Ecosystem Services Research Program Pollutant-based studies: Nitrogen

July 14-15, 2009 SAB presentation

Our goal: connect the effects of increasing reactive nitrogen to ecosystem services, in order to improve policy and management related to nutrients.

ESRP Organizational Matrix

Projects and Long term Goals →		LTG 3 Pollutant-Specific Studies: 6%	LTG 4 Ecosystem Specific Studies: 23%		LTG 5: Community Based Demonstration Projects: For National, Regional, State and Local Decisions 28%					Theme Leads
	Cross Program Themes and Research Objectives	Nitrogen (6%)	Wetlands (22%)	Coral Reefs (5%)	Willamette (11%)	Tampa Bay (4%)	Mid-West (4%)	Coastal Carolinas (8%)	Southwest (1%)	
Integration, Well-Being, Valuation, Decision Support, Outreach and Education LTG 1 9%	Ecosystem Services and Human Well-Being (3%)									Laura Jackson
	Valuation of Ecosystem Services									Wayne Munns--Consultation Committee
	Decision Support (6%)									Ann Vega
	Outreach & Education to									Open
Inventory, Map, and Forecast Ecosystem Services at multiple scales LTG 2 31%	Landscape Characterization and Mapping (12%)									Anne Neale
	Inventory and Monitoring of Services (14%)									Mike McDonald
	Modeling (5%)									Tom Fontaine--Consultation Committee
Pollutant Specific Studies LTG 3	Nitrogen (6%)									Jana Compton
Eco-system Specific Studies LTG 4	Wetlands (22%)									Janet Keough
Project Area Leads	Rick Linthurst and Iris Goodman	Jana Compton	Janet Keough	Bill Fisher	David Hammer	Marc Russell	Randy Bruins/ Betsy Smith	Deborah Mangis	Nita Tallent-Halsell	Rick Linthurst and Iris Goodman
					Hal Walker: Place Based Coordinator					

ESRP-N began as a row and has expanded to integrate across columns, particularly in LTG2.

Nitrogen Writing & Implementation Team

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NRC post-doc NHEERL-WED

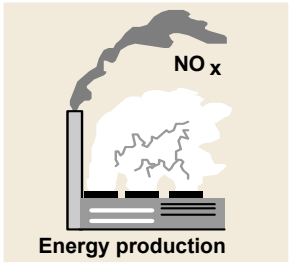
Expert hire: John Harrison
Washington State University,
Vancouver, Washington

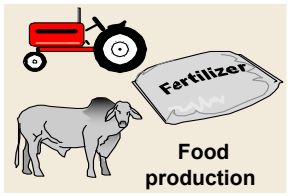
Outline of presentation

- Background
- Research directions and early results
  - Much new since 2008 SAB review
  - Implementation plan external review May 2009; Final version now in management approvals
  - National, Regional and Place-based work
- Science needs and the end goals

Why Nitrogen and Ecosystem Services?

- Nitrogen is a critical component of energy, food, and fiber production, benefiting humans in many ways.

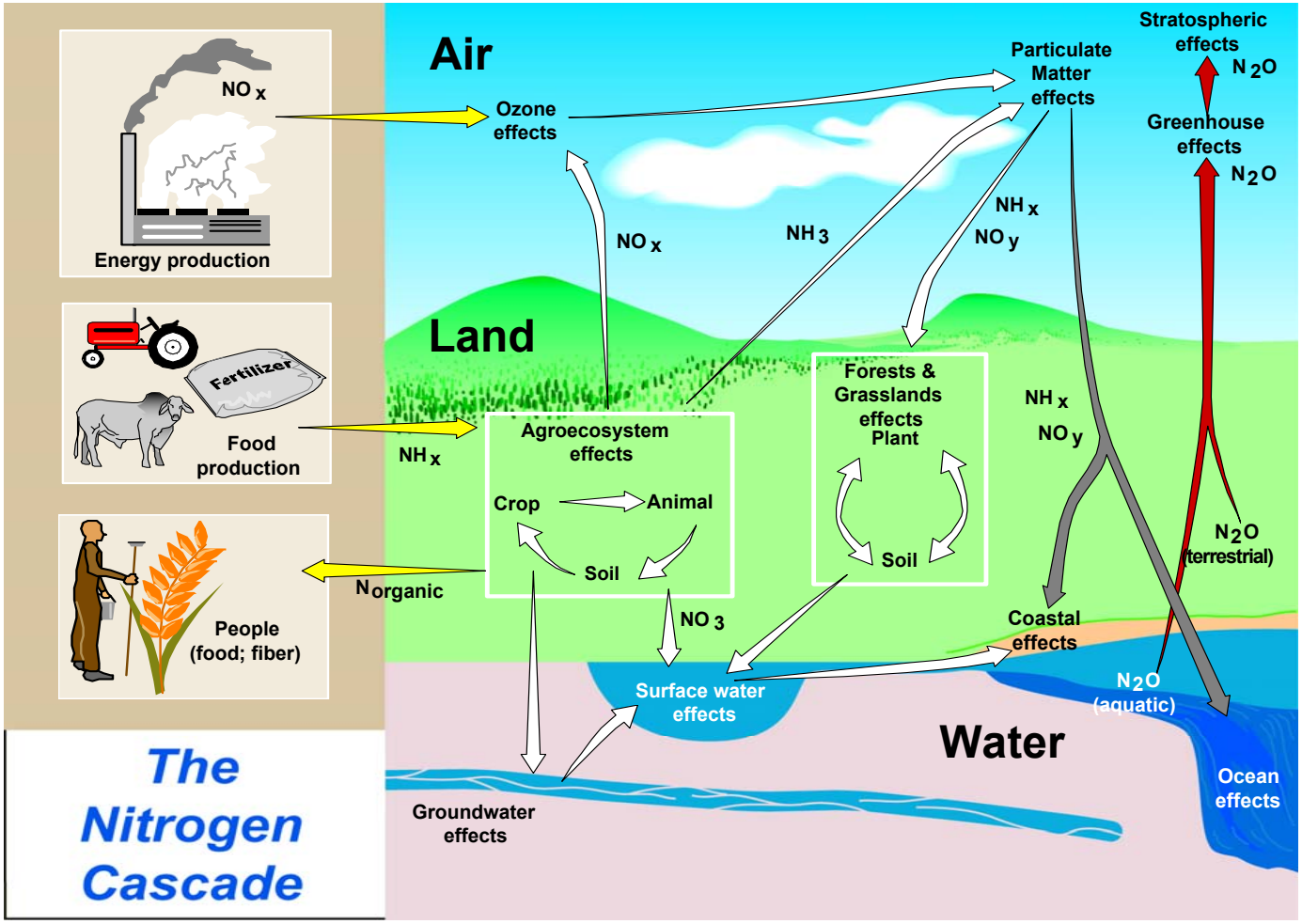




from Galloway et al. (2003)

Why Nitrogen and Ecosystem Services?

- However, N is a major stressor for many ecosystems.



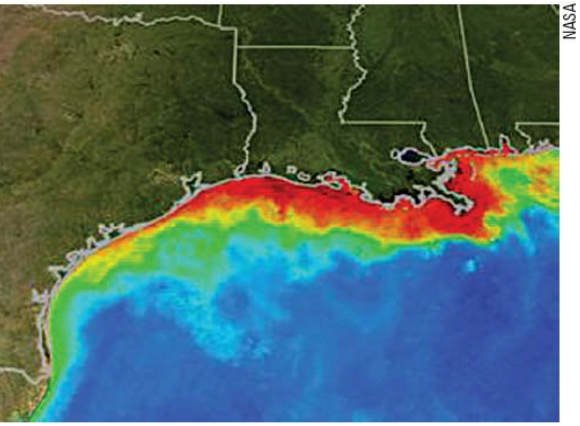
from Galloway et al. (2003)

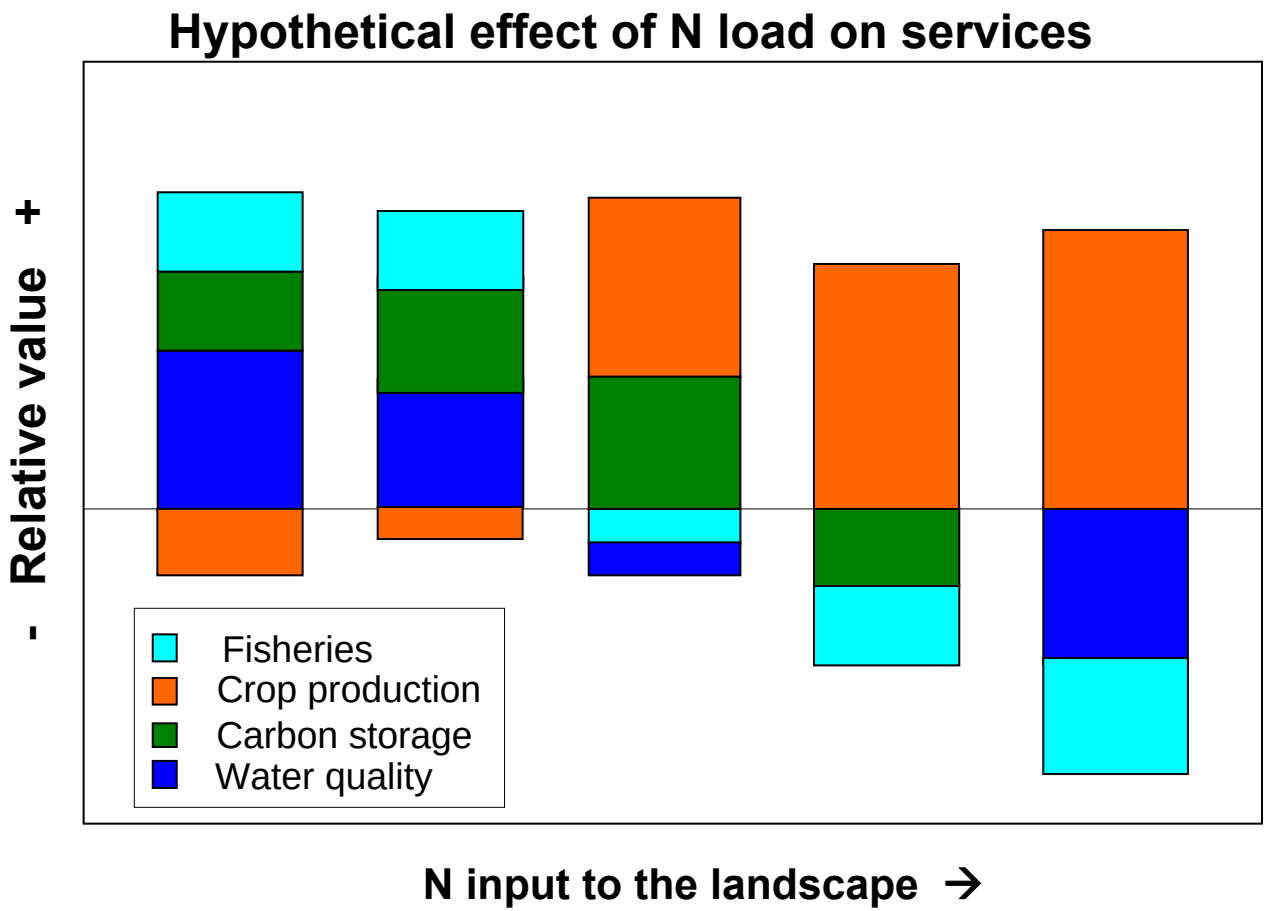
Why N and Ecosystem Services for EPA?

- Air quality regulations
  - Currently National Ambient Air Quality Standards review process underway for secondary NOxSOx standard (current standards set in 1971)
  - Ecosystem service impacts included in risk assessment
- Water quality regulations
  - Nitrogen in top 3 of stressors causing stream impairment
  - Nutrient criteria needed for many streams
  - Seasonal hypoxia, algal blooms, fisheries impact in many areas
- EPA's SAB Integrated Nitrogen Committee
  - Draft report calls for greater intra- and interagency cooperation
  - Ecosystem services viewed as one tool to improve management

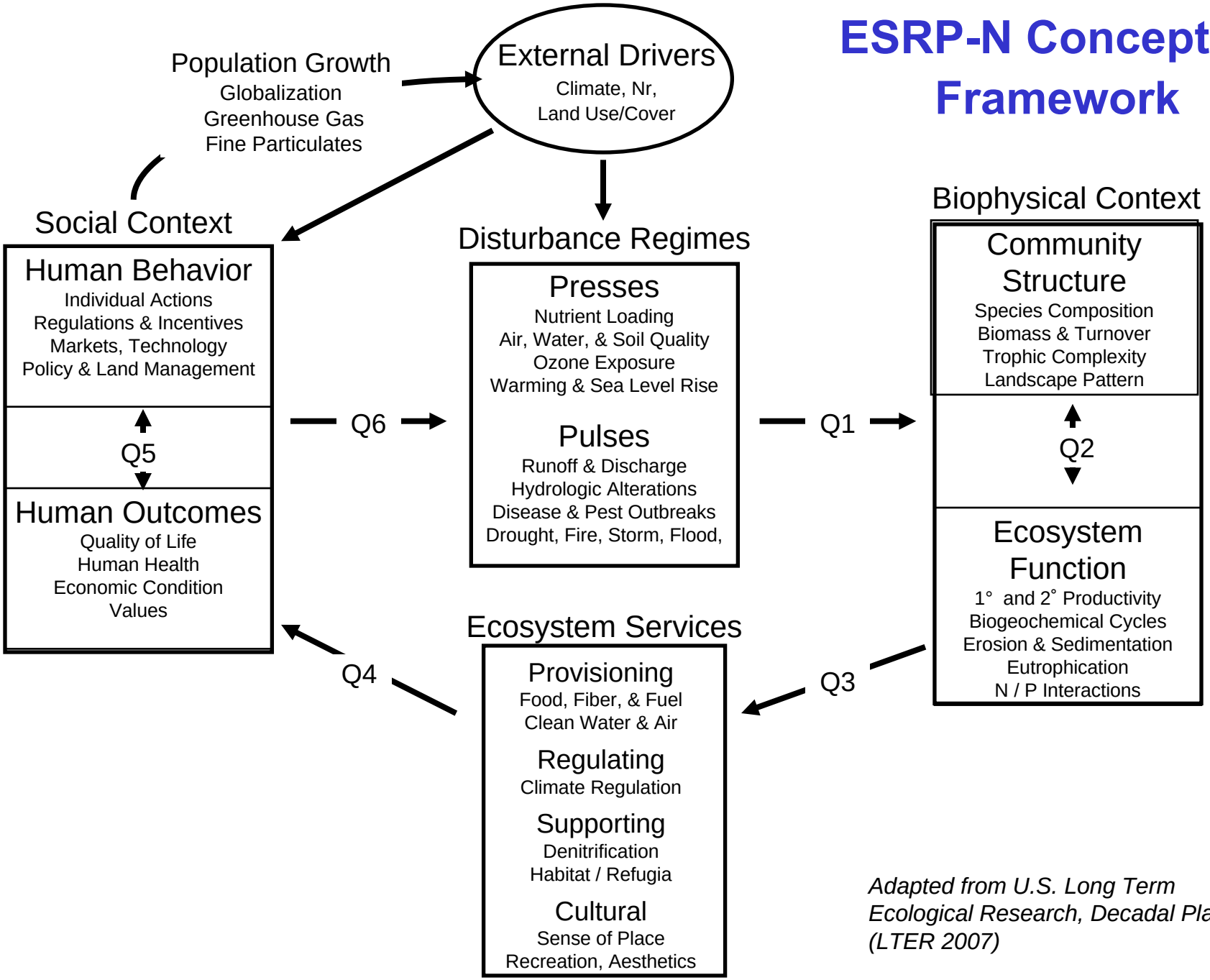
Key question for ESRP-Nitrogen:

How do we use nitrogen most efficiently to balance human needs with impacts on water, air and aquatic life?





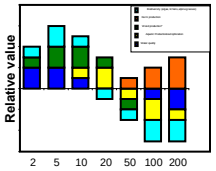
ESRP-N Conceptual Framework



Adapted from U.S. Long Term Ecological Research, Decadal Plan (LTER 2007)

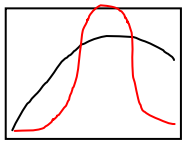
ESRP-N “Road Map”

Identify and bundle Services

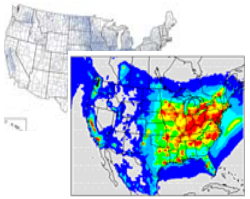


Decision Support

Develop ESRFs (effects of drivers on ES)



Maps of N loads

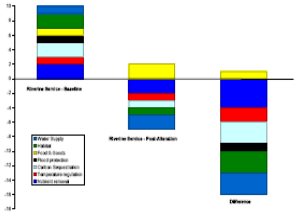


Mapping

Place-based Studies

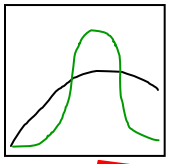
Response of ES bundles to mgmt/policy change

Modeling



Decision Support

Develop Ecological Response Functions

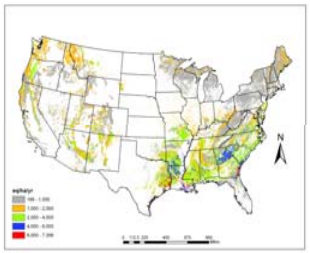


Place-based Studies

System-based Studies

- Terrestrial
- **Wetlands**
- Freshwater
- Coastal
- **Corals**

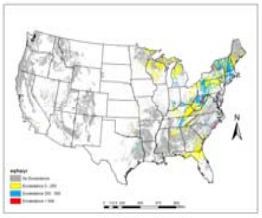
Available relationships of sensitive ecosystems
(e.g. Critical Loads, Indicators, TMDLs)



Monitoring

(plus NCEA assessment and OAR and Interagency work on Critical Loads)

Create maps of At risk Ecosystems



Colored boxes identify work with other ESRP themes

ESRP-N Research Themes

- **National Scale Themes**
  - Theme 1: Nutrient Loading (sources, flux and fate)
  - Theme 2: Identification of Services
- **Regional Scale Themes**
  - Theme 3: Nutrient Cycling and Ecosystem Services
  - Theme 4: Tipping Points in Ecosystem Condition and Services

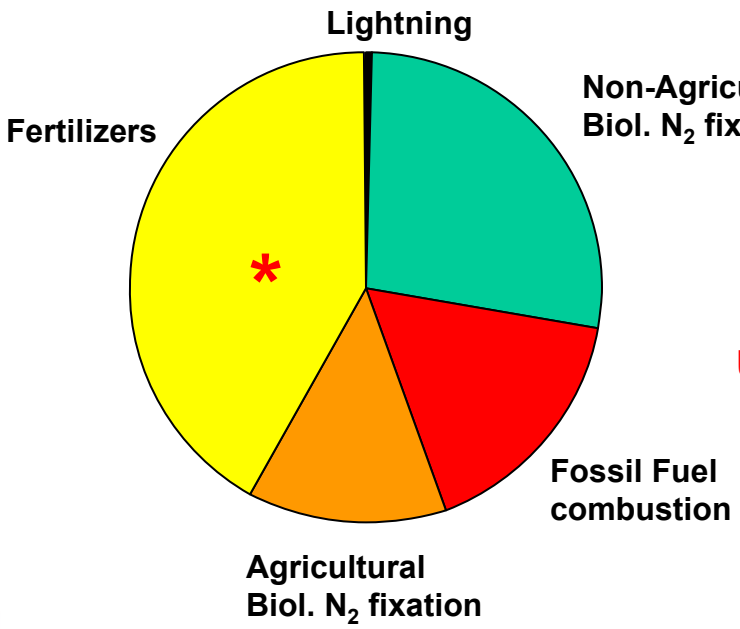
Will include phosphorus where possible. We hope this work will inform management of other nutrients.

Theme 1 – N sources and removal

- N sources at National Scale
  - Deposition - CMAQ
  - Confined Animal Feedlots - Mapping
  - Fertilizers – with Mapping
  - Sewage Treatment Plants - Mapping
- Modeling tools to estimate N removal
  - SPARROW (workshop fall 2009)
  - Global NEWS (with expert John Harrison)
  - Estuarine fate modeling (AED)

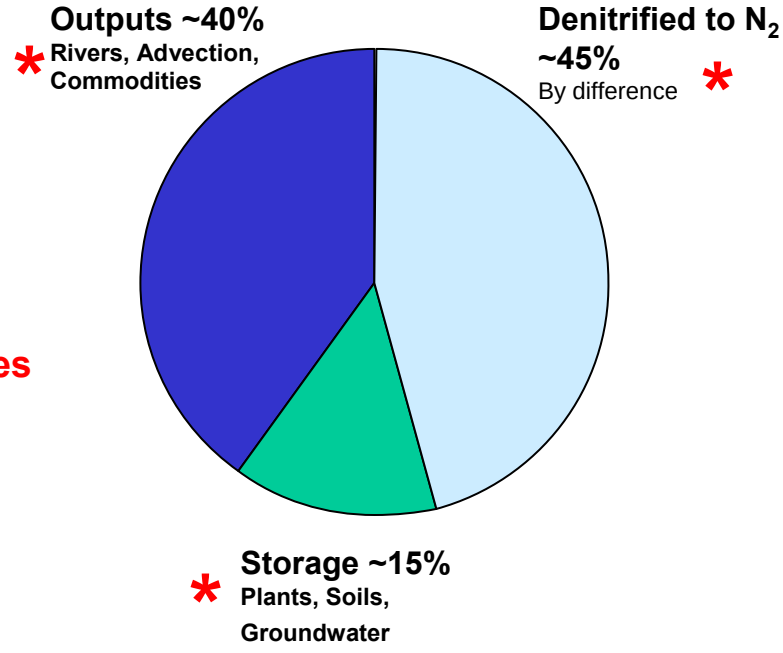
Human activities accelerated transfer of N from the atmosphere to biosphere

Nitrogen fixed from atmosphere
North America early 1990s
25 Tg N yr^{-1}



*Greatest Uncertainties

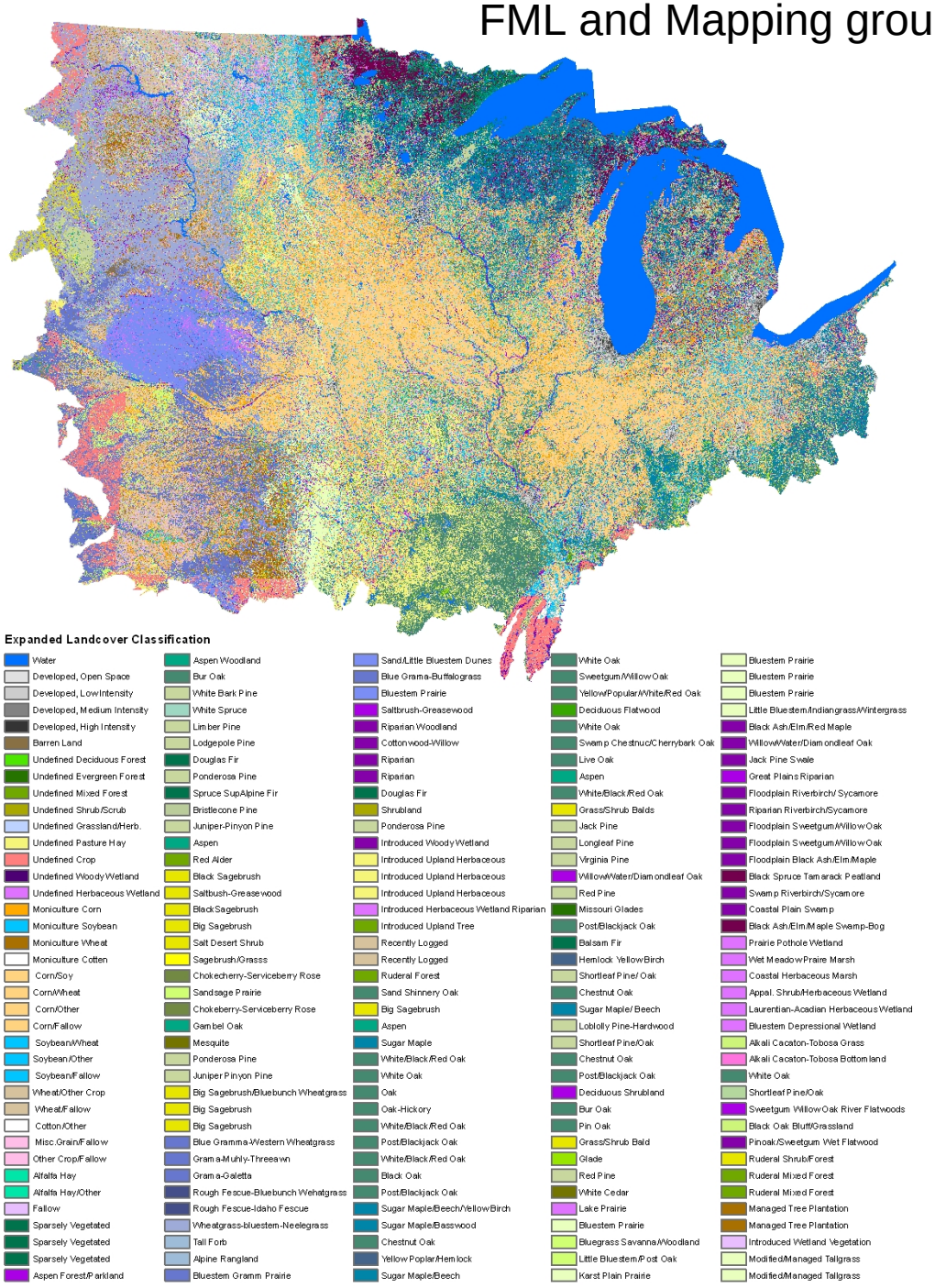
Fate of fixed N



Galloway et al. 2004 Biogeochemistry

Land use and N inputs

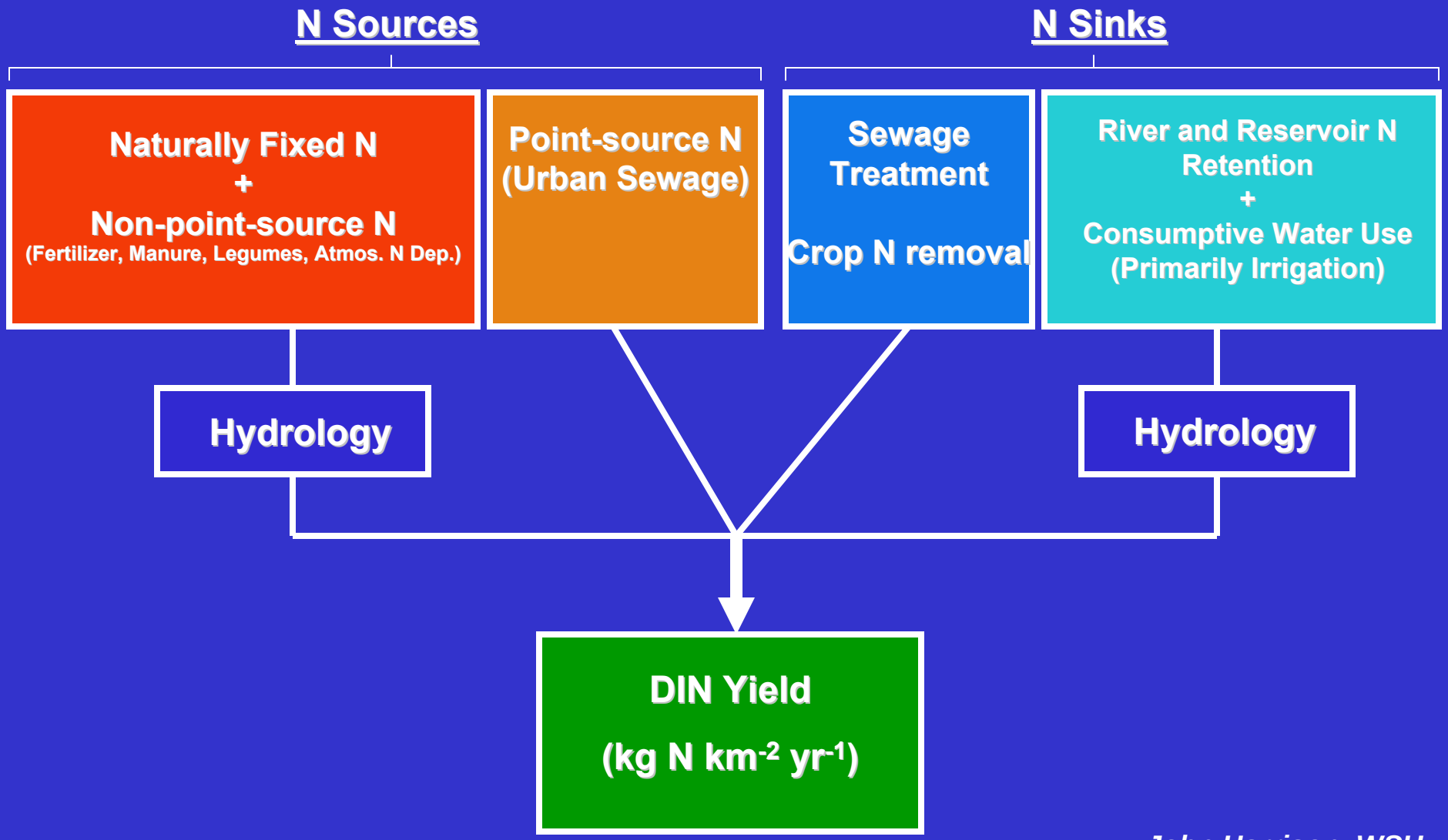
- **Better land use information and spatial resolution → better N accounting**
- **Partition fertilizer application by crop type**
- **National coverage 2011**



Modeling and ESRP-N

- National run of NEWS-DIN
- Regional run of NEWS-DIN for Mississippi Basin
- Approaches for estimating N removal by river networks, and lakes/reservoirs
- Comparisons of SPARROW, NEWS, AGNPS (& others) for “weight of evidence” approach to N removal and futures projections - similar to IPCC

NEWS-DIN Model Structure



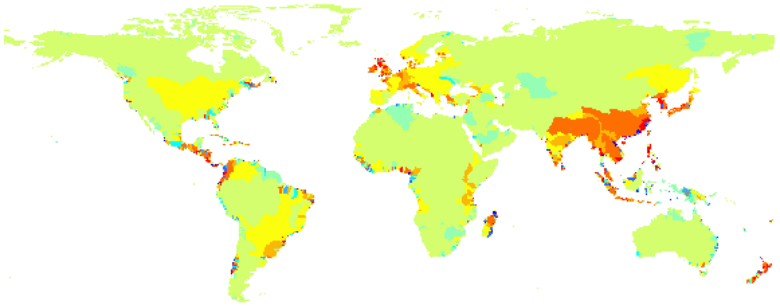
John Harrison, WSU

Scenario DIN yields (kg N/km^2/yr)

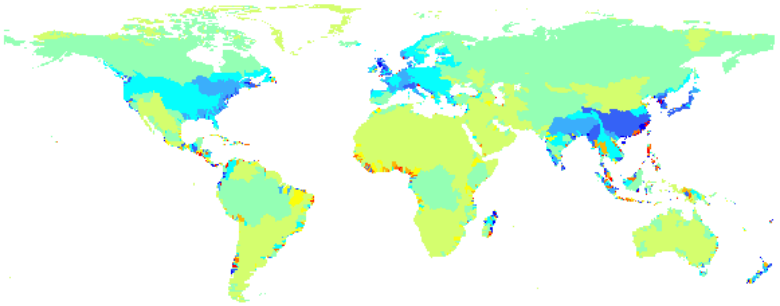
2030 scenarios vs. mean 2030 rate

→ Different actions = very different outcomes

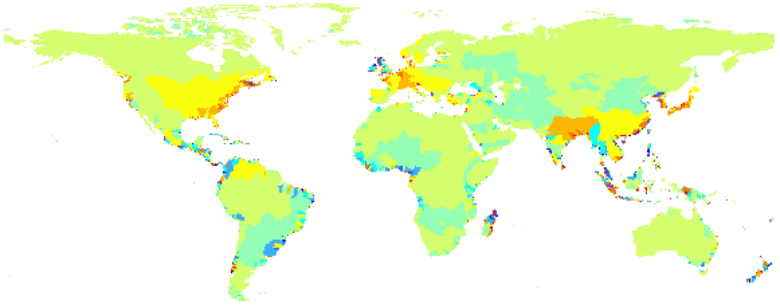
Global Orchestration



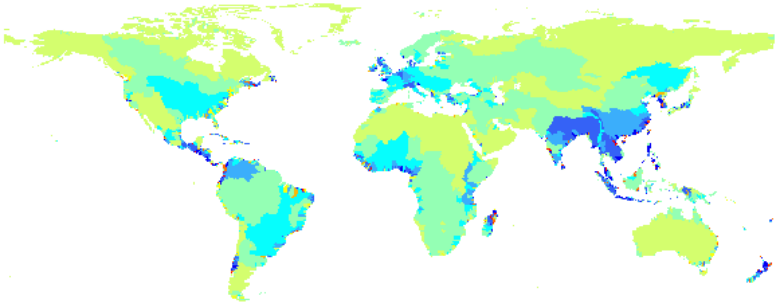
Techno-garden



Order from Strength

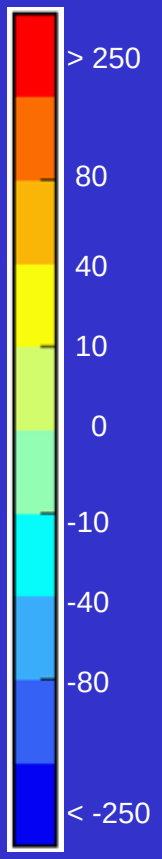


Adapting Mosaic



N yield change

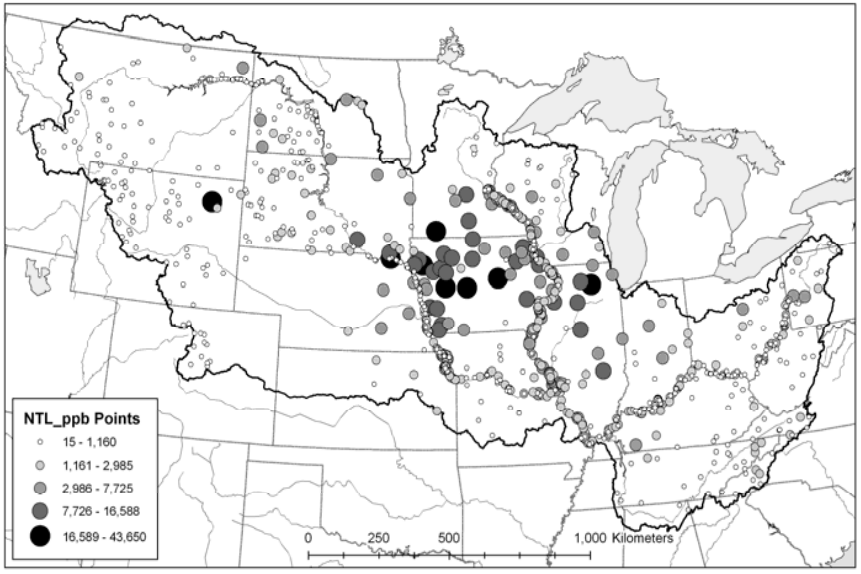
kg N/km^2/yr

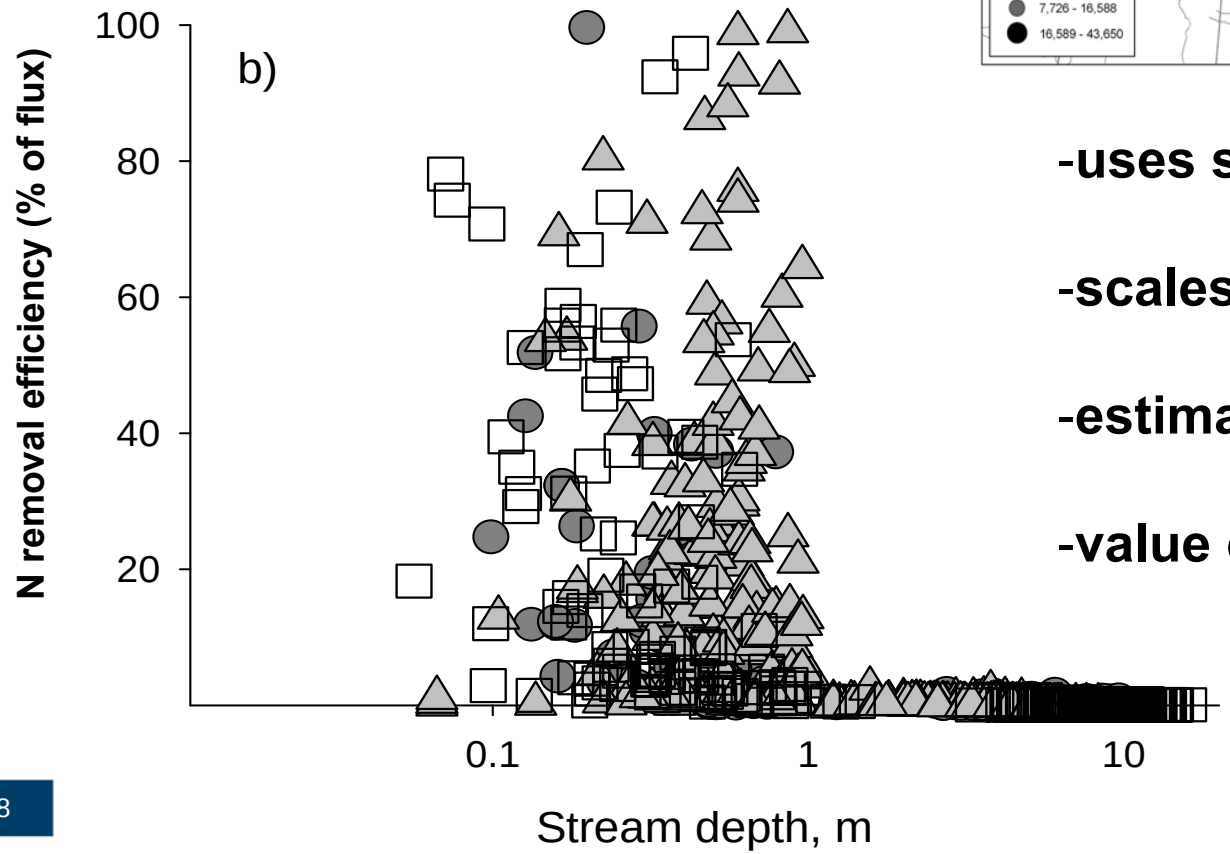


Run 4, 5/22/08

John Harrison, WSU

N removal: Ecosystem service

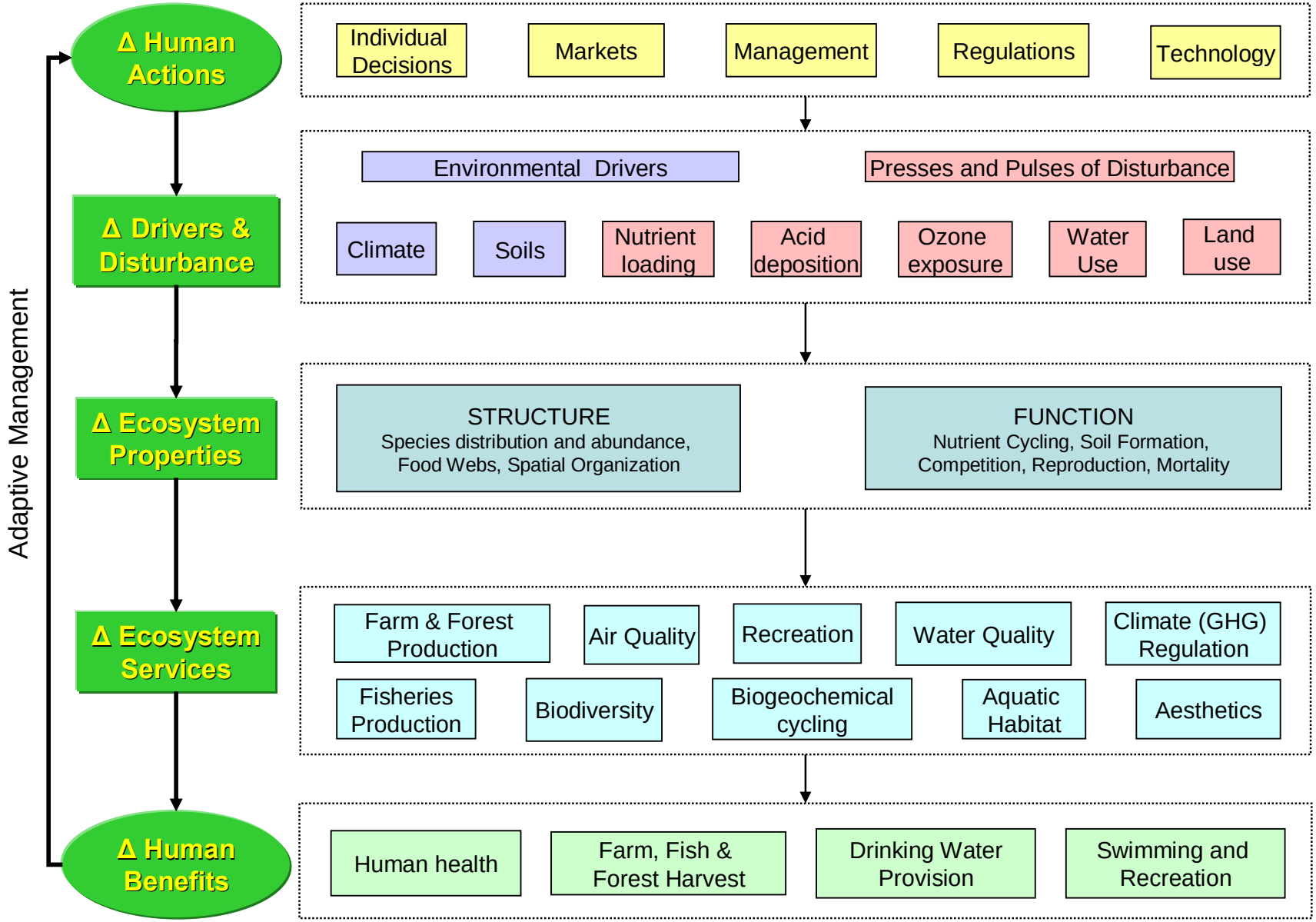




- -uses stream survey data
- -scales with stream depth
- -estimate for network
- -value of stream N removal

Brian Hill and Dave Bolgrien, in review

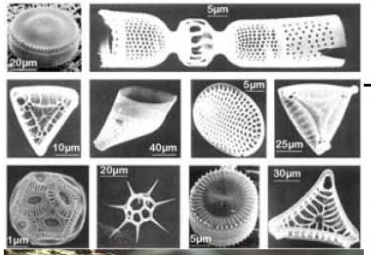
Theme 2: Identification of Services and Relationship to Nitrogen inputs



State of Science paper 2010 –sources

- ESRP-N literature survey
  - 1900+ references; with Holly Campbell (JD, LLM, MS)
- National Ambient Air Quality Standards process
  - Integrated Science Assessment (ISA) for Oxides of Nitrogen and Sulfur – Ecological Criteria (Final Report 12/08)
  - Risk and Policy Assessments underway
  - These include impacts on Ecosystem Services
- EPA's Science Advisory Board
  - Integrated Nitrogen Committee (final report Fall 2009)
  - Gulf of Mexico Hypoxia 2007 report
- Multiple recent special issues on denitrification

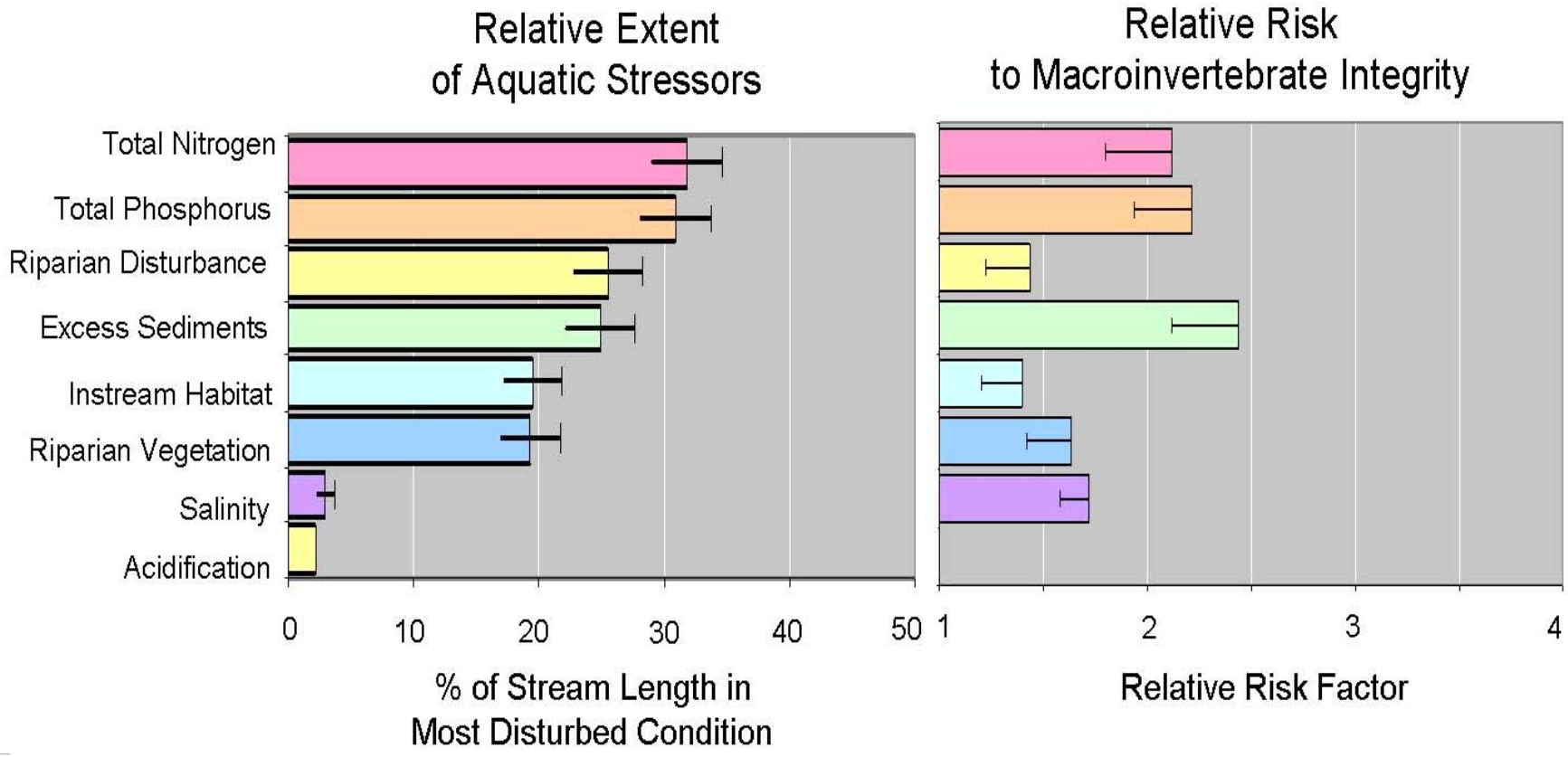
Deposition Levels & Ecological Effects



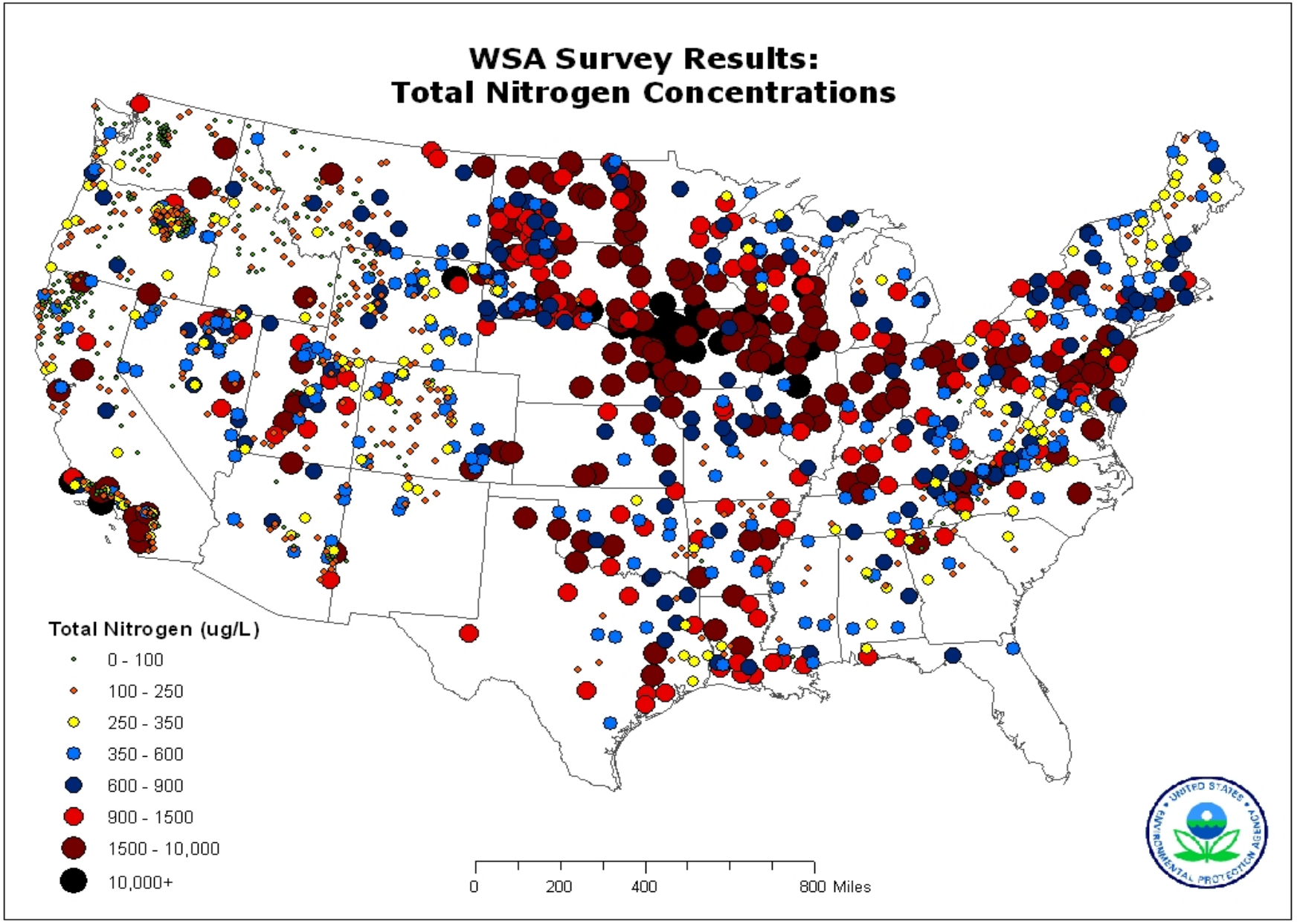
Kg N/ha/yr	Ecological effect
~1.5	Altered diatom communities in high elevation freshwater lakes and elevated N in tree leaf tissue high elevation forests in the western U.S.
3.1	Decline of sensitive lichen species in the western U.S.
4	Altered growth and coverage of alpine plant species in the western U.S.
5	Onset of decline of species richness in grasslands of the U.S. and U.K.
5.5-10	Onset of nitrate leaching in Eastern forests of the U.S.
5-10	Multiple effects in tundra, bogs and freshwater lakes in Europe

Integrated Science Assessment (ISA) for Oxides of Nitrogen and Sulfur - Ecological Criteria EPA 2008

EPA-Office of Water National Stream Survey
- Nitrogen is key stressor for stream impairment



EPA Wadeable Streams Assessment (2006)



EPA Wadeable Streams Assessment (2006)

Wetland N service hierarchy

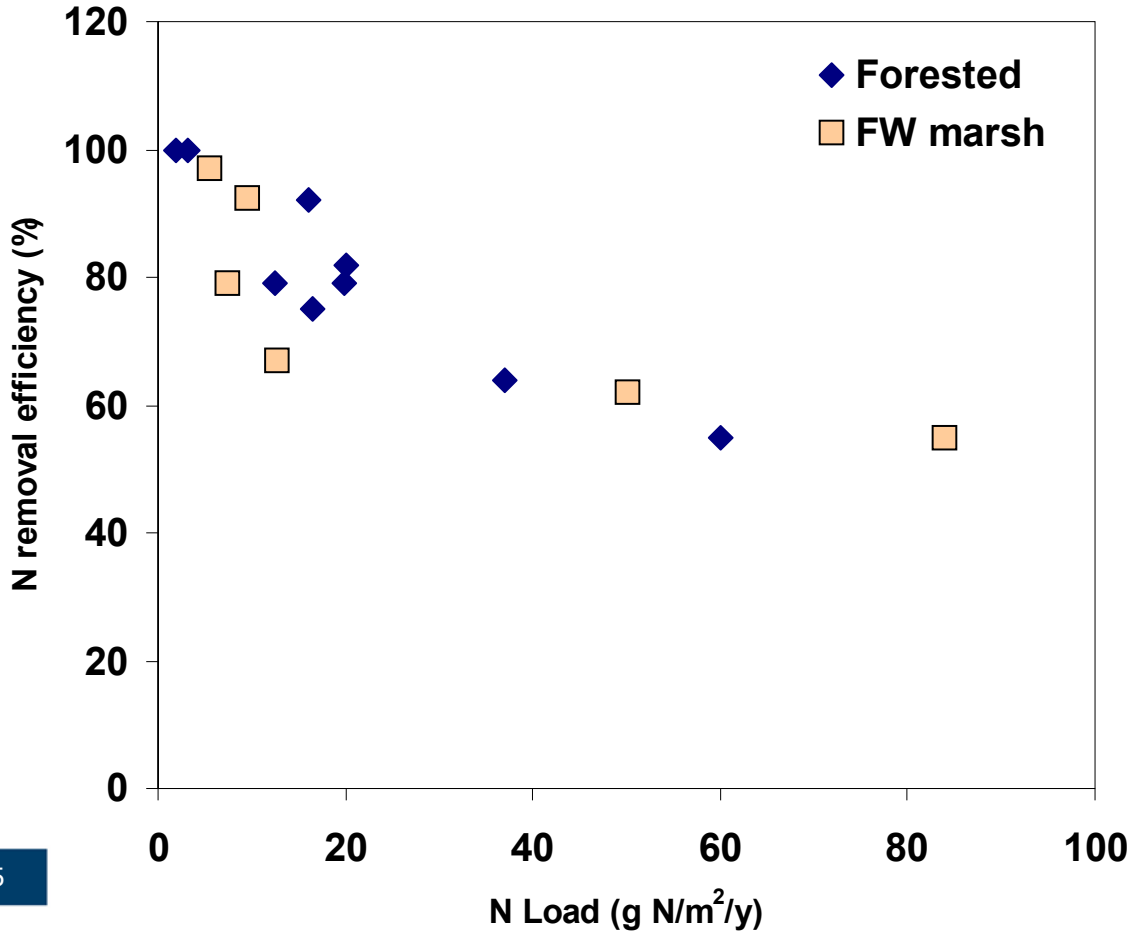
Nr	Affected Ecosys-tem	Ecosystem Effect	Primary Symptom	Secondary Symptom	Ecological Indicators	Impact on Ecological Endpoints	Affected Ecosystem Services	Economic Indicator of Affected Ecosystem Services
	Wetlands (N-limited)	Primary production	Fertiliza-tion	Above-ground biomass increase	Plant bio-mass, den-sity, species composition, denitrifica-tion, loss of sensitive species	Improved habitat, in-creased C se-questration, increased N removal, spe-cies shifts, changes in water storage[1]	Provisioning, regulating, cultural	C & N re-moval, fishery production, water storage, endangered species loss
	Wetlands (not N-limited)	Eutrophi-cation	Plant succes-sion	Soil and water quality degrada-tion	Species com-position, diversity, sulfides, algae blooms	Degraded habitat, HAB risk, decreased N removal, increased N_2O emission	Provisioning, regulating, cultural	N removal, fishery pro-duction, HABs, biodi-versity, aes-thetics, GHG increase

[1]Loss of N-sensitive species in bogs can reduce water retention and storage.

Steve Jordan, NHEERL-GED

Gulf of Mexico Coastal Wetlands

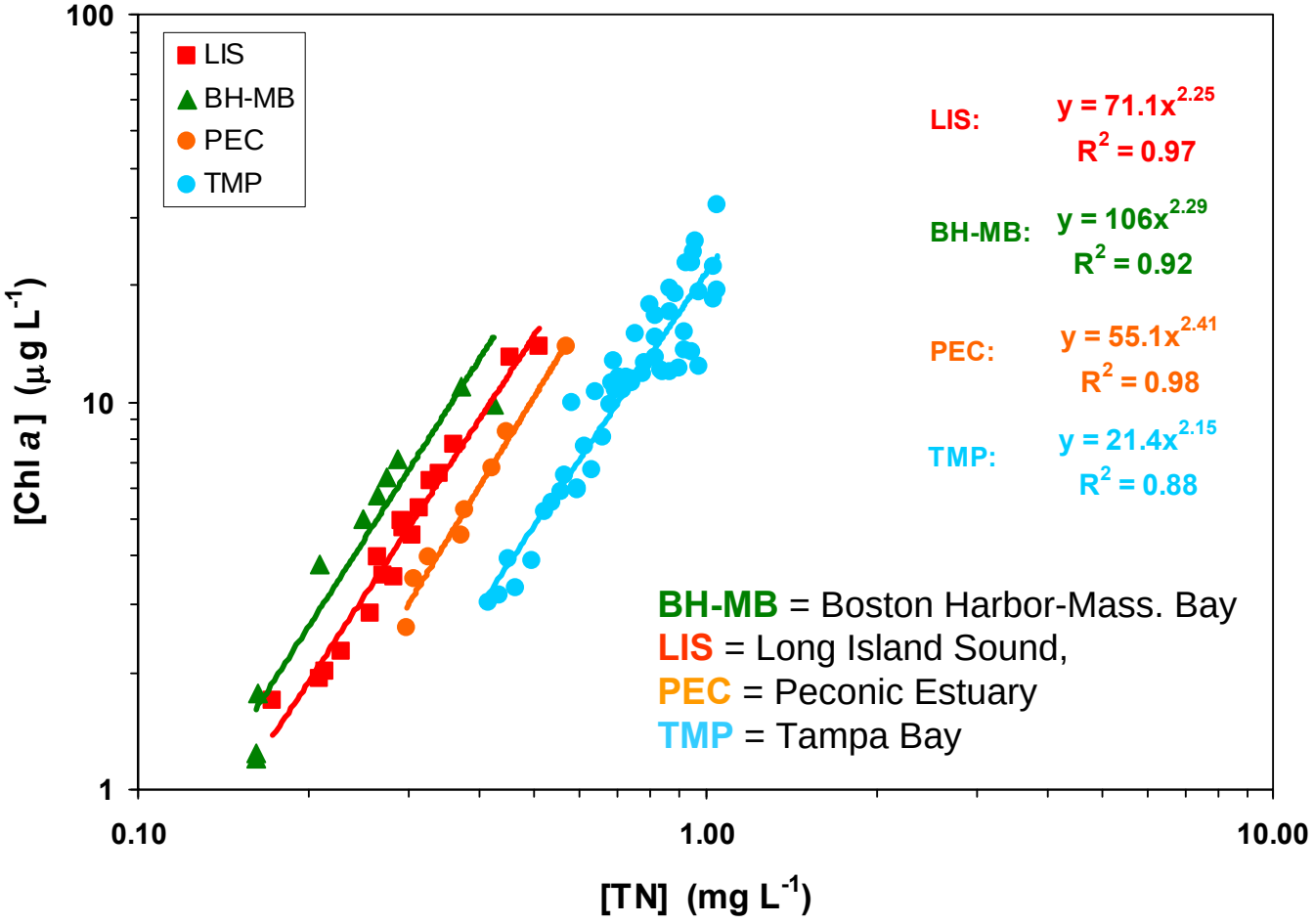
N removal efficiency



- Higher N load – less % N removed
- Values from literature, mostly LA & WWT
- Need values for salt marsh, mangroves, rest of GOM

Virginia Engle EPA-NHEERL-GED et al.

Chlorophyll *a* – TN relationships for Four Estuarine Embayments

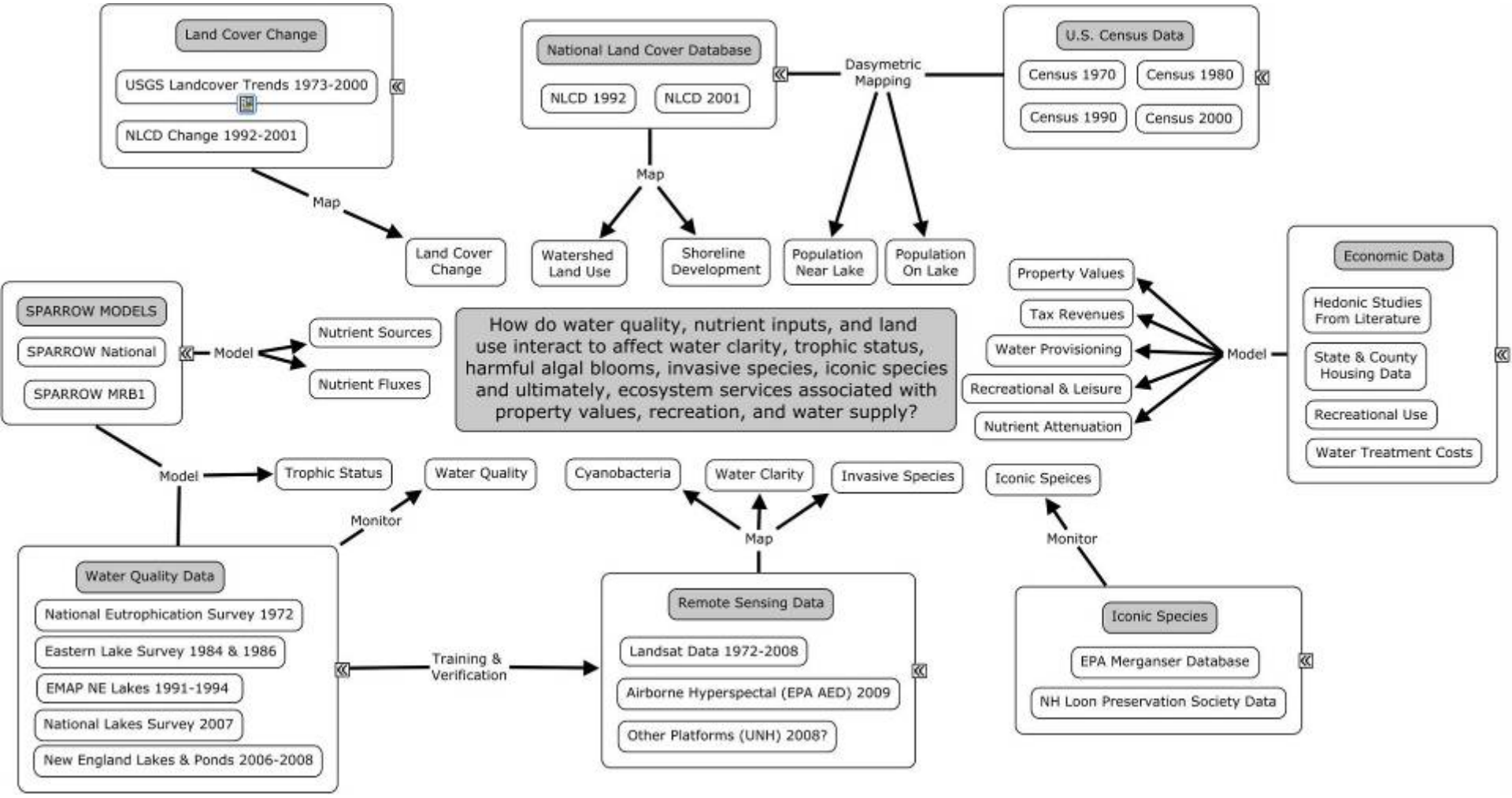


The vertical displacements of these four systems are quantitatively explained by water clarity.

Edward Dettmann et al. (EPA-NHEERL-AED)

The EPA Atlantic Ecology Division

Northeast Lakes Concept Map



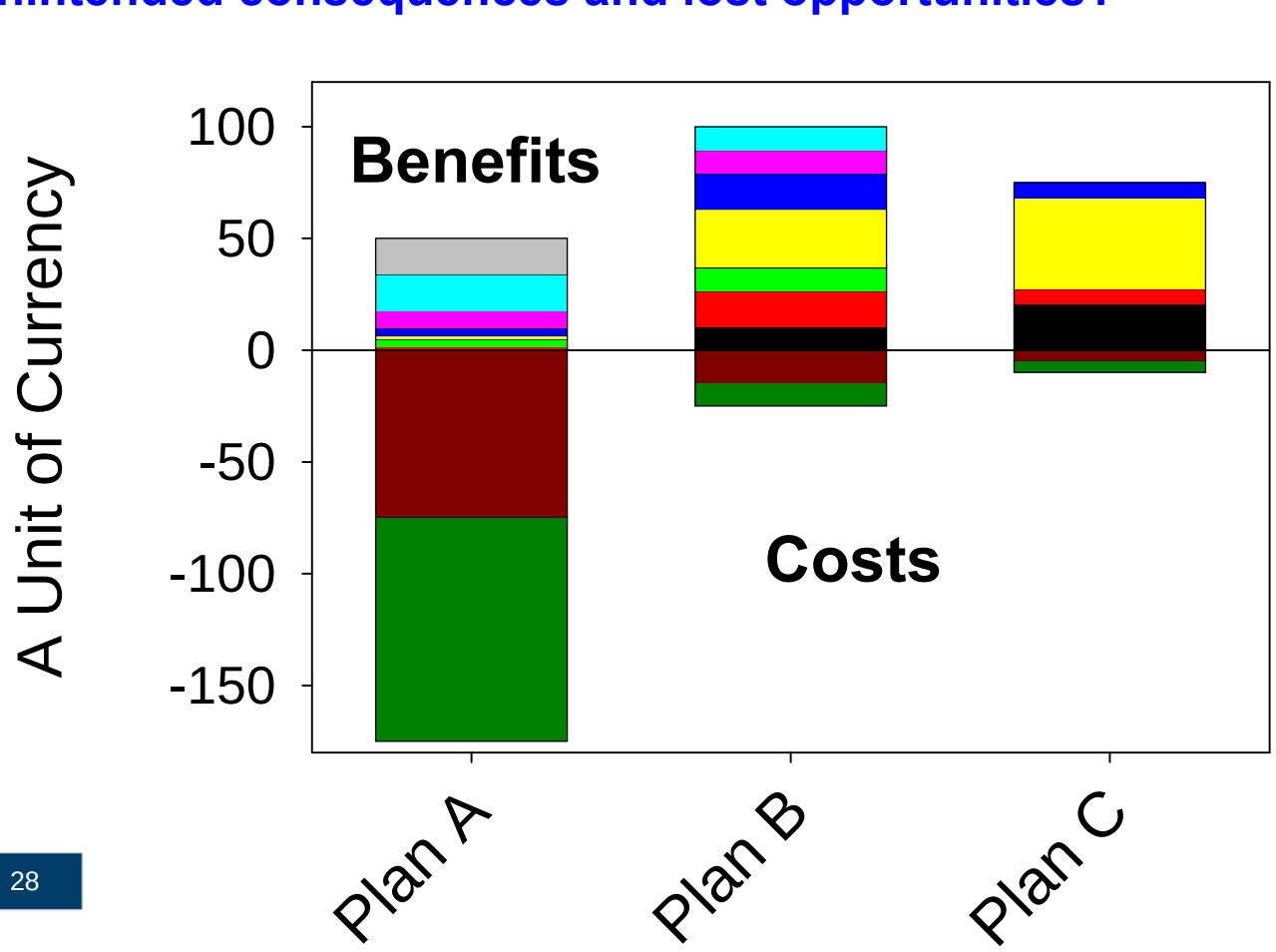
Hal Walker, Bryan Milstead NHEERL-AED

Northeastern Lakes Evaluation of Management Alternatives

How will local or regional management choices affect the delivery of ecosystem service benefits to stakeholders?

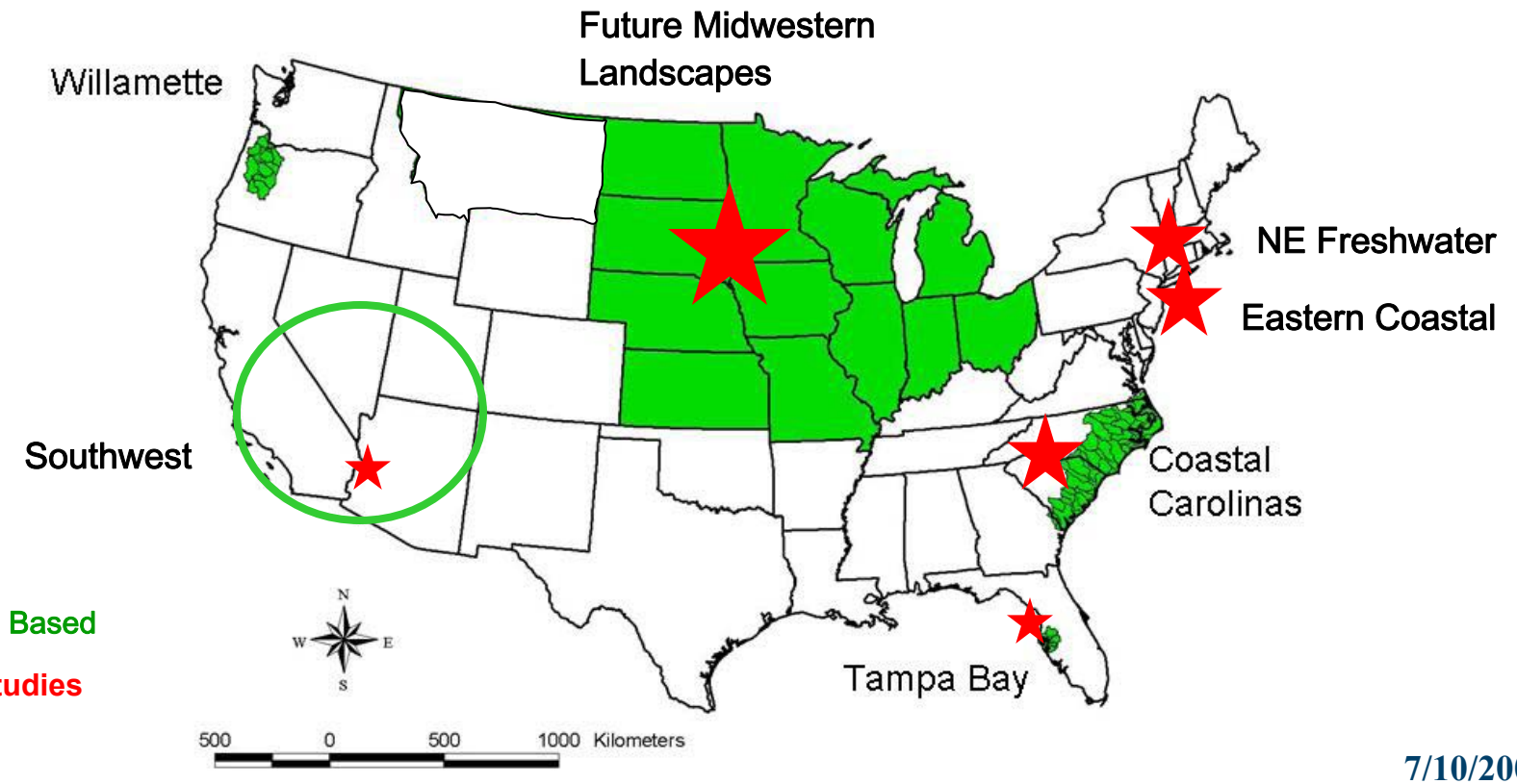
What tradeoff and conflicts will occur among users?

Who will benefit from management choices and who will pay the cost of unintended consequences and lost opportunities?



Hal Walker, Bryan Milstead NHEERL-AED

Place-based studies are being used to compare methods for a variety of environmental settings, scales, & stakeholder issues, and to look at future scenarios.



Research Questions	Theme 1: Nutrient loading	Theme 2: Service Measures	Theme 3: Nutrient cycling	Theme 4: Tipping Points	Place-Based FML	Place-Based Tampa	System-Based Wetlands
R1. N delivery and removal	■		■	■	■	■	
R2. N impacts on structure and function (ERF development)			■	■	■	■	■
R3. N impacts on multiple services (ESRF development)		■	■	■	■	■	
R4. Identification of key services impacted by N		■	■	■	■	■	■
R5. Human health and well-being impacts		■				■	
R6. Human benefits & decisions impacted by N		■			■	■	
R7. Tradeoffs between N and services		■			■	■	■
R8. Technology and restoration impacts on N		■			■	■	■
R9. Effectiveness of management and policy options to reduce N		■		■	■	■	■
R10. Human decisions and N delivery	■	■	■	■	■	■	

Challenges for ESRP-N

- **Nutrients are a substantial and persistent problem**
  - N removal may decrease with N load
  - Population growth and water treatment (→3°)
  - Climate change interactions
- **Strategic approach.** Nitrogen comes from many sources, has many processes, many fates, many systems impacted. Deciding where to focus our limited energy while not neglecting the whole is key.
  - ***Media -*** Land, air, water.
  - ***Sources -*** Power plants, mobile sources, fertilizers, etc.
  - ***Scale -*** Produce tools and information that can/will be used.
  - ***Spatial and temporal variability -*** Timing of inputs vs. impacts.
  - ***Regulatory and Management options*** - sewage treatment, wetland restoration, emission reductions, reducing fertilizer applications, better feedlot management, BMPs, etc.
- **Ecosystem services is new territory.** No reviews or models exist to link N and ecosystem services – we must create these.
- **Models.** How do we best use models to address our questions? Which models?

The end result of this work will be the development of credible, scientifically-based methods to:

- Inventory, measure and map ecosystem services related to reactive nitrogen at multiple scales;
- Connect the effects of reactive nitrogen to ecosystem services;
- Provide regulatory community with sound data and tools that represent the appropriate uncertainties in order to understand N impacts on ecological and human systems, so decisions can be made.

Thank you

Jana Compton, ESRP-N lead
compton.jana@epa.gov

Timeline for ESRP-N

FY09 FY10 FY11 FY12

Implementation Plan – April 2009

Review paper on ES and reactive N – draft fall 2009

Theme 1
Theme 2
Theme 3
Theme 4

National NEWS model – 2010

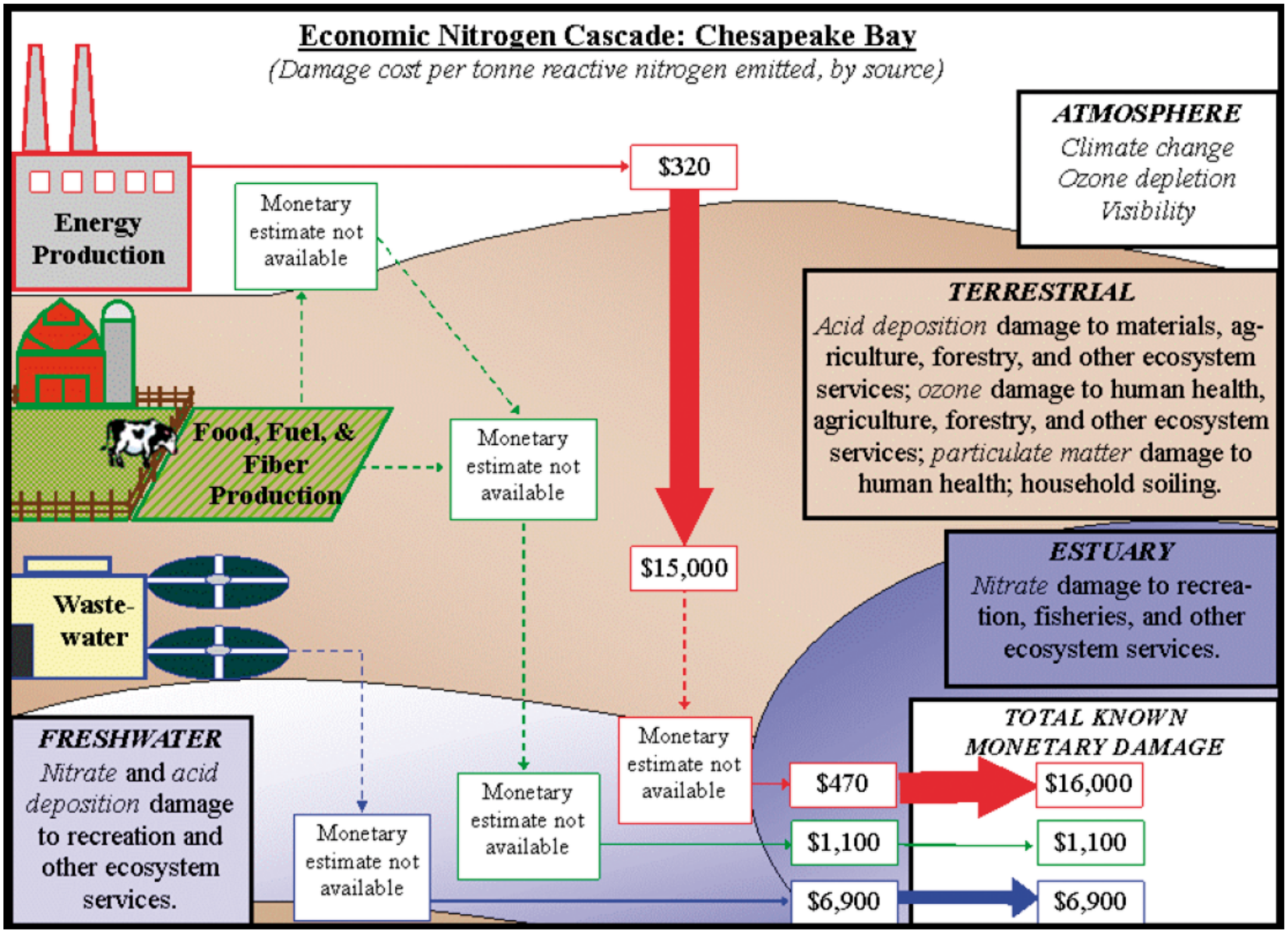
Regional NEWS (MidWest) – 2011

Ecosystem services and nutrient cycling – site-specific studies

Sensitive ecosystems and critical loads – 2011

Report on the value of ecological services provided by and affected by Nr - 2012

Economic N cascade



Moomaw and Birch 2005 Science in China