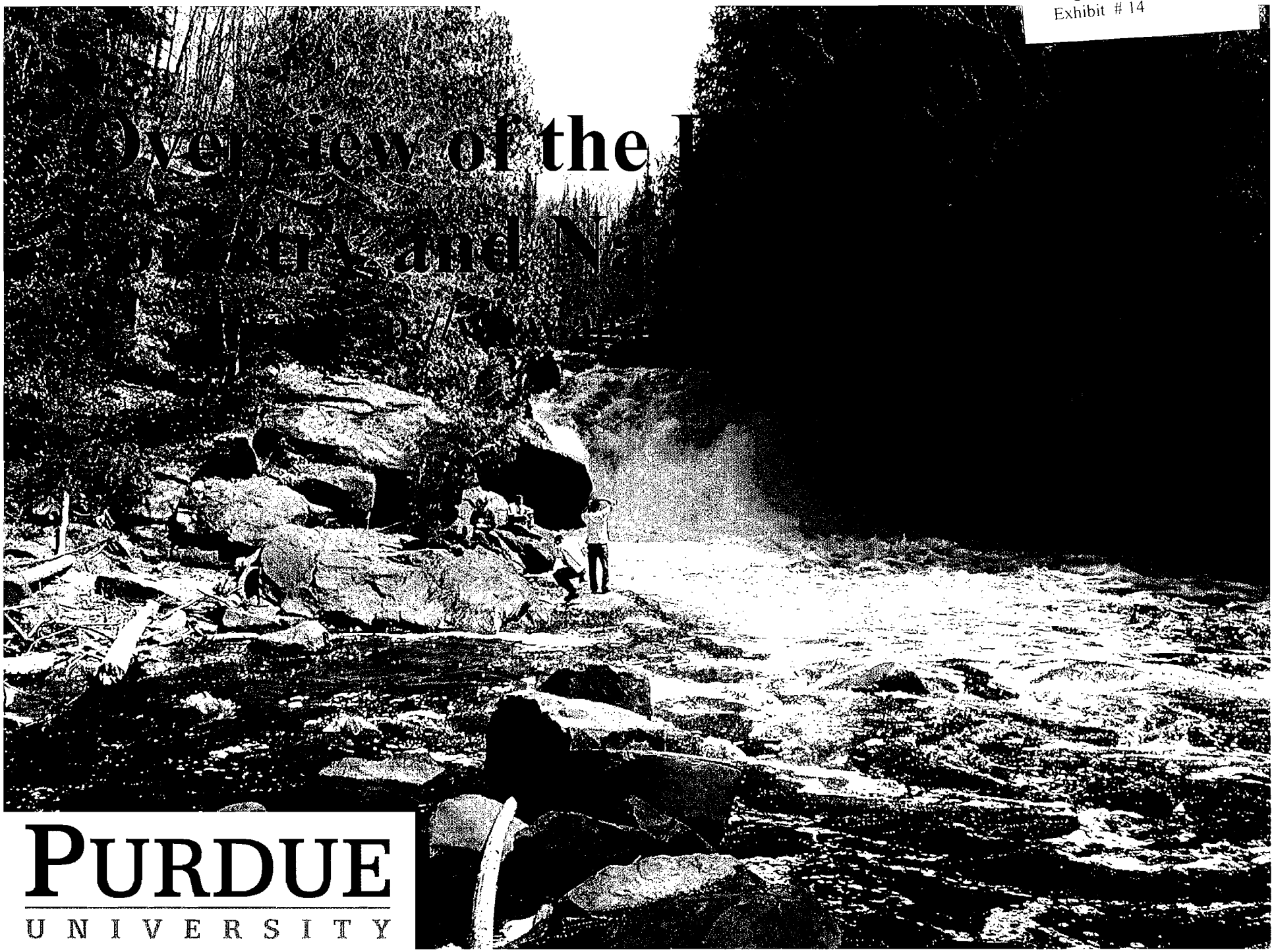
NRSC
Aug. 28 & 29, 2012
Exhibit # 14



Overview of the

PURDUE
UNIVERSITY

Department of Forestry and Natural Resources

- 300+ Undergraduates majoring in
  - Fisheries and Aquatic Sciences (certified)
  - Forestry (accredited)
  - Wildlife (certified)
  - Natural Resources Planning and Decision Making
  - Wood Products Manufacturing Technology

Department of Forestry and Natural Resources

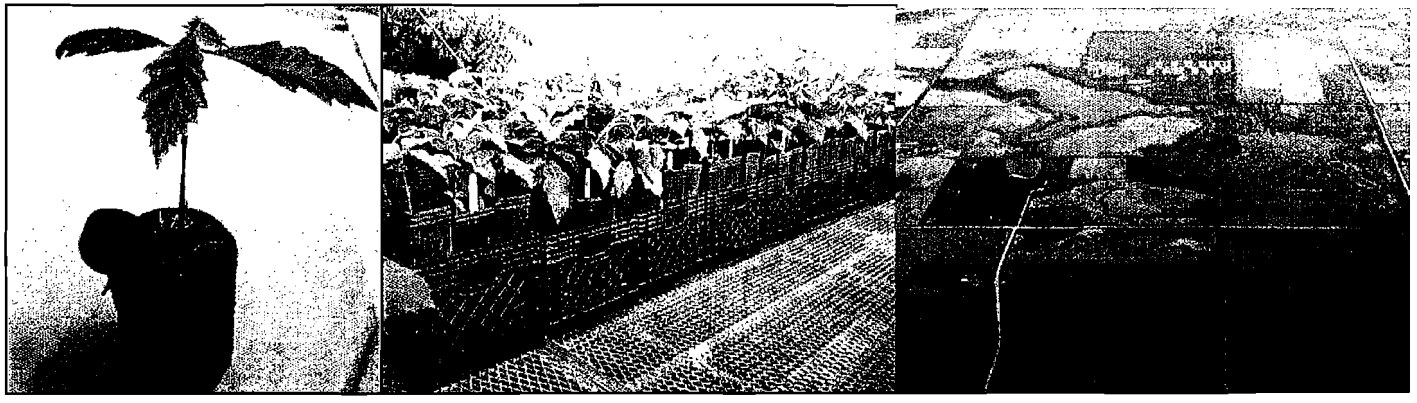
- 86 Graduate students studying toward
  - Master of Science
  - Master of Science in Forestry
  - Doctor of Philosophy
  - Research areas:
    - Fisheries and aquatic sciences
    - Forest biology
    - Genetics
    - Natural resource and environmental policy
    - Quantitative resources analysis
    - Wildlife science
    - Wood science and technology

Department of Forestry and Natural Resources

- Personnel
  - 29 tenure-track faculty + 2 visiting faculty
  - 9 adjunct faculty
  - 7 postdoctoral associates and visiting scientists
  - 49 administrative/professional staff and support staff

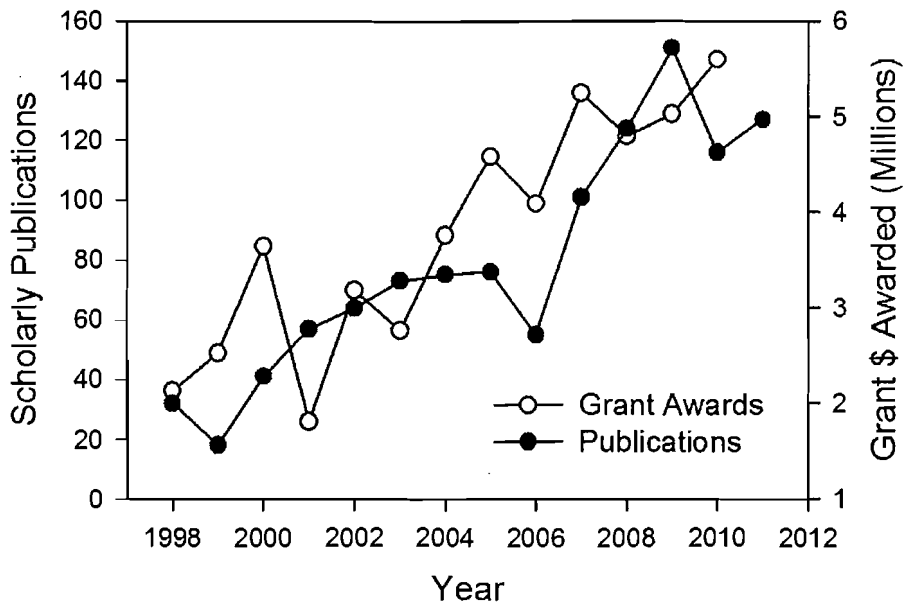
Department of Forestry and Natural Resources

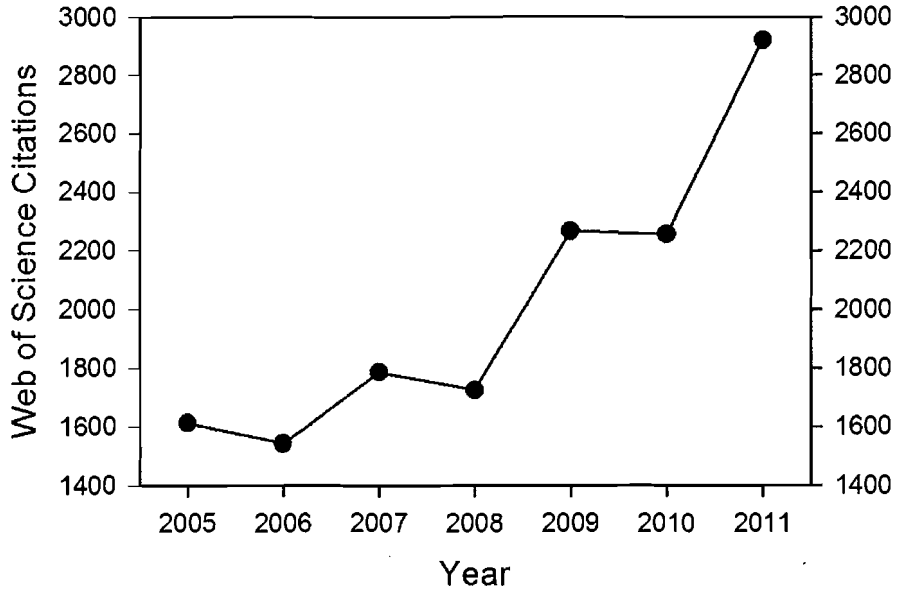
- Areas of Expertise in:
  - Applied Ecology
  - Sustaining Hardwood Ecosystems
  - Hardwood Improvement & Regeneration
  - Natural Resources Genetics
  - Land-Use Sustainability



Department of Forestry and Natural Resources

- Growth in Scientific Productivity and Impact:





Department of Forestry and Natural Resources

- Rankings of Research Program
  - 5th nationally (2007 Academic Analytics)
  - National Research Council 2010 rankings for Forestry and Forest Science (n = 33):
    - 7th overall
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Forestry & Natural Resources

PURDUE UNIVERSITY

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Forestry & Natural Resources

PURDUE UNIVERSITY

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Forestry & Natural Resources
PURDUE UNIVERSITY

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Forestry & Natural Resources

PURDUE UNIVERSITY

Some FNR Extension and Research Activities

- Hardwood Tree Improvement and Regeneration Center (HTIRC)
  - Fine hardwood tree improvement
  - Chestnut restoration
  - Butternut conservation
- Hardwood Log Scanning
- Hardwood Ecosystem Experiment
- Woody Biomass/Biofuels
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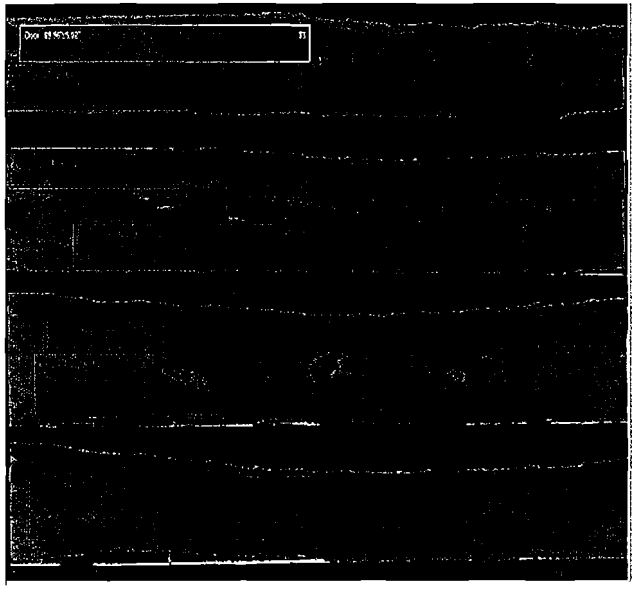
- Log and Lumber Grading
- Climate Change and Eastern Forests
- Forest Products Web Community



Some FNR
Extension and Research Activities

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- Local Decision Maker
- Useful to Usable (U2U) integrated research/extension project
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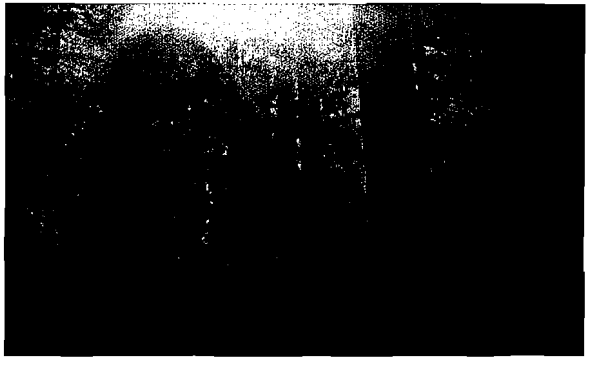

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Aug. 28 & 29, 2012
Exhibit # 15

Overview of The Hardwood Ecosystem Experiment

Mike R. Saunders

Department of Forestry & Natural Resources

Purdue University

Indiana Natural Resources and Water Resources Study Committees

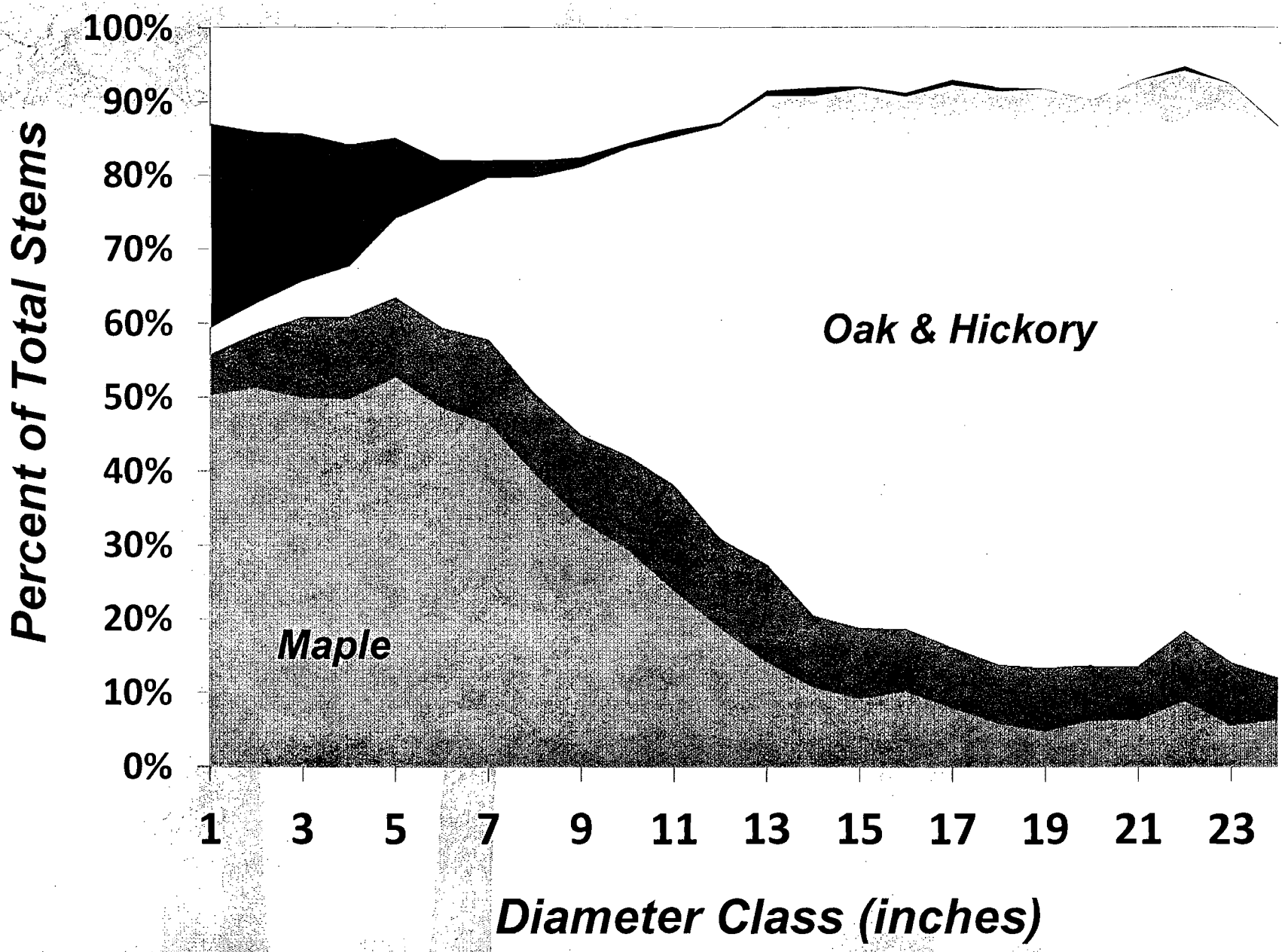
Purdue University, West Lafayetee

August 29, 2012

Backdrop

- Forest management in Indiana is facing numerous obstacles:
  - Public perception
  - Threatened & endangered species (Cerulean warbler, IN bat)
  - Conflicting game species management concerns
  - Invasive species (bush honeysuckle, EAB, tree-of-heaven)
  - Potentially major shifts in forest community composition

HEE pre-treatment data from over 37,000 trees



A Long-Term Partnership

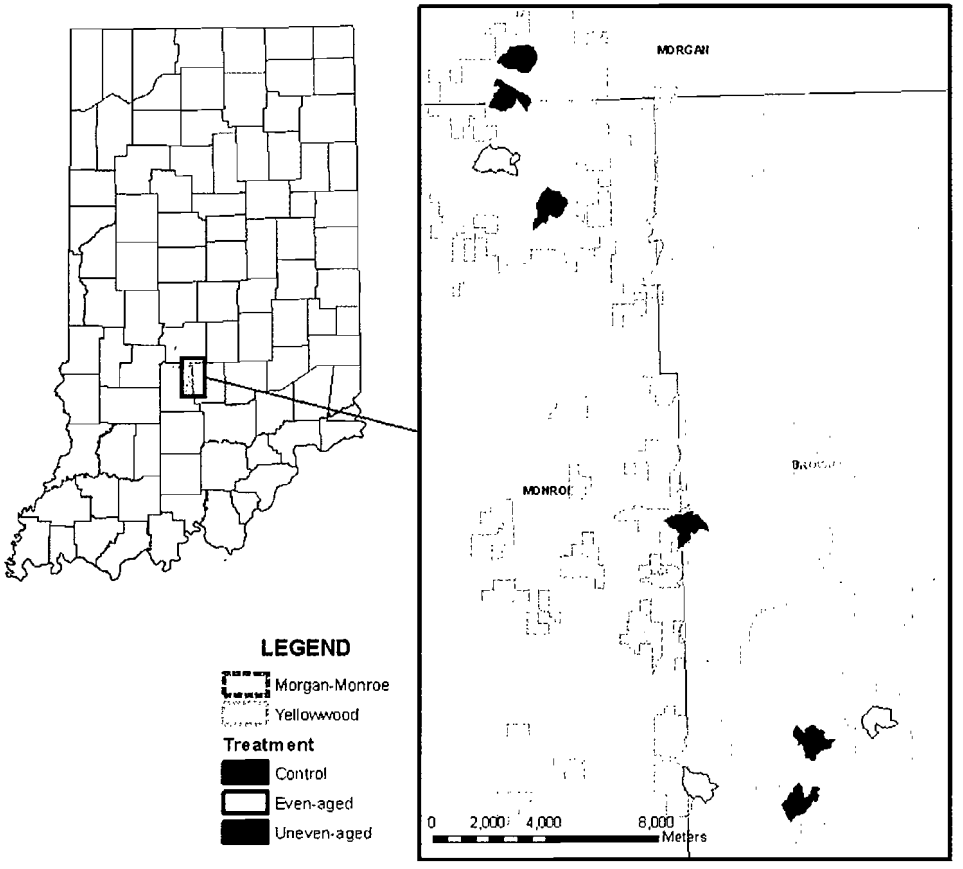
- HEE initiated in May 2006 as a proposal to the Indiana Division of Forestry (DoF)
- Multiple university, NGO and government partners
- Current funding from DoF through 2014.
- In total, this has been a >$2.0M effort on behalf of the state and all partners.

HEE Primary Objectives

1. Develop even- and uneven-aged silvicultural systems that maintain oak-dominated forest communities and landscapes
2. Determine the impacts of these systems on communities of herbaceous, avian and terrestrial amphibian species groups
3. Determine the social and economic ramifications of these systems in both the local and regional communities
4. Provide demonstration sites and develop novel educational materials and techniques to engage the public concerning forest management

Study Area

- Located near Bloomington, IN
- Units are 280-370 ha each, with 80 ha core trt. area
- Blocked random design, with 3 trts



Three Treatments to Be Studied for 100 Years!

1. No harvest
   - Experimental control
   - *What happens to oak ecosystems if timber harvesting is abandoned on public lands?*
2. Uneven-aged
   - Management control
   - *Can current, predominant timber management practices maintain oak in forest ecosystems?*
3. Even-aged
   - A different approach for Indiana

Uneven-Aged Management

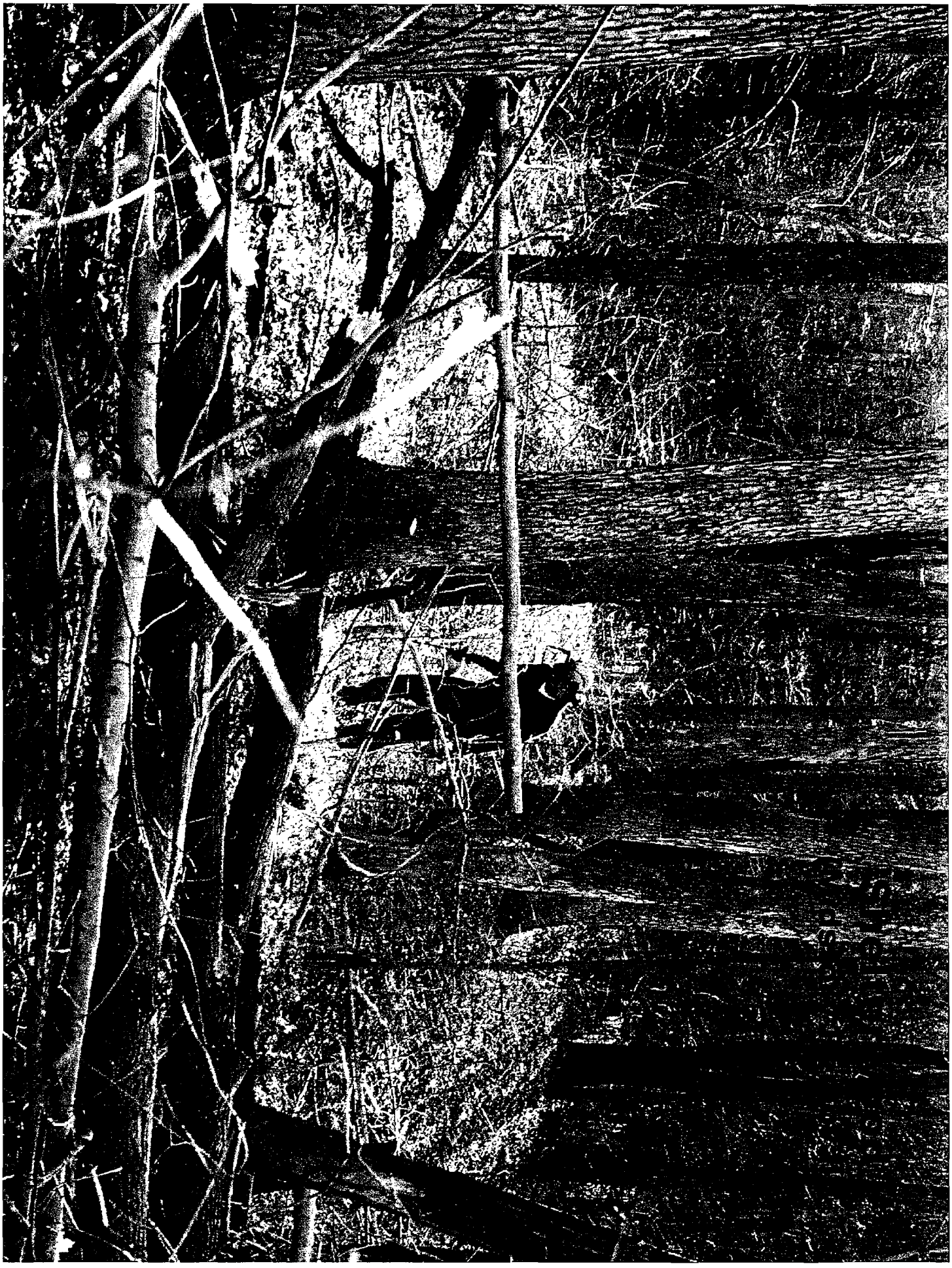
Single-tree selection w/patch cuts

- Eight patch cuts per unit
  - Vary in size (2 – 2.0 ha, 2 – 1.2 ha, 4 – 0.4 ha)
  - Paired across aspect
  - Only 1st entry
  - Post-harvest TSI to deaden non-oak and coppice oak
- Single-tree selection in matrix
  - Residual BA of 16-23 m^2/ha of trees > 25 cm DBH
  - 20 yr cutting cycle
  - No follow-up TSI

Even-Aged Management

Four 4.0 ha harvests per unit every 20 years:

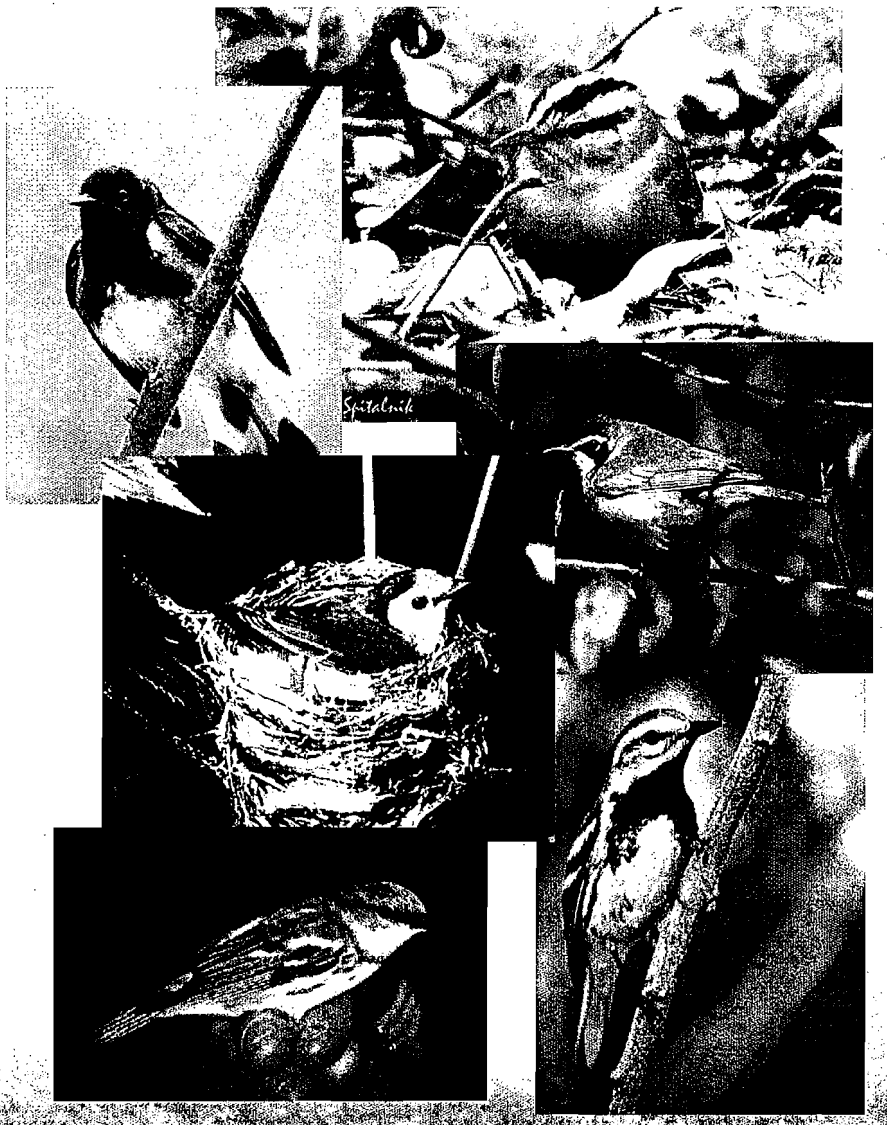
- 3-stage shelterwood (2 – NE, SW)
  - Year 0: Midstory non-oaks < 25 cm DBH & small cull
  - Year 5-10: Overstory to a residual BA of 13-16 m^2/ha
  - Year 10-20: Remaining overstory
  - Mid-rotation thinning possible
- Silvicultural clearcut (2 – NE, SW)
  - Post-harvest TSI to deaden non-oaks and coppice oak
  - Enrichment planting likely
  - Early crop-tree release and mid-rotation thinning possible



Overview of Research Activities

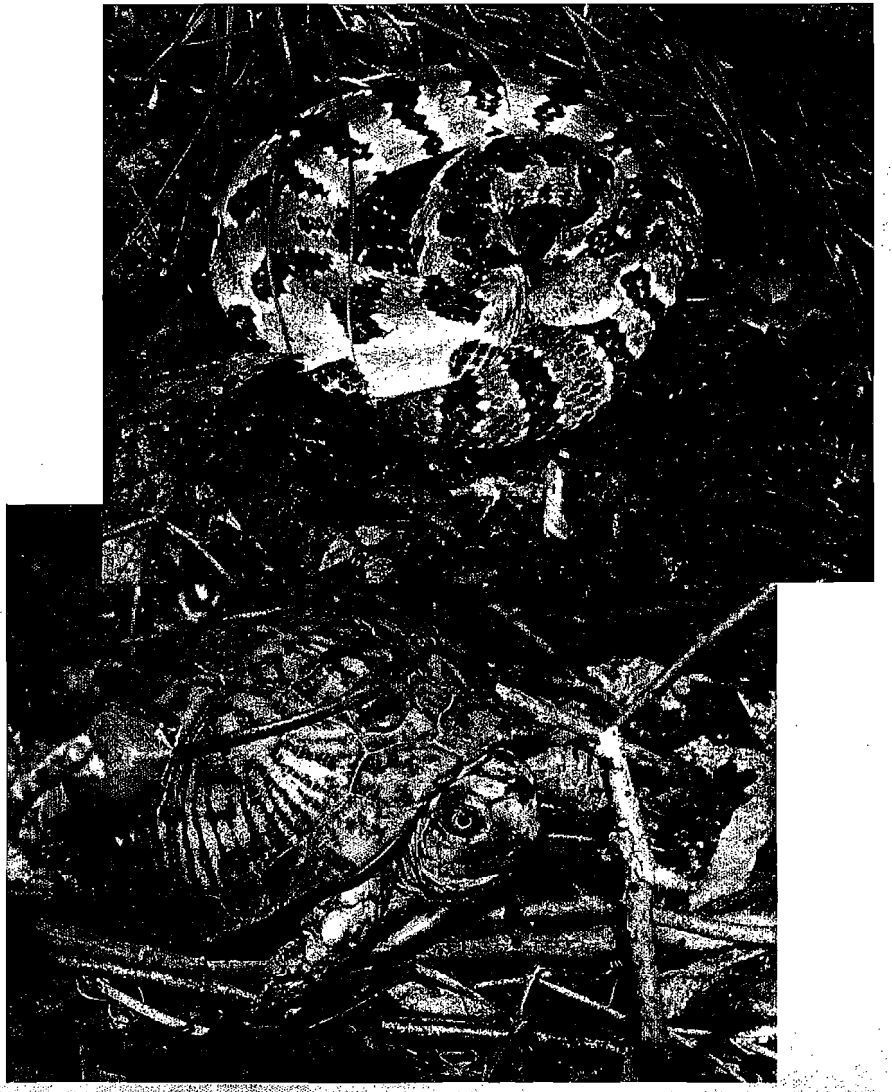
1. Songbirds (B. Dunning)
   - Point counts throughout each unit at multiple times
   - >10,000 counts
   - Forest breeders most common; nest parasites and predators abundant

2. Cerulean warblers (K. Islam)
   - Point counts & mapped territories in each unit
   - Over 50 individuals followed



Overview of Research Activities

3. Rattlesnakes & box turtles (B. MacGowan & R. Williams)
   - 45 snakes and 93 turtles tracked via radio telemetry between 2007-09
   - Minor differences in turtle home range sizes seen in pre- vs. post-harvest conditions.

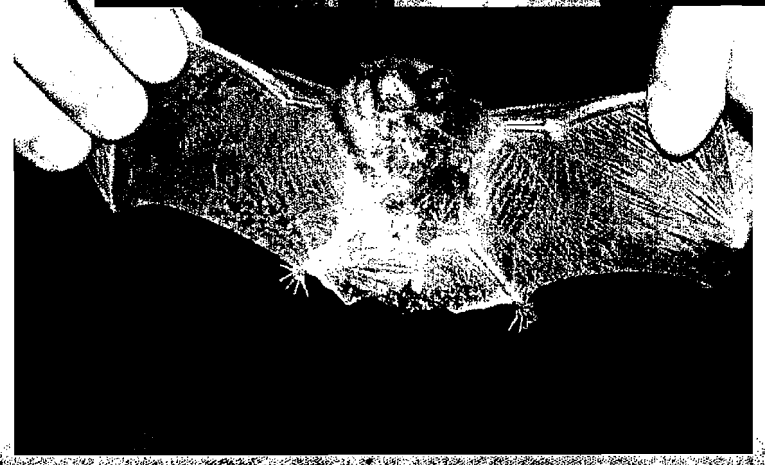


Overview of Research Activities

4. Small Mammals (R. Swihart)
   - Gridded (9 x 3, 30 m spacing) trapping stations at 32 locations
   - > 8,000 captures of 7 species from 2007-12
   - For most species, no difference between sites in abundance or diversity
   - Post-harvest differences still being analyzed

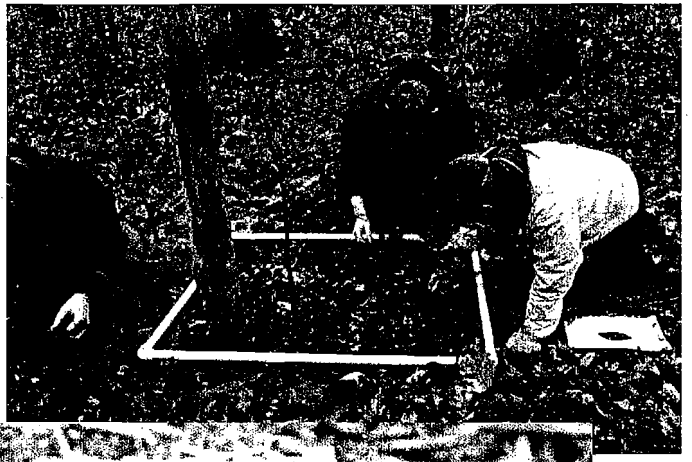
Overview of Research Activities

5. Bats (D. Sparks)
   - Mist-netting at 2 sites in each unit
   - From 2006-09, 475 bats of eight species captured including 16 Indiana bats
   - Acoustic sampling in each unit (total of 4,332 calls)



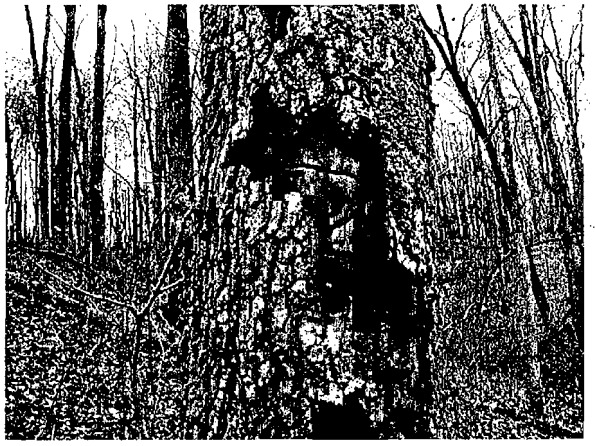
Overview of Research Activities

7. Salamanders (R. Williams)
   - 66 cover object grids sampled twice plus quadrat surveys sampled once
   - >12,000+ captures of six species over past 5 years

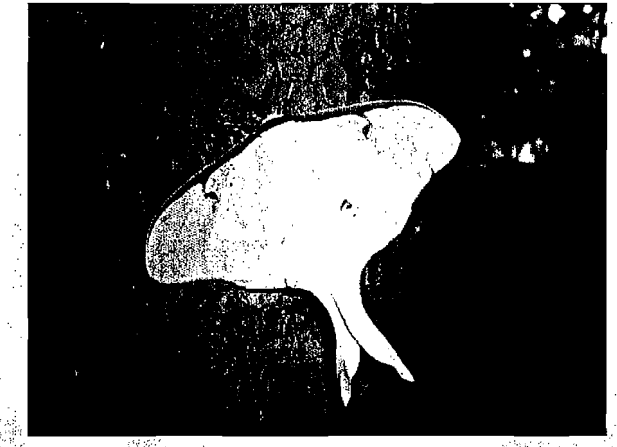


Overview of Research Activities

8. Wood-boring and longhorned beetles (J. Holland)
   - 36 trap arrays across 9 units
   - 4,249 individuals, representing 104 species captured from 2007-09



9. Moths (K. Summerville)
   - Intensive trap sample in 3 units only in 2008
   - >18,000 individuals captured, representing 324 species

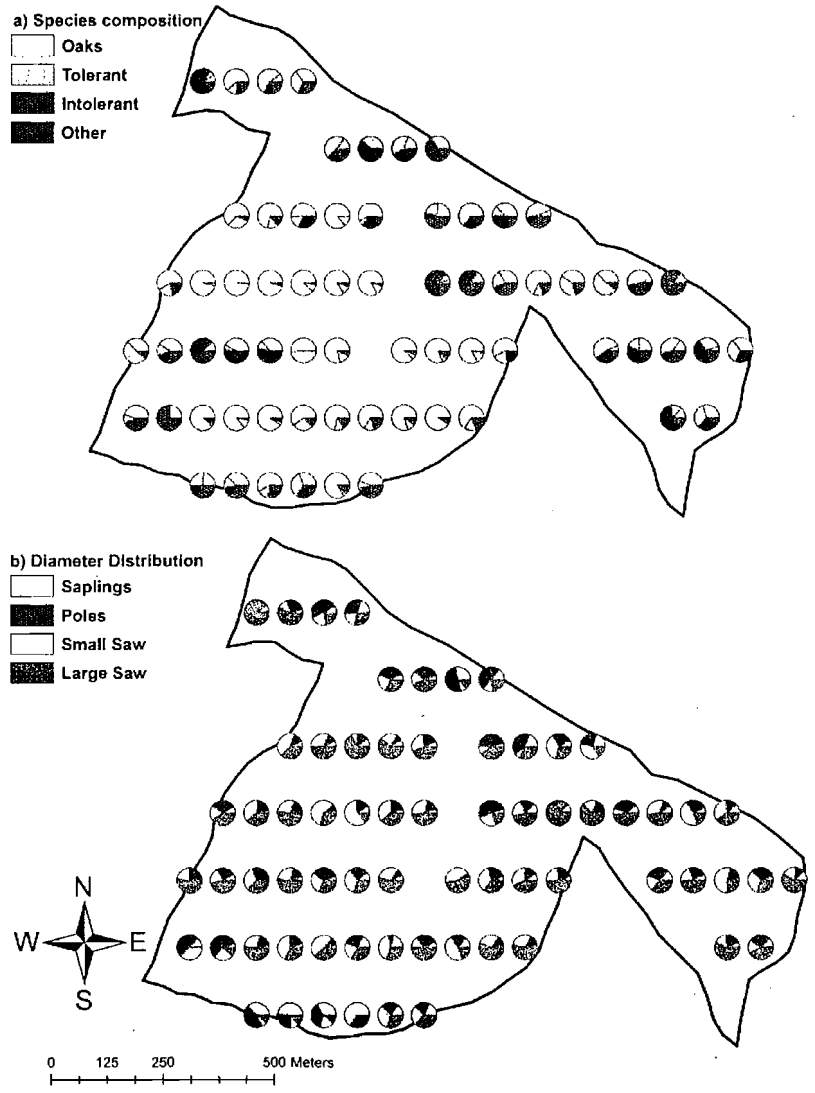


Overview of Research Activities

10. Oak Mast
    (R. Swihart & J. Riegel)
    - Traps on 108-112 trees with differing exclosures for different seed predators
    - Acorns x-rayed for weevil infestation (≈20-40%, depending on yr)
    - Mice are largest mast users, but variable by yr; deer have minimal effects

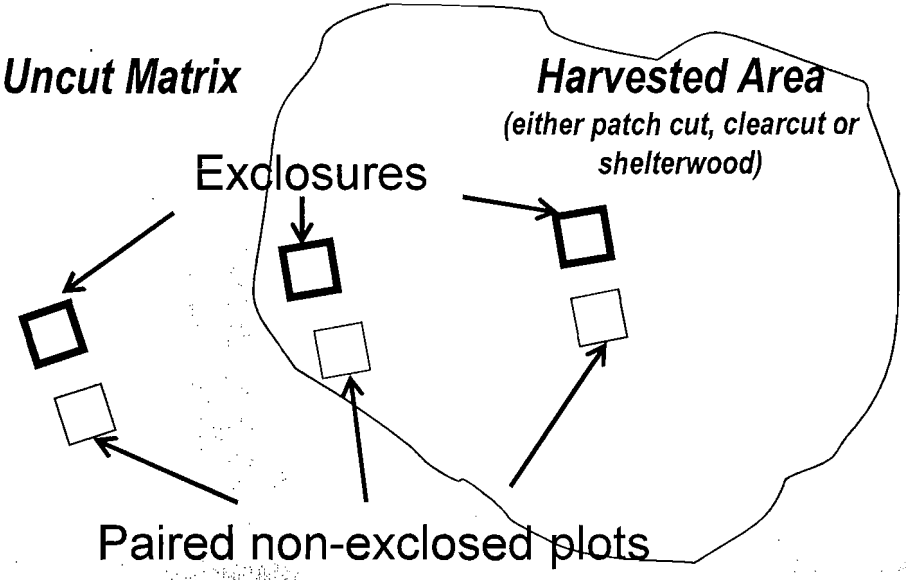
Overview of Research Activities

11. Structure & adv. regen. (M. Saunders)
    - 716 pts on grid across all 9 units
    - Stem-mapped
    - Pre-harvest inventory done
        - >37,000 trees
    - Post-harvest inventory in 2013



Overview of Research Activities

11. Deer impacts (S. Haulton, R. Swihart, M. Saunders)
    - 28 – 484 m^2 exclosures across all treatments
    - Nested exclosures within (like mast study)
    - Additional exclosures for sprouts
    - Follow 10+ years
    - Angie Shelton from IU starting using these exclosures this past summer.



Overview of Research Activities

12. Social values (B. Hoover)
    - Multiple surveys of local users and surrounding landowners
    - Higher stand density is more acceptable
        - People do not like clearcuts.

Your Views on Indiana Public Forests

The purpose of this questionnaire is to obtain information about your forest values and attitudes towards management of public forests. This questionnaire is part of a research project being conducted by the Department of Forestry and Natural Resources at Purdue University.

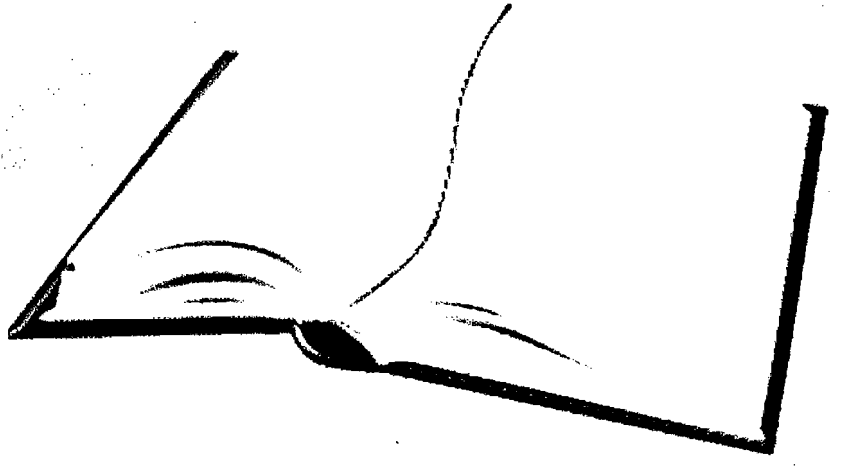
To help us understand the various opinions of outdoor recreationists, please take a moment to share your views. This questionnaire is voluntary and anonymous and will take approximately 15 minutes to complete.

No personal information will be collected, so **please do not write your name on the questionnaire.**

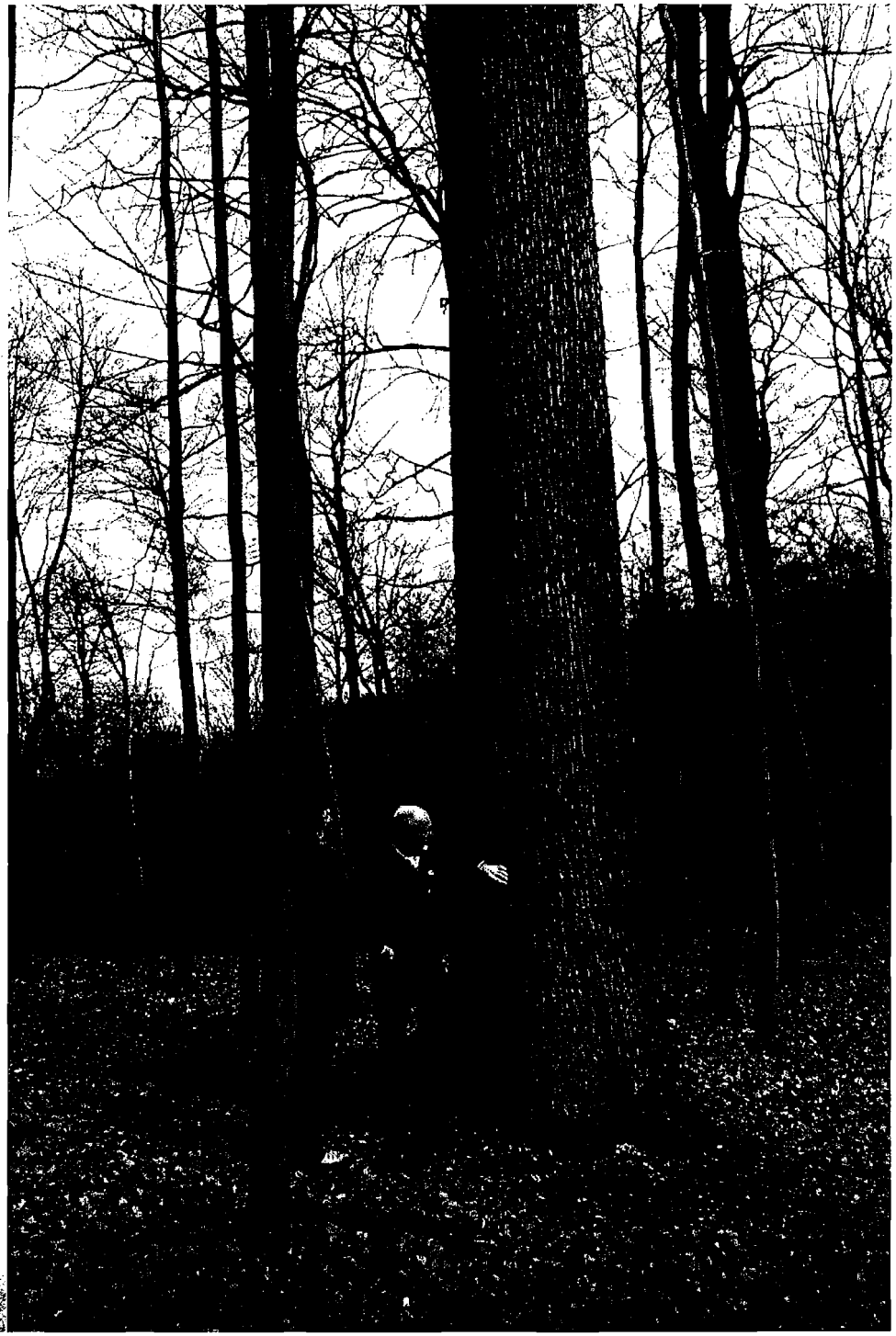
If you have questions or want further information, please contact Shannon Rogers at srogers@purdue.edu or Bill Hoover, Ph.D. at whoover@purdue.edu, (765) 494-3580.

Participants must be 18 years of age or older.

All pre-treatment data has been summarized in a USFS general technical report to be published in 2013.



Questions?



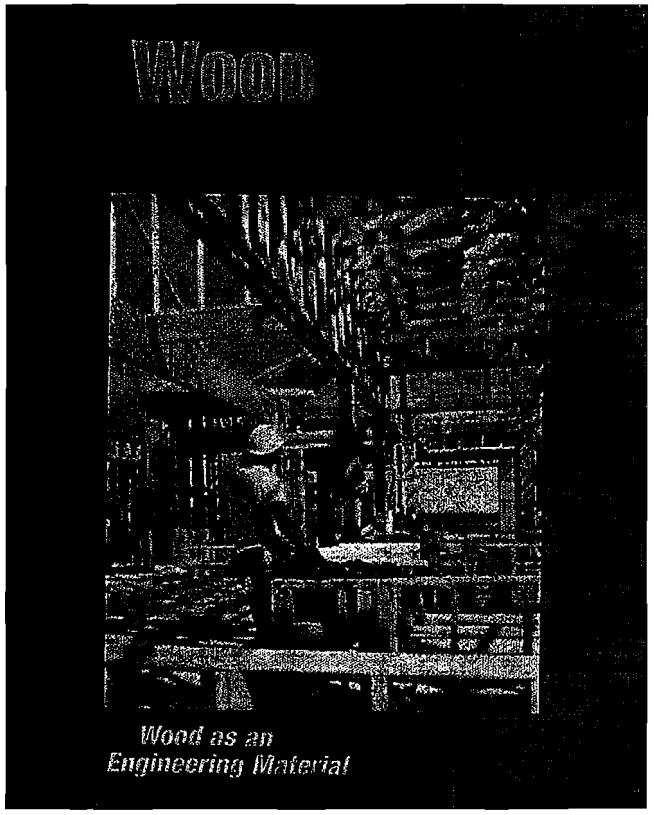
NRSC
Aug. 28 & 29, 2012
Exhibit # 16

Woody Biomass Project
for

Natural Resources Study Committees

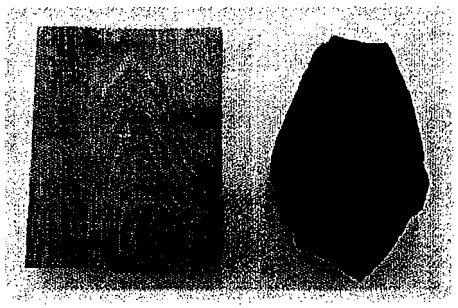
August 28-29, 2012
West Lafayette, Indiana

- Wood is very common material and timber is a very common resource but neither is well understood and emotions often overshadow science in timber harvesting.



Wood and Timber Facts (IN)

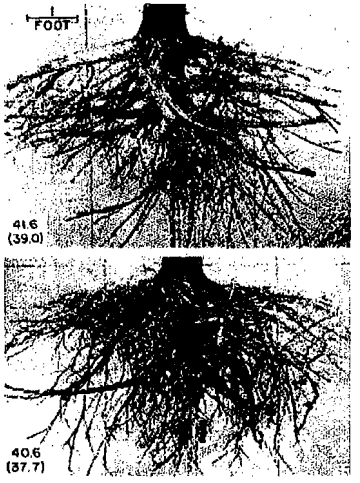
- 3.8 times more wood is being grown than removed
- 6th largest manufacturing industry is wood (hardwood lumber production is about 60% of its peak)
- 20% of the state land area is forested
- Nearly 50% of dry wood is carbon



- Carbon dioxide is the most abundant green house gas
- Wood contains no mercury or other heavy metals and very little sulfur
- Forest lands are also home to flora and fauna, provide clean water and air, and are used for recreation.

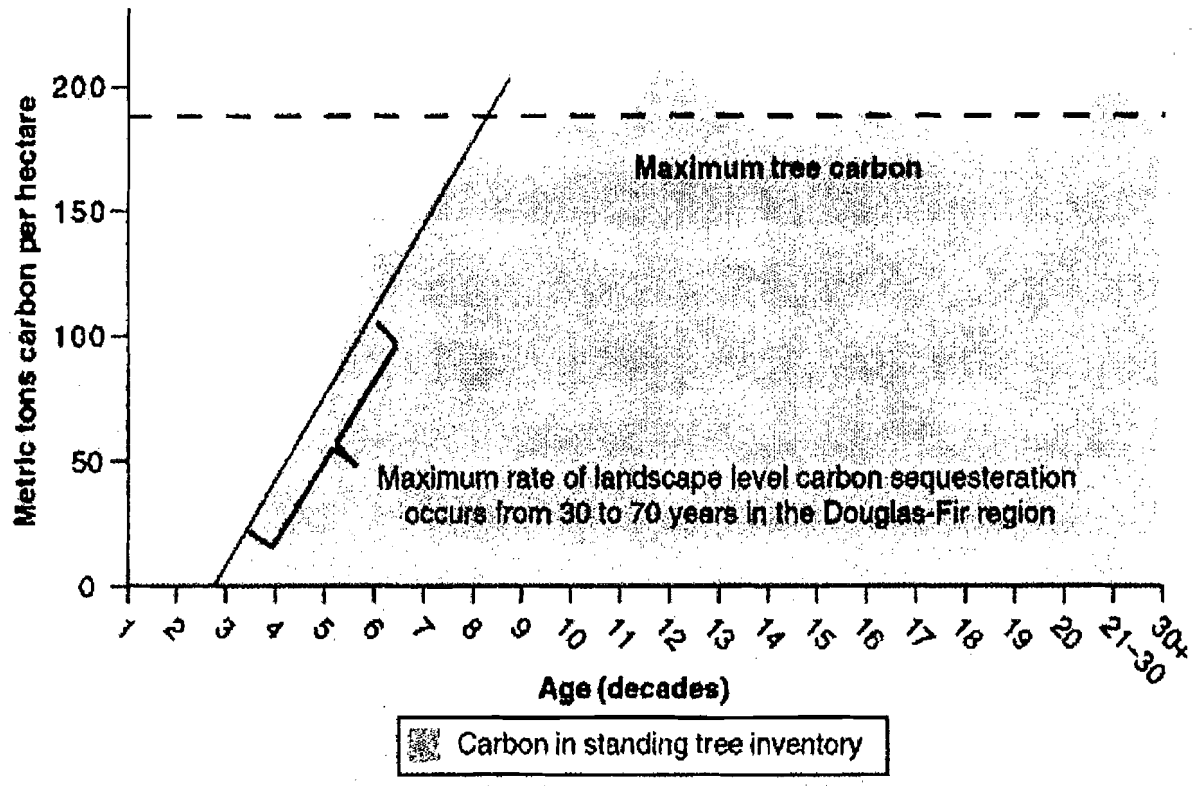
Wood as an Energy Source and as a Raw Material

- When wood is burned, carbon dioxide is released but unlike fossil fuels, this carbon is recaptured so long as the trees grow back.
- **In addition**, when products such as housing, furniture, etc. are made from wood, the carbon is permanently sequestered.
- **In addition**, the carbon from tree roots remains in the soil.



Impact of forest preservation on carbon storage

- Forest carbon growth rates slow with age
- Little or no increase in carbon storage when the forest reaches maturity.

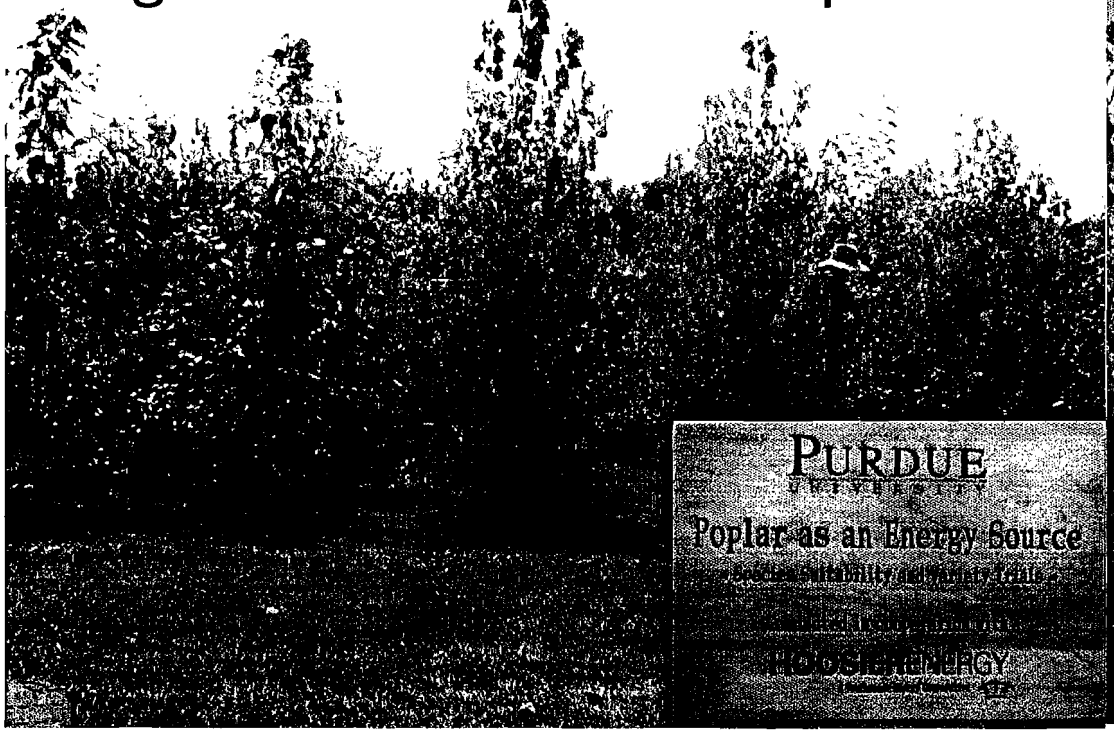


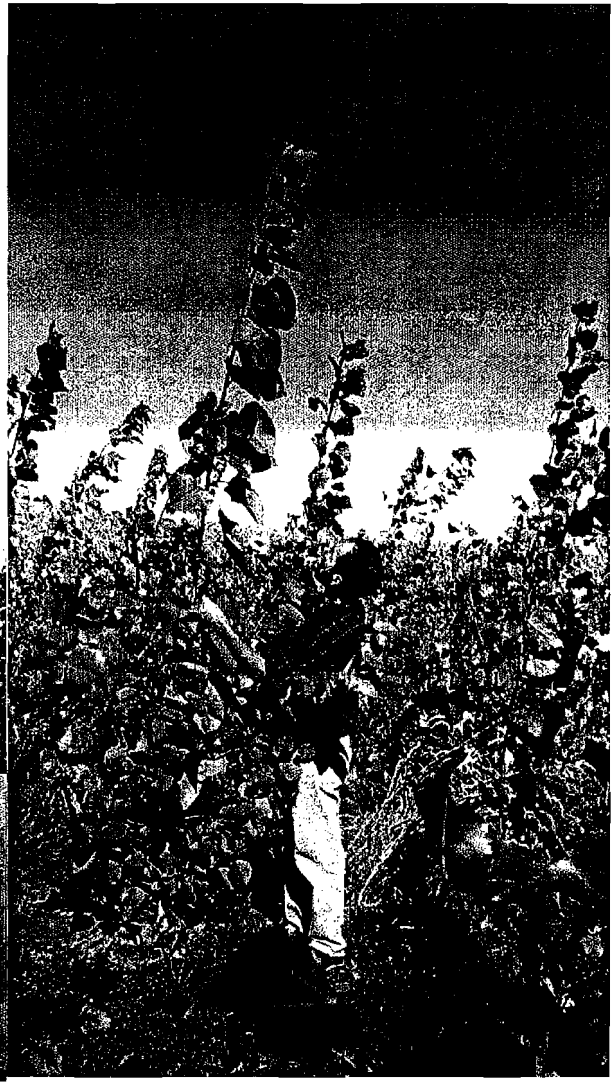
Data relates to Douglas-Fir in Western Washington. Bruce Lippke et al, 2011, drawing on US Forest Service Forest Inventory

Wood as an Energy Crop

- Hybrid poplar (cross between aspen and cottonwood)

  Can produce as much as other agricultural biomass crops





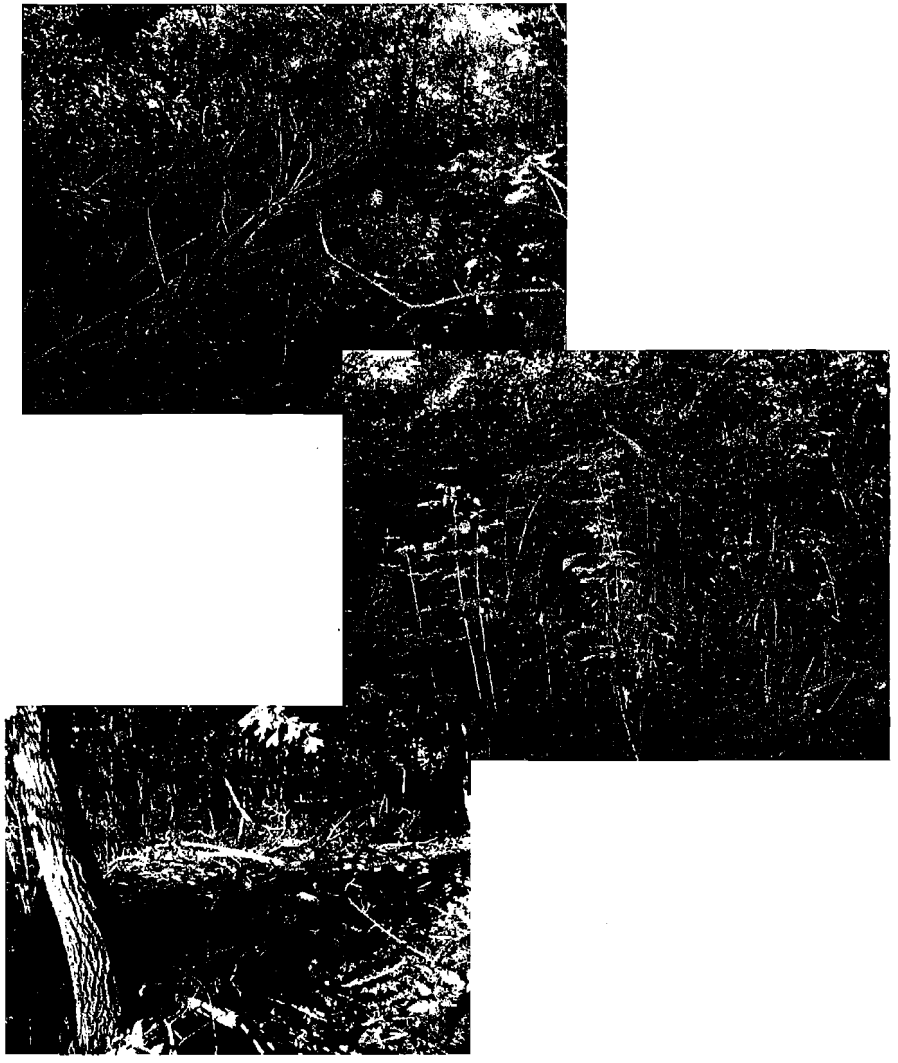
Wood Bio Energy in Indiana

- Need to protect high valued quality stands from harvesting damage
- Need to not jeopardize existing hardwood industry and current users of biomass (i.e. Koetter and Smith, Fiber By Products, Domtar Paper, etc.)
- Harvesting residues, non-merchantable timber, wood from abused sites, land clearing, urban wood, and demolition wood are possibilities
- Need to consider other forest attributes

Ecological Unknowns of Biomass Harvest

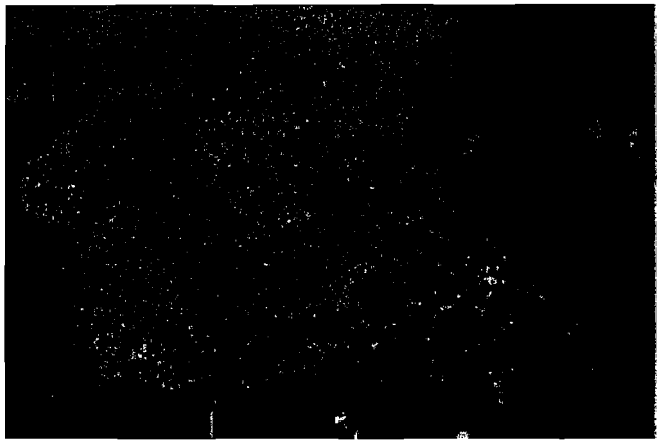
- Ecologists refer to the woody biomass on forest floor as "downed woody debris" or "coarse woody debris".

- It plays major ecological roles in healthy forests, for instance in nutrient cycling.

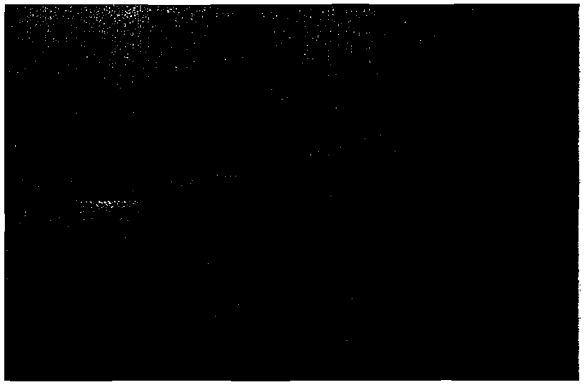


Ecological Unknowns of Biomass Harvest

- Most native forest organisms in Indiana respond primarily to the structure of the forest – not presence of certain plant species.

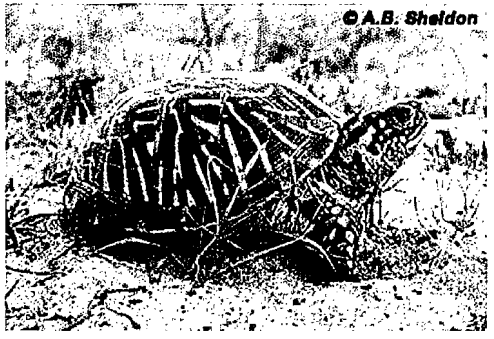


- Downed woody debris provides that structure.

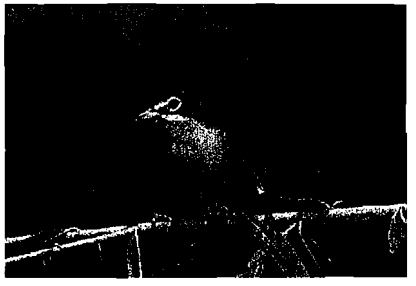


Ecological Unknowns of Biomass Harvest

- Many native animals depend on woody debris in our forests for nesting, feeding and protection from predators.



Timber harvest provides a “pulse” of change in this structure. How will animals respond to removal?



Woody Biomass in IN Program

Woody Biomass in Indiana

Clifty Falls State Park
Madison, Indiana

September 26-28, 2012

Wednesday, September 26, 2012 (Afternoon Concurrent Sessions)

- **Managing Central Hardwoods for Biomass Harvesting**
  Sponsored by Indiana Society of American Foresters
  Half-day session with invited speakers focusing on forest management issues. ... (includes break, dinner, and mixer)

- **Impact of Woody Biomass Harvesting on Wildlife Management**
  Sponsored by Indiana Chapter of the Wildlife Society
  Half-day session with invited speakers focusing on ecological sustainability of biomass harvesting, wildlife populations in intensively managed forests, and dead wood cycles in Indiana forests. (includes break, dinner, and mixer)

Thursday, September 27, 2012

- **Woody Biomass Use in Indiana**
  Sponsored by Purdue University
  Full-day session with invited speakers focusing on woody biomass and developments in the central states, economics and policy issues related to cellulosic biofuels, technology for harvesting and processing woody biomass, urban trees for mulch and energy, biodiversity impacts of biomass harvesting, poplar plantations as woody biomass and panel discussion... (includes breaks and buffet lunch)

Friday, September 28, 2012

- **Field Tour at SEPAC**
  Werner Logging of Jasper, Indiana

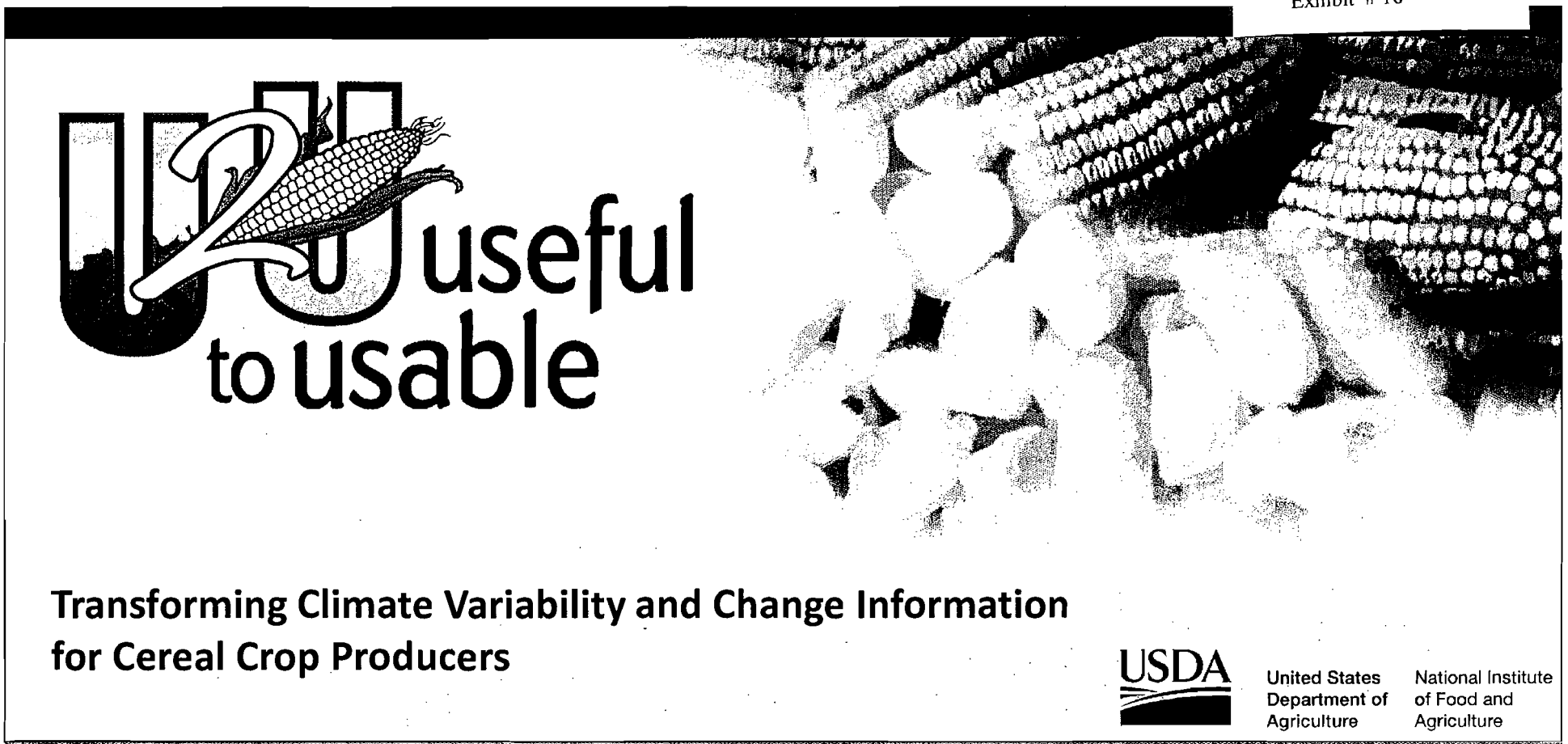
Sponsored By

- Purdue University, Department of Forestry and Natural Resources
- Indiana Society of American Foresters
- Indiana Wildlife Society

In Cooperation with

- Indiana Biomass Working Group
- Renewable Resources Extension Act (RREA)
- HTIRC
- Indiana Hardwood Lumbermen's Association

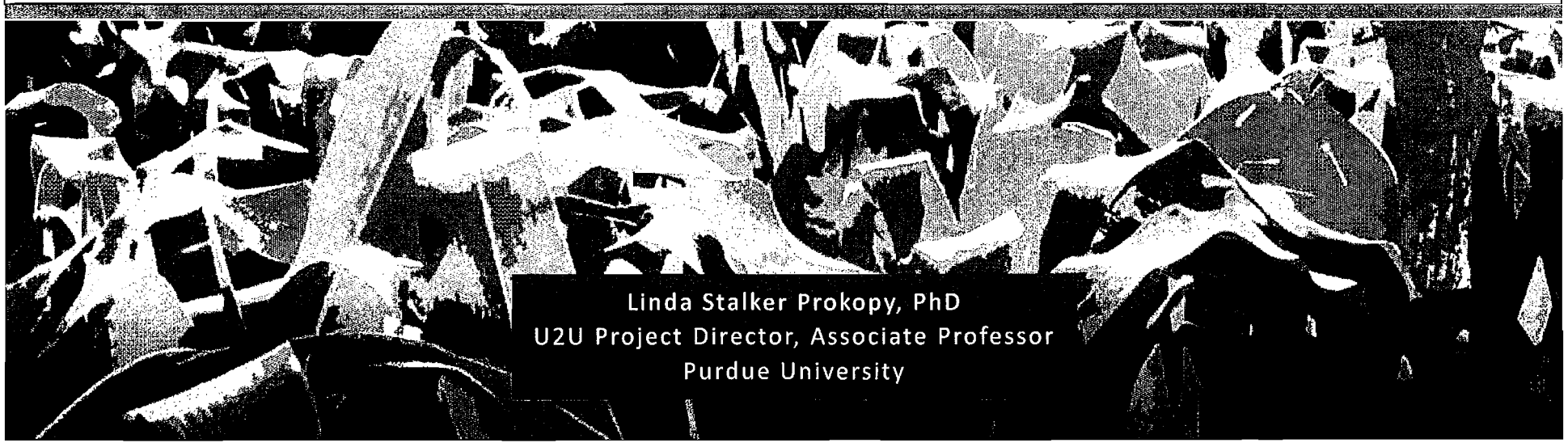
NRSC
Aug. 28 & 29, 2012
Exhibit # 18



Transforming Climate Variability and Change Information for Cereal Crop Producers

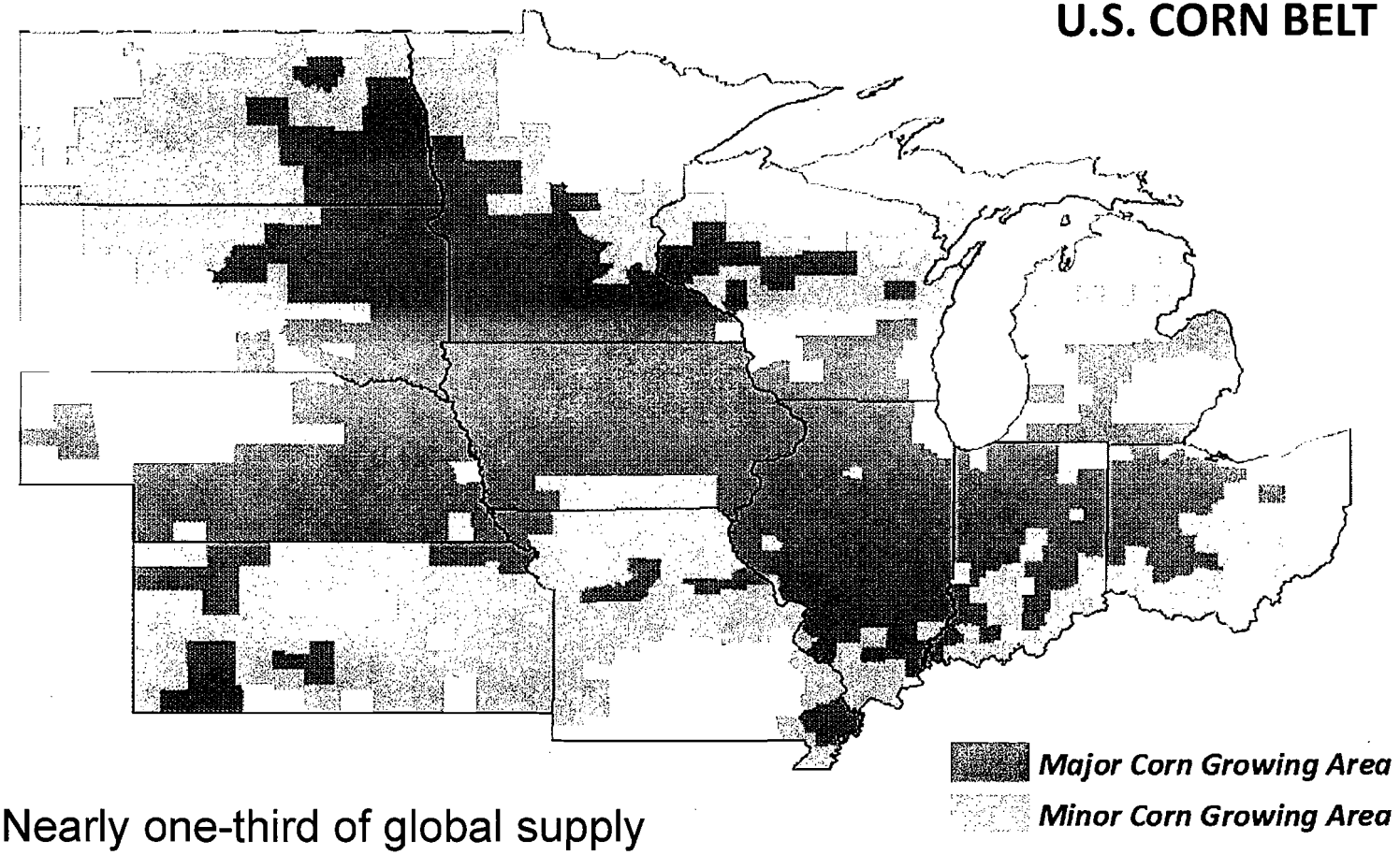
USDA United States Department of Agriculture

National Institute of Food and Agriculture



Linda Stalker Prokopy, PhD
U2U Project Director, Associate Professor
Purdue University

U.S. CORN BELT



- Nearly one-third of global supply
- Over $100B to US economy

U.S. Drought Monitor

North Central States

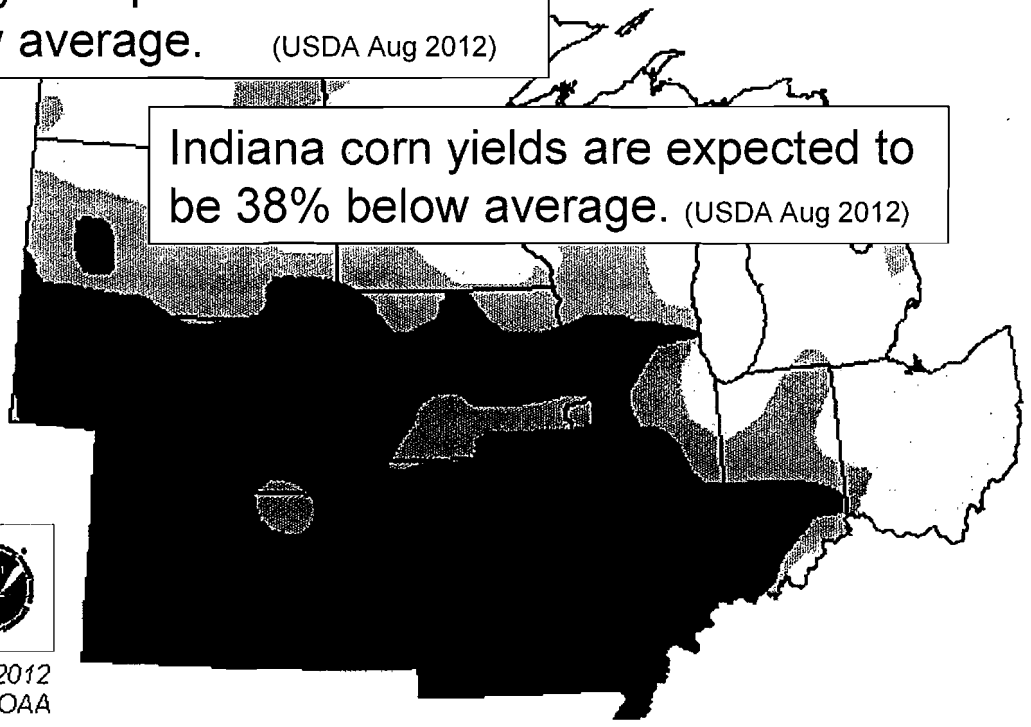
August 21, 2012

U.S. Corn yields predicted to be 22% below average. (USDA Aug 2012)

Indiana corn yields are expected to be 38% below average. (USDA Aug 2012)

Intensity:

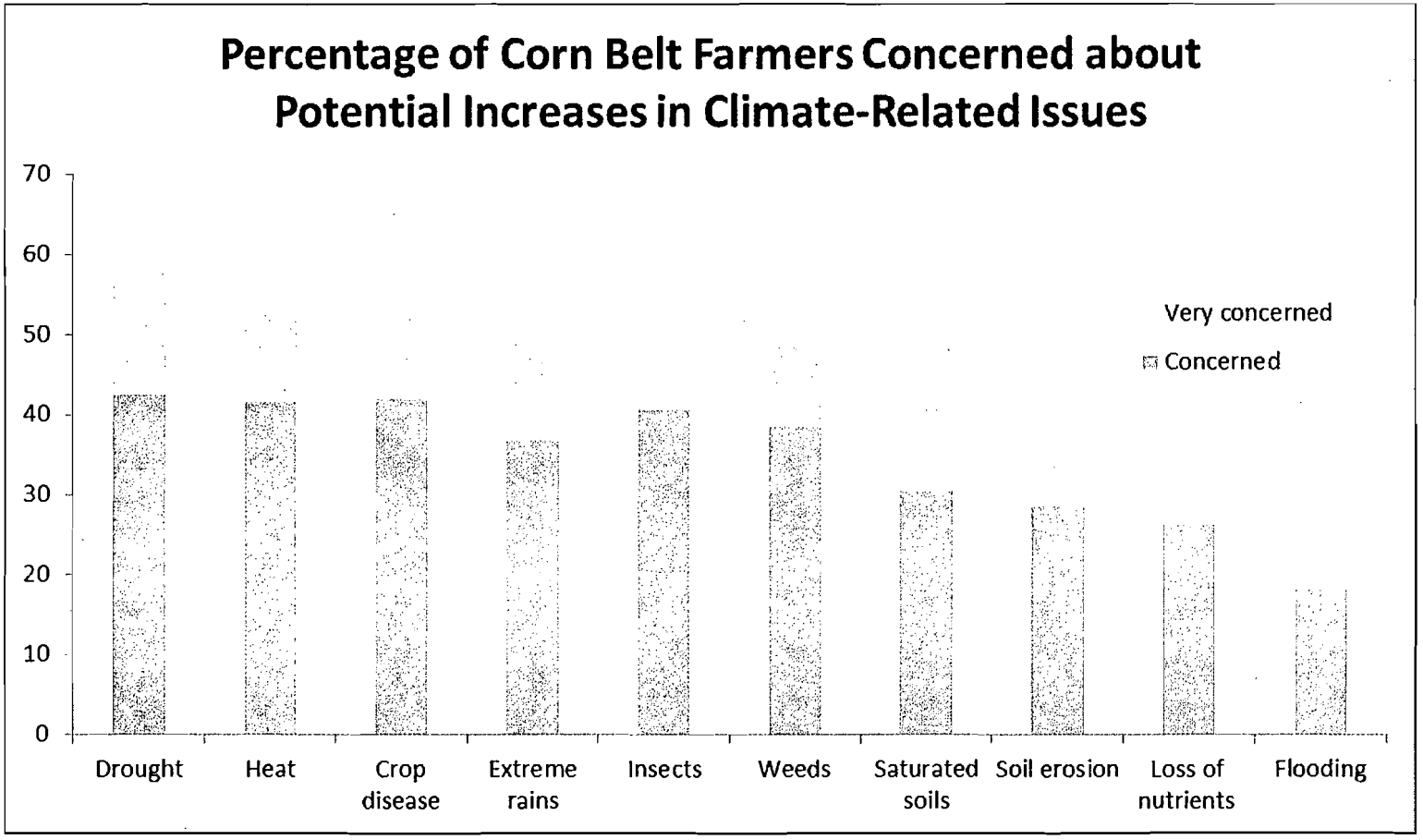
- D0 - Abnormally Dry
- D1 - Drought Moderate
- D2 - Drought Severe
- D3 - Drought Extreme
- D4 - Drought Exceptional



USDA

Released Thursday, August 23, 2012
Michael Brewer, National Climatic Data Center, NOAA

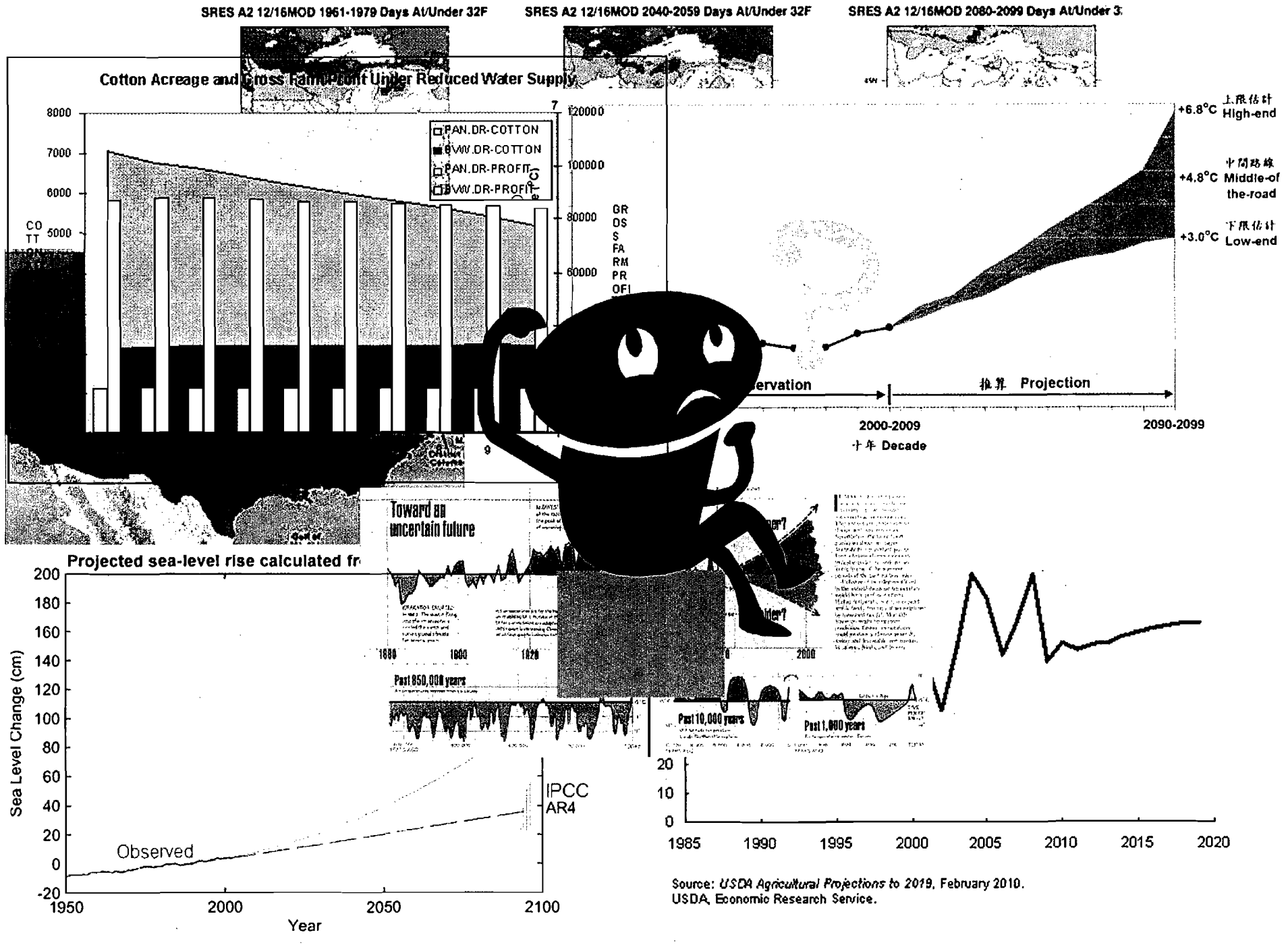
Farmers are concerned about climate impacts



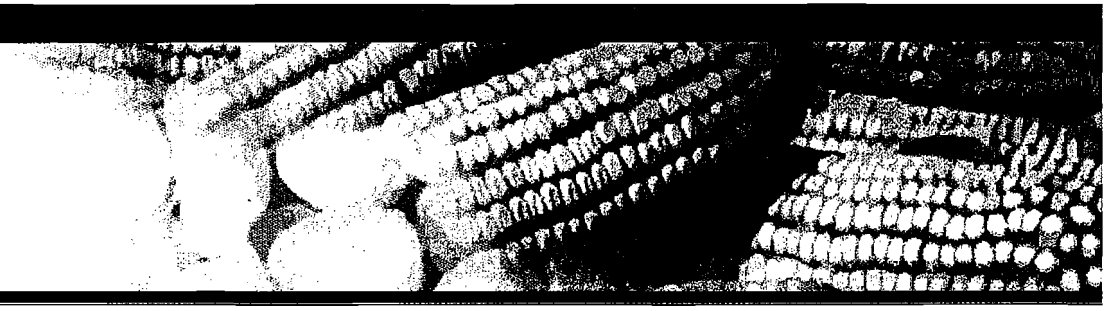
* Based on a survey of 4,778 Corn Belt farmers in Feb-Mar 2012

Agriculture and Climate Change

- Corn Belt crop production highly dependent on favorable temperatures and appropriate precipitation patterns
- Climate variability limits season-to-season predictability and lessens ability to maintain viable farm operations
- Producers need enhanced information for decision making


SRES A2 12/16MOD 1961-1979 Days At/Under 32F
SRES A2 12/16MOD 2040-2059 Days At/Under 32F
SRES A2 12/16MOD 2080-2099 Days At/Under 3
Cotton Acreage and Gross Farm Profit Under Reduced Water Supply
PAN.DR-COTTON
BVW.DR-COTTON
PAN.DR-PROFIT
BVW.DR-PROFIT
+6.8°C 上限估計 High-end
+4.8°C 中間路線 Middle-of the-road
+3.0°C 下限估計 Low-end
推算 Projection
2000-2009
2090-2099
十年 Decade
Toward an uncertain future
Past 850,000 years
Past 10,000 years
Past 1,000 years
Projected sea-level rise calculated fr
Sea Level Change (cm)
Observed
IPCC AR4
Year
Source: USDA Agricultural Projections to 2019, February 2010.
USDA, Economic Research Service.

U2U Vision



- Transform existing climate information into usable knowledge for agricultural decision making
- Give farmers the resources and training to more effectively manage variable climate conditions
- Increase Extension capacity to address agro-climate needs

More resilient and profitable farms in a changing climate

Collaborators

State climatologists

Crop modelers

Agronomists

Economists

Social scientists

RCC staff

MICHIGAN STATE UNIVERSITY

UNIVERSITY OF Nebraska Lincoln

PURDUE UNIVERSITY

UW Extension Cooperative Extension

ILLINOIS

HIGH PLAINS REGIONAL CLIMATE CENTER

MRCC Midwestern Regional Climate Center

IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY

National Drought Mitigation Center

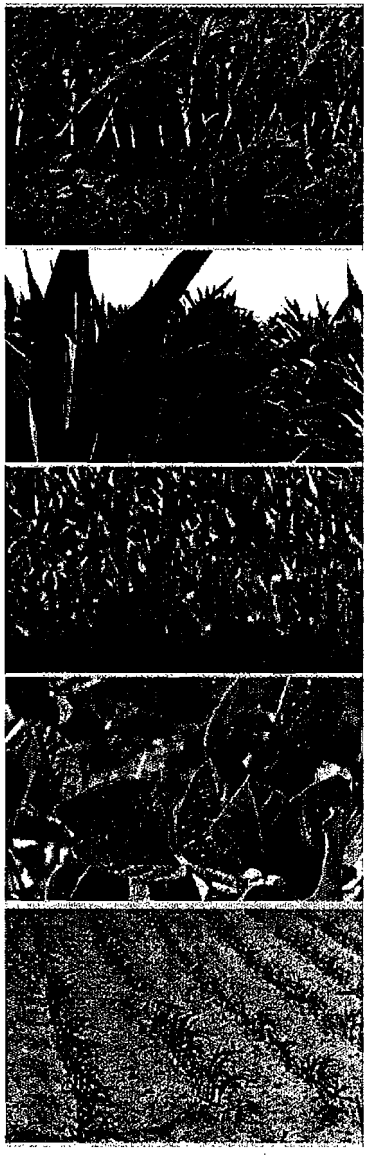
MICHIGAN

Objectives – Five Year Plan (2011-2016)

1. Examine impacts of past/future climate on crop productivity and implications for farm management
2. Understand stakeholder needs
3. Design decision support tools and prepare training materials and delivery approaches
4. Pilot test tools, methods and outreach
5. Disseminate across 12 state region

Not clear yet what resources will be needed!

Key Issues



Examine the financial, production, and environmental outcomes of short-term management decisions and long-term investment planning under different climate scenarios.

Impact/interaction of weather and climate on:

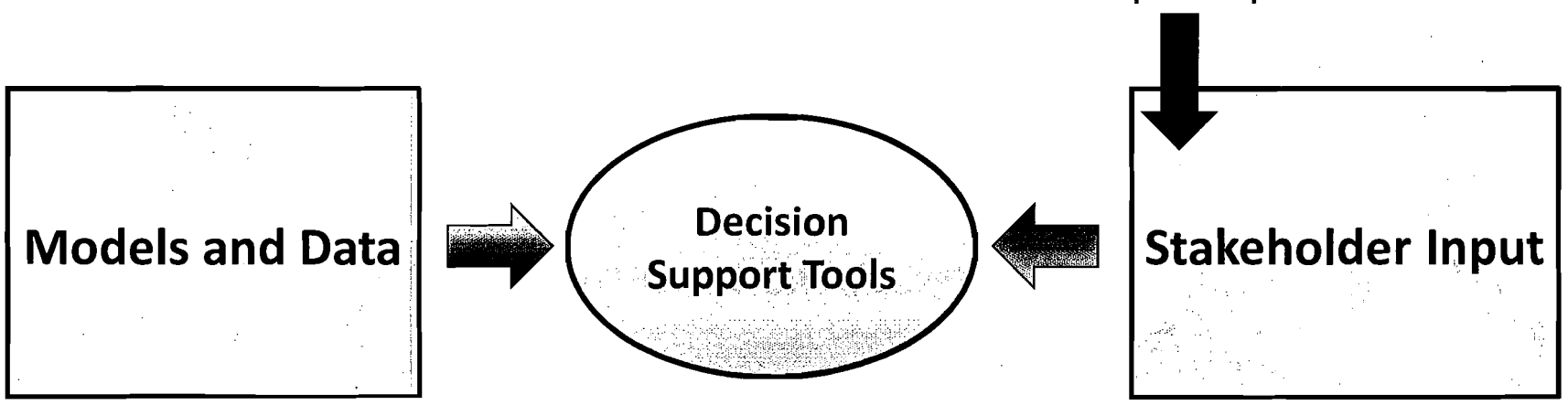
- Spatial and temporal variability of yields
- Nitrogen management
- Fieldwork opportunities
- Planting date
- End of season crop dry-down rates
- Cost effectiveness of irrigation and tiling

Informed by Stakeholders

Current Work

- Model the impact of climate and farm management on crop productivity and profits
  - Using past and future climate scenarios
- Understand beliefs and concerns about climate change and willingness to use climate information
  - Surveys of farmers and advisor groups

- Critical to building usable tools
- Unique aspect of U2U



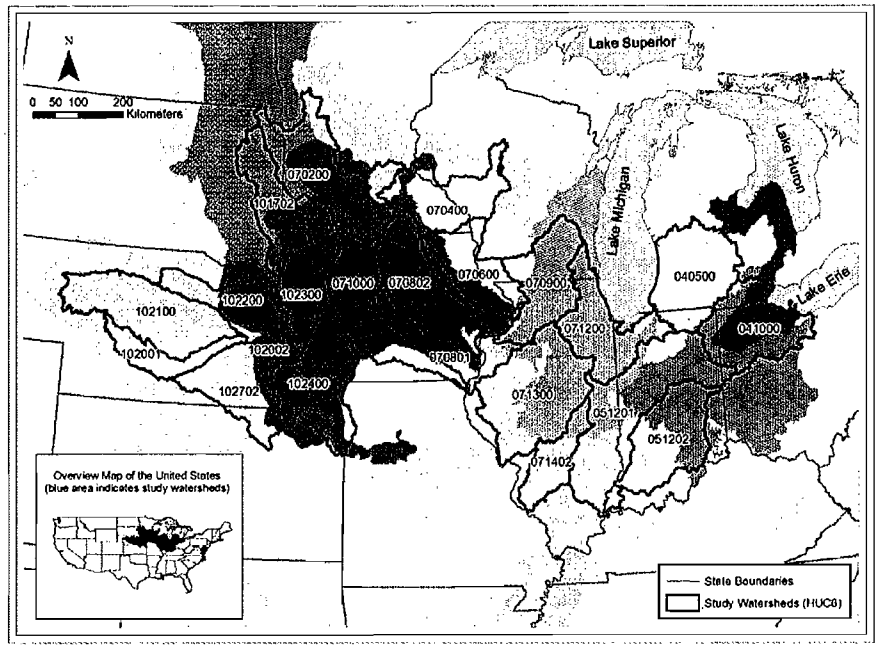
Climate Needs Assessment Surveys

Producer Survey

- CS-CAP partnership
- +19,000 farmers, 22 HUC6 watersheds
- 60% of US corn production

Advisor Survey

- 8,000+ advisors
- Crop consultants, Extension, bankers, agro-business, state and federal, etc.
  - Extension in all 12 states
  - Other types in IA, IN, MI, and NE



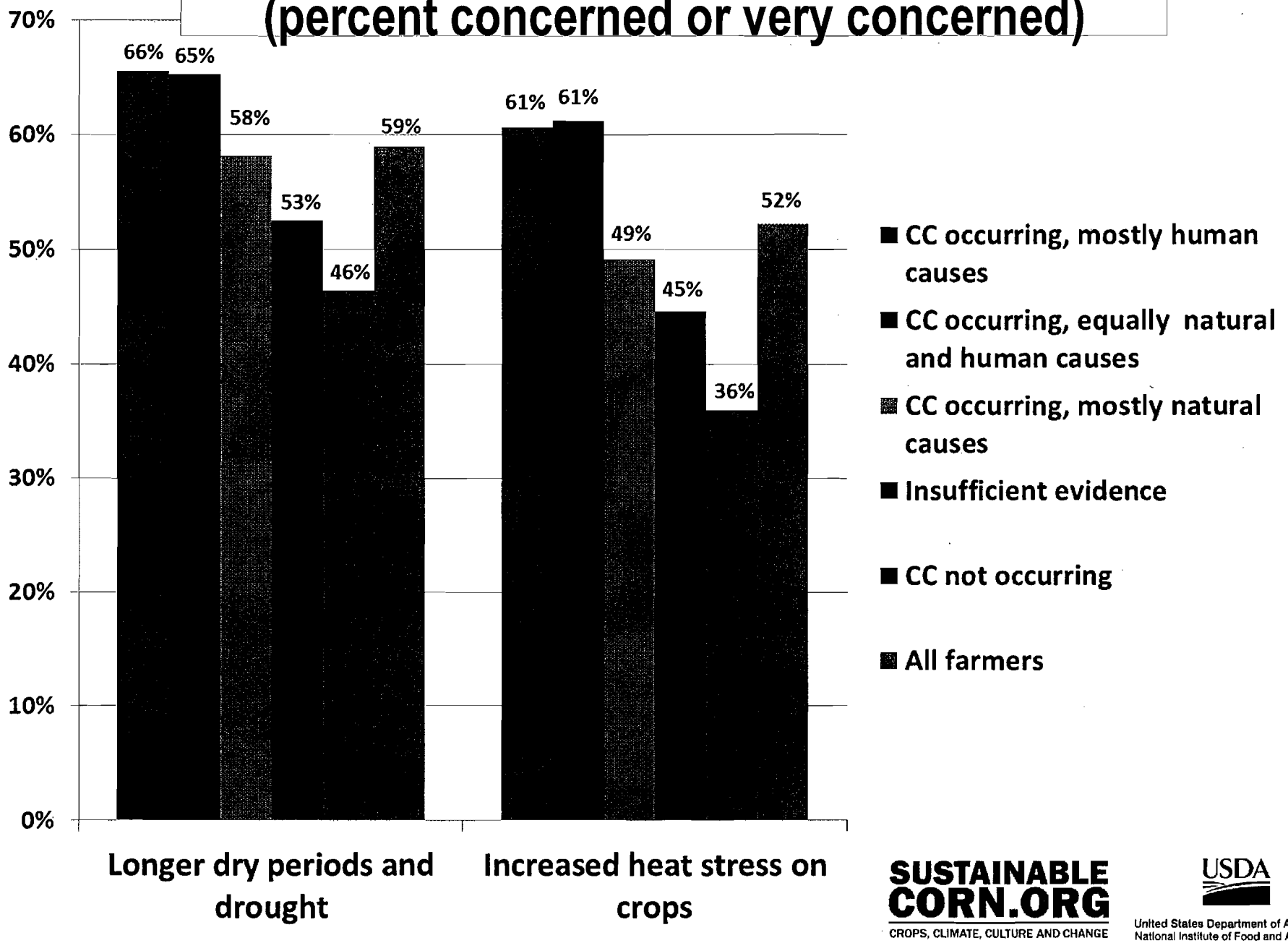
Questions:

- Use of weather/climate information
- Risk management strategies
- Climate change concerns and beliefs
- Influential information sources

"There is increasing discussion about climate change and its potential impacts. Please select the statement that best reflects your beliefs about climate change:"

	Producers	Advisors
Climate change is occurring, and it is caused mostly by human activities	8%	12.6%
Climate change is occurring, and it is caused equally by natural changes in the environment and human activities	33%	37%
Climate change is occurring, and it is caused mostly by natural changes in the environment	25%	24.9%
There is not sufficient evidence to know with certainty whether climate change is occurring or not	31%	23.3%
Climate change is not occurring	4%	2.3%

Concerns about Drought and Heat (percent concerned or very concerned)



SUSTAINABLE CORN.ORG
CROPS, CLIMATE, CULTURE AND CHANGE

USDA
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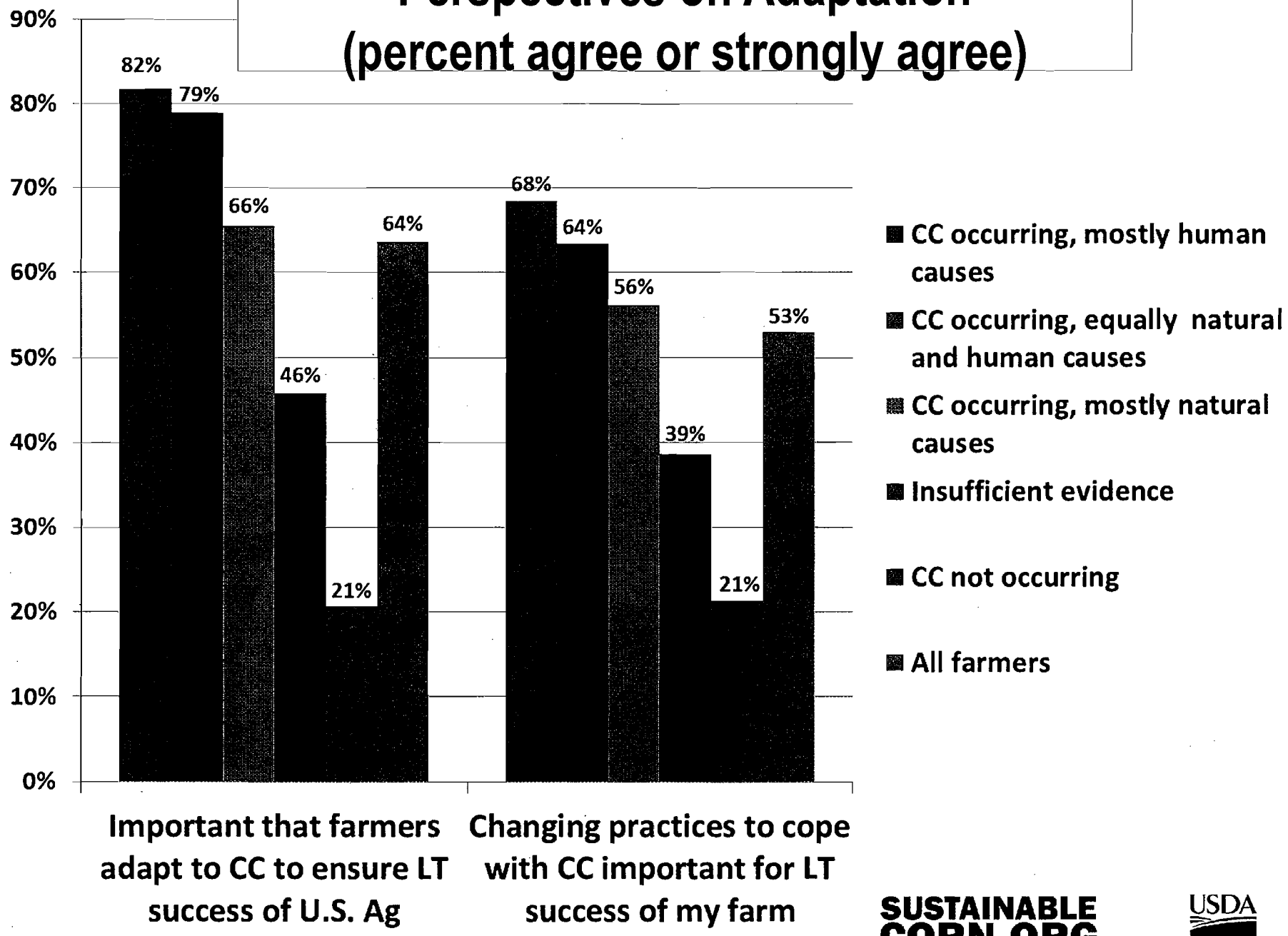
National Institute of Food and Agriculture

Perspectives on Adaptation (percent agree or strongly agree)



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USDA
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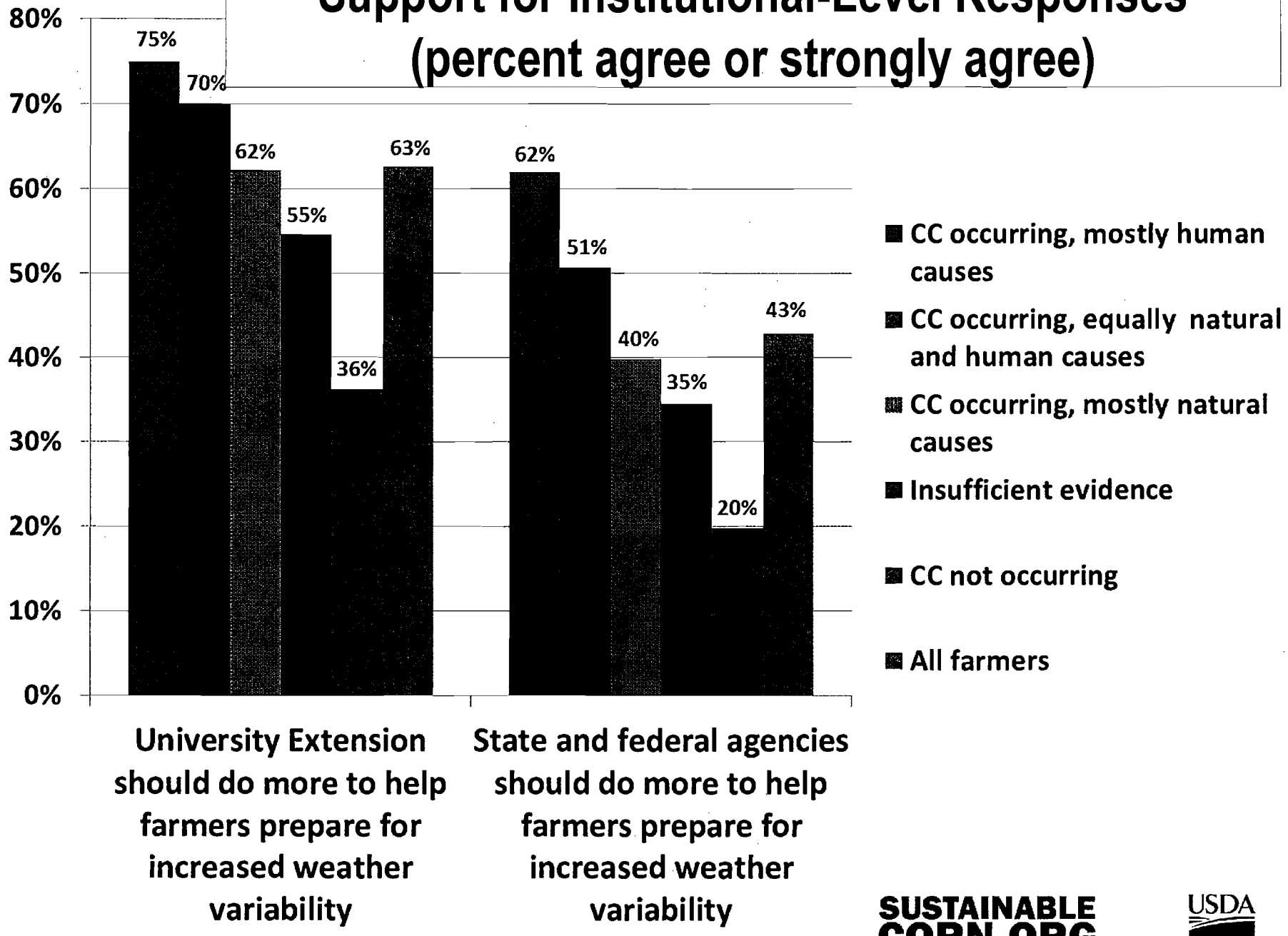
Support for Institutional-Level Responses (percent agree or strongly agree)



SUSTAINABLE CORN.ORG
CROPS, CLIMATE, CULTURE AND CHANGE

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

Why it Matters

- Climate change beliefs influence…
  - Perceived risk of climate impacts (drought, floods, etc.)
  - Willingness to use climate tools and information
  - Risk management roles, responsibilities, and beliefs
  - Trusted information sources

We need to recognize and respond to these differences in our tools, training, and communication!

U2U Next Steps

- Develop decision tools and resources, iterative approach
  - Focus groups will involve stakeholders
- Dissemination
  - Understand how information flows through agricultural communities
  - Build interactive information delivery system
  - Training for Extension, farmers, etc.
- Evaluation
  - Ensure effectiveness of tools and outreach
- Continue building partnerships
  - Increase Extension capacity
  - Longevity of decision tools

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- PUBLICATIONS AND PRESENTATIONS
- ADVISORY COMMITTEE
- TEAM
- FUNDING
- CONTACT US
- INFORMATION FOR PROJECT PERSONNEL
- DIRECT LINK TO DATA

USDA United States Department of Agriculture National Institute of Food and Agriculture

Useful to Usable (U2U): Transforming Climate Variability and Change Information for Cereal Crop Producers

Introduction

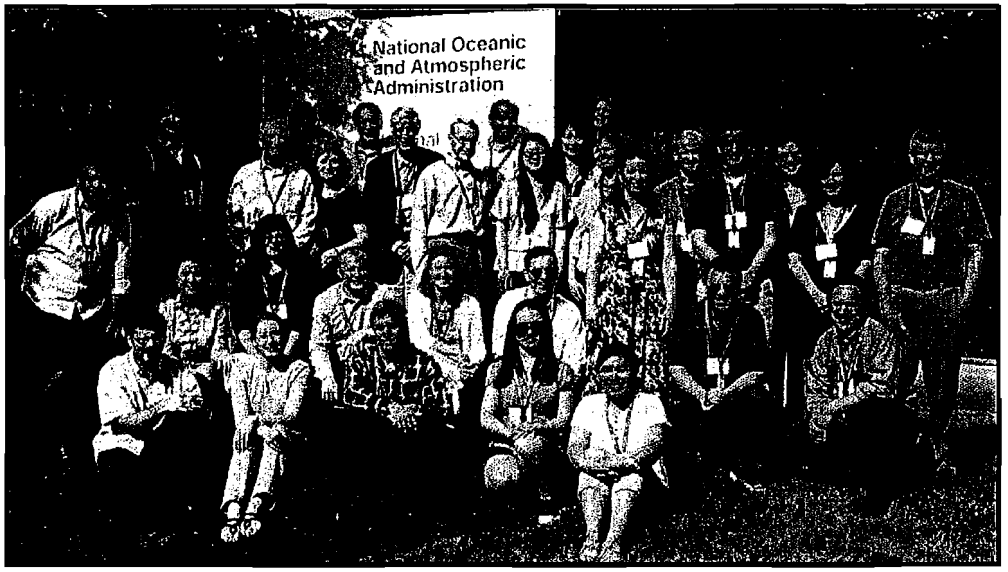
Weather and climate patterns are a driving force behind the success or failure of cropping systems. With U.S. corn and soybean production accounting for nearly one-third of global supplies and contributing $100 billion annually to the national economy, the ability to successfully produce crops under more variable climate conditions is critical.

Useful to Usable (U2U): Transforming Climate Variability and Change Information for Cereal Crop Producers, is an integrated research and extension project working to improve farm resilience and profitability in the North Central Region by transforming existing climate information into usable knowledge for the agricultural community. Our goal is to help producers make better long-term plans on what, when and where to plant, and also how to manage crops for maximum yields and minimum environmental damage.

Objectives

1. Use existing data and models to better understand the contributions of anomalous weather to crop variability and implications for future management options.
2. Understand the use and value of climate information for agricultural decision making, and determine effective methods for disseminating usable climate knowledge.
3. Develop tools, training materials, and implementation approaches that lead to more effective decision making and the adoptions of climate-resilient farm practices.
4. Evaluate the effectiveness of decision support tools and materials in four pilot states, refining resources as needed based on stakeholder feedback.

Thank you!



Purdue University: Linda Prokopy (Lead), Corinne Alexander, Larry Biehl, Otto Doering, Bruce Erickson, Ani Elias, Sajeeve E.M., Patrick Freeland, Ben Gramig, Olivia Kellner, Xing Liu, Amber Mase, Dev Niyogi, Paul Preckel, Carol Song, Melissa Widhalm, Lan Zhao

Iowa State University: Roger Elmore, Chad Hart, Jean McGuire, Lois Wright Morton, Gene Takle, Adam Wilke

Michigan State University: Gopal Alagarswamy, Jeff Andresen, Jim Hilker

South Dakota State University: Dennis Todey

University of Illinois: Jim Angel, Beth Hall, Steve Hilberg, Atul Jain

University of Michigan: Maria Lemos, Yun-Jia Lo

University of Minnesota: Tom Bartholomay, Whitney Meridith

University of Missouri: Pat Guinan, Ray Massey

University of Nebraska-Lincoln: Juliana Dai, Tonya Haigh, Cody Knutson, Tapan Pathak, Martha Shulski

University of Wisconsin: Tom Blewett, Rebecca Power, John Kriva

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