LARGE FLOODPLAIN RIVER RESTORATION: LESSONS FROM THE UPPER MISSISSIPPI RIVER

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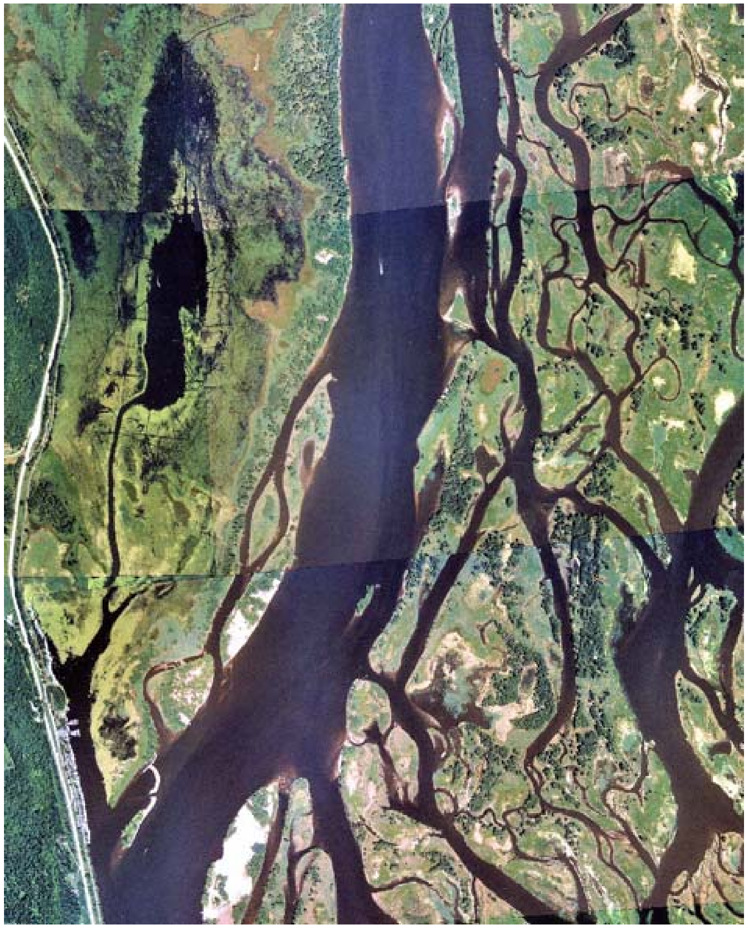
Outline

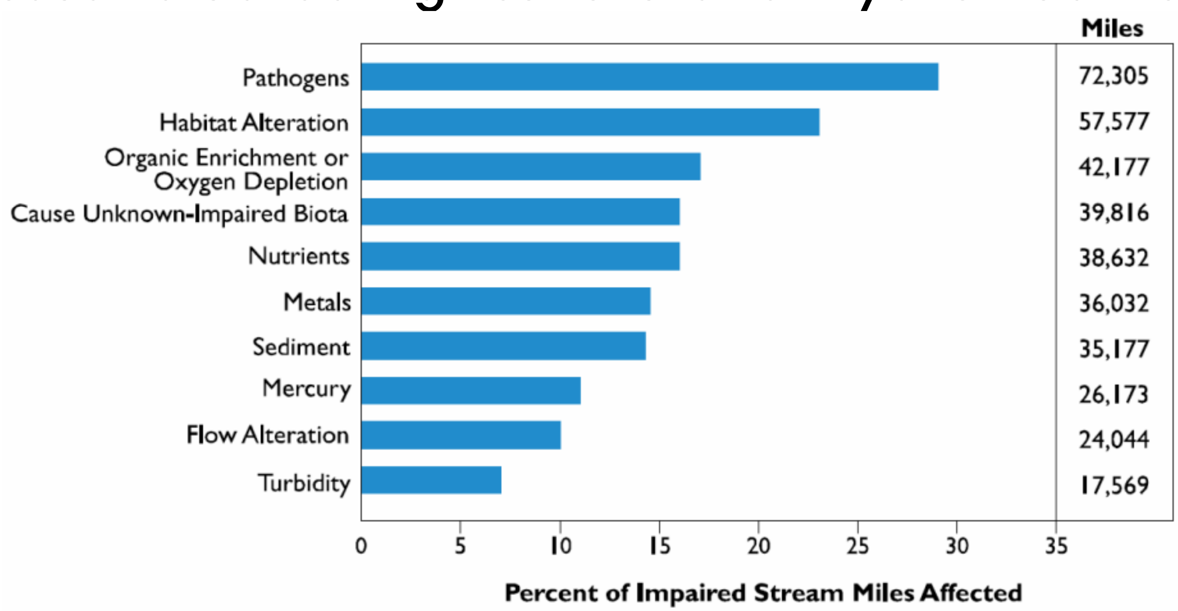
- Overview of river/stream restoration
- What is a large river and how it works
- The case for large river restoration
- 5-minute break
- Past and ongoing restoration efforts
- Discussion



Stream/River Degradation

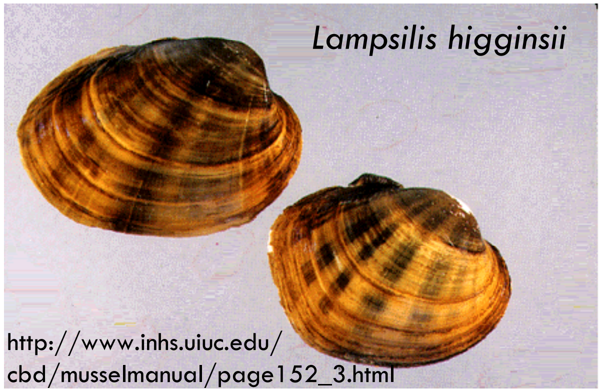
Stream and River Quality is Declining

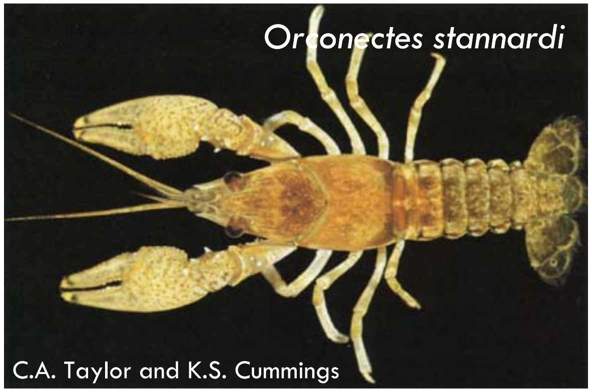
- Clean Water Act 1972
  - Mostly addressed point sources
- 44% of assessed rivers in the U.S. are listed as impaired or polluted (2004 EPA National Water Quality Inventory)
  - Causes listed as Agriculture and Hydromodification



Stream and River Quality is Declining

- Extinction rates of North American freshwater fauna are five times that for terrestrial biota
  - Estimated at 4% per year
  - Same rate as tropical forest deforestation
- Mussel, Crayfish, and Amphibian diversity projected to be most affected





Ricciardi, A., and J.B. Rasmussen. 1999. Extinction rates of North American freshwater fauna. Conserv. Biol. 13: 1220-1222.

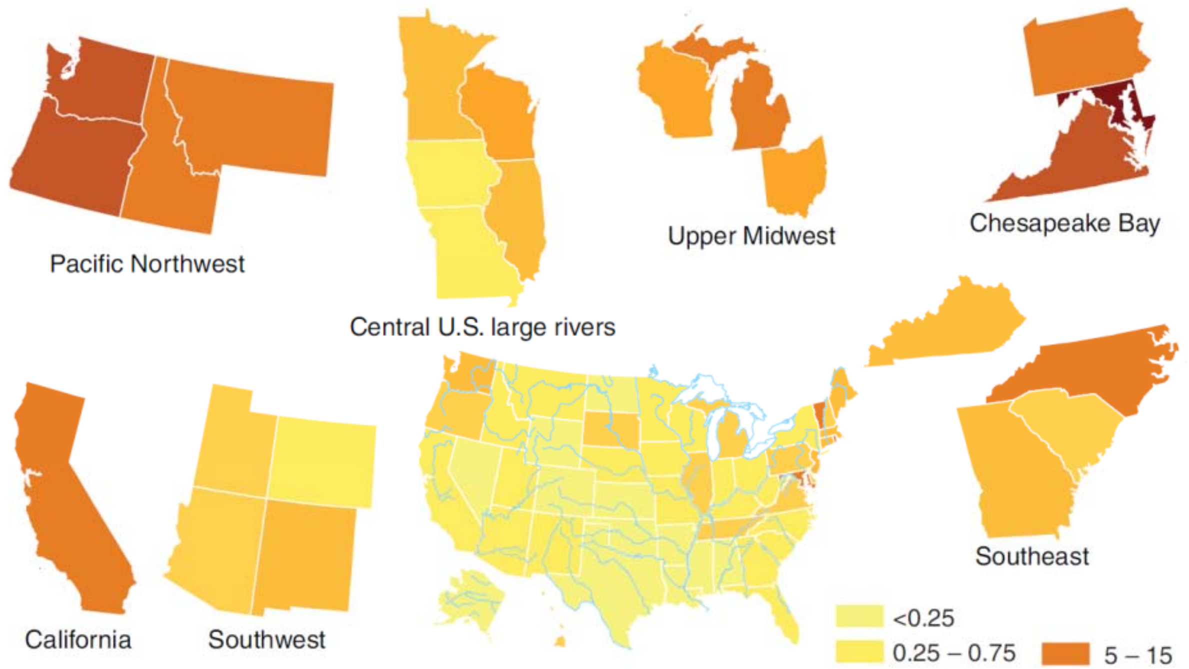
River Restoration: a necessity, not a luxury

- Margaret Palmer

Image Credit: USDA NRCS

River Restorations in the United States

- Tens of thousands of restoration projects in the past couple of decades
  - >$15 Billion since 1990



Project density (no. of projects per 1000 river km) from national coverage databases only versus in-depth regional project record summaries (all data sources) [table S1 (*17*) part h].

Bernhardt, E.S. and 22 others. 2005. Restoration of U.S. Rivers: A National Synthesis. *Science. 308: 636–637*

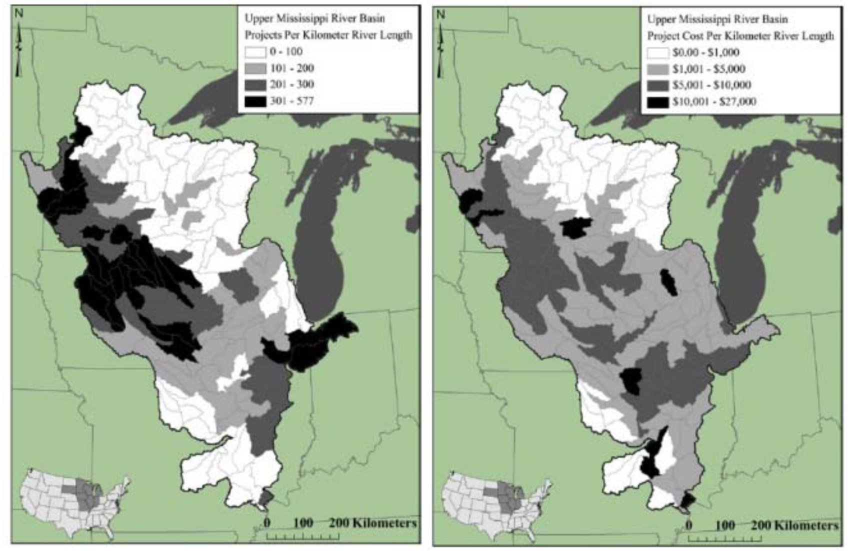
River Restorations in the United States

- Most commonly stated goals for river restoration in the U.S.
  - Enhance water quality
  - Manage riparian zones
  - Improve in-stream habitat
  - Fish passage
  - Bank stabilization
- Mostly small projects
  - <$45,000
  - <1 km of stream length

Bernhardt, E.S. and 22 others. 2005. Restoration of U.S. Rivers: A National Synthesis. *Science. 308: 636–637*

UMR Basin Restoration: Number, Cost, and Type 1972-2006

- Total river "enhancement" projects on navigated and non-navigated rivers: 62,108
- Total project spending: $1.6 billion
- Water quality management most common project goal
- Navigable River projects:
  - Creation/enhancement of floodplain wetlands (mainly USDA Wetland Reserve projects)
  - Flow regime management
  - Dredging



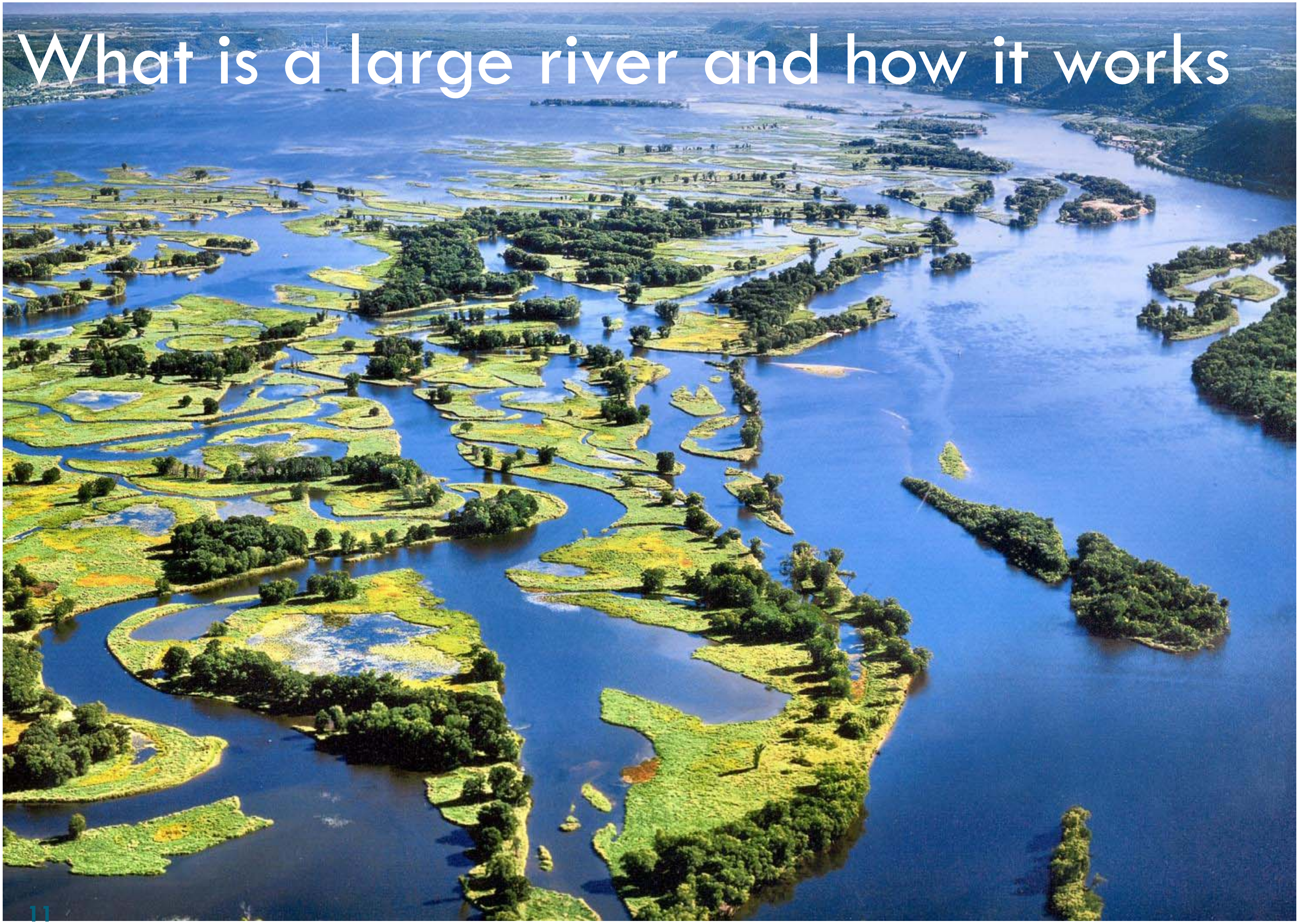
O'Donnell and Galat. 2007. River enhancement in the UMR Basin: approaches based on river uses, alterations, and management agencies. Restor. Ecol. 15: 538-549

Five criteria for ecological success

1. A guiding image exists: A dynamic ecological endpoint is identified *a priori* and used to guide the restoration
2. Ecosystems are improved: The ecological conditions of the river are measurably enhanced
3. Resilience is increased: The river ecosystem is more self-sustaining than prior to the restoration
4. No lasting harm is done: Implementing the restoration does not inflict irreparable harm
5. Ecological assessment is completed: Some level of both pre- and post-project assessment is conducted and the information is made available

Palmer, M.A. and 22 others. 2005. Standards for Ecologically Successful River Restoration. *Journal of Applied Ecology. 42:* 208–217.

What is a large river and how it works



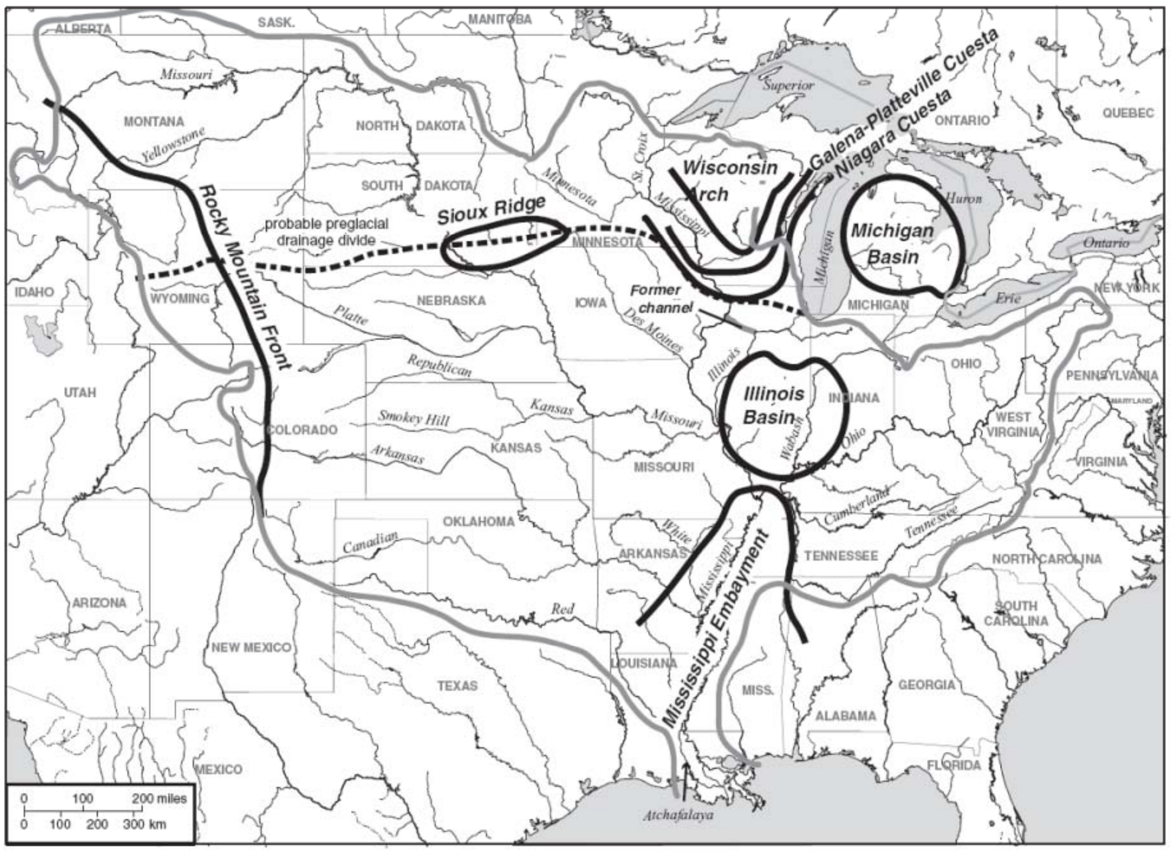
Upper Mississippi River, Lower Navigation Pool 8 (Photo: Robert Hurt)

Upper Mississippi River Basin

- Modern Mississippi River Basin Drains >3.2 million km^2, 41% of lower 48 and small part of Canada
- Upper Mississippi River Basin accounts for 16.5% of total watershed

Major Structural Features

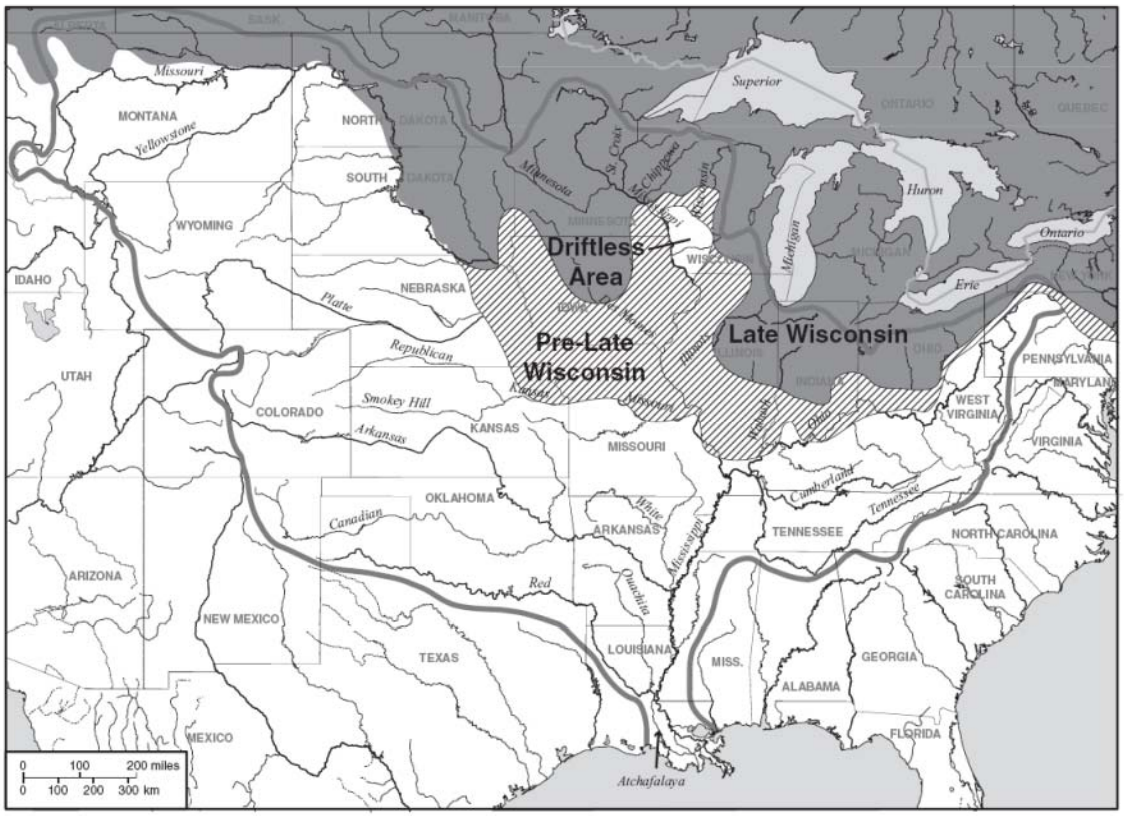
- Pre-glacial drainage divide of Mississippi Basin may have been Niagaran cuesta
- Drainage of pro-glacial lakes cut channel across resistant bedrock cuestas 2.5-3 mya
- Mississippi River now flows through narrow gorges in Pools 10-12



Knox, 2007

Quaternary Age Glaciations

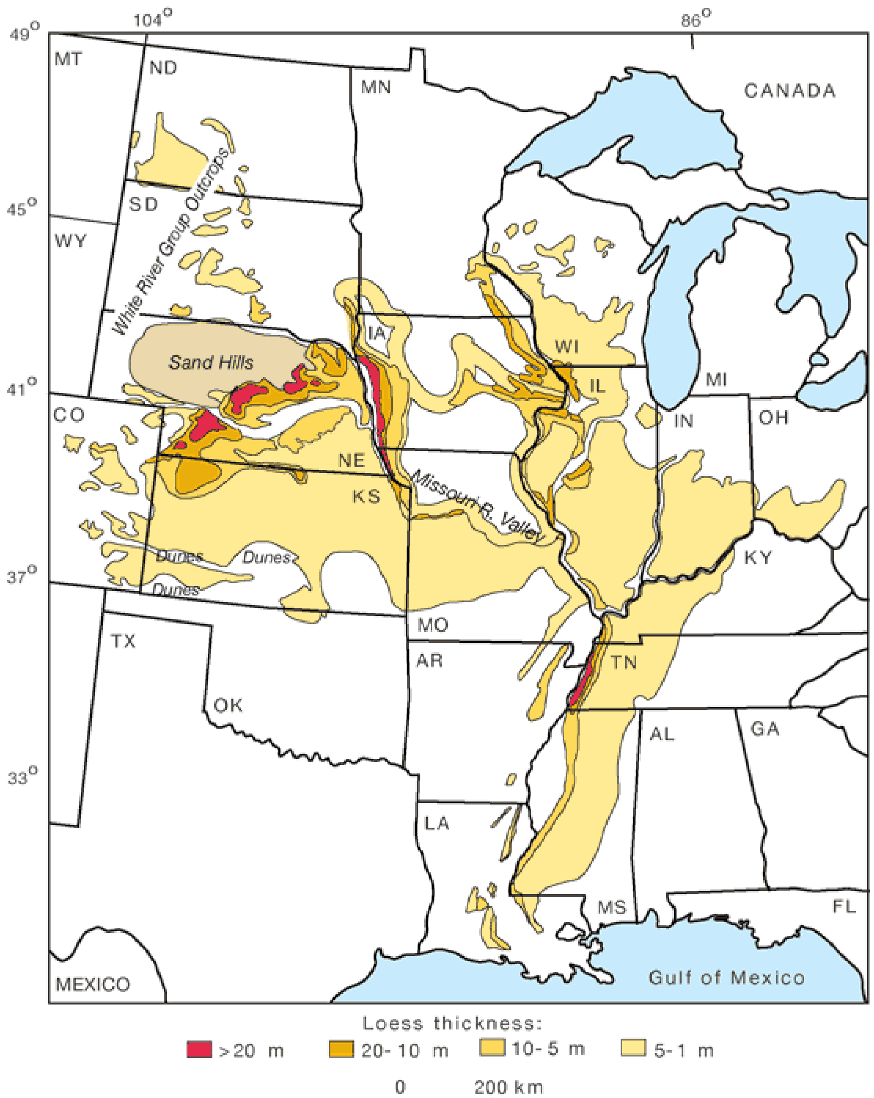
- Repeated glaciations over past 2.5 to 3 million years
- 25 kya ice re-advanced into Mississippi Basin, causing massive floodplain aggradation
- Drainage of pro-glacial lakes and low sediment concentrations caused episodes of incision
- Post-glacial Mississippi aggradation averaged 0.09 cm/yr from re-worked tributary fill



Knox, 2007

Loess Cover

Peoria Loess Thickness (Mason et al., 2006)



- Loess → wind-blown silt
- >65% silt
- Very easily eroded
- High suspended load in Mississippi River after natural vegetation cover disturbed

Pre-1850 Vegetation Cover

- Pre-European-American settlement vegetation in Driftless Area dominated by Oak Savanna, Prairie, and Southern Upland Forest → high surface cover

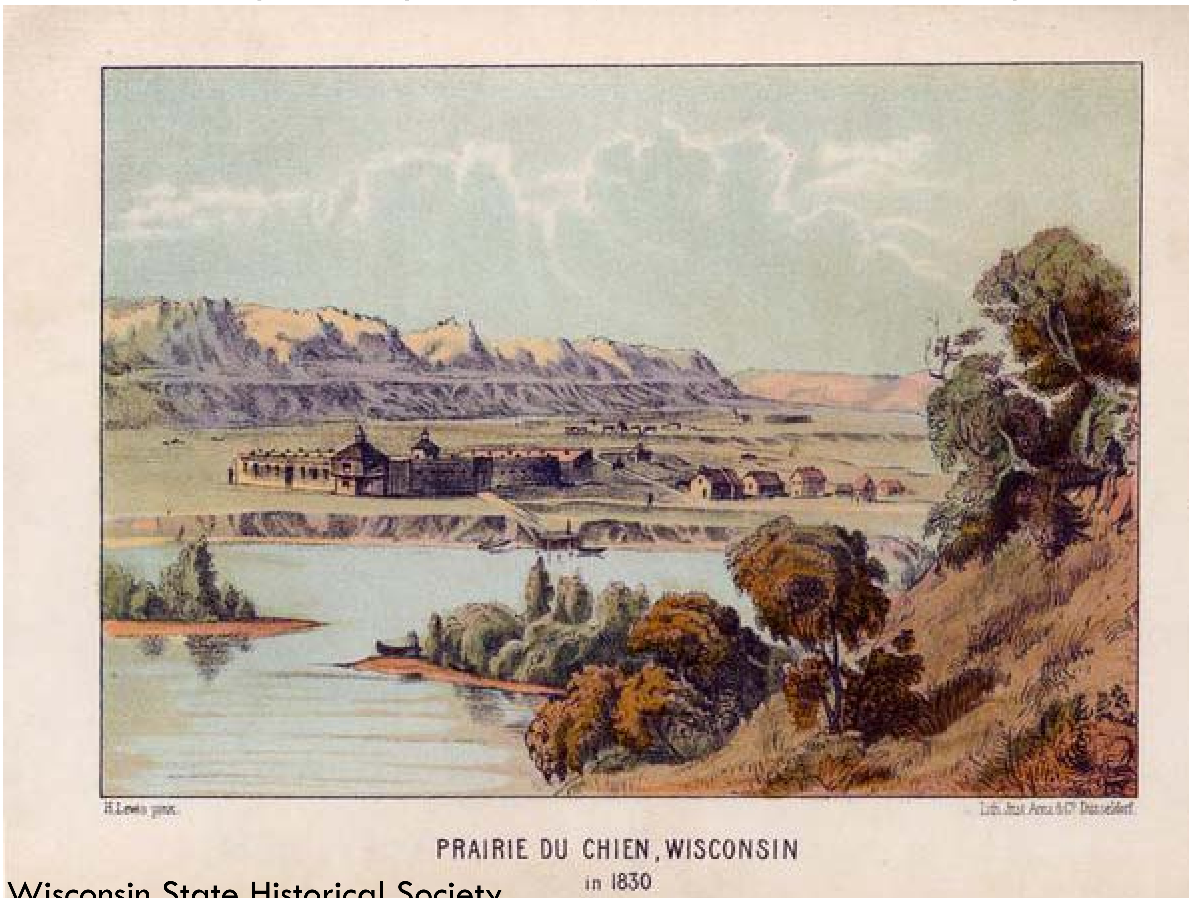
Oak Savanna

Pleasant Valley Conservancy

Southern Upland Forest

Pre-1850 Mississippi River

- "…I would mention the important fact that there is but very little material in suspension in the waters of the upper Mississippi. What material there is in motion is dragged by the current along the bottom….No rapid filling up by deposition takes place, as it does in muddy rivers….chutes for long years filled up at their head remain below nearly as deep as ever" (G.K. Warren, 1867 as quoted in Knox, 2006).



Wisconsin State Historical Society

Land Cover/Use Change

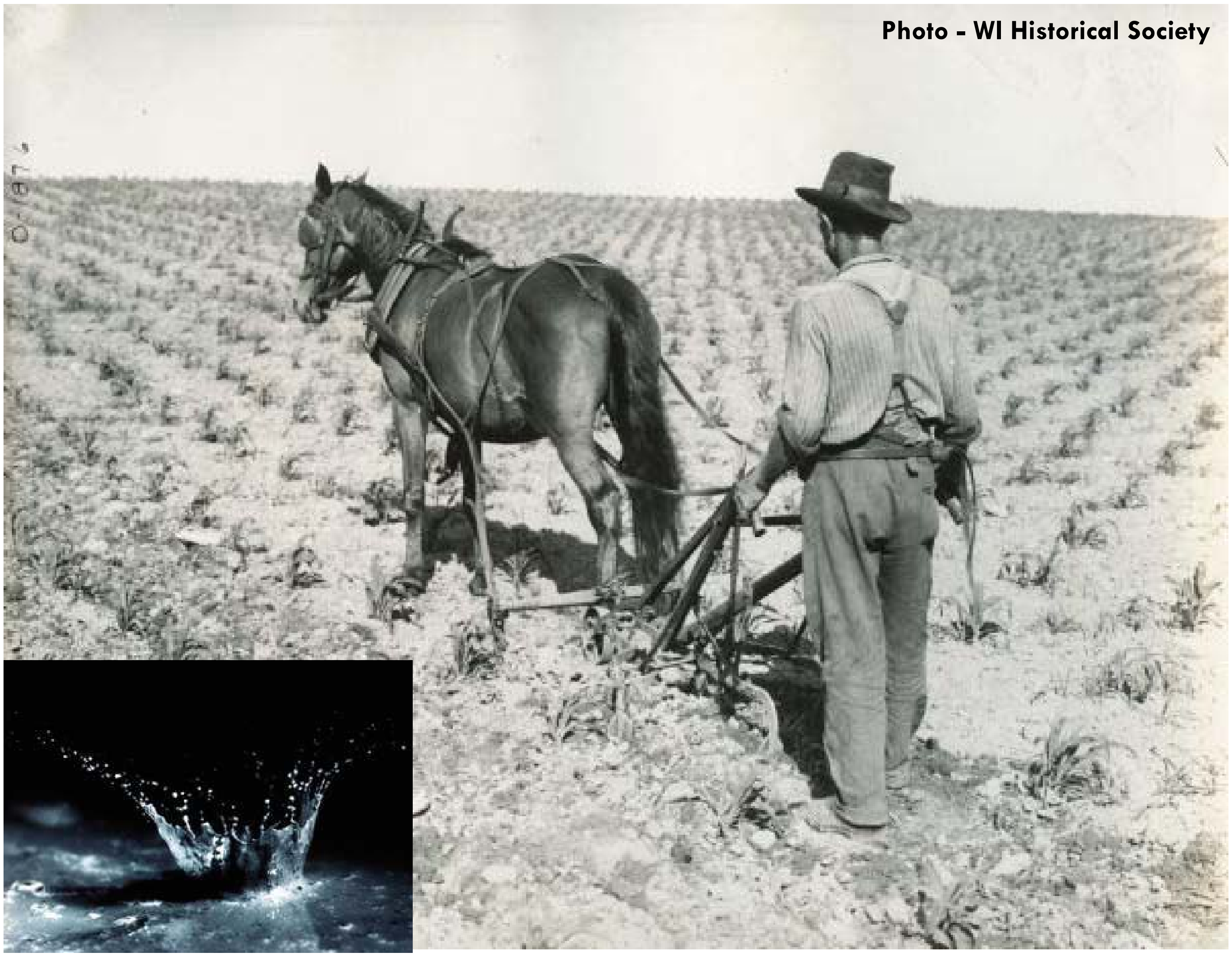


Photo - WI Historical Society

Land Cover/Use Change

50 Foot Deep Gulley Erosion, McPeak Farm, WI - 1928

USACE Navigation Projects

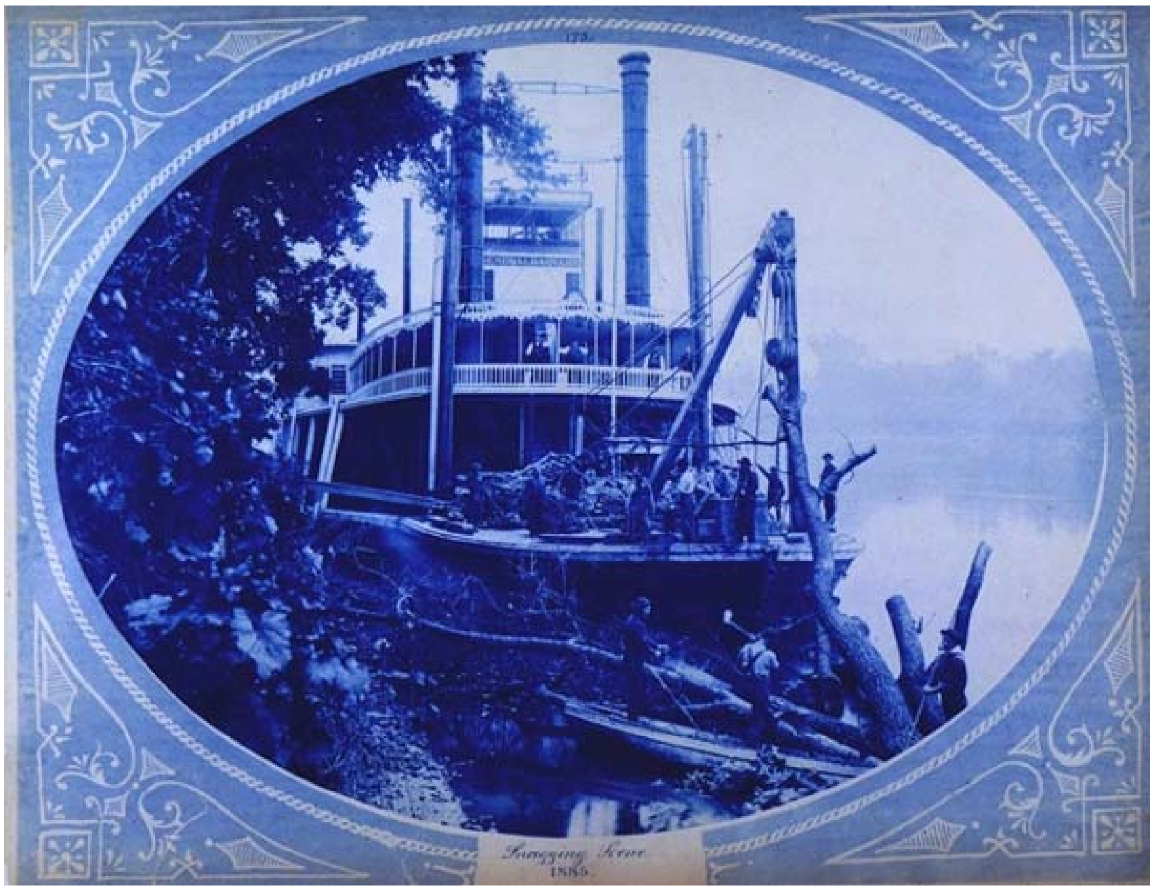


Photo: Henry Bosse

Large Woody Debris Removal

- 1866 Rivers and Harbors Act → Corps directed to survey UMR b/w St. Anthony Falls to Rock Island
- 1868 dredging and snag removal began to improve steamboat navigation

USACE Navigation Projects

Franklin's Coulee near Nininger, MN – 1891

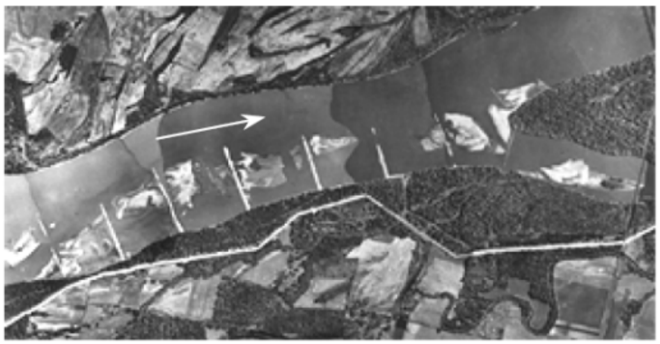
Photo: Henry Bosse

Wing Dams

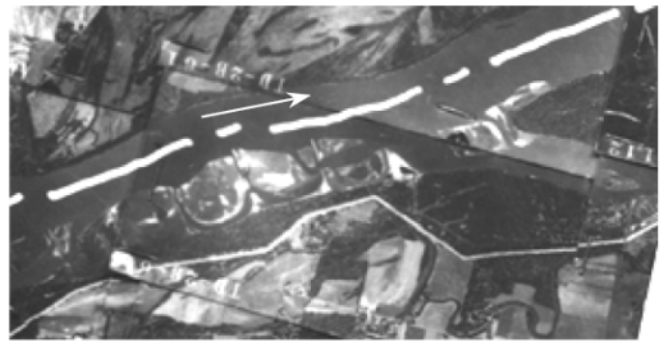
- Construction began in late 1800s
- Control flow hydraulics (magnitude, direction, velocity)
- Increase sediment transport capacity of main channel
- Average of 3 to 9 per river mile

Wing Dams & Side Channel Closing Dams

- Sediment accumulates in flow separation zone b/w dams
- Wider, shallower main channel transformed to narrower, deeper channel



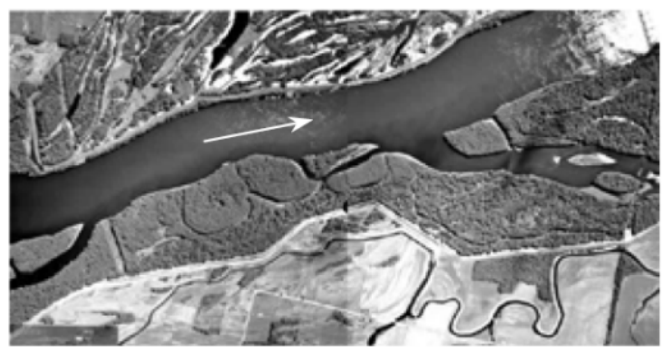
Summer 1930 (Pre-Dam)



July 1941 (W.S.El. = 528.02 ft)

Pool 18, UMR
RM 428-431

September 1975 (W.S.El. = 528.00 ft)



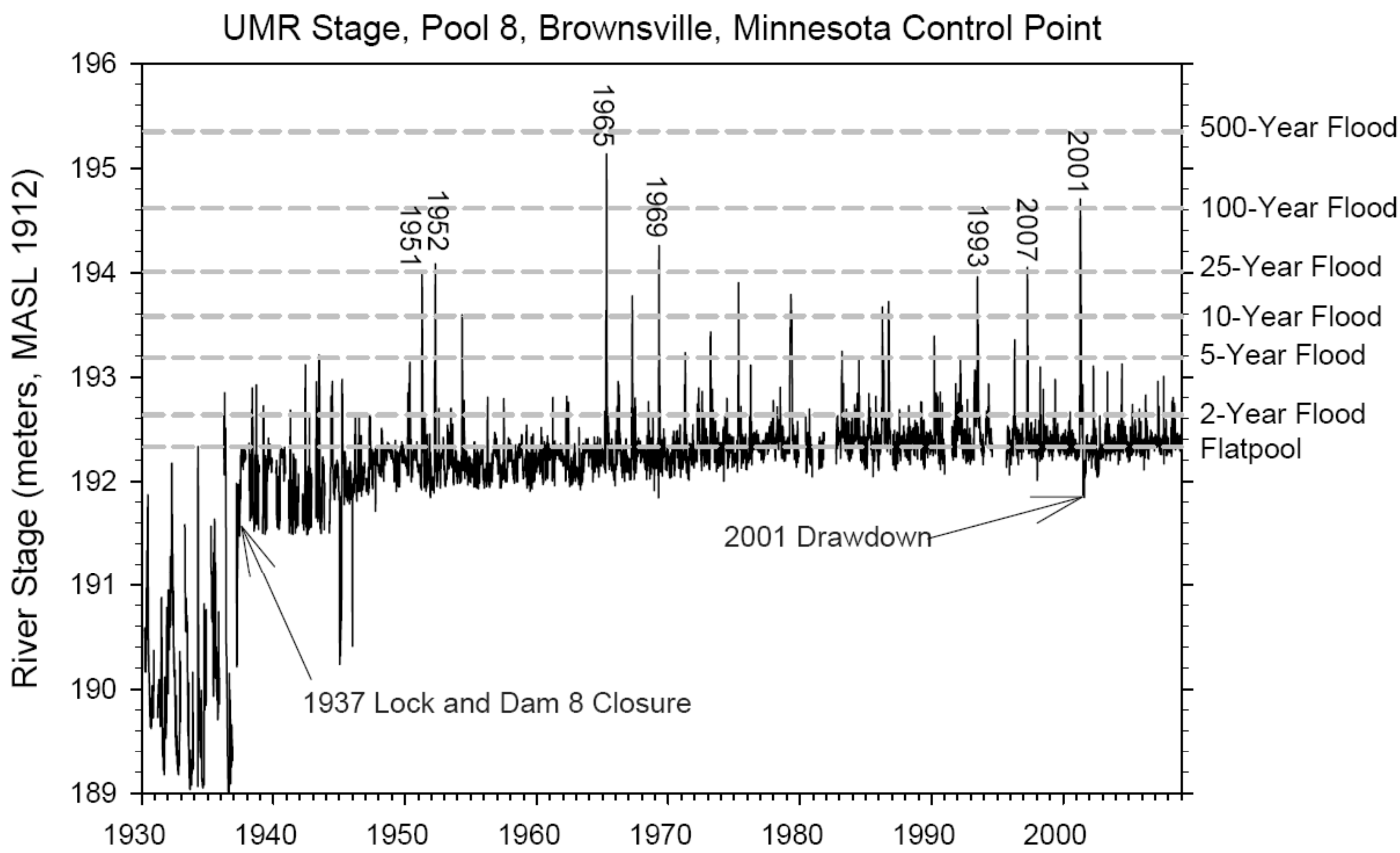
September 1994 (W.S.El. = 527.96 ft)

West Consultants, 2000

Lock and Dam Closure

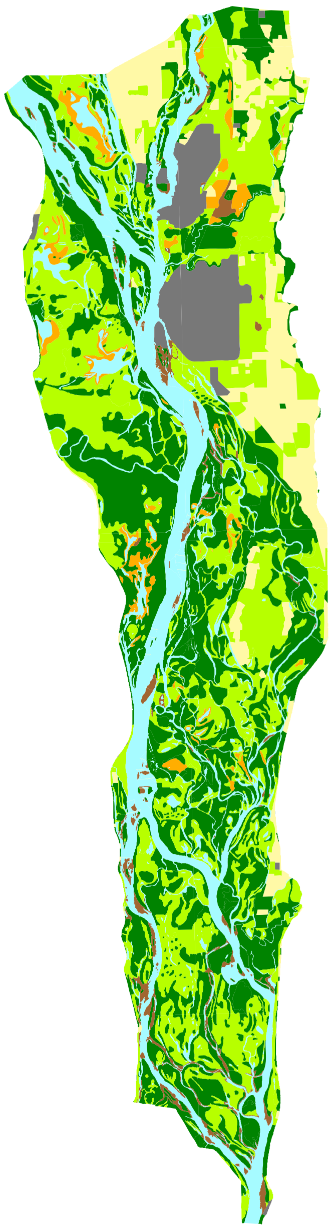
- 27 L&Ds constructed, mainly in 1930s → provide 9 foot navigation channel
- Converted river into a series of slackwater pools

Lock and Dam Closure

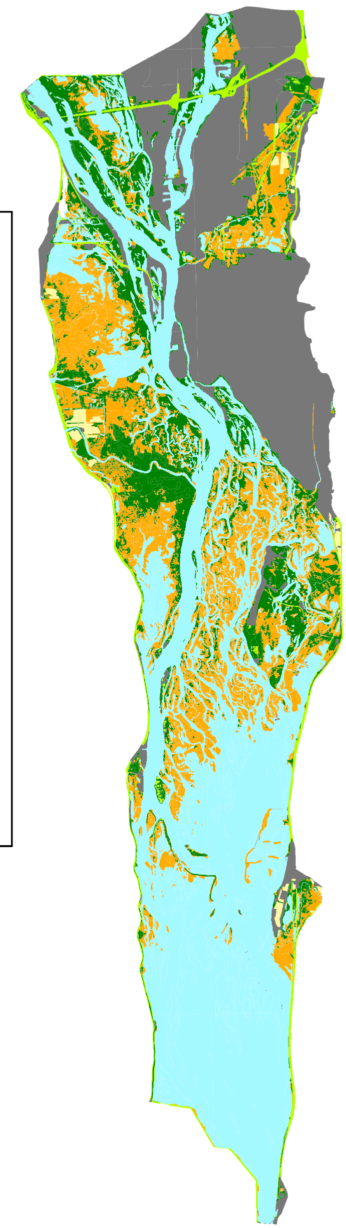


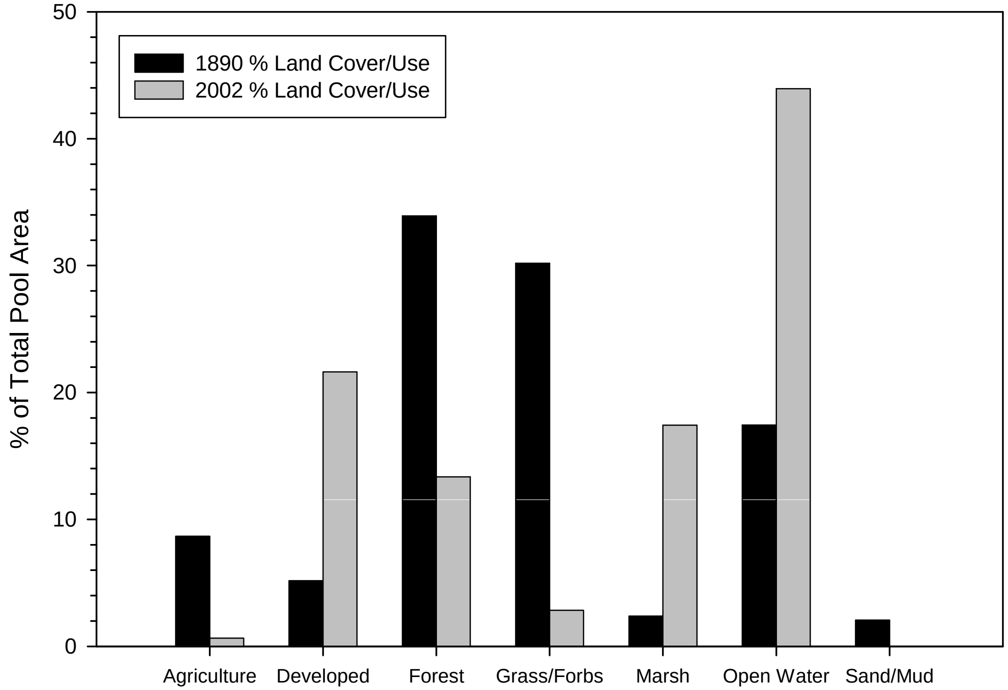
Flood frequency & river stage data from U.S. Army Corps of Engineers, St. Paul Water Control Center

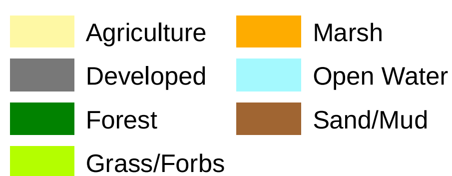
1890 Land Cover



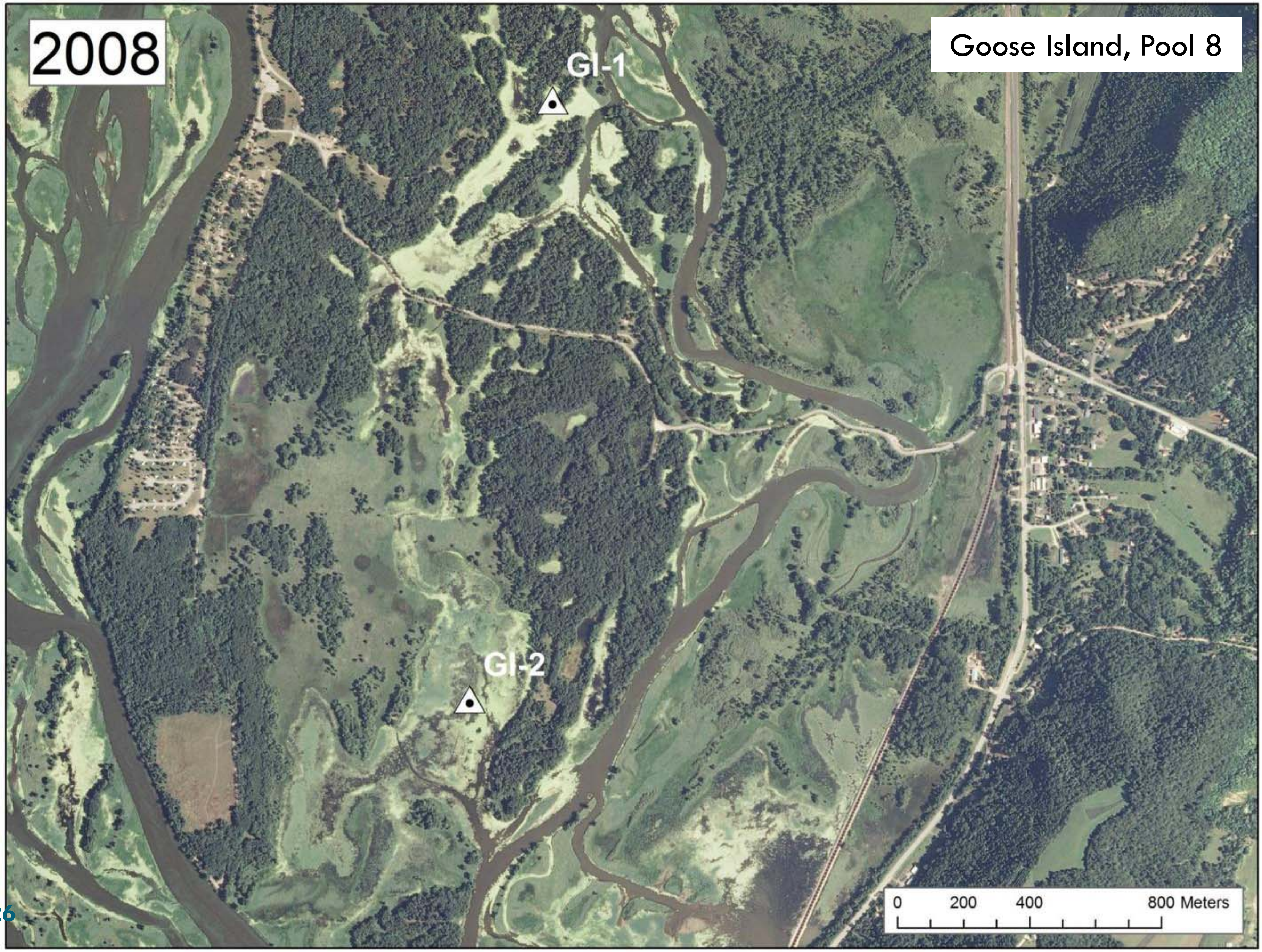
2000 Land Cover



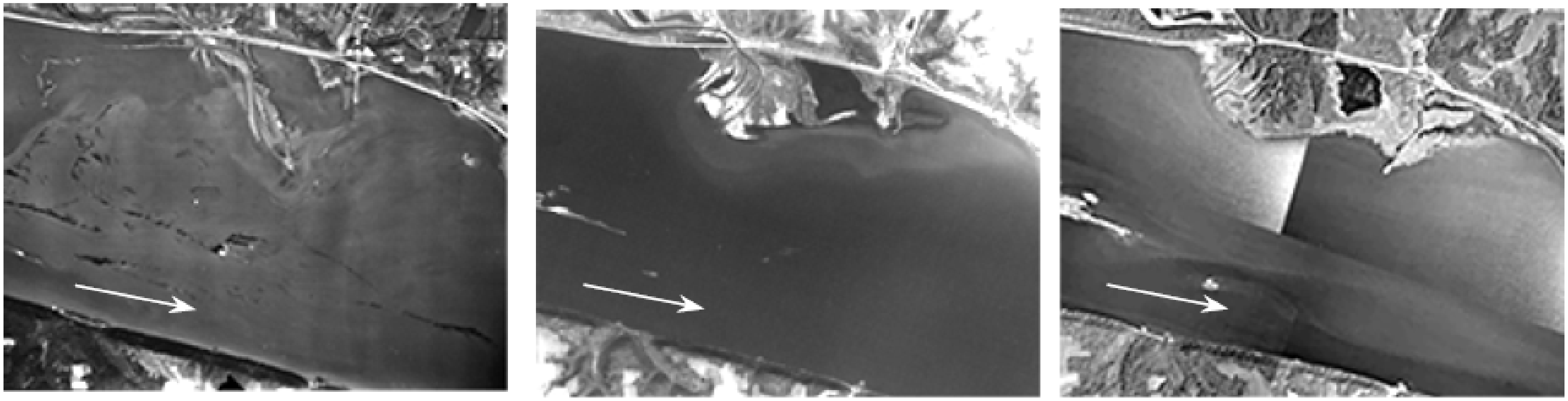




GIS data provided by USGS Upper Midwest Environmental Sciences Center

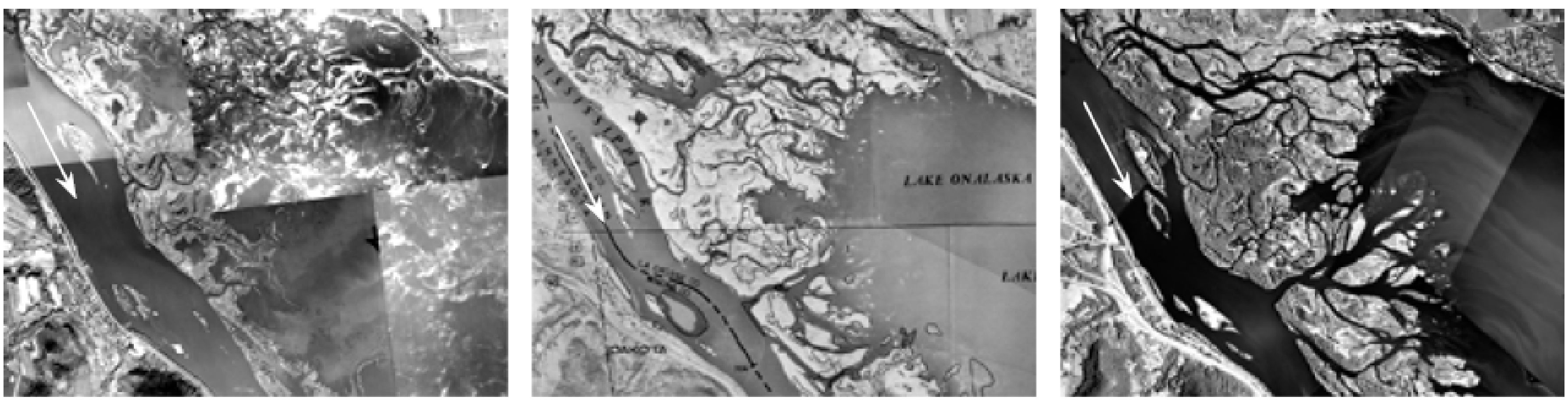

2008
Goose Island, Pool 8
GI-1
GI-2
0 200 400 800 Meters

Tributary Delta Formation, Pool 11, RM 593



September 1940 (W.S.El. = 610.24 ft) | April 1964 (W.S.El. = 612.23 ft) | May 1994 (W.S.El. = 611.93 ft)

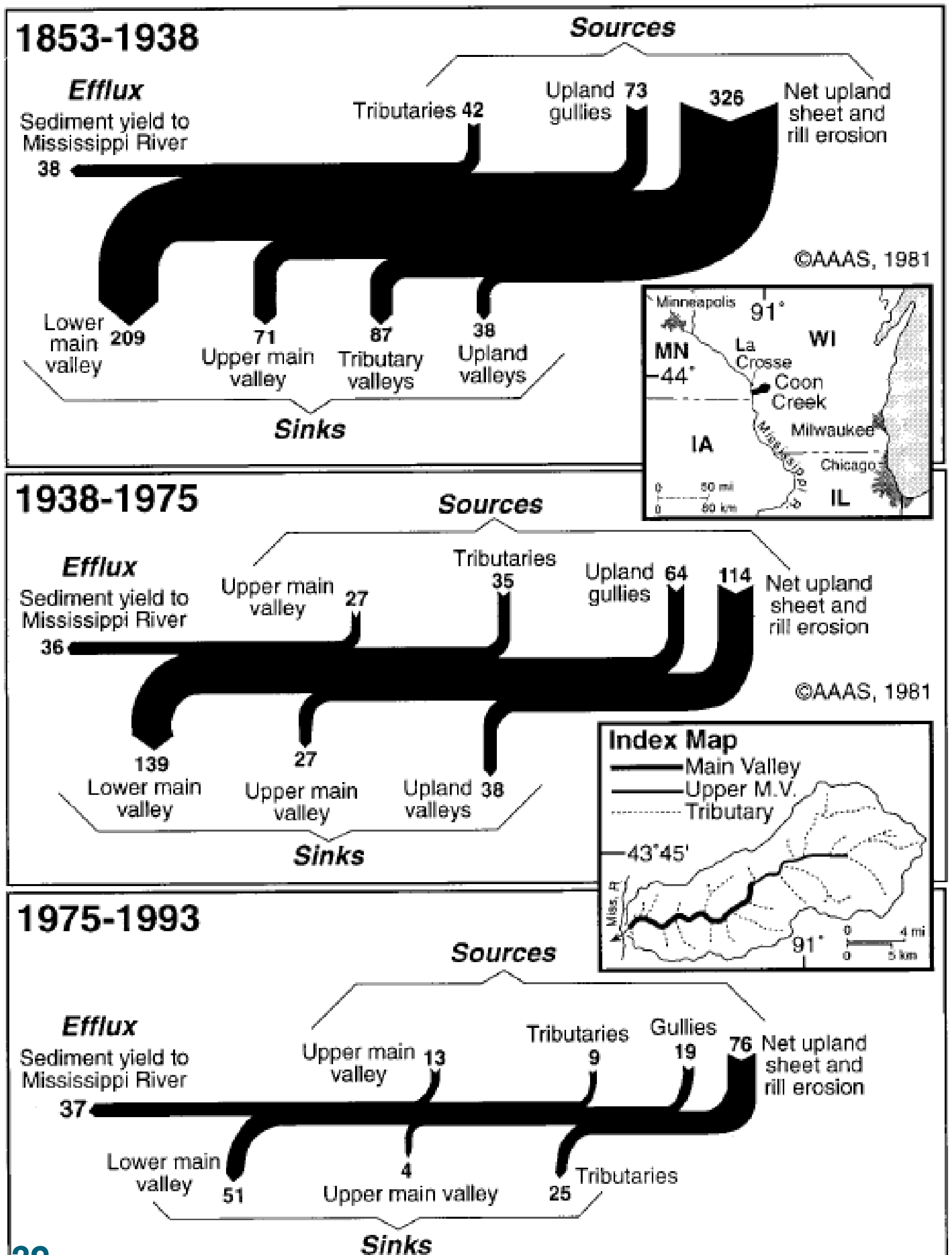
Impounded Backwater Delta Formation, Pool 7, RM 706.5



September 1938 (W.S.El. = unknown) | 1973 (W.S.El. = unknown) | August 1996 (W.S.El. = unknown)

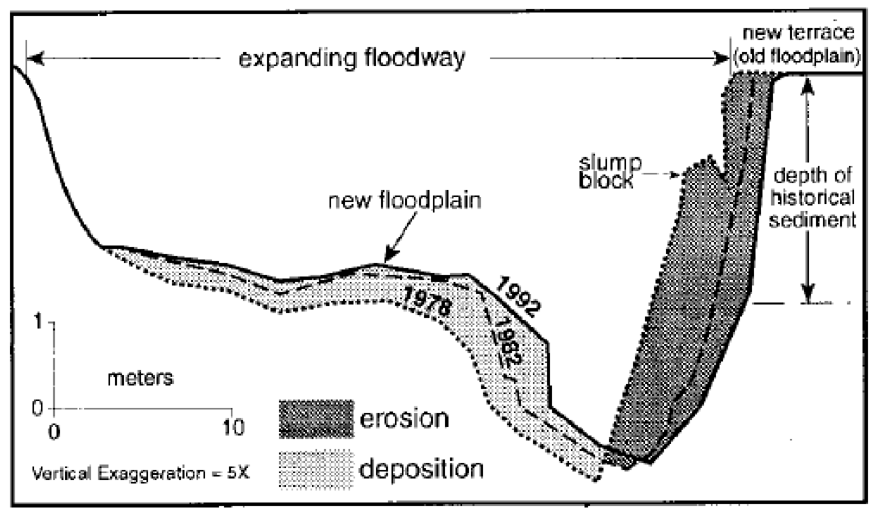
West Consultants, 2000

Improved Land Management

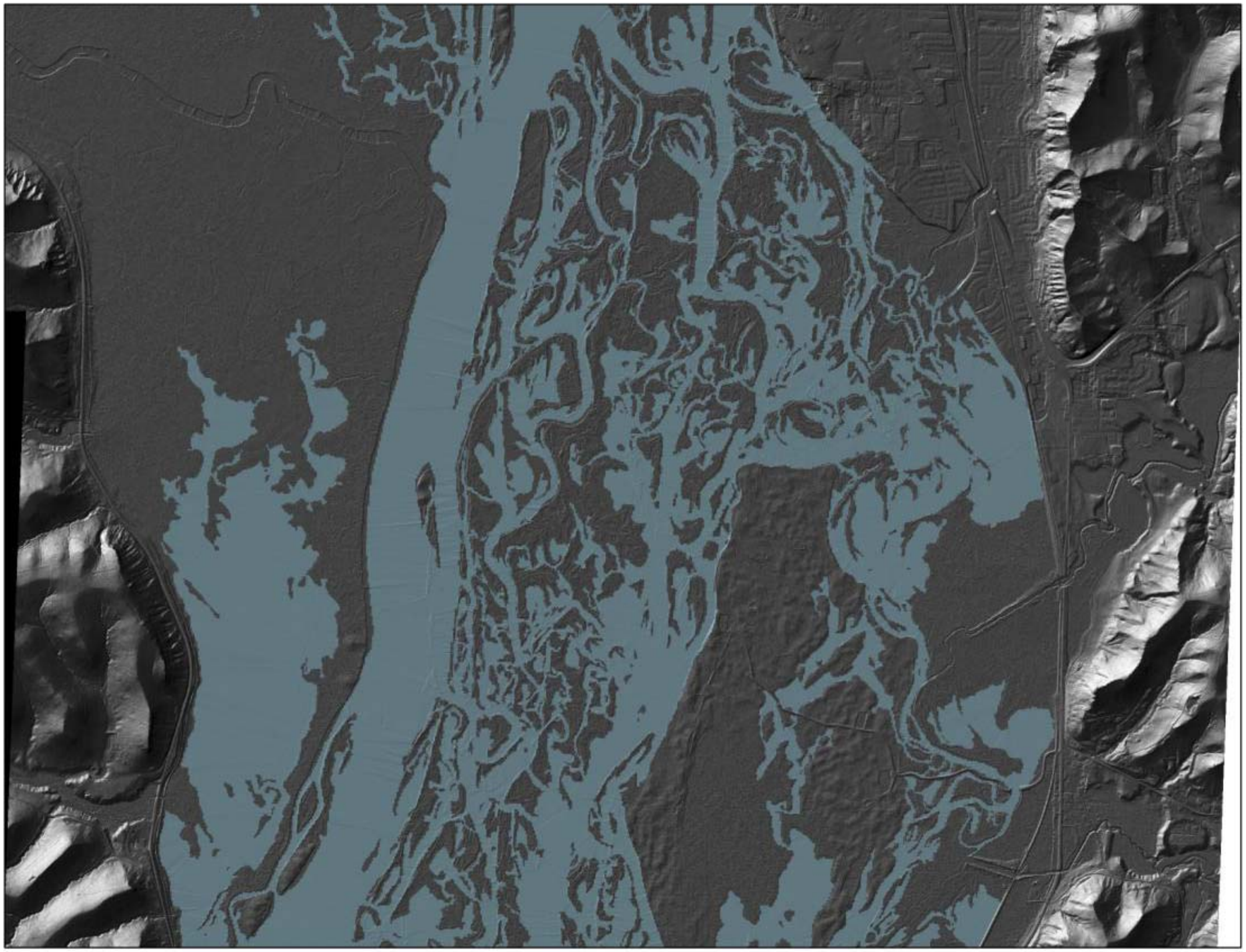


Trimble et al., 1999

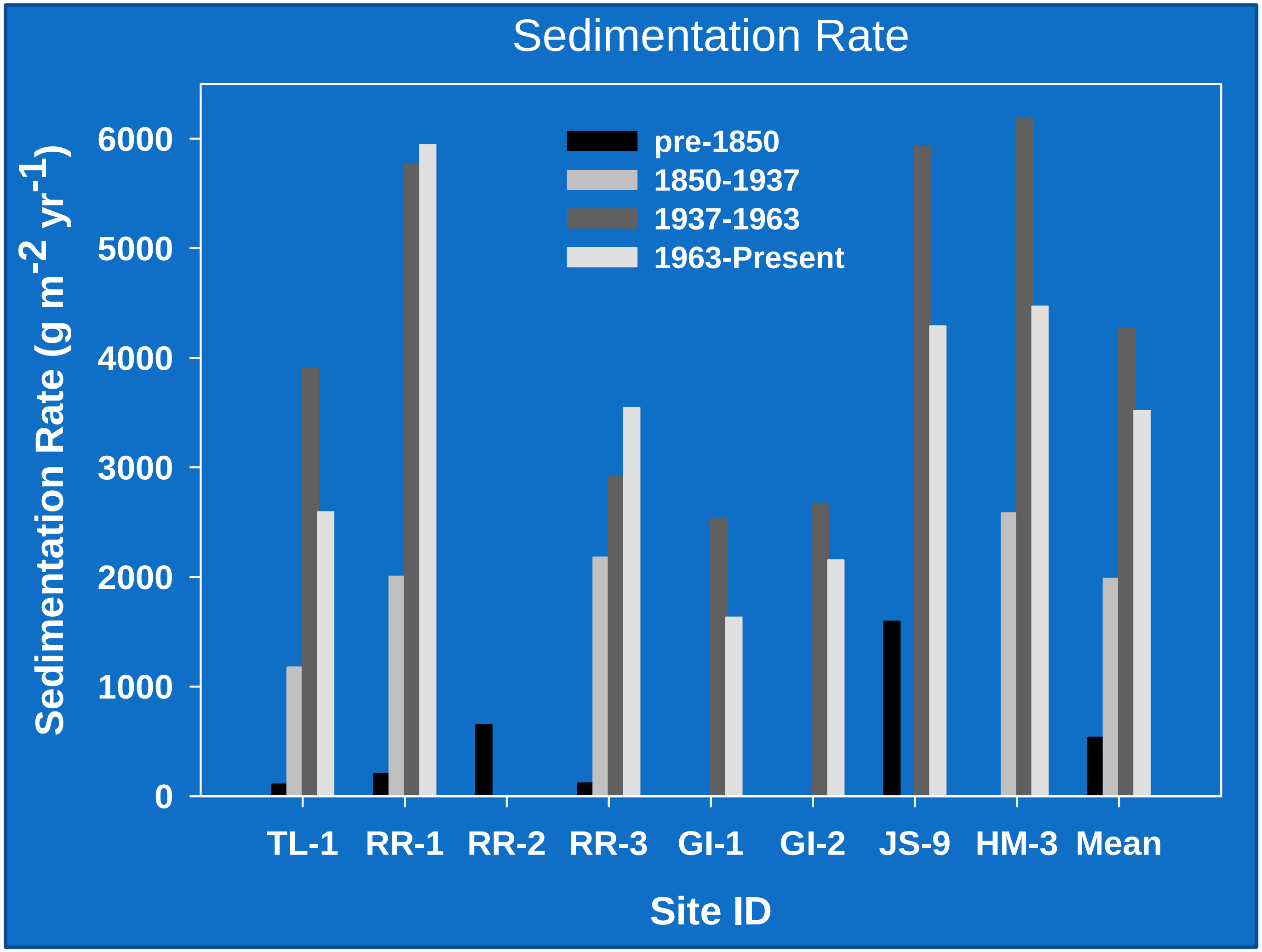
- Despite major improvements in land use, sediment delivery to the Mississippi River remains high
  1. Tributaries efficiently flush sediment downstream
  2. Cleaner water is more erosive, remobilizing historical sediment



Complex Floodplain Geomorphology



- Sedimentation rates vary considerably over space due to geomorphic complexity
- Order of magnitude increase following European-American settlement
- Nitrogen, carbon, and phosphorus sequestration rates increased by factors of 8.7, 8.0, and 25, respectively



Rivers Flood

- Few human-constructed levees north of Rock Island, IL (Wildlife & Fish Refuge)
- Flood control levees increase in density moving down the upper Mississippi River

Goose Island, 2001 Flood

Photo - UMESC

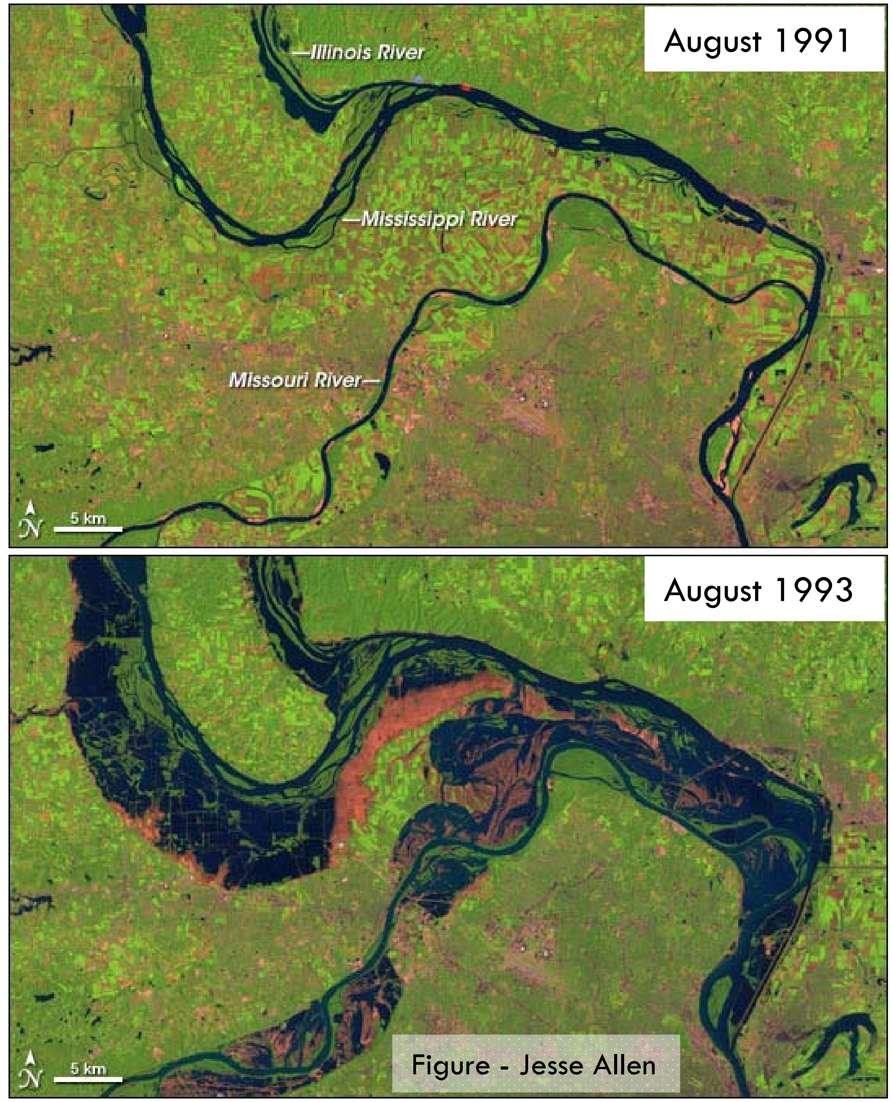
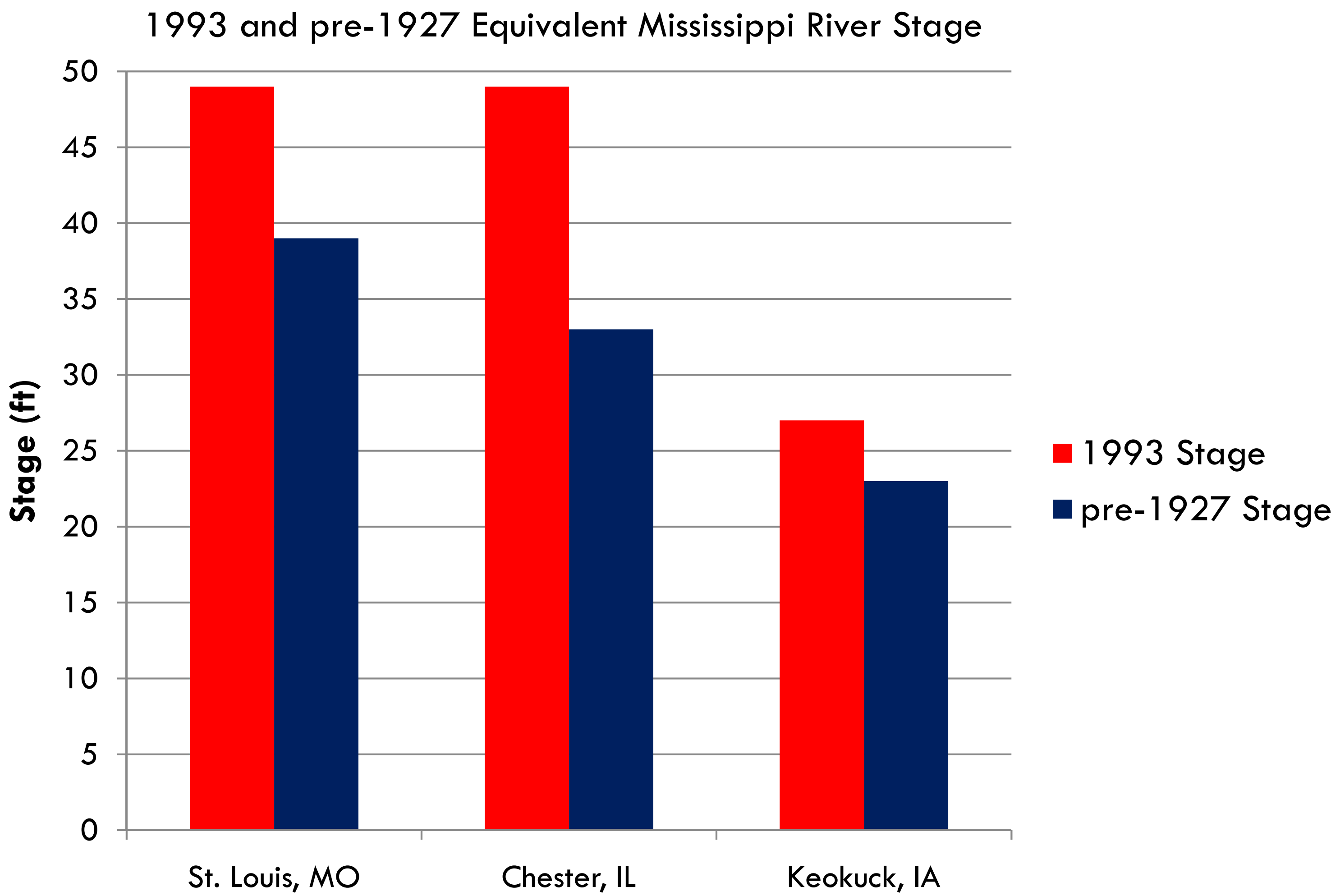


Figure - Jesse Allen

Effect of River Constrictions



Data from Leopold, 1994

Floodwater Storage

- Levee failure causes temporary stage decline
- Once storage fills, river continues to rise

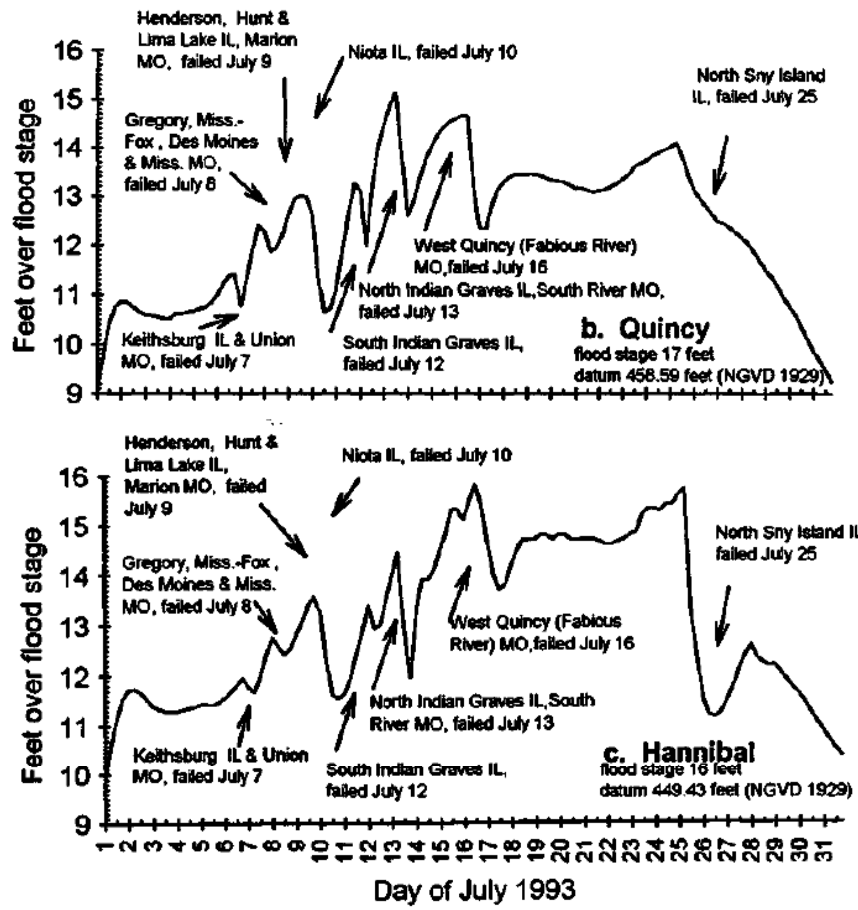
1993 Flood (Larson, 1997):

- 40 of 226 federal levees failed or overtopped
- 1043 of 1345 non-federal levees failed or overtopped

Mississippi River near Quincy, IL - June 2008

Photo: (Steve Bohnstedt)

Effect of Levee Failures, Miss. R. July 1-31, 1993



McConkey et al, 1994

Sediment Storage

2008 Upper Mississippi River Flood, Pool 11 – June 15th, 2008

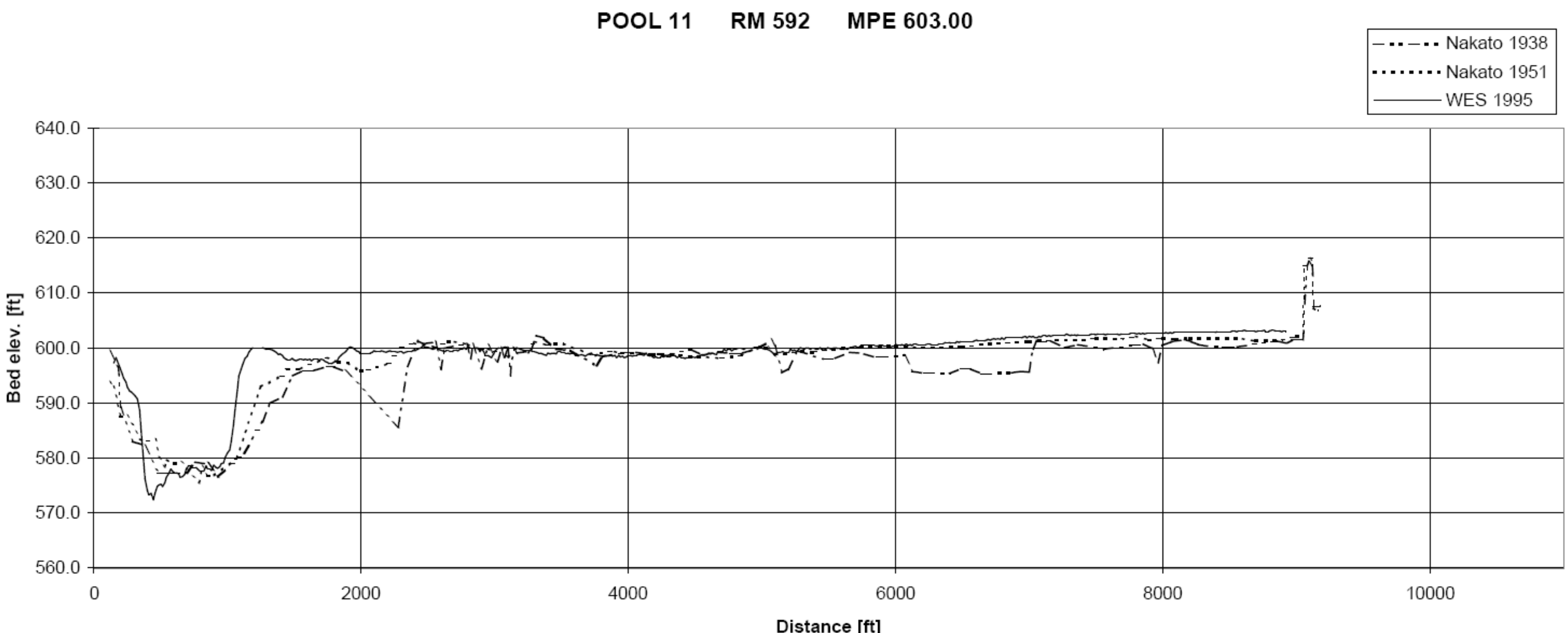
Photo - Colin Belby

Sediment Storage

2008 Upper Mississippi Flood Sedimentation, Pool 11 - July 22nd, 2008

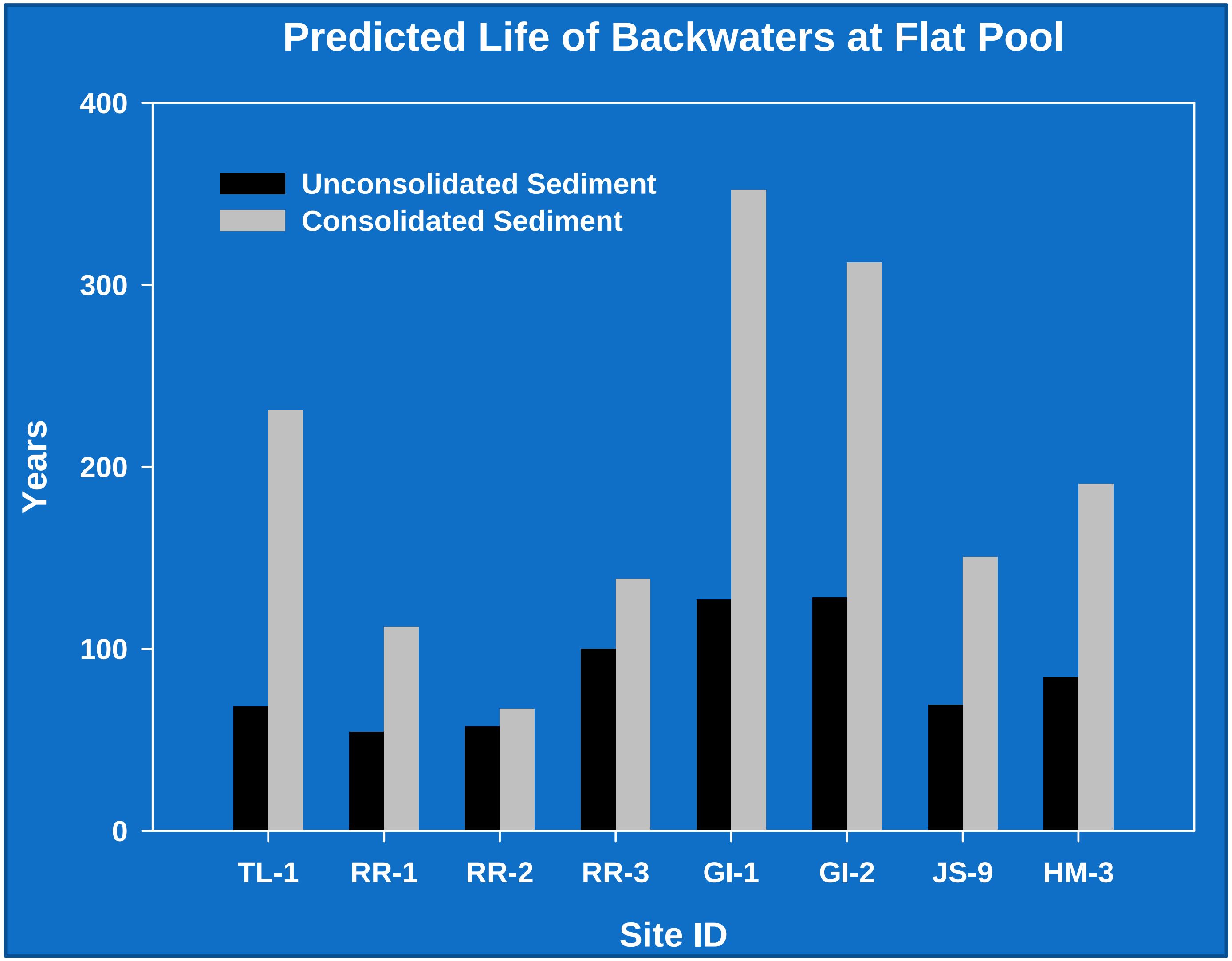
Floodplain Homogenization

- Floodplain deposition has resulted in a loss of habitat diversity
- Rapid deposition of fine sediment in middle reach of pools
- Island erosion and sediment redistribution in lower reach of pools



West Consultants, 2000

Sediment Storage



Unconsolidated = current wet bulk density

Consolidated = bulk density after periodic dessication

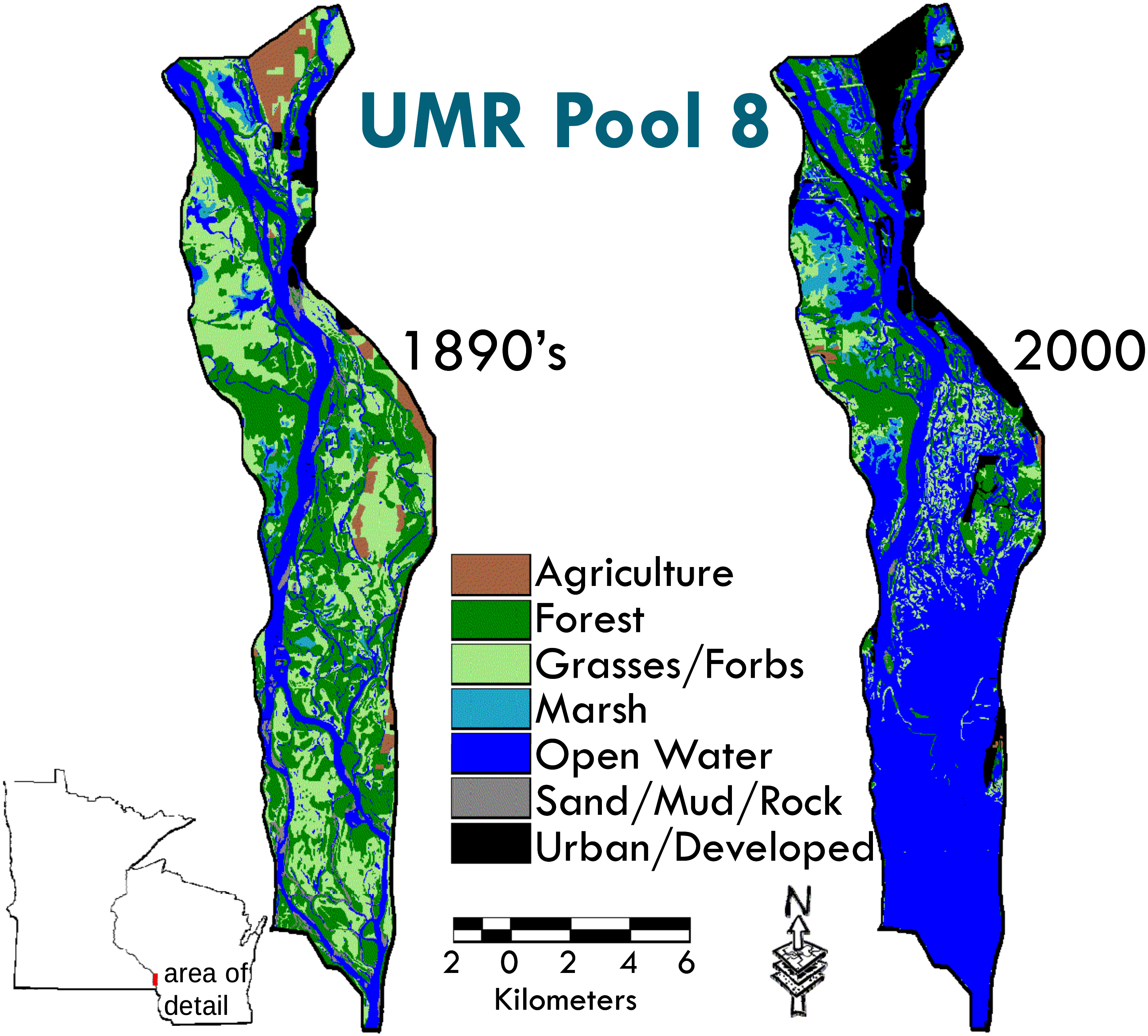
The case for large river restoration

Upper Mississippi River, Lower Navigation Pool 8 (Photo: Robert Hurt)

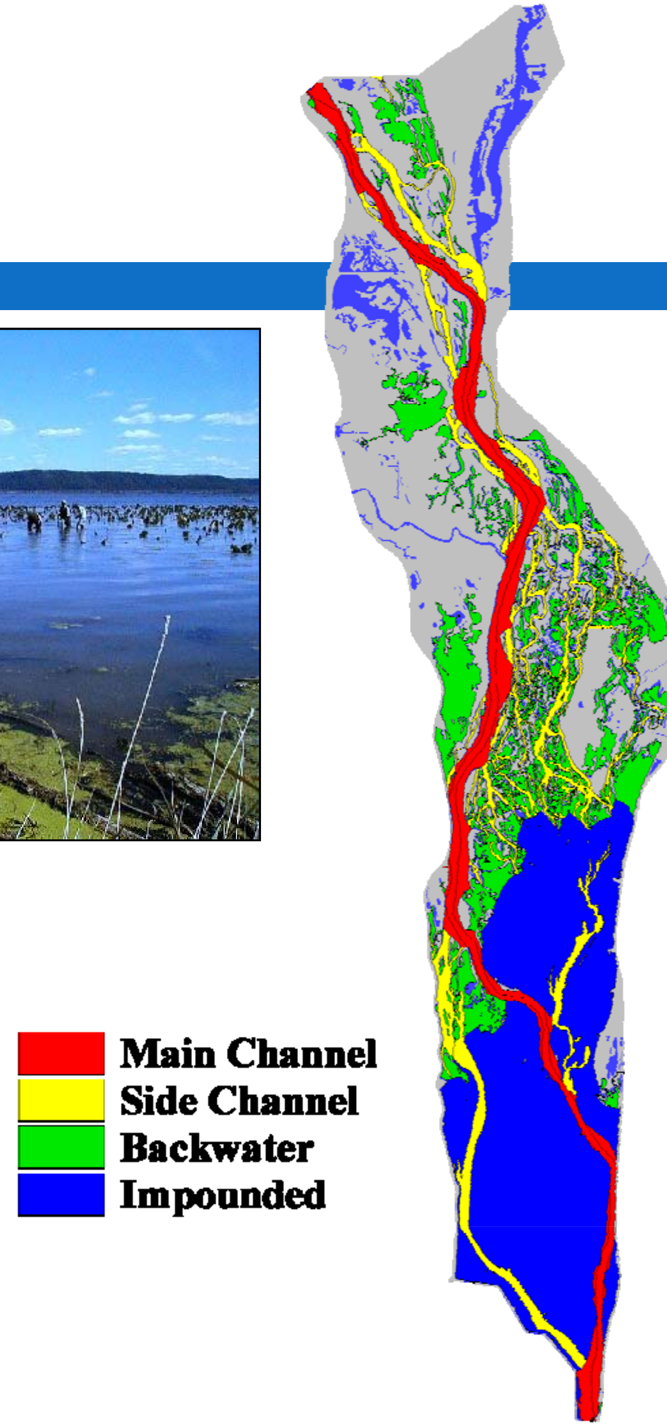
Why should we restore large rivers?

- Return to more “original” state (Guiding Image)
- Aesthetic reasons
- Ecosystem services of large rivers
  - Flood water storage/mitigation
  - Sediment storage
  - Habitat/biodiversity
  - Nutrient cycling and carbon sequestration

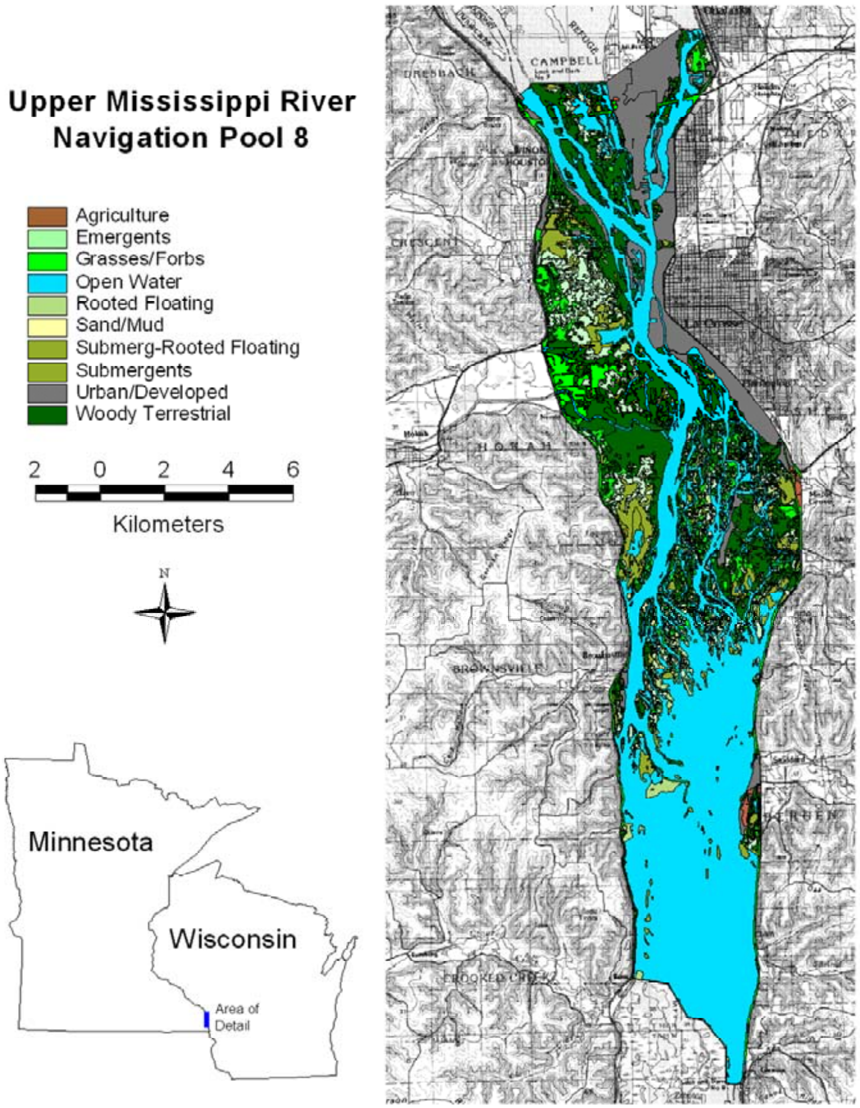
UMR Pool 8

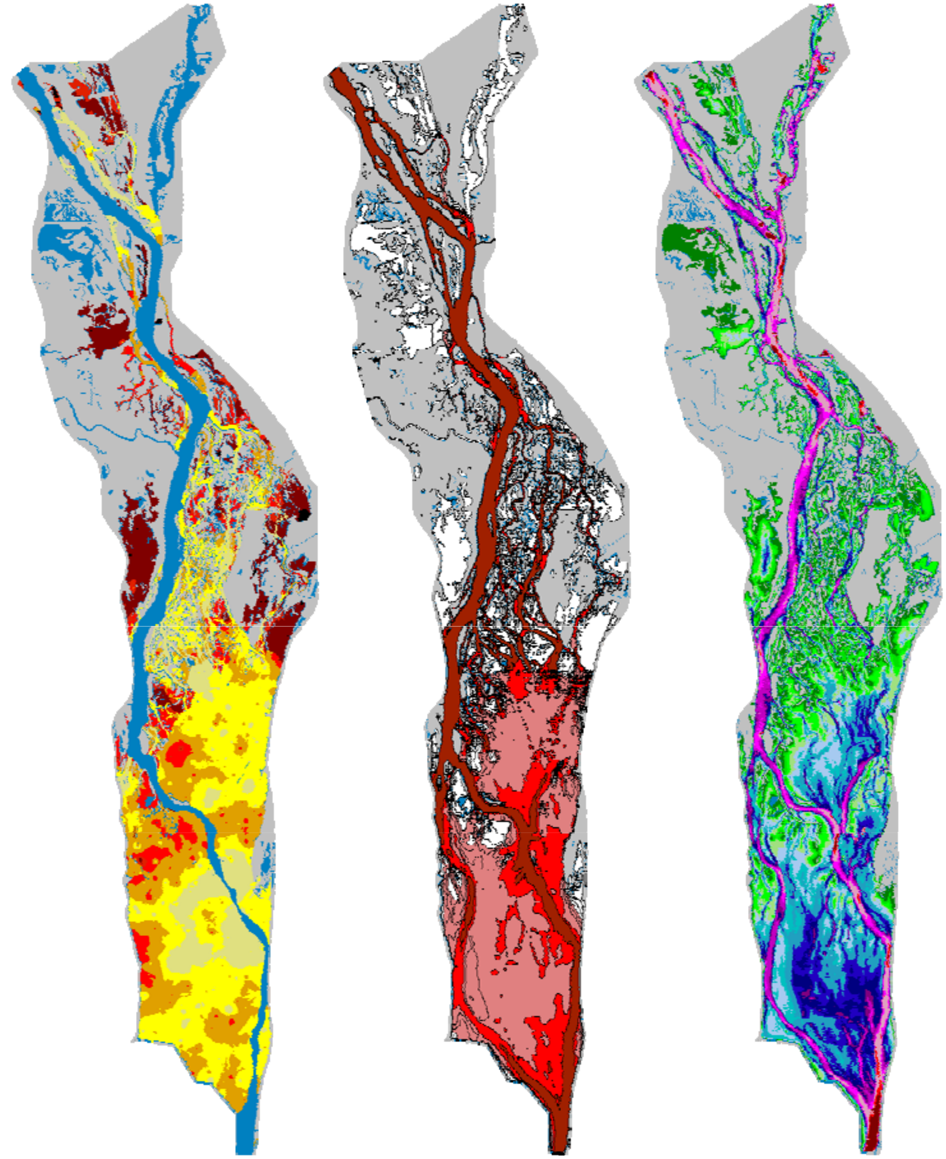

1890's
2000
Agriculture
Forest
Grasses/Forbs
Marsh
Open Water
Sand/Mud/Rock
Urban/Developed
2 0 2 4 6
Kilometers
N
area of detail

Aquatic Habitats in UMR

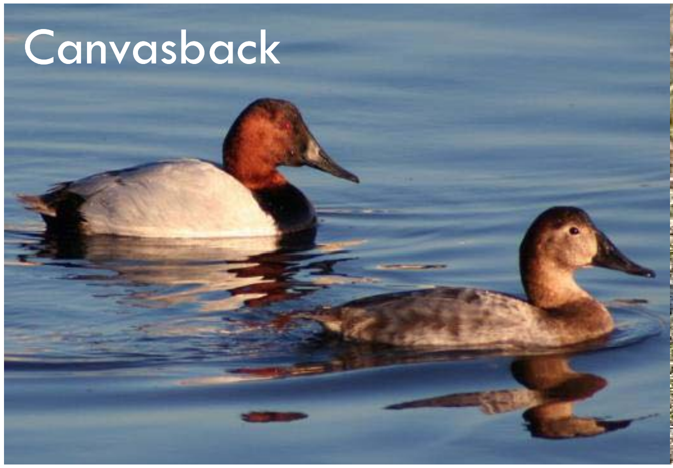


Spatial Heterogeneity – UMR Pool 8



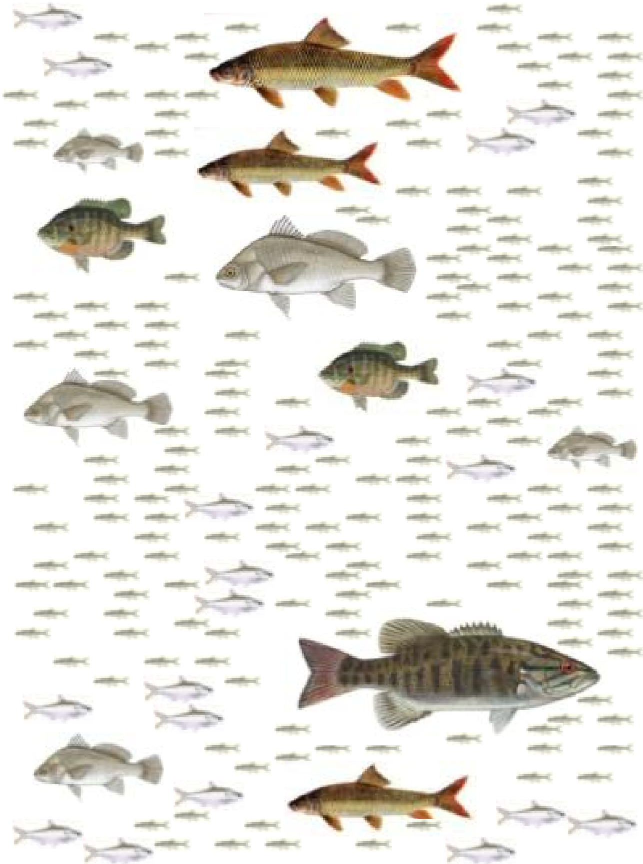


Wildlife Habitat in UMR

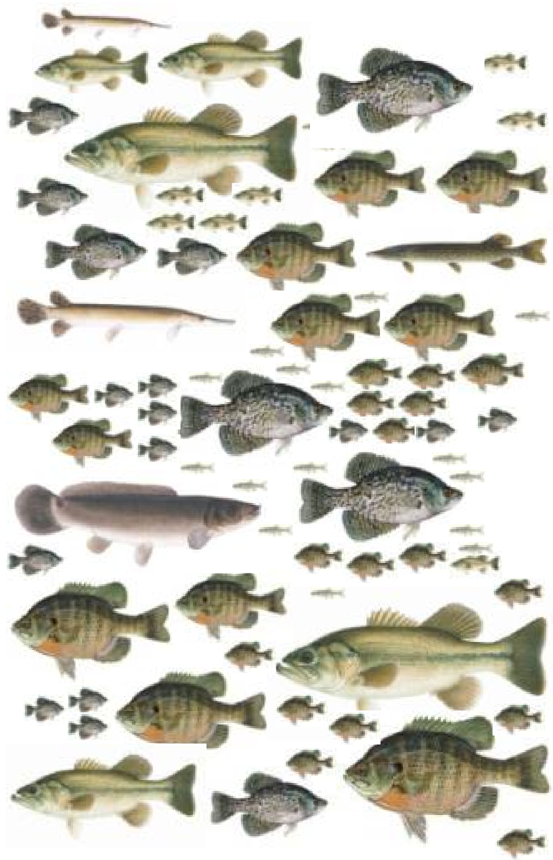


Fish Usage of River Habitats

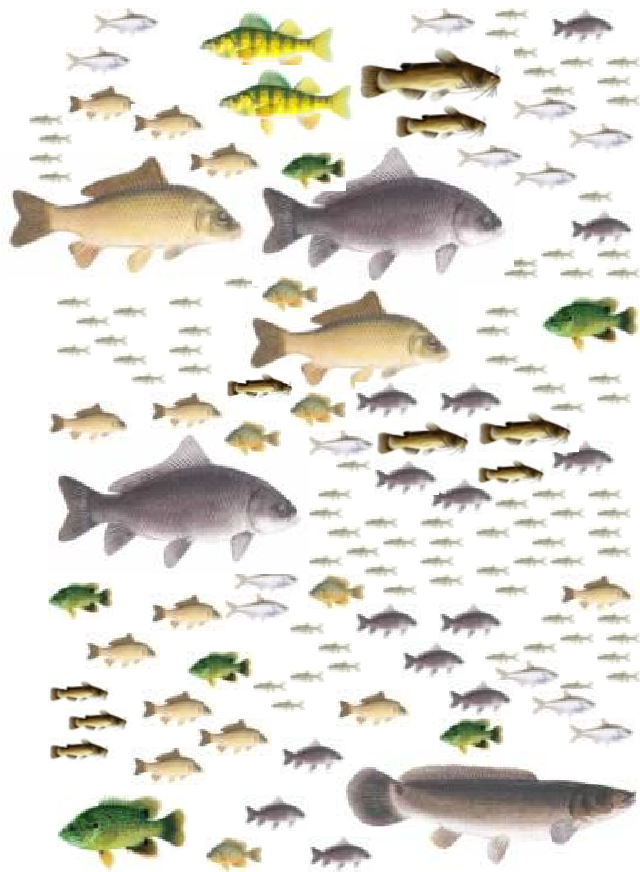
Main channel



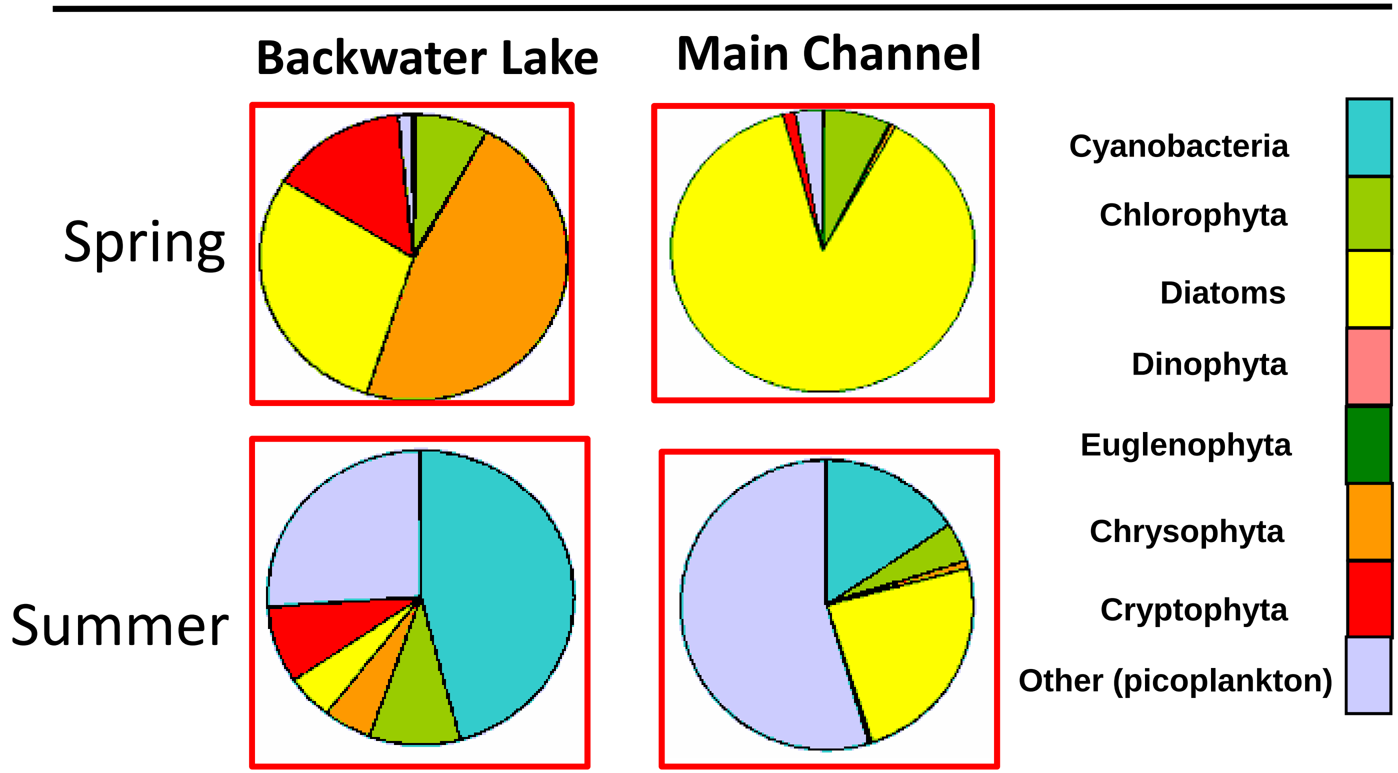
Multiple connection backwaters



Isolated backwaters



Seasonal Variation in Phytoplankton Community Composition, Pool 8 UMR



Summer, Backwater: cyanobacteria, picoplankton

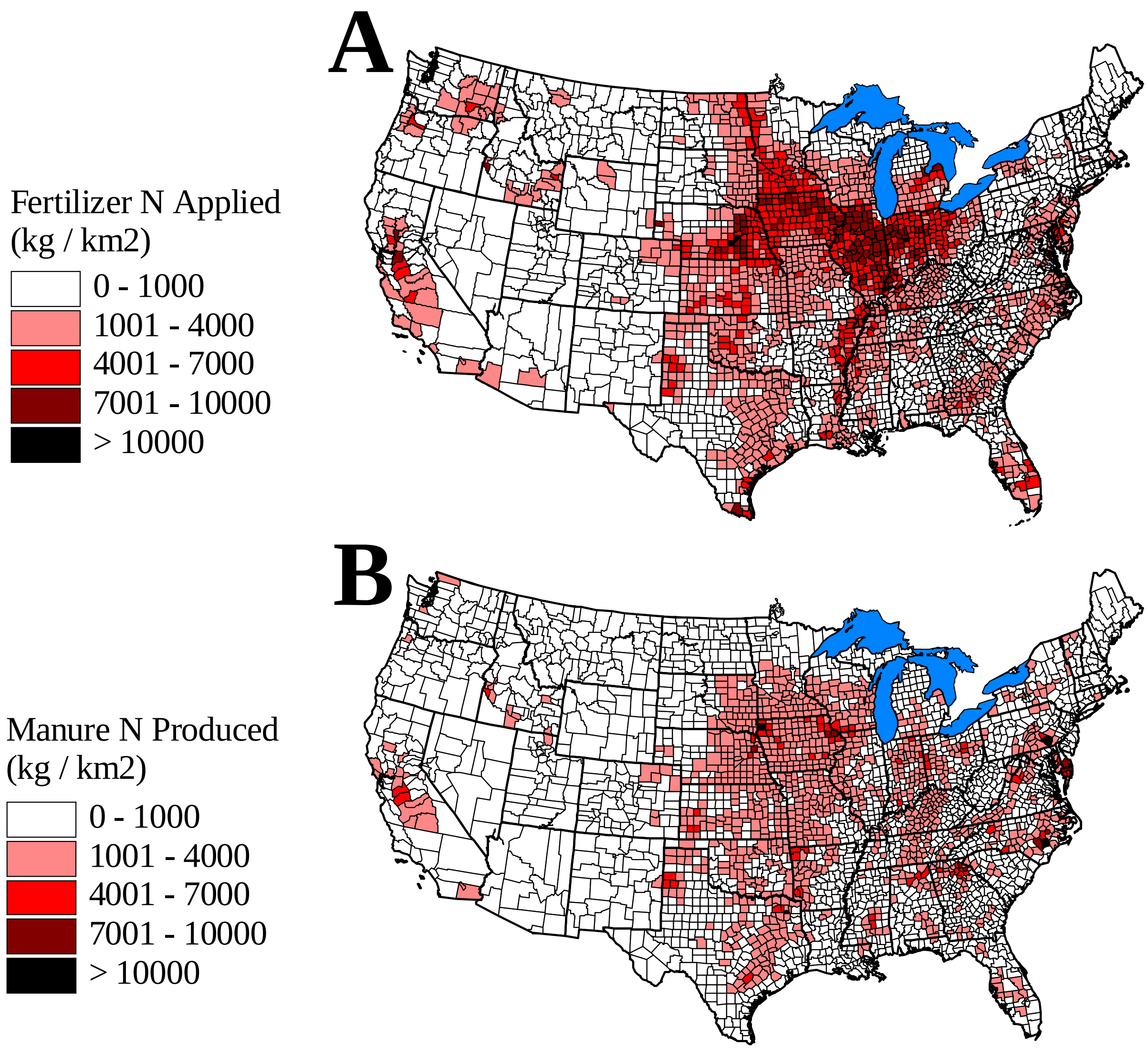
Summer, Mainchannel: picoplankton, diatoms, cyanobacteria

Spring, Backwater : chrysophytes/diatoms

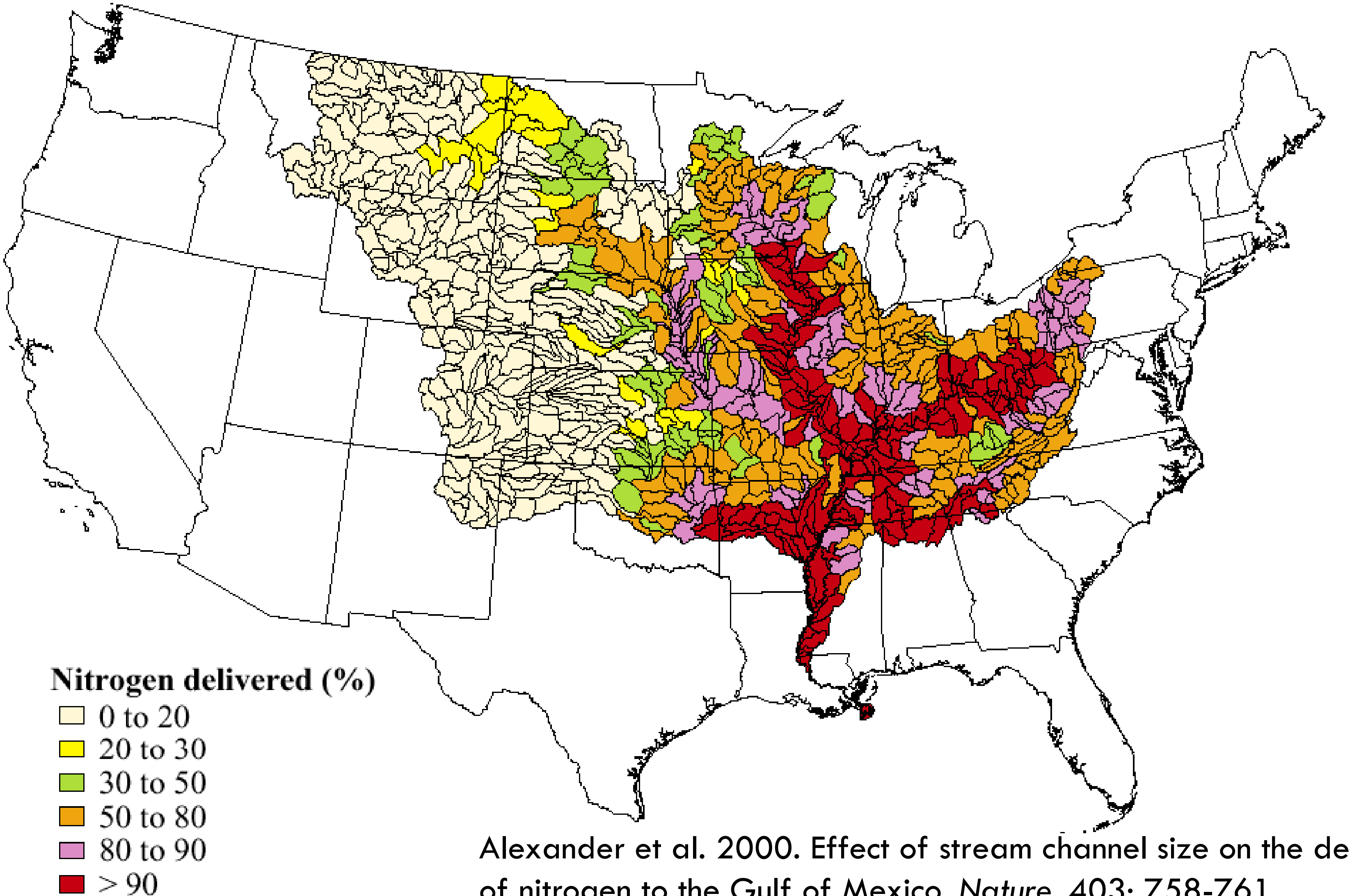
Spring, MainChannel: diatoms

Data source: Jillian Decker and John Wehr, Fordham University (LTRMP samples from 2005, n=2)

Nitrogen Sources in the United States

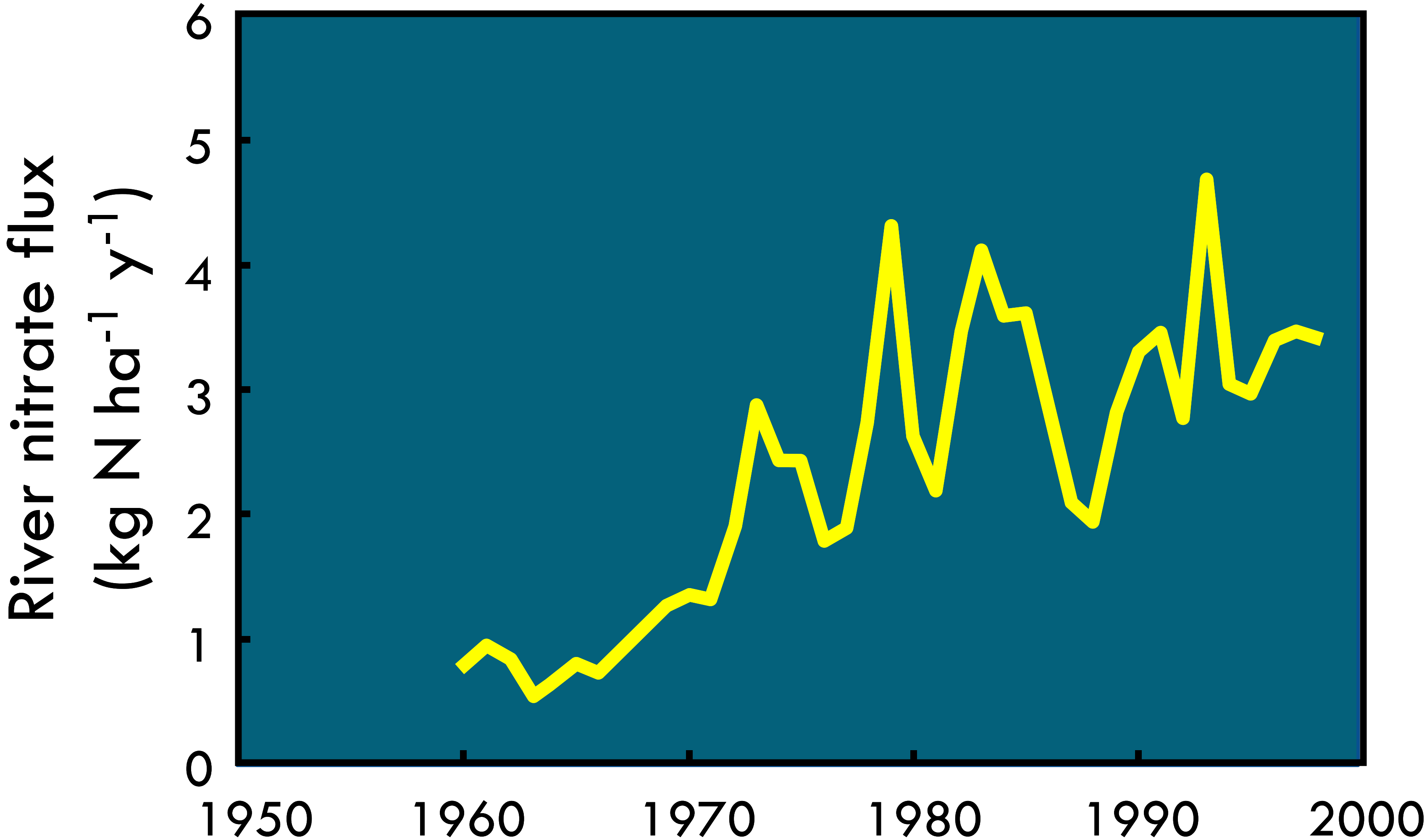


Percent N Delivered to Gulf of Mexico



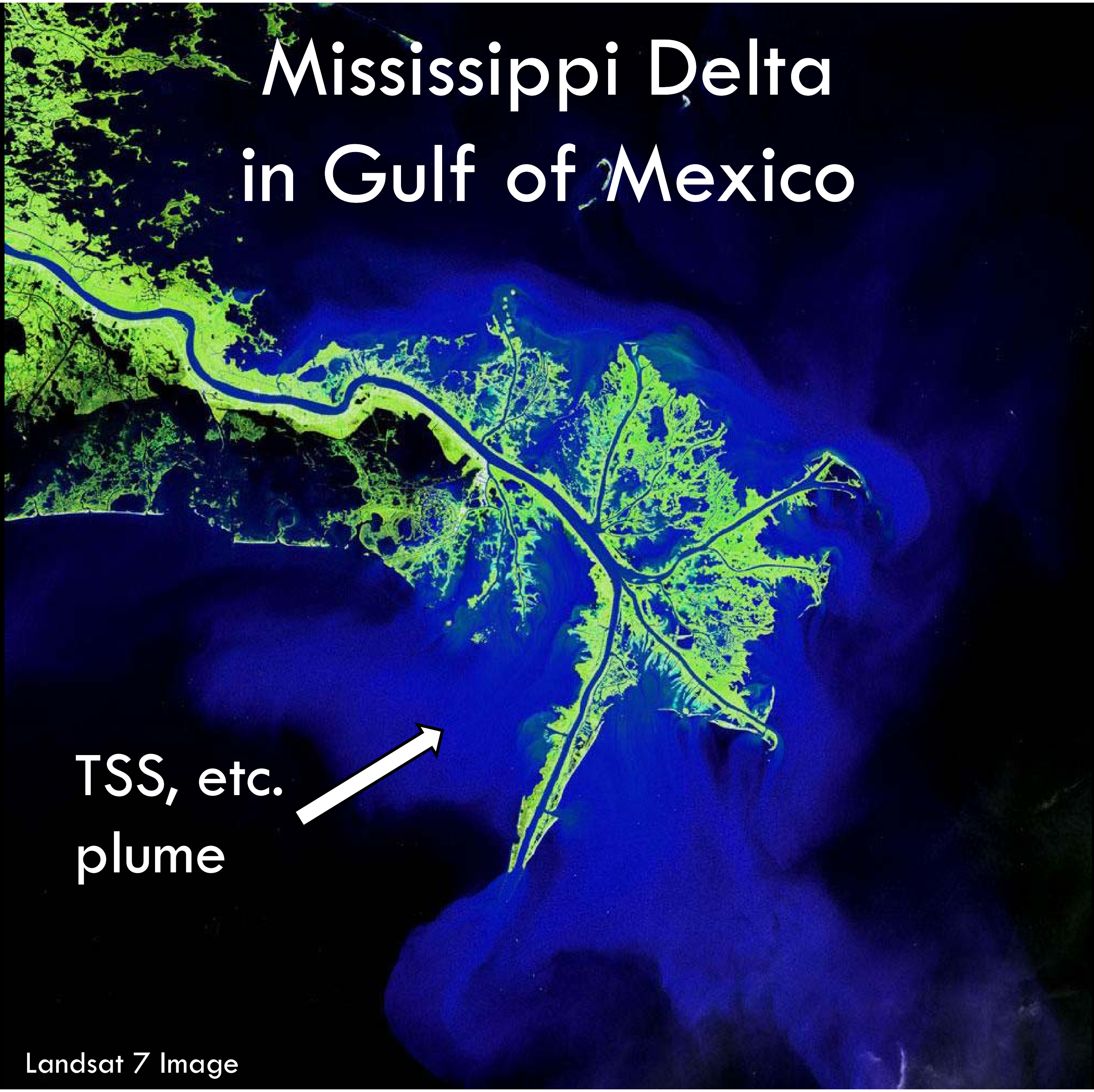
Alexander et al. 2000. Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico. *Nature*. 403: 758-761.

Nitrate Flux in the Mississippi River



McIsaac et al. 2001. Nitrate flux in the Mississippi River. *Nature*. 414: 166-167.

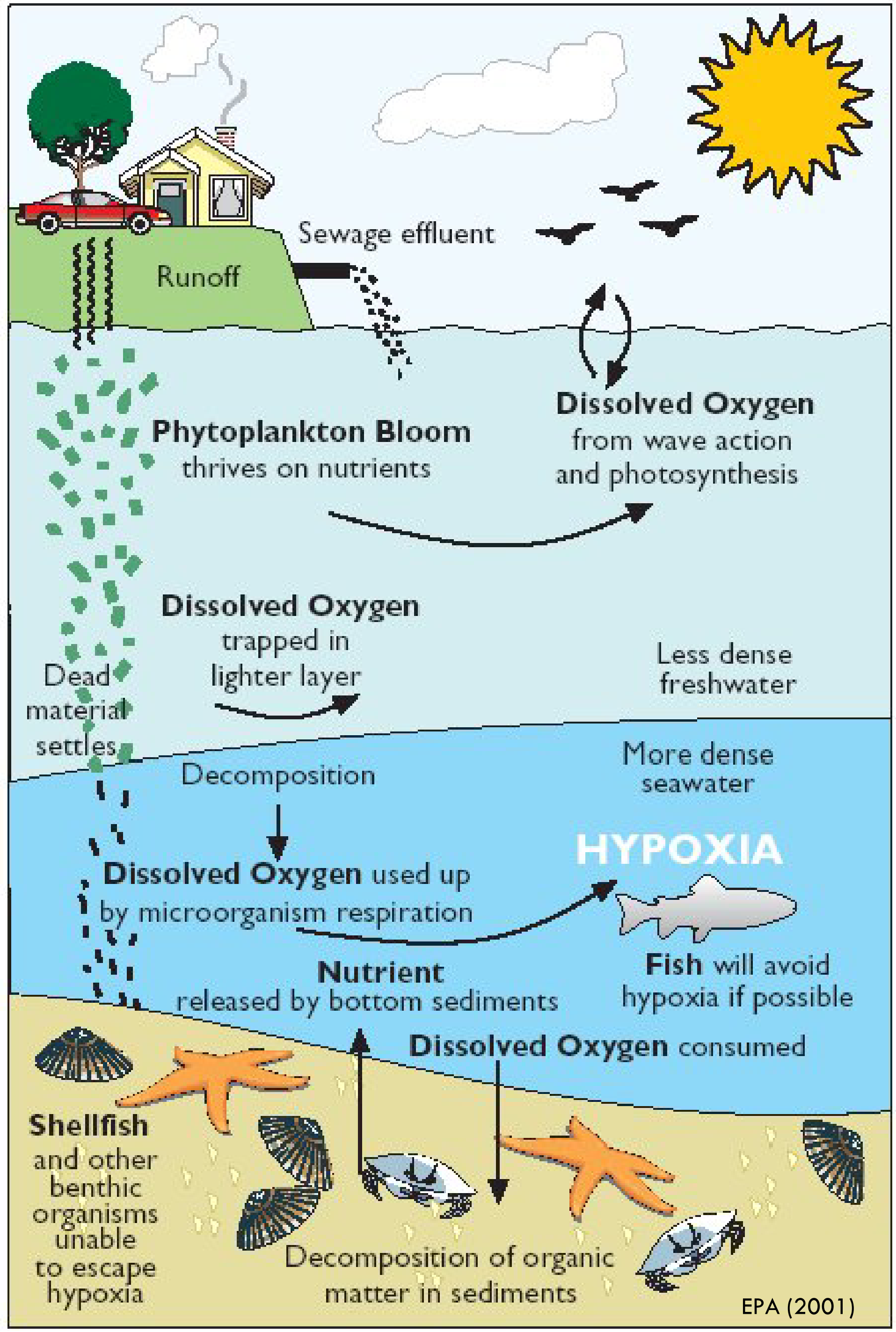
Mississippi Delta in Gulf of Mexico



Landsat 7 Image

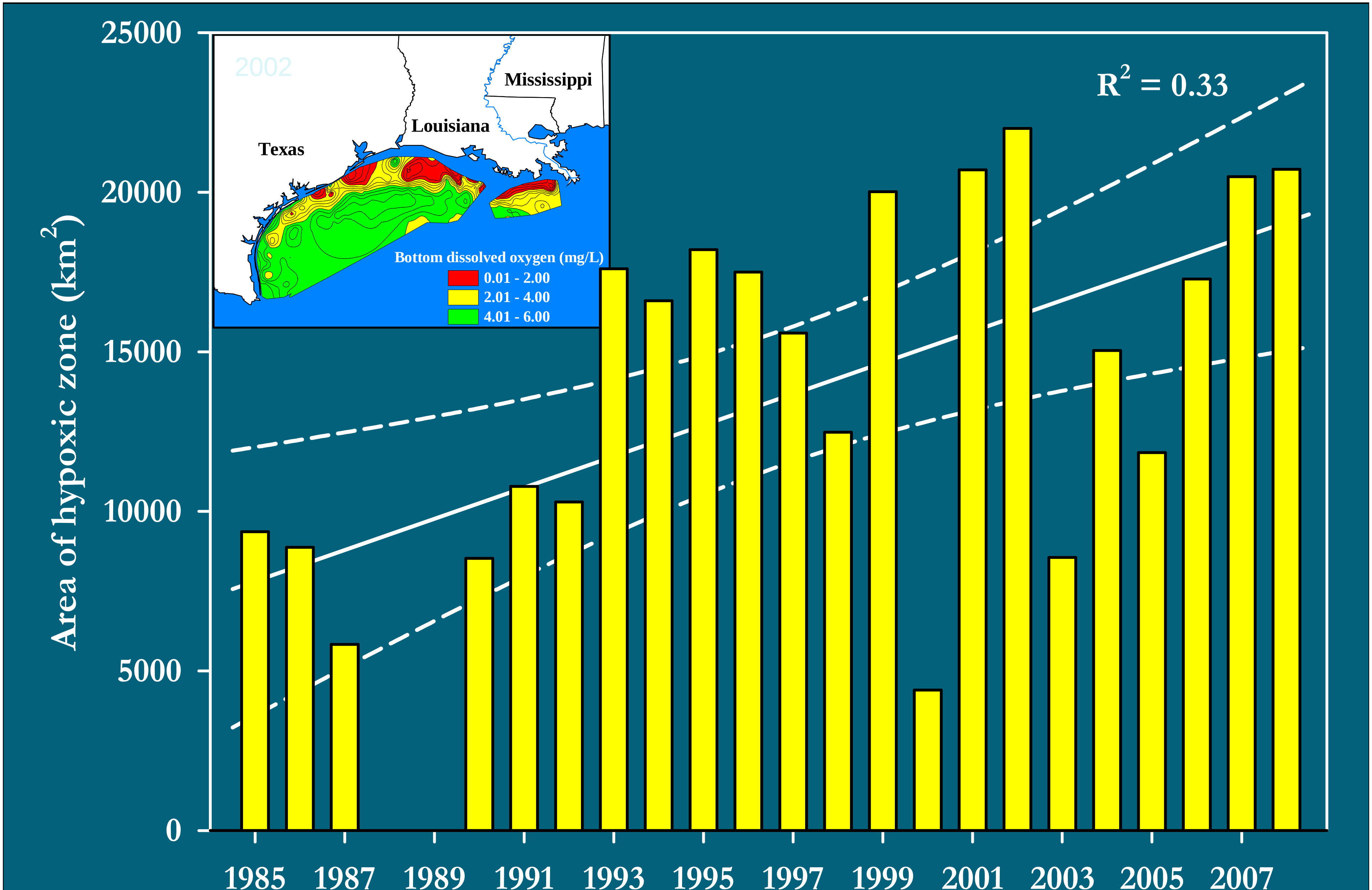
Hypoxia

- Seasonal low dissolved oxygen (DO) concentration (< 2 mg L^{-1})
  - Usually only affects bottom waters
- Cause by high nutrient (N & P) input
  - Phytoplankton bloom
  - Phytoplankton die and sink
  - Microbial decomposition of dead plankton consumes DO

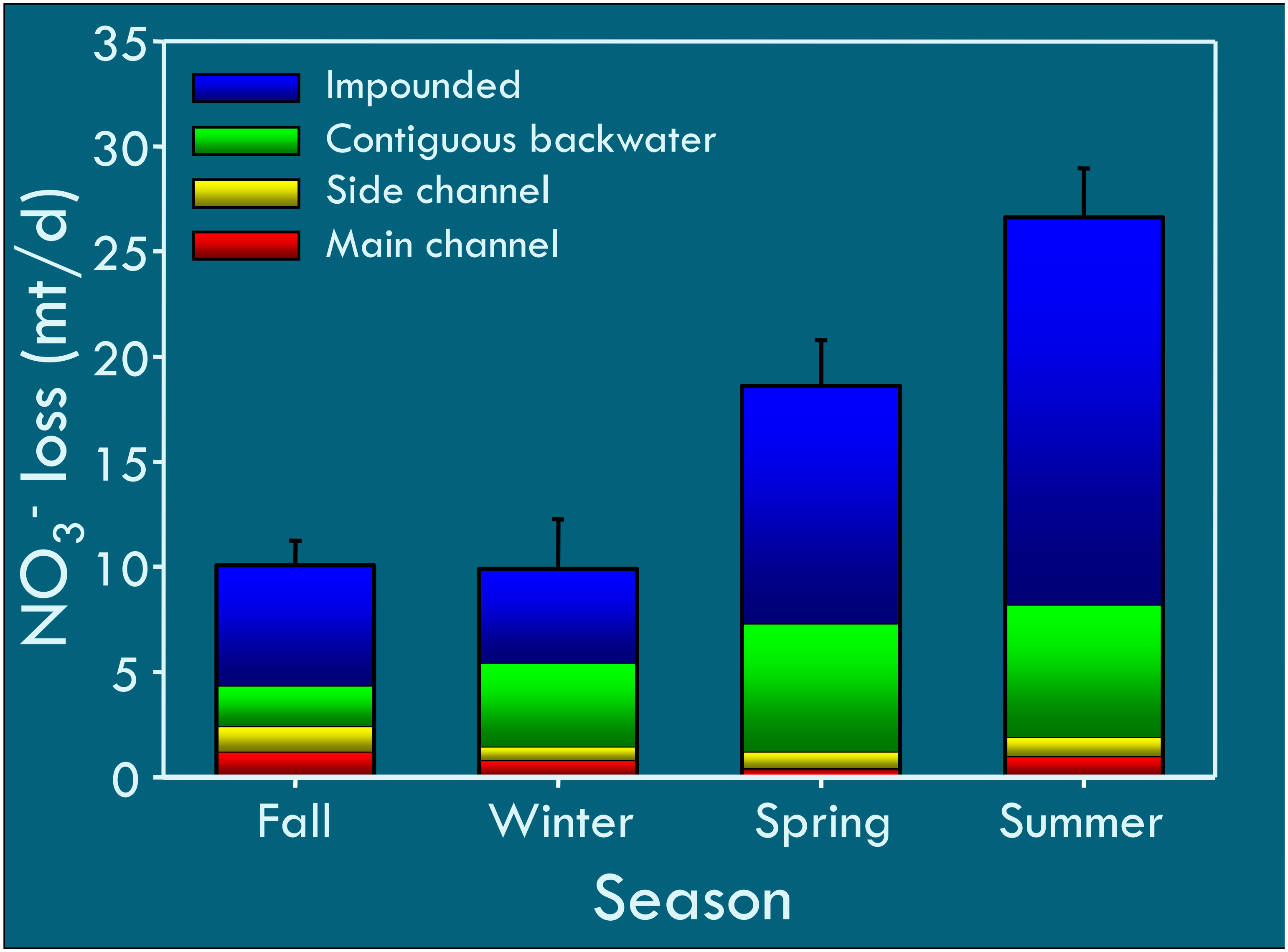


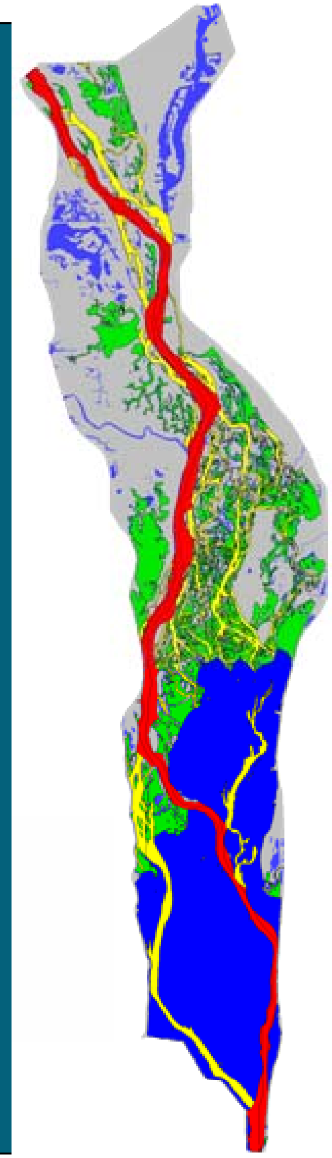
EPA (2001)

Hypoxia – Gulf of Mexico



UMR Pool 8 - Nitrate Loss from Denitrification





Richardson et al. 2004. Denitrification in the Upper Mississippi River: rates, controls, and contribution to nitrate flux. *CJFAS*. 61: 1102-1112.

Restoration of Large Rivers

- Vital to work toward "original" complexity and heterogeneity
  - Physical structures
    - Prop-killers – rocks, wood
  - Main channel, backwaters, side channels
    - Velocity (energy) gradients, deposition zones, sediment composition,
    - Biodiversity (plant, animal, microbes) depends on all of these areas
    - Nutrient processing
  - Connectivity among habitats is also important

Past and ongoing restoration efforts

Upper Mississippi River, Lower Navigation Pool 8 (Photo: Robert Hurt)

Outline

- Connectivity defined
- Ecological processes mediated by river-floodplain connectivity
- Some recent research on the UMR focused on connectivity issues
- Examples and outcomes of restoration on the UMR linked to connectivity
- Final thoughts

Connectivity: what is it and what are the implications for river restoration?

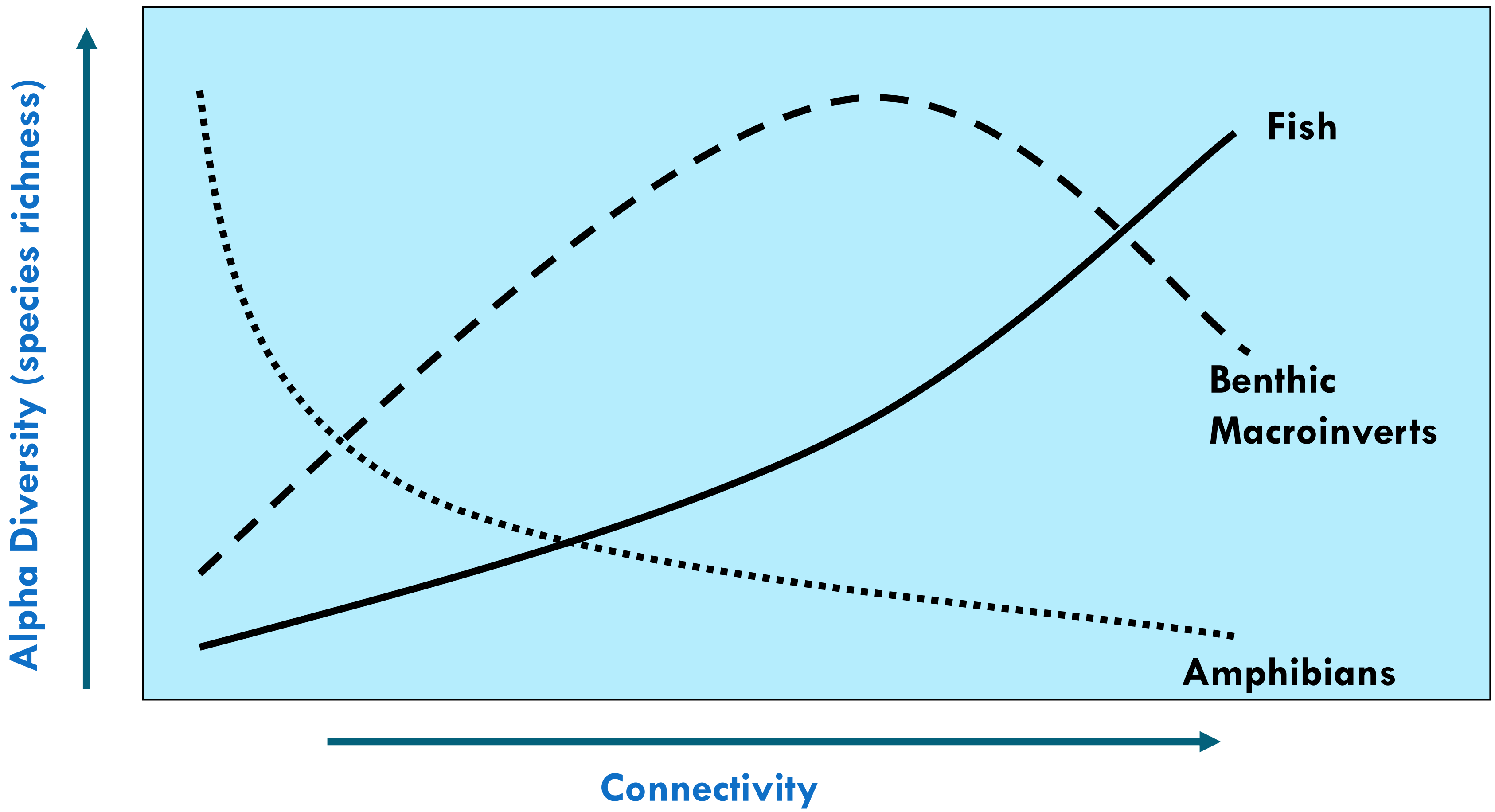
Connectivity: Water-mediated fluxes of material, energy, and organisms within and among components of the ecosystem (Kondolf et al. 2006).

Far-reaching effects on many biological and physical variables and processes:

- Hydraulic retention time
- Density and composition of suspended particles (including macro- and micro-organisms)
- Distribution and cycling of dissolved nutrients
- Thermal regime
- Dissolved oxygen concentration
- Primary production and algal species
- Indicator of food source and organism "health" e.g., essential fatty acids and other biomarkers.

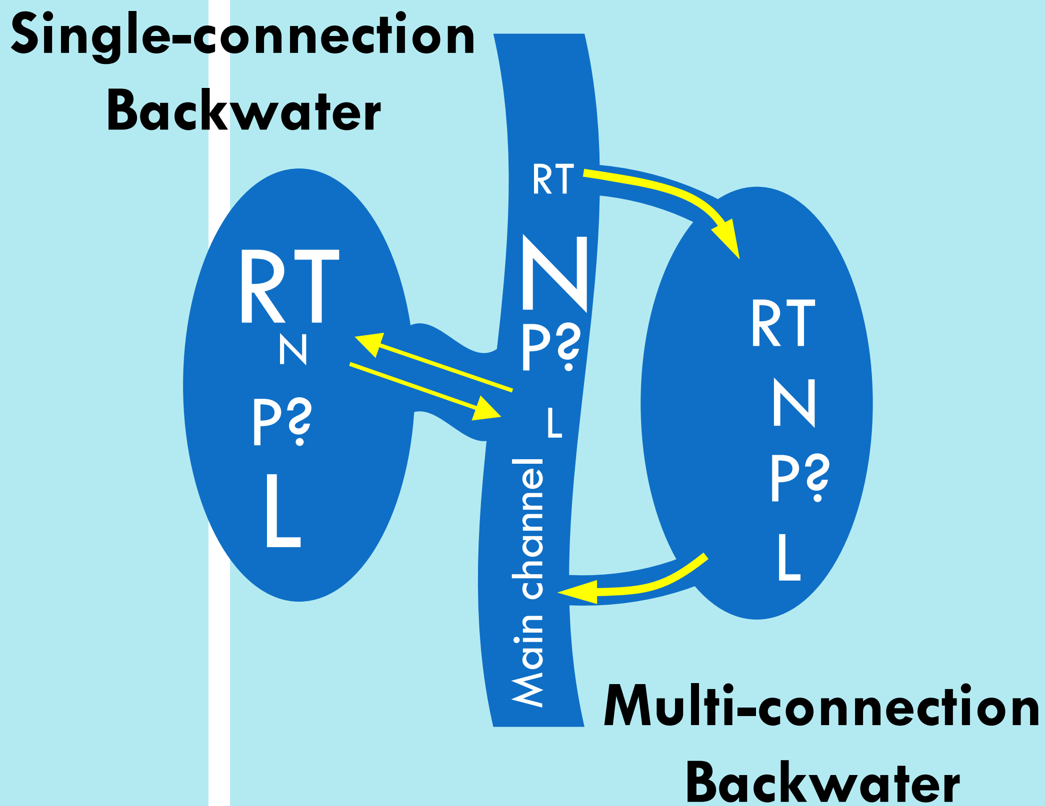
Relations between connectivity and diversity in large flood plain rivers

(Danube River floodplain : Tockner et al 1998; Amoros and Bornette 2002)



Amoros and Bornette. 2002. Connectivity and biocomplexity in water bodies of riverine floodplains. Freshw Biol. 47: 761-776; Tockner et al 1998. Conservation by restoration: the management concept for a river-floodplain system on the Danube River in Austria. Aquatic Conservation 8: 71-86.

Arrangement of connected channels and backwaters matters!



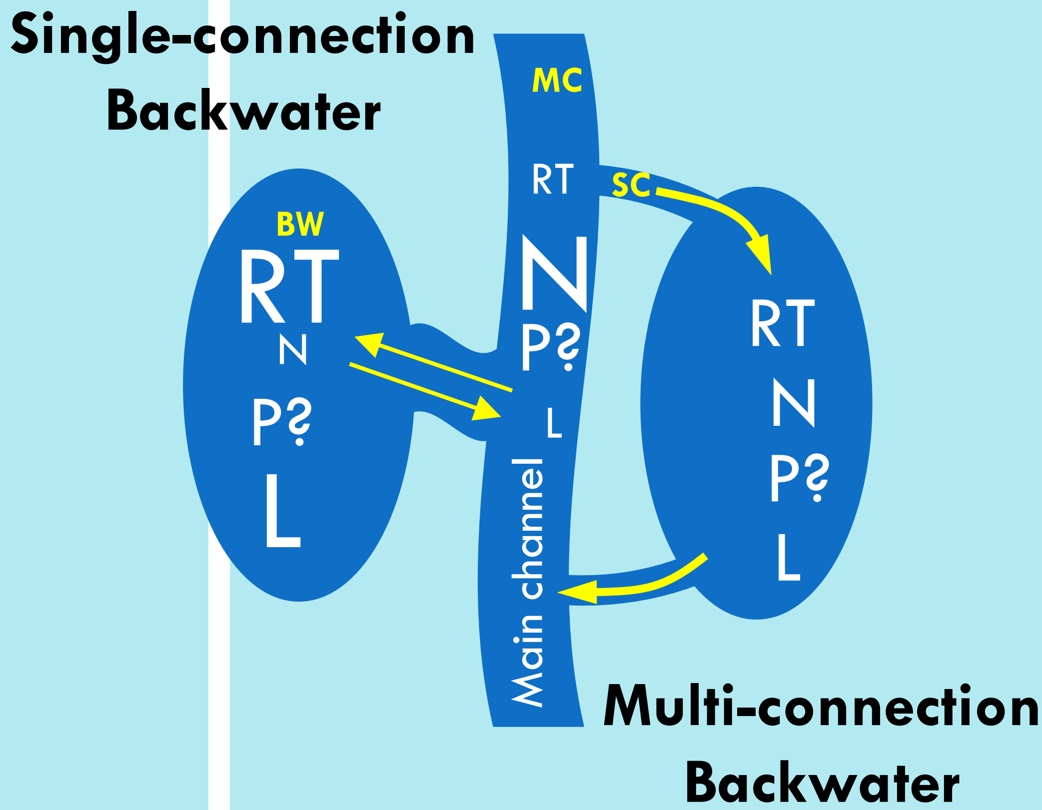
- **Residence Time**
  - Difficult to measure quantitatively
- **Nitrogen**
  - Source: channel
- **Phosphorus**
  - Source: channel and sediments
- **Light availability**
  - Light extinction
  - Depth

Potential effects of connectivity and geomorphological arrangements

Single inflow - longer average retention times, greater flood-dependency

Multiple inflow/outflows – shorter retention times, particle delivery, poorer light regime, higher dissolved inorganic N.

Flow regime affects processes and connectivity



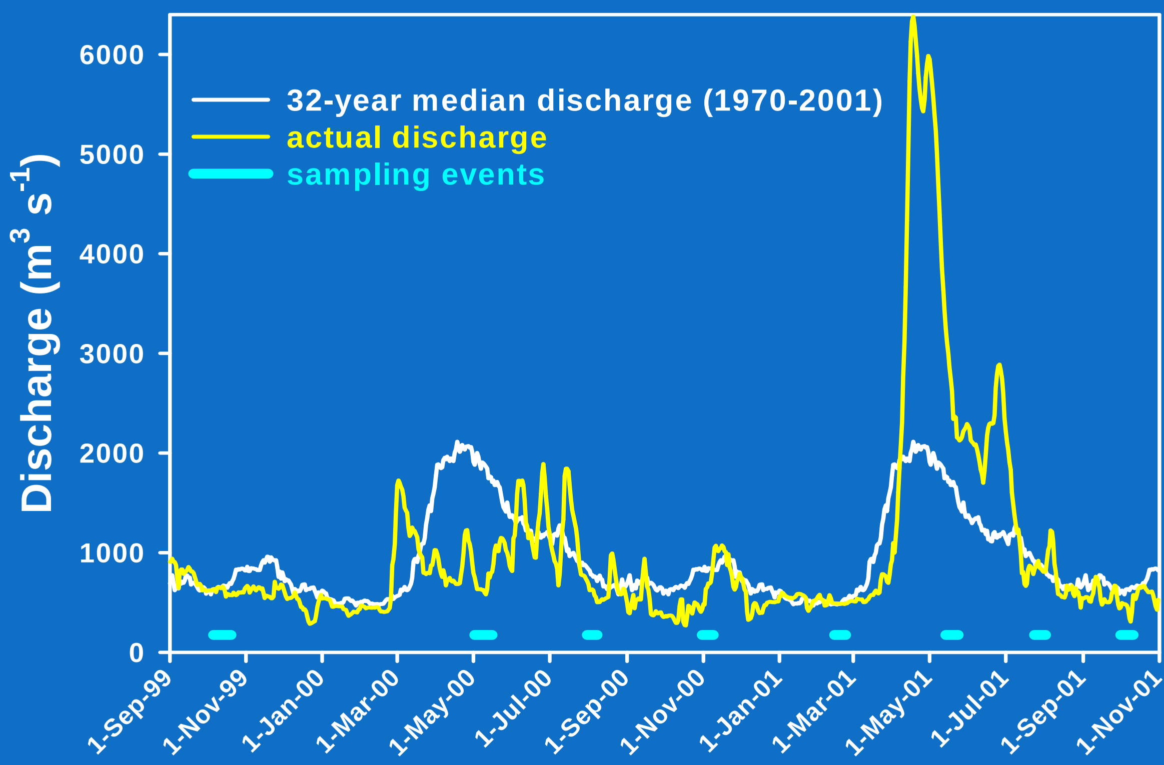
- **Residence Time**
  High Flows: MC~SC<BW
  Low Flows: MC<<SC<<BW
- **Nitrogen (DIN)**
  High Flows: MC~SC~BW
  Low Flows: MC>>SC>BW
- **Phosphorus (SRP)**
  High Flows: MC~SC~BW
  Low Flows: MC~SC~BW
- **Light availability**
  High Flows: MC~SC<BW
  Low Flows: MC<<SC<<BW

Potential effects of connectivity and geomorphological arrangements

<u>High flows</u>: N, P, suspended sediments relatively homogeneous distribution across the floodplain

<u>Low flows</u>: BW: DIN and ISS loss in BW, VSS and SRP increase;
MC: DIN, ISS, SRP generally remain high

Flood Pulse in the Upper Mississippi River:
Variation in discharge at La Crosse, WI



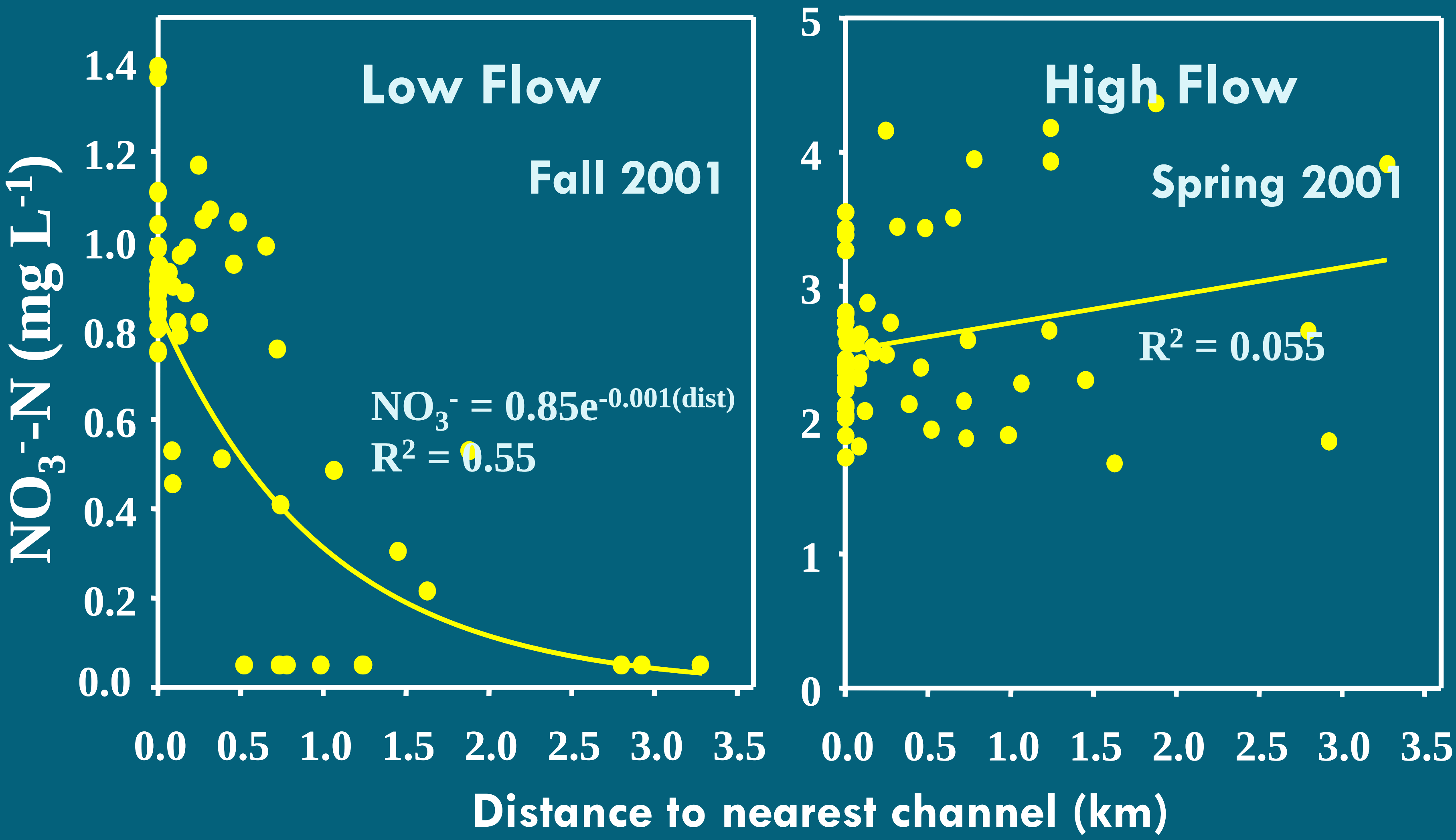
Base flow
(~ 900 m^3 s^{-1})

Flood
(6500 $m^3 s^{-1}$)

Root River

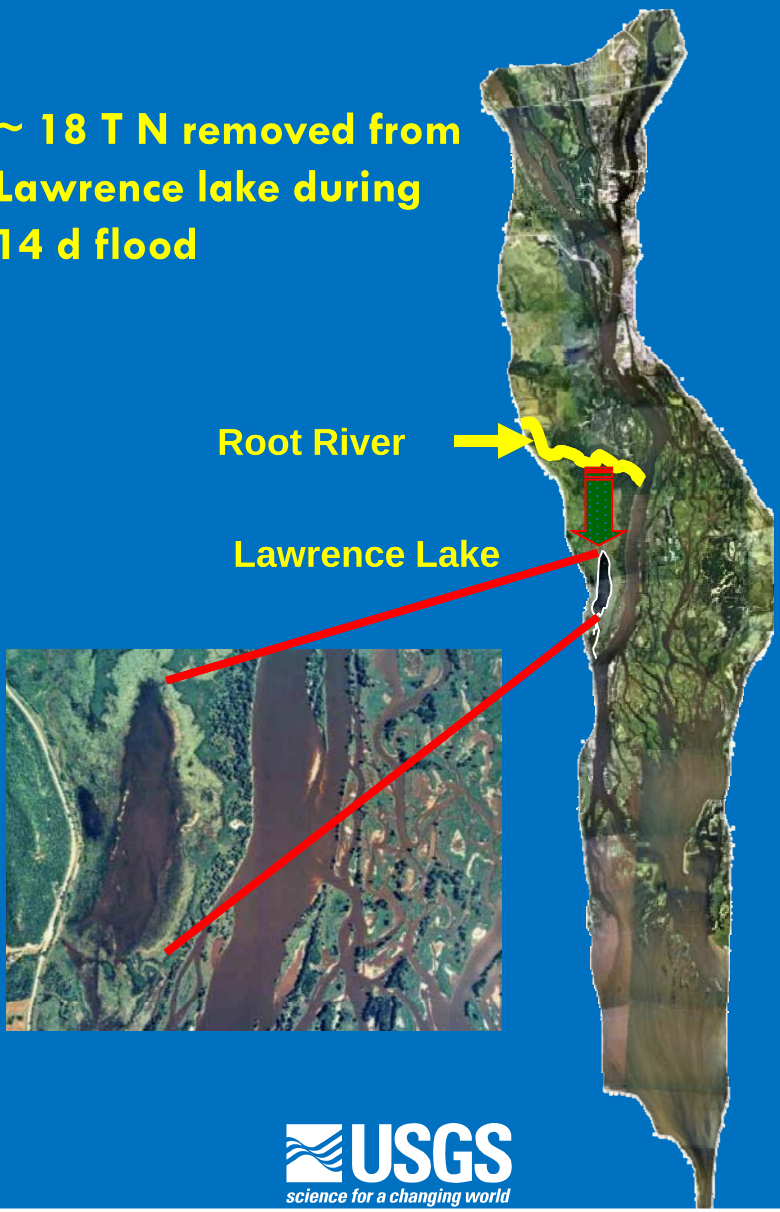
Lawrence Lake

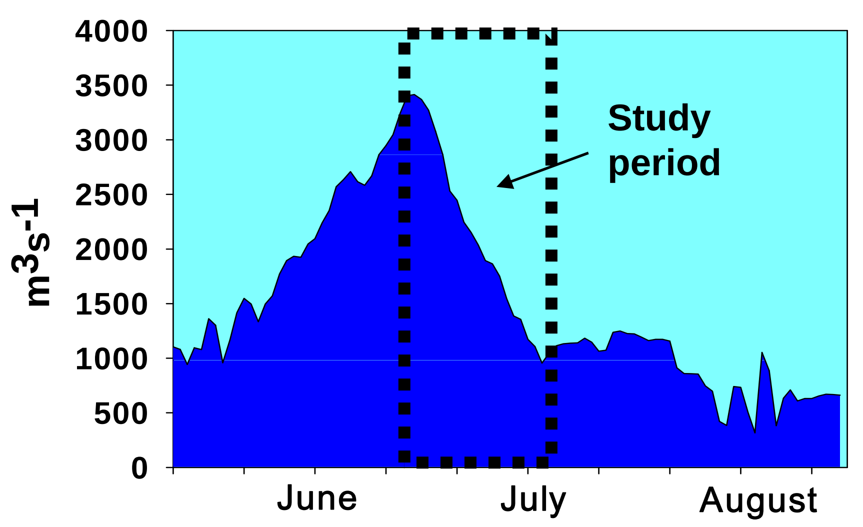
RIVER DISCHARGE AFFECTS DISTRIBUTION OF NITRATE ACROSS THE FLOOD PLAIN

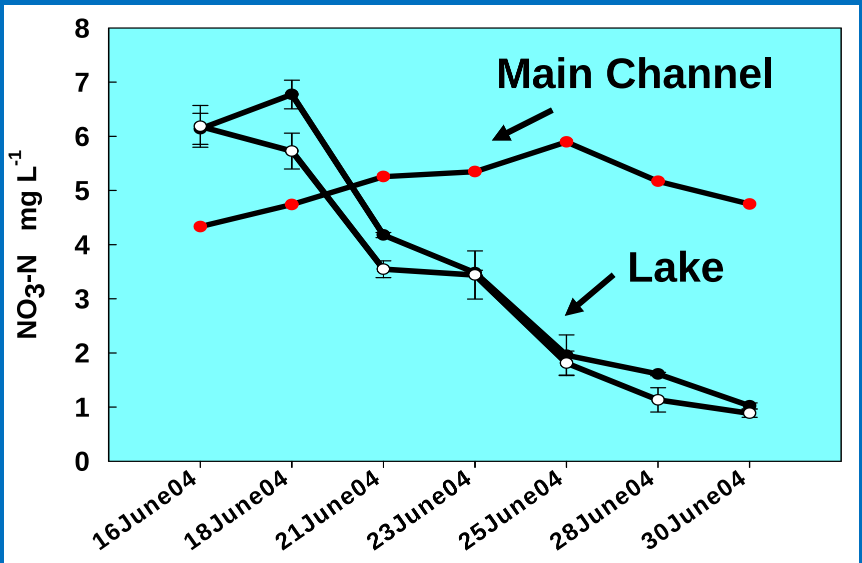


Backwater lake flooded in summer 2004 with both Root River and Mississippi River water.

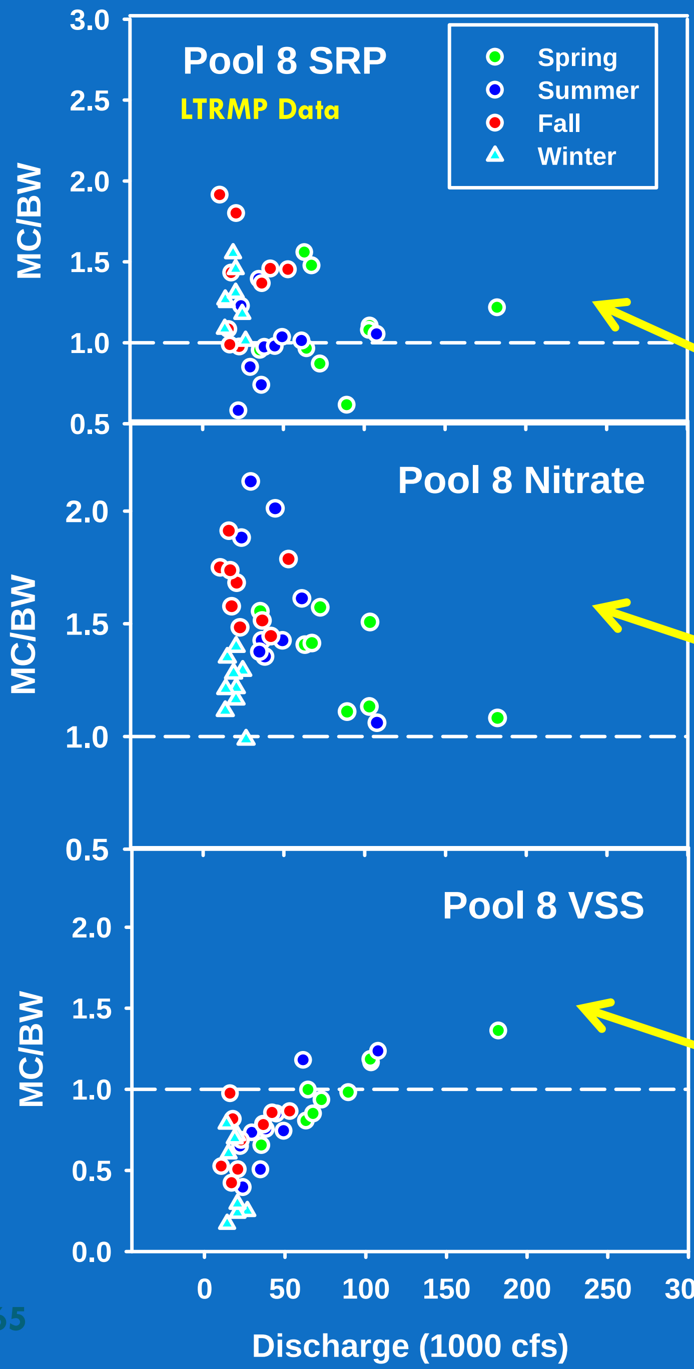
~ 18 T N removed from Lawrence lake during 14 d flood







USGS
science for a changing world



HYDRAULIC CONTROL: distribution of soluble P, NO_3^- and volatile suspended solids (VSS) (data from the Long Term Resource Monitoring Program)

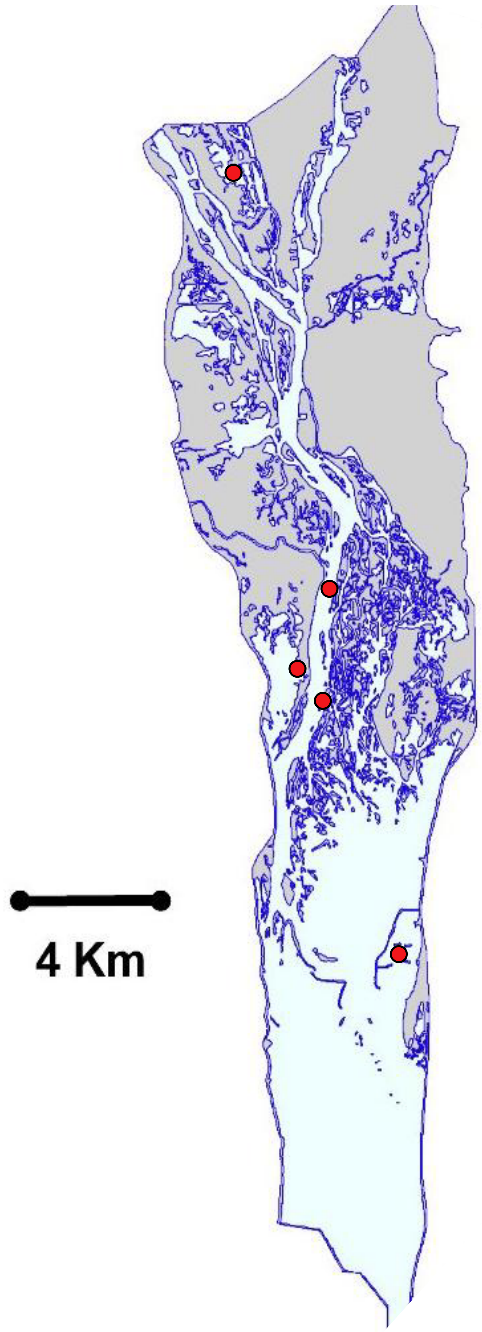
Soluble P – concentrations likely controlled by combination of loading (flow) and sediment redox and backwater oxygen dynamics.

Nitrate – distribution extremely sensitive to river flows. Backwaters depleted of nitrate via denitrification and assimilation – replenished during floods. Main channels always with highest concentrations – little biological removal.

VSS – biogenic sources in backwaters (algal production, bioturbation) dominate VSS production at all but the highest river flows.

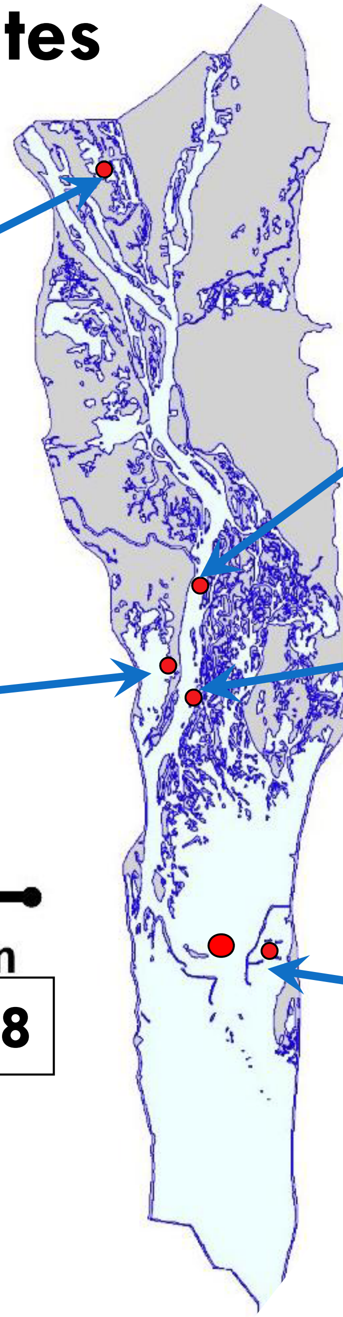
Connectivity Relevant Studies

1. **Connectivity Campaign (APE funding):** 2008 (6 sites – April-October, continuous WQ, bi-weekly LB-DB productivity, nutrients, seston, zoopl., fish, lipid and stable C&N isotope analysis on all tissues)
2. **Lipids in channels and backwater food webs (USGS Base) :** 2005 – 2006 (survey of lipids in seston, macroinvertebrates, fish)
3. **Long Term Resource Monitoring Program** (1993 – present) – 150 random sites sampled quarterly in River in 4 Navigation Pools
,



Connectivity Study Sites
SU 2008

Round Lake
Backwater, Multiple Connection



Main Channel (RM 693)

Main Channel (RM 691)

Lawrence Lake
Single Connection Backwater

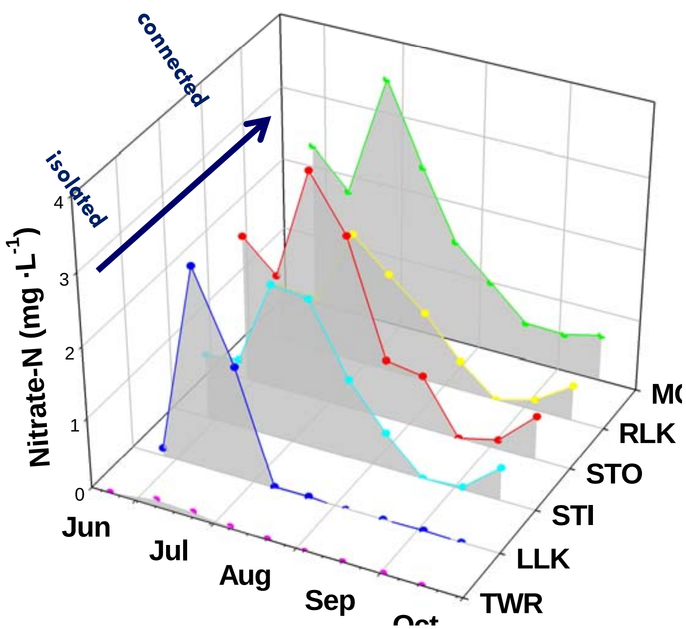
4 Km

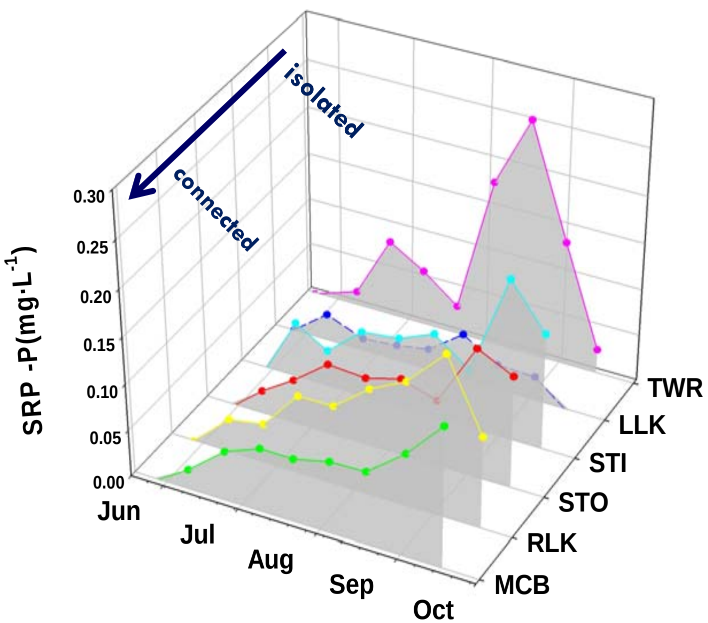
Pool 8

Stoddard Islands HREP
Backwater, Multiple Connection

Trempealeau NWR
Backwater, Isolated
(Pool 6)

Nitrate and soluble P dynamics across a connectivity gradient in the UMR





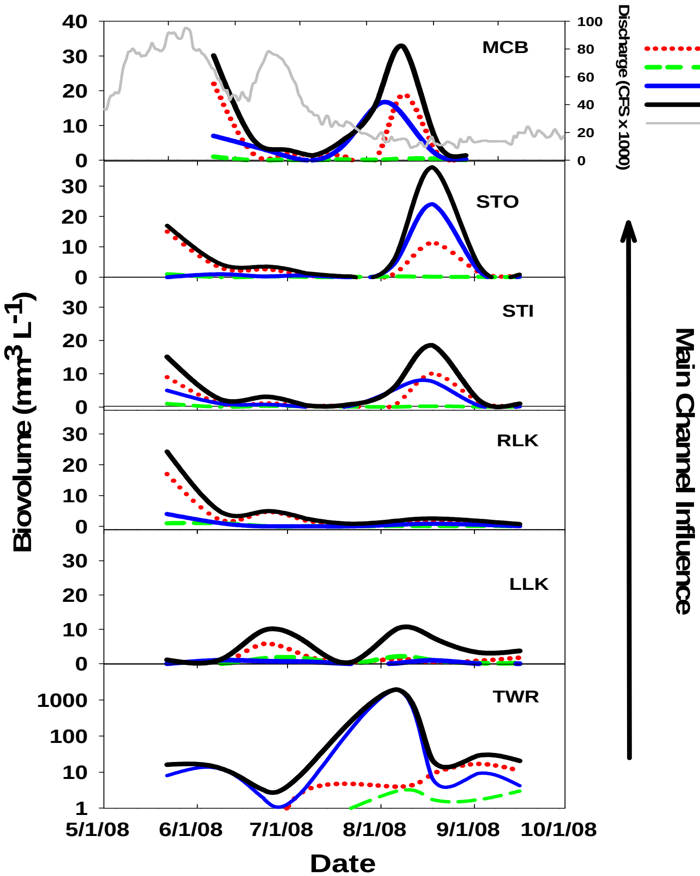
Nitrate concentrations highest in Main Channel through out summer.

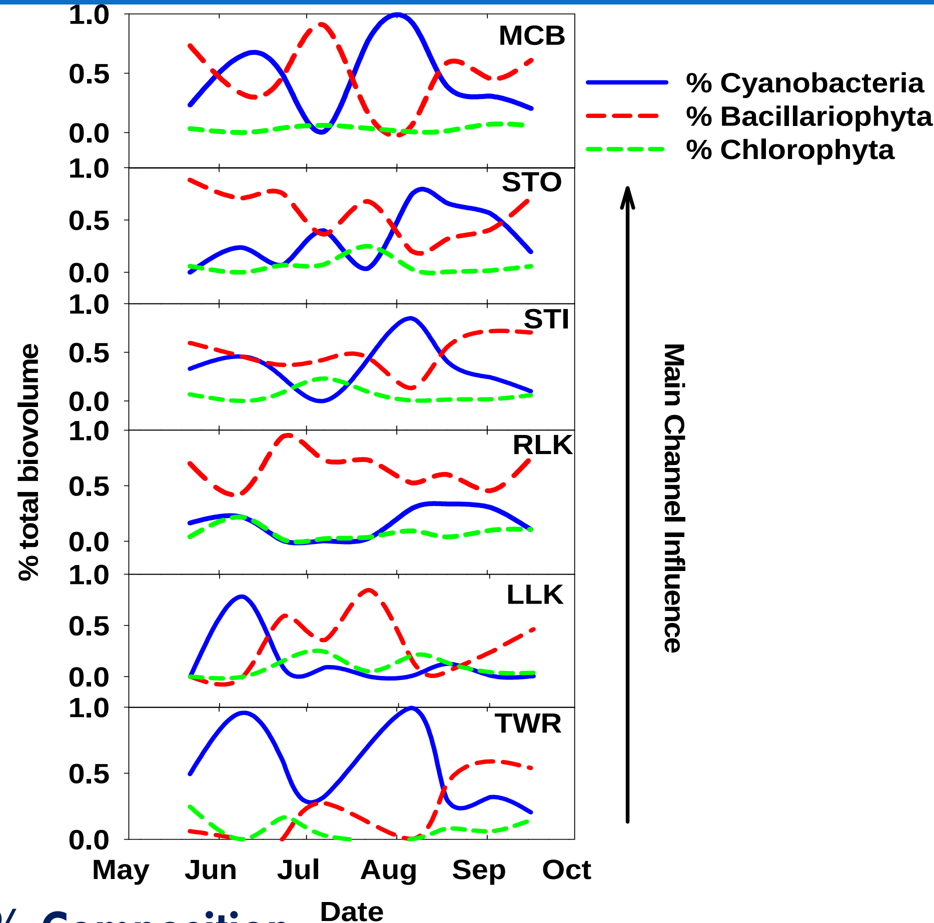
Nitrate depletion nearly complete in most isolated backwater.

SRP concentrations highest in most isolated backwater.

SRP highly variable but not tightly linked to connectivity gradient.

Phytoplankton density and composition in the UMR across a connectivity gradient





Phytoplankton density

-strongly affected by main channel flows

-Stoddard Island HREP with less phytoplankton

-Round Lake strongly affected by macrophytes

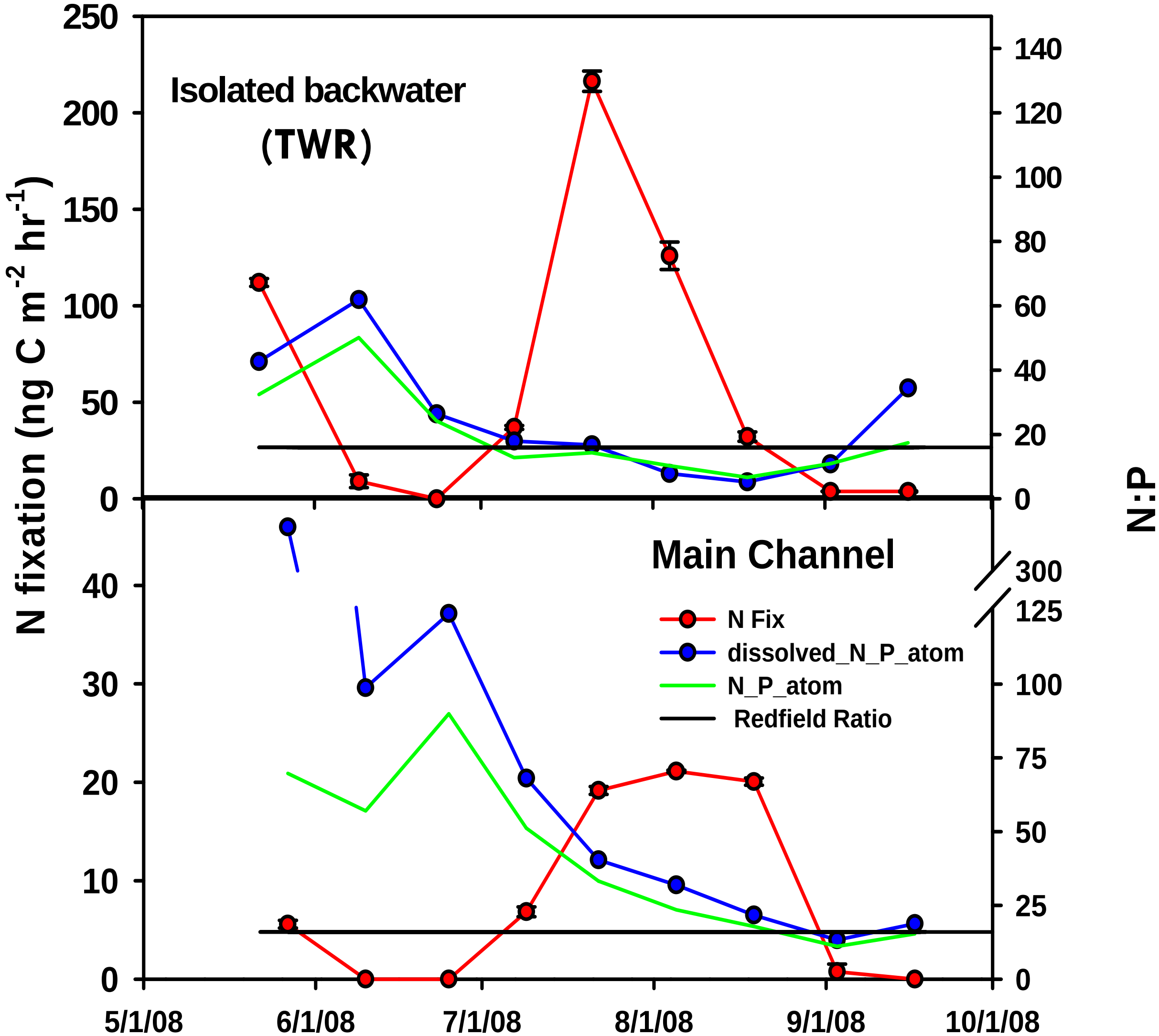
-TWR highly productive, most isolated site

% Composition

-Dominated by diatoms in spring, cyanobacteria. in fall, esp in isolated backwaters

-Complimentarity between cyanobacteria and diatoms

Connectivity and nitrogen fixation

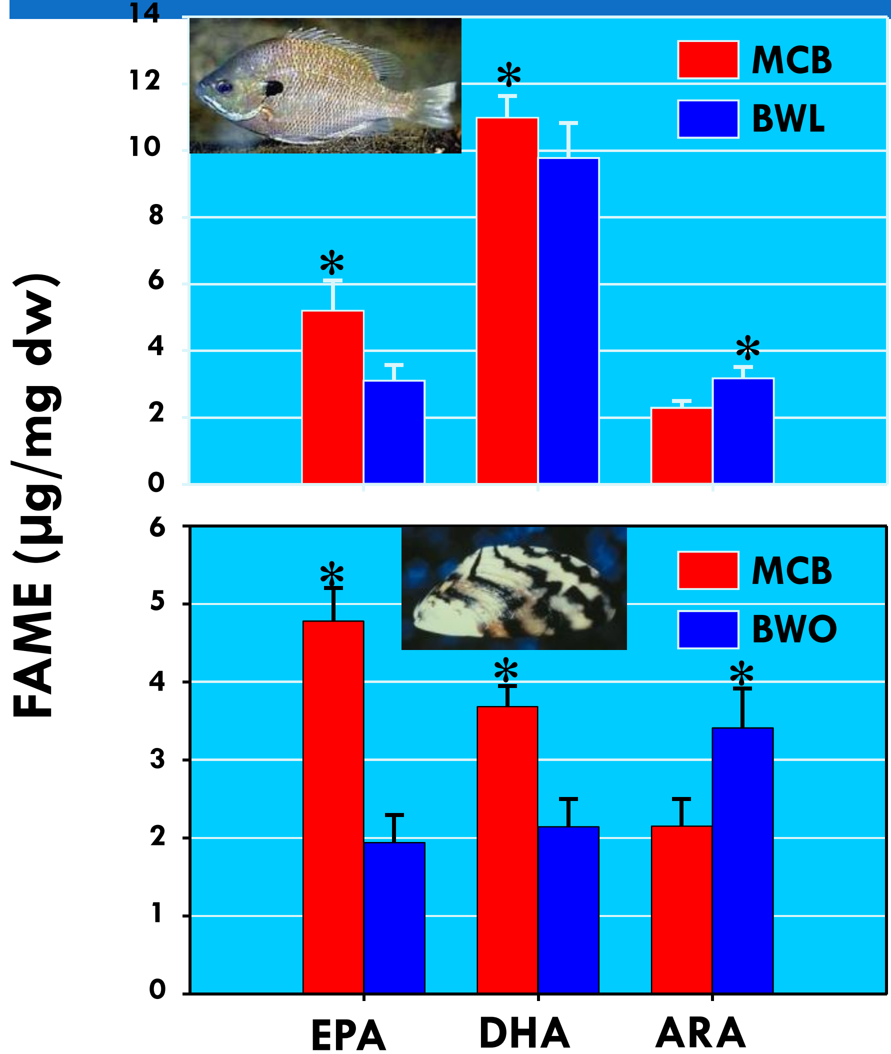


Initiated earlier in isolated backwaters

Occurs at much higher rates in backwaters than main channel

Coincides with declining N:P ratios and appearance of heterocystic Cyanobacteria (*Microcystis, Anabaena*, and *Aphanizomenon)*

Tissue lipid concentrations (essential fatty acids) of fish and filter feeders vary by habitat.



YOY Bluegill from Main channel border (MCB) and Backwater Lawrence lake (BWL)

MCB with elevated EPA, DHA
BWL with elevated ARA

Zebra mussels in Main channel border (MCB) and Backwater Lake Onalaska (BWO)

MCB with elevated EPA, DHA
BWO with elevate ARA

Effects of channel-floodplain connectivity:

Putting the pieces together (*with a large dose of speculation*)

1. DIN concentrations across the floodplain are strongly affected by interaction of discharge and geomorphology.

2. Dissolved P distributions are less dependent of discharge and geomorphology.

3. Late summer phytoplankton community structure appears linked to DIN/SRP ratios: backwaters become N-limited and cyanobacteria become dominant.

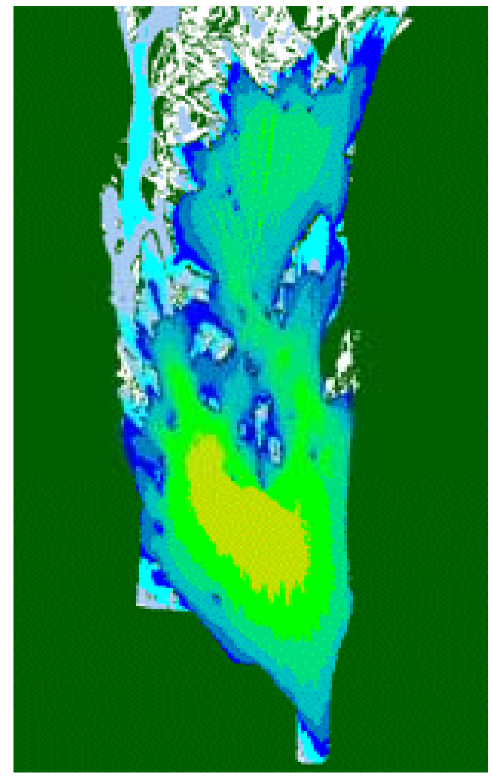
4. Late summer shifts in phytoplankton in backwaters, from lipid-rich (diatoms & cryptophytes) to lipid poor (cyanobacteria), appear to result in food webs deficient in essential fatty acids (DHA, EPA).

5. Has implications for health and production of organisms and ecosystems.

UMR “Guiding Image” and Some Restoration Approaches

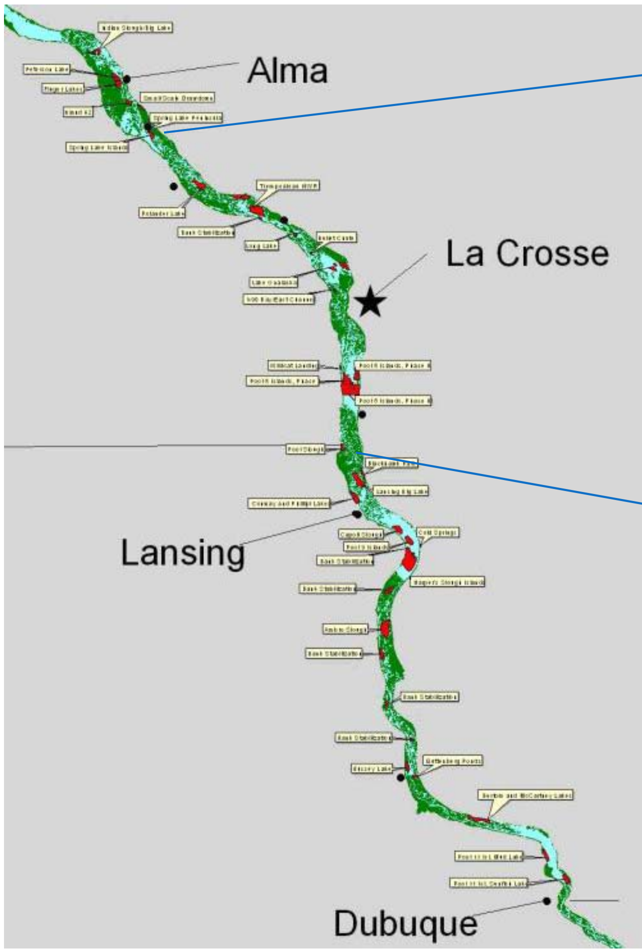
- **Enhanced Lateral Connectivity**
  - Finger lakes, Pool 4-5
- **Water level management (WLM)**
  - Navigation Pools 5, 6, 8
- **Island Building**
  - Navigation Pools 5, 7,8

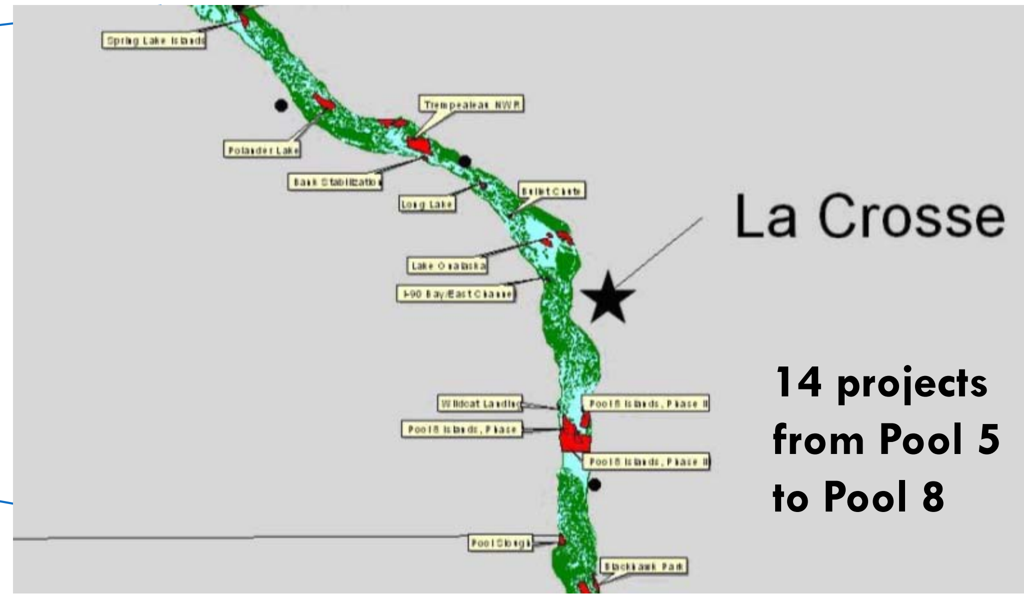
The Pool 8 Image:
1940’s – 1950’s conditions



1954

Distribution of Habitat Rehabilitation Projects (HREP) via the Environmental Management Program (ACOE)





- The Habitat Rehabilitation and Enhancement Projects (HREPS) restoring lost habitat or protecting existing habitat within the floodplain of the Mississippi and Illinois Rivers.

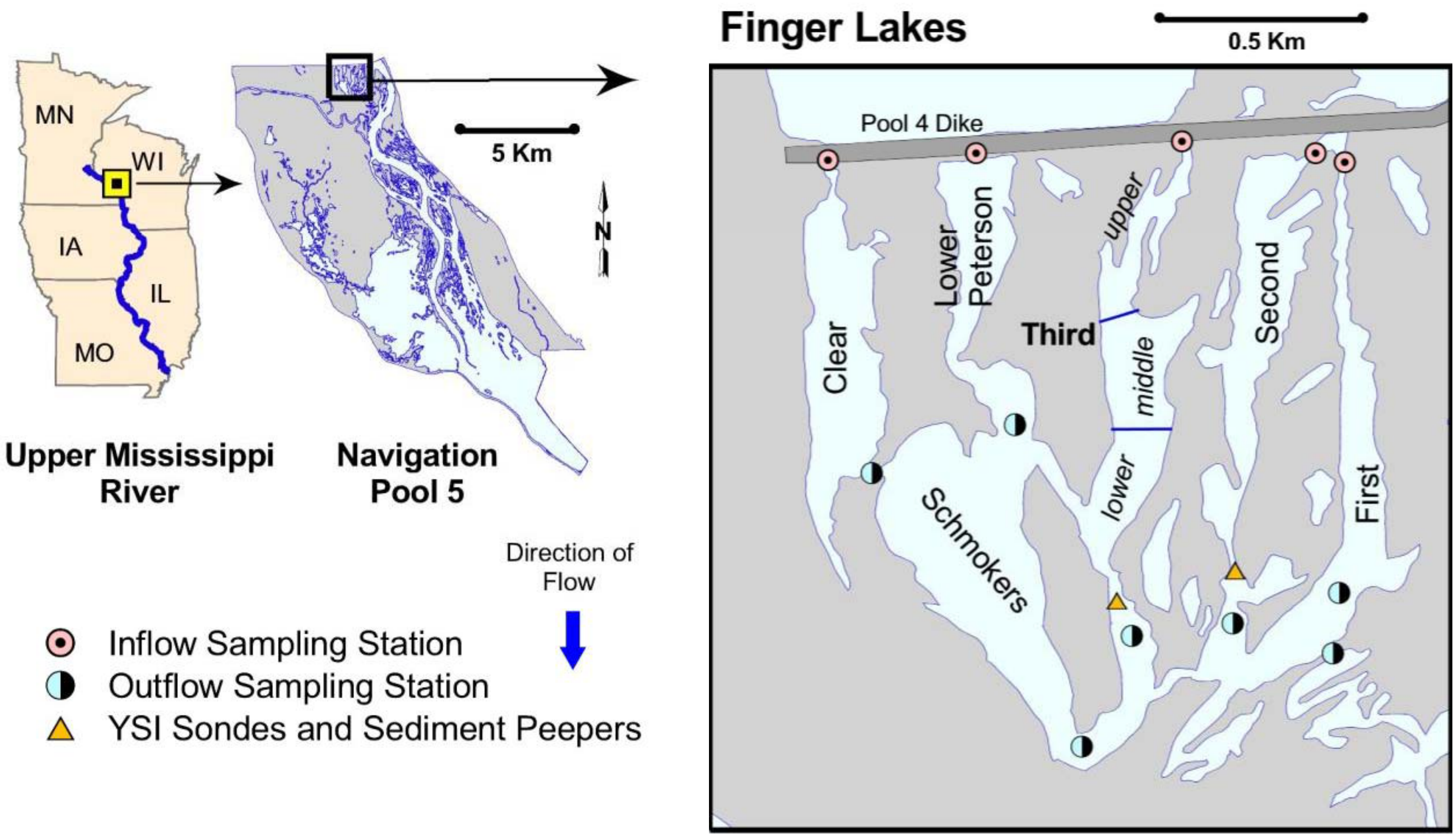
- In the past 20 years over 48 projects have been constructed affecting more than 75,000 acres of river and floodplain habitat.

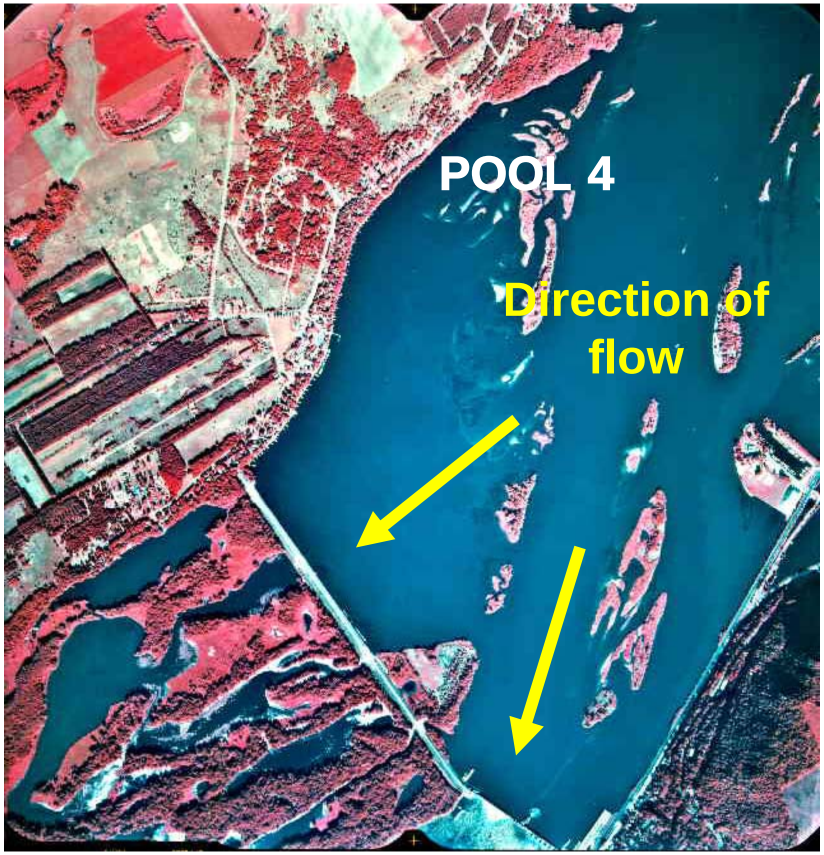
- More projects are planned, waiting for funding.

Lateral Connectivity Projects

- Guiding Vision – to increase flow between main channels and off-channel floodplain areas (as exemplified by upper sections of Navigation Pools)
- Expected outcomes:
  - Increased winter dissolved oxygen concentrations
  - Increased winter temperatures
  - Increased overwinter centrarchid survival
  - Increased fishing opportunities
  - Improved water quality through elevated nitrate removal

Reconnected backwater lakes:
The Finger Lake system, Navigation Pool 5





Flow regulation via valved culverts at upper end of each lake; inflow ~1.0 m^3s^{-1}, max = 1.6 m^3s^{-1}).

Connectivity and overwintering habitat for Centrarchids: Finger Lakes winter telemetry study

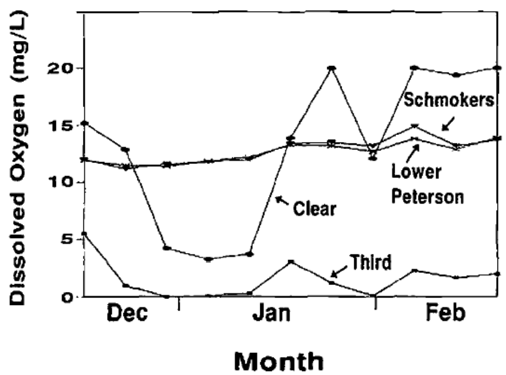
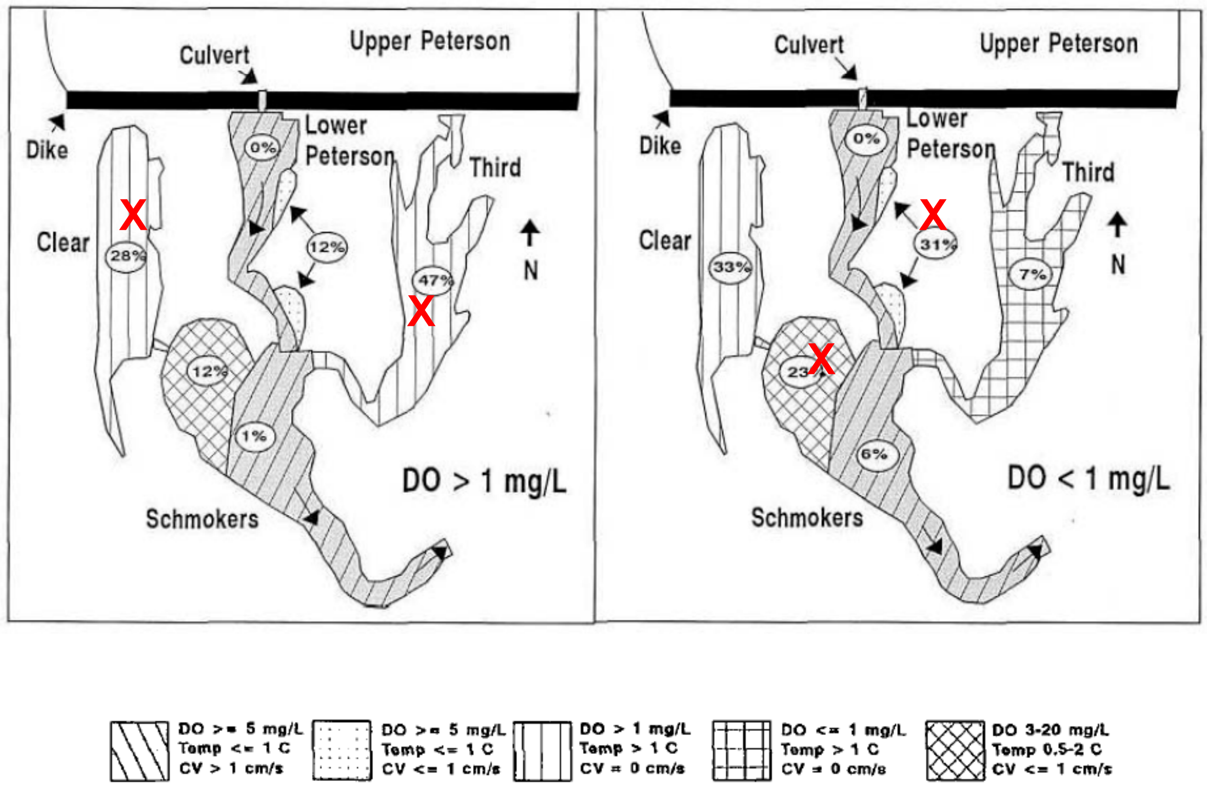


FIGURE 3.—Dissolved oxygen concentrations at mid-lake and mid-depth in Clear, Lower Peterson, Schmokers, and Third lakes between December 16, 1991, and February 22, 1992.



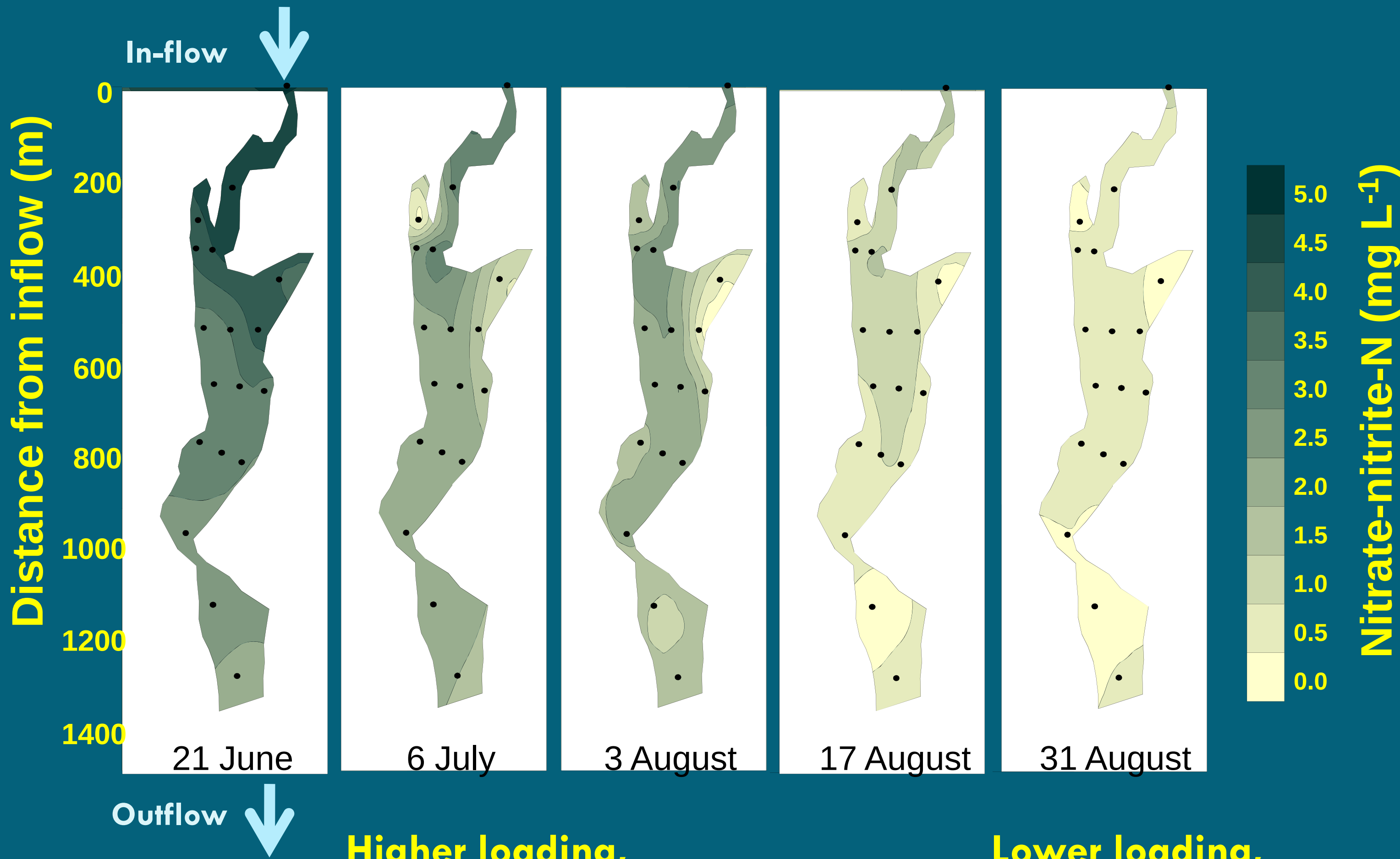
-When DO > 1mg/L Fish in warmer water (Clear & Third L.)

-When DO < 1mg/L fish move to colder but O2-rich water)

-Avoided >1 cm/s water velocity

Knights et al. 1995. Responses of bluegills and black crappies to dissolved oxygen, temperature, and current in backwater lakes of the UMR during winter. N. Am. J. Fish. Managem. 15: 390-399.

Connectivity and spatial variation of nitrate concentration in Third Lake*

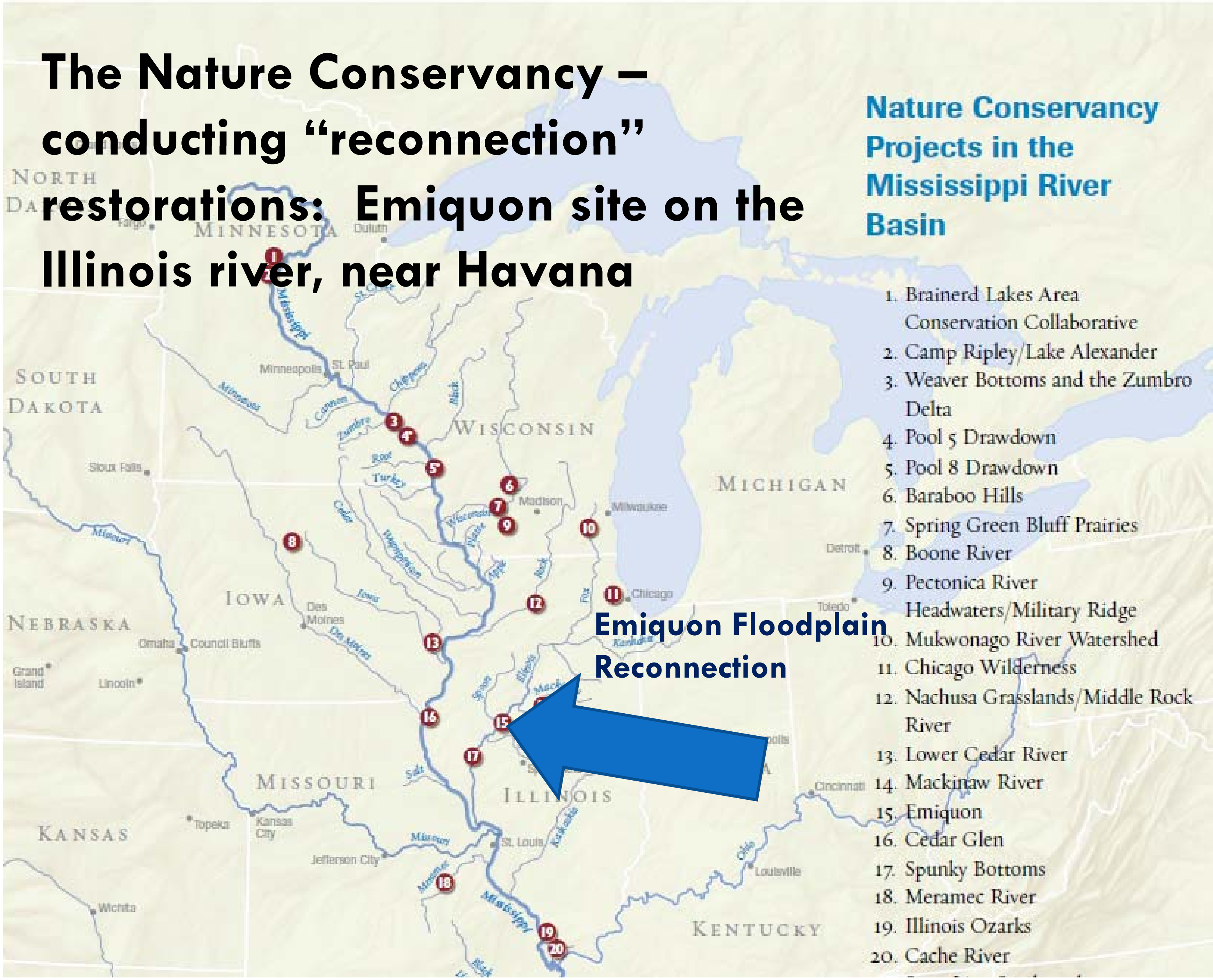


Higher loading, higher NO3 removal

Lower loading, lower NO3 removal

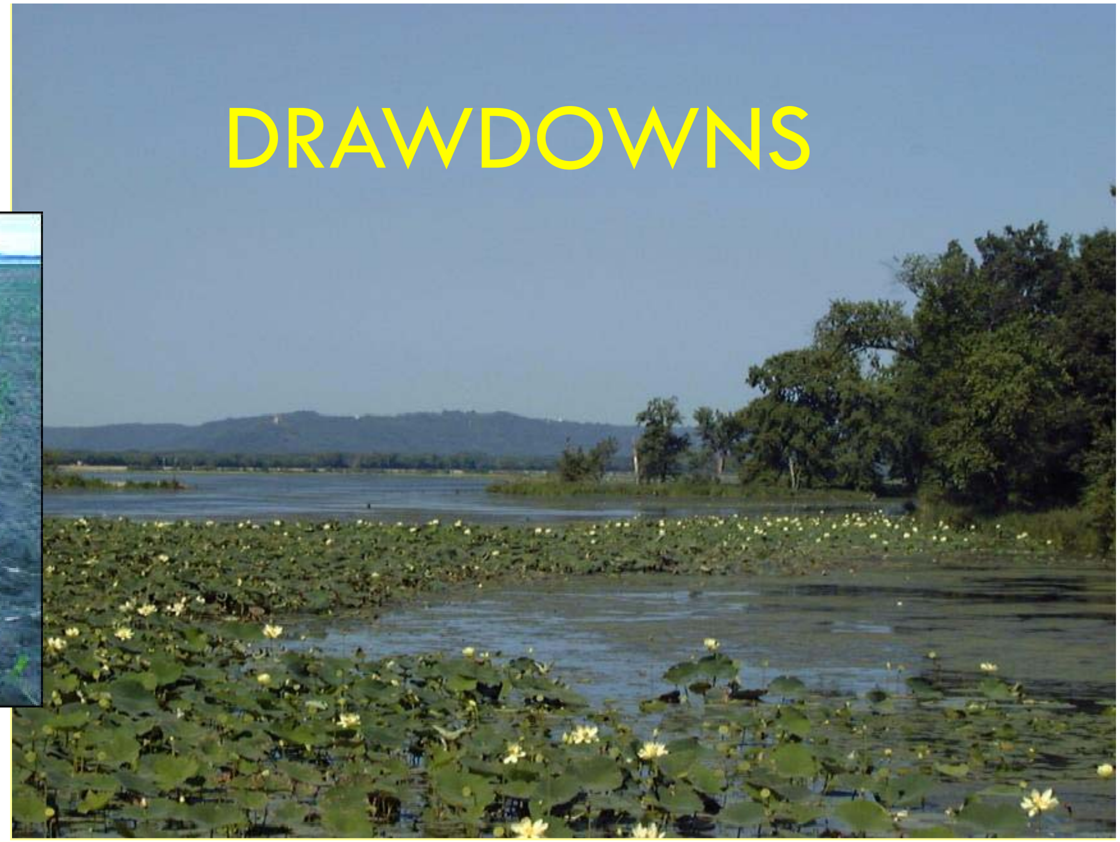
* James et al 2008 Effects of water residence time on summer nitrate uptake in flow-regulated Mississippi River backwater. River Research and Application 24: 1206-17

The Nature Conservancy – conducting “reconnection” restorations: Emiquon site on the Illinois river, near Havana



Outcomes of Lateral Connectivity projects

- **Enhancement of over-wintering habitat for centrarchid fish, but needs control of inflow rates.**
- **Nitrogen dynamics (removal) tightly linked to rates of inflow, backwater surface area, and load rate.**
  - Unknown role of unintended consequences (e.g., sediment loading, macrophyte erosion, eutrophication, reductions of N/P ratios, carbon storage, greenhouse gas flux).
- **Reclamation of farmed floodplain holds promise for improvement of biodiversity and N removal –(e.g., TNC Emiquon/Spunky Bottom).**

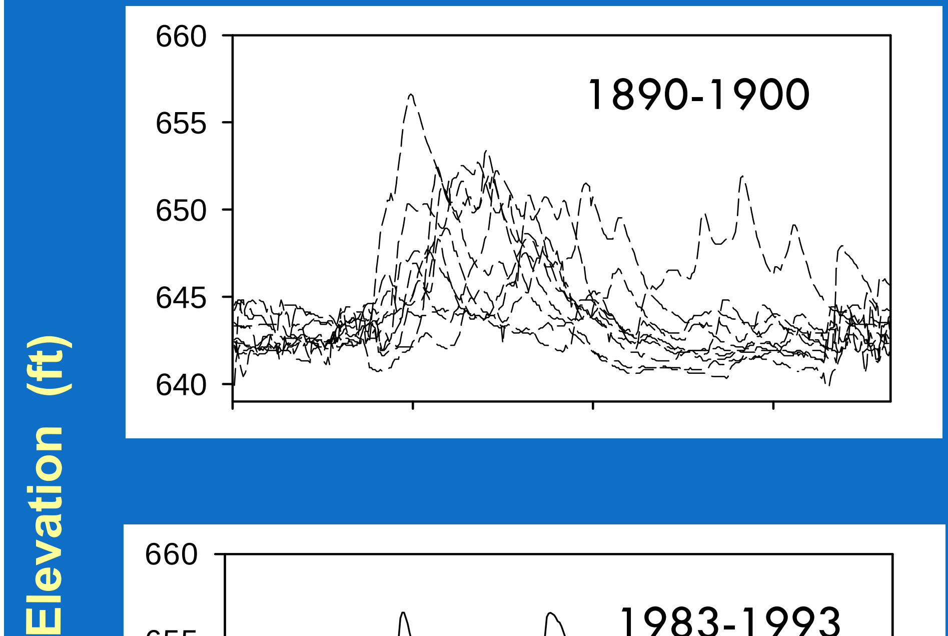


Pool 5 drawdown response, Weaver Bottoms

Water Level Drawdown

- **Guiding Vision – to restore a more "natural" [pre- lock and dam] hydrograph.**
- **Expected outcomes:**
  - Increased water clarity
  - Increased sediment compaction
  - Increased growth of rooted macrophytes
  - Increased fish production, waterfowl feeding

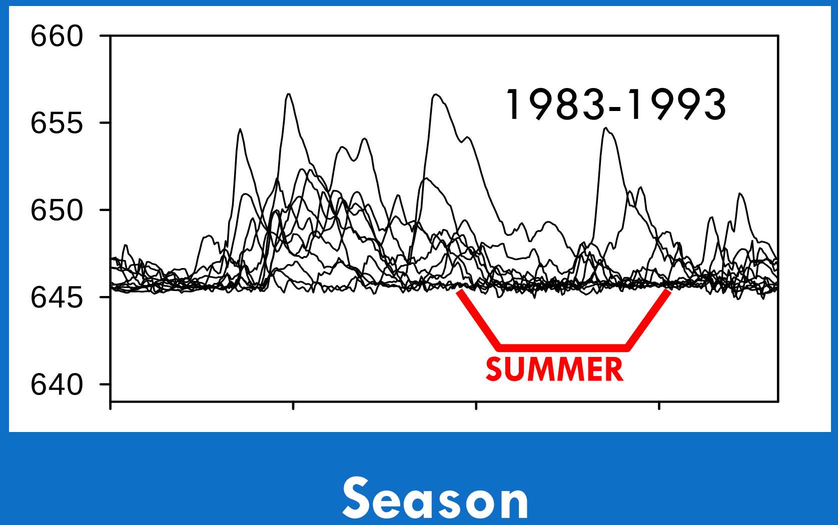
Effect of water management for navigation:
Water elevation at Winona, MN



Daily River Stage: 1890-1900

Mean stage: 645, but variation extreme.

Resulted in more dynamic channel form, more variable light penetration, variable sediment wetting and drying.

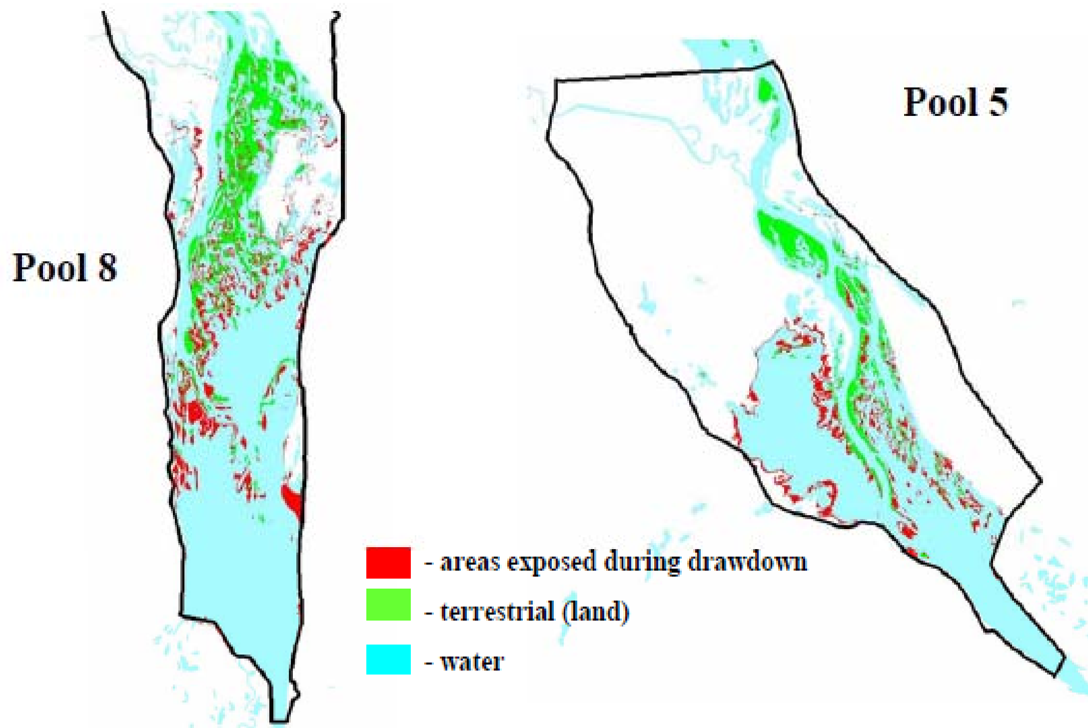


Daily River Stage: 1983-1993

Mean stage: 648, but low end of hydrograph truncated

"Water level management" Designed to simulate historical low summer river stage.

Pool 8 Drawdowns: 2001 & 2002
Pool 5 Drawdowns: 2005 & 2006
Pool 6 Drawdown: Planned



1,954 acres exposed on July 21, 2001

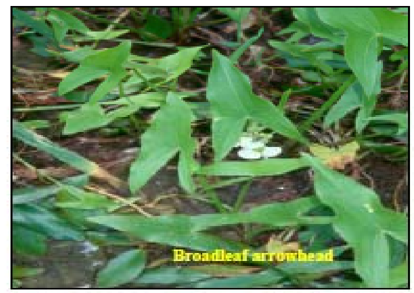
1,032 acres exposed on July 15, 2005

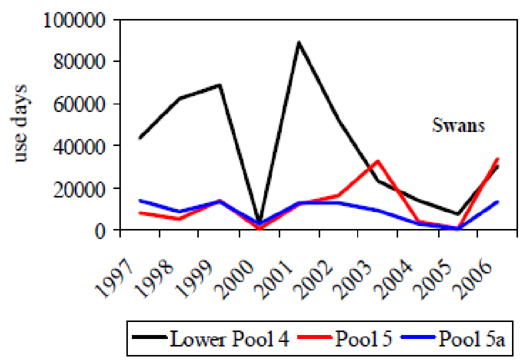
Pool 5 Drawdown: Response of waterfowl

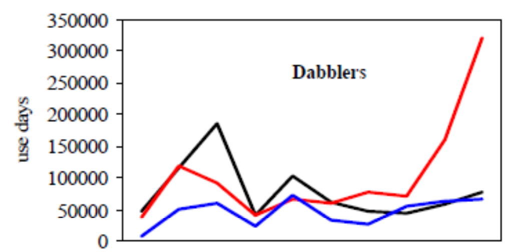
Increased use of drawdown Pools by dabbling and diving ducks; tundra swans response equivocal. Probably related to increased density of tuberous emergent vegetation. Hard to separate from Island building effects.

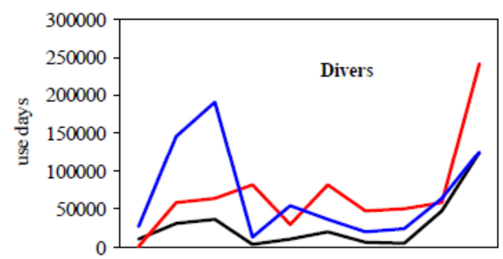
Tundra Swans

Swans are especially fond of arrowhead tubers and are often concentrated around large beds of this important emergent plant species.







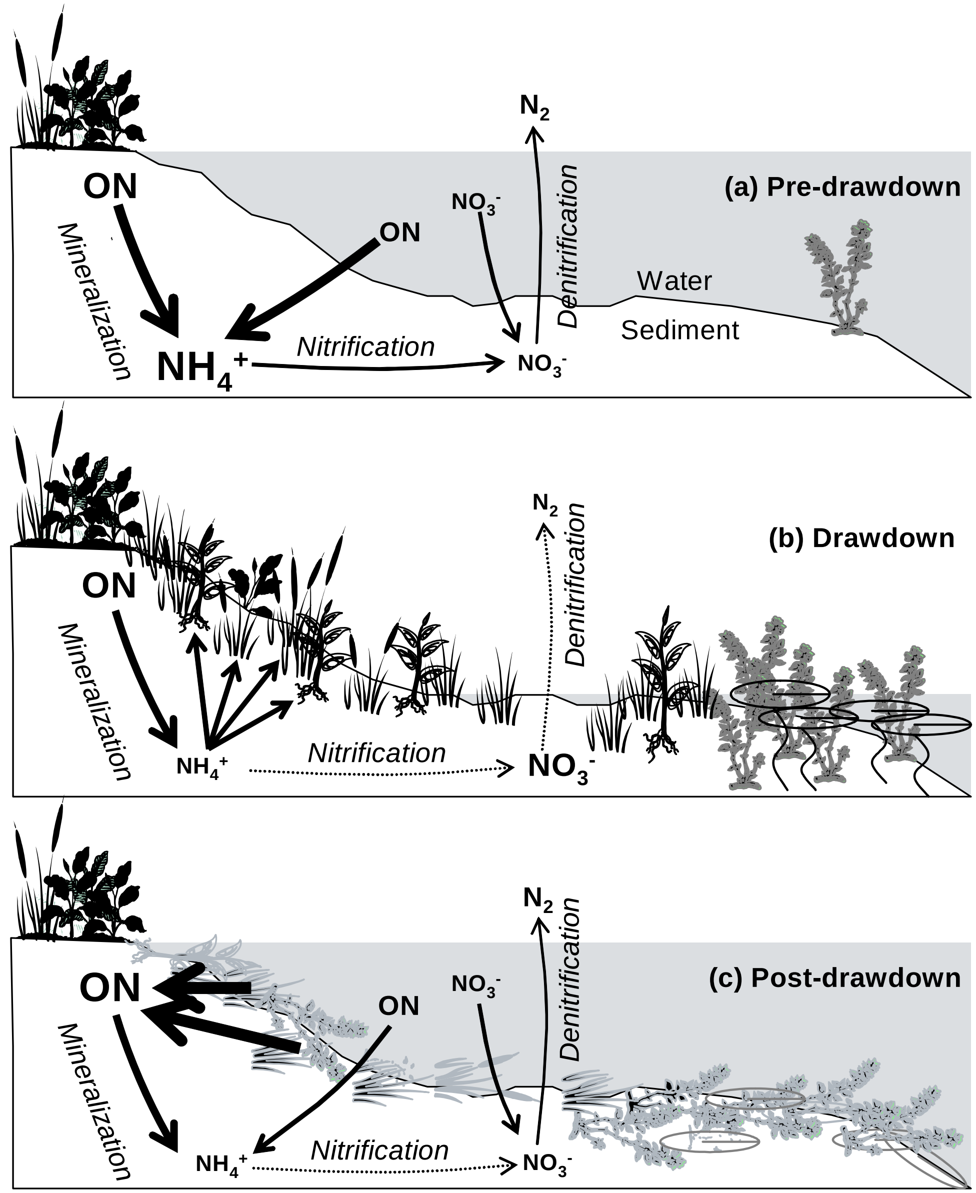


Drawdown reduces nitrogen loss – interferes with NO3 delivery to bioactive sediment

(a) Pre-drawdown: Coupled Denitrification-Nitrification important in organic sediment of backwaters and impoundments; mineralization of Organic N drives NH4-nitrification dynamics.

(b) Drawdown: Denitrification is minimal; Macrophyte uptake of nitrogen mobilizes organic N (nitrate laden water shipped directly downstream)

(c) Re-wetting: Macrophyte decomposition, organic N mobilization; downstream loss during floods?



Measured outcomes of WLD

- Some increase in water clarity
- Increased density and diversity of rooted macrophytes
- Increased waterfowl use
- No detectable change in fish or invertebrate production
- Apparent carry over effect of drawdowns on emergent macrophyte populations.
- Reduced nitrogen retention
- Mussel mortality?
- Self-sustaining?

ISLANDS

Oct 1961

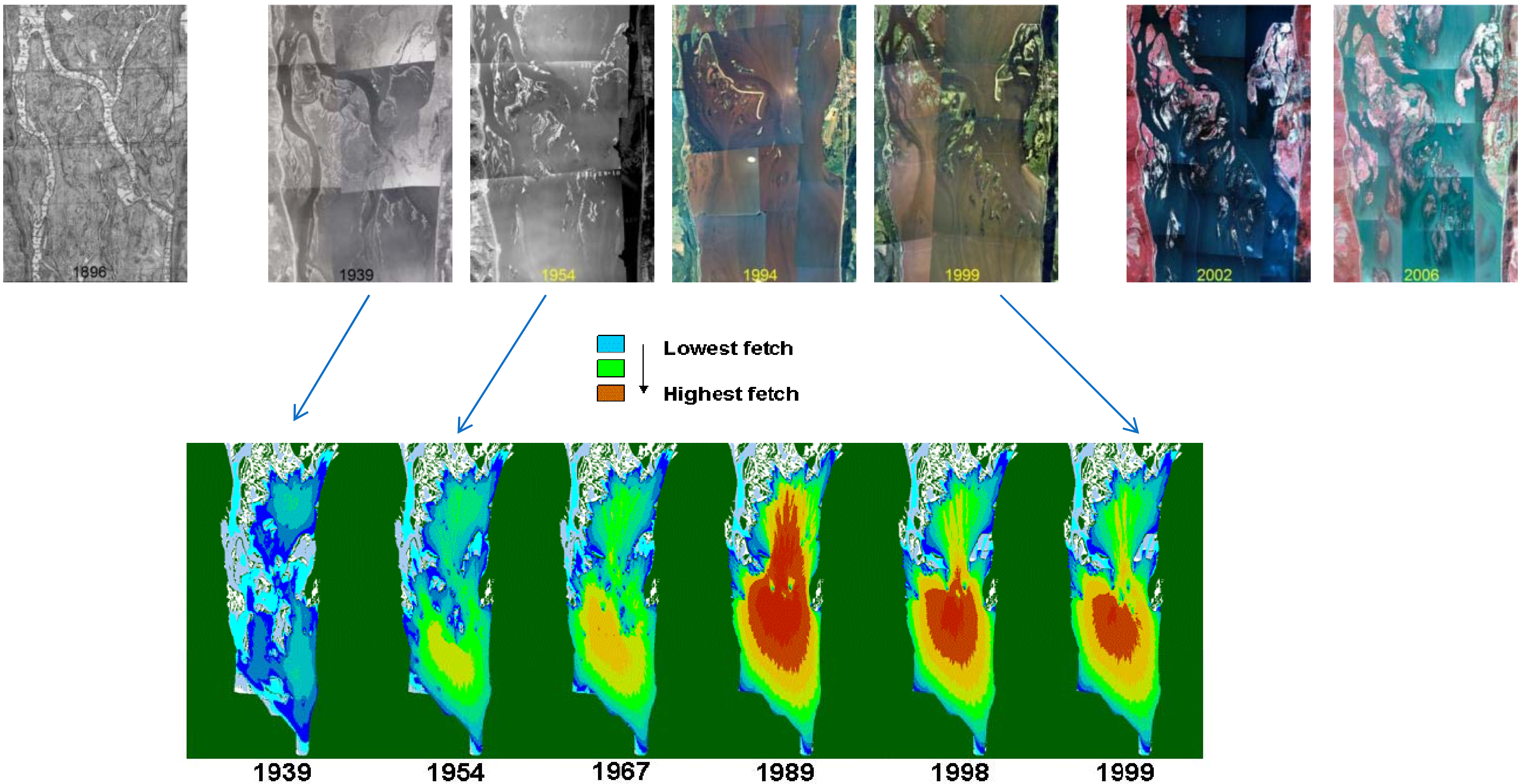
August 1994

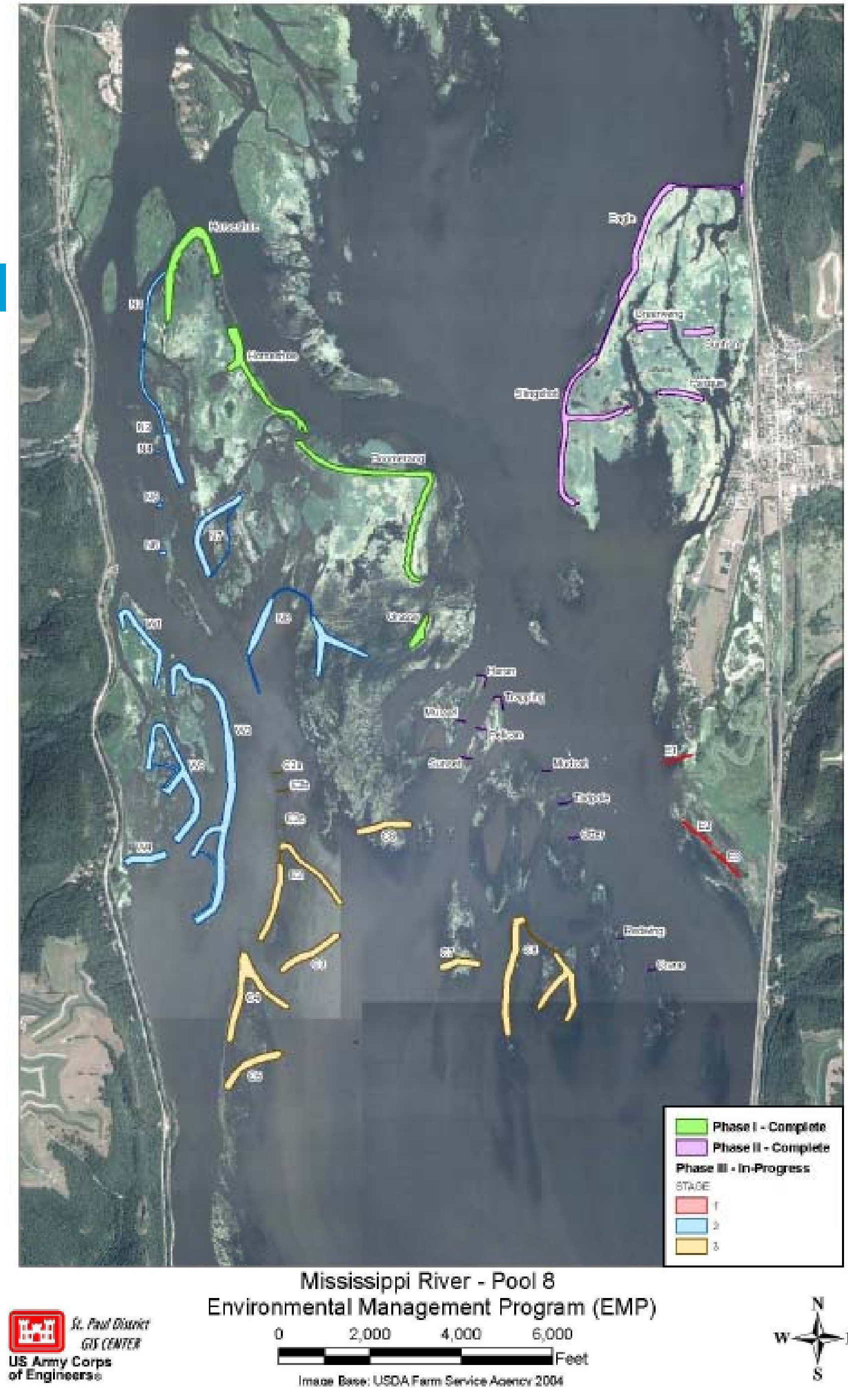
August 2000

Island Building

- Guiding Vision: Rebuild historic islands and geomorphic diversity (Janvrin: "reduce connectivity")
- Expected outcomes:
  - reduce wind-fetch,
  - increase water clarity
  - provide water fowl
  - Increase fish production
  - increase regions of longer hydraulic retention times

Historic changes in Pool 8 island morphology, reconstruction, and wind fetch (1896 – 2006)





Pool 8 Island Project

- Project calls for a total of 24 islands, including 7 "seed" islands (1986 – present).

- 12 islands have been constructed.

- Constructed with dredged material and protected with rock structures and vegetation to prevent erosion.

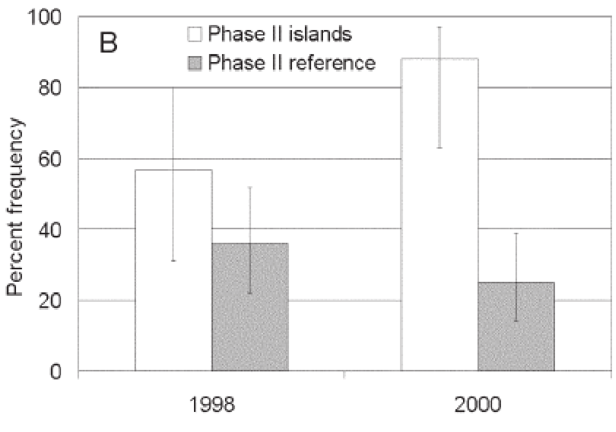
-Protect existing habitat and provide conditions - reestablishment of aquatic plant beds;

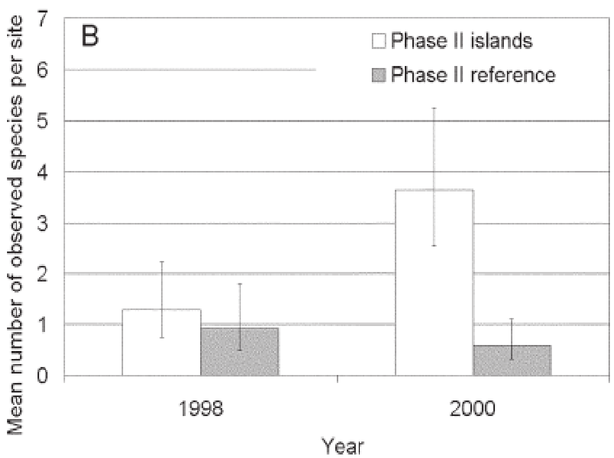
-Deepwater habitat;

- Benefiting a wide spectrum of fish and wildlife in the 3,000-acre area.

http://www.mvp.usace.army.mil/environment/default.asp?pageid=80

Macrophyte response to island construction has been striking

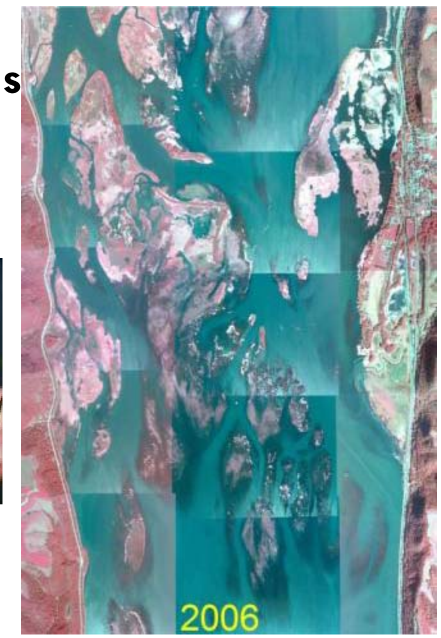




Significant increase in frequency of occurrence of macrophytes adjacent to new islands

Significant increase in species richness adjacent to new islands.

Most common macrophytes: *Elodea canadensis* (1998) and *Heterantha dubia* (2000)



Langrehr et al. 2007. Evaluation of aquatic macrophyte community response to island construction in the UMR. Lake and Reserv. Managem. 23: 313-320

Islands as attractors and producer of river fish

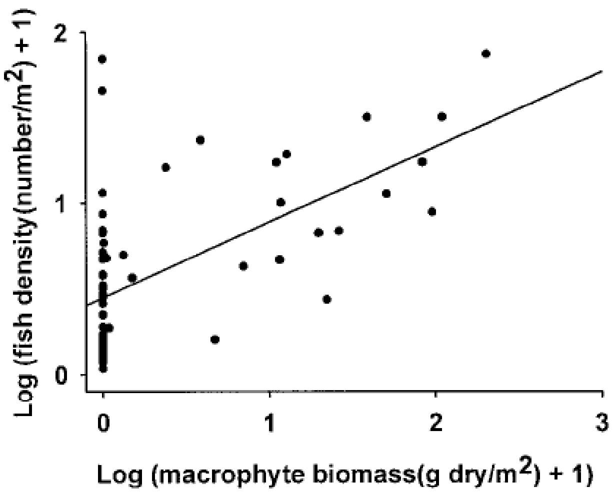
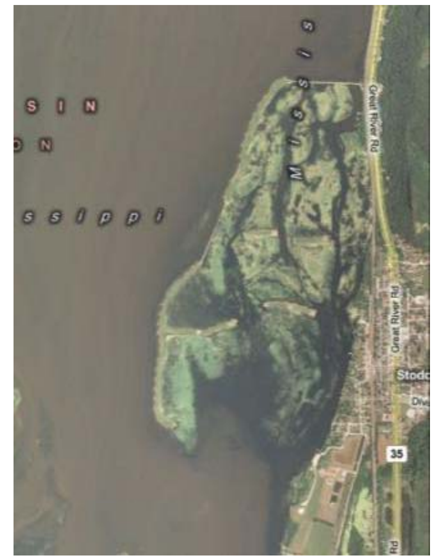


FIGURE 3.—Regression of total fish density versus aquatic macrophyte biomass at 62 sampling sites around islands in the upper Mississippi River near La Crosse, Wisconsin, studied during July–September 1990 (r^2 = 0.36).

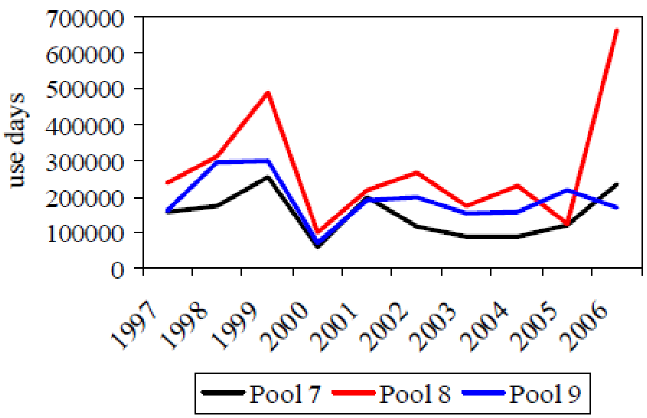
Small fishes more abundant adjacent to islands.

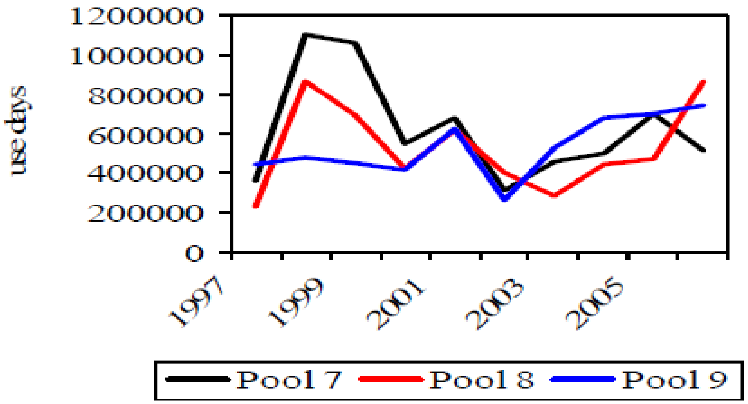
Correlated to increased abundance of macrophyte beds commonly found in "flow shadow" of islands.



Johnson and Jennings. 1998. Habitat associations of small fishes around islands in the UMR. N. Am. J. Fish. Managem. 18: 327-336

Tundra Swans and Dabbling Duck populations on Pool 8 have increased during Island Building and Drawdowns





J. Nissen – USFWS, K. Kenow - UMESC

Measured outcomes of island building

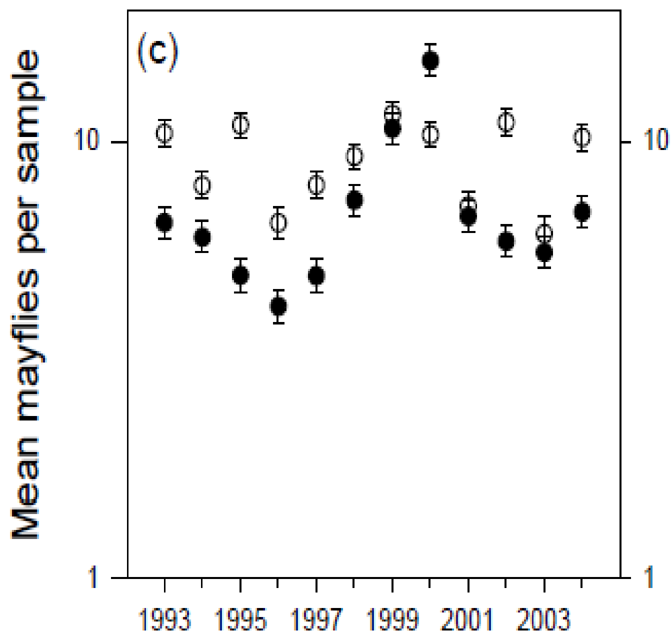
- Increased fish production (See Janvrin)
- Decreased chlorophyll a
- Increased benthos – *Hexagenia*
- Equivocal effects on suspended inorganic solids
- Increased rooted aquatic macrophyte density and diversity

- Appears relatively sustainable over the long term

Difficult to detect cumulative effects of large river restoration efforts

"restoration effects were observed for CHL and mayflies while evidence in favor of restoration effects on inorganic suspended solids was equivocal"

Restoration area v Pool 13 impoundment, negative reference



Test hypothesis effect of island construction will be:

- ***similar to*** **that of "positive control areas" (a proximate area comprising contiguous backwater areas)**

- ***less similar*** **to "negative control areas" (nearby impounded areas).**

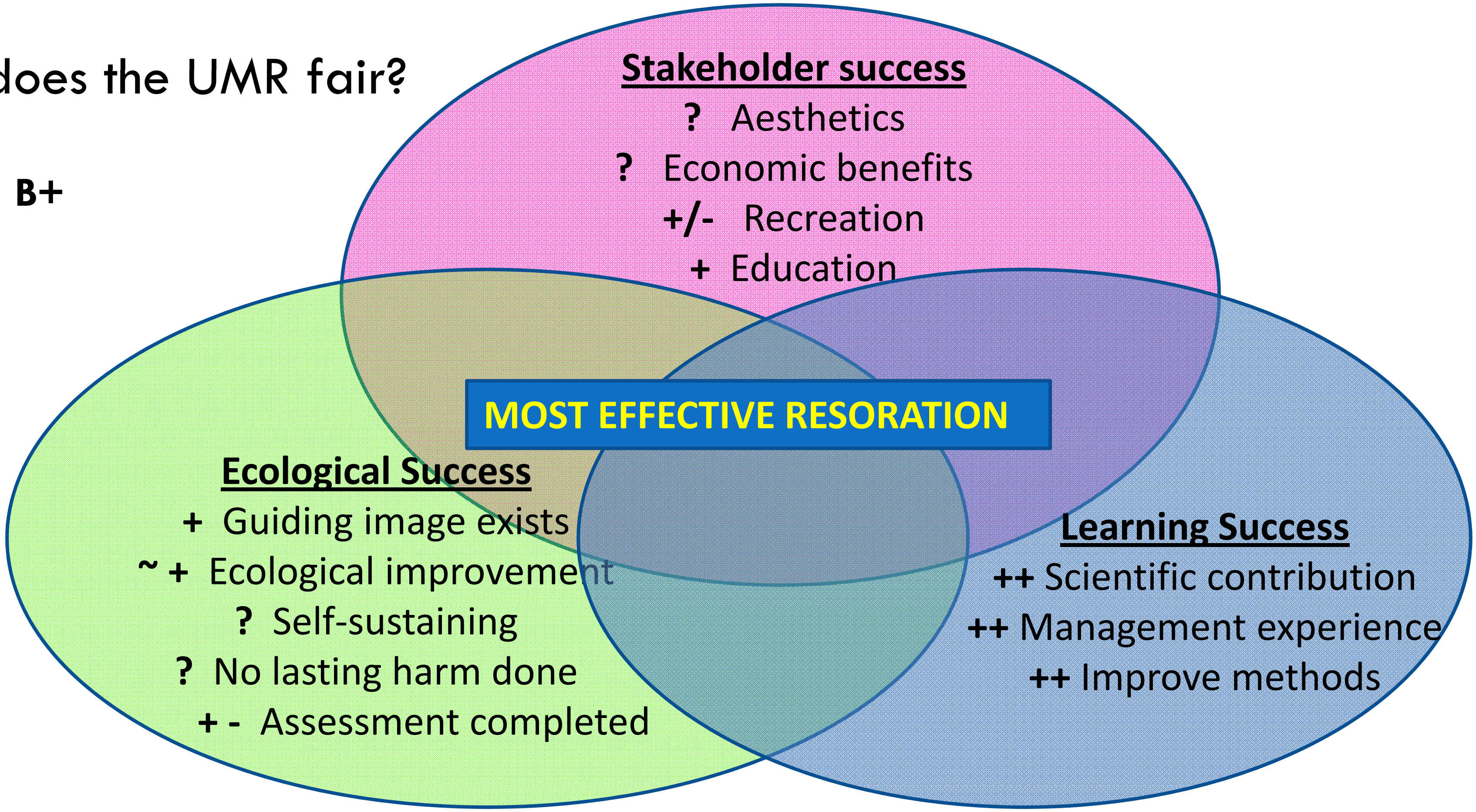
Gray et al., Cumulative effects of restoration efforts on ecological characteristics of an open water area within the Upper Mississippi River, in press, River Research and Applications.

Factors leading to "most effective restoration"

(Palmer et al. 2005)

How does the UMR fair?

UMR: B+



Palmer et al. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology 42: 208-217

Additional Comments (Our view of the world)

- UMR restoration process and outcome globally unique
  - Danube restoration is a far second
- Cooperation and collaboration among agencies is generally outstanding
- Funding is quite high and driven by the USACE Environmental Management Program
  - Strong local and federal political support
- Guiding image is visual, not necessarily functional
- System-wide tests of restoration impacts difficult and uncommon
- Focus on "harvestable" resources (source of funding)
- Little systemic focus on ecological process that support harvestable resources


Questions?