Valuing Aquatic Ecosystem Services from Reductions in Nutrient Loadings

Presented by:
George Van Houtven (RTI International)
Co-Authors:
Carol Mansfield (RTI), Dan Phaneuf (NCSU), Roger von Haefen (NCSU), Ken Reckhow (Duke), Melissa Kenney (Johns Hopkins)

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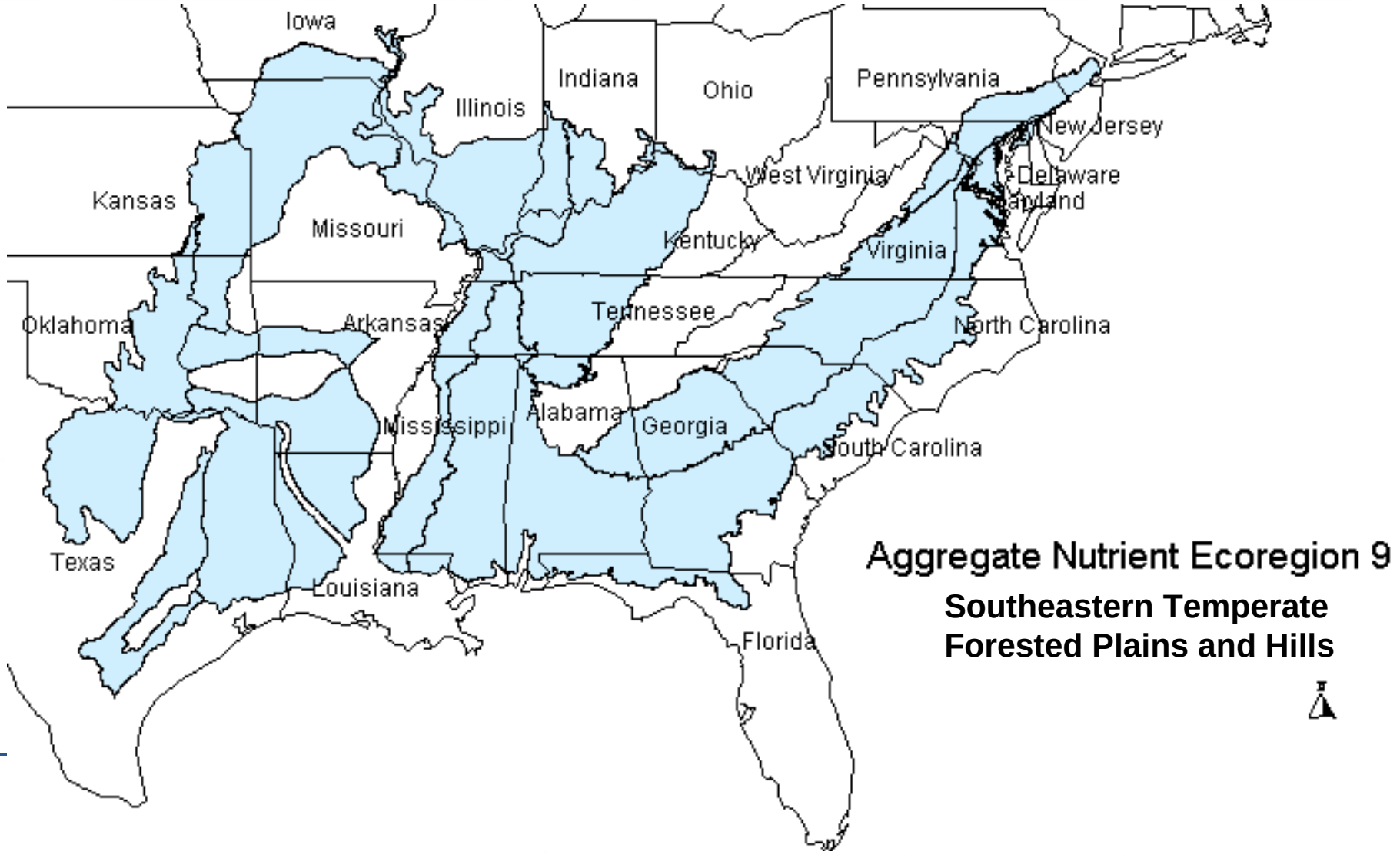
Background and Motivation

- Nutrient pollution is among top 5 sources of designated use impairments…
  - States charged with selecting nutrient concentration criteria
  - EPA is encouraging *quantitative* (numeric) ambient criteria
    - → How to set? Use costs and benefits?
  - Many states require assessment of costs/benefits for criteria selection
    - → How to measure?
    - → Apparent and concentrated costs, subtle and diffuse benefits
- EPA solicited proposals to help states with benefits measurement

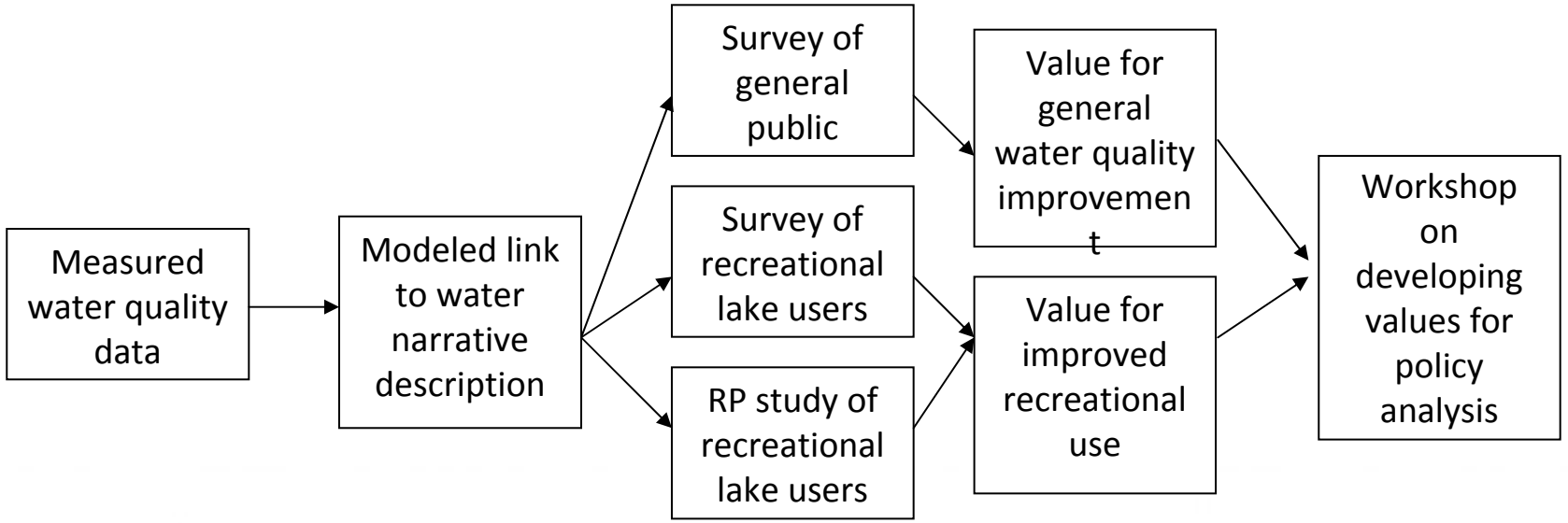
Project Objectives

- Develop an integrated modeling approach to evaluate the benefits of protecting aquatic ecosystems services by reducing nutrient pollution in lakes:
  - Develop models for mapping measured water quality (e.g. TN, TP) to a lake eutrophication index
    - Use expert elicitation and data from North Carolina lakes and reservoirs
  - Develop models for mapping changes in the lake eutrophication index to dollar-measured benefits
    - Communicate lake ecosystem attributes and services associated with eutrophication levels
    - Elicit values for changes in the levels and spatial distribution of lake eutrophication
  - Transfer knowledge on the framework and its application via a training workshop
    - Apply model results to estimate benefits for lakes in Ecoregion IX

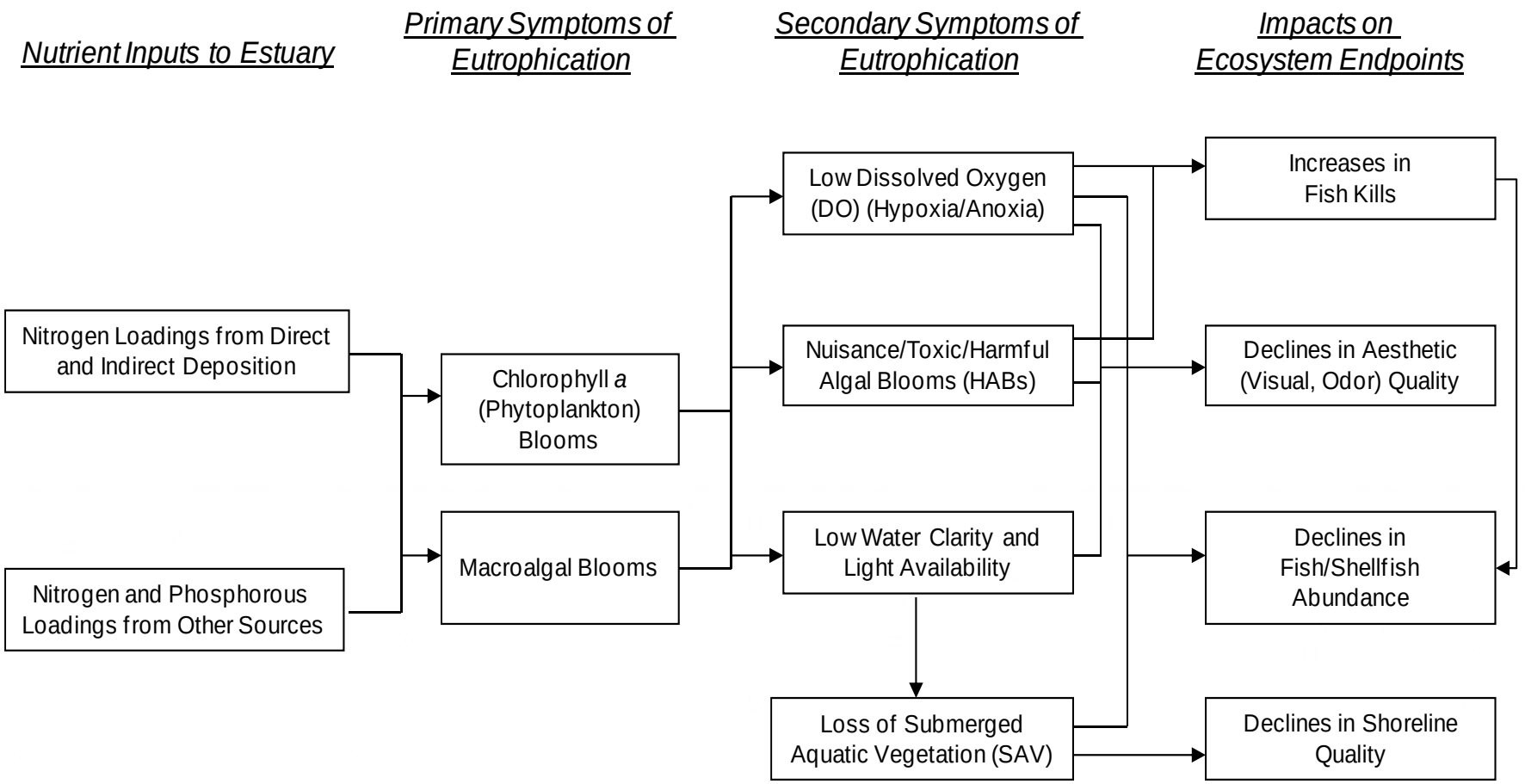
Study Area: EPA Nutrient Ecoregion IX for Lakes and Reservoirs



Overview of Research



Conceptual Model of Eutrophication Impacts



Mapping Water Chemistry to the Eutrophication Index

- Expert Elicitation: 14 water quality experts were presented with the same 100 rows of water chemistry data, each representing a different lake in North Carolina.
  - Example row:

Photic Total Nitrogen	Photic Total Inorganic Nitrogen	Photic Total Phosphorus	Photic Chlorophyll a	Surface Dissolved Oxygen	Secchi Depth	Photic Turbidity
0.46 mg/l	0.02 mg/l	0.03mg/l	38 μg/l	6.3 mg/l	1.3 m	3.9 NTU

  - Elicitation Task: Imagine 100 different lakes with the characteristics specified by the given data row. Of the 100 lakes, how many of the lakes would you expect to fall into each of the following five categories of eutrophication?

Lake Eutrophication Categories

Category	Water clarity	Color	Algae	Nutrient levels	Oxygen	Odor	Aquatic life
1	Excellent	None	Very little	Very low	Very high	No	Very healthy, abundant
2	Good	Little	Little	Low	High	Little	Healthy, abundant
3	Fair	Some	Moderate	Moderate	Moderate	Little	Somewhat healthy, abundant
4	Poor	Noticeable	High	High	Low	Noticeable	Unhealthy, scarce
5	Poor	Considerable	Very high	Very high	Low to no	Strong offensive	Unhealthy, scarce or none present

Ordered Logit Analysis of Expert Responses

- Dependent Variable: Category with highest selected probability mass by expert is assigned a 1 (others 0)
  - N = 1400 = 14 x 100

Model 2

VARIABLE	ESTIMATE	STD. ERROR	Z-RATIO	P-VALUE
Total Nitrogen	0.436	0.301	1.450	0.147
Total Inorganic Nitrogen	0.873	0.494	1.770	0.078
Total Phosporous	9.792	2.463	3.980	0.000
Chlorophyll	0.076	0.012	6.530	0.000
Suface Dissolved Oxygen	-0.004	0.050	-0.080	0.933
Secci Depth	-0.730	0.139	-5.240	0.000
Turbidity	0.017	0.009	1.960	0.050
Cut 2	-1.112	0.764		
Cut 3	0.535	0.546		
Cut 4	3.044	0.394		
Cut 5	6.264	0.561		

Mapping Eutrophication Index to Monetary Values

- Stated Preference (SP) Surveys
  - Communicate lake attributes/ecosystem services associated with each eutrophication category
  - Describe scenarios involving tradeoffs between lake eutrophication conditions and some form of “payment” (i.e., choice-based conjoint scenarios)
    - Lake site choice for recreational users
    - Lake improvement policy choice for general public
- Revealed Preference (RP) Analysis
  - Use data on actual lake recreation site choices to measure tradeoffs
- Combined RP-SP Analysis

Stated Preference Surveys

- Knowledge Networks Internet Panel
  - Sample 1: N=700 from NC, SC, and VA
  - Sample 2: N=500 from KY, TN, GA, AL, MS
- Lake site choice for recreational users
  - Tradeoff lake water quality (eutrophication index), travel distance, and other lake characteristics (e.g., facilities)
- Lake improvement policy choice for general public
  - Tradeoff increase in % of lakes in better eutrophication categories against household payments

Communicate Lake Attributes and Ecosystem Services for Eutrophication Categories

POOR	
COLOR	
CLARITY	Can see 1-2 feet deep
ODOR	Noticeable unpleasant odor, lasting about 1 week, occurs 3-4 times a year
FISH	A few mostly small and rough fish present
ALGAE	blooms: mid-size areas, lasting about 1 month, occur 5 times a year mats: large clusters are present for almost half the year

GOOD	
COLOR	
CLARITY	Can see 5-8 feet deep
ODOR	Faint unpleasant odor, lasting about 1 day, occurs at most 2 times a year
FISH	Moderately large and diverse population of fish.
ALGAE	blooms: Small area occurs less than 2 times a year mats: small clusters in a few parts of the lake occur at most 2 times a year

Revealed Preference Analysis

- Use data from the National Survey of Recreation and the Environment (NSRE) to estimate a simple lake recreation "random utility" site choice model

$$U_{ji} = \alpha_j + \delta p_{ji} + \varepsilon_{ji}, \quad j = 1, \ldots, J,$$

  - α_j represents a site-specific constant
  - p_{ij} represents travel cost by individual *i* to site *j*
  - εji represents random unobserved component

Combined RP and SP Model

- Combine results of RP model with the recreation site choice SP model to estimate parameters of a full random utility model (RUM)

$$U_{ji} = \sum_{l=1}^{L} \beta_l e_{lj} + \delta p_{ji} + \xi_j + \varepsilon_{ji}, \quad j = 1, \ldots, J,$$

  - e_j represents eutrophication index at site *j*
  - ζ_j represents all non-eutrophication characteristics at site *j*

- Use full RUM to estimate recreation benefits of changes in eutrophication at specific lakes

Even further down the road…

- Use combined model results to develop benefit estimation tool for analysis of nutrient reduction policies
  - Output from our project is a framework for non-experts to conduct benefits estimate for policy purposes
- Conduct training workshop for state-level water quality managers
  - Planned for end of project ≈ Spring 2010
  - Target audience is people who need to do benefits assessment for proposed water quality criteria