Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

INTRODUCTORY REMARKS BY

MIKE SHAPIRO
DEPUTY ASSISTANT ADMINISTRATOR,
U.S. EPA, OFFICE OF WATER

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

October 26-27, 2004
Wyndham Washington Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Cynthia Morgan and the Project Officer, Ronald Wiley, for their guidance and assistance throughout this project.

DISCLAIMER

These proceedings are being distributed in the interest of increasing public understanding and knowledge of the issues discussed at the workshop and have been prepared independently of the workshop. Although the proceedings have been funded in part by the United States Environmental Protection Agency under Contract No. 68-W-01-055 to Alpha-Gamma Technologies, Inc., the contents of this document may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

Transcript of Introductory Remarks

Mike Shapiro, Deputy Assistant Administrator
U.S. EPA, Office of Water

It's a pleasure to be here. My role really is to come here as, basically, your primary customer, from our perspective. As Robin (Jenkins) mentioned, the Office of Water has a strong interest in advancing the art of assessing the benefits from ecological improvements. That stems very directly from the mission of our office and our experience in implementing our statutory mandates over the last three decades. The Clean Water Act, which is one of the two main statutes that our office implements, provides the national goal that "wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water be achieved." That's just the interim goal, but we haven't gotten there quite yet, even though I believe 1983 was the date we were supposed to achieve it. There are a whole variety of reasons for that. That part of the statute clearly was aspirational—no one sued us over missing that deadline. However, I think it emphasizes a couple of key aspects of implementing the Clean Water Act.

First and foremost, I think the notion that the importance of the quality of aquatic systems beyond just straight contribution to human health is an overriding concern in the Clean Water Act, much more so than in a number of the other statutes that I've been charged with administering during my tenure at EPA. So, built into the decision making process really is a very direct requirement that we look at ecological values holistically in order to provide guidance and criteria in establishing basic water quality standards, as well as in developing mandatory national regulations—for example, under the effluent guidelines program. Probably more significantly, it's built into how we have to evolve a strategy for managing and maintaining water quality in this country. So, at each layer in the decision making process—from establishing strategic approaches to setting and achieving water quality goals to developing implementation programs and establishing specific criteria or regulations—we have to consider (and more often than not, it's become an overriding driver) ecological factors in our decision making and how we set priorities and how we go about evolving strategies and in specific actions that we have to take.

As the challenge of implementing our water programs becomes greater and greater, we have to cope with very difficult and expensive issues to manage—such as contributions from non-point source pollution, such as getting increasingly more stringent controls over point sources that have already been through one or two generations of regulation. We also find that increasingly we have to demonstrate not just that that's a good thing to do, but that we can, first of all, *evaluate* the ecological impacts of what we plan to do, and secondly, and increasingly more significantly, *quantify* the benefits of those impacts if we are going to have an effective public policy debate over the evolution of water programs in this country. And that's occurring, I think, for fundamentally the right reasons: the nation is making *huge* investments in environmental quality across *all* the media. We face a significant challenge in all our media over the next several decades to not only maintain the gains of the past but to achieve the goals that we seek for protecting human health and the environment, and we want to know how to make the best decisions. We want to know as a society where to invest resources and how to use those resources that we do invest in the most effective way possible. You are a very *impressive* community of researchers, and we are asking for your help in developing some of the basic tools that we in the Office of Water, as well as EPA's other program offices, need to inform those decisions.

It's no secret to any of you that as compared to assessing and valuing human health effects we've trailed far behind in the area of ecological benefits, both because some of the underlying ecosystem modeling has had to be developed and because of some of the very challenging valuation issues posed by evaluating and valuing ecosystem services. I think that gap is beginning to close, and in fact I think one of the impressive things about this two-day meeting is the research products that are already beginning to become available that many of you will be speaking about over the course of the coming days. I think that some of that work, which is cutting edge, will pave the way to closing the gaps that we're facing.

I think that the Office of Water, together with ORD (Office of Research and Development) and OPEI (Office of Policy, Economics, and Innovation), have really undertaken a sustained effort to support research in this area. Robin mentioned a number of the aspects of that sustained effort, and you'll be hearing more about them this morning. One is the Ecological Benefits Assessment Strategic Plan, which is largely an internal-driven document that has laid out the fundamental priorities and principles underlying our sustained support for ecological research. There's also the Science Advisory Board Committee on Valuing Protection of Ecological Systems, which you'll be hearing about shortly. That group is charged with providing us input and guidance as we try to develop our research programs and apply new methodologies. We're also anxiously awaiting the National Research Council's Report on Assessing and Valuing the Services of Aquatic Systems, which again you'll be hearing more about later today. We're very much looking forward to the guidance that that NAS panel provides, and the support and interest in that panel is not exclusive to EPA—it also has been supported by the Army Corps of Engineers and the Department of Agriculture, two of our key federal partners in managing and implementing water quality programs.

So, the interest in this area and the importance of the work that you're doing (although I like to speak of myself as your primary customer) really goes well beyond the Office of Water and well beyond the Environmental Protection Agency as, increasingly, management of the nation's water resources has to become a coordinated effort, certainly across several key federal agencies as well as other levels of government.

I'd just like to close by emphasizing one point. In my tenure at EPA I think one of the dramatic challenges we've faced across the years has been the speed by which we can convert cutting edge research into tools that we can use in our day-to-day business of environmental decision making, whether through rule-making or through guidance or through a variety of other mechanisms. As I'm sure many of you are well aware, our practice lags what is available in the research community by a number of years—often, too many years in my view. So, as each of you thinks about the work you're doing and the research and new tools that you're developing, I hope that you bear in mind the importance of the *development* part of research and development. We need you to help us by applying your methods increasingly to examples that are representative of the kind of work that we do so that we can close the gap between research and practice as quickly and effectively as possible. We encourage you to establish the appropriate tools and verify your work so that we can really take what you're doing and incorporate it into our decision making as quickly as possible. Hopefully, that will be a theme that connects many of the different sessions that we have. We're very eager to follow the work that all of you are doing and to apply it, as appropriate, to the decisions that we have to make every day in the Office of Water and at the Environmental Protection Agency.

I'd certainly like to thank all of you for your contributions to date and look forward to the result of the next two days as well as the ongoing research that you're conducting.

Thank you.

Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

PROCEEDINGS OF

SESSION I: SELECTED ECOLOGICAL VALUATION ACTIVITIES AT EPA

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

October 26-27, 2004
Wyndham Washington Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Cynthia Morgan and the Project Officer, Ronald Wiley, for their guidance and assistance throughout this project.

DISCLAIMER

These proceedings are being distributed in the interest of increasing public understanding and knowledge of the issues discussed at the workshop and have been prepared independently of the workshop. Although the proceedings have been funded in part by the United States Environmental Protection Agency under Contract No. 68-W-01-055 to Alpha-Gamma Technologies, Inc., the contents of this document may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

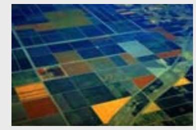
TABLE OF CONTENTS

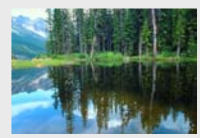
Draft Ecological Benefits Assessment Strategic Plan

Nicole Owens

October 2004

The following material describes the Draft Ecological Benefits Assessment Strategic Plan. The Plan has not undergone a final review and should not be construed to represent Agency Policy.





Workgroup Members

- OAR
  - Linda Chappell
- OPPTS
  - Lynne Blake-Hedges
  - TJ Wyatt
- OPEI
  - Rich Iovanna
  - Sabrina Lovell
  - Steve Newbold
  - Nicole Owens
- ORD
  - Randy Bruins
  - Wayne Munns
  - Will Wheeler
- OSWER
  - David Charters
- OW
  - Joel Corona
  - Doug Norton
- Contractor support, ICF
  - Margaret McVey

2

EPA and Ecological Benefits

- The mission of EPA is to protect human health and the environment.
- To that end, EPA
  - Develops and enforces regulations
  - Sponsors and develops voluntary programs and partnerships
  - Conducts and sponsors environmental research
- Identifying, quantifying, and monetizing ecological benefits can improve decision-making.
- Benefit-cost analysis required by executive order and statute.
- EPA is increasingly asked to provide concrete support for programmatic decisions

3

Ecological Benefits

- Any improvements in human well-being that are derived from ecosystem services.
- Difficult to quantify and monetize.
- Current state of the practice values a limited set of ecological services affected by Agency actions.

4

Goal of the Strategic Plan

"To improve the Agency's ability to identify, quantify, and value ecological benefits in order to improve decision-making and better communicate the results of Agency actions."

5

Objectives of the Strategic Plan

- "Clearly describe some of the major technical and institutional issues that prevent the Agency from conducting accurate and comprehensive ecological benefits assessments on a routine basis."
- "Identify directions for future research, data collection, and development of analytical tools."

6

Objectives of the Strategic Plan

- "Propose activities to foster increased collaboration and coordination among the Agency's ecologists, economists, and other analysts in conducting ecological benefits assessments."
- "Propose institutional mechanisms to facilitate adaptive implementation of this Strategic Plan, including periodic adjustments of the Plan to reflect progress in the state of knowledge."

The Plan will help Offices develop program-specific Action Plans to guide investment in the development of the methods, models, and data needed to conduct accurate and comprehensive ecological benefits assessments.

7

Contents of the Plan

8

Contents Cont'd

Section 4 – Improving Ecological Benefits Assessments

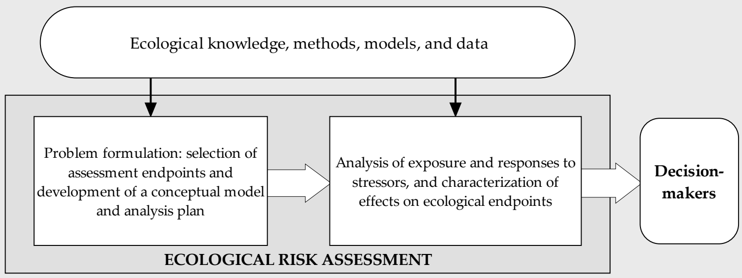
9

Contents Cont'd

Section 5 – Implementation

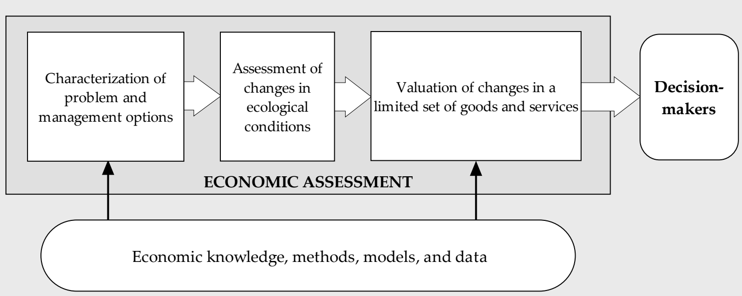
10

Ecological and Economic Assessments are Usually Separate



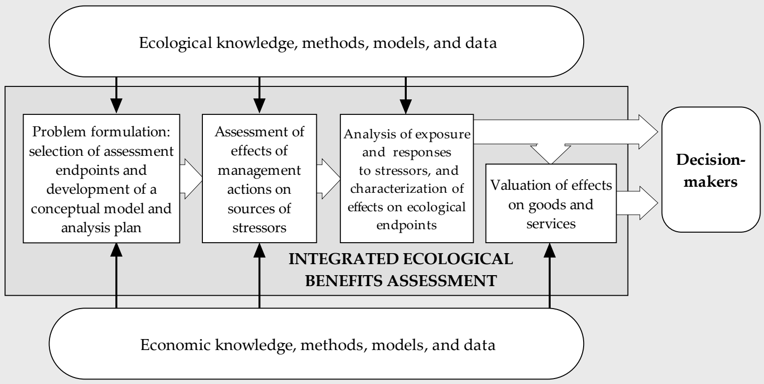
11

Ecological and Economic Assessments are Usually Separate



12

A More Integrated Process



13

Section 4

- Describes some of the major ways in which EPA could improve its capabilities for conducting rigorous and comprehensive ecological benefits assessments on a routine basis.
- Describes key issues associated with ecological benefits assessments and actions that should lead to improvements.
- The actions address directions for future research, data collection, development of analytical tools, and institutional changes.

14

Example Issues and Actions

Issue: Communication between ecologists and economists within EPA.

Action: Provide formal and informal opportunities for communication among disciplines.

Action: Provide basic training in the fundamentals of other disciplines.

Issue: Collaboration between ecologists and economists.

Action: Explore methods for expanding the use of ecological risk assessment information in economic benefits assessments.

Action: Require multi-disciplinary participation in assessing ecological benefits.

Action: Develop guidelines for planning and conducting ecological benefits assessments.

Example Issues and Actions

Issue: Ability to predict changes in ecosystem processes in response to changing environmental stressors. Action: Identify which ecosystem processes are most important to benefits assessments at EPA.

Action: Identify which of the important ecosystem processes need further research to allow model development.

Action: Develop a catalogue of existing relevant ecosystem process models at different geographic scales to support benefits assessment.

Action: Expand portfolio of models to address the ecosystem processes important to benefits assessment at multiple geographic scales.

Action: Address data needs for those models.

Action: Evaluate other options for estimating changes in ecosystem processes.

Example Issues and Actions

Issue: Using existing valuations studies for benefit transfer.

Action: Encourage researchers to estimate values for a wider variety of ecological resources.

Action: Encourage researchers to use standardized measures of ecological resources in valuation studies.

Action: Encourage researchers to estimate and report values for a greater range of ecological changes.

Action: Support the development of new publication outlets.

17

Section 5

- Identifies Agency actions needed to implement the Plan.
  - *Further define research and development needs and communicate those needs by developing office-specific Action Plans.*
  - Develop a systematic method to guide prioritization of the investment opportunities identified in the Plan and individual program office Action Plans.
  - Track progress and integrating ecological benefits assessment into the Agency's base programs.

18

Status

- SAB Committee on Valuing the Protection of Ecological Systems and Services review January 2005
- SAB Review Draft available late fall 2004
- Want a copy?
  - Sign-up sheet on registration table
  - Email owens.nicole@epa.gov

19

Valuing Ecological Protection: A Tangle, a Web, or a Fabric?

A Look at the Work of the SAB Committee on Valuing the Protection of Ecological Systems and Services

EPA SAB Staff Office

History of Project

- SAB's Executive Committee conceived Project (2002)
- Project within SAB mission
  - To provide external, independent advice on the scientific and technical aspects of environmental issues to help inform environmental decision-making
  - Advice directed at the technical bases of EPA policies, regulations, research, and science programs
- Project supported as an SAB priority by EPA's Science Policy Council

EPA SAB Staff Office

Charge to the Committee

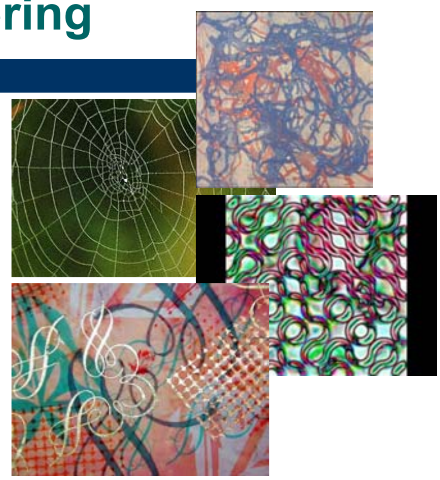
- To assess:
  - Agency needs and the state of the art and science of valuing protection of ecological systems and services
  - To identify key areas for improving knowledge, methodologies, practice, and research
- A multi-disciplinary, multi-year effort

Formation of Committee

- Committee formed in August 2003
- 24 members – with experience, expertise, and range of views in different fields
  - 7 Economists
  - 8 Environmental Scientists (Ecologists/Biologists)
  - 9 “Others”:
    - Decision Science
    - Engineering
    - Law
    - Philosophy
    - Political Science
    - Psychology

Strategy and Steering

- "Value" – untangling its meanings
- Important to provide advice to help EPA make decisions
- Steering Committee established – February 2004



EPA SAB Staff Office

Focusing on 4 Types of EPA Needs

1. Valuation of ecological benefits for National Rulemaking
2. Assessing options, priority setting for Regional decision-making
3. Assessing ecological benefits for GPRA compliance
4. Communicating ecological benefits to the public

EPA SAB Staff Office

Key Technical Issues

- Addressing non-use values
- Expressing data quality and uncertainty
- Appropriate use of monetized, quantified, and qualitative methods
- Assumptions about:
  - Elasticity and substitution
  - Transferability
  - Stability of ecological systems
  - Discounting benefits
- Appropriate role of public in developing scientific information

EPA SAB Staff Office

Planned Committee Activities

- Advisory on Agency draft *Ecological Benefits Assessment Strategic Plan*
- Public meetings/workshops focused on EPA decision needs
- "Example Exercises" to meet those needs
- Public meetings on key technical issues
- Learning from/building on work of others
- Final report (2005-2006) addressing EPA's needs

EPA SAB Staff Office

US EPA Science Advisory Board (SAB) Committee on Valuing the Protection of Ecological Systems and Services
Fact-Sheet

Charge

The SAB initiated this project to assess Agency needs and the state of the art and science of valuing protection of ecological systems and services, and then to identify key areas for improving knowledge, methodologies, practice, and research.

Committee Membership

The Committee is an inter-disciplinary group (24 Members) of ecologists, economists, engineers, other environmental specialists, and related disciplines. A committee roster is attached to this fact sheet. The Committee has organized a Steering Group to assist the Chair and the Designated Federal Officer, Dr. Angela Nugent, in planning the work of the Committee.

Approach

To fulfill this charge, the SAB Committee appointed by the Administrator will conduct a multiyear initiative with the goal of providing a first approximation of the advice needed by the Environmental Protection Agency.

- They will also advise the Agency on its draft *Ecological Benefits Assessment Strategic Plan*
- They will host workshops on science-based approaches to valuing the protection of ecological systems and services used in practice by groups outside EPA: in other federal agencies, state governments, environmental groups, business entities and international organizations.
- The Committee will focus on specific EPA decision-making needs by reviewing a range of EPA analyses supporting those needs and by intensively working on related "examples."
- At the conclusion of the two-year initiative, the Committee will issue a final report assessing overall Agency needs and provide advice for strengthening the Agency's approaches for valuing the protection of ecological systems and services, their use by decision makers, and the key research areas needed to strengthen the science base.

Specific Areas of Focus on EPA Decision-Making Needs

- Needs for benefit assessments supporting regulations protecting ecological systems and services
- Regional needs for assessing and communicating the value of protecting ecological systems and services
- Needs for assessing and communicating to Congress, the Executive Branch, and the public the value of EPA's programs protecting ecological systems and services under the Government Performance and Results Act
- Needs for information/communication products to communicate to the general public about EPA regulatory decisions protecting ecological systems and services and information/communication products encouraging voluntary actions to protect ecological systems and services

Status of Work

- The Committee held an "Initial Background Workshop" on October 27, 2004. The purpose was to identify the range of EPA's needs for science-based information on valuing the protection of ecological systems and services.
    - Minutes are posted on the web at: http://www.epa.gov/science1/04minutes/cvpess_102703m.pdf.

- The Committee held a "Workshop on Different Approaches and Methods for Valuing the Protection of Ecological Systems and Services" on April 13-14, 2004.
    - Minutes are posted on the web at: http://www.epa.gov/science1/04minutes/valueprotecosys41304min.pdf

- The Committee held an Advisory Meeting focused on support documents for national rulemakings on June 14-15, 2004.
    - Minutes are posted on the web at: http://www.epa.gov/science1/04minutes/cvpess_061404m.pdf

- The Committee held an advisory meeting in San Francisco on Sept. 13, 14, and 15 focused on regional science needs, work-products, and activities by holding panel discussions, briefings, and break-out groups.
    - Minutes are posted on the web at: http://www.epa.gov/science1/04minutes/cvpess_091304m.pdf

  .

- The Committee will hold an advisory meeting on Jan. 25 and 26, 2005. The purpose of this meeting will be to review EPA's Draft Ecological Benefits Assessment Strategic Plan and Related Charge Questions and then to discuss science needs, work-products, and activities related to requirements under the Government Performance and Results Act for valuing the protection of ecological systems and Services.
    - Background materials for the meeting will be posted on the SAB web site (www.epa.gov/sab) as they become available.

For Additional Information

Please contact the Designated Federal Officer, Dr. Angela Nugent by email at nugent.angela@epa.gov or by phone at 202-343-9981.

U.S. Environmental Protection Agency
Science Advisory Board
Committee on Valuing the Protection of Ecological Systems and Services

CHAIR
Dr. Domenico Grasso, Rosemary Bradford Hewlett Professor and Chair, Picker Engineering Program, Smith College, Northampton, MA

MEMBERS
Dr. William Louis Ascher, Dean of the Faculty, Bauer Center, Claremont McKenna College, Claremont, CA

Dr. Gregory Biddinger, Environmental Programs Coordinator, ExxonMobil Biomedical Sciences, Inc, Houston, TX

Dr. Ann Bostrom, Associate Professor, School of Public Policy, Georgia Institute of Technology, Atlanta, GA

Dr. James Boyd, Senior Fellow, Director, Energy & Natural Resources Division, Resources for the Future, Washington, DC

Dr. Robert Costanza, Professor/Director, Gund Institute for Ecological Economics, School of Natural Resources, University of Vermont, Burlington, VT

Dr. Terry Daniel, Professor of Psychology and Natural Resources, Department of Psychology, Environmental Perception Laboratory, University of Arizona, Tucson, AZ

Dr. A. Myrick Freeman, Research Professor of Economics, Department of Economics, Bowdoin College, Brunswick, ME

Dr. Dennis Grossman, Vice President for Science, Science Division, NatureServe, Arlington, VA

Dr. Geoffrey Heal, Paul Garrett Professor of Public Policy and Business Responsibility, Columbia Business School, Columbia University, New York, NY

Dr. Robert Huggett, Consultant and Professor Emeritus, College of William and Mary, ,

Dr. Douglas E. MacLean, Professor, Department of Philosophy, University of North Carolina, Chapel Hill, NC

Dr. Harold Mooney, Paul S. Achilles Professor of Environmental Biology, Department of Biological Sciences, Stanford University, Stanford, CA

Dr. Louis F. Pitelka, Director and Professor, Appalachian Laboratory, University of Maryland Center for Environmental Science, Frostburg, MD

Dr. Stephen Polasky, Fesler-Lampert Professor of Ecological/Environmental Economics, Department of Applied Economics, University of Minnesota, St. Paul, MN

Dr. Paul G. Risser, Chancellor, Oklahoma State Regents for Higher Education, Oklahoma City, OK

Dr. Holmes Rolston, University Distinguished Professor, Department of Philosophy, Colorado State University, Fort Collins, CO

Dr. Joan Roughgarden, Professor, Biological Sciences and Evolutionary Biology, Stanford University, Stanford, CA

Dr. Mark Sagoff, Senior Research Scholar, Institute for Philosophy and Public Policy, School of Public Affairs, University of Maryland, College Park, MD

Dr. Kathleen Segerson, Professor, Department of Economics, University of Connecticut, Storrs, CT

Dr. Paul Slovic, Professor, Department of Psychology, Decision Research, Eugene, OR

Dr. V. Kerry Smith, University Distinguished Professor, Department of Agricultural and Resource Economics, College of Agriculture and Life Sciences, North Carolina State University, Raleigh, NC

Dr. Robert Stavins, Albert Pratt Professor of Business and Government, Environment and Natural Resources Program, John F. Kennedy School of Government, Harvard University, Cambridge, MA

Dr. Barton H. (Buzz) Thompson, Jr., Robert E. Paradise Professor of Natural Resources Law and Vice Dean , Stanford Law School, Stanford University, Stanford, CA

SCIENCE ADVISORY BOARD STAFF

Dr. Angela Nugent, Designated Federal Officer, 1200 Pennsylvania Avenue, NW, Washington, DC, Phone: 202-343-9981, Fax: 202-233-0643, (nugent.angela@epa.gov)

Valuing Ecosystem Services

Toward Better Environmental Decision-Making

National Research Council
Mark Gibson
Study Director

Presentation to U.S. EPA Workshop:
Improving the Valuation of Ecological Benefits
October 26, 2004

Available on-line at http:/www.nap.edu/catalog/11139.html

Committee and Process

- 5 meetings, 1 consensus report, extensive external review process
- Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems:
  - GEOFFREY M. HEAL, Chair, Columbia University
  - EDWARD B. BARBIER, University of Wyoming
  - KEVIN J. BOYLE, University of Maine
  - ALAN P. COVICH, University of Georgia
  - STEVEN P. GLOSS, U.S. Geological Survey
  - CARLTON H. HERSHNER, JR., Virginia Institute of Marine Science
  - JOHN P. HOEHN, Michigan State University
  - STEPHEN POLASKY, University of Minnesota
  - CATHERINE M. PRINGLE, University of Georgia
  - KATHLEEN SEGERSON, University of Connecticut
  - KRISTIN SHRADER-FRECHETTE, University of Notre Dame

Report Reviewers

- Mark Brinson, East Carolina University
- J. Baird Callicott, University of North Texas
- Nancy Grimm, Arizona State University
- Michael Hanemann, University of California, Berkeley
- Peter Kareiva, The Nature Conservancy
- Raymond Knopp, Resources for the Future
- Sandra Postel, Global Water Policy Project
- Robert Stavins, Harvard University

Statement of Task

The committee will evaluate methods for assessing services and the associated economic values of aquatic and related terrestrial ecosystems. The committee's work will focus on identifying and assessing existing economic methods to quantitatively determine the intrinsic value of these ecosystems in support of improved environmental decision-making, including situations where ecosystem services can be only partially valued. The committee will also address several key questions, including:

Statement of Task
(continued)

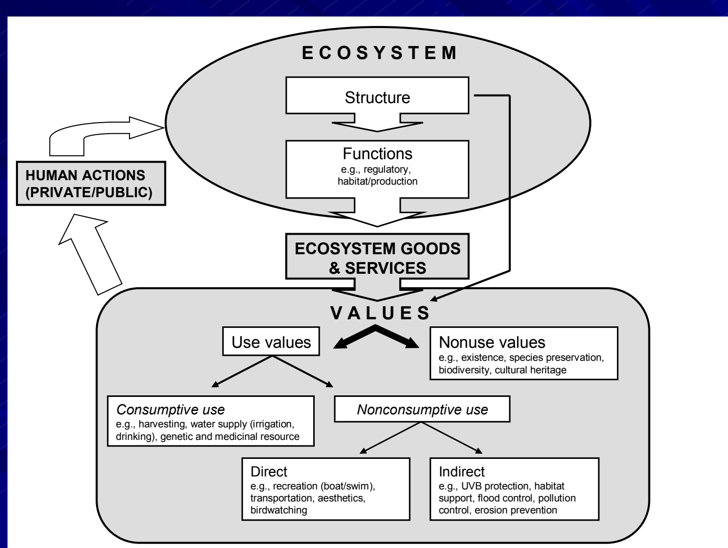
- What is the relationship between ecosystem services and the more widely studied ecosystem functions?
- For a broad array of ecosystem types, what services can be defined, how can they be measured, and is the knowledge of these services sufficient to support an assessment of their value to society?
- What lessons can be learned from a comparative review of past attempts to value ecosystem services—particularly, are there significant differences between eastern and western U.S. perspectives on these issues?
- What kinds of research or syntheses would most rapidly advance the ability of natural resource managers and decision-makers to recognize, measure, and value ecosystem services?
- Considering existing limitations, error, and bias in the understanding and measurement of ecosystem values, how can available information best be used to improve the quality of natural resource planning, management, and regulation?

Report Organization

Introduction and Overview

- The study was conceived in 1997 at a strategic planning session of Water Science and Technology Board of the NRC
- In early November 1999 the NRC organized and hosted a planning workshop to assess the feasibility of and need for an NRC study of the functions and associated economic values of aquatic and terrestrial ecosystems
- The report focuses on the goods and services provided by aquatic and related terrestrial ecosystems and reflects an intentional effort to focus on management and valuation issues confronting state and federal agencies for these ecosystems
- Because the principles and practices of valuing ecosystem goods and services are rarely sensitive to whether the underlying ecosystem is aquatic or terrestrial, the report's various conclusions and recommendations are likely to be directly or at least indirectly applicable to the valuation of the goods and services provided by any ecosystem

Connections Between Ecosystem Structure and Function, Goods and Services, Policies, and Values



The Meaning of Value and Use of Economic Valuation

- Recent philosophical debates regarding ecosystem value generally derive from two points of view (1) values of ecosystems and their services are non-anthropocentric and (2) all values are anthropocentric
- Although economic valuation does not capture all sources or types of value, it is much broader than usually presumed. It recognizes that economic value can stem from the use of an environmental resource (*use values*), or from its existence even in the absence of use (*nonuse value*)
- The broad array of values included under this approach is captured by using the total economic value (TEV) framework. The TEV framework helps to provide a checklist of potential impacts and effects that need to be considered in valuing ecosystem services
- A valuation question can be framed in terms of two alternative measures of value, willingness to pay (WTP) and willingness to accept (compensation) (WTA). These two approaches imply different presumptions about the distribution of property rights and can differ substantially
  - In many contexts, methodological limitations necessitate the use of WTP rather than WTA

The Meaning of Value and Use of Economic Valuation
Major Recommendations

- Policymakers should use economic valuation as a means of evaluating the trade-offs involved in environmental policy choices; an assessment of benefits and costs should be part of the information set available to policymakers in choosing among alternatives
- Economic valuation of changes in ecosystem services should be based on the comprehensive definition embodied in the TEV framework, including both use and nonuse values
- The valuation exercise should be framed properly. In particular, it should value the *changes* in ecosystem good or services attributable to a policy change

Aquatic and Related Terrestrial Ecosystems

- The phrase "aquatic and related terrestrial ecosystems" recognizes the impossibility of analyzing aquatic systems absent consideration of the linkages to adjacent terrestrial environments
- There have only been a few attempts to develop explicit maps of the linkage between aquatic ecosystem structure/function and value. There are, however, a multitude of efforts to separately identify ecosystem functions, goods, services, values, and/or other elements in the linkage
- From an ecological perspective, the value of specific ecosystem functions/services is entirely relative. The spatial and temporal scales of analysis are critical determinants of potential value
- There remains a need for a significant amount of research in the ongoing effort to codify the linkage between ecosystem structure and function and the provision of goods and services for subsequent valuation
- A comprehensive identification of all functions and derived services may never be achieved; nevertheless, comprehensive information is not generally necessary to inform management decisions

Aquatic and Related Terrestrial Ecosystems
Major Recommendations

- Aquatic ecosystems generally have some capacity to provide consumable resources, habitat for plants and animals, regulation of the environment, and support for nonconsumptive uses, but considerable work remains to be done in documentation of the potential of various aquatic ecosystems for contribution in each of these broad areas
- Because delivery of ecosystem goods and services occurs in both space and time, investigation of the spatial and temporal thresholds of significance for various ecosystem services is necessary to inform valuation efforts
- Natural systems are dynamic and frequently exhibit nonlinear behavior, and caution should be used in extrapolation of measurements in both space and time. Methods are needed to assess and articulate this uncertainty as part of system valuations

Methods of Nonmarket Valuation

- Although a variety of nonmarket valuation approaches are currently available, no single method can be considered best at all times and for all types of aquatic ecosystem applications
- Revealed-preference methods can be applied only to a limited number of ecosystem services. However, both the range and the number of services that can potentially be valued are increasing with the development of new methods
- Stated-preference methods can be more widely applied, and certain values can be estimated only through the application of such techniques
  - However, the credibility of estimated values for ecosystem services derived from stated-preference methods has often been criticized
- Benefit transfers and replacement cost and cost of treatment methods are increasingly being used in environmental valuation, although their application to aquatic ecosystem services is still limited and potentially problematic
- Only a limited number of ecosystem services have been valued to date, and effective treatment of aquatic ecosystem services in benefit-cost analyses requires that more services be valued

Methods of Nonmarket Valuation
Major Recommendations

- Specific attention should be given to funding research at the "cutting edge" of the valuation field, such as dynamic production function approaches, general equilibrium modeling of integrated ecological-economic systems, conjoint analysis, and combined stated-preference and revealed-preference methods
- Specific attention should be given to funding research on improved valuation study designs and validity tests for stated-preference methods applied to determine the nonuse values associated with aquatic and related terrestrial ecosystem services
- Benefit transfers should be considered a "second-best" method of ecosystem services valuation and should be used with caution and only if appropriate guidelines are followed
- The replacement cost method and estimates of the cost of treatment are not valid approaches to determining benefits and should not be employed to value aquatic ecosystem services. In the absence of any information on benefits, and under strict guidelines, treatment costs could help determine cost-effective policy action

Case Studies and Lessons Learned

- Chapter 5 provides a series of case studies of the integration of ecology and economics necessary for valuing the services of aquatic and related terrestrial ecosystems
  - First reviewed are situations in which the focus is on valuing a single ecosystem service. Even when the goal of a valuation exercise is focused on a single ecosystem service, a workable understanding of the functioning of large parts or possibly the entire ecosystem may be required
  - Attempts to value multiple ecosystem services are reviewed next. Since ecosystems produce a range of services, and these services are frequently closely connected, it is often hard to discuss valuation of a single service in isolation. In addition, valuing multiple ecosystem services typically multiplies the difficulty of evaluation
  - Last to be reviewed are analyses that attempt to encompass all services produced by an ecosystem. Such efforts will typically face large gaps in understanding and information in both ecology and economics
- Chapter 5 also includes an extensive discussion of various implications and lessons learned from the case studies that are reviewed. For some policy questions, enough is known about ecosystem service valuation to help in decision-making. For others, knowledge and information may not yet be sufficient to estimate the value of ecosystem services with enough precision to answer policy-relevant questions

Case Studies and Lessons Learned
Major Recommendations

- Estimates of ecosystem value need to be placed in context; assumptions about conditions in ecosystems outside the target ecosystem and assumptions about human behavior and institutions should be clearly specified
- Concerted efforts should be made to overcome existing institutional barriers that prevent ready and effective collaboration among ecologists and economists regarding the valuation of ecosystem services. Furthermore, existing and future interdisciplinary programs aimed at integrated environmental analysis should be encouraged and supported

Judgment, Uncertainty, and Valuation

- The valuation of aquatic ecosystem services inevitably involves investigator judgments and some amount of uncertainty. Although unavoidable, uncertainty and the need to exercise professional judgment are not debilitating to ecosystem valuation
  - It is also important that the sources of uncertainty be acknowledged, minimized, and accounted for in ways that ensure that a study's results and related decisions regarding ecosystem valuation are not systematically biased and do not convey a false sense of precision
- There are several cases in which investigators must use professional judgment in ecosystem valuation regarding how to frame a valuation study, how to address the methodological judgments that must be made during the study, and how to use peer review to identify and evaluate these judgments
  - However, when such judgments are made it is important to explain why they are needed and to indicate the alternative ways in which judgment could have been exercised
- Just as there are different types of uncertainty in ecosystem valuation, there are also different ways and decision criteria that an analyst can use to allow for (and reduce) uncertainty in the support of environmental decision-making

Judgment, Uncertainty, and Valuation
Major Recommendations

- If the good or service being valued is unique and not easily substitutable with other goods or services, then the decision to use WTP or WTA are likely to result in very different valuation estimates
  - In such cases, the committee cannot reasonably recommend that the analyst report both sets of estimates in a form of sensitivity analysis because this may effectively double the work; rather, the analyst should document carefully the ultimate choice made and clearly state that the answer would probably have been higher or lower had the alternative measure been selected and used
- Ecosystem valuation studies should undergo external review by peers and stakeholders early in their development when there remains a legitimate opportunity for revision of the study's key judgments
- Analysts should establish a range for the major sources of uncertainty in an ecosystem valuation study whenever possible
- Under conditions of uncertainty, irreversibility, and learning, there should be a clear preference for environmental policy measures that are flexible and minimize the commitment of fixed capital or that can be implemented on a small scale on a pilot or trial basis

Ecosystem Valuation: Synthesis And Future Directions

- Chapter 7 seeks to synthesize the current knowledge regarding ecosystem valuation in a way that will be useful to resource managers and policymakers as they incorporate the value of ecosystem services into their decisions, and includes the following:
  - A synthesis of the report's general premises (10 total)
  - A synthesis of the report's major conclusions
  - Guidelines and a checklist for conducting ecosystem services valuation
  - Overarching recommendations for conducting ecosystem valuation
  - Overarching research needs, which imply recommendations regarding future research funding

VALUING ECOSYSTEM SERVICES

TOWARD BETTER ENVIRONMENTAL DECISION-MAKING

Lake Mendota, Wisconsin. Photo courtesy Wisconsin Department of Natural Resources

Until the economic value of ecosystem goods and services is acknowledged in environmental decision-making, they will implicitly be assigned a value of zero in cost-benefit analyses, and policy choices will be biased against conservation. The National Research Council report, *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*, identifies methods for assigning economic value to ecosystem services—even intangible ones—and calls for greater collaboration between ecologists and economists in such efforts.

The millions of miles of rivers, streams, coastline, and acres of estuaries, wetlands, lakes, and reservoirs throughout the United States host a vast array of aquatic ecosystems that provide many benefits to humans. These ecosystems produce not only goods such as lumber and fish, but they also provide a number of important functions or services that play crucial roles in supporting human, animal, and plant populations. These services include nutrient recycling, habitat for plants and animals, flood control, and water supply (see Box 1).

Human activities often compete with ecosystem survival. For example, should a wetland be drained for suburban housing? Although the economic value of the new houses may be known, it is not as easy to quantify the value the lost ecosystem services of the wetland that would affect plant and animal life, alter storm runoff patterns, and interfere with water reclamation, among other impacts. Likewise, the decision to build a dam to meet drinking water and electricity needs could have dramatic consequences on downstream ecosystems.

In order to appropriately assess environmental policy alternatives and the decisions that follow, it is essential to consider not only the value of the human activity, but also to consider the value of the ecosystem service that could be compromised. Despite a growing recognition of the importance of ecosystem services, their value is often overlooked in decision-making, and, to date, that value has not been well quantified.

Valuation Should Measure Trade-Offs

The Catskills/Delaware watershed provides 90 percent of the drinking water for the New York City metropolitan area. Historically, the watershed has produced high quality water with little contamination, but increased housing developments, septic systems, and agriculture caused water quality to deteriorate. By 1996, New York City had two choices: build a water filtration system at an estimated cost of up to $6 billion or protect its major watershed.

When possible in environmental decision-making, policymakers should use economic valuation as a way

Box 1. Examples of Services from Various Aquatic Ecosystems

Wetlands transform inputs (nutrients, energy) into valuable outputs (fish, crustaceans, and mollusks).

Floodplains along rivers and coasts provide flood protection, water reclamation, pollution abatement, underground water recharge, and recreation.

Mountain watersheds provide water supply, recreation (e.g., hiking, camping, and fishing).

THE NATIONAL ACADEMIES™
Advisers to the Nation on Science, Engineering, and Medicine

to quantify the trade-offs in a policy choice. In order to protect the Catskills watershed, measures were taken to help limit further development, improve sewage systems, and reduce the impact of agriculture by using less fertilizers and building up riparian zones along river banks at a total projected investment of about $1 to $1.5 billion. New York City water managers chose to protect the watershed.

Link Economic and Ecological Models

In the Hadejia-Jama'are floodplain in Northern Nigeria, economists and hydrologists worked together to estimate both upstream benefits and downstream consequences of several proposed dam and water diversion projects. A 1998 study showed that the benefit of the project was $3 million in irrigation and potable water, but that downstream floodplain losses would result in about $23 million dollars in costs; an estimated net loss of $20 million. A study in 2001 found that a one meter drop in groundwater would result in an estimated $1.2 million loss in dry season agriculture and a $4.8 million loss in domestic water consumption for rural households.

Economists already produce estimates of value for environmental decision-making. However, the strength of their analysis depends in large part on how well the underlying ecology of an ecosystem is understood and measured. Ecologists are challenged because ecosystems are complex, dynamic, variable, interconnected, and nonlinear, and because our understanding of the services they provide and how they are affected by human actions are imperfect and difficult to quantify.

In an analysis, it is important to ensure that the ecosystem is well understood and also that the study is designed so that output from ecological models can be used as input to the economic models so that the two can be linked effectively. The example of the Nigerian floodplain also illustrates the importance of measuring expected *changes* in the ecosystem for a given ecological impact. Other changes that could be measured include stream flow, water temperature, and changes in the plant life and fish of the floodplain.

Consider All Ways Ecosystems are Valued

Clean drinking water, food production, and recreation are all services of a lake ecosystem, but it is not easy to measure each one separately or to resolve conflicting views on which is more or less important to a management decision. Many economists use the **Total Economic Valuation (TEV) Framework** to incorporate the multiple ways that individuals or groups could value an ecosystem—most of which have no market or commercial basis (see Figure 1). Elements of the framework include:

- **Use and Nonuse Values:** Although different TEV frameworks are used to assess value, most

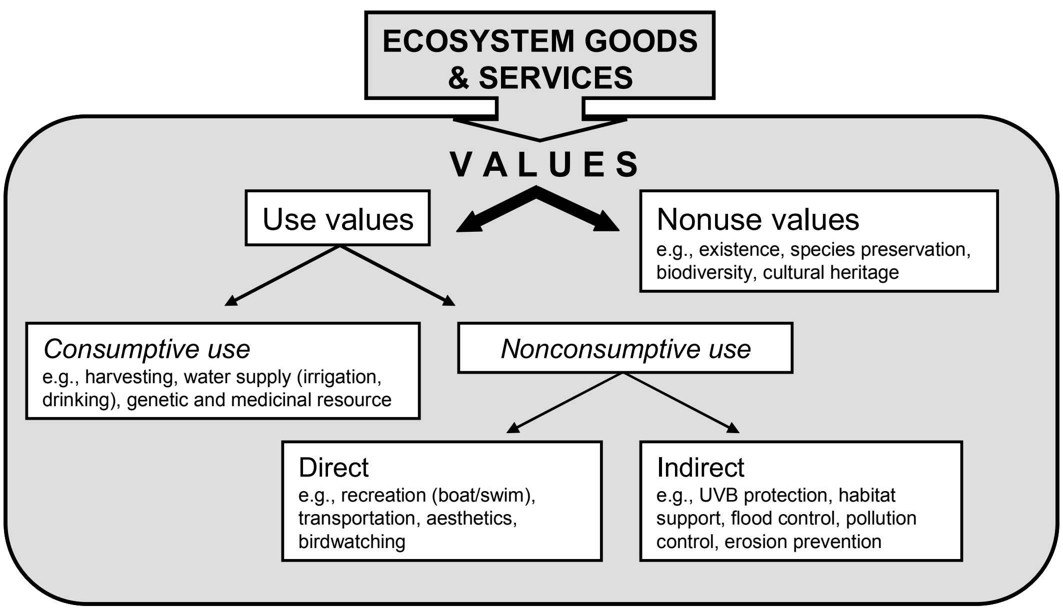


Figure 1. The figure shows the multiple types of values from ecosystem goods and services that are considered within a total economic valuation (TEV) framework.

of them include both “use” and “nonuse” values. For example, an oil spill on a popular beach that prevents people from using it represents lost use value. Alternatively, if the oil spill did not disrupt beach use, but damaged plant and animal life offshore, this would represent a lost nonuse value. Use values can be further divided into consumptive uses (goods, water supply) and nonconsumptive uses (recreation, habitat support, flood control).

- **Willingness to Pay and Willingness to Accept:** If the quality of a freshwater lake were improved to enhance sportfishing, the economic measure of the value of such an improvement to a recreational angler would be measured by his *willingness to pay* for such a change. If however the quality of a lake was worsened from its current level, then the economic measure to a recreational angler would be his *willingness to accept* compensation for the damage, or the minimum amount of money the angler would accept as compensation.

Quantify Ecological Impacts

How can a dollar amount be applied to ecosystem changes? There are several economic methods that can be used to place a value on ecosystem services (see Box 2). These methods base values on various aspects of consumer and producer behaviors, and draw on stated or revealed individual preferences.

In the Great Lakes, policymakers conducted a complex analysis to decide whether and how to control the sea lamprey, an invasive species that preys on the native lake trout, sturgeon, salmon, and other large fish. One study polled 2,000 Michigan anglers to estimate the value to them of a higher catch rate at various fishing sites, taking into consideration distance and travel costs to those sites. The study showed that even a 10% increased catch rate would have a value of about $3.3 million to fisherman. This value was compared against the cost of various methods to control the sea lampreys, for example using a lampricide treatment, so that an appropriate decision could be made.

Specific attention should be paid to pursuing research at the “cutting edge” of the valuation field to support this type of analysis. Because they are time consuming, project-specific valuations have sometimes been replaced by the benefits transfer method, which assesses value based on an existing study of a similar ecosystem. However, benefit transfer methods should be considered second best to careful analysis of the specific ecosystem in question.

Incorporating Judgment and Uncertainty

Perhaps the most important choice in any ecosystem valuation study is how the initial question is framed. In the Catskills/Delaware watershed, policymakers made the critical decision early on that it was not necessary to value all the services of the watershed, but instead to focus only on water quality. Other judgments may be necessary in framing an issue, for example the choice between using the

Box 2. Assigning a Dollar Value: Nonmarket Valuation Methods

Following are some of the most common methods that are used to measure the economic value of ecosystems services.

Household Production Function Methods model consumer behavior based on the assumption that ecosystem services can be substitutes for or complementary to a marketed commodity. Travel-cost models infer the value of an ecosystem according to the travel time and costs needed to visit it. Averting behavior models quantify what people would spend to avoid a negative impact on health, for example installing a filter if water quality is poor. Hedonic methods analyze how characteristics, including environmental quality, alter how much people would pay for something.

Production Function Methods model the behavior of producers and their response to changes in environmental quality that influence production. These methods have been applied to explore the habitat-fishery, water quality-fishery linkages, and erosion control and storm protection.

Stated-Preference Methods are commonly used to measure the value people place on a particular environmental item. Examples include how much people would pay annually to obtain swimmable, fishable, and drinkable freshwater, or to protect

Pooling Revealed- and Stated-Preference Methods uses combined data from different valuation methods to estimate a single model of preferences.

Benefit Transfer Methods estimate the value an ecosystem based on existing studies of a roughly similar ecosystem.

concept of willingness to pay or willingness to accept in an analysis.

Uncertainty can arise at many steps in an analysis. For ecosystem valuation, one of the biggest sources of uncertainty is the lack of probabilistic information about the likely magnitudes of some variables. Other sources of uncertainty arise from models or parameters used. Economic factors can introduce uncertainty as well. For example, how does the degree of visible cleanliness or the degree of development and crowding affect the value of a popular recreational watersite?

Although uncertainty and judgment are inevitable, they are not debilitating to ecosystem valuation and do not undermine the validity of the analysis. It is only necessary to provide a clear explanation of how judgments were made and how uncertainties were accounted for.

Overarching Recommendations

When faced with environmental policy decisions that seek to balance human activity and conservation, the process of valuing ecosystem services can inform the policy debate and lead to better decision-making. The report makes the following recommendations for how policymakers should conduct ecosystem valuations:

- Seek to evaluate trade-offs: where possible, value should be measured in a way that makes analysis of trade-offs possible. If the benefits and costs of an environmental policy are evaluated, then the benefits and costs associated with the changes in an ecosystem service must be evaluated as well.
- Frame the valuation appropriately: Measure changes in ecosystem services, rather than the value of an entire ecosystem.
- Delineate all sources of value from the ecosystem and determine whether they are captured in the valuation.
- Quantify ecological impacts where possible beyond a simple listing and qualitative description of affected ecosystem services.
- Make sure that economic and ecological models are appropriately linked. The output from ecological modeling must be in a form that can be used as an input to economic analysis.
- Seek to value the goods and services most important to a particular policy decision.
- Base economic valuation of ecosystem changes on the total economic value framework. Include both use and nonuse values.
- Consider all relevant impacts and stakeholders in the scope of the valuation.
- Scrutinize any extrapolations made across space (from one ecosystem to another), time (from present to future impacts), and scale (from small to large changes) to avoid extrapolation errors.

Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems: Geoffrey M. Heal (Chair), Columbia University, New York; **Edward B. Barbier**, University of Wyoming, Laramie; **Kevin J. Boyle**, University of Maine, Orono; **Alan P. Covich**, University of Georgia, Athens; **Steven P. Gloss**, Grand Canyon Monitoring and Research Center, U.S. Geological Survey, Flagstaff, Arizona; **Carlton H. Hershner**, Virginia Institute of Marine Science, Gloucester Point; **John P. Hoehn**, Michigan State University, East Lansing; **Catherine M. Pringle**, University of Georgia, Athens; **Stephen Polasky**, University of Minnesota, St. Paul; **Kathleen Segerson**, University of Connecticut, Storrs; **Kristin Shrader-Frechette**, University of Notre Dame, Notre Dame, Indiana; **Mark C. Gibson** (Study Director) and **Ellen A. De Guzman** (Research Associate), Water Science and Technology Board.

This brief was prepared by the National Research Council based on the committee's report. For more information, contact the Water Sciences and Technology Board at 202-334-3422. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making* is available from the National Academies Press, 500 Fifth Street, NW, Washington, DC 20001; 800-624-6242 or 202-334-3313 (in the Washington area); www.nap.edu.

Summary of the Q&A Discussion Following Session I

Bob Leeworthy (NOAA)
Classifying what he had to say as more of a comment than a question, Dr. Leeworthy stated that "in leading many exercises in NOAA in actual management policy applications," he and his colleagues have found that in their dealings with communities, if they don't address "market economic impacts on local sales, income, and employment," they are "shown the door" and are "considered to be irrelevant." He said that he thinks economists need to be careful not to focus just on the net economic values "that we as economists all agree to, but which everyone else would think are irrelevant."

Mark Gibson (National Academy of Sciences)
Mr. Gibson responded that the committee at first was trying to get . . . the economists, and ecologists and the environmental philosopher "on the same sheet of music." Further, he explained that what was presented was "a very short, quick snapshot of the work" and he hoped that a closer inspection of the report would yield more information relevant to the work being done by Dr. Leeworthy and his colleagues at NOAA.

Ann Watkins (U.S. EPA, Office of Air and Radiation)
Addressing her question specifically to Angela Nugent but opening it to other comments, as well, Ms. Watkins said, "I noticed that you mentioned GPRA (the Government Performance and Results Act) as one of the things that you have considered as you looked at the questions that we have to answer, and you also looked at PART" (the Program Assessment Rating Tool), both of which are components of OMB's (Office of Management and Budget) analysis of our different programs. She said that she knew of "several programs [that] have been zeroed out because they can't provide a measure of value that is sufficient for OMB's standards under this PART analysis."

Angela Nugent (U.S. EPA, Science Advisory Board Staff Office)
Dr. Nugent responded that "the GPRA piece is yet to be done by the committee, but it's part of the grand plan." She went on to explain that "as we design our survey of what the Agency is struggling with, I think a necessary part of that is dealing with this program assessment review tool of OMB and seeing how it has been applied to programs whose primary thrust is eco-protection and how the Agency can actually strengthen its science base to make that case." She went on to assert that certain groups within EPA have already begun developmental programs to "strengthen the science" or identify how it can be strengthened. Stating that "all these things that we are now treating as separate threads obviously need to be woven together," Dr. Nugent identified the "ultimate revision of the steering committee" as a "move to a situation where all of these kinds of analyses, regional, national, park level . . . would support each other."

Ed Bender (U.S. EPA, Office of the Administrator)
Dr. Bender opened by stating, "It's very important to value things, because we don't protect them unless we value them." He continued, "However, in ecological risk assessment, one of the fundamental gaps is that *most* of the assessment endpoints deal with individual species—not really with what ecology is about." Dr. Bender wondered if any of the panelists "had noticed that kind of problem and had any thoughts about how economists might be able to help us look at the more complex and higher order interactions that I know you're *trying* to look at as you look at ecosystem goods and services."

Mark Gibson
Mr. Gibson said he would love to have a committee member help address that comment, and began by saying, "There are key studies, I believe in Chapter 4, that talked about invasive species and trying to evaluate . . ."

Ed Bender
(interrupting) "They're an organism. I'm talking about the interaction of organisms with each other as well as with their environment, or habitat loss, or some of the other things that we say are so important, yet we don't really have much information—those are not really addressed in ecological risk assessments."

Geoffrey Heal (Columbia University)
Identifying himself as the Committee Chair, Dr. Heal stated, "I'm not certain that we really address exactly the issue you're dealing with, but what we've done in the report is to look at the valuation of ecosystem services—those services that come from the operation of the ecosystem as a whole, and it relates to the services provided by the ecosystem to the existing structure, for instance the physical and chemical . . . and certain regulatory functions. To the extent that relationships between individual species or the existence of particular species affects the services or improves the services that come out of an ecosystem, then I guess the result you could lay out can, in some instances, attach value to the existence or the interaction between the individual species. It's not the task of the report, really, but whether we construe this, it will place a value on a particular species, other than maybe its charismatic value, because that's a non-use value. But to the extent that species don't obviously have a straight existence value because of their charismatic characteristics, I don't think we really address the issue how you would value individual species. I guess the perspective we would take is that species are part of what makes an ecosystem function, and if you would pull a species out of an ecosystem—particularly pull a keystone species out of an ecosystem, for example—the services provided by the system can collapse. So, there's the *implicit* value in the species because of that.

Nicole Owens (U.S. EPA, NCEE)
Dr. Owens offered "one quick response to that: One of the things we talk about in the strategic plan is how they can use that kind of information to communicate functioning of ecosystems to the public, and also use that to address uncertainty and how you might describe how uncertain some of our estimates of the changes in ecosystems might be to

the public. She added, “That should come in handy whether you’re developing either surveys or focus groups—to use that information you may have on one species to try and convey to the public something about the functioning of the whole ecosystem.”

Al McGartland (U.S. EPA, NCEE)
“I have some advice for Dr. Leeworthy: At EPA sometimes we can shame the decision-makers into listening about benefits—after all, decision-makers should be interested in improving the welfare of society. I often refer back to the GDP accounts—a lot of the welfare improvements that come from environmental improvements don’t get captured in the GDP accounts, and that’s actually, I think, a good hook into benefit analysis.”

“My question really is that I struggle with benefits and ecosystem stuff—it seems this whole spatial dimension is a big problem: ecologists like to do these very localized things, and of course national regulations require national benefits. I ask the panel and Geoff and maybe others later to address the question: Is that a show-stopper or is there hope on the horizon for dealing with that?”

Mark Gibson
Mr. Gibson’s general response was that the issue is, in fact, a concern of ecologists and it is addressed in his Chapter 3, along with “focused conclusions and recommendations in that regard.” He concluded by saying he would not characterize it as a “show-stopper” but that it was a difficult issue for the committee to tackle and they went as far as they could in developing conclusions and recommendations to that effect.

Liz Strange (Stratus Consulting, Inc.)
In response to Dr. Bender’s question, Dr. Strange stated that she and her colleagues did some work in the last few years where they looked “specifically at the eco-risk assessment framework at EPA and tried to think in terms of ecosystem services, the goods and services provided by ecosystems, as potential assessment endpoints.” She went on to say the she thinks “that’s one of the ways to get at what you’re talking about because, of course, those goods and services depend upon ecological structures and functions—in some cases depend on individual species or communities.” Dr. Strange said she believes that on the Global Change Research Program website there is a copy of that framework, which “essentially was integrating the eco-risk framework of EPA with the natural resource damage assessment approach that focuses on ecological . . . services.”

As an example of “another attempt to try and get at those things and integrate those things,” Dr. Strange also mentioned that she previously worked with one of the members of Mr. Gibson’s committee, Al Kovitch, on “an EPA/NSF-funded project looking at ecological integrity and what are some of the endpoints that you can use to present to the public information about what we mean by *ecological health* or *ecosystem services*.” She closed by adding that “there was an evaluation study associated with that research.”

Angela Nugent
Dr. Nugent referred back to the question about spatial scales and said that the issue came up when they did an example exercise on the CAFO (Concentrated Animal Feeding Operations) analysis. She said some folks on the committee were strong proponents of "having case studies be part of the benefits assessment supporting the rule, either as stand-alone case studies or something that could be used to test and validate the national model . . ." Dr. Nugent continued by saying that there is a general sense, especially at the region level, that "there's a tremendous opportunity there to build on this local experience, and maybe there are some leads on the empirical side that will help us answer the question you asked." She said she thinks people on the SAB Committee are going to look more in depth at this question of spatial scale—and also temporal scale, the duration of a study and what assumptions are made about change over time.

END OF SESSION I Q&A

Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

PROCEEDINGS OF

SESSION II: CLEANING OUR COASTAL WATERS: EXAMINATIONS OF THE BENEFITS OF IMPROVED WATER QUALITY

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

October 26-27, 2004
Wyndham Washington Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Cynthia Morgan and the Project Officer, Ronald Wiley, for their guidance and assistance throughout this project.

DISCLAIMER

TABLE OF CONTENTS

Session II: Cleaning Our Coastal Waters: Examinations of the Benefits of Improved Water Quality

Draft Document: Do Not Quote, Cite or Distribute

The Value of Improvements to California's Coastal Waters: Results from a Stated-Preference Survey

by

Nicole Owens and Nathalie B. Simon
National Center for Environmental Economics
United States Environmental Protection Agency

October 2004

The Value of Improvements to California's Coastal Waters: Results from a Stated-Preference Survey

Nicole Owens and Nathalie B. Simon[1]
National Center for Environmental Economics
United States Environmental Protection Agency

I. Introduction

The United States Environmental Protection Agency's (EPA) Office of Water is responsible for regulating and monitoring national water quality. In order to make sound policy decisions, policy makers need information on the benefits, costs, and other effects of alternative options for addressing environmental problems. In the case of policies affecting water quality, estimates of the public's willingness to pay for improvements in fresh water quality generally begin with estimates provided by Mitchell and Carson (1993). This study, however, does not address salt water areas.

The coasts and estuaries comprise a substantial part of our national resource base; these coastal areas are depended upon for the aesthetic, economic, ecosystem, and recreational services they provide. For example, gross annual income from coastal commercial fisheries is close to $2 billion (1998$). However, coastal areas are also the most highly developed and populated areas in the nation. This narrow fringe–comprising 17% of the contiguous U.S. land area–is home to more than 53% of the nation's population. Further, this coastal population is increasing by 3,600 people per day, giving a projected total increase of 27 million people between now and 2015 (NOAA, 1998).

As coastal population has increased, the environmental quality of some of these areas has declined or is threatened. Serious water pollution problems persist and, as such, many future water policies will likely focus on coastal areas. The lack of estimates of the benefits of improvements to these areas makes designing effective policies particularly difficult.

The purpose of this study is to estimate willingness to pay for water quality improvements in California's coastal waters. Currently, States, tribes, and other jurisdictions measure water quality by determining if water bodies are clean enough to support basic uses, such as swimming, fishing, and aquatic life support. Thus, this study will estimate willingness

---

[1]Prior to her death in 2000, Elizabeth McClelland was heavily involved in the project. The authors also wish to thank Kevin Boyle, Don Dillman, George Parsons, and V. Kerry Smith for their reviews of various drafts of the survey.

to pay for improvements coinciding with these uses.[2] The remainder of the paper provides some information on EPA's valuation of water quality improvements, detailed descriptions of the survey development process, information on the final version of the survey, a discussion of the supporting theoretical model, as well as preliminary results.

II. Valuing Changes in Water Quality

Up to this point, changes in surface water quality have been valued using a Mitchell and Carson (1993) study carried out in 1983. Mitchell and Carson determined respondents' willingness to pay to improve water quality from boatable (the lowest rung on the heirarchical water quality ladder developed by Resources For the Future) to fishable (sport fishing only, no concern about consumability); and from fishable to swimable.[3] The water quality ladder defined these uses in terms of conventional pollutants (dissolved oxygen, BOD, TSS, etc.). However, this study is not appropriate for valuing changes in coastal water for a number of reasons. First, these values were obtained for inland fresh waters only and cannot be used to value coastal water quality improvements. Second, toxic substances and nutrients were excluded from the study since the water quality ladder only concerns conventional pollutants.

In addition, the water quality ladder is now an out-of-date conceptual framework. EPA provides water quality information in The National Water Quality Inventory Report to Congress (305(b) report). These documents provide information on the Nation's water quality, identifies widespread water quality problems of national significance, and describes various programs implemented to restore and protect our waters. The 305(b) Report's use designations are now more complex. Not only do they deal with issues concerning the consumability of fish and shell-fish (often constrained by toxic substances), they also deal with the health of aquatic environments (affected not only by conventional pollutants but also by toxics and nutrients). This increase in complexity obviates the use of a hierarchical ladder because different uses are affected by different combinations and concentrations of the three main types of contaminants in a non-hierarchical manner. Some contaminants affect some uses while others affect other uses. For example, the presence of pathogens, a conventional pollutant, in water restricts swimming and shellfish consumption, but would have little or no effect on the health of the aquatic

---

[2]Although we will ultimately hope to develop specialized surveys that elicit residents' willingness to pay for improvements for each of the uses in each coastal state and one survey that elicits inland residents willingness to pay for improvements in coastal waters, this paper describes the development of only one of the state specific versions, California. The combination of these surveys will provide us with coastal residents' willingness to pay to improve home-state coastal water and inland residents willingness to pay to improve coastal water. We will not capture coastal residents' willingness to pay to improve out-of-state coastal water. These values may be elicited through another but similar project.

[3]EPA has also funded a freshwater quality valuation survey. The survey, developed under the lead of Kip Viscusi, received final clearance from the Office of Management and Budget in 2004.

environment.

Additionally, the National Water Pollution Control Assessment Model, under development by Research Triangle Institute for EPA, determines the number of river and shoreline miles, and estuary and lake square miles, that would meet the various use designations given different concentrations of contaminants. This model is expected to evaluate the prospective changes in water coastal quality that would be brought about by different regulations or other initiatives. Our survey has been developed to provide meaningful estimates of the value of improvements to coastal waters, given the structure of the model; hence, water quality improvements are described in percentage terms and separate values are obtained for each use.

III. Development of Survey Instrument

The survey instrument was developed over the course of two years through a series of focus groups and protocol interviews primarily conducted in coastal states. The instrument has also evolved dramatically as a result of feedback received from a peer review panel consisting of Kevin Boyle, Don Dillman, George Parsons, and V. Kerry Smith.

Six initial focus groups were held in four areas of the country - Edison, NJ (1); Santa Monica, CA (2); Washington, DC area (2) and one in a completely non-coastal environment (St. Louis, MO). The first focus group was held in Edison, followed by those in Saint Louis, Santa Monica, and Washington, DC respectively. These focus groups were held primarily to learn what qualities the public values in coastal water, whether or not respondents are familiar with certain terms, and to test early versions of descriptive text and valuation questions.

A. Initial Design

During initial phases of the project, it was thought that the survey would have multiple sets of valuation questions, treating coastal water and estuarine water separately. Hence, one important purpose of the first two focus groups was to gauge participant's familiarity with the term "estuary." Discussions pertaining to coastal water concentrated on participants' uses and experiences and, as expected, participants had no difficulty answering questions concerning coastal water. When the discussion focused on estuarine waters, however, it became readily apparent that participants had little understanding of the term and that the survey would need to provide respondents with some background information on this topic. Specifically, participants in the first focus group were generally unfamiliar with the term. Only one participant knew that an estuary is an area of transition between fresh and salt water. Similarly, none of the participants in the second focus group could define the term "estuary" and very few had heard of the term. During these groups, a more detailed explanation of estuaries, their uses and locations was given to participants by the facilitator. After these explanations were provided, participants noted that they were familiar with and/or had visited several estuaries including Tampa Bay, Chesapeake Bay, and Puget Sound. Many participants correctly noted that there is no "bright line" between coastal water and estuarine water and it is virtually impossible to improve one type of water without improving the other. Hence, later versions of the survey combine the two types of water and discuss them at the same time.

B. Early Survey Draft

The first draft of the questionnaire was written in March 2000. Appendix 1 contains portions of this initial survey. This draft questionnaire was structured in four parts: introduction, willingness to pay for water quality improvements, use descriptions and allocation, and demographic questions. We intended to distribute this questionnaire to a nationally representative sample using a phone-mail-phone administration mode. We planned to develop two versions of this questionnaire -- one for coastal states and one for inland states -- to elicit willingness to pay values for national coastal water improvements. An allocation question would allow us to attribute values for different uses.

The introduction began with a warm-up question asking respondents to select the three most important environmental problems in their state from a list. This was followed by a definition of coastal waters and descriptions of estuaries and near-shore waters, giving features, natural uses, recreational uses, commercial uses and examples. Each description was then followed by several questions designed to elicit the respondent's familiarity with each water type.

The second section of the questionnaire began with a second ranking question in which respondents were asked to select the three most important *coastal* environmental problems in their home state. A description of water quality in the United States followed, including a brief explanation of the government's rating system and the largest sources of coastal water pollution. Water quality was described as "good" if the water supports each of three uses: swimming, production of fish and shellfish safe for consumption, and diversity of aquatic life. The questionnaire then provided the number of miles of shoreline and the area classified as estuaries in the U.S., together with the percentage of total coastal waters classified as "good" and "not good". The three sources of coastal water pollution were identified as agriculture, industries, and households and short lists of examples of the types of pollution contributed by each source were given (e.g., runoff of crop fertilizers and pesticides for agriculture and runoff of lawn fertilizers and pesticides for households).

A coastal water improvement program was then introduced preceded by a brief statement indicating that if nothing is done conditions can at best be expected to remain the same but may worsen due to increases in population. The program was described in rather vague terms but was couched as being led by "agencies in charge of coastal water quality, fish and wildlife." The program would clean up half of the "not good" areas so that only 20% remain categorized as such. A broad list of possible clean-up efforts that could be included as part of the program were provided, including activities such as removing sources of pollution, planting water-side vegetation to absorb run-off, etc. This program description was then followed by a single referendum question in which respondents were asked to state whether or not they would vote for or against the program if it costs their household $X per month in the form of increased federal taxes.

The third section of the questionnaire zeroed in on the three uses and attempted to elicit the respondent's preferences across the three uses. A description of each of the three uses and the hazards of using coastal waters classified as not supporting each particular use followed. The necessity for different types of clean-up efforts to remedy problems affecting each of the three uses was then explained in an attempt to educate respondents to the fact that, in some sense, clean-up efforts are separable across the three uses. An allocation question in which respondents were asked to allocate each dollar spent on coastal water clean-up across the three uses rounds out the third section of the questionnaire. Our thought was that this question would ultimately be used to attribute values for coastal water improvements by use.

The fourth and final section of the questionnaire contains standard demographic questions and questions regarding the respondent's recreational activities.

C. Protocol Interviews

Several versions of the draft questionnaire were tested through a series of four sets of protocol interviews in coastal states on the east coast - Tampa, Portland (Maine), Baltimore, and Richmond. In each location, at least two versions of the survey instrument were tested in 18 completed interviews. Respondents were provided with a copy of a survey and asked to complete it to the best of their ability. Once the respondent completed the paper version of the questionnaire, an interviewer went through the questionnaire with the respondent to discuss his/her responses and thoughts regarding the questions.

Experience in Tampa, Florida

The protocol interviews held in Tampa marked the first time potential respondents reviewed the survey instruments. For this occasion, we developed two versions of the survey instrument with the most marked changes occurring in the willingness to pay scenario and the description of the clean-up efforts by use. One version established a permanent increase in monthly federal taxes to pay for the proposed coastal water improvement program. The other described the increase in monthly taxes as occurring over a five-year period and provided much more detail (including examples) of how and why improving coastal waters for each use would require different clean-up efforts.

Reactions to the survey instrument were varied. While some respondents found the survey interesting, others found it tedious and difficult to follow. It was apparent after reviewing all of the comments that many changes needed to be made. In addition to numerous simplifying wording changes, we identified areas requiring major revision.

A flaw in the survey concerned the description of coastal water uses and the allocation question. A number of participants were confused by the allocation exercise and failed to complete it properly. Those participants that understood the exercise, in general, summarily rejected the separability of clean-up efforts, believing instead that by allocating more funds to creating a diverse aquatic environment, they would ultimately be improving coastal water conditions for swimming and production of fish and shellfish safe for human consumption as well. Our attempts at providing convincing information to the contrary failed. Those respondents who received the version with the additional information still felt that they would get "more bang for their buck" if they allocated the entire sum to creating a diverse aquatic environment, even though they purportedly read and understood the additional paragraphs.

Experience in Portland, Maine

Armed with the feedback from Tampa, we revised our survey instruments substantially. We dramatically changed the formatting of the survey, making it more "user friendly." Complicated skip patterns were replaced with arrows and new headings were introduced to help set the questions apart from the information presented. While these changes certainly made the survey instrument more visually appealing, the more important changes were to the willingness to pay scenario and the allocation question.

After much discussion, we decided to abandon the referendum style question devised for the Tampa interviews and substantially revise the allocation question. While we felt it was still important to obtain values for coastal water improvements by use, we decided to attempt to elicit these values directly rather than through the allocation question. This change would require reordering the information presented in the questionnaire so that a discussion of the various uses preceded the willingness to pay questions. In order to convince respondents of the contribution of households to the degradation of coastal waters, we added the following statement:

> Much of the pollution affecting estuaries and near-shore waters is caused by the every day living habits of the American people. Although the amount each household adds to the problem of coastal water pollution may seem small, **together** residential communities have a **large negative impact** on coastal water quality.

We also decided that we should attempt to obtain values for local improvements, compared to national improvements, for each use in coastal states. Rather than provide respondents with general information regarding the condition of coastal waters in the U.S., we revised the background information preceding our scenario to include a table showing the percent of coastal waters as well as the number of miles of coastal waters that were rated as good for each of the three uses. We then replaced our referendum style question with a series of three scenarios, each describing a program that would improve coastal waters for a particular use. Each scenario was accompanied by a table showing the current coastal water conditions by use and the expected improvement brought about by the program in question. The row containing the use for which conditions would be improved was shaded to draw attention to the change. A double-bounded dichotomous choice question eliciting the respondent's willingness to pay for the improvement through an increase in income taxes rounded out the scenario.

Since this new version of the survey instrument would allow the estimation of willingness to pay values for percent changes in coastal water improvements by use, we no longer needed to rely on the allocation question to obtain these values. Still, we decided to include a different allocation question for use in coastal states to elicit respondents' preferences for local versus national coastal water improvement programs. For respondents in these states living within 100 miles of coastal waters, we devised a question in which respondents would be asked to allocate funds for improving each of the three uses across local (affecting coastal conditions within 100 miles of their home) and national programs.

We developed two basic versions of the new questionnaire for testing in Portland, Maine. The most marked difference in the two versions was the inclusion of a willingness to pay question in one version in which the program improved coastal water for all three uses.

The reactions to our two survey instruments from the participants in Portland were encouraging. The respondents reacted positively to our new layout and simplified wording, reporting generally that the questions were easy to read and understand. In addition, respondents were much more willing to accept that households were large contributors (if not the largest contributors) to the degradation of the coastal environment.

The feedback on our new willingness to pay questions was equally positive. Respondents found the table format outlining the “before” and “after”conditions easy to follow and comprehend. Even those respondents who admitted that they did not believe it was possible to improve conditions for only one use without affecting conditions for all three uses reported to focus on the highlighted use when answering the willingness to pay questions.

The allocation question continued to be a problem for some respondents. While several respondents did not understand the allocation exercise at all, failing to perform any allocation whatsoever, others were not certain whether they were to allocate funds across national and local programs for each use or allocate funds across uses separately for national programs and then local programs.

Experience in Richmond, Virginia

In spite of the progress we made in the versions tested in Portland, Maine, we came away with three major concerns. First, we were concerned that respondents were not considering the magnitude of the improvements in the willingness to pay questions but rather were focusing simply on the use that was being affected by the program. While we were not prepared to abandon the question format yet, we knew we needed to test the willingness to pay questions more carefully in the next round of protocol interviews. Second, we were concerned that respondents in coastal states were responding to the willingness to pay questions as if the programs were affecting local coastal water conditions rather than national coastal water conditions. This too would need closer scrutiny in the next round of interviews. Finally, we recognized that we needed to revise the allocation question if we hoped to get meaningful and useful responses. In addition to formatting changes, we realized that we would need to change our definition of “local.” We realized that respondents generally had difficulty discerning which coastal waters were within 100 miles of their homes and we recognized that it would be difficult for us to determine which households in our sample lived within 100 miles of coastal waters. We found in our discussions with respondents that it was easier for them to envision and discuss state coastal water conditions than those in a smaller area.

After considerable reflection, we decided to develop state-specific versions of the questionnaire that could be used to elicit willingness to pay values for improvements to state coastal waters. Although we realized that developing and administering separate state-specific versions of the questionnaire would considerably increase the costs of survey administration, we remained unconvinced that our allocation question could obtain equivalent "local" values. The state-specific versions of the questionnaire would be similar to the "national" version with the primary differences being that the scenarios would provide "before" and "after" conditions specific to a state and that no allocation question would be asked.

We also began to consider a more flexible mode of administration: the internet. Several survey firms currently offer the option of internet survey administration. These firms have recruited panels of potential respondents (in exchange for internet access) from which they are able to draw representative samples. This administration mode allows great potential for tailoring surveys to specific categories of respondents. As information about these survey firms spread, we became more and more intrigued with the idea of conducting a computer-based, internet survey as opposed to a mail survey. This survey mode would allow us greater flexibility in question presentation and would allow us to easily tailor survey instruments to particular states.

We developed and tested our first state-specific version of the survey instrument in Richmond, Virginia along side a national version of the survey instrument containing a number of formatting changes. Again, the survey instrument was met with generally positive feedback. Our fears regarding the focus on the use affected rather than on magnitude of the improvement in our willingness to pay questions was confirmed, however. Respondents reported not paying much attention to either the percent change or the number of miles affected by each program. Rather, they reported being concerned primarily with the use enjoying the improvement. The formatting changes to the allocation question in the national version of the questionnaire improved the performance of the question.

Experience in Baltimore, Maryland

Because our willingness to pay question continued to meet with difficulties, we decided to change our approach yet again. Rather than present a program that affects only one use and ask a double-bounded dichotomous choice question to elicit willingness to pay, we decided to employ a conjoint approach. We modified our survey instrument so that in each scenario we present the respondent with two programs, each affecting the percent of water considered "good" for each use by a different amount. The effects of the two programs and the monthly costs to the household for each are shown in a table accompanying each scenario. The respondent is then asked to choose between the two programs with the status quo (no program) also provided as an option. By varying the percent of miles affected by each program as well as the uses affected, we will arrive at a willingness to pay for a percent improvement for each use. Each respondent will be asked to answer four questions of this sort.

For our protocol interviews in Baltimore, Maryland, we again developed both a national and a state specific version of the questionnaire. The conjoint approach was used in both versions. In general, this approach met with great success. Respondents seemed to focus on all aspects of the program – the uses affected, the magnitude of the changes, baseline conditions, and cost – before answering.

D. Computerized Versions of the Survey

Following our protocol interviews in Baltimore, Maryland, we made minor wording changes to the survey and then began the process of having the our "pen and paper"survey computerized. The benefits of using this mode of administration are numerous. First, using a computerized format for the survey simplifies the process for respondents in that confusing skip patterns are eliminated. The respondent sees only those questions that pertain to him. Computerized surveys also create the potential for greater use of colorful and more meaningful graphics to enhance the survey. In addition, the threat of interviewer bias is eliminated. Finally, the administration time is significantly reduced in that completed interviews are automatically downloaded to a database, simplifying the data cleaning process and allowing quick turn-around.

We decided to have the pilot survey administered by Knowledge Networks, a California-based survey firm, to a random sample of approximately 600 California residents via WebTV. Knowledge Networks maintains a large, national panel of respondents recruited through a random process. Potential respondents are contacted by mail and provided introductory materials about the company, together with a small monetary incentive for reading the materials. Recipients are then contacted by phone and invited to enroll in the panel, along with other household members. Panel members are provided the WebTV hardware and a monthly subscription to the service which provides internet access. In exchange, respondents are asked to complete surveys via the internet on a regular basis. Knowledge Networks maintains that its panel is fairly representative of the population.[4]

Knowledge Networks has a sizable panel enrolled in California enabling us to conduct a pilot survey in that state in addition to a full scale survey should changes need to be made to the survey following the pilot. In order to test the computerized version fully, we decided to conduct protocol interviews with panel members. We began tailoring our state specific version to California, with the most dramatic changes to the survey taking place in four different areas. First, because Knowledge Networks collects a variety of demographic questions on a regular basis from panel members and makes this information available to its clients, we were able to dramatically shorten the demographic section of the survey. Second, our peer review panel suggested that we add questions from established national surveys in order to both gauge the representativeness of our sample and match our respondents with respondents to these larger surveys. In response to this suggestion, we added questions from the Panel Study of Income Dynamics and from the National Survey on Recreation and the Environment. Third, we added more detailed information on the quality of California's coastal waters and added more information on the quality of coastal water in other states. Fourth, many of the initial questions were re-ordered in order to improve the flow of the survey.

Once the survey was computerized, we conducted protocol interviews with approximately 16 of Knowledge Network's panel members. Each participant took the survey as

---

[4]More information about Knowledge Networks can be obtained from the company's website: www.knowledgenetworks.com.

though in their own home and then went through a detailed debriefing session. Respondents took approximately 30 minutes to complete the survey and most said it was quite interesting. It was clear that respondents were able to understand all of the information provided in the survey.

Minor changes were made to the survey as a result of the protocol interviews. These included eliminating an initial series of questions that asked respondents' opinions concerning a variety of state issues or problems. It was initially thought that this would be a good introductory question for respondents, but most found it difficult. This, along with the fact that it increased the length of the survey while not providing us with vital data, led us to remove this set of questions. Another area of the survey that needed improvement concerned the information provided about other coastal states as a comparison. Data included for North Carolina was found to be incorrect and many respondents noted that it was surprising that the water quality in North Carolina was so low. Further, we needed to adjust the placement of information for states that do not report water quality information to avoid confusion. Initially, the way in which we conveyed this information suggested that these states had no water rated as good.

IV. Description of Survey Instrument

The pilot survey took place in California using the survey instrument described in more detail below. The survey instrument is specific to the state of California and can be used to estimate willingness to pay for water quality improvements by three specific uses: swimming, production of fish and shellfish safe for human consumption, and support of diverse aquatic life.[5]

The California survey instrument is described in more detail below. In general, the questionnaire is comprised of four distinct parts: an introductory section, a section focusing specifically on California's coastal waters, a section containing the choice questions, and finally a section containing standard questions about labor market activity. A hard copy of the survey is provided in Appendix 2.

A. Part 1: Introduction

The first section of the survey provides respondents with a definition of coastal waters and a detailed description of their natural, commercial and recreational uses. Following a

[5]Once analysis of the pilot data is complete and we are convinced of the adequacy of the questionnaire, we hope to develop parallel versions of the survey instrument for the remaining 20 coastal states as well as a version for inland states. The coastal state versions of the survey will elicit resident's willingness to pay for coastal water improvements within the state. The inland version of the survey will elicit willingness to pay for coastal water improvements generally. While we will not be able to gauge willingness to pay of coastal state residents for improvements outside of their state of residence from the surveys we plan to develop, we anticipate that the information gathered from these surveys will provide potentially useful information for benefits analysis all the same.

welcome statement, and a general definition of coastal waters, the respondent is provided with use information in a simple table (see Figure 1). This table is followed by a map highlighting all of the coastal states in the 48 contiguous states in the U.S. (see Figure 2).

The respondents' familiarity with coastal waters is then gauged through a series of questions about recent trips to coastal waters and water recreation activities. For those respondents who report visiting coastal areas in the last 12 months, detailed information about the number of days participating in each of the activities is collected, including the number of days in California. A number of these questions are borrowed from the National Survey on Recreation, allowing direct comparison of results. Similar information is collected for freshwater recreation activities.

B. Part 2: California's Coastal Waters

This section delves into a respondent's familiarity with pollution sources as well as his perception of California's coastal water quality. In addition, it defines and describes the three use categories and the water quality rating system employed by the EPA.

This section begins by showing a map of California's coastline with various coastal water areas specifically indicated on the map (see Figure 3). Respondents are then asked about the location of their primary residence with respect to coastal waters and the location of other properties the household might own. Length of residence in California is also requested.

Respondents are then provided with a list of potential environmental problems that could affect coastal waters and are asked to rate the seriousness of each problem for the state of California on a scale from 1 to 5. Problems included in this list range from animal waste runoff, to discharges and overflows from sewage treatment plants, to beach erosion. The list of problems includes industrial, agricultural, and household sources of coastal water pollution and is provided to each respondent in a randomized fashion. Following the list of potential coastal water problems, respondents are asked to indicate which source (industry, agriculture or households) is the largest source of coastal water pollution in California in their view. They are also asked to report whether they believe coastal water quality has improved or not in the last five years.

The water quality rating system used by federal and state governments is then described to the respondents and information is given on the ratings California's coastal waters have received for the three defined uses of swimming, production of fish and shellfish that are safe for human consumption, and support of diverse aquatic life (including fish, shellfish, plants, mammals, birds, etc. that live near aquatic environments). Information on California's coastal waters is provided in pie charts, an example of which is shown in Figure 4. The information provided is taken directly from The National Water Quality Inventory Report to Congress (305(b) report).

Comparisons of California's water quality by use with that of other coastal states is provided in a series of three bar charts -- one for each use-- showing the ranking of states by water quality level. An example of the bar charts is shown in Figure 5.

The final question in this section asks respondents to indicate which of the three uses is the most important to them.

C. Part 3: Choice Questions

The third part of the questionnaire is comprised of the choice questions. Respondents are presented with a series of five questions in which they are asked to select between two programs to improve coastal water quality. In each choice set, respondents are also able to select the status quo, should they find neither of the two programs satisfactory. Each of the two programs has an associated household tax increase to cover the cost of implementation.

Information regarding water quality across three use definitions (swimming, production of fish and shellfish deemed safe for human consumption, and the support of diverse aquatic life) under each program, including the status quo, is provided in tabular format together with the cost to each household for each program. Color is used in the table to help respondents distinguish between the three alternatives. The programs differ, not only in the level of household tax, but the degree to which they improve water quality across the three use definitions. A sample question is provided in Figure 6.

The questions are structured in such a way as to facilitate comparison between the programs with at most two water quality attributes varying at different levels across the two new programs being introduced. In some instances, however, respondents are asked to choose between two programs that offer varying magnitudes of uniform changes across uses. Each of every respondent's five responses will be treated as a separate observation.

D. Part 4: Demographic Information

The fourth and final section of the survey is comprised of demographic questions. The series of demographic questions required in our survey instrument is curtailed due to the availability of this information from Knowledge Networks. As noted above, Knowledge Networks collects and routinely updates standard demographic information on each panel member and makes this available to its clients. In so doing, burden on the panel members is reduced and the length of the survey shortened.

V. Economic Model

In choice experiments such as ours, individuals are typically asked to choose from alternatives with varying attributes from a choice set. In making their selections, respondents weigh the importance of the different attributes and implicitly trade one characteristic for another, selecting the alternative that provides them with the greatest utility. The probability of choosing any specific alternative can then be modeled straightforwardly using standard random utility models. These types of models have been used to ascertain the value of beaches (Parsons et al. 2000), water quality in freshwater lakes (Needelman and Kealy, 1995; Bockstael, Hannemann and Kling, 1987), and woodland caribou habitat enhancement (Adamowicz et al., 1998).

A. Basic Model

Consider the following representation of an individual's utility associated with program *i*:

$$U_i = \beta x_i + \varepsilon_i \tag{1}$$

where x_i is a vector of explanatory variables, including program attributes, cost of the program and other individual characteristics. Effects of unobserved variables are captured by ε_i, a random term distributed as iid extreme value (weibull). A decision maker will choose program *i* from his choice set *J* if that alternative provides greater utility than the other two alternatives: $U_i > U_j$ for all $j \neq i$.

The probability that an individual chooses program *i* from set *J* is given by:

$$\Pr(i) = \frac{\exp(\beta x_i)}{\sum_{j \in J} \exp(\beta x_j)} \tag{2}$$

where the numerator is the exponential of the utility associated with program *i* and the denominator is the sum, over all programs in the choice set, of the exponential utility associated with each possible program. These probabilities are then entered in a standard likelihood function of the following form:

$$L = \prod_{n=1}^{N} \prod_{j=1}^{J} \Pr_{jn}^{\delta_{jn}} \tag{3}$$

where $\delta_{in} = 1$ (for $i \in J$) if individual *n* selects program *i* and =0 otherwise. Parameters are selected so as to maximize *L*.

One advantage of choice experiments such as ours relative to traditional contingent valuation is that they allow researchers to infer the value of the specific attributes in addition to situational changes. Random utility models do not allow direct estimation of the value of particular attributes; rather, the researcher must estimate the probability that a specific alternative will be selected and can then infer the value of the various characteristics using the estimation results. Once estimated, the model results can be used to estimate welfare changes associated with the improvement or decline of specific attributes.

Ultimately, we are interested in estimating the welfare changes associated with improvements in water quality for the three use definitions in California. The gain in consumer surplus associated with an improvement in the quality of water for swimming, for instance, can be calculated as the change in expected utility divided by the individual's marginal utility of income given by

$$W^s = \frac{\ln \sum_{i=1}^{J} \exp(X_i^* \beta) - \ln \sum_{i=1}^{J} \exp(X_i \beta)}{\beta_{tax}} \tag{4}$$

where β_{tax} is the marginal utility of income estimated in the logit model, X_i is the vector of water quality measures under the status quo, and X_i* is the vector of water quality with improved quality of waters for swimming.

VI. Data and Preliminary Results

The survey was fielded to 746 Knowledge Networks panel members in two waves, the first (a pretest) on June 4, 2004 and the second on July 1, 2004. Data collection continued through August 1, 2004. The pretest was fielded to 141 Knowledge Networks panel members. In late June, we examined respondents' answers to survey questions and in addition to precoding several open ended questions, determined that no changes needed to be made to the conjoint design in the survey instrument. We received 606 completes, yielding a completion rate of 81%. Table 1 contains descriptive statistics for the full dataset.

Table 1 Descriptive Statistics n=606				
Variable	Mean	Std Dev	Min	Max
Male	0.50	0.50	0	1
Age	43.16	15.54	18	96
Household size	2.66	1.41	1	10
Income	52681.00	40095	2500	187500
Black	0.05	0.22	0	1
Hispanic	0.28	0.45	0	1
Other minority	0.14	0.35	0	1
Children	0.30	0.46	0	1
Recreational swimmer in past 12 months	0.25	0.43	0	1
Recreational fisher in past 12 months	0.10	0.30	0	1
Recreational boater in past 12 months	0.16	0.37	0	1
Observed wildlife in past 12 moths	0.49	0.50	0	1
Eat seafood at least one time per month	0.60	0.49	0	1

Preliminary conditional logit model results are promising and consistent with expectations (Table 2). Regarding the choice specific attributes, as the cost associated with the programs increases, respondents are less likely to choose a program over status quo conditions. In addition, as the miles good for swimming, fishing, and aquatic life support associated with the programs presented to respondents increases, respondents are more likely to choose a program over the status quo. The interpretation of the remaining variables in the regression is slightly different as the variables represent individual specific attributes. As income increases respondents are more likely to move away from the status quo, males are more likely to choose the status quo. As age and household size increase, respondents are more likely to choose a program. Only three of the included participation variables are significant - recreational fishers and boaters, and those eating seafood are more likely to choose a program over the status quo.

As these results are extremely preliminary, we plan to continue exploring alternative models, to estimate elasticities of probabilities with respect to program cost, and to develop willingness to pay estimates for improvements in the percent of miles good for each of the three uses explored in the survey.

Table 2 Preliminary Model Results Conditional Logit n=606		
Variable	Estimate	T-Value
Cost	-0.008***	-8.93
Miles good for swimming	0.04***	4.54
Miles good for fishing	0.05***	5.53
Miles good for supporting aquatic life	0.11***	12.63
Male	0.23***	2.60
Age	0.01***	5.55
Household size	0.10***	3.22
Income	-3.04 10-6***	-2.73
Black	0.26	1.21
Hispanic	-0.09	-0.91
Other minority	0.20	1.50
Recreational swimmer in past 12 months	-0.18*	-1.63
Recreational fisher in past 12 months	-0.01	-0.04
Recreational boater in past 12 months	-0.22*	-1.63
Observed wildlife in past 12 moths	-0.8	-0.89
Eat seafood at least one time per month	-0.17*	-1.81
*** significant at 1% * significant at 10% Log Likelihood -2402		

Figure 1: Description of Coastal Waters

More Information on Coastal Waters:	
Coastal waters may have:	shallow waters, marshes, sandy beaches, mud and sand flats, rocky shores, oyster reefs, river deltas, tidal pools, sea grass beds and swamps.
Natural uses include:	food, shelter and breeding grounds for many fish, shellfish, mammals and shorebirds.
Recreational uses include:	boating, fishing, shell-fishing, swimming, snorkeling and bird-watching.
Commercial uses include:	ports and marinas supporting shipping and industrial uses; breeding grounds for some commercial fish and shellfish.
Examples of coastal waters are:	the water along Chesapeake Bay, Clearwater Beach (Florida), Ocean City (Maryland), Venice Beach (California), Galveston Bay, Puget Sound, San Francisco Bay, Tampa Bay and lots of smaller bays and inlets where freshwaters and saltwaters mix.

Continue

Figure 3 Map of California

Figure 2: Map showing states with coastal waters in the contiguous states in the U.S.

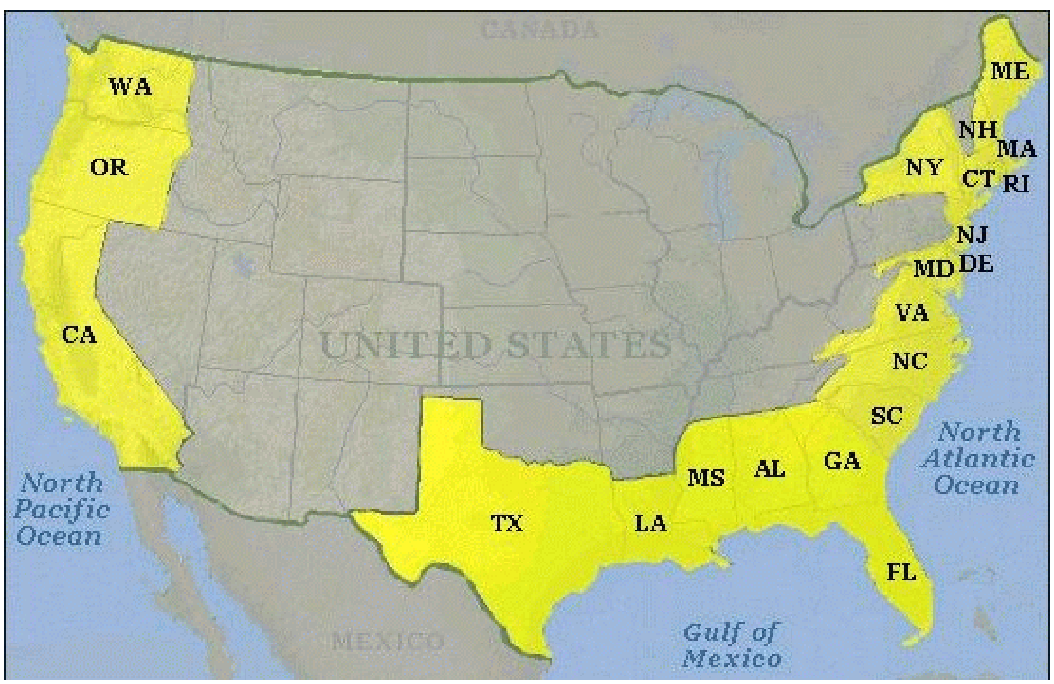
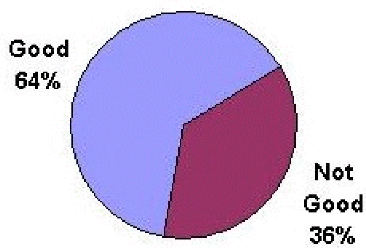


Figure 4: Sample Pie Chart Showing Coastal Water Quality of California Waters by Use



Production of fish and shellfish that are safe to eat

Figure 5:
Sample Bar Chart Comparing the Quality of California's Coastal Waters with Other Coastal States

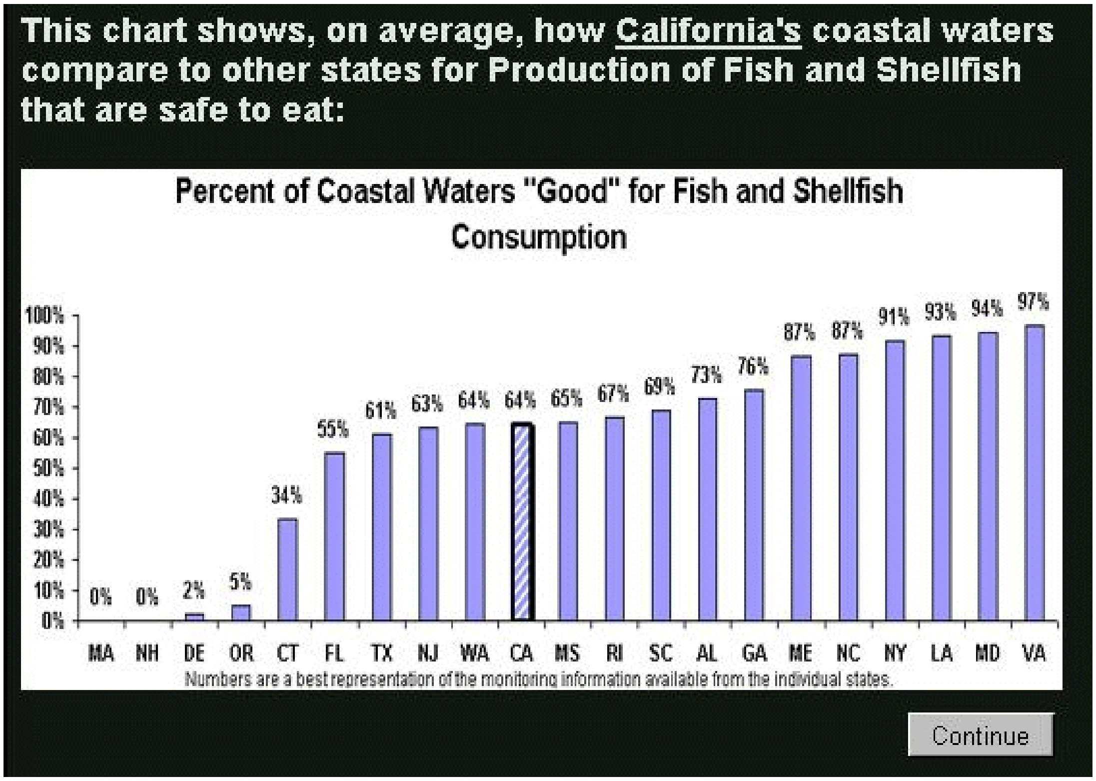


Figure 6: Sample Choice Question

	Your Three Choices and How They Would Affect the Quality of California's Coastal Waters Percent of California's Coastal Waters Rated as "Good"		
	Present Conditions	**Program 1 (Conditions after 3 years)**	**Program 2 (Conditions after 3 years)**
Swimming	42% of miles are good	5% gain to 47% good	0% gain to 42% good
Fish and shellfish safe for eating	64% of miles are good	5% gain to 69% good	0% gain to 64% good
Habitat to support a large number of different kinds of fish, birds, mammals and plants	52% of miles are good	5% gain to 57% good	0% gain to 52% good
Yearly Tax Change for your household (permanent tax)	No increase in taxes	Your taxes increase by $80 per year	Your taxes increase by $40 per year

Which one of the options listed in the table above would you choose?

Select one answer only

- Present Conditions: No change in your taxes, and the percent of coastal waters that is good for each purpose stays the same as it is now
- Program 1: Your taxes increase $80 per year to get the improvements shown under this program
- Program 2: Your taxes increase $40 per year to get the improvements shown under this program
- Don't know

References

Adamowicz, Wiktor, Peter Boxall, Michael Williams, and Jordan Louviere (1998), "Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation," *American Journal of Agricultural Economics*, 80(1):64-75.

Bockstael, Nancy E., W. Michael Hanemann, and Catherine L. Kling (1987), " Estimating the Value of Water Quality Improvements in a Recreational Demand Framework," *Water Resources Research*, 23(5): 951-960.

Mitchel, Robert and Richard Carson (1993), "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable and Swimmable Quality Water," *Water Resources Research*, 29.

National Oceanic and Atmospheric Administration (1998), "State of the Coast." http://state-of-coast.noaa.gov/

Needelman, Michael S., and Mary Jo Kealy (1995), "Recreational Swimming Benefits of New Hampshire Lake Water Quality Policies: An Application of a Repeated Discrete Choice Model," *Agricultural and Resource Economics Review,* April: 78-87.

Parsons, George R., D. Matthew Massey, Ted Tomasi (2000), "Familiar and Favorite Sites in a Random Utility Model of Beach Recreation," *Marine Resource Economics*, 14: 299-315.

Train, Kenneth E. (2000), "Mixed Logit Models for Recreation Demand," in *Valuing Recreation and the Environment*, Joseph A. Herriges and Catherine L. Kling (eds.). Edward Elgar: Northamptom, MA.

Appendix 1: Portions of Initial Draft

WATER QUALITY IN THE UNITED STATES

The government rates water as either ***good*** or ***not good***.

Water quality is ***good*** if the ocean shoreline or estuary

- is a safe place to swim,
- has fish and shellfish that are safe to eat, and
- supports many kinds of plants, fish, and other aquatic life.

Water quality is ***not good*** if the ocean shoreline or estuary

- is an unsafe place to swim due to pollution,
- has fish and shellfish that are unsafe to eat due to pollution, or
- supports only a small number of different kinds of plants, fish and other aquatic life.

Of our nation's more than 58,000 miles of ocean shoreline and 34,000 square miles of estuaries,

- 60 % are rated "good"
- 40% are rated"not good"

Much of the pollution affecting estuaries and near-shore waters is caused by the every day living habits of the American people. Some of the largest sources of pollution include:

Agriculture

- Runoff of crop fertilizers and pesticides
- Runoff of animal waste from fields and pastures
- Overflows from animal waste holding areas

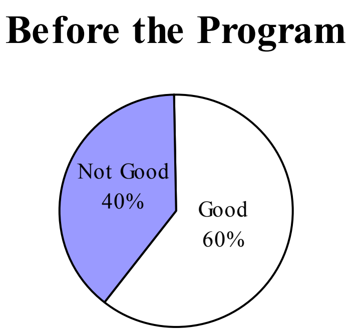
Industries

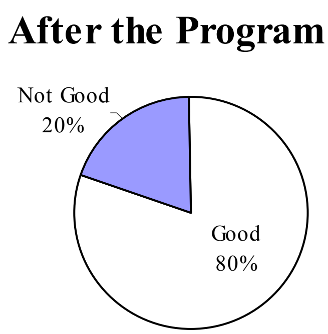
- Overflows from sewage treatment plants
- Discharges from industrial processes

Households

- Runoff of automobile grease and oil
- Runoff of lawn fertilizers and pesticides
- Overflows from septic systems
- Runoff of paints and chemicals
- Seepage of household waste from landfills

Existing fines on industry and taxes support current water quality levels, but in order to improve the quality of the water, additional funds are needed. If nothing more is done, conditions can, at best, be expected to remain the same but may worsen due to increased population.





Suppose a program were proposed where the agencies in charge of coastal water quality, fish, and wildlife were to clean half of the “not good” areas so that the percent “good” would be 80%.

The program would likely take three years before noticeable results could be seen.

Methods for clean-up depend upon the exact problem but would include things like:

- removing sources of pollution
- planting water-side vegetation to absorb run-off
- controlling runoff and seepage from areas with pollution
- protecting sensitive environmental areas.

5-1 Keeping in mind that your household would have less money each month to spend on other things, would you vote for or against the program if the cost to your household would be a permanent $100 per month in increased federal taxes (that is, $1200 per year). (Please check one.)

❒ For ❒ Against ❒ Don't know

5-2 What is the maximum you would be willing to pay per month for this program? __________

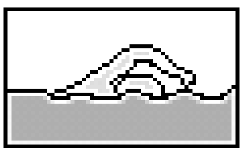
5-3 Please take a few minutes to tell us why you voted the way you did.

WAYS TO IMPROVE COASTAL WATER

For those areas of the coast where the water quality is "not good," the clean-up efforts in the program we talked about above will depend upon the type of water quality problem that exists, and the importance that persons like yourself place on various uses.

For those areas of the coast that have water that is "not good," there are 3 specific ways that our coastal waters could be improved:

- Making water swimmable,
- Making fish and shellfish safe to eat,
- Creating a diverse environment.



Making coastal water swimmable

Making coastal water swimmable means getting rid of the types of pollutants that can make people sick when they go swimming. Sometimes direct contact with the polluted water can cause illnesses such as stomach illnesses, earaches or infections.

6-1 Have you ever heard of coastal beaches being closed to swimmers because of polluted waters? (Please check one.)

❒ Yes ❒ No ❒ Don't know

If **no** or **don't know**, please skip question 6-2. If **yes**, please answer question 6-2.

6-2 Has a beach you were visiting ever been closed to swimmers because of polluted waters? (Please check one.)

❒ Yes ❒ No ❒ Don't know

Making fish and shellfish safe to eat

Making fish and shellfish safe to eat means getting rid of the types of pollutants that build up in the bodies of some fish and shellfish that can make people sick in the short and long run. Eating raw, contaminated fish or shellfish can cause stomach illnesses. Eating large amounts of contaminated fish or shellfish over a long period of time (even when cooked) can cause other long-term serious health problems such as cancer and liver disease.

6-3   Have you ever heard about fish advisories that limit the amount of coastal fish or shellfish that should be eaten because of polluted waters? (Please check one.)

❒ Yes ❒ No ❒ Don't know

6-4   Have you ever limited the amount of coastal fish or shellfish you've eaten or refrained from eating coastal fish or shellfish as a result of a fish advisory issued because of polluted waters? (Please check one.)

❒ Yes ❒ No ❒ Don't know

Creating a diverse environment in the water

Creating a diverse environment means getting rid of the types of pollutants that keep many plants, fish, and other life from living in water. Although some fish and plants can live in polluted waters, cleaning up the waters will allow a greater number of different types of fish and aquatic life to thrive.

6-5   Have you ever been to an estuary or near-shore area that is a "wildlife refuge," "protected wetland," "bird sanctuary" or similar restricted access area? (Please check one.)

❒ Yes ❒ No ❒ Don't know

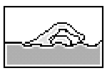
Clean-up effort

Cleaning up coastal waters for each of these purposes requires a different kind of effort. While some efforts will affect more than one use, each of the uses must be approached separately to affect a change for that use. This is because the types of pollutants that make swimming unsafe are different from the types of pollutants that make fish and shellfish unsafe to eat. These are different from the pollutants that keep the environment in the water from being diverse.

This means it is possible to improve conditions in coastal water so that it is swimmable but this same water may still not be able to support a diverse environment. This same water may also still not be good enough to support fish and shellfish that are safe for people to eat.

It is also possible to improve conditions in the coastal waters and estuaries so that the fish and shellfish caught in these waters are safe to eat, without increasing the kinds of fish and aquatic life that are able to survive in the waters. These same waters may still not be safe for humans to swim in even though the fish caught in these waters are safe to eat.

RATING OF USES



7-1 Please take a moment to think about the three ways of improving coastal water we have discussed. In your opinion, how much of each dollar spent on coastal water clean-up should go to each of the three improvement categories? (Please write percent in box.)

Improvement Category	**Percent of $1 spent on clean-up**
Making coastal water swimmable	%
Making the fish and shellfish that live in coastal water safe to eat	%
Creating a diverse environment in coastal water	%
Total (should add to 100%)	100 %

APPENDIX 2: QUESTIONNAIRE

California Survey

Thank you for agreeing to help us by completing this survey. This survey asks for your opinions about coastal waters in California. Your opinions and those of others completing this survey are <u>very important</u> and may be used to help prioritize programs that may affect your local area. There are no right or wrong answers; we are simply interested in your opinions and your experiences.

OMB Approval No: 2090-0024
Approval Expires 01/31/2005

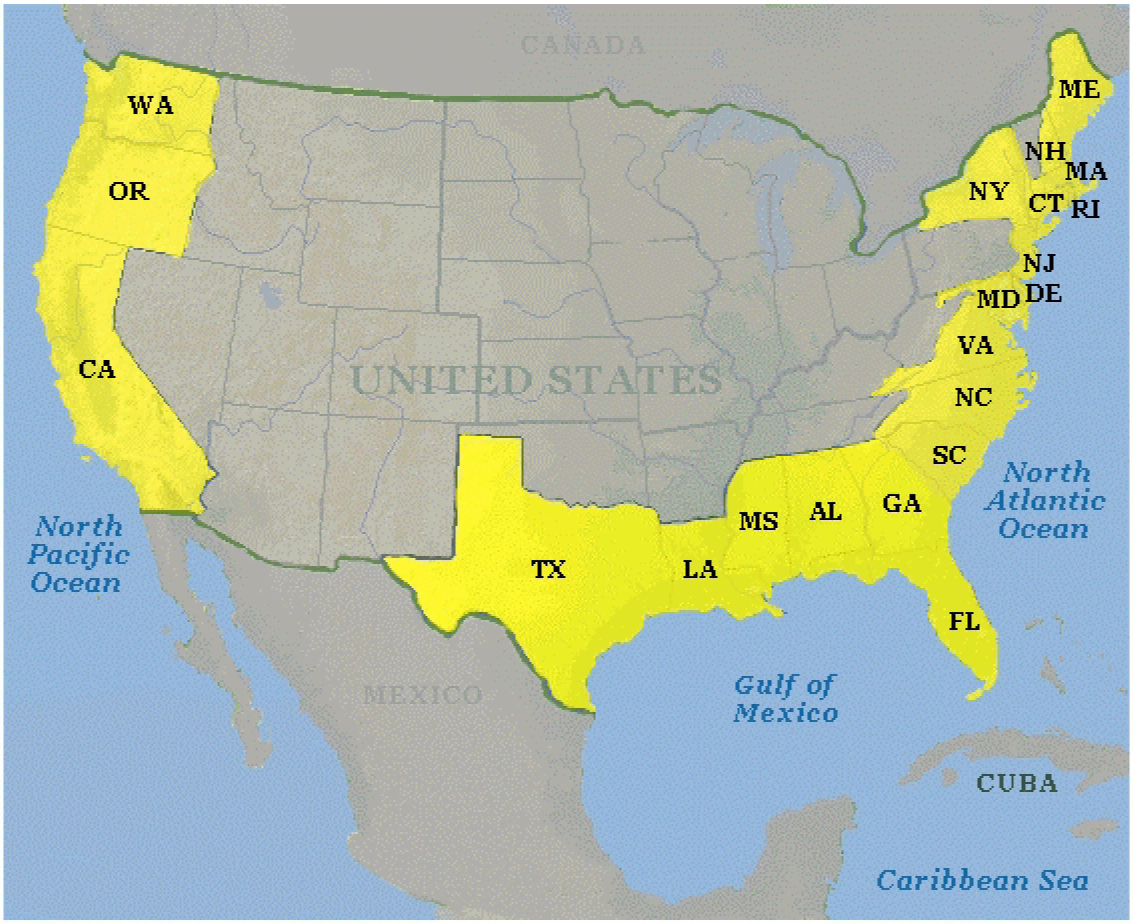
According to the Paperwork Reduction Act of 1995, an agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is xx-xx. The time required to complete this information collection is estimated to average between 20 and 30 minutes.

We'd like to start by giving you some information about coastal waters and asking about your experiences. By coastal waters we mean the shallow salt waters within two miles of shorelines of oceans, bays, seas, or gulfs including the areas where freshwater rivers mix with saltwater.
The next screen contains more information about coastal waters.

More Information on Coastal Waters:

Coastal waters may have:	shallow waters, marshes, sandy beaches, mud and sand flats, rocky shores, oyster reefs, river deltas, tidal pools, sea grass beds and swamps.
Natural uses include:	food, shelter and breeding grounds for many fish, shellfish, mammals and shorebirds.
Recreational uses include:	boating, fishing, shell-fishing, swimming, snorkeling and bird-watching.
Commercial uses include:	ports and marinas supporting shipping and industrial uses; breeding grounds for some commercial fish and shellfish.
Examples of coastal waters are:	the water along Chesapeake Bay, Clearwater Beach (Florida), Ocean City (Maryland), Venice Beach (California), Galveston Bay, Puget Sound, San Francisco Bay, Tampa Bay and lots of smaller bays and inlets where freshwaters and saltwaters mix.

Of the 48 contiguous states in the US, 21 have coastal waters. These states are shown in yellow on the map.



Q1 **In the past 12 months, have you visited <u>any</u> coastal waters for recreation or pleasure in one or more of the 21 coastal states shown on the map?** *(select one answer only)*

❒ Yes **(skip to Q3)**
❒ No
❒ Don't know **(skip to Q5)**

Q2 **Have you ever visited any coastal waters in any of the 21 coastal states shown on the map?** *(select one answer only)*

❒ Yes
❒ No **(skip to Q5)**
❒ Don't know **(skip to Q5)**

Q3 **Does your household own a boat that is used <u>primarily on coastal waters</u>?** *(select one answer only)*

❒ Yes
❒ No **(skip to Q5)**
❒ Don't know **(skip to Q5)**

Q4 **For which activity do you use your boat <u>the most</u> on coastal waters?** *(select one answer only)*

- ❒ Recreational fishing
- ❒ Recreational boating
- ❒ Commercial fishing
- ❒ Chartered boat rides
- ❒ Chartered fishing trips
- ❒ Other (please specify ___________________________________)
- ❒ Don't know

Q5 **How often do you eat seafood?** *(select one answer only)*

- ❒ More than 3 times per week
- ❒ 2-3 times per week
- ❒ 1 time per week
- ❒ 2-3 times per month
- ❒ 1 time per month
- ❒ Less than once per month
- ❒ Never **(skip to Q8)**
- ❒ Don't know **(skip to Q8)**

Q6 **About how much money per *month* do you spend on seafood that you personally eat?** *(select one answer only)*

- ❒ Less than $5
- ❒ Between $5 and $9.99
- ❒ Between $10 and $19.99
- ❒ Between $20 and $29.99
- ❒ Between $30 and $39.99
- ❒ Between $40 and $49.99
- ❒ More than $50
- ❒ Don't know

Q7 **Does any of the seafood you eat come from California waters?** *(select one answer only)*

- ❒ Yes
- ❒ No
- ❒ Don't know

Q8 **Have you ever heard about fish advisories that limit the amount of coastal fish or shellfish from California that one should eat because of pollution?** *(select one answer only)*

- ❒ Yes
- ❒ No
- ❒ Don't know

Q9 If Q1 = No or Don't know, skip to instructions before Q9h

[For the following activities in Q9, if 0 days or "Don't recall" is selected, skip to the next activity. If 0 days or "Don't recall" is selected for trips in California, skip to the next activity.

The next few questions are about your coastal water recreation activities over the last year. During the last 12 months, on how many different days did you personally participate in each of the following activities? ***(select one answer from each row in the grid) (Randomize order)***

		Number of Different Days in the Last 12 Months						
		0 days	1-2 days	3-5 days	6-10 days	11-20 days	More than 20 days	Don't recall number of days
a.	Fish in coastal waters? (up to 2 miles from shore)	❒	❒	❒	❒	❒	❒	❒
a_1	If a >0 then ask: How many of these days were single-day trips in California?	❒	❒	❒	❒	❒	❒	❒

If single day trips in California >0 then ask:

Thinking about your most recent single-day fishing trip to coastal water in California, what was the name of the coastal fishing site you visited on this most recent trip?

Name_________

What is the name of the city or town closest to (Name)?

City/Town_______________

About how many miles is (Name) from your home?

Miles ___________

About how long did it take you to get from your home to (Name)?

Hours _____ Minutes _______

	Number of Different Days in the Last 12 Months						
	0 days	1-2 days	3-5 days	6-10 days	11-20 days	More than 20 days	Don't recall number of days
(if a_1>0, then ask) Did you eat any of the fish you caught on this trip? ❒ Yes ❒ No, didn't eat any fish ❒ No, didn't catch any fish ❒ Don't know							
b. deep-sea fish (more than 2 miles from shore)?	❒	❒	❒	❒	❒	❒	❒
If b>0 then ask:							
How many of these days were single-day trips in California?	❒	❒	❒	❒	❒	❒	❒
c. boat or sail on coastal waters?	❒	❒	❒	❒	❒	❒	❒
If c>0 then ask:							
How many of these days were single-day trips in California?	❒	❒	❒	❒	❒	❒	❒

If single day trips in California >0 then ask:

Thinking about your most recent single-day boating trip to coastal water in California, what was the name of the coastal boating site you visited on this most recent trip?

Name_________

What is the name of the city or town closest to (Name)?

City/Town_______________

About how many miles is (Name) from your home?

Miles ___________

About how long did it take you to get from your home to (Name)?

		Number of Different Days in the Last 12 Months					
	0 days	1-2 days	3-5 days	6-10 days	11-20 days	More than 20 days	Don't recall number of days
Hours _____ Minutes _______							
d. visit a beach on coastal waters for any outdoor recreation activities?	❐	❐	❐	❐	❐	❐	❐
If d>0 then ask:							
How many of these days were single-day trips in California?	❐	❐	❐	❐	❐	❐	❐
e. swim in coastal waters?	❐	❐	❐	❐	❐	❐	❐
If e>0 then ask:							
How many of these days were single-day trips in California?	❐	❐	❐	❐	❐	❐	❐

If single day trips in California >0 then ask:

Thinking about your most recent single-day swimming trip to coastal water in California, what was the name of the coastal swimming site you visited on this most recent trip?

Name_________

What is the name of the city or town closest to (Name)?

City/Town_______________

About how many miles is (Name) from your home?

Miles ___________

About how long did it take you to get from your home to (Name)?

Hours _____ Minutes _______

f. observe wildlife near coastal waters?	❐	❐	❐	❐	❐	❐	❐
If f>0 then ask:							
How many of these days were single-	❐	❐	❐	❐	❐	❐	❐

	Number of Different Days in the Last 12 Months						
	0 days	1-2 days	3-5 days	6-10 days	11-20 days	More than 20 days	Don't recall number of days
day trips in California?							

Q9g [ask only if Q1 = 1] **Thinking about the number of days you spent participating in each of the coastal water activities we asked about, would you say that this was a typical recreational year for you?** *(select one answer only)*

- ❒ Yes (skip to instructions before Q9h)
- ❒ No
- ❒ Don't know (skip to instructions before Q9h)

Briefly explain why the past 12 months were not a typical recreational year for you?

____

This next set of questions asks about *freshwater* recreation activities. By "freshwater" we mean waters in inland lakes, ponds, rivers, streams, etc., excluding areas where freshwaters and saltwaters mix.

During the last 12 months, on how many different days did you personally participate in each of the following activities? *(select one answer from each row in the grid) (Randomize order)*

		0 days	1-2 days	3-5 days	6-10 days	11-20 days	More than 20 days	Don't recall number of days
h.	fish in a *freshwater* lake, pond, river or stream?	❒	❒	❒	❒	❒	❒	❒
i.	boat or sail on a *freshwater* lake, pond, river or stream?	❒	❒	❒	❒	❒	❒	❒
j.	visit a beach on a *freshwater* body for any outdoor recreation activities?	❒	❒	❒	❒	❒	❒	❒
k.	swim in a *freshwater* lake, pond, river or stream?	❒	❒	❒	❒	❒	❒	❒
l.	observe wildlife near a *freshwater* lake, pond, river, or stream?	❒	❒	❒	❒	❒	❒	❒

Now we would like to ask you about <u>coastal waters in California</u>. Here is a map showing the California coast.

Q10 Is your primary residence located within 10 miles of coastal waters? ***(select one answer only)***

- ❒ Yes
- ❒ No
- ❒ Don’t know

Q11 Aside from your primary residence, does your household own any property in California within 10 miles of coastal waters? *(select one answer only)*

- ❒ Yes
- ❒ No (skip to Q13)
- ❒ Don’t know (skip to Q13)

Q12 What other type of coastal property does your household own? *(select all that apply)*

- ❐ Residential, single family home
- ❐ Residential, condominium -- one unit
- ❐ Residential, condominium -- multiple units
- ❐ Residential, apartment building
- ❐ Commercial
- ❐ Don't know

Q13 How long have you lived in California? *(select one answer only)*

- ❐ **Less than 1 year**
- ❐ **1-5 years**
- ❐ **6-10 years**
- ❐ **11-20 years**
- ❐ **Over 20 years**
- ❐ **Don't know**

Q14 The next question is about problems that may be affecting coastal waters in California. Please rate the seriousness of each problem by selecting a number from 1 to 5, with 1 meaning "not at all serious" and 5 meaning "very serious." *(select one answer from each row in the grid) (Randomize order)*

How would you rate the seriousness of each of the following problems in California in terms of its impact on coastal waters?	Not at all Serious 1	2	3	4	Very Serious 5	Don't know
pesticide and fertilizer runoff from farm areas	❐	❐	❐	❐	❐	❐
discharges and overflows from sewage treatment plants	❐	❐	❐	❐	❐	❐
discharges from oil refineries and other industrial waste	❐	❐	❐	❐	❐	❐
seepage of waste from landfills	❐	❐	❐	❐	❐	❐
storm water runoff from roads and highways	❐	❐	❐	❐	❐	❐
pollution from commercial shipping (including oil and chemical spills)	❐	❐	❐	❐	❐	❐
pollution from recreational boats (including oil and gasoline spills and debris)	❐	❐	❐	❐	❐	❐
litter and other debris	❐	❐	❐	❐	❐	❐
animal waste runoff from farms and ranches	❐	❐	❐	❐	❐	❐
beach erosion	❐	❐	❐	❐	❐	❐

other (please specify___________________) ❐ ❐ ❐ ❐ ❐ | ❐

Q15 Most coastal water pollution comes from one or more of the following sources. Which one of these do you believe is the largest source of <u>coastal water pollution</u> <u>in California</u>? *(select one answer only) (Randomize order)*

- ❐ <u>Agriculture sources</u> including runoff of crop fertilizers and pesticides, runoff of animal waste from fields and pastures, and overflows from animal waste storage areas.
- ❐ <u>Industry sources</u> including overflows from sewage treatment plants, discharges from industrial processes, absorption of waste into the soil at landfills, accidents, and spills.
- ❐ <u>Household sources</u> including runoff of automobile grease and oil, runoff of lawn fertilizers and pesticides, overflows from septic systems, runoff of paints and chemicals, and absorption of waste into the soil at landfills.
- ❐ Don't know

Q16 Now, we would like to ask you about coastal waters in California.

Would you say that in the last five years California's coastal waters have gotten cleaner, stayed the same, or gotten dirtier? *(select one answer only)*

- ❐ Gotten cleaner in the last five years
- ❐ Stayed the same in the last five years
- ❐ Gotten dirtier in the last five years
- ❐ Don't know

Q17 Which one of the following is your <u>main</u> source of information on the condition of California's coastal waters? *(select one answer only)*

- ❐ Newspapers
- ❐ Magazines
- ❐ Television broadcast news
- ❐ Internet
- ❐ Personal experience
- ❐ Friends and family

The federal government and states use information on pollution concentrations to rate the quality of coastal waters for different uses.

Coastal water is rated as "good" or "not good" based on its ability to support the following three uses:

- **recreational swimming**
- **the production of fish and shellfish that are safe for people to eat**
- **the ability to support a large number of different kinds of fish, birds, mammals and plants.**

The following describes what it means for water to be “good” for each use.

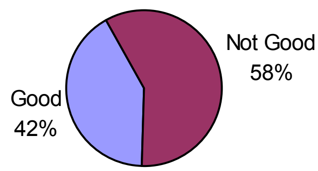
- **Recreational swimming:**
  If water is “good” for recreational swimming it means that it is free from the types of pollutants that make people sick (stomach illnesses, earaches, rashes or infections, and in rare cases long-term health effects) when they go swimming. In other words, if water is rated “good” for swimming, people can swim in the water without risk of illness.

- **Fish and shellfish safe for eating:**
  If water is rated “good” for fish and shellfish consumption it means that the fish are free from contamination that can make people sick. Some types of pollutants build up in the bodies of some fish and shellfish and can cause stomach illnesses and other health problems in people.

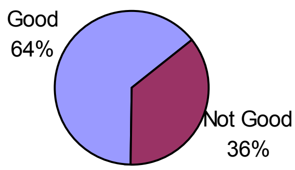
- **Large number of different kinds of fish, birds, mammals and plants:**
  If water is rated “good” for supporting large numbers of different kinds of life, it means that the water is free from the types of pollutants that keep many fish, birds, mammals and plants from living in water. In other words, “good” water allows a greater number of different kinds of fish and aquatic life to thrive.

  For each of the uses above, water is considered “not good” if it does not support the use all of the time because of pollution.

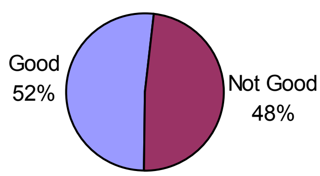
The pie charts below show the percent of California coastal waters that, on average, is "good" and "not good" for each of the three uses.



Swimming



Production of fish and shellfish that are safe to eat

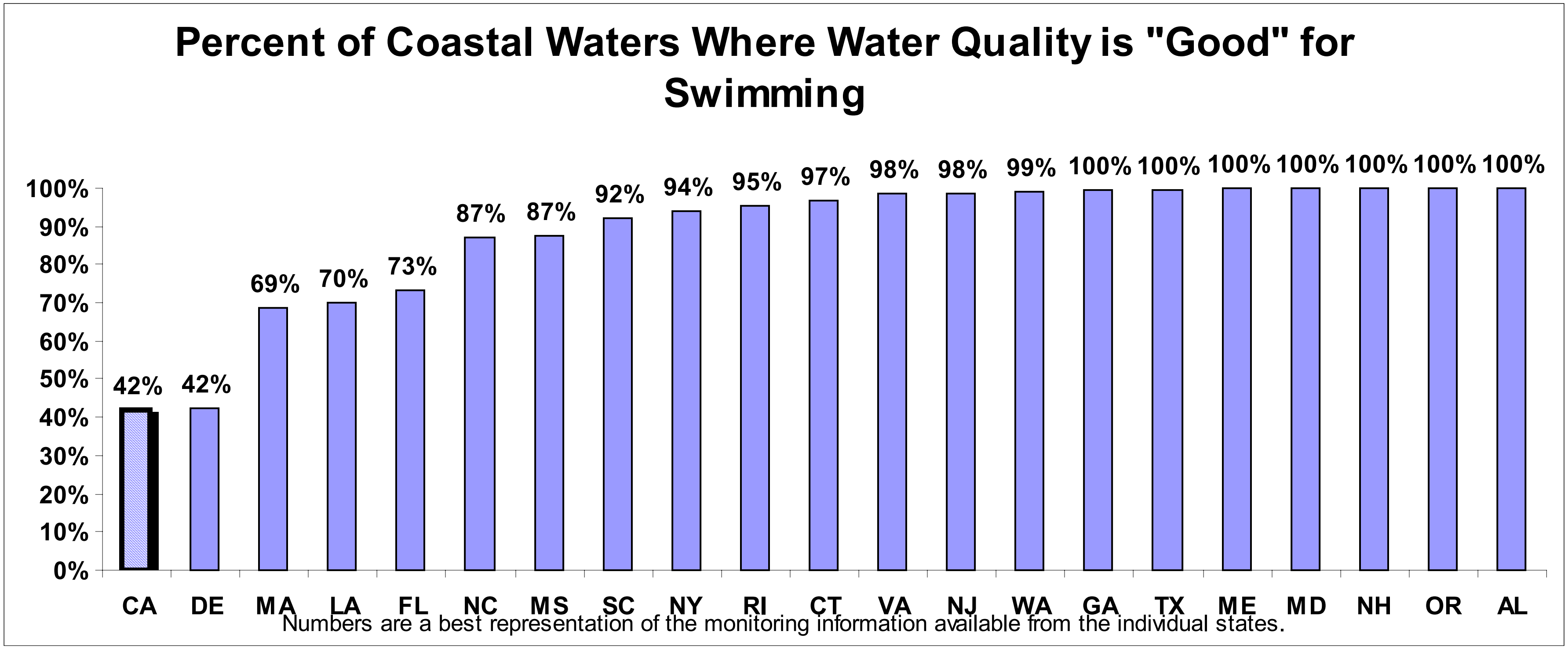


Supports a large number of different kinds of fish, birds, mammals and plants

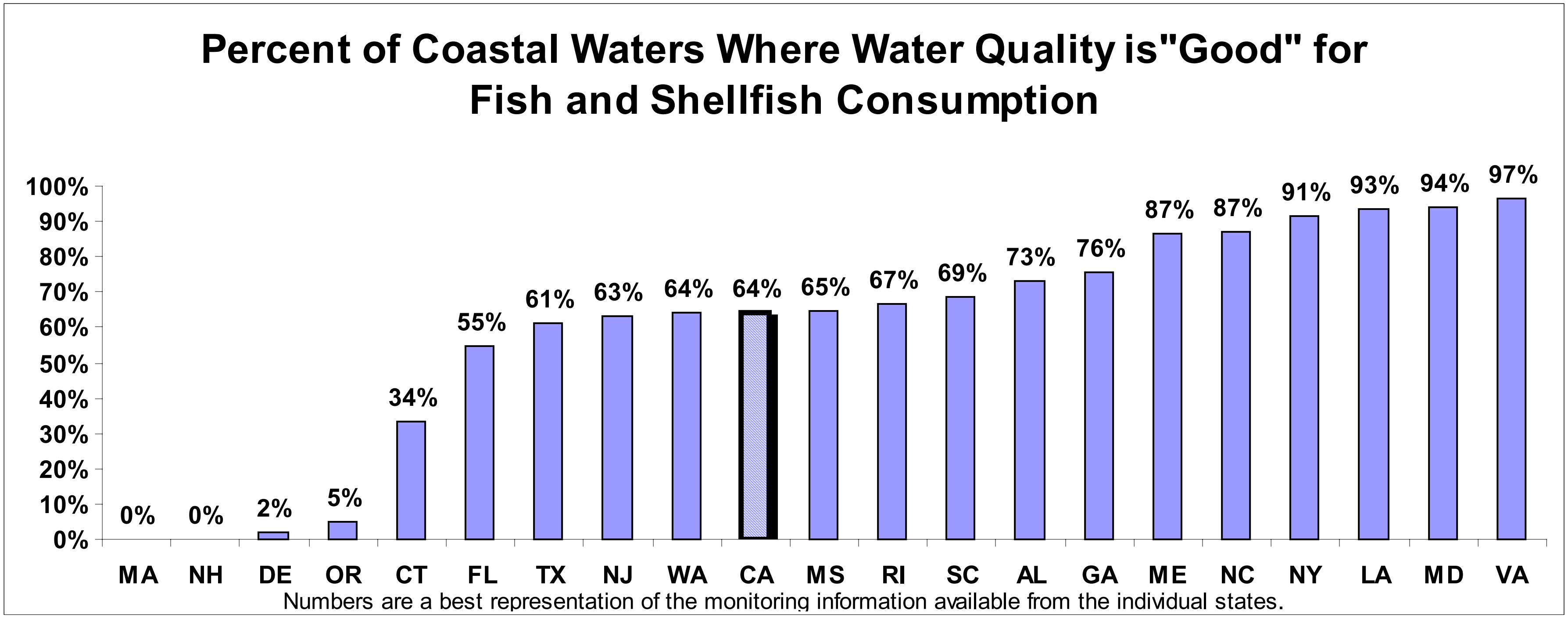
Q18 For which of the three uses we just described is water quality the most important to you? *(select one answer only)*

- ❒ Recreational swimming
- ❒ Fish and shellfish safe for eating
- ❒ Large number of different kinds of fish, birds, mammals, and plants
- ❒ Don't know

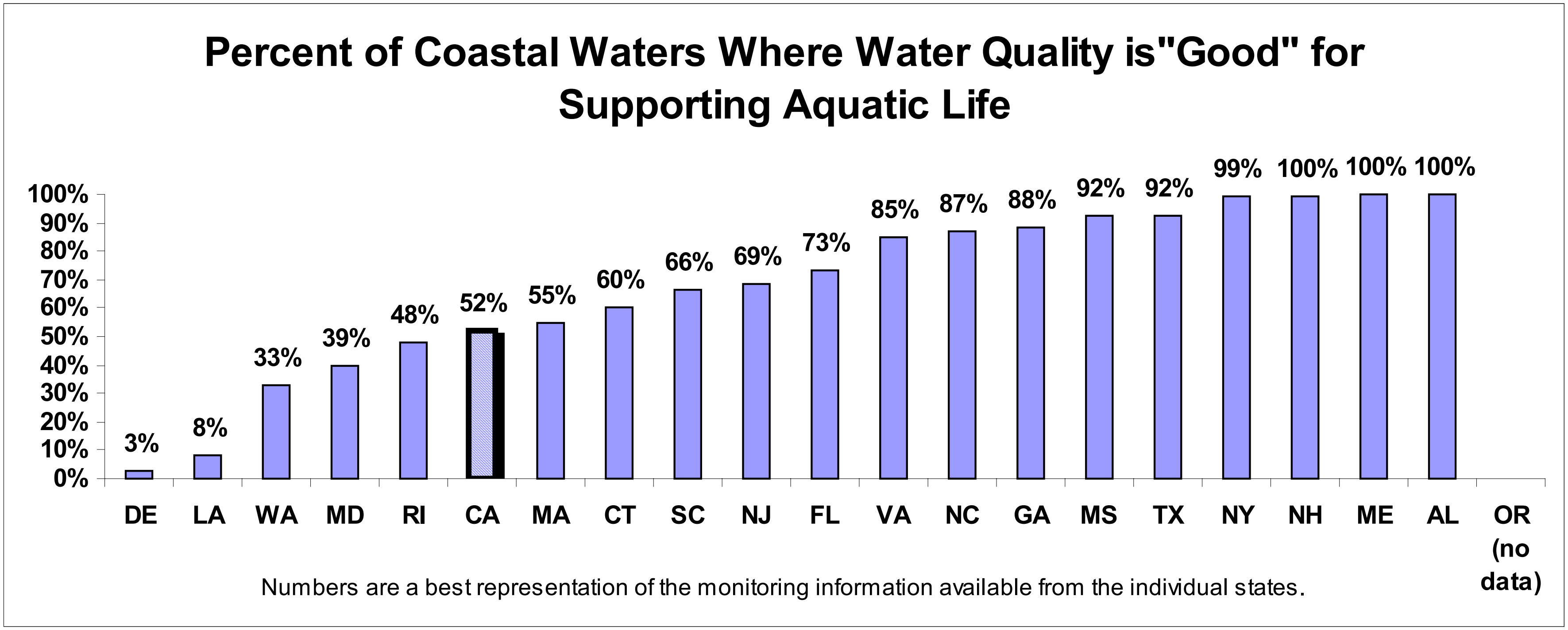
This chart shows, on average, how the water quality of California's coastal waters compare to the water quality of other states for Swimming:



This chart shows, on average, how the water quality of California's coastal waters compare to the water quality of other states for the Production of Fish and Shellfish that are safe to eat:



This chart shows, on average, how the water quality of California's coastal waters compare to the water quality of other states for supporting large numbers of different kinds of fish, birds, mammals and plants:



Now we would like to know whether or not you would support a program that increases the percent of California's coastal waters that are "good" for swimming, eating fish and shellfish, and supporting a large number of different kinds of wildlife.

Currently, taxes on households, industries, and agriculture as well as fines on agriculture and industry pay for the programs that support current water quality. If nothing more is done, the quality of coastal waters will remain about the same.

To improve the quality of the water, new programs will be needed as well as new funds to pay for them.

On the next several screens, we will give you information on programs that improve California's coastal waters. You will be asked to compare two programs at a time with the present conditions and to select which program, if any, you prefer.

The table on the next screen shows the percent of coastal waters that will improve under each of two new programs and the taxes required from each household to fund the new programs.

As you make your choice, please keep in mind the following:

- **Even though each program improves coastal waters in different ways, both would take three years before the improved water returns to "good."**
- **Neither program would improve the quality of freshwater lakes and rivers or coastal waters in other states where swimming and fishing may take place or where a healthy aquatic environment may exist.**
- **Selecting a program means that your household would have less money to spend on other things.**
- **It is already possible in some places in California to swim in and eat the fish from the same coastal waters. These same waters in some cases may also support a healthy aquatic environment.**

	Your Three Choices and How They Would Affect the Quality of California's Coastal Waters Percent of California's Coastal Waters Rated as "Good"		
	Present Conditions	**Program 1 (Conditions after 3 years)**	**Program 2 (Conditions after 3 years)**
Swimming	42% of miles are good	_% gain to __% good	_% gain to __% good
Fish and shellfish safe for eating	64% of miles are good	_% gain to __% good	_% gain to __% good
Habitat to support a large number of different kinds of fish, birds, mammals and plants	52% of miles are good	_% gain to __% good	_% gain to __% good
Yearly Tax Change for your household (permanent tax)	No Increase in Taxes	Your taxes increase by $___ per year	Your taxes increase by $___ per year

Q19 Which one of the options listed in the table above would you choose? *(select one answer only)*

- ❒ Present Conditions: No change in your taxes, and the percent of coastal water that is "good" for each purpose stays the same as it is now
- ❒ Program 1: Your taxes increase by $___ [fill with program 1 amount] per year to get the improvements shown under this program
- ❒ Program 2: Your taxes increase by $___ [fill with program 2 amount] per year to get the improvements shown under this program
- ❒ Don't know

For those that choose the Present Conditions (Q19==1):

19A. You chose Present Conditions over the two programs offered. Which of the following reasons BEST describes why you made this choice? (*select one answer only*)

1. The improvements were not large enough for the money.
2. I am satisfied with the way things are now.
3. I am opposed to higher taxes.
4. I do not believe the programs will work as stated.
5. I do not have enough information to make a good decision.
6. I do not trust the government to run the programs well.
7. Someone else should pay for the improvements.
8. Other (Please specify _____________)

For those that choose a program (Q19==2 OR 3):

19b. Which of the following reasons BEST describes why you chose this program? (*select one answer only*)

1. The program I selected was less expensive than the other but still provided some improvements.
2. The program I selected was more expensive than the other but provided larger improvements in areas I care about.
3. The program I selected provided larger improvements than the other in areas I care about.
4. I am most concerned about improvements for swimming and picked the program with the largest improvement in this area.
5. I am most concerned about seafood consumption and picked the program with the largest improvement in this area.
6. I am most concerned about wildlife habitat and picked the program with the largest improvement in this area.
7. I was indifferent between the programs but wanted to pick something.
8. Other (Please specify __________)

The screen before the next choice questions should read:

Now consider two <u>different</u> programs – programs 3 and 4. As before, the table on the next screen shows the percent of coastal waters that will improve under each new program and the taxes required from each household to fund the new programs.

As you make your choice, please keep in mind the following:

- **Even though each program improves coastal waters in different ways, both would take three years before the improved water returns to "good."**
- **Neither program would improve the quality of freshwater lakes and rivers or coastal waters in other states where swimming and fishing may take place or where a healthy aquatic environment may exist.**
- **Selecting a program means that your household would have less money to spend on other things.**
- **It is already possible in some places in California to swim in and eat the fish from the same coastal waters. These same waters in some cases may also support a healthy aquatic environment.**

The screen before the third choice questions should read:
Now consider two <u>different</u> programs – programs 5 and 6. As before, the table on the next screen shows the percent of coastal waters that will improve under each new program and the taxes required from each household to fund the new programs.

As you make your choice, please keep in mind the following:

- **Even though each program improves coastal waters in different ways, both would take three years before the improved water returns to "good."**
- **Neither program would improve the quality of freshwater lakes and rivers or coastal waters in other states where swimming and fishing may take place or where a healthy aquatic environment may exist.**
- **Selecting a program means that your household would have less money to spend on other things.**
- **It is already possible in some places in California to swim in and eat the fish from the same coastal waters. These same waters in some cases may also support a healthy aquatic environment.**

The screen before the fourth choice questions should read:
Now consider two <u>different</u> programs – programs 7 and 8. As before, the table on the next screen shows the percent of coastal waters that will improve under each new program and the taxes required from each household to fund the new programs.

As you make your choice, please keep in mind the following:

- **Even though each program improves coastal waters in different ways, both would take three years before the improved water returns to "good."**
- **Neither program would improve the quality of freshwater lakes and rivers or coastal waters in other states where swimming and fishing may take place or where a healthy aquatic environment may exist.**
- **Selecting a program means that your household would have less money to spend on other things.**
- **It is already possible in some places in California to swim in and eat the fish from the same coastal waters. These same waters in some cases may also support a healthy aquatic environment.**

The screen before the last choice question should read:

Now consider two final programs – programs 9 and 10. As before, the table on the next screen shows the percent of coastal waters that will improve under each program and the taxes required from each household to fund the new programs.

As you make your choice, please keep in mind the following:

- **Even though each program improves coastal waters in different ways, both would take three years before the improved water returns to "good."**
- **Neither program would improve the quality of freshwater lakes and rivers or coastal waters in other states where swimming and fishing may take place or where a healthy aquatic environment may exist.**
- **Selecting a program means that your household would have less money to spend on other things.**
- **It is already possible in some places in California to swim in and eat the fish from the same coastal waters. These same waters in some cases may also support a healthy aquatic environment.**

See attached excel spreadsheet for tax and percent changes for all versions.

Q20a In the last few questions we asked you to consider different programs that would improve coastal water quality. Did you think the improvements would take place in a specific part of California? *(select one answer only)*

❒ Yes (please let us know where you thought the improvements would take place___)
❒ No (skip to Q21a)
❒ Don't Know (skip to Q21a)

Q20b Why did you think the improvements would take place here?

____

Q20c Would you have answered differently if the improvements were to take place somewhere else in California? *(select one answer only)*

❒ Yes
❒ No
❒ Don't Know

(If Q1=”yes”)

Q20d Given that you have limited time and resources, if you could not enjoy coastal water recreational activities at the location of your choice, would you look for another location or would you engage in other activities?

- ❒ Look for another location
- ❒ Do other activities (e.g., swim at neighborhood pool or fresh water lake, fish in freshwater stream or river, play tennis, go shopping, etc.)

Q21a In the questions that asked you to consider different programs that would improve coastal water quality suppose that we told you that all improvements in swimming would take place in “bays,” “estuaries,” or “inlets” rather than in California’s ocean waters directly. Do you think you would have answered these questions differently? *(select one answer only)*

- ❒ Yes
- ❒ No (skip to Q22)
- ❒ Don’t Know (skip to Q22)

Q21b Please take a moment to tell us why?

____

Q21c When we asked you to choose between different programs for improving the water quality of California’s coastal waters, was there anything about the questions or descriptions that seemed confusing?

- ❒ Yes-→What was confusing? ____
- ❒ No

Q21d When we asked you to choose between different programs for improving the water quality of California’s coastal waters, did the programs and their impacts seem believable?

- ❒ Yes
- ❒ No-→Why not? ____

Q21e1. Of the following issues, which do you consider the most important?

- ❒ Pollution of drinking water
- ❒ Pollution of rivers, lakes and reservoirs
- ❒ Contamination of soil
- ❒ Air pollution
- ❒ The loss of natural habitat for wildlife
- ❒ Coastal Water pollution
- ❒ Extinction of plant and animal species

- ❒ Urban sprawl and loss of open spaces

[Only show items that were not selected in previous questions]
Q21e2-Q21e7. Of the remaining issues, which do you consider the most important?

- ❒ Pollution of drinking water
- ❒ Pollution of rivers, lakes and reservoirs
- ❒ Contamination of soil
- ❒ Air pollution
- ❒ The loss of natural habitat for wildlife
- ❒ Coastal Water pollution
- ❒ Extinction of plant and animal species
- ❒ Urban sprawl and loss of open spaces

We would now like to learn a little bit more about you and your household. This last set of questions is for background purposes only. We would like to remind you that all information you provide will be confidential, and your name will not be associated with any responses in this survey.

Q22 Are you a member of an environmental, conservation or outdoor sporting organization? *(select one answer only)*

- ❒ Yes
- ❒ No
- ❒ Don't know

Q40 How many people in your household contributed to your income in 2003?

____________ Number of people

Standard Knowledge Networks Questions

Do you have any comments on the survey in general?

____

Thank You!! We appreciate your help with this important study.
Please feel free to share any comments you have about this survey or the topic of water quality.

The Recreational Benefits of Improvements in New England's Water Quality: A Regional RUM Analysis

George R. Parsons
COLLEGE OF MARINE STUDIES AND DEPARTMENT OF ECONOMICS
UNIVERSITY OF DELAWARE, NEWARK, DE 19716

Erik C. Helm
U.S. EPA, OFFICE OF SCIENCE AND TECHNOLOGY
1200 PENNSYLVANIA AVE., WASHINGTON D.C. 20460 (4303T)

Tim Bondelid
RTI
RESEARCH TRIANGLE PARK, NC 27709

This study was funded by the U.S. Environmental Protection Agency's Office of Policy, Economics, and Innovation through Cooperative Agreement CR82486-01-02

1. Introduction

The purpose of this paper is to measure the economic benefits to recreation from improved water quality in six northeastern states. The states include Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. All lakes, rivers, and coasts (oceans and bays) in the region are included in the analysis. The benefits are measured using separate random utility maximization (RUM) models for fishing, boating, swimming, and viewing. All models are for day-trip recreation which accounts for approximately 77% of all water based recreation trips in the region. The models are estimated using data from the 1994 National Survey of Recreation and the Environment (NSRE) and water quality modeling simulations based on the National Water Pollution Control Assessment Model, Version 1.1 (NWPCAM1.1) (RTI, 2000).

We consider three welfare scenarios in our analysis. The first two are hypothetical. They assume that all water bodies in the region attain some minimum level of quality. We consider a moderate and then a high level of quality defined by levels of biological oxygen demand, dissolved oxygen, total suspended solids, and fecal coliforms. The third scenario considers a simulation of the actual improvement realized under the Clean Water Act through 1994.

Our paper is organized into 4 sections. Section 2 lays out the RUM models. Section 3 discusses our application and the data. Section 4 presents the parameter estimates and welfare results. Section 5 restates some of the important caveats in our analysis.

2. The Model

We estimate separate models for fishing, boating, swimming, and viewing. Each is estimated in two stages: participation and site choice. The participation model considers the total number of trips a person makes over the season. Site choice considers the site chosen for the last trip taken. A site is a lake, segment of a river, or segment of a coastline. The two models are linked using an approach suggested by Bockstael, Hanemann, and Kling (1987) and latter adapted by Hausman, Leonard, and McFadden (1995).

It is easiest to describe the model beginning with site choice. An individual is assumed to visit one of S possible recreation sites on a given day. Let $i = 1,..., S$ denote a site. Each site i gives a person utility U_i . This site utility depends on the cost of reaching the site and the characteristics of the site

$$(1) \qquad U_i = tc_i \beta_{tc} + x_i \beta_x + \varepsilon_i$$

where tc_i is the trip cost of reaching site i , x_i is a vector of characteristics of site i , and ε_i is a random term. The βs are parameters to be estimated. The vector x_i includes characteristics of the sites that matter to individuals when making site choice – water quality, access and so forth.

A person is assumed to visit the site that gives the highest utility. That utility is called the person's trip utility and is defined as

$$(2) \qquad V = Max\{U_1, U_2,....,U_S\}.$$

Substituting equation (1) into (2) gives

(3) $V = Max\{tc_1 \beta_{tc} + x_1 \beta_x + \varepsilon_1, tc_2 \beta_{tc} + x_2 \beta_x + \varepsilon_2,...., tc_S \beta_{tc} + x_S \beta_x + \varepsilon_S\}$

Now consider a change a water quality at one or more sites. Assume that x_i represents site characteristics at site i without an improvement in water quality and assume that x^*_i represents site characteristics at site i with an improvement. Only the element pertaining to water quality in x_i has changed between the two states of the world. For some sites there may be no change.

Without the change in water quality a person's trip utility is V shown in equation (3). With the change in water quality and assuming the change only takes place at sites 1 and 2, trip utility is

(4) $V^* = Max\{tc_1 \beta_{tc} + x^*_1 \beta_x + \varepsilon_1, tc_2 \beta_{tc} + x_2 \beta_x + \varepsilon_2,...., tc_S \beta_{tc} + x_S \beta_x + \varepsilon_S\}$

The change in utility due the water quality improvement is

(5) $\Delta w = V^* - V$.

If a person visits site k without the improvement in water quality, but chooses to visit site 1 now that it is cleaner, trip utility increases by $\Delta w = U^*_1 - U_k$. If the person visited site 1 without the water improvement and continues to visit site 1 with the improvement, trip utility increases by $\Delta w = U^*_1 - U_1$. The person makes the same trip but enjoys cleaner water. If the person visited site k without the improvement and continues to visit site k after the improvement there is no change in welfare. Perhaps sites 1 and 2 are located far from the person's home or have other features the person dislikes. Finally, if there is a relative change in water quality at sites 1 and 2, the person may shift from one site to the other and have a change in welfare. For example, a shift from site 1 to 2 would give an increase of $U^*_2 - U_1$. In any case all of these pathways to utility change are captured in equation (5) in Δw.

The change in trip utility is converted to money terms by dividing Δw. by the negative of the coefficient on trip cost. In the RUM model $-\beta_{tc}$ is a measure of the marginal utility of income. It tells us how much an individual's site utility would increase if trip cost were to decline for that trip. The increase in welfare due to an improvement in water quality at sites 1 and 2 is

(6) $cs = \Delta w \,/ - \beta_{tc}$.

In application, we use an expected value for Δw. because its actual value is random and unknown. To see this substitute equations (3) and (4) into equation (5). Assume the parameters β are known or estimated. Since each site utility has a random component ε_i, Δw . and cs must also be random. For this reason, the statistical expected values of V and V^* are used in application. The expected increase in welfare due to a water quality improvement is

(7) $cs = \{E(V^*) - E(V)\} / - \beta_{tc}$

where E denotes an expected value over the site utilities and will depend on the distribution of the errors terms in each site utility. Equation (7) gives a per trip value for the change in water quality.

The site choice model is usually estimated using some form of a multinomial logit model. We use a simple logit model in our application. A person's probability of visiting site k on a given choice occasion in a simple logit model is

$$(8) \qquad pr(k) = \exp(tc_k \beta_{tc} + x_k \beta_x) / \sum \exp(tc_i \beta_{tc} + x_i \beta_x) .$$

This form applies for any site and implies the following log-likelihood function

$$(9) \qquad \Lambda(\beta) = \prod \prod d_i^j \ln pr(i)$$

where $d_i^j = 1$ if individual j visited site i and $d_i^j = 0$ if not. The $pr(i)$ in equation (9) takes the form shown in equation (8). This function gives the likelihood of observing the patterns of visits actually observed a dataset. The parameters β are chosen to maximize $\Lambda(\beta)$. These estimated parameters, in turn, may be used to estimate per trip welfare shown in equation (7). In the simple logit model expected trip utility takes the form

$$(10) \qquad E(V) = \ln \sum \exp(tc_i \beta_{tc} + x_i \beta_x) .$$

This is sometimes called the 'inclusive value'. The per trip value of a water quality improvement then is

$$(11) \qquad cs = \{ \ln \sum \exp(tc_i \beta_{tc} + x^*_i \beta_x) - \ln \sum \exp(tc_i \beta_{tc} + x_i \beta_x)\} / - \beta_{tc}$$

where x^*_i is with the improvement and x_i is without.

Our participation decision models the number of trips an individual takes during a year. The participation function takes the Poisson form

$$(12) \qquad pr(R_j = r_j) = e^{-\lambda j} \lambda^{rj}_j / y_j! \qquad \qquad \ln \lambda_j = \alpha_u(\hat{\Gamma}_j) + \alpha_z z_j$$

where r_j is the number of trips taken by person j during the season. $\hat{\Gamma}_j = E(\hat{V}) / - \hat{\beta}_{tc}$ is a monetized utility index or consumer surplus for a recreation trip predicted using the parameter estimates from the site choice model. The vector z_j is a set of individual characteristics for person j believed to influence trip taking, like family size, age and so forth.

This is Hausman, Leonard, and McFadden's (1995) formulation of the participation model. It is a simple adaptation of Bockstael, Hanemann, and Kling's (1987) model. The adaptation is the monetization of the expected utility. Since this is a linear transformation of a scalar, the models are the same. The transformation merely rescales the parameter estimate on the index. Neither model is strictly utility theoretic.

Using an estimated participation model in a Poisson form, Hausman, Leonard, and McFadden (1995) show that the annual change in welfare due an improvement in water quality like that discussed above is

(13) $CS = (\hat{r}^*_j - \hat{r}_j) / \hat{\alpha}_u$

where $\hat{r}^*_j$ and $\hat{r}_j$ are predicted values of trips for person *j* from the participation model with and without the change in water quality, and $\hat{\alpha}_u$ is the coefficient on $\hat{I}_j = E(\hat{V}) / -\hat{\beta}_{tc}$ in the same model. See Parsons, Jakus, and Tomasi (1999) for more detail on the participation function.

3. Application and Data

Our application is to six northeastern states: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island. All rivers, lakes, and coasts in the region are included in the analysis. The data are from two sources. The trip and respondent characteristic data are from the 1994 National Survey of Recreation and the Environment (NSRE94). The site characteristic data were developed using NWPCAM1.1, a national water quality simulation model that is built around the RF1 river/stream network database (EPA's Reach File 1).

In the NSRE94 individuals throughout the United States were contacted at random by phone and asked to report the total number of day and overnight trips taken separately for viewing, boating, fishing, and swimming at domestic water-based recreation sites over the past twelve months. See Appendix A for the survey questions defining recreation uses. Each person was also asked to report the site visited on the last trip for each type of recreation and to report the location of his or her hometown. As usual demographic data were gathered for each respondent. This included income, age, job status, family size, and other characteristics. Our sample includes all individuals surveyed from the six northeastern states. Our sample size is 632. Table 1 presents descriptive statistics over the sample population. Our analysis is for day trips only. The participation rates and average number of trips for each type of recreation are

Recreation Use	Percent of the Sample Taking at Least One Day Trip to a Water-based Recreation Site Over the Past 12 Months (n = 632)	Average Number of Day Trips Taken by People Taking at Least One Trip During the Year
Viewing	25%	7.08
Boating	14	8.80
Fishing	12	10.06
Swimming	24	10.05

These rates are from the general population and exclude overnight trips. About 77% of all trips were day-trips. Our analysis accounts for most of the day-trips taken to sites in the region -- less than 3% of the "last trips" in the NSRE94 to the six states were taken by residents outside the region. The average distances traveled on a day trip in our sample and average distance to all sites in the choice set are

Recreation Use	Average Distance Traveled On Day Trips (miles)	Average Distance to all Sites in the Choice Set (miles)
Viewing	72	104
Boating	61	104
Fishing	50	104
Swimming	54	104

The maximum distance to a site in the choice set is 200 miles. Again, these are day trips only and ignore trips taken by persons outside the region.

The site characteristic data were constructed using NWPCAM 1.1 and the EPA's RF1 database. There are 20,925 rivers, 2,975 lakes, and 1,231 coasts in the data set. A site on a river is defined as a stretch of river from one confluence to another without a major tributary, lake, or population center intervening. If a major tributary, lake, or population center is passed, a new site is defined. A coastal site is defined as the coastal line along a bay or ocean between the mouth of a major river or beginning of a new municipality and the mouth of another major river or beginning of a new municipality. The lake data set is all major lakes and ponds in the region. A single lake, no matter how large, is never divided into more than one site.

Site-specific water quality data were estimated using NWPCAM 1.1 (RTI, 2000). In this model, place-specific pollutant loadings from both point and nonpoint sources across the nation are linked and routed through the RF1 surface water network. The model incorporates a hydrodynamic and water quality modeling algorithm that allows it to estimate instream pollutant concentration throughout the network for dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TSS) and fecal coliform bacteria (FCB).

In our application we estimate separate models for each recreation type. Because of the large number of sites in each person's choice set, we estimate the model using a random draw of sites. Each person's choice set includes his or her actually chosen site plus 36 other randomly drawn sites. Each choice set for estimation is composed of 12 rivers, 12 lakes, and 12 coasts. See Parsons and Kealy (1992) for more on estimation with randomly drawn choice sets.

Each model considers four basic attributes for site utility in equation (1): trip cost, resource type, choice set size, and water quality. Trip cost is the sum of travel and time cost

(14) $tc = (.35 + rtdist) + (income / 2040) * (rtdist / 40)$

where rtdist is round trip distance and income is annual income. Round trip dist is the linear distance between each site and a person's hometown. Travel cost is assumed to be 35 cents per mile. The opportunity cost of an hour is approximated using annual income divided by 2040 which is the typical number of hours worked in a year. The average travel speed is assumed to be 40 miles per hour.

Resource type is a set of dummy variables distinguishing river, lake and coastal sites. Choice set size is a control variable to account for the fact that even though each person has the same number of alternatives in the choice set in estimation (36 sites), in reality some will have far more than others. Persons with larger choice sets, all else constant, are more likely to take a trip.

Water quality is defined as low, medium, or high. This is an index based on the levels of biological oxygen demand, total suspended solids, dissolved oxygen, and fecal coliform. The cut offs for high and medium are

	Biological Oxygen Demand (mg/L)	Total Suspended Solids (mg/L)	Dissolved Oxygen (% saturation)	Fecal Coliforms (MPN/100mL)
High Water Quality	<1.5	<10	>.83	<200
Medium Water Quality	<4	<100	>.45	<2,000

All four object measures must be below (or above in the case of dissolved oxygen) the cutoffs shown before the site is classified as having that quality level. If any single characteristic falls short of its cut off for medium quality, the site is classified as low quality. Sites with low water quality have no plant or animal life and often have visible signs of pollution (trash, oil). Site with medium water quality have some game fishing and usually few visible signs of pollution. Sites with high water quality are suitable for extensive human contact, have the highest natural aesthetic, and support high quality sport fisheries.

The water quality data are based on NPWCAM1.1 pollutant loading data and water quality modeling results (for mid-1990's conditions). Coastal water quality is based on the predicted water quality at the mouths of nearby rivers. In some instances, watershed averages are used when data were missing from the simulation results. The distribution of water quality across sites is

	Percent of all Rivers	Percent of all Lakes	Percent of all Coasts
High Quality	49.9%	28.5%	30.8%
Medium Quality	36.4	59.9	37.7
Low Quality	13.7	11.6	31.5

Site utility takes the following form in our application

$$(15) \quad U^m_i = \beta^m_{tc} tc_i + \beta^m_r riv_i + \beta^m_c cst_i + \beta^m_{hi} hwq_i + \beta^m_{mid} mwq_i + \ln(size) + \varepsilon^m_i$$

where i denotes a site and m denotes a recreation use (m = viewing, boating, fishing, or swimming). The choice set size variable is estimated with its coefficient set equal to one since it is entered as a weighting factor only. This gives us 20 parameters to estimate in the site choice model -- 5 parameters in each of the four models. More complex versions of the model which included site size, separate measures for each objective water quality measure in our index, and an intermediate step in water quality between our high and medium gave rise to models that failed to converge and in the isolated cases where convergence was achieved gave results that ran strongly against our priors.

Four participation models, one for each recreation use, were estimated separately in Poisson form and included the attributes shown in Table 1. The expected utility index $(\hat{I}_j / -\beta_{tc})$ in these regressions was constructed from the relevant site choice stage. All participants and nonparticipants were included in each regression. Attempts to estimate the model by full information maximum likelihood, once again, lead to convergence problems. The results shown here are based on sequential estimation.

We consider three welfare scenarios using our model. The first two assume water quality at all sites attains some minimum level. The first assumes water quality attains at least a medium level as defined above at all sites in the region. Under this scenario 13.7% of all rivers, 11.6% of all lakes, and 31.5% of all coasts realize water quality improvements. The second assumes water quality attains a high level of quality at all sites. This is a significant improvement in water quality in the region affecting 50.1% of all rivers, 71.5% of all lakes, and 69.2% of all coasts over the six northeastern states.

The last scenario considers the water quality we are likely to have realized in 1994 in the absence of the Clean Water Act and assuming no state, local, or judicial controls were otherwise established. In this scenario we assume water quality improves from a hypothetical 'no-CWA' state of the world to current conditions. This is approximately the recreational benefits realized due to the existence of the Clean Water Act in 1994. The 'no-CWA' conditions were estimated using the same simulation model used to estimate current conditions. Pollutant loadings were adjusted in that model to reflect loads likely to have been attained in the absence of the Clean Water Act. To get an idea of how the CWA simulation is changing water quality in the model, consider the following table. The table reports the value of the ratio

$$\frac{\text{Number of sites at quality level wq with the improvement}}{\text{Number of sites at quality level wq without the improvement}}$$

where wq = low, medium or high. The table shows the degree of shift from lower to higher quality sites.

	River Ratio	Lake Ratio	Coast Ratio
high	1.25	1.44	1.10
medium	1.01	.94	1.17
low	.56	.07	.79

The next section presents the parameter estimates and welfare results for each of these scenarios.

4. Parameter Estimates and Welfare Results

The parameter estimates for the site choice model are shown in Table 2. For the most part, the signs are as expected. The coefficient on trip cost is negative and significant in all four models. Recall that this variable is used as the marginal utility of income and is important in converting measures of utility change into dollars. The coefficients on the resource type dummies suggest that coasts, all else constant, are the most important resource for recreation use. Recall that lake is the excluded category so the resource type coefficients are interpreted relative to lakes. The coefficient on coast is highest for viewing and lowest for fishing. The coefficient on river suggests that river sites, all else constant, are the lowest valued among the three resource types except for boating. There are a number of large rivers in the region where boating is quite popular. This, no doubt, accounts for the result on boating. The negative river coefficient for swimming is largest capturing the infrequent use of rivers in this activity.

The coefficient on middle WQ is positive and significant in two of the four models – fishing and swimming. This implies that moving from low to middle level water quality imparts benefits mostly to fishing and swimming uses. Between these two recreation types the utility is increased most for fishing. Boating also has a positive but insignificant coefficient on middle WQ. Viewing has a negative and insignificant coefficient. Modest improvements in water quality appear to yield little or no increase in utility for these recreation uses.

The coefficient on high WQ is positive and significant in all four models as one would expect. The coefficients also show that high water quality gives higher utility than middle water quality. Again, going from low to high water quality, the utility increase is greatest for fishing and swimming. However, the coefficients on viewing and boating imply utility increases for these recreation uses as well. It is interesting to note that for fishing most of the increase in utility comes from moving from low to middle water quality. For viewing and boating almost all of the utility increase comes from moving from middle to high water quality.

The results of the Poisson models are shown in Table 3. The coefficient on the monetized utility index (expected utility or inclusive value from the site choice stage divided by the negative of the 13 coefficient on trip cost) is positive in all four regressions. This coefficient gives us some idea of how responsive participation in each recreation use will be to improvements in water quality. Viewing and fishing participation are the most responsive to improvements. Swimming is somewhat less responsive and boating shows little if any responsiveness.

Income has a positive effect on viewing, boating, and fishing participation and a negative affect on swimming. Urbanities have lower participation rates in all uses, all else constant, but the effect is insignificant in the viewing model. As one ages the probability of participating in all four recreation uses decreases. Retired folks have a higher probability of participating in boating and fishing and a lower probability in viewing and swimming. Men have higher probabilities of participating in boating and fishing, and women in viewing and swimming. Education level increases ones probability of participating in all uses except for fishing where it has a negative and significant affect on participation. Unemployed also increases the probability for all uses except fishing but the coefficient is insignificant. Being a student increases the likelihood that you will participate in viewing and swimming. Being a homemaker increases your likelihood for swimming only. Larger families have higher probabilities for viewing and boating. Having more leisure hours increases one's probability of participating in all uses but fishing. And finally, owning a boating dramatically increases one's probability of boating and fishing and to a lesser extent viewing. We excluded boat ownership from the swimming model.

Now we turn to annual benefit estimates for water quality improvements. The annual average per person benefits over all resource types for our three scenarios are as follow

	Viewing	Boating	Fishing	Swimming
All sites improve to middle WQ	—	\$.04	\$3.14	\$5.44
All sites improve to high WQ	\$31.45	\$8.25	\$8.26	\$70.47
Improvements due to Clean Water Act (CWA)	\$.47	\$.62	\$2.40	\$5.59

These averages include participants and nonparticipants and are computed using equation (13).[1] The first two scenarios use current conditions as the baseline. The CWA scenario uses pre-CWA water quality as the baseline. Table 5 shows the same results for each scenario by recreation use and separately for improvements to rivers only, lakes only, and coasts only.

For modest improvements in water quality (to middle WQ) almost all of the benefits go to fishing and swimming. The annual fishing benefit is about \$3 per person. The annual swimming benefit is about \$5. Again, this includes participants and nonparticipants. Table 5 shows a negative benefit for viewing due to the negative coefficient on middle WQ in the view model. In the table above, I have simply recorded no benefit for viewing. Table 5 also shows that most of the swimming benefit is coming from cleaning up the coast, and most of the fishing benefit is coming from the clean up of coasts and lakes.

For significant improvements in water quality (to high WQ), all four recreation uses realize benefits and the benefits are must larger. Swimming and viewing are the highest at \$70 and \$31 per person. Boating and fishing are about \$8 per person. For fishing 38% this benefit is realized in moving from low to middle quality, and 62% is realized in moving from middle to high quality. For swimming the same incremental benefits are 8% and 92%. And, as noted earlier for viewing and boating, nearly all of the benefit is realized in the second increment. Most the benefits are coming through a clean up of the coastlines.

[1]Per trip values using equation (11) are also provided Table 4. Since annual values are typically of more interest for policy we focus our discuss on these.

For improvements due the Clean Water Act, all recreation uses realize benefits. Swimming and fishing are the largest at $6 and $2 per person. Viewing and boating are positive but less than $1 per person. In this case the source of most of the benefits are the rivers and lakes where the CWA has had it largest effect.

Table 6 shows aggregate benefits for each scenario. These are calculated by multiplying the mean per person benefit for each state by its population in 1994 over the age of 16. All numbers are in 1994 dollars. Summarizing Table 6, we have

	All sites Attain medium WQ	All sites attain high WQ	Due to the Clean Water Act
Total Benefit in Millions of 1994 Dollars	$77	$1,295	$99
Distribution of Total Benefits by recreation use:			
Viewing	0%	26%	5%
Boating	0%	7%	7%
Fishing	36%	7%	26%
Swimming	63%	60%	61%

The aggregate benefits to the region range from $ 77 million for improvements to medium water quality to $1.3 billion for improvements to high water quality. Again the benefits go mostly to swimming and fishing for a medium clean-up. The benefits go mostly to swimming and viewing for improvements to high water quality. Overnight trips, non-recreation use, and nonuse values are excluded from these numbers.

The aggregate benefits due to the Clean Water Act in 1994 dollars are $99 million. These estimates assume the controls set by the Act are not in place and are not replaced by any state, local or judicial controls. The estimates are based on RTI’s simulation model. The benefits go mostly to fishing and swimming.

5. Caveats

While our models give plausible results for broad changes in water quality across the region, several caveats in the research are worth repeating.

◊ Using finer measures of water quality in the RUM model persistently led to complications in the econometrics, usually a model that failed to converge. By finer measures, we mean using the objective water quality variables separately and having an intermediate step between high and medium quality.

◊ More complex specifications (nested and mixed logit models), models with more site characteristics, and estimating by full information maximum likelihood, also created problems with convergence and implausible parameter estimates.

◊ There is no coastal water quality simulation model per se. The RTI model essentially uses water quality estimated from the mouths of rivers near coastal sites. And, the coastlines are by far the most aggregated sites. Since coastlines were the source of many of the benefits, caution is warranted.

◊ Water quality data at a site level were not available for many lakes in our data set. For these lakes we used a watershed average water quality.

◊ Our baseline pre-CWA water quality levels assume no local, state, or judicial action in the absence of the CWA. This is an extreme position that leads to some overstatement of the benefits attributed to the CWA.

◊ Our benefits measures exclude overnight trips, non-recreation uses of the water, some smaller water bodies, and nonuse value. This leads to some understatement of the benefits for each scenario.

References

Bockstael, N. E., W. M. Hanemann, and C. Kling (1987). "Estimating the Value of Water Quality Improvements in a Recreational Demand Framework," Water Resource Research, 23(5): 951- 960.

Hausman, J.A., Leonard, G.K., and Mcfadden, D. (1995). "A Utility-Consistent Combined Discrete Choice and Count Data Model: Assessing Recreational Use Losses Due to Natural Resource Damage," Journal of Public Economics, 56, 1-30.

Parsons, G. R., P. Jakus, and T. Tomasi (1999). "A Comparison of Welfare Estimates from Four Models for Linking Seasonal Recreation Trips to Multinomial Logit Models of Choice," Journal of Environmental Economics and Management, 38: 143-59.

Parsons, G. R. and M. J. Kealy (1992). "Randomly Drawn Opportunity Sets in a Random Utility Model of Lake Recreation," Land Economics, 68, 93-106.

Parsons, G. R., D. M. Massey, and G.R. Parsons (2000). "Familiar and Favorite Sites in a Random Utility Model of Beach Recreation," Marine Resource Economics 14, pp. 299-314.

Research Triangle Institute (RTI). 2000. National Water Pollution Control Assessment Model (NWPCAM) Version 1.1. Final report prepared for the U.S. Environmental Protection Agency, Office of Policy, Economics and Innovation, Washington, DC.

Table 1: Descriptive Statistics

	Description	Sample Mean
Income	Annual income	\$56,574
Urban	Urban dummy (=1 if live in an urban area)	.18
Age	Age	43
Retired	Retirement dummy (=1 if retired)	.18
Gender	Gender (=1 if male)	.42
Education	Level of education (scale 1-5)	4.4
Unemployed	Unemployment dummy (=1 if unemployed)	.13
Student	Student dummy (=1 if full time student)	.10
Homemaker	Homemaker dummy (=1 if homemaker)	.22
Family Size	Number of people in family at home	2.9
Leisure Hours	Leisure hours per week	21.8

Table 2: Random Utility Model of Site Choice

	Viewing	Boating	Fishing	Swimming
Price	-.042 (33.1)	-.062 (24.8)	-.055 (21.1)	-.030 (36.0)
River	-.090 (5.6)	.716 (3.9)	-.689 (4.4)	-5.489 (7.7)
Coast	4.59 (37.7)	3.54 (24.1)	1.865 (11.2)	3.69 (44.2)
High WQ	.421 (2.56)	.496 (1.73)	.912 (3.16)	.881 (6.7)
Middle WQ	-.136 (1.4)	.016 (0.1)	.898 (4.94)	.325 (3.6)
Log-Likelihood	-.335	-5.13	-4.91	-13.44

Table 3: Poisson Participation Model

	Viewing	Boating	Fishing	Swimming
LOG INCLUSIVE/β_{tc}	0.0064 (13.498)	0.0012 (1.226)	0.0051 (5.772)	0.0017 (5.006)
INCOME	0.98E-06 (1.459)	0.31E-05 (3.664)	0.77E-05 (10.942)	-0.24E-05 (-3.873)
URBAN	-0.0134 (-0.222)	-0.8017 (-6.269)	-0.8967 (-8.321)	-0.1391 (-2.291)
AGE	-0.0125 (-6.249)	-0.0230 (-7.541)	-0.0212 (-8.570)	-0.0145 (-7.248)
RETIRED	-0.5016 (-3.663)	1.1352 (5.069)	0.5027 (3.576)	-0.8049 (-6.642)
GENDER	-0.4950 (-9.869)	0.1895 (2.568)	1.2663 (15.552)	-0.2319 (-4.724)
EDUCATION	0.1314 (9.000)	0.0406 (1.848)	-0.1668 (-8.981)	0.2254 (16.362)
UNEMPLOYMENT	-0.6402 (-4.955)	-0.6904 (-3.356)	0.0602 (0.534)	-0.2889 (-2.586)
STUDENT	0.6564 (10.351)	-0.3914 (-3.220)	-0.5052 (-4.611)	0.2846 (4.351)
HOMEMAKER	-0.6104 (-8.014)	-1.0769 (-6.087)	0.0310 (0.243)	0.3243 (5.616)
FAMILY SIZE	-0.0407 (-2.673)	-0.1185 (-4.285)	0.0642 (3.516)	0.1240 (11.243)
LEISURE HOURS	0.0081 (8.444)	0.0040 (3.353)	-0.0037 (-2.339)	0.0079 (8.889)
BOAT OWNED	0.5422 (4.400)	2.7759 (34.360)	1.7806 (26.152)	--
Log-Likelihood	-3708	-1176	-2229	-3878

Table 4: Mean Per Trip Benefits Per Person (1994$)

	Viewing	Boating	Fishing	Swimming
Due to Clean Water Act:				
All Sites	$0.22	$0.49	$1.45	$1.69
Rivers Only	0.10	0.28	0.45	0.01
Lakes Only	0.13	0.12	0.58	0.72
Coasts Only	-0.03	0.07	0.38	0.93
Sites Attain Middle WQ:				
All Sites	-0.48	0.03	1.67	1.48
Rivers Only	-0.01	0.003	0.13	0.0006
Lakes Only	-0.05	0.007	0.87	0.31
Coasts Only	-0.41	0.02	0.70	1.19
Sites Attain High WQ:				
All Sites	9.75	5.99	3.87	19.43
Rivers Only	0.82	1.82	0.76	0.03
Lakes Only	2.17	1.63	1.10	5.96
Coasts Only	7.41	3.07	2.19	15.29

Table 5: Mean Annual Benefits Per Person (1994$)

	Viewing	Boating	Fishing	Swimming
Due to Clean Water Act:				
All Sites	$0.47	$0.62	$2.40	$5.59
Rivers Only	0.21	0.36	0.72	0.03
Lakes Only	0.38	0.17	0.95	2.58
Coasts Only	-0.13	0.07	0.65	3.04
Sites Attain Middle WQ:				
All Sites	-1.61	0.04	3.14	5.44
Rivers Only	-0.02	0.003	0.54	0.002
Lakes Only	-0.15	0.01	1.29	1.06
Coasts Only	-1.43	0.03	1.34	4.41
Sites Attain High WQ:				
All Sites	31.45	8.25	8.26	70.47
Rivers Only	2.25	2.51	1.86	0.11
Lakes Only	6.21	2.39	1.73	21.20
Coasts Only	24.67	4.01	4.39	55.50

Table 6: Annual Aggregate Benefits (millions of 1994$)

	Viewing	Boating	Fishing	Swimming	Total
Due to Clean Water Act:					
All Sites	$5.120	$6.893	$26.298	$61.085	$99.333
Rivers Only	2.336	3.990	7.921	0.292	14.539
Lakes Only	4.198	1.850	10.431	28.271	44.749
Coasts Only	-1.410	0.744	7.077	33.214	39.625
Sites Attain Middle WQ:					
All Sites	-17.614	0.418	34.340	59.490	76.634
Rivers Only	-0.242	0.035	5.903	0.019	5.715
Lakes Only	-1.650	0.092	14.151	11.639	24.233
Coasts Only	-15.691	0.290	14.688	48.220	47.506
Sites Attain High WQ:					
All Sites	344.015	90.268	90.318	770.725	1295.326
Rivers Only	24.558	27.499	20.312	1.152	73.520
Lakes Only	67.958	26.128	18.939	231.838	344.863
Coasts Only	269.766	43.815	48.028	606.958	968.567

Appendix A
Survey Questions Defining Four Recreation Uses

Boating

Did you leave from your home to take any trips or outings where the primary purpose was to go boating in the last 12 months? Boating inludes trips to go motorboating, sailing, windsurfing, canoeing or kayaking, rowing, tubing or other floating. Please do not include trips taken for any other primary purpose such as swimming, fishing, or to just be near water.

Fishing

Did you leave from your home to take any trips or outings where the primary purpose was to go fishing in the last 12 months? Please do not include trips taken for any other primary purpose such as swimming, boating, or to just be near water.

Swimming

Did you leave from your home to take any trips or outings where the primary purpose was to go swimming outdoors in something other than a pool in the last 12 months? Please do not include trips taken for any other primary purpose such as fishing, boating, or to just be near water.

Viewing

Did you leave from your home to take any trips or outings where the primary purpose was to visit a beach or waterside in the last 12 months? Please do not include trips taken for any other primary purpose such as fishing, boating, or swimming. Please include trips for example, your picnics, nature study outings, and vacations, where you purposely chose to be by the water.

Valuing Water Quality Changes Using a Bioeconomic Model of a Coastal Recreational Fishery

AUTHORS:

Matt Massey & Steve Newbold
U.S. EPA – National Center for Environmental Economics
Washington, DC

Brad Gentner
U.S. NOAA – National Marine Fisheries Service
Silver Spring, MD

ABSTRACT:

Most previous studies on the effects of water quality on recreational fishing have focused on a single element in the chain of effects that connect water quality changes to the welfare of anglers. Due to a scarcity of detailed water quality data, most of these studies have also been forced to examine water quality effects across large aggregated areas. The result is a large number of studies that are difficult to combine to evaluate specific water quality policies in a comprehensive manner. This paper describes a bioeconomic model of a coastal recreational fishery that combines standard models of fish population dynamics, angler catch, and recreation site choice. We use a structural modeling approach that allows us to combine a variety of data sources and provides more flexibility for evaluating various water quality policies than most previous valuation models.

First, we develop a population model that describes the influence of water quality on overall fish abundance through the effects of dissolved oxygen (DO) on the survivorship of young juvenile fish. The population model is based on data on survival, reproduction, and the effects of DO on juvenile fish from the fisheries science literature and government reports. The model is calibrated using average historic recreational harvest levels in and out of the study area and historic commercial harvest levels for the entire fishery.

Second, we estimate a catch model that describes the influence of fish abundance and water quality on anglers' average catch rates. The catch model is estimated using a combination of three data sources. First, we use monthly data on water quality conditions from 23 water quality monitoring stations distributed throughout Maryland four coastal Bays. Next, we incorporate catch data from a sample of anglers who fished for summer flounder. Each fisherman reported their date and location fished, catch, fishing methods, and some personal characteristics. Lastly, we include a measure of fish abundance from fishery-independent data collected in bottom trawl surveys, all in

Maryland's coastal bays in 2002. The disaggregated nature of this data allows us to estimate spatially and temporally varying catch rates.

Third, we estimate a recreation demand model that describes the welfare effects and changes in trip demand from changes in catch rates. The recreation demand model is based on data from a stated choice survey of anglers who fish for summer flounder on the Atlantic coast. In the survey, respondents were asked to choose between two flounder fishing trips of varying quality (catch, regulations, cost, etc.) and a "do something else" option. Using this model we estimate the value of several changes in water quality typically valued in the literature and changes in participation rates.

Next, we integrate the population, catch, and recreation demand models to create a bioeconomic model that accounts for the feedback on the fish population through changes in the overall harvest pressure in the recreational fishery on the fish stock. The bioeconomic model is used to estimate the aggregate benefits to recreational anglers from several illustrative scenarios of changes in water quality. Results indicate that improving water quality throughout the range of the species could lead to substantial increases in the fish population and associated benefits to recreational anglers from increased catch rates. Water quality improvements confined to Maryland's coastal bays alone would have much smaller impacts. Because DO appears to only weakly affect the "catchability" of summer flounder (i.e., the average angler catch conditional on fish abundance); the largest effects predicted by the model come from the long run impact of DO on fish abundance through its affect on juvenile survival. This finding suggests that studies that simply include DO measures as site characteristics (and as a proxy for short run catchability effects) may be missing the major (long term) effects of DO on fish and fishermen. Important areas for improved data collection and model development are also discussed.

Session II: Cleaning Our Coastal Waters: Examinations of the Benefits of Improved Water Quality

Discussant: Bob Leeworthy, Leader Coastal and Ocean Resource Economics Program, Special Projects, National Ocean Service, National Oceanic and Atmospheric Administration

The Value of Improvements to California's Coastal Waters: Results From a Stated-Preference Survey, by Nicole Owens and Nathalie Simon

Comments:

1. The procedures followed in designing the survey questionnaire and sample design were very good. In reviewing the paper, I was quite surprised that the same procedures were used that we at NOAA are currently using in designing a survey to value the coral reefs in Hawaii. The use of focus groups, protocol interviews (one-on-one interviews with debriefings), a large-scale pre-test, and final survey with peer review used seems to have become a standard model. And, I think the model is a good one. It appears much was learned in the process and significant changes in both questionnaire and sample design as a result.
2. The decision to switch from a contingent valuation approach to a state-preference approach appears to be a good decision. This approach seems better fitted to the problem and the approach seems to have strong scientific backing.
3. The use of an Internet Panel (Knowledge Networks) also appears to be a good decision. The use of Knowledge Networks Internet Panels has not been fully endorsed to date for policy/management application by the U.S. Office of Management and Budget (OMB). Several papers to be presented at this workshop demonstrate that Knowledge Network's Internet Panels can provide "representative samples" for a variety of applications, especially for environmental/ecological benefit estimation. So again, I think the sample design used has scientific support. As a note, we at NOAA are also planning to use Knowledge Network's Internet Panel for our study to estimate the economic value of Hawaii's Coral Reefs. We will seek nothing less than approval to apply to policy/management. Again, I believe the science presented at this workshop supports that decision.
4. I have some problems with a couple of the survey questions. Specifically, Questions 3 and 4.

   Q3. Does your household own a boat that is <u>used primarily on coastal waters</u>?
   Q4. For which activity do you use your boat <u>the most</u> on coastal waters?

__ recreational fishing
__ recreational boating
__ commercial fishing
__ charter boat rides
__ charter fishing trips
__ other (please specify) ___________________

I am not sure how this information can be used. Using the qualifier in Q3 that the boat had to be primarily used on coastal waters doesn't make sense to me. I think a great deal of information is lost for a variable, which might be an important explanatory variable.

If I use my boat 51% of the time in freshwater and 49% of the time in coastal waters, this question says it is not important to know that I use my boat 49% of the time in coastal waters. Many studies have identified boat ownership as an important variable in explaining use and use value. Conditioning use to primarily used is potentially losing important information.

A similar problem exists with Q4. Conditioning the identification of activity to the most use looses potentially important information. From 1987 to 1992, we conducted the Public Area Recreation Visitors Survey (PARVS) at 50 coastal sites from Maine to Washington. What we learned was that for coastal sites with multiple attributes, people engaged in multiple activities. And, at very few sites did a majority of users indicate that there was one activity that was the "main reason for visiting the site" or the "main activity" they participated in during the visit to the site. I would have changed to check all that apply and possibly followed this up with estimates of the number of days of each activity over the past 12 months in coastal waters. You could use responses here to identify the most important use based on relative days of use.

5. A similar problem exists for Q9. Why limit information on trips to single day trips? Are multiple-day trips of no value? In the Florida Keys, very few trips are day trips. And almost all trips are multiple activity trips with no activity being either the "main reason for the trip" or the "main activity" on the trip. Coastal water quality is critical to the Florida Keys. In 1995-96, we estimated over 2.5 million visitors spent over 13 million days in outdoor recreation activity. I think you are missing a significant amount of activity by limiting your analysis to day trips. I would agree that, because you are limiting the current application to residents of California, day trips will be a relatively high percent of trips, but I still don't understand the logic of dropping this portion of total activity dependent on coastal water quality.
6. It was never made clear why the trip questions were being asked. Will there be an attempt to do a revealed preference set of trip models using the random utility model approach? If so, was there any thought to designing a revealed preference

approach consistent with the stated-preference approach i.e., a joint estimation of RP and SP data?
Adamowicz et al (1994) combined revealed and stated preference methods for valuing environmental amenities. In 1996, the Association of Environmental and Resource Economists (AERE) workshop was devoted to this topic. Experts from the marketing and transportation fields were invited to share their experiences with combining revealed and stated preference data. Among the lessons learned was that combining revealed and stated preference data yielded better predictions of demand for a good or service across many types of goods and services. Of course we don't ever actually observe consumer's surplus, so one makes the inference that if we are predicting demand for a good or service better, we are estimating consumer's surplus better. I didn't see any mention of this in the paper.

7. The empirical results presented in the current paper are labeled as preliminary, so I didn't take them too seriously. However, I did have trouble with some of the interpretations of the conditional logit model presented in Table 2 on page 16. Only one paragraph on page 15 is presented with explanations.
I was, at first, a little confused, but the interpretation seems to be that, for individual attributes, a positive coefficient means these factors (e.g. age, male, black and household size) increase the probability that a person will choose the status quo and a negative coefficient means these factors (e.g. income, Hispanic, eating seafood, and participation in recreation activities) increase the probability that a person will choose one of the programs (i.e., moves away from the status quo). I think a little more explanation would help here.
8. I never saw the dollar amounts used. How many values? What was the range of values? And, How were the range of values determined?

The Recreational Benefits of Improvements in New England's Water Quality: A Regional RUM Analysis, by George Parsons, Erik C. Helm and Tim Bondelid

Comments:

1. The analysis uses data from the 1994-95 National Survey on Recreation and the Environment (NSRE). I am and have been the Co-leader of NSRE since the early 1990's. It is stated in the opening paragraph of the paper "All models are for day-trip recreation which account for approximately 77% of all water based recreation trips in the region" (region being the Northeast region).
This estimate of day-trips accounting for 77% of all water based recreation trips in the region is not correct. First, the trips were conditioned on an activity being the primary purpose of the trip. As discussed above, NOAA's work through PARVS revealed people are often not willing to say that their trips to coastal areas were based on any one activity being either the main reason for the visit or the main activity on their visit. So, the trip data obtained in NSRE 1994-95 was only a sub-set of the total number of trips. Second, even though NSRE 1994-95 included both day-trips and multiple-day trips, modeling was limited to day-trips. On this latter sub-setting, our profession seems to find multiple-day trips to be

difficult to implement with the random utility model or that modeling multiple-day trips requires a separate model. Multiple-day trips are a large proportion of total use in the coastal areas. We need to model multiple-day trips that are not conditioned on one activity being either the main reason for the trip or the main activity or we are not accounting for much of the use. Above, in my comments on the previous paper, I said that in the Florida Keys multiple-day trips, with no one activity being either the main reason for the trip or the main activity on the trip, account for almost all trips. Coastal water quality is important in the Florida Keys and we need models to deal with these issues. This is less a criticism of this paper and more a challenge offered to our profession.

2. Paper Caveats. "*Using finer measures of water quality in the RUM model persistently led to complications in the econometrics, usually a model that failed to converge*". I think this is probably related to caveat number 3 that "*there is no coastal water quality simulation model per se*". At NOAA, we currently have a project on estimating the value related to water quality changes in Southern California. In this project, we have ambient water quality measures for each beach on each day. Water quality is statistically significant in all models estimated, including full information maximum likelihood estimations. Matching up better water quality data to NSRE data is something for future research.

Valuing Water Quality Changes Using a Bioeconomic Model of a Coastal Recreation Fishery, by Matt Massey, Steve Newbold and Brad Gentner.

Comments:

1. Overall this is a very impressive effort. The underlying model seems sound. However, I don't think the actual application matches up with the model presented in equations 1-4. A bioeconomic model that doesn't explicitly model total effort and the institutional structure underlying the human system isn't a real bioeconomic model. The interplay of the biological system and the human system are fundamental. The use of calibration to account for the human system is quite clever, but it leaves me with not much confidence in the result.
   If the fishery management situation in place can be described as a common property resource with an open-access fishery, then I think we would predict that there would be "no benefits" realized from water quality improvements. The commercial and/or recreational fishermen would dissipate any benefits. I saw no discussion of the current institutional arrangement in the fishery selected for application of the model.
2. As far as I could determine, equation 3 (trip demand) was never estimated. Instead, a stated-preference model was implemented that only partially accounts for changes in trip demand. Again, a bioeconomic model that doesn't explicitly model total fishing effort is not much of a bioeconomic model.

Comments on Session II

Cleaning Our Coastal Waters: Examination of the Benefits of Improved Water Quality

Nancy Bockstael

INTRODUCTION

The term "ecological benefits" often conjures up images of obscure and indirect pathways through which ecosystems affect humans. These are pathways that are difficult to define, and for which related behavior is difficult to observe. Yet water-based recreation, the target of much past non-market valuation activities, remains an important pathway through which ecosystem health affects humans. As such it deserves continued study.

The three preliminary analyses in this session are quite different in the commodity valued and the type of data relied on, but all three focus on measuring the benefits of water quality through traditional recreation pathways and all three use a random utility model framework to model choice and estimate welfare measures.

In what follows I will try to point out what I think to be some vulnerabilities in the current preliminary versions of these analyses. While my comments may seem diffuse, I'll attempt to organize them around two general themes:

- How is the environmental quality variable measured and how is it incorporated into an underlying model of individual preference revelation?
- Is the choice behavior underlying the use of the random utility model made clear and are welfare measures consistent with this model?

DEFINITION AND MEASUREMENT OF THE ENVIRONMENTAL QUALITY VARIABLE

Owens and Simon, '*The Value of Improvements to California's Coastal Waters: Results from a Stated-Preference Survey*'

The first of the three papers, the one by Owens and Simon, seeks a means of valuing water quality improvements in coastal waters. Contrary to what is implied in their introduction, there have been many previous attempts to do this for specific estuaries or other limited geographical extents, mostly using revealed preference data. But there is no systematic treatment of benefits from coastal water quality improvement that can be transferred to other areas and used to evaluate EPA's water quality policies at the national level. My sense is that a systematic, transferable type of analysis is the ultimate goal of Owens and Simon's work. Although this particular study targets the coastline of California only, this coastline represents a large share of the coastal waters of the US, making the geographical extent of this study quite a bit larger than most salt water recreational studies.

The intent is to estimate the benefits from coastal improvements through a stated preference exercise. Most of the paper describes the careful pre-testing process through which a well-designed survey has emerged. I have no particular expertise in survey design and will leave the critique of this survey to others, but one aspect of the survey troubles me. I am unclear as to environmental commodity being valued. The commodity might appear to be quite specific; it is an increase in the miles of California coastline that are rated "good" in terms of being safe for swimming, producing fish and shellfish that are safe for eating, or supporting habitat for "large numbers of fish, birds, mammals and plants."[1]

While there are clearly ambiguities in the last definition, the really troubling aspect of the valuation question seems to be that it does not specify *where* along California's extensive coastline these improvements would take place. This information would not necessarily be very important if the authors sought to reveal respondents non-use values for improvements in the health of ecological resources. And indeed this may be what is being sought in questions about increases in ratings of habitat. But the questions related to safety of fish consumption and ratings for swimming would certainly appear to relate to use. This interpretation is further supported by the large number of use-related questions asked in the survey, which suggests both to the survey respondent and to the rest of us that recreational *use* values are of interest to them. Yet how can a respondent give a credible use value answer to a question framed with no locational information. This is directly contradictory to the premise of travel cost models that use behavior in the face of varying travel costs to reveal demand curves whose estimation gives us consumer surplus answers. In that model, the distance to a recreational site represents a cost that cannot be counted in the surplus measure. The presence of travel costs plays a major role in the model and accounts for much of the resulting variation across people in valuation measures.

The authors ask follow-up questions about whether the respondent thought the improvements would take place in a specific part of California – and if so, where. This information may shed some light on what respondents were thinking when giving their answers and may even give the authors a way to untangle the problem. It is not so important that use and non-use values be estimated separately, but it is important that a cogent story of what is being valued can be told. For example, if people tended to respond that they did not think about where the improvements would take place, I'm not sure I would know how to interpret their bids. And if they responded that they thought these improvements would occur many miles from their home, then I would wonder if we were missing a portion of benefits attributable to use. Finally, if they assumed improvements would occur close to home, are we left with no measure of the benefits of

[1] The added miles are represented in terms of "percent increase" but the authors use this term loosely, no doubt in an attempt to make the question understandable. But it can easily convey the wrong idea to respondents. The authors appear, for example, to label a change from 40% to 50% of the coastline as a 10% increase. Perhaps wording this as an increase of 10 percentage points would be both more accurate and still understandable.

cleanup for non-locals? Any effort that can be made to resolve this ambiguity in the location of clean-up will be well worth it.

Parsons, Helm, and Bondelid, '*The Recreational Benefits of Improvements in New England's Water Quality: A Regional RUM Analysis*'

A second paper in this session, the one by Parsons, Helm, and Bondelid, is a heroic attempt to use existing information from past surveys to value water quality improvements in New England. I use the term "heroic" because this is a very difficult thing to do, and yet the returns from doing it well could be enormous. The potential contribution of this paper is in developing a means to use the data from the 1994 National Survey of Recreation and the Environment and water quality simulations from the National Water Pollution Control Assessment Model of RTI to generate systematic and comparable benefit estimates of water quality improvements for water resources throughout the U.S.

In this paper, recreationists are viewed as choosing among recreation sites represented by all lakes and stretches of riverfront and coastline within 200 miles of their home. Four water quality measures – biological oxygen demand, dissolved oxygen, total suspended solids, and fecal coliforms - are generated by the simulation model for each of the over 25,000+ sites within New England. Assuming such simulated measures are accurate, [2] we are still left with the question: by what means do recreationists perceive these water quality measures? Recreational modelers have long been concerned about possible discrepancies between the dimensions of water quality that can be measured objectively and those that people can perceive or learn about. Some signals may well connect (however loosely) the objective and perceived measures, but the form the connection takes must be thought through carefully. In this paper, the four objective measures are converted into one variable that takes on only three levels. This does not necessarily help the correspondence between objective measures and perception, since the thresholds chosen may have little to do with how people perceive water quality differences. The use of this one "tri-nary" variable is brought into further question, since it is considered equally applicable to swimming, fishing, viewing and boating decisions.[3]

Economists are continually reminded by statisticians and econometricians[4] that correlation is not causation. Put another way, unless we are fairly certain we have controlled for unobserved heterogeneity in our data, our econometric results may be reflecting the effect of omitted variables that are highly correlated with the variables of interest in our models. The paper by Helm, Parsons and Bondelid would seem especially vulnerable to this accusation. The alternative sites vary only in terms of travel

[2] We are told that the measures for coastline are likely inaccurate because the measures are extrapolated from the nearest river mouth. This will be especially troublesome for swimming which does not tend to occur in such areas and will usually underestimate water quality because pollutants from rivers will not yet have been diluted by ocean currents.

[3] This is in direct contrast to the Owens and Simon paper that attempts to convince people that different environmental quality criteria matter for water to be ranked safe for swimming, safe for producing edible seafood, and good for fish, bird, mammal and plant habitat.

[4] By this I mean the work often referred to as quasi-controlled experiments, matching, or exploiting regression discontinuities.

cost, the set of two dummy variables signaling whether the site is a lake, river or coastline, and the set of two dummy variables signaling the level of the 'tri-nary' water quality variable. One distance related variable and two categorical measures are hardly sufficient in describing the multiple differences in the vast number of lake, river and coastline recreational sites within 200 miles of any individual[5]. Given the size of New England, a very large proportion of the 25,000+ sites will be within 200 miles of most individuals. But the geographic size of New England is misleading, as characteristics of sites that can be expected to matter to people vary dramatically over its range, even holding the category (river, coast or lake) constant. Water temperatures and local amenities, to name only two considerations, will be drastically different over sites. How can we possibly interpret with any confidence the coefficients associated with the simple categorical water quality measures when so much is left out of the model?

The failure of attempts to model recreational decisions in the more logical nested framework, as well as the failure of more complete site descriptors to generate usable results, suggests a certain instability. It also suggests the likelihood that the model is missing something important. It would be especially illustrative if the water quality levels could be mapped. This might reveal the types of omitted variables (especially those that tend to vary spatially, such as water temperature, fish species, etc.) that need to be controlled for in making sense of this problem. With out a careful consideration of what is being left out of this model, we can have no confidence that the significant coefficients are reflecting any response to water quality variation at all.

Massey and Newbold, '*Valuing Water Quality Changes Using a Bioeconomic Model of a Coastal Recreational Fishery*'

The third paper, by Massey and Newbold, uses contingent rather than revealed behavior and draws on an already existing study rather than a new data undertaking. The particular appeal of this paper is its attention to the pathways by which changes in water quality affect recreational fishermen. In this sense, it is a particularly appropriate paper for a workshop on the Valuation of Ecological Benefits.

In this paper, the water quality variable of interest from the perspective of policy is dissolved oxygen (*DO*). In their conceptual model, the authors consider how water quality affects stock abundance (given population dynamics) and catchability at any site (given that fish may migrate to avoid areas with low dissolved oxygen). They also allow for the fact that water quality might directly affect site desirability. By giving careful attention to the biological modeling, interesting non-linearities and thresholds are induced so that dissolved oxygen measures affect recreationists' decisions in realistic ways. The result that *DO* appears only to affect fishermen through its affect on stock abundance has interesting implications. If this is true, then effects will only be realized in the long run and attempts to pick up such effects with a simple behavioral model including some simple measure of current *DO* linearly will miss the point. I do not have the expertise to

[5] Given the size of New England, all 25,000+ sites could be within 200 miles of some individuals and most individuals will have an enormous number of site alternatives defined this way.

comment on the quality of the biological modeling, but the spirit of this research seems to be just exactly what we need.

EXTRACTING WELFARE MEASURES FROM RANDOM UTILITY MODELS

The random utility model has become the workhorse of environmental valuation. These types of choice models are the rule rather than the exception in revealed preference as well as stated preference data analysis. The random utility model can be a very plausible model of behavior, since individuals often choose among discrete alternatives. In its simplest form, both estimation and welfare measurement are easy to accomplish, reducing barriers to its use. In fact, the random utility model has become so ubiquitous in the literature that I wonder whether it is not often treated too cavalierly.

All three papers in this session use a random utility framework, although one paper models stated preference responses, another contingent behavior, and a third revealed behavior. There is a tendency in these papers (as well as others in the literature) to reduce the underlying theoretical model's discussion to a boiler-plate presentation ending in the usual formula for calculating welfare measures from estimated coefficients. Paying little attention to the details of getting welfare measures from these models would be OK, if it were not for the fact that we know welfare measures in these models are sensitive to the details of the problem. Herriges and Kling recently compared welfare measures derived from a random utility model applied to exactly the same data but incorporating different functional forms and different variants of a measure of environmental quality. They also compared welfare measures across different linked models, again with different functional forms at the two stages. The results are quite startlingly different and suggest that the devil is definitely in the details.

With this is mind, let us quickly review the models estimated in the three papers. Owens and Simon estimate the parameters of a conditional indirect utility function based on stated choices among hypothetical programs that would improve different amounts of coastline in exchange for different tax payments. With parameter estimates in hand, the authors indicate that future welfare measurement will be based on the formula:

$$\frac{\ln \sum_j \exp(X_j^{\,*}\beta) - \ln \sum_j \exp(X_j^{\,0}\beta)}{(-)\beta_{tax}}$$

where the X's are explanatory variables from the random utility model, the β's are estimated parameters, β_{tax} is the coefficient on the tax variable, and X^0 and X^1 are the values of the explanatory variables given the status quo level of water quality and those resulting from projected improvements. The formula and definitions of the X's are difficult to square with the earlier definitions of the j subscripts which were defined as indexes of different programs (water quality improvements and public expenditures?). What is the summation really over?

An additional problem arises in the use of β_{tax}, the coefficient on the tax (i.e. cost) variable in the model. The authors refer to this as the marginal utility of income. The well-known formula for compensating variation in the context of a random utility model is really given by:

$$CV = \frac{\ln \sum_j \exp[v(y - p_j, q_j^{1})] - \ln \sum_j \exp[v(y - p_j, q_j^{0})]}{\beta_y}$$

where *v* is the conditional indirect utility function (conditional on the discrete choice made), q_j^0 and q_j^1 are the initial and subsequent levels of environmental quality in alternative *j*, *y* is income and p_j is the cost of alternative *j*. This is the definition of *CV* only if the errors are additive and Type I extreme value and the income minus price term enters linearly into the conditional indirect utility function. If the income minus price term does not enter linearly, then the welfare measure has no closed form solution (although it is possible, but difficult, to iteratively solve this problem.) Most important, the nature of the underlying random utility model is such that income minus price appears in the model as one term. And it is only because of this feature of the random utility model that the coefficient on price (or cost or tax payment) has the interpretation of the marginal utility of income. This fact accounts for its prominent place in the *CV* formula.

In their preliminary data analysis, the authors estimate a model with both price and income included separately. Space does not allow a complete discussion of the implications of this, but at the very least this compromises the interpretation of any measure such as the above since we have to ask: if the coefficient on price is (minus) the marginal utility of income, how do we interpret the coefficient on income? It may well be true that we expect substantively different behavior from different types of people and those types may be well proxied by income. But such a story requires telling and the source of differences in response needs to be made clear. If the different responses are truly due to income effects, then the simple linear form of the random utility model is inappropriate since it implies constant marginal utility of income over the range of the choices. We can't have the story both ways and some reconciliation is necessary. Admittedly the authors' analysis was purely preliminary and done without time for thought. Subsequent analysis will no doubt give much more careful treatment to the underlying theory, the underlying behavioral model, the role of income and the resulting welfare measures.

Interestingly, Massey and Newbold also include income separately from price in their model but interpret the coefficient on price rather than the coefficient on income as the marginal utility of income. Here again the underlying theoretical model is a boiler-plate presentation and not particularly relevant to the problem at hand. Massey and Newbold use a repeated nested logit model so as to be able to treat the responses to four different contingent behavior experiments in a consistent framework. Parameters are assumed to vary randomly across respondents (as in Train's mixed logit models) but to remain constant over multiple responses of the same individual. Since Herriges and Phaneuf have investigated this type of model with an error components interpretation, the authors may wish to compare their approach to that of these other authors.

While the idea of applying a repeated nested logit model to the contingent behavior data is an intriguing one, the authors realize that the data really will not support this interpretation. The repeated nested logit was developed as an internally consistent means of capturing the participation as well as the site choice dimension of the recreation decision. However, the contingent behavior experiment, which does allow the respondent to “opt out” of the choice experiment by taking no trip, is fundamentally different from a recreationist’s day-to-day decision about whether to take a trip or not. Treating the contingent behavior responses as if they mimicked people’s day-to-day recreation decisions is misleading. The contingent experiment contains an implicit assumption that the individual would be free to pursue recreation on every choice occasion. No information about weather, work obligations, etc. are explicitly or implicitly introduced.

More attention to the underlying theoretical model is given by Parsons, Helm and Bondelid who base their linked model on an approach originally suggested by Hausman, Leonard and McFadden. In this model a random utility model is first estimated and then a price index of sorts is calculated using the standard log sum formula divided by the coefficient on price. This pseudo-price index is included in a count model (Poisson model) of number of trips. It is now well-known that none of the linked models are internally consistent – they do not derive from a consistent theoretic model of utility maximizing behavior. Since the few models that are internally consistent have other drawbacks (e.g. inflexibility of functional form choice and difficulty of estimation of the Kuhn Tucker model), this is not necessarily a bad choice of approaches as it might approximate behavior if not be exactly utility theoretic. While linked models of this sort have some appeal, deriving the welfare measure from the participation decision rather than the random utility portion of the model is perhaps less appealing. As Smith and Herriges and Kling have shown, the pseudo-price index is not a price and can not be treated as such in the count demand function. Therefore, a consumer surplus measure that must necessarily be based on such an interpretation of the price index is questionable.

CONCLUSIONS

All three papers have the potential to contribute to the literature. Each has a particular strength and each is a good beginning in analyzing benefits from water quality improvements. In finishing these analyses the authors have several areas in which they could make their papers stronger. One has to do with improving the link between recreationists’ water quality perceptions on the one hand and objective measures that policy changes are likely to affect on the other. Clearly this link induces more vulnerability in revealed than stated preference analyses, but even in the context of contingent valuation or behavior, one needs to be sure that the policy variable links clearly to a commodity the respondents are understanding and bidding for.

So much attention needs to be paid to the careful acquisition of the considerable data needed to accomplish these studies that the last steps of the benefit measurement sometimes are taken for granted. But in the end, benefit measures depend on the details, and a cavalier treatment of the random utility model will lead to indefensible welfare measures. The fact that - unlike price changes, for example - welfare consequences can never be observed even after the fact places a heavy burden on welfare economists to get the underlying story right.

References:

Hausman, J. G. Leonard, and D. McFadden. 1995. “A Utility-Consistent, Combined Discrete Choice and Count Model: Assessing Recreational Use Losses Due to Natural Resource Damage”. *Journal of Public Economics*, Vol 56, pp 1-30.

Herriges, J. and C. Kling. 1999. “Corner-Solution Models of Recreation Choice.” In J. Herriges and C. Kling (eds.), *Valuing Recreation and the Environment*, Chapter 6, pp 163-197. Edward Elgar, Northampton, MA.

Herriges, J., and D. Phaneuf. 2002. “Inducing Patterns of Correlation and Substitution in Repeated Logit Models of Recreation Demand.” *American Journal of Agricultural Economics*, Vol 84 (4), pg 1076-1090.

Summary of the Q&A Discussion Following Session II

Scott Swinton (Michigan State University)
Directing his question to Matt Massey, Dr. Swinton referred to the structure of the bioeconomic model that was used, which, "like any system model, has boundaries." He wondered, "If we were to try and open the boundaries a little bit further and understand what drives the driving variable of your model, which was dissolved oxygen, I'm curious about how changes in agricultural management can change water quality rather than just saying 'Okay, suppose we have bad water quality, then what does it cost us?'" Dr. Swinton closed by asking, "How would you extend that?" and "What affects dissolved oxygen and water quality?"

Matt Massey (U.S. EPA, NCEE)
Dr. Massey acknowledged that the model currently "doesn't deal with that at all—we just sort of *assume* water quality conditions and *assume* policy somewhere else affects them and makes those changes, and we just run the changes through." He continued, "It's conceivable we could add another step that would model agricultural use and residential and commercial development that would allow us to simulate changes in dissolved oxygen and runoff and those types of things." Admitting that "it would be a great thing to do," Dr. Massey went on to explained that they "had a terrible time getting the data together" just to do what they did. He said that with the recreation data they used, they had to go with stated preference data rather than with the revealed preference data they actually preferred because they just couldn't get people to cooperate in providing those data. He clarified that Steve Newbold, one of his co-authors who was "the ecologist of the group, had to throw his credentials around" to get much of the data that biologists were reluctant to share. He closed by reiterating that the idea, though "possible" and "interesting" is "kind of beyond the scope of what they're doing now."

Alan Krupnick (Resources for the Future)
Directing his comment to Nathalie Simon and Nicole Owens, Dr. Krupnick stated, "Some of us who are working on stated preference techniques have two issues that come up with your work, that we all wrestle with as well. One is the units of measurement for these attributes." Citing specifically the unit of "percentage of miles that are changed," Dr. Krupnick wondered whether, using information from focus groups or other observations they have, the researchers "could comment on that particular measure—whether you tried others—and how to communicate these things to people." He added that, "Some of Nancy's [Bockstael] comments get to this as well, about sort of the location of where these are and so on."

Dr. Krupnick went on to say, "The second part that struck me is I think that you have a very abstract program for actually bringing about these changes, and I'm wondering if people really were willing to *accept* that. It would be a *good* thing if they did, because it's hard to come up with a program that is kind of transparent to people and doesn't get in the way of their responses and meet their protests. But I'm wondering if people really did accept that because in all these programs you've got switches—you know, some help swimming more than help aquatic health, and so on. I wonder if you get much push back from people about: What are these programs? What are their components? How do we know they'll work?"

Nathalie Simon (U.S. EPA, NCEE)
Dr. Simon addressed Dr. Krupnick's first comment by saying, "Basically, we *did* try other units of measure. We started off looking at the number of miles, and then we also tried in other versions of the survey both number of miles and percentage change." She said they found that "people really were focusing on the percentage change and seemed to like that better."

In addressing the second comment, Dr. Simon said she thought that for the most part people were willing to accept the abstract program. She added that funding issues seemed to be the more critical concern—"people didn't want higher taxes for any reason." Dr. Simon closed by saying they are still working through that and still need to clean up their data.

Nicole Owens (U.S. EPA, NCEE)
Dr. Owens said, "I think Nathalie is right—most people did seem to buy the scenario." She expounded that in the survey and in their one-on-one interviews, they made an effort to ensure that people understood that "sometimes it's different kinds of contaminants that might be affecting one of these types of use." She concluded by saying that "it was easy for people to see that it's possible to reduce or eliminate a contaminant that affects whether or not they can swim" in a particular area or to conceive of some other single-issue program, but they were not readily able to conceive of multi-concern programs, such as those that also looked at fish population or some other ecological factors.

Spencer Banzhaf (Resources for the Future)
Dr. Banzhaf requested "more discussion related to Nancy's [Bockstael] comment about putting income and cost in the model separately," and he stated his support for this approach. He continued, "It seems to me there are two ways to think about what's going on here," and he used a corollary example of modeling restaurant choice to make his point. "We see richer people going to more-expensive restaurants and different kinds of restaurants than we see poorer people. One way to model that is that rich and poor people have different marginal utilities of income—rich people can afford to go to these more-expensive types of restaurants. And so we'd model that in a certain way in the structural model, by putting in that your income affects your restaurant choice. Another possibility is that there's heterogeneity in tastes for different kinds of restaurants, and there's something about class, as well as maybe race, or education, or other kinds of internals we see—something about class and income that has certain kinds of people sorting to different kinds of places. And that piece is just really a taste shifter." Dr. Banzhaf closed by clarifying that he was not disagreeing with Nancy's broader point that

“the devil is in the details and you have to pay attention to how you model it,” but it seems to him that the choice isn’t quite so obvious.

Nancy Bockstael (University of Maryland)
Dr. Bockstael stated that had she had more time she “would have gone into this very topic.” She said she agrees completely that “income shows up as significant in a lot of these models, in the sense that it’s really proxying for education and preferences or something like that. Moyer really has done some nice work on this, where he has viewed it as that. He has treated people in different income ranges and allowed the coefficients on various things to change in those ranges, so that you don’t have the problem of introducing income continuously in a model where it’s not going to make any sense. You know, you can’t start with a utility theoretic model and then decide you’re going to just throw whatever in. You have to have a way of introducing that that makes sense, and I think that the best way that it makes sense, from my perspective any way, is the way that Moyer uses it—shifting the parameters discreetly but allowing marginal utility to be constant over large ranges so that it’s only a glitch at certain thresholds. But, I say it’s proxying something else.”

Patricia Casano (General Electric Company)
Prefacing her comment by clarifying that she is “*not* an economist,” Ms. Casano addressed Nathalie and Nicole and said she was “struck by the results you put up indicating that 25% of the survey respondents had used coastal waters for recreational swimming; 10% had used coastal waters for fishing and that sort of thing.” She said that she wasn’t questioning whether the numbers were right or not but stated that they “seemed *really low*” to her and she was surprised by the indication that “less than a majority, generally speaking, of the survey respondents used coastal waters for any of the scenarios that you were looking at.” Ms. Casano closed by asking, “Does *that* play into your analysis of the results at all, and if so, how?”

Nathalie Simon
Dr. Simon responded by clarifying that “those variables were measuring recreation over the last twelve months” only, not over a lifetime. However, she allowed that they still might appear low to Ms. Casano. She continued, “We *did* include them in the initial regression that we ran, so it does figure into that—it was part of that conditional logit model. But, again, we’re still exploring a number of different functional forms, and we still have a lot of work to do in terms of our analysis.”

Kerry Smith (North Carolina State University)
Dr. Smith expressed a multi-faceted concern with the issue raised earlier in Spencer Banzhaf’s comment. He said, “The first issue I want to raise is: What income? In the second two papers, if I remember correctly, we had a repeated mixed logit and a standard model. Well, when we repeat, that implies a certain number of choice occasions that are

embedded in the no trip alternative. So, implicitly, we have to ask ourselves: What is the relevant budget for each of those *created* choice occasions? And, I don't mean these comments to be critical, because I've done the same thing—I don't know what to do. But we've got a question of *total* income versus *relevant* income for the choice that you're representing, and *that's* at *least* as important as how you introduce the income in the first place, as well as assuming how many *choices* there are—and we just fabricate that, typically."

Dr. Smith continued with his second point: "If we're going to say: Okay, income proxies for something else about people, then we've got to begin to question: What the heck is the travel cost coefficient? Because the way we can interpret that as the marginal utility of income is based on a prior set of restrictions that we've already imposed to recover that, so we're still in the scoop, I think."

"Of course the third issue that arises in these sorts of models is the link between time horizon of choice and the implicit substitution assumptions we're making as we evaluate those. This bears a little bit on what Bob [Leeworthy] was talking about: As we move to other kinds of trips, we're going to get more and more into these kinds of issues. Now, I don't think any of us has the answers, and we're not going to get the best model—the question is judging how *bad* do we get, which is essentially, I think, what Nancy's comment was: When we array all these models, how do we make a judgment about what's important and what is not important for the use of the model?"

END OF SESSION II Q&A

Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

PROCEEDINGS OF

KEYNOTE ADDRESS: THE ECONOMICS OF ECOSYSTEM SERVICES

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

October 26-27, 2004
Wyndham Washington Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Cynthia Morgan and the Project Officer, Ronald Wiley, for their guidance and assistance throughout this project.

DISCLAIMER

These proceedings are being distributed in the interest of increasing public understanding and knowledge of the issues discussed at the workshop and have been prepared independently of the workshop. Although the proceedings have been funded in part by the United States Environmental Protection Agency under Contract No. 68-W-01-055 to Alpha-Gamma Technologies, Inc., the contents of this document may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

TABLE OF CONTENTS

Summary of Keynote Address: The Economics of Ecosystem Services

Geoffrey Heal, Columbia University

Dr. Heal opened by saying, "I want to talk about what I think of as an emerging area, which I've loosely called "The Economics of Ecosystem Services," not because that's a really snappy title but because I couldn't think of anything better. It's an area that's attracting an increasing amount of interest both in academia and in policy circles, and you've seen some evidence of that already so far today." He referred particularly to three governmental committees that are examining the general area of economics in ecosystems, two internal to EPA and one external at the National Academy of Sciences, about which Mark Gibson had already given a presentation (see Session I). Dr. Heal said he has had the pleasure of serving on two of those three committees that are at work in this area of increasing concern.

Reiterating that this is basically a relatively new area of focus, Dr. Heal stated that it dates back, as far as he can see, "to 1997 with the publication of a book, edited by Gretchen Daily in the biology department at Stanford, called *Nature's Services: Societal Dependence on Natural Ecosystems*." Saying that "interaction between economics and ecologists goes back further than that," he cited the *Journal of Ecological Economics* and "the Beijer Institute in Sweden, which also works on the economics/ecology interface and has been doing this since about 1990. However, neither the economics community nor the Beijer group, of which I'm a part, really focused on the concept of ecosystem services, and I'm going to argue during my talk that that concept of ecosystem services is really a very important one and is a rather powerful organizing concept. The introduction of the concept has really made a difference in the way we think about things."

Dr. Heal went on to quote the following lines spoken by Teddy Roosevelt nearly a century ago: "The nation behaves well if it treats natural resources as assets which you must turn over to the next generation increased, and not impaired, in value." He went on to ask rhetorically whether this was "the first statement of the importance of strict sustainability—by a Republican president no less?" (laughter) He continued, "It's clear that Roosevelt, interestingly, was thinking about natural resources as assets, and in fact, as a form of capital, and that's an issue I want to come back to." Dr. Heal stated that this new field of ecological economics is "possibly even a new paradigm," although he uses that term "with great caution because it's hugely over-used, in many ways."

He continued by enumerating the various components of "society's capital": physical capital (buildings, computers, etc.); human capital; intellectual capital; social capital; "and last, but not least, natural capital." Dr. Heal said these all represent assets that yield a return to society, "and they're all assets in which we can make an investment."

Focusing on the concept of natural capital, Dr. Heal sought to identify its components. He stated, "Certainly since Hotelling's 1931 paper on the Economics of Exhaustible Resources we've known that mineral resources are a form of capital. What Hotelling did in that 1931 paper was essentially to take a capital theoretic approach to the management of natural resources, though I guess "capital theoretic" wasn't a current phrase in 1931." He went on to remind the audience that the famous Hotelling Rule that came out of that paper, which says that "the rate of capital gain on a resource should equal the rate of interest, is essentially an asset management rule—a rule for efficient management of assets which, incidentally, was developed by those researchers way before any general theory of efficient management of assets." Dr. Heal identified "environmental systems, as a whole" as another more-intangible type of important natural capital asset, and he gave the example of lakes and rivers that are used to generate hydropower. He cited Sweden, in particular, which gets "about 75% of its electric power from hydroelectricity, so the Swedish system of lakes and rivers is a massive public utility and represent a large fraction of Sweden's natural assets in the public utility area."

Dr. Heal said, "Extending this line of argument more generally we can think of ecosystems as assets, as part of our natural capital stock." He reiterated that all forms of capital provide services—they provide a return, "and the return that natural capital provides is the services of natural ecosystems." He explained, "Now, there are two concepts coming together when I make that statement: there's the concept of natural capital from economics, and there's the concept of ecosystem services, which basically comes from ecology. Ecologists, I guess, developed this concept of ecosystem services as a way of characterizing *how* ecosystems matter to society, what *services* ecosystems *provide* to society." Dr. Heal went on to identify some typical classifications of the nature of some of these services provided to society by ecosystems: climate stabilization, pollination and other assistances to food production, waste decomposition, recreation, etc. He added, "There's a review of these in the National Academy of Sciences' volume that Mark (Gibson) was talking about earlier," and went on to summarize that "ecosystem services are the return on natural capital, and natural capital essentially consists of ecosystems. The economic value of natural capital is obviously the present value of the ecosystem services it provides."

Stating that this idea could be taken in several different directions, Dr. Heal clarified, "What I want to do for the bulk of my talk, actually, is talk about the National Academy of Sciences report and how it develops some of these ideas, but let me first take a little digression into the area of sustainability, which has been an area of interest to me for quite a long time." Allowing that there are a number of different ways of defining sustainability, he said that most of the definitions "revolve around the concept of natural capital, so I'm just trying to indicate that the concept of natural capital has applications in a variety of areas. One way of defining sustainability is to say that sustainable income is the interest on capital stocks—all of the capital stocks taken together." Dr. Heal added, "That's a Hicksian concept," and reminded the audience that Hicks defined income as "the maximum amount you can spend today consistent with spending the same amount indefinitely into the future." He pointed out that "There's a concept of sustainability right there in that concept of income that Hicks developed back in the 1930's, but if you think about what that means, it really means that income is interest on capital, broadly defined."

Exploring more definitions of sustainability that support both weak and strong versions of sustainability, Dr. Heal pointed out one in which "the weak version of sustainability is policy that keeps the *total* value of *all* capital constant—preferably increasing, but at least constant. So, non-decreasing value of *tota*l capital stocks is what is sometimes described as weak sustainability. Non-decreasing value for natural capital *alone* is what is sometimes referred to as strong sustainability." He stated that he didn't wish to go into the merits or demerits of the various definitions, but was "just trying to emphasize the point that natural capital, whose value is the present discounted value of ecosystem services, is a key concept in discussions of sustainability." He also added that "one of the interesting consequences of keeping a non-decreasing total value for all capital stocks is that it implies the present discounted value of future welfare is non-decreasing."

Returning to the issue of ecosystem services, Dr. Heal commented that ecosystem services are frequently public goods (such as those he had mentioned previously: climate stabilization, pollination, etc.). Furthermore, he stated that "a great majority of them are non-market goods, so when it comes to valuing them, this raises some questions, but questions that are fairly conventional in the field of environmental economics—questions which are, in fact, the lifeblood of environmental economics." He pointed out one aspect of ecosystem services which is "certainly rather distinctive, and that's that there is frequently a considerable amount of uncertainty about the functional relationship between the *state* of an ecosystem and the *services* that it provides."

Switching to a discussion of "the National Academy of Sciences report (the National Research Council report) and how it addresses some of these things," Dr. Heal said that the report starts off by "classifying the various ways in which ecosystems and ecosystem services can have value." He described this as a "conventional classification into use and non-use values, with a sub-classification of the use values into direct and indirect values" and added that "there's a two-way classification which is central to the report. One is a classification of the types of values that ecosystem services can have. The second, obviously, is a classification of how you can go about valuing them." Emphasizing that this is all fairly standard economics, he identified the optional ways to value them: "with revealed-preference techniques, with stated-preference techniques, or with some combination of the two." He added that in writing the report, he and the others spent some time "trying to work out when one or the other is more appropriate and which of the various techniques is more appropriate for which particular types of services." He also stated that "the discussion of these issues in the report does address some of the issues raised by the NOAA Blue Ribbon Commission on Contingent Valuation and some of the critics of the CV approaches there. I don't think we have anything enormously original to say about that, but I think there's quite a clear integration of the literature on that within that section of the report."

Dr. Heal identified one of the key questions that they focused on in the report is "how the services provided by an ecosystem (i.e., the services provided by natural capital) change as the ecosystems are impacted by human activity." He presented the example of how the extent of mangrove swamps and other types of coastal wetlands affect the productivity of offshore fisheries and identified the pertinent questions as: "What *exactly* is the functional relationship there—how much will a change that we make in the extent of coastal wetlands affect fisheries and on what sort of timescale?" As another example, he brought up an issue that he has been involved with: New York City's decision to conserve the Catskills watershed. The primary question they have dealt with here is: "How does the extent of a watershed and the nature of the vegetation in that watershed affect the watershed's ability to provide ecosystem services?" He identified the two "critical ecosystem services" that most watersheds provide as water purification and stabilization of stream flow and said, "If you're thinking about the conservation of a threatened watershed because of the value of those services, then it's actually quite important to have some understanding how different ways of using that watershed and different levels of human impact on that watershed will affect the provision of those services." Ideally, he said, you're looking for some kind of functional relationship between the state of the watershed and the services it provides.

Dr. Heal went on to say that "we don't have to answer that type of question if all we want to do is to value the current services of ecosystems, but if we want to value *changes* in the services that result from extended human activity or from policy intervention, then we *do* have to answer these sorts of questions about what's the nature of the link from the physical characteristics of an ecosystem and the extent of the ecosystem and the human intervention in the ecosystem through to the services that it provides." For emphasis, he repeated, "If we want to value the *change* in natural capital which comes from the destruction or the conservation of a system like a watershed or a wetland, then we have to be able to answer those kinds of questions." He went on to state that "the biggest challenge that we face here is linking changes in the bio-geo-chemical state of an ecosystem to a change in the service flow," and he said that the NAS report pushes quite hard for more of the integrated economic and ecological modeling that is required to address this.

He continued, "What we really need here, ultimately, is what I might loosely call an ecological/economic production function, which is a function that has ecological variables as its domain and economic variables as its range. Basically, you would then perform economic analysis on that production function—you want to be able to differentiate that production function and find the marginal productivity of this type of change in the vegetation, this type of change in the extent of the area, etc." Dr. Heal stated that with this marginal productivity, you could then conduct policy analyses. He went on to explain that ecologists characterize ecosystems in terms of their structure and their functions, and he clarified structure as meaning "a description of the things that are in it—the species, the number of each species, the structure of the soil, the climate, the vegetation, and things like that." He clarified functions as "the flow of energy through the ecosystem, the productivity of the ecosystem, and a range of variables like that" and he said that "the ecosystem, acting through its structure and functions, produces ecosystem goods and services, which are of importance to humans. As we said before, those services have use and non-use values, consumptive and non-consumptive uses and so on. Then, of course, human activities, in principle, have an impact on the structure of the ecosystem and therefore affect the ecosystem services."

"What we really want to be able to do is to go right through that system from the top down to the bottom and say how a human action will affect the structure and function of an ecosystem and, in turn, affect the extent of the goods and services provided, and therefore the value of those goods and services provided. Then you can use that calculation in a cost-benefit analysis to compare it with the alternatives available." Dr. Heal admitted that this can be quite a complex thing to do, and it isn't easy to link the economic and ecological models. He characterized ecological models as having "a habit of being fairly complex," often involving non-linearities, thresholds, and irreversibilities. He said that although these complications also existed in economic models, they seem to be "more dominant and more central to the true characteristics" in ecological models.

To provide an example of "what you run into when you try to do this type of stuff," Dr. Heal brought up the case of Lake Mendota, a lake beside the campus of the University of Wisconsin-Madison, which he termed "the most widely studied lake in the world, by far." He cited studies that looked at the eutrophication of the lake and estimated that 70% of the fertilizer applied to the farmland surrounding the lake actually ends up in the lake. The high level of phosphorous in the fertilizer causes the lake "to sort of switch states, biologically speaking, and become eutrophied. There's a huge reservoir of phosphorous in the sediment at the bottom of the lake, and under certain conditions this phosphorous is released into the lake water, causing a sudden pulse in the water's phosphorous level." He went on to explain that while the amount of phosphorous leaving the lake by means of an outflowing stream is directly proportional to the concentration of phosphorous in the lake, the inflow is more complicated. There's a basic rate of phosphorous inflow, which is set by the rate of fertilizer use by the farmers on the adjacent land and the rate of rainfall, but "once the concentration of phosphorous in the lake water reaches a certain critical level, phosphorous is released from the sediment into the water and you get a sudden increase in the rate of phosphorous inflow into the lake because of that. So, you end up with a sort of S-shaped relationship between phosphorous concentration and phosphorous inflow because of that pulse."

Dr. Heal went on to identify different equilibrium points along the relationship curve. In particular, he pointed out a lower point, at which the lake was healthy and usable, and a higher point, at which the lake was eutrophied. He pointed out that a sudden heavy rainfall can "kick" the phosphorous concentration from the lower, normal equilibrium value up to the high-concentration equilibrium value, where the lake is eutrophied, and it can be very difficult to move the phosphorous concentration back once it has been elevated in such a way. He concluded, "The point here is not to give you lectures on lake ecology, but to illustrate the complexity of these ecological models and the complexity, therefore, of the linked economic/ecological models, because the services that this ecosystem provides depend on which of these equilibria we're at. At the lower level, it can provide quite a high level of services; at the higher level, on the other hand, it provides a much lower level of services. The relationship between the inputs to the system and the ecosystem services it provides is actually given by a quite complex dynamic process where what's happening today depends not only on the inputs today but on a whole history of past inputs. This makes it quite difficult to write down the kind of production function I was describing before, and in ecology this kind of thing is quite common."

Dr. Heal provided another example based on the responses of watersheds to oxides of nitrogen, citing a study done on the Catskills by researchers at the Institute for Ecosystem Studies. In this situation, the water bodies' natural ability to buffer the effects of the deposition of oxides of nitrogen keeps the chemistry of the water at a steady state until the buffering capacity is exhausted—then there is a sudden change in the chemistry of the water, producing a relationship between the inputs and the outputs which is highly non-linear and which also depends on the history of past inputs rather than just on current levels of inputs. He summed up the situation by saying, "While I think we definitely need to link the economic and ecological models, it's complicated and it's understandable that it hasn't been very extensively done to date. There are a small number of good examples, but that number really ideally should be much greater."

Dr. Heal commented that Chapter 5 of the report presents some of the examples he has referred to and pulls together "a whole range of case studies which try to integrate ecological and economic thinking in the valuation of ecosystem services." He further clarified that the chapter begins with "some relatively simple cases involving a single service provided by an ecosystem—the decision on policy issues is made on the basis of a single service, usually something to do with water," for example drinking water, flood control, and fisheries. Then the report goes on to look at more complicated examples representative of ecosystems that provide many different services "all of which matter for the policy decision, and therefore you have to worry about valuation of *all* of the services and about the impact of human activity on the provision of all of the services." Dr. Heal stated that there are some "really quite good case studies" that focus simply on single-service situations, but when you progress to the more common multi-service situations "there is regrettably a paucity of really well-worked case studies." He cited the Lake Mendota example as one that "has been very well worked with some really effective integrative studies."

Saying that the last topic he wanted to address was "the issue of uncertainty," to which an entire chapter of the report is devoted, Dr. Heal said, "I think it's implicit in what I've said so far that in any attempt to link economic and ecological modeling there will be a significant level of uncertainty in the final output." Though this is always the case in the statistical analysis of economic studies, he said it's "particularly pronounced" in the type of situations being discussed. He stated that's one of the reasons why in the report they emphasize the need for a sensitivity analysis, and they recommend "both conventional sensitivity analysis and also Monte Carlo analysis when the data are sufficient and the opportunities are available for that."

Dr. Heal said that in the report they also "talk at some length about option values, which are very important in this context." This is because we're dealing with ecosystems in which there are "potentially significant irreversible changes" due to human activity while at the same time being uncertain about the consequences of the changes. However, over time, we may learn something about these consequences. As Dr. Heal stated, "That's a classic situation for the existence of a quasi-option value." He explained, "Quasi-option values (or just option values, for simplicity) are associated with situations where there's a potentially irreversible change and you don't know the full consequences of that change although you may learn about the consequences of that change over time. Then what the theory of option values tells you is that there is a real merit, or advantage, to maintaining a flexible stance and using the available time to learn more about the importance of the system that you're thinking about conserving or changing." Dr. Heal said he and his colleagues noticed that "there are actually no studies at all of the significance of option values associated with avoiding irreversible changes in complex ecosystems." He added, "Let me emphasize the issue again, just in case I didn't make this clear: When you're looking at the costs and benefits of changing an ecosystem and making potentially irreversible changes, then on the benefits side associated with conserving the system you should enter a number which reflects this option value, a number that reflects the fact that if you conserve the system you can, in the future, revisit the decision on whether to damage it or not when you have better understanding of the consequences of that. That's what we call the quasi-option value—that's what Arrow and Fisher first analyzed in the QJE [*The Quarterly Journal of Economics*] paper back in the 1970's."

Dr. Heal went on to say that none of the studies cited in the report look at option values at all, and he added that he is not aware of any attempts by researchers in the field to compute option values for their ecological/economic studies. Stating again that he believes this is an important area for empirical research, he said it has left "a big gap in our understanding of some of the numerical issues in the conservation of these ecosystems." He added that when you talk about this type of uncertainty, ecologists always raise the issue of adaptive management, which means "managing an ecosystem, if it's possible to control it in some sense, in such a way as to actually *learn* about its behavior—in effect, experimenting to some degree with the ecosystem so as to get more information about the parameters of the system and how it responds in various ways." Dr. Heal noted that the issue of adaptive management is dealt with in the report and went on to say that from an economic perspective it is interesting that "there's an interaction between this ecologist's concept of adaptive management and the economist's concept of option value." He clarified by stating that "one of the things that gives a flexible stance an option value in the face of a potentially irreversible change is that if you postpone making the change, you get a better estimate of the value of making or not making the change. If you can actually experiment through adaptive management, you can potentially increase the value that you get from learning in a situation like that, so there can be an interesting positive interaction between option values and adaptive management."

A concept that "comes up naturally when you're talking about uncertainty in this context," and one of the issues that Dr. Heal and his colleagues "discussed at some length in the report is the issue of the precautionary principle." He briefly reviewed the history of this principle, which was advanced in the Rio Declaration in the early 1990's, became commonplace in European legislation on environmental conservation, and is often cited by NGO's as an argument for not making certain types of change. Dr. Heal said, "I have to say that, potentially slightly controversially, the committee saw little value added in the precautionary principle. It seemed to us that many of the issues that motivate people to talk about the precautionary principle and lead them to *advocate* the precautionary principle *are in fact* actually adequately captured in concepts that economists already have—namely the concepts of risk aversion and option value." Dr. Heal said, "If you approach a decision from the perspective that society may be very risk averse, and particularly may be very risk averse about making irreversible changes (and this is captured in the concept of option value), then I think actually there's little value added by using this so-called precautionary principle. Much of it is already there in the body of economic thinking about decision-making under uncertainty, but we haven't done a terribly good job of articulating that connection."

Dr. Heal returned at the end of his talk to why he believes it's interesting and useful to think in terms of ecosystem services. He believes that the ecosystem services approach gives researchers a better handle on understanding why the conservation of natural environments matters from an economic perspective. He said there are currently "some big shortcomings in the way we go about this." He acknowledged that "we're very good at talking about why pollution is bad for people's health, and a lot of the ways in which we *pitch* the conservation of our natural environments is in terms of the impact on human health." He also stated that we know that people have a willingness to pay for conservation, for example on the issues of wilderness areas and threatened species, but he added that "we're not particularly good at actually articulating in detail to a skeptic *why* it *matters* that we conserve the natural environment and *why* it *matters* that we conserve threatened species."

Dr. Heal believes that "thinking in terms of natural capital, and in terms of natural capital as providing ecosystem services, which are a return on that natural capital, can give us a much better handle on explaining in detail why the conservation of the natural environment works." He said that in his view, "One of the ultimate challenges in this area is explaining why biodiversity conservation matters and why extinction matters. Almost all environmental economists are personally concerned about the extinction of species—it matters to most of you in this room that species go extinct." He raised the question: "Is this purely a moral judgment?—Is this purely an aesthetic judgment?—Or is there also a sense of an economic element in this as well?" He believes, "Thinking in terms of ecosystem services does *potentially* give you a handle for analyzing your concerns about extinction and about biodiversity loss in economic terms rather than in moral or aesthetic terms." Dr. Heal was quick to add, "I'm not undervaluing moral or aesthetic thinking at all, but it often doesn't have much impact on policy makers, I regret to say. Economic thinking, on the other hand, tends to have much more impact on policy makers."

In closing, Dr. Heal stated, "If you think about ecosystems providing services and about the range of the services provided as a function of the biodiversity inherent in those ecosystems and of certain species in those ecosystems being key to the way those ecosystems operate, then you can get a different model of why it matters to conserve species and to conserve biodiversity. That extra way of thinking—having that extra element in the economist's toolkit—I think is ultimately one of the most valuable contributions of this type of approach to environmental economics."

"Thank you."

Summary of the Q&A Discussion Following the Keynote Address

Nancy Bockstael (University of Maryland)
Dr. Bockstael commented, "Geoff, you had a slide in which you talked about the bio-geo-chemical changes that might happen in the ecosystem and how they might affect ecosystem services. There was quite a bit of detail on that slide, and then there was an arrow that went around the corner, and it sort of stood for feedbacks. I think this arrow hides a lot and raises an interesting question that EPA has asked me over and over again in my work on land use, which is: If land use change affects ecosystems, what are the feedbacks from the ecosystem back to human's decisions to change land use? My answer is that there aren't obvious feedbacks that affect the demand for land use change. The resulting ecosystem changes affect people through different pathways. The *ways* in which we *benefit* from some of the *improvements* in these ecosystems or that we *lose* from changes in the land use hit different people in different ways – through water recreation or storm damage, for example. But there a logical feedback mechanism that causes the land use change decisions naturally to adjust. We develop areas, we affect stream health, we affect stream geomorphology—but none of that feeds back on the demand for housing and the development decisions, so the public sector has a role here I guess. I'm wondering if this issue of that feedback arrow and that the feedbacks aren't clear came up in your discussions . . . and if they aren't clear, is that a pervasive thing—and if so, are there any indications for what we do in this area? I know that's not a very well-formed question, but . . ."

Geoffrey Heal (Columbia University)
Dr. Heal responded, "No, it seems a very *good* question, though it seems a very *hard* question—and a very *interesting* question. I guess part of what you're saying there—and I'm more re-phrasing the question than answering it, really—is that the impacts that you and I and others have on ecosystems don't come back directly to us." Dr. Heal said that, instead, our impacts "occur as external effects imposed on other people," who can potentially be a long way away. He used the example of people in New York City who "escape" on weekends to the Catskills and because of their activities while up there "impose a negative external effect on people a couple hundred miles away. You don't *see* it. So, one thing that comes out of this is that you *need* to *choose* the scale for decision making very carefully. A lot of land use planning in the U.S. is carried on at a very, very micro scale—and these data are too small to capture for many of these effects. So, that's another reason why I'm integrating the valuation of watersheds into a valuation of Chesapeake Bay, for example—it gives you a chance to operate on a scale big enough that you capture some of these effects and you can bring them back into your position paper." He offered the further example of another study he was involved with which looked at pollutant accumulations in the Gulf of Mexico that came primarily from the Mississippi River, representing a drainage basin of almost half the continental U.S.

He continued, "The arrow that you were talking about was really designed to indicate that human activity impacts ecosystems . . . and that impact is *not* well understood. Even if you *know*, for example, how much development has occurred in an otherwise pristine ecosystem, ecologists *can't* really tell us very much precisely about *how* that impacts the ecosystem's watershed population, for example. There's no simple functional relationship between the amount of pollutant in the Catskills and the quality of the water that New York City gets."

Dr. Heal concluded by stating that part of the underlying problem here is that "we just need a lot more research on *how* human transformation of ecosystems affects the services they can provide—but this has been a very complicated relationship" which is often not easy to see "because the cause and the effect are spatially quite separate."

Nancy Bockstael
Dr. Bockstael interjected, "I would add that sometimes they're *temporally* quite separate."

Dr. Heal
Dr. Heal responded, "Yes, you're quite right. With species extinction, for example, there are a lot of species around that the ecologists like to call the walking dead." He explained that these are species whose populations are low and population/genetics modeling indicates that they'll become extinct at some point "but they may be around another 50 or 100 years before the last one dies. So, there can be long time lags between the necessary conditions for extinction being in place and the actual extinction occurring."

Marca Weinberg (U.S. Department of Agriculture, Economic Research Service)
Posing a follow-up question to Dr. Bockstael's, Dr. Weinberg commented, "What we struggle with a lot is the linking question that you started with—how do you *link* policies and outcomes?—in particular, the value of changes in the natural environment that are *initiated* by the policies or that *might* be initiated by hypothetical policies." Saying that she agreed that bioeconomic modeling and process modeling are really critical to understanding these systems, she asked: "Since most policy is at the federal scale, how do you *design* data collection efforts or modeling efforts to allow an assessment of the benefits or costs of national-scale policies?"

Geoffrey Heal
Dr. Heal answered, "I'm not sure that the relevant policies are always at the federal level. . . . To the extent that the relevant issues are land-use issues, they are often very locally controlled, on a surprisingly small scale. That sometimes makes it harder rather than easier because if you want to control the management of a watershed and it's a large watershed, you may actually end up talking to 10 to 15 independent sovereign entities in order to get their perspective on that." Dr. Heal continued by saying that in his view, "that's actually a significant weakness in environmental protection. . . . it would be desirable to have land use decisions made on the basis of larger entities. Land use could *really* be managed that way because there's a significant influence that way—there's the potential for disaster, but there's also the potential for somewhat more straightforward solutions . . ."

Addressing the other issue that was raised concerning linking policies to outcomes, Dr. Heal commented, "The point I was trying to make for part of my talk was that the link between the physical nature of an ecosystem and the services it provides is very weak—we don't understand that well. It's partly a question of collecting data, but it's also a question of doing some modeling. There are actually quite a lot of data in the Heinz Center that Tom Lovejoy runs . . . a lot of data on the state of the U.S. ecosystems and the way these have evolved over time. But, no one has tried to map that into statements about services and to evaluate services to human communities. That remains to be done."

Marca Weinberg
Dr. Weinberg said she agreed, but she thinks "that's exactly the disconnect—the Heinz data, by-and-large, is national scale and so it's *not* very helpful in informing decisions that happen at the *local* scale. . . . We do have a lot of federal policies that affect resource usage." She concluded by saying that she believes we could benefit from "some deep thinking about how to develop models capable of informing those decisions."

Geoffrey Heal
Dr. Heal responded by saying some of that is being done in the area of non-point source pollution, a major source of impacts on ecosystems.

Sasha Sud (Ontario Ministry of Natural Resources)
Mr. Sud said that he is presently working on a project looking at road development and motors and how they affect ecosystem services. He stated, "Hypothetically, in trying to value the impact of developing a road and seeing the impact on ecosystem services, I'd say one of the services that we're looking at is water purification, and you're trying to value the impact of how much *less* water purification takes place when you develop a road over a wetland, for instance, and you disrupt the water cycle of that region. One of the ways to value it would be to see how much *less* water gets purified—put a value to it—and then value the ecosystem service based on the price of the water found in that region." Saying that this price differs by region, he wondered what would be a good way to put a value to an ecosystem service in a situation such as this.

Geoffrey Heal
Dr. Heal responded that "values of ecosystem services are invariably geographically specific," offering the comparison of the value of water in the Sahara versus the value in the Great Lakes area. . . ." He closed by saying, "If you can identify a relationship between road construction and the nature of the watershed services, I think you will have done very well. Of course, that's not an easy thing to do at all."

Avery Sen (National Oceanic and Atmospheric Administration)
Admitting that he is not an economist but is starting to work on the economics in social sciences, Mr. Sen addressed Dr. Heal saying he enjoyed the presentation and that it seems

"the conclusion that you draw, or what you observe, is that economics is slowly being integrated into the rest of the natural sciences—physics, chemistry, and biology. As a consequence, what I see is that there are going to be inherent limits to growth. There are some people, I suppose, who won't like the idea that there *are* limits to growth imposed by the physical world, and I'm wondering what obstacles you might see to your work" and how those obstacles might be overcome.

Geoffrey Heal
Dr. Heal responded, "I guess some bits of environmental economics are about the extent that we observe physical limits to growth. I think the standard economic response here is that if you price [changes focus here]—well, there are different types of growth: there's environmentally intensive growth and there's environmentally conservative growth. For instance, there are different ways of generating energy—there are those ways that are environmentally intensive and those that are not. Part of the problem we have at the moment is that we just don't price environmental services right. You know, for the type of growth that we have and the general type of economic activity we have, it's probably excessively intensive in the use of the environment and excessively intensive in the impact on the environment."

He concluded by saying, "I don't think that there are significant physical limits to growth that we're about to bump up against—that is, that we *have* to bump up against and we're *about* to bump up against—we don't *have* to. I think the reasons that we may possibly bump up against them is not that there are real constraints on growth but that we're simply not *steering* our growth in the right direction. . . . and we're not getting prices right—we're not *pricing* environmental services appropriately. . . . So, I don't see physical limits as being a real issue. What I see [the need for] is thinking more smartly and growing more smartly, just by considering environmental constraints."

Avery Sen
Mr. Sen clarified his position by saying, "I guess my question was more along the lines of what *perceptions* might be to limits to growth and what effects the perceptions may have as opposed to whether or not there will be limits."

Geoffrey Heal
Dr. Heal responded: "Well, a large fraction of the population receives no benefits whatsoever from growth, as far as I can see." [laughter] He stated that his concern was more with "getting people to start realizing that there *might* be limits to growth."

Clay Ogg (U.S. EPA, National Center for Environmental Economics)
Dr. Ogg commented, "One of the few successful T&DO's (time and displacement optimization) of an agricultural wathershed, where they actually are claiming that they reached their objectives, is in the Neuse watershed in North Carolina. They've basically tracked what it is that accomplished their objective and it seems to be buffers and following a nutrient recommendation, both of which would have been very relevant to the

example that you used here." He went on to say, "The USDA, in its new Conservation Security Program, pays farmers approximately 5% of their rent in exchange for adopting a set of practices that are geared to reach a certain watershed objective or a certain set of local objectives. It's a national program but it's keyed in to reaching what I think we could call an ecosystem objective. What's happening is that their people are identifying a very *small* set of changes that they ask farmers to make—very *focused*. . . . Your part of the job is very, very difficult. The choices that agriculture has in terms of practical options that they can actually carry out as part of the programs they have out there are very limited. So, I think that having the whole team together is kind of critical given the fact that, otherwise, the kinds of tasks you described here seem absolutely monumental. I think we have to ground it in terms of: Here are our choices—let's try to figure out what are the ecosystem benefits of carrying out what we can do here."

Geoffrey Heal
Dr. Heal replied, "I wasn't aware of that North Carolina case—it sounds interesting. It all sounds pretty similar to what is being done in the Catskills watershed. They're planning for . . . essential organic farming methods . . . and things like that. At some point it will be interesting, when we get enough data on these things, to use these as a study of what is the functional relationship between implementation measures like that and the impact on the water quality and the stream flow and things of that sort."

(Unidentified, U.S. Forest Service)
Stating that the U.S. Forest Service routinely gets hit by lawsuits and challenges regarding the studies they do and the documents they produce, he said he understands very well the complexity of mapping ecological impacts or landscape impacts into ecological outputs. He continued, "One of the things from your talk that I have a bit of a quantitative issue with is that for us (the Forest Service), I don't think it's a question of overvaluing economic outputs versus non-economic outputs—it's usually about jobs versus ecosystem services, and jobs in some markets constitute a non-market value if you look at it. My *main* question is: Given the complexity of some of these issues of trying to go through the whole contingent evaluation process or perhaps a cost-benefit analysis approach to decision making, there is an alternative model and that alternative model is public participation in a broader circle of choice model. It *can* incorporate ecosystem information into the social choice process. Given those two competing models, there might be ways in which they could support each other, but there also might be ways in which there apparently would be a conflict technological/technocratic models and social choice models. Have you guys looked at those issues?"

Geoffrey Heal
Dr. Heal answered, "No, we specifically *don't* look at those issues in the report because the mandate of the report was to look at the economic valuation of ecosystem services for use in regulatory evaluation, cost-benefit studies, and things like that. I'm aware of what you're saying—there are obviously two radically different alternative methods and . . ."

The Questioner
Interrupting, the questioner said, "Given the complexity of what you're talking about, especially when you're talking about project-level decision making and localizing the decision making process, what sort of implications do you think it has for the institutions?"

Geoffrey Heal
Dr. Heal continued, "I don't really see them as alternatives—I see them as operating together. One of the things that studies of the type I was talking about here do is they provide data for the political discussion and the political process. If there's a discussion about conservation of a particular wetland, and an economic study suggests this is very cost-effective or very cost-ineffective, then that study will impact the political discussion. At certain levels [of the decision making process], the economic analysis is dominant, but once you get to the very *top* of the decision making process it's almost always a social choice political process. At that point, the economic variables are influential—it becomes hard for politicians to argue against a very convincing economic case—but they're not determinant."

Kerry Smith (North Carolina State University)
Dr. Smith referred to Dr. Heal's comments on "quasi options" and questioned whether there actually had been a measure of quasi options. He said he felt the raw material was there, and he cited Eric Helm's talk from Session II, which involved a retrospective study which looked at scenarios designed to discover "what would happen *if* we did not take a particular action and what was the string of benefits that were associated with that action?" He said the reason he thinks that has the raw material to get at a quasi option value is because one has to "*pretend* that that decision would be irreversible—you can't reverse that outcome. That's one of the key elements—we want the *additional* speculative value of what we learn as a consequence of not taking irreversible action." He continued by asserting that in and of itself that ability to go back and to reconstruct "what the past might have been . . . doesn't actually help very much in thinking about *future* decisions"—it doesn't *inform* future choices. Dr. Smith then posed the question: "Could we take the existing information that we've already developed in a range of situations and *design* these scenarios in such a way that we could identify . . . the attributes of the uncertainty that's inherent in the decision process *for which we have already learned something*? Then we could go back and say, "Okay, these look to be important in that circumstance." He closed by saying, "That would not be a valuation exercise when you're talking to *any one person* buy it *would* be a *diagnostic* evaluation of decision processes—and it seems to me that's what you're calling for."

Geoffrey Heal
Dr. Heal responded, "Yes, that's a very interesting point—I'd have to think about that a little bit, but that's a very suggestive idea." He said they'd have to go back and pry up some data from 1972-1977, but judged that that would not be impossible.

Kerry Smith
Dr. Smith continued, "Look at the information *base* at the time the decision was made, and then *compare* that information base with what we learned as a consequence of the activity and then design all the different *attribute* sets that would characterize the uncertainty."

Geoffrey Heal
Dr. Heal responded, "You're right, it would provide us with data on the past choice, but to me it would be interesting just to get *some sense* of the order of magnitude of these option values. One of the things I find frustrating is not knowing whether these are negligible or potentially quite significant, and I don't actually even have an intuition on that myself. So, that type of exercise would be useful for that purpose."

END OF KEYNOTE Q&A

Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

PROCEEDINGS OF

SESSION III, PART 1: KEEPING WATER FRESH: THE VALUE OF IMPROVED FRESH WATER QUALITY

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

October 26-27, 2004
Wyndham Washington Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Cynthia Morgan and the Project Officer, Ronald Wiley, for their guidance and assistance throughout this project.

DISCLAIMER

TABLE OF CONTENTS

Recreation Demand Using Physical Measures of Water Quality[1]

Kevin J. Egan, Joseph A. Herriges, and Catherine L. Kling

Department of Economics, Iowa State University

John A. Downing

Department of Ecology, Evolution and Organismal Biology, Iowa State University

August 13, 2004

[1]Funding for this project was provided by the Iowa Department of Natural Resources and the U.S. Environmental Protection Agency's Science to Achieve Results (STAR) program. Although the research described in the article has been funded in part by the U.S. Environmental Protection Agency's STAR program through grant (R830818), it has not been subjected to any EPA review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

Abstract

This paper incorporates a rich set of physical water quality attributes, as well as site and household characteristics, into a model of recreational lake usage in Iowa. Our analysis shows individuals are responsive to physical water quality measures and WTP estimates are reported based on improvements in these measures.

1 Introduction

Over three decades have lapsed since the passage of the 1972 Clean Water Act (CWA), yet progress towards meeting the standards set forth in the CWA has been slow in the area of nonpoint source pollution. The most recent National Water Quality Inventory (USEPA,[17]) categorizes forty-five percent of assessed lake acres in the U.S. as impaired, with the leading causes of these impairments being nutrients and siltation. Moreover, few states have developed the priority ranking of their impaired waters or determined the Total Maximum Daily Loads (TMDLs) as required under Section 303(d) of the CWA.[1] Legal actions by citizen groups have prompted renewed efforts towards developing both the priority listing and associated TMDL standards.[2] However, the task facing both the EPA and state regulatory agencies remains a daunting one. The prioritization process alone, which is all the more important given current tight budgets, requires information on the cost of remediation and the potential benefits that will flow from water quality improvements. Both types of information are in short supply. The purpose of this paper is to help fill this gap by providing information on the recreational value of water quality improvements as a function of detailed physical attributes of the water bodies involved. The water quality values are obtained from a recreation demand model of lake usage in the state of Iowa, combining trip and socio-demographic data from the Iowa Lakes Valuation Project and an extensive list of physical water quality measures collected by Iowa State University's Limnology Lab.

Recreation demand models have long been used to value water quality improvements, but studies typically rely on limited measures of water quality. The most commonly used indicators are fish catch rates (e.g., [3], [11]). However, catch rates are themselves endoge-

[1] TMDL's specify the amount of a pollutant that a water body can receive and still meet existing water quality standards.

[2] As of March 2003, there have been approximately 40 legal actions taken against the USEPA in 38 states concerning the implementation of Section 303(d) of the CWA.

nous, depending on both fishing pressure and the abilities of the anglers, and provide only indirect measures of the underlying water quality. Physical water quality measures, such as secchi depth and bacteria counts, are used only sparingly, in large part due to limitations in available data. Phaneuf, Kling and Herriges [14] use fish toxin levels in their model of Great Lakes fishing, but the toxin levels were available only for a limited number of aggregate sites in the region. Parsons and Kealy [13] use dummy variables based on dissolved oxygen levels and average secchi depth readings to capture the impact of water quality on Wisconsin lake recreation. Similarly, Parsons, Helm, and Bondelid [12] construct dummy variables indicating *High* and *Medium* water quality levels for use in their analysis of recreational demand in six northeastern states. These dummy variables are based on pollution loading data and water quality models, rather than direct measurements of the local water quality. In all of these studies, the physical water quality indicators are found to significantly impact recreation demand, but, due to the limited nature of the measures themselves, provide only a partial picture of value associated with possible water quality improvements.

Bockstael, Hanemann, and Strand's [2] analysis of beach usage in the Boston-Cape Cod area has perhaps one of the most extensive lists of objective physical water quality attributes included in a model of recreation: oil, fecal coliform, temperature, chemical oxygen demand (COD), and turbidity. However, the study also points out one of the frequently encountered problems in isolating the impact of individual water quality attributes - multicollinearity. Seven additional water quality measures were available to the analysts: color, pH, alkalinity, phosphorous, nitrogen, ammonia, and fecal coliform. These latter variables were excluded from the analysis due to correlations among the various groups of water quality measures. The five water quality variables used were chosen because they were either directly observable by recreationists or highly publicized. While these choices are certainly reasonable given limitations in the available data, the lack of direct information on how nutrient levels (phosphorous and nitrogen) impact recreational usage is unfortunate in the context of setting TMDL standards in midwestern states, where nutrient loadings are of particular concern.

The contribution of the current paper lies in our ability to incorporate a rich set of physical water quality attributes, as well as site and household characteristics, into a model of recreational lake usage in Iowa. Trip data for the study are drawn from the 2002 Iowa Lakes Survey, the first of a four year project aimed at valuing recreational lake usage in Iowa. The survey was sent to a random sample of 8,000 Iowa households, eliciting information on their recreational visits to Iowa's 129 principle lakes, along with socio-demographic data and attitudes towards water quality issues. The unique feature of the project, however, is that a parallel inventory of the physical attributes of these lakes is being conducted by Iowa State University's Limnology laboratory.[3] Three times a year, over the course of a five year project, eleven distinct water quality measurements are being taken at each of the lakes, providing a clear physical characterization of the conditions in each lake. Moreover, due to the wide range of lake conditions in the state, Iowa is particularly well suited to identifying the impact of these physical characteristics on recreation demand. Iowa's lakes vary from a few clean lakes with up to fifteen feet of visibility to other lakes having some of the highest concentrations of nutrients in the world, and roughly half of the 129 lakes included in the study are on the EPA's list of impaired lakes.

The remainder of the paper is divided into five sections. Section 2 provides an overview of the two data sources. A repeated mixed logit model of recreational lake usage in Iowa is then specified in Section 3. The mixed logit model allows for a wide variety of substitution patterns among the recreational sites and for heterogeneity among households in terms of their reaction to individual site characteristics. (See, e.g., [7],[10], and [16]). Parameter estimates are reported in Section 4. In Section 5, we illustrate not only the implications of

[3]The limnological study is funded by the Iowa Department of Natural Resources.

the model in terms of recreational value of meeting the objectives of the CWA (i.e., removing all of the lakes in the state from the impaired water quality list), but also how the model can be used to prioritize the remediation task. Conclusions from the paper are provided in Section 6.

2 Data

Two principle data sources are used in developing our model of recreational lake usage in Iowa: the 2002 Iowa Lakes Survey and the physical water quality measures collected by Iowa State University's Limnology laboratory. As noted above, the 2002 Iowa Lakes Survey is the first survey in a four year study of lake usage in the state. The focus of the survey was on gathering baseline information on the visitation patterns to Iowa's 129 principle lakes, as well as socio-demographic data and attitudes towards water quality issues. After initial focus groups and pre-testing of the survey instrument, the final survey was administered by mail in November 2002 to 8,000 randomly selected households in the state. Standard Dillman procedures ([5]) were used to insure a high response rate.[4] Of the 8,000 surveys mailed, 4,423 were returned. Allowing for the 882 undeliverable surveys, this corresponds to an overall response rate of sixty-two percent.

The survey sample was initially paired down to 3,859 households as follows. Those individuals who returned the survey from out of state were excluded (thirty-eight observations). It is not feasible to ascertain whether these respondents have permanently left the state or simply reside elsewhere for part of the year. Respondents who did not complete the trip questions or did specify their numbers of trips (i.e. they simply checked that they had visited a given lake) were excluded (224 observations). Lastly, anyone reporting more than fifty-two total single day trips to the 129 lakes were excluded (133 observations). In the analysis

[4]Complete details of the survey design and implementation can be found in [1].

below, only single day trips are included to avoid the complexity of modeling multiple day visits. Defining the number of choice occasions as fifty-two allows for one trip per week to one of the 129 Iowa lakes. While the choice of fifty-two is arbitrary, it seems a reasonable cut-off for the total number of allowable single day trips for the season.[5] This last step eliminated approximately three percent of the returned surveys. Finally, due to the large number of respondents, the overall sample was randomly divided into three segments; specification, estimation, and prediction portions. The analysis reported here comes from the specification stage using 1,286 observations. Once the estimation stage is reached, the results will be free from any form of pretest bias and the standard errors will be not be biased by the extensive specification search.[6]

Table 1 provides summary statistics for trip and the socio-demographic data obtained from the survey. The average number of total single day trips for all 129 lakes is 6.68 varying from some respondents taking zero trips and others taking fifty-two trips. In general, the survey respondents are more likely to be older, male, have a higher income, and to be more educated than the general population. Schooling is entered as a dummy variable equaling one if the individual has attended or completed some level of post high school education.

The physical water quality measures used in modelling recreational lake usage in Iowa were gathered by Iowa State University's Limnology laboratory. Table 2 provides a listing of the water quality attributes and 2002 summary statistics for the 129 lakes used in our analysis. All of the physical water quality measures are the average values for the 2002 season. Samples were taken from each lake three times throughout the year, in Spring/early Summer, mid-Summer, and late Summer/Fall to include seasonal variation.

Each of the water quality measures help to characterize a distinct aspect of the lake

[5] Sensistivity analysis, raising the allowable number of trips per year above fifty-two, indicated that the results were not sensitive to the choice of this cut-off.

[6] Creel and Loomis [4] use a similar procedure in investigating alternative truncated count data estimators.

ecosystem. Secchi depth indicates the lake depth at which the bottom of the lake can still be seen, providing an overall water clarity measure. Chlorophyll is an indicator of plant biomass or algae, which in turn leads to greenness in the water. Three nitrogen levels are gathered. In addition to total nitrogen, NH3+NH4 measures particular types of nitrogen, such as ammonia, that can be toxic, whereas NO3+NO2 measures the nitrate level in the water. Total phosphorous is an important indicator of water quality in Iowa, as it is usually the principal limiting nutrient which determines algae growth. Silicon is important to diatoms, a key food source for marine organisms. The acidity of the water is measured by "pH" with levels below 6 or above 8 indicating unhealthy lakes. As Table 2 notes, all of the pH levels in this sample are tightly clustered between 7.3 and 10. Alkalinity is the concentration of calcium or calcium carbonate in the water. Plants need carbon to grow and all carbon comes from alkalinity, therefore alkalinity is an indication of the abundance of plant life. Inorganic suspended solids (ISS) consist basically of soil and silt in the water due to erosion, where as volatile suspended solids (VSS) consists of organic matter. Increases in either ISS or VSS levels will decrease water clarity. With the exception of pH levels, Table 2 demonstrates that there is considerable variation in water quality conditions throughout the state. For example, secchi depth varies from a low of 0.09 meters (or 3.5 inches) to a high of 5.67 meters (over 18 feet). Total phosphorus varies from 17 to 453 ug/L, some of the highest concentrations in the world.

In addition to trip and water quality data, two other data sources were used. First, the travel costs, from each survey respondent's residence to each of the 129 lakes, were needed. The out-of-pocket component of travel cost was computed as the roundtrip travel distance multiplied by $0.25 per mile.[7] The opportunity cost of time was calculated as one-third the estimated roundtrip travel time multiplied by the respondent's wage rate. Table 3 provides

[7] *PCMiler (Streets Version 17)* was used to compute both roundtrip travel distance and time.

summary statistics for the resulting travel cost variable. The average price of a recreational trip to a lake is \$136, although perhaps a more meaningful statistic is the average price of a lake visit, \$85.

Second, lake site characteristics were obtained from the Iowa Department of Natural Resources [9]. Table 3 provides a summary of these site characteristics. As Table 3 indicates, the size of the lakes varies considerably, from 10 acres to 19,000 acres. Four dummy variables are included to capture different amenities at each lake. The first is a "ramp" dummy variable which equals one if the lake has a cement boat ramp, as opposed to a gravel ramp or no boat ramp at all. The second is a "wake" dummy variable which equals one if wakes are allowed and zero otherwise. About 66% of the lakes allow wakes, whereas 34% of lakes are "no wake" lakes. The "state park" dummy variable equals one if the lake is located in a state park, which is the case for 38.8% of the lakes in our study. The last dummy variable is the "facilities" dummy variable. Facilities include things like restrooms, picnic tables, or vending machines. A concern may be that facilities would be strongly correlated with the state park dummy variable. However, while fifty of the lakes in the study are located in state parks and fifty have accessible facilities, only twenty six of these overlap.

3 The Model

The Mixed Logit model was chosen since it exhibits many desirable properties including, "it allows for corner solutions, integrates the site selection and participation decisions in a utility consistent framework, and controls for the count nature of recreation demand (Herriges and Phaneuf, [7])."

Assume the utility of individual i choosing site j on choice occasion t is of the form

$$U_{ijt} = V\left(X_{ij}; \beta_i\right) + \varepsilon_{ijt}, \;\; i = 1, ..., N; \;\; j = 0, .., J; \;\; t = 1, ..., T \tag{1}$$

where V represents the observable portion of utility, and from the perspective of the researcher, ε_{ijt}, represents the unobservable portion of utility. A mixed logit model is defined as the integration of the logit formula over the distribution of unobserved random parameters (Revelt and Train, 1998). If the random parameters, β_i, were known then the probability of observing individual i choosing alternative j on choice occasion t would follow the standard logit form

$$L_{ijt}\left(\beta_i\right) = \frac{\exp\left(V_{ijt}\left(\beta_i\right)\right)}{\sum\limits_{k=0}^{J} \exp\left[V_{ikt}\left(\beta_i\right)\right]}. \tag{2}$$

Since the β_i's are unknown, the corresponding unconditional probability, $P_{ijt}\left(\theta\right)$, is obtained by integrating over an assumed probability density function for the β_i's. The unconditional probability is now a function of θ, where θ represents the estimated moments of the random parameters. This repeated Mixed Logit model assumes the random parameters are $i.i.d.$ distributed over the individuals so that

$$P_{ijt} = \int L_{ijt}\left(\beta\right) f\left(\beta|\theta\right) d\beta. \tag{3}$$

No closed form solution exists for this unconditional probability and therefore simulation is required for the maximum likelihood estimates of θ.[8]

Following Herriges and Phaneuf [7], a dummy variable, D_j, is included which equals one for all of the one through J recreation alternatives and equals zero for the stay-at-home option ($j = 0$). Including the stay-at-home option allows a complete set of choices, including in the population those individuals who always "stay at home" on every choice occasion and do not visit any of the sites. It is convenient to partition the individual's utility into the stay-at-home option or choosing one of the J sites

$$U_{ijt} = \begin{array}{l} \beta^{z'} z_i + \varepsilon_{i0t} \\ \beta_i' x_{ij} + \alpha_i + \varepsilon_{ijt}, \ j = 1, ..., J \end{array}, \tag{4}$$

[8]Randomly shifted and shuffled uniform draws are used in the simulation process (Hess, Train, and Polak, [8]). The number of draws used in the simulation is 750.

where α_i is the random parameter on the dummy variable, D_j, which does not appear since it equals one for $j = 1, ..., J$ and zero for $j = 0$. The vector z_i contains socio-demographic data such as income and age, and x_{ij} represents the site characteristics that vary across the lakes, including attributes such as facilities at the lake as well as water quality measures. Notice the parameters associated with the socio-demographic data are not random as this information does not vary across the sites.[9]

The random coefficient vectors for each individual, β_i and α_i, can be expressed as the sum of population means, b and a, and individual deviation from the means, δ_i and γ_i, which represents the individual's tastes relative to the average tastes in the population (Train, [16]). Therefore redefine

$$\beta_i' x_{ij} = b' x_{ij} + \delta_i' x_{ij} \tag{5}$$

$$a_i = a + \gamma_i \tag{6}$$

and then the partitioned utility is

$$U_{ijt} = \begin{matrix} \beta^{z'} z_i + \eta_{i0t} \\ \beta_i' x_{ij} + a + \eta_{ijt}, \;\; j = 1, ..., J \end{matrix} , \tag{7}$$

where

$$\eta_{ijt} = \begin{matrix} \varepsilon_{i0t} & & i = 1, ..., N; \;\; t = 1, ..., T \\ \delta_i' x_{ij} + \gamma_i + \varepsilon_{ijt}, & j = 1, ..., J; & i = 1, ..., N; \;\; t = 1, ..., T \end{matrix} \tag{8}$$

is the unobserved portion of utility. This unobserved portion is correlated over sites and trips due to the common influence of the terms δ_i' and γ_i which vary over individuals. For example, an individual who chooses the stay-at-home option for all choice occasions would have a negative deviation from a, the mean of α_i, while someone who takes many trips would have a positive deviation from a, allowing the marginal effect to vary across individuals. However, the parameters do not vary over sites or choice occasions; thus, the same preferences are used

[9] It is possible to interact the socio-demographic data with the sites, if one believed for example that income would effect which lake was chosen.

by the individual to evaluate each site at each time period. Since the unobserved portion of utility is correlated over sites and trips, the familiar IIA assumption does not apply for mixed logit models.

In particular, we model the utility individual i receives from choosing lake j on choice occasion t as

$$U_{ijt} = \begin{array}{l} \beta^{z'} z_i + \varepsilon_{i0t} \\ -\beta^P P_{ij} + \beta^{q'} Q_j + \beta_i^{a'} A_j + \alpha_i + \varepsilon_{ijt},\ j = 1, ..., J \end{array}, \tag{9}$$

where z_i is the socio-demographic data summarized in Table 1, P_{ij} is the travel cost from each Iowan's residency to each of the 129 lakes, as calculated with PCMiler (Table 3). The vector Q_j denotes the physical water quality measures (Table 2) and A_j represents the attributes of the lake (Table 3). As shown in equation (9), notice that the parameters on the lake attributes and the dummy variable, D_j, are random. These six variables are assumed to be independently normally distributed with the mean and dispersion of each variable estimated.

Finally, we estimate two models. The first specification, model A, includes six physical water quality measures. Included are the four paramount variables for nutrient criteria (USEPA [17]): total phosphorus, total nitrogen, chlorophyll, and Secchi depth, as well as inorganic suspended solids and organic suspended solids, which we consider to be crucial indicators as well. A second model, model B, includes the complete list of eleven water quality measures. Estimating two models allows us to observe the stability of the parameters across different specifications.

4 Results

The results for Model A and B are divided into two Tables, 4a and 4b. For both models, the coefficients for the socio-demographic data, price, and the random coefficients on the amenities are given in Table 4a. Table 4b lists for both models the coefficients for the physical water quality measures. All of the coefficients are significant at the 1% level except for a few of the socio-demographic data. For model B, with eleven physical water quality measures, only the "male" dummy variable is not significant. In Model A, income, household size, and the quadratic term on age are insignificant. Note that the socio-demographic data are included in the conditional indirect utility for the stay-at-home option. Therefore, the negative income coefficient indicates that as income rises the respondents are less likely to stay at home and more likely to visit a lake (i.e. lake visits are a normal good). Males, higher educated individuals, and larger households are all more likely to take a trip to a lake. Age has a convex relationship with the stay-at-home option and therefore a concave relationship with trips. For Model B, the peak occurs at about age 37, which is consistent with the estimate of larger households taking more trips, as at this age the household is more likely to include children.

The price coefficient is negative as expected and identical in both models. Now turning to the amenities parameters, again all of the parameters are of the expected sign. As the size of a lake increases, has a cement boat ramp, gains accessible facilities, or is in a state park, on average leads to increased trips. Notice however the large dispersion estimates. For example, in model A the dispersion on the size of the lake indicates 11.1% of the population prefers a smaller lake, possibly someone who enjoys a more private experience. The large dispersion on the "wake" dummy variable seems particularly appropriate given the potentially conflicting interests of anglers and recreational boaters. Anglers would possibly prefer "no wake" lakes and recreational boaters would obviously prefer lakes that allow wakes. It seems the population is almost evenly split with 56.9% preferring a lake that allows wakes and 43.1% preferring a "no wake" lake. Lastly, the mean of α_i, the trip dummy variable, is negative indicating that on average the respondents receive higher utility from the stay-at-home option, which is expected considering the average number of trips is 6.7 out of a possible 52 choice occasions.

The physical water quality coefficients are reported in Table 4b and are relatively stable across the two models. For both models A and B, secchi depth is positive and the suspended solids, both organic and inorganic (volatile), are negative, indicating the respondents strongly value water clarity. However, the coefficient on chlorophyll is positive suggesting on average respondents do not mind some variation of green water. The negative coefficient on total phosphorus, the most likely principal limiting nutrient, indicates higher algae growth leads to fewer recreational trips.

The only physical water quality coefficient to change qualitatively across the two specifications is total nitrogen which is positive in model A. Total nitrogen having a positive coefficient is consistent with expectations given the negative sign on total phosphorus. With such large amounts of phosphorus in the water, more nitrogen can actually be beneficial by allowing a more normal phosphorus to nitrogen ratio. If the ratio becomes too imbalanced more problematic blue-green algae blooms become dominant. Total nitrogen is negative in model B, but two other forms of nitrogen are included with the nitrates form (NO3+NO2) being positive, possibly for the same reason as just discussed.

Continuing with the additional measures in model B, alkalinity has a positive coefficient, consistent with alkalinity's ability to act as a buffering capacity on how much acidity the water can withstand before deteriorating. Since all of the lakes in the sample are acidic (i.e. pH greater than 7) a positive coefficient for alkalinity is expected. The positive coefficient on Silicon is also consistent since Silicon is important for diatoms, which in turn are an important food source for marine organisms. Lastly, pH is entered quadratically reflecting the fact that low or high pH levels are signs of poor water quality. However, as mentioned, in our sample of lakes all of the pH values are normal or high. The coefficients for pH show a convex relationship (the minimum is reached at a pH of 8.2) to trips, indicating that as the pH level rises above 8.2, trips are predicted to increase. This is opposite of what we expected and further specifications will consider this fact.

5 Welfare Calculations

Given the random parameters, β_i, the conditional compensating variation associated with a change in water quality from Q to Q' for individual i on choice occasion t is

$$CV_{it}(\beta_i) = \frac{-1}{\beta^p}\left\{\ln\left[\sum_{j=0}^{J}\exp\left(V_{ijt}\left[Q';\beta_i\right]\right)\right] - \ln\left[\sum_{j=0}^{J}\exp\left(V_{ijt}\left[Q;\beta_i\right]\right)\right]\right\}$$

which is the compensating variation for the standard logit model. The unconditional compensating variation does not have a closed form, but it can be simulated by

$$CV_{it} = \frac{1}{R}\sum_{r=1}^{R}\frac{-1}{\beta^p}\left\{\ln\left[\sum_{j=0}^{J}\exp\left(V_{ijt}\left[Q';\beta_i^r\right]\right)\right] - \ln\left[\sum_{j=0}^{J}\exp\left(V_{ijt}\left[Q;\beta_i^r\right]\right)\right]\right\}$$

where R is the number of draws and r represents a particular draw from its distribution. The simulation process involves drawing values of β_i and then calculating the resulting compensating variation for each vector of draws, and finally averaging over the results for many draws. Following Von Haefen [18], 2,500 draws were used in the simulation.

Three water quality improvement scenarios are considered with the results from Model A used for all the scenarios. The first scenario improves all 129 lakes to the physical water quality of West Okoboji Lake, the cleanest lake in the state. Table 5 compares the physical water quality of West Okoboji Lake with the average of the other 128 lakes. All of West Okoboji Lake's measures are considerably improved over the other 128. For example, West Okoboji Lake has slightly over 5 times the water clarity, measured by secchi depth, of the other lakes. Given such a large change, the annual compensating variation estimates of \$208.68 for every Iowa household seems reasonable (Table 7). Aggregating to the annual value for all Iowans simply involves multiplying by the number of households in Iowa which is 1,153,205.[10] Table 7 also reports the average predicted trips before and after the water

[10] Number of Iowa Households as reported by Survey Sampling, Inc., 2003.

quality improvement. Improving all 128 lakes to the physical water quality of West Okoboji Lake leads to a reasonable 14.1% increase in average trips. As expected, the predicted trips to West Okoboji Lake fall by 19.8% from 0.39 average trips per Iowa household to 0.31. Iowans can now choose the nearest lake with the attributes they prefer, instead of traveling further to West Okoboji Lake.

The next scenario is a less ambitious, more realistic plan of improving nine lakes to the water quality of West Okoboji Lake (see table 5 for comparison). The state is divided into nine zones with one lake in each zone, allowing every Iowan to be within a couple of hours of a lake with superior water quality. The nine lakes were chosen based on recommendations by the Iowa Department of Natural Resources for possible candidates of a clean-up project. The annual compensating variation estimate is $39.71 for each Iowa household. As expected, this estimate is 19.0% of the value if all lakes were improved, even though the scenario involves improving only 7.0% of the lakes. This suggests location of the improved lakes is important and to maximize Iowan's benefit from improving a few lakes, policymakers should consider dispersing them throughout the state.

The last scenario is also a policy oriented improvement. Currently of the 129 lakes, 65 are officially listed on the EPA's impaired waters list. TMDL's are being developed for these lakes and by 2009 the plans must be in place to improve the water quality at these lakes enough to remove them from the list. Therefore, in this scenario the 65 impaired lakes are improved to the median physical water quality levels of the 64 non-impaired lakes. Table 6 compares the median values for the non-impaired lakes to the averages of the impaired lakes. The table indicates the median values of the non-impaired lakes seems an appropriate choice with physical water quality measures higher than the averages of the 65 impaired lakes, but much below those of West Okoboji Lake. This scenario is valued considerably lower than the first two water quality improvement scenarios. The estimated compensating variation per Iowa household is \$4.87. Consistent with this, the predicted trips only increase 0.3% over the predicted trips with no improvement in water quality. A reasonable conclusion is Iowan's have an abundance of lakes at this threshold level, and bringing the low quality lakes up to this level is not much of a benefit.

6 Conclusions

The first year survey of the Iowa Lakes Project gathered recreation behavior to 129 of Iowa's principal lakes. This data was combined with extensive physical water quality measures from the same set of lakes gathered by the Iowa State University Limnology Lab. Our analysis employing the repeated mixed logit framework, shows individuals are responsive to physical water quality measures and it is possible to base willingness to pay calculations on improvements in these physical measures. In particular we considered three improvement scenarios, with the results suggesting Iowans more highly value a few lakes with superior water quality rather than all recreational lakes at an adequate level, as determined by being listed as an impaired lake by the Environmental Protection Agency.

A number of important practical findings come directly from this work. Limnologists and other water quality researchers should be interested in the results of this paper, since the general belief is that visitors care about water clarity as measured by secchi depth (how many meters beneath the surface of the water a secchi dish is visible) or water quality in general. By estimating the partial effects of a list of physical measures, we have determined which significantly affect recreationist's behavior. Limnologists and water resource managers can then use this information about what physical lake attributes visitor's trip behavior responds to in designing projects for water quality improvements. Our results indicate water clarity is very important as evidenced by the secchi dish and suspended solids parameters. Also, nutrients in general are found to decrease recreation trips.

The findings from this study also have direct relevance for environmental protection managers and citizens concerned with the water quality in that they can be used to prioritize clean-up activities to generate the greatest recreation benefits for a given expenditure. Not only can the findings be used to determine which lakes and in what order to clean them, but also the most efficient levels of improvement.

Table 1. 2002 Iowa Lakes Survey Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Total Day Trips	6.68	10.46	0	52
Income	$56,140	$37,436	$7,500	$200,000
Male	0.67	0.46	0	1
Age	53.36	16.47	15	82
School	0.66	0.47	0	1
Household Size	2.61	1.32	1	12

Table 2. Water Quality Variables and 2002 Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Secchi Depth (m)	1.17	0.92	0.09	5.67
Chlorophyll (ug/l)	41	38	2	183
NH3+NH4 (ug/l)	292	159	72	955
NO3+NO2 (mg/l)	1.20	2.54	0.07	14.13
Total Nitrogen (mg/l)	2.20	2.52	0.55	13.37
Total Phosphorous (ug/l)	106	81	17	453
Silicon (mg/l)	4.56	3.24	0.95	16.31
pH	8.50	0.33	7.76	10.03
Alkalinity (mg/l)	142	41	74	286
Inorganic SS (mg/l)	9.4	17.9	0.6	177.6
Volatile SS (mg/l)	9.4	7.9	1.6	49.9

Table 3. Summary Statistics for Lake Site Characteristics

Variable	Mean	Std. Dev.	Min.	Max.
Travel Cost	135.79	29.47	94.12	239.30
Acres	672	2,120	10	19,000
Ramp	0.86	0.35	0	1
Wake	0.66	0.47	0	1
State Park	0.39	0.49	0	1
Facilities	0.39	0.49	0	1

Table 4a. Repeated Mixed Logit Model Parameter Estimates (Std. Errs in Parentheses)[a]

	Model A: 6 Water Quality Measures		Model B: 11 Water Quality Measures	
Variable	Mean	Dispersion	Mean	Dispersion
Income	-0.008^* (0.007)		-0.12^* (0.007)	
Male	-4.98^* (0.42)		-0.31 (0.42)	
Age	-0.24^* (0.07)		-0.58^* (0.08)	
Age^2	0.0001 (0.00006)		0.0078^* (0.0007)	
School	-4.45^* (0.40)		-3.44^* (0.40)	
Household	-0.41 (0.17)		-1.24^* (0.17)	
Price	-0.17^* (0.0006)		-0.17^* (0.0007)	
Log(Acres)	4.60^* (0.064)	3.81^* (0.057)	5.13^* (0.067)	4.05^* (0.06)
Ramp	11.60^* (0.78)	17.85^* (0.51)	14.87^* (0.89)	18.79^* (0.59)
Facilities	1.18^* (0.26)	18.09^* (0.28)	3.54^* (0.24)	16.78^* (0.25)
State Park	8.00^* (0.26)	15.15^* (0.27)	6.67^* (0.24)	13.99^* (0.27)
Wake	2.76^* (0.30)	15.81^* (0.33)	-1.64^* (0.30)	15.57^* (0.29)
α	-8.97^* (0.05)	3.01^* (0.04)	-9.19^* (0.05)	3.12^* (0.04)

* Significant at 1% level.

[a] All of the parameters are scaled by 10, except α (which is unscaled) and the income coefficient (which is scaled by 10,000).

Table 4b. Repeated Mixed Logit Model Parameter Estimates (Std. Errs in Parentheses)[a]

Variable	Model A: 6 Water Quality Measures	Model B: 11 Water Quality Measures
Secchi Depth (m)	0.78*	0.84*
	(0.05)	(0.07)
Chlorophyll (ug/l)	0.054*	0.06*
	(0.03)	(0.003)
NH3+NH4 (ug/l)		−0.002*
		(0.0006)
NO3+NO2 (mg/l)		3.16*
		(0.19)
Total Nitrogen (mg/l)	0.31*	−3.21*
	(0.01)	(0.19)
Total Phosphorous (ug/l)	−0.0033*	−0.016*
	(0.001)	(0.001)
Silicon (mg/l)		0.81*
		(0.02)
pH		−136.72*
		(5.83)
pH^2		8.35*
		(0.34)
Alkalinity (mg/l)		0.038*
		(0.002)
Inorganic SS (mg/l)	−0.010*	−0.089*
	(0.008)	(0.009)
Volatile SS (mg/l)	−0.18*	−0.28*
	(0.01)	(0.02)
LogLik	-47,740.38	-47,494.17

*Significant at 1% level.

[a] All of the parameters are scaled by 10.

Table 5. West Okoboji Lake vs. the other 128 Lakes

	West Okoboji Lake	Averages of the other 128 Lakes	Averages of the 9 Zone Lakes
Secchi Depth (m)	5.67	1.13	1.23
Chlorophyll (ug/l)	2.63	41.29	40.13
Total Nitrogen (mg/l)	0.86	2.22	3.64
Total Phosphorous (ug/l)	21.28	106.03	91.11
Inorganic SS (mg/l)	1.00	9.49	9.52
Volatile SS (mg/l)	1.79	9.43	8.42

Table 6. 64 Non-impaired Lakes vs. the 65 Impaired Lakes

	Median of the 64 Non-impaired Lakes	Averages of the 65 Impaired Lakes
Secchi Depth (m)	1.27	0.70
Chlorophyll (ug/l)	23.25	56.76
Total Nitrogen (mg/l)	1.11	2.77
Total Phosphorous (ug/l)	58.79	153.70
Inorganic SS (mg/l)	3.51	20.42
Volatile SS (mg/l)	6.02	15.49

Table 7. Annual Compensating Variation Estimates using Model A

Average CV	All 128 Lakes Improved to W. Okb.	9 Zone Lakes Improved to W. Okb.	65 Impaired Lakes Improved to Median
per choice occasion	\$4.01	\$0.76	\$0.09
per Iowa household	\$208.68	\$39.71	\$4.87
for all Iowa households	\$240,649,000	\$45,788,092	\$5,612,219
Predicted Trips (9.80 with current water quality)	11.18	10.06	9.83

References

[1] Azevedo, C.D., K.J. Egan, J.A. Herriges, and C.L. Kling (2003). *Iowa Lakes Valuation Project: Summary and Findings from Year One.* Final Report to the Iowa Department of Natural Resources, August.

[2] Bockstael, N.E., W.M. Hanemann, and I.E. Strand (1986). *Measuring the Benefits of Water Quality Improvements Using Recreationd Demand Models*, report presented to the Environmental Protection Agency under cooperative agreement CR-811043-01-0, Washington, D.C.

[3] Chen, H. Z., F. Lupi, and J. P. Hoehn (1999). "An Empirical Assessment of Multinomial Probit and Logit Models for Recreation Demand," in Herriges, J.A., and C. L. Kling, *Valuing Recreation and the Environment: Revealed Preference Methods in Theory and Practice*, Cheltenham, UK: Edward Elgar, pp. 141-161.

[4] Creel, M.D., and J.B. Loomis (1990). "Theoretical and Empirical Advantages of Truncated Count Data Estimators for Analysis of Deer Hunting in California." *American Journal of Agricultural Economics* **72**(2): 434-41.

[5] Dillman, D. A. (1978) *Mail and Telephone Surveys – The Total Design Method*, New York: Wiley

[6] Hanemann, W.M. (1978) "A Methodoligical and Empirical Study of the Recreation Benefits from Water Quality Improvements." Ph.D. dissertation, Department of Economics, Harvard University.

[7] Herriges, J., and D. Phaneuf (2002). "Introducing Patterns of Correlation and Substitution in Repeated Logit Models of Recreation Demand." *American Journal of Agricultural Economics* **84**: 1076-1090.

[8] Hess, S., K. Train, and J. Polak (2003). "On the use of randomly shifted and shuffled uniform vectors in the estimation of a Mixed Logit model for vehicle choice." Working paper.

[9] Iowa Department of Natural Resources (2004), *Fishing Guide for Iowa Lakes*.

[10] McFadden, D., and K. E. Train (2000). "Mixed MNL Models for Discrete Response." *Journal of Applied Econometrics* **15**(September/October): 447-70.

[11] Morey, E.R., R. D. Rowe, and M. Watson (1993). "A Repeated Nested-Logit Model of Atlantic Salmon Fishing." *American Journal of Agricultural Economics* **75**(August): 578-592.

[12] Parsons, G.R., E. C. Helm, and T. Bondelid (2003). "Measuring the Economic Benefits of Water Quality Improvements to Recreational Users in Six Northeastern States: An Application of the Random Utility Maximization Model." Working paper, University of Delaware, July.

[13] Parsons, G.R., and M.J. Kealy (1992). "Randomly Drawn Opportunity Sets in a Random Utility Model of Lake Recreation." *Land Economics* **68**(1): 93-106.

[14] Phaneuf, D.J., C.L. Kling, and J.A. Herriges (2000). "Estimation and Welfare Calculations in a Generalized Corner Solution Model with an Application to Recreation Demand." *The Review of Economics and Statistics* **82**(1) (February): 83-92.

[15] Revelt, D., and K. Train (1998). "Mixed Logit with Repeated Choices: Households' Choices of Appliance Efficiency Level." The Review of Economics and Statistics 80: 647-57.

[16] Train, K. (1998). "Recreation Demand Models with Taste Differences Over People." *Land Economics* **74** (2) (May): 230-239.

[17] U.S. Environmental Protection Agency (2000). "Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs." Office of Water, Office of Science and Technology, Report EPA-822-B00-001, Washington, D.C.

[18] Von Haefen, R. (2003). "Incorporating observed choice into the construction of welfare measures from random utility models." Journal of Environmental Economics and Management 45: 145-65.

Choice Margins and the Measurement of Ecological Benefits:

The Case of Urban Watersheds

V. Kerry Smith, Daniel J. Phaneuf, and Raymond B. Palmquist *

October 13, 2004

Draft please do not cite without permisssion

Abstract

This paper outlines a new method for measuring the marginal willingness to pay for the services provided by ecological resources. The framework takes advantage of the choices consumers make for observable private goods affected by one or more of these services. Each of these decisions corresponds to a choice margin. The methodology uses the distinction between long and short run choices to integrate a hedonic property value model with recreation demand models differentiated by local housing neighborhoods. The demand models are used to develop a consistent quantity index for the contribution of the ecological services to the recreational activities that are expected to be possible in different residential locations. The hedonic model estimates the marginal value for small changes in this quality adjusted index for recreational opportunities. A new database on recreational activities linked with housing sales is used to evaluate the services provided by an urban watershed. The results support the proposed logic and indicate that marginal benefits of protecting watersheds, measured under the two different perspectives, are comparable, with the long run measure slightly larger than the benefits measured using ex post recreation choices.

Key Words: ecological services, marginal willingness to pay, joint hedonic and random utility models.

JEL Classification numbers: Q 26, Q 51, Q 57.

* Thanks are due Jaren Pope for excellent research assistance with this project, as well as Brian Stynes, Melissa Brandt, Michael Darden, Eric McMillan, and Vincent McKeever for assistance in the development of the household survey. Thanks are also due Alex Boutaud and Jack Crawley for assuring the multiple drafts of this paper were successfully completed. Partial support for this research was provided by the U.S. Environmental Protection Agency through Star grant # R-82950801.

I. Introduction

One of the most important challenges facing environmental policy analysts today stems from the need to measure the gains or losses arising from changes in the services of ecological resources.[1] In this paper we consider one aspect of these challenges – the task of measuring the welfare impacts of changes in water quality in a rapidly growing urban watershed. In many areas of this country increasing demands for residential housing and the subsequent development of supporting retail services have taxed the ability of watersheds to provide basic ecological services. At the same time, much of the growth in housing demand can be broadly viewed as amenity-driven. As a result, there is a fundamental tradeoff to be faced between the largely private benefits from increased development and the public costs of the amenity consequences stemming from development-related land cover changes. Designing effective public policy to address this tradeoff requires information of several types. Among these is an understanding of the economic benefits from enhancing the amenities provided by urban watershed services.

Three sources of benefit information are usually noted in providing responses to these needs: (a) contingent valuation (or conjoint) studies with hypothetical plans to improve (or avoid deterioration in) existing ecological resources such as wetlands (see Johnston et al. [1999], Bateman et al. [2004] and Woodward and Wui [2001] as examples); (b) hedonic property value models, using proxy measures, such as distance

[1] There are many potential examples supporting this judgment. The U.S. Environmental Protection Agency has recently established a federal advisory committee to consider the valuation of activities to protect ecological systems and services. Similar efforts are currently underway under the auspices of the National Academy of Sciences. Internationally the United Nations sponsored the Millennium Ecosystem Assessment which sought to evaluate how changes in ecosystems services affect human well being and the types of responses that can be adopted at local, national and global scales to improve ecosystem management.

between homes and the resource of interest to take account for the resource's effect on property values, (Leggett and Bockstael [2000], Mahan, Polaksy and Adams [2000]); and (c) travel cost recreation demand models estimating the value of amenity changes as they relate to the value of recreation visits (see Phaneuf [2002] and Egan, Herriges, Kling, and Downing [2004]). Applications using these approaches argue that they can address the general problem of valuing changes in ecosystem services, but their results remain somewhat disjointed. Each strategy exploits a different margin of choice and as a result appears to arise from a different model. Little guidance has been offered to explain the relationship between these methods' estimates of the values associated with enhanced ecosystem services.[2]

This paper proposes a framework to address these limitations by combining aspects of both the hedonic and recreation demand models. We develop a spatially varying, theoretically consistent index that summarizes the effects of watershed quality measures on the local recreation opportunities available because a household selects a residential neighborhood. We use a hedonic model to estimate the effect of both this index and the general amenity impacts on property values. Our strategy exploits the distinctive margins of choice associated with the different benefit measurement models. These choice margins relate to decisions with unique temporal dimensions. Short term, local recreation choices are used to develop indexes of how watershed quality affects the amount of recreation available. Asset values, the sales prices for private homes in our case, are determined by long term residential choices. They also depend on amenities.

[2] One of the reasons for this disparity stems from differences in the ways each method measures the environmental services linked to choices of private goods. Efforts to use joint estimation linking two or more methods have generally taken place where there is a well defined measure of these services (see Cameron [1992a] as an example).

To assure we can integrate the results from these two choices, we develop a framework that distinguishes the influence of amenities on expected local recreation from amenities as neighborhood attributes. Our choice margin approach exploits the logic of Pollak's [1969] conditional demand framework in describing the use of long and short run decisions to identify the value of water quality as it is reflected in both recreation opportunities and general amenity effects.

We evaluate our proposal using a new database gathered for Wake County, North Carolina. These data integrate property sales, recreation trips for a sample of over two thousand homeowners, and measures of the characteristics of the sub-hydrologic units comprising the county's watersheds. We estimate separate random utility models for local recreation trips for each of nineteen housing areas. Each model takes account of the travel time required for these short recreational outings and includes indexes of the watershed quality in the hydrological areas containing each recreation site. Our recreation quantity index is defined as the average of the conditional expected utility associated with the opportunities available in each housing area. By measuring the value of expected behavior arising from these short term trips (using the actual behavior of current residents) we have a consistent index of the importance of watershed quality for the outings available to each housing market area. Our framework provides a consistent bound for the marginal willingness to pay. It is estimated using the influence of this index on housing prices. We use a recent proposal to increase sewage capacity and permit growth in Granville County, which adjoins our study area, to illustrate how the framework can be applied. We treat the change as affecting the quality in a popular lake and assume for the calculations that it would lead to the loss of this recreational area for local outings.

The remainder of the paper is organized as follows. In the next two sections we discuss the conceptual basis for our approach and outline an operational model. This is followed by sections describing the Wake County database, our empirical specifications, and our estimates along with a policy application. The final section provides discussion of the general implications of our proposal.

II. Parsing Information from Different Choices

A. Conceptual Background

A choice margin describes an opportunity for an individual to make a decision that leads to the acquisition of both a private good *and* the services of a non-market good. These decisions can take place in both the long run and in day to day decisions, sometimes characterized as the short run. Long run choices involve the selection of neighborhoods and the purchase (or rental) of housing units. Short run decisions are conditional on these longer term selections and can involve trips to local recreation sites for short outings. Once a housing location choice is made, a household allocates remaining monetary and time resources to other purchased goods, leisure, and recreation. These decisions contribute to well-being in the short-run. As a result, it seems reasonable to expect that when deciding on a residential location the household considers the portfolio of amenities conveyed by the location, the accessibility of areas for recreation, and how these (or other) amenities relate to the quality of recreation opportunities. These factors will contribute to the expected future gains from recreation trips originating from the location.

To model these decisions formally we artificially divide the decision process into two steps, for each potential location and housing choice, a household is hypothesized to evaluate the short run decisions that could be made for recreation outings to maximize utility subject to its resource constraints at that location. Preferences are assumed to be a function of recreation trips, $x(q)$, a numeraire good z, and housing services $h(a,q)$ which at this stage are treated as quasi-fixed. The term a designates a vector of housing attributes including location specific characteristics. In equation (1) below we also include the term e to include unobserved heterogeneity in households that is not known by the analyst.

$$u = u(x(q), h(a,q), z, e) \tag{1}$$

$h(a,q)$ is treated as "given" from the perspective of the choices of $x(q)$ and z. This implies we can deduct its "cost" from income to derive the resources available for the short run budget constraint. That is, the income available for the next stage of the process – selecting $x(q)$ and z – is constrained by the remaining disposal income (i.e., $m = m^* - p_h(a,q)$ with m^* the full income and $p_h(a,q)$ the hedonic price function in annual terms).[3] The budget constraint for these short run decisions is given in equation (2).

$$m = m^* - p_h(a,q) = z + p_x \cdot x(q) \tag{2}$$

The first order conditions imply solutions for the recreation demands, other market goods, with the indirect utility function $V(p_x, m, q, e)$. This structure in turn implies that the

[3] We assume one unit of housing is consumed so $p_h(a,q)$ is the annual expenditure on housing.

realized ex post benefits for a given household from visits to recreation sites can be defined by equation (3).

$$MCS(q,e) = \int_{p_x}^{p_x^c} -\frac{V_{p_x}(\cdot\ ,q,e)}{V_y(\cdot\ ,q,e)} dp_x \tag{3}$$

where p_x^c denotes the choke price for visits to the recreation site.

Using recreation demand models to estimate the benefits from an improvement in q requires describing how $MCS(q, e)$ changes with q. This analysis expands the integral given in (3) so that it considers changes in both p_x and q. We designated this expression as $\overline{MCS}(q^0, q^1)$.

This measure corresponds to the area between the two Marshallian demand curves at different values for q as defined in equation (4) below. The vertical line after the expression defined by Roy's identity, $(-V_{p_x}/V_m)$, designates that each Marshallian demand is evaluated at a different value for q. This expression is the type of analysis we discussed at the outset. It uses one type of choice margin, namely what is used to describe the consumption of recreation trips under different amenity conditions, to recover a measure of the value of the changes in amenity services from q_0 to q_1. To assure it is the full economic value for this change, conventional practice assumes x and q are weak complements. In addition, a symmetry condition, parallel to that imposed with multiple price changes, assures the consistency of line integrals. This logic follows from Palmquist [2004] and is one interpretation of the Willig [1978] condition usually cited as required for consistent measures of the consumer surplus arising from quality changes.

$$\overline{MCS}^A(q^o, q^1) = \int_{p_x^0}^{p_x^c(q^1)} \left(\left(-V_{p_x}/V_m\right)\Big|_{q^1} \right) dp_x - \int_{p_x^0}^{p_x^c(q^1)} \left(\left(-V_{p_x}/V_m\right)\Big|_{q^0} \right) dp_x \tag{4}$$

To consider the potential for linkages between models associated with long and short run decisions, consider how the value of trips at a given quality level might influence other decisions. Equation (3) provides a summary of the gains due to the household's ability to take trips to the recreation site. It is the ex post benefit from the access conditions giving rise to recreation trips at a given quality level. In making a residential choice, it seems reasonable to suppose that households consider, ex ante, the expectation of what these benefits would be for each possible neighborhood. In other works, households consider the value of the recreation options implied by the choice of each neighborhood. Each area, in principle, provides somewhat different access conditions to recreation opportunities. As a result, we can argue that the expected benefits available from a residential location can be seen as an attribute of the location. With this simple model, we can define the expected benefits from recreation at a given residential location by

$$EMCS(q) = E[MCS(q,e)] \tag{5}$$

The expectation operator in this case is with respect to the heterogeneity across households in the location, both observed and unobserved. The latter is identified in our model by e. Equation (5) is not a household-specific measure. It is a measure of the average recreation opportunities available because a household has the access defined by one location compared to no access. Of course, in practice the choice is based on each neighborhood's relative value, so the default of no access becomes irrelevant. The expectation is across diverse households conditional on the level of q at each specific location. Using a long run perspective, we hypothesize that this value would be capitalized into housing prices in equilibrium.

To consider the long run version of our model we need to return to equation (1) and assume for each location a household has evaluated the potential for different patterns of local outings. This process implies that including $EMCS(q)$ in the preference function in equation (1) allows us to account for the sub-optimization that takes place conditional on a location. More formally, equation (6) offers a simple description for this objective function and (7) the relevant budget constraint

$$\max u(h(a,q), EMCS(q), z) \tag{6}$$

$$m^* = p_h(a,q) + p_x \cdot \tilde{x}(q, p_x, m(m^*)) + z \tag{7}$$

where $\tilde{x}(q, p_x)$ represents the optimized value of x (given the allocation of income relevant to choices of x with each housing location and $p_h(\, . \,)$). $m(m^*)$ acknowledges the separability in the decision process that we imposed on this problem -- recreation is based on the housing decision so the income remaining $m(m^*)$ is the connection associated with the budget decomposition in the choice process.

$p_h(a,q)$ is the hedonic price function. With x and z assumed to be selected as part of a separate decision process, optimal for each $h(a,q)$, we can recast the problem in equations (6) and (7) by holding $EMCS(q)$ constant for a location. Then the decision process involves selecting the location that is best, given the recreation and z choices that would be made for that location. The first order conditions in this case reflect the re-allocations in recreation use (captured through $\frac{\partial EMCS}{\partial q}$) and the changes in housing as in equation (8).

$$\frac{\dfrac{\partial u}{\partial EMCS}\cdot\dfrac{\partial EMCS}{\partial q}+\dfrac{\partial u}{\partial h}\cdot\dfrac{\partial h}{\partial q}}{\dfrac{\partial u}{\partial z}}=\frac{\partial p_h}{\partial q} \qquad (8)$$

Households choose a residential location such that, at the margin, the value of expected recreation plus aesthetic benefits of the location are balanced against the implicit marginal purchase price of the amenities. Equation (8) implies that the elements of q can influence home prices both directly through the amenity effect and indirectly through the recreation effect.

Identifying these effects in hedonic models has proven challenging, and to our knowledge no studies have isolated both the direct and indirect effects shown in equation (8). Most hedonic studies rely on ad hoc proxy variables to control for the two effects. In the next sub-section we suggest how information from a recreation survey can be combined with housing sales information to operationalize our choice margin logic

B. Empirical Implementation

The approach outlined above, using the distinction between long run housing choices and short run recreation decisions, requires that we augment housing sales price information with recreation data. By matching the recreation usage of current residents to specific homes we can characterize both the relevant choice alternatives and the patterns of use. For example, suppose an urban watershed can be divided into J areas corresponding to well-defined real estate markets. The spatial layout of the landscape and existing amenity levels convey a similar portfolio of recreation opportunities (and qualities) to each resident in each of these market areas. Denote the set of recreation sites in each housing market area j by K_j and the amenities levels at these sites by q_j. Given observations on visits to sites by residents of zone j it is possible to estimate a random utility model of site choice. Denote the indirect utility for a visit by person i to site k by

$$u_{ik} = a + bt_{ik} + dq_k + e_{ik}, \quad k = 1,\ldots,K_j, \quad i = 1,\ldots,N_j \tag{9}$$

where t_{ik} is a measure for the time cost for visiting site k, (a,b,d) denote parameters to be estimated, e_{ik} can be assumed to be a random error term distributed type I extreme value, and N_j is the number of person-trips observed in market area j. Given the error distribution, estimation of the parameters in (9) for observed trips originating from market area j is straightforward, and the expected maximum utility from the opportunities available for a trip originating in market area j is given in equation (10).

$$\hat{E}u_j(q) = N_j^{-1}\sum_{i=1}^{N_j}\ln\left[\sum_{k=1}^{K_j}\exp(\hat{v}_{ik})\right], \tag{10}$$

where $\hat{v}_k$ is the predicted deterministic component of utility (i.e., $\hat{b}t_{ik} + \hat{d}q_k$, a cannot be identified, but does not affect the properties of the index).

The expected value of anticipated recreation derived from a location, as defined in equation (10), can also be interpreted as a "quantity index" for the set of recreation alternatives available in a given neighborhood. It is consistent with the outline we developed above. In this case, a linear expression for the outing choice model (i.e. equation (9)) allowed us to avoid considering the allocation of income to local outings.[4] We have also avoided assumptions about "pricing" the time (t_{ik}) required for these trips, because our objective is to measure an index for the recreational choice opportunities conveyed by each location. While we can use the model underlying (9) to measure the

[4] This assumption of locally constant marginal utility of income implies that the Marshallian measure of the value of trips and the Hicksian measure will be equal. Because our focus is on choices among locations for trips without a stay-at-home option, we do not consider selection effects arising from our survey response rate. This is an area for future research.

economic value of changes in the attributes of that choice set, our primary objective is to develop the quality adjusted quantity index.[5] A random utility framework assumes each trip decision is independent of every other such choice. Thus, under these conditions (and in the absence of income effects) equations (6) and (10) provide comparable measures for the effects of recreation for housing choices. The random utility approach has the added advantage of easily reflecting a wide array of site alternatives.

Thus, our index collapses a large amount of spatially explicit information on site availability and quality into a single variable that varies across the urban landscape. With a measure of the recreation alternatives available to homebuyers when they select each location, it is possible to isolate the effects of changes in ecological services as they affect local recreation. This strategy also does not preclude considering how amenities contribute to neighborhood attributes. These two terms are the elements isolated in equation (8). For our hedonic model, we adopt a semi-log specification for the price functions as in equation (11).[6] $q(d_i)$ is the distance proxy used to describe the neighborhood amenity effect of a resource that is described using a measure of the distance between the house and that resource.

$$\ln p_{ij} = a_o + \sum_{l=1}^{s} b_l a_{li} + g_1 \hat{E} u_{ji} + g_2 q(d_i) + u_i \qquad (11)$$

A measure bounding the welfare effects associated with changes in the ecological services water based recreation sites in urban watersheds can then be distinguished based

[5] This strategy does not require that we measure the opportunity cost of time. It can be assumed to be a source of unobserved heterogeneity. In separate research with this same sample we found that the opportunity cost of time can vary with the amount of time required for these types of outings (see Palmquist, Phaneuf, and Smith [2004]).

[6] Cropper, Deck, and McConnell's [1988] simulation experiments suggest that when the independent variables in hedonic models are replaced with proxy variables or the specifications are likely to be incomplete, simpler specifications for the price function such as the semi log have superior properties based on estimates of the marginal willingness to pay.

on how the change in q influences Eu_j. With the semi log form these would be given in equation (12).[7]

$$\Delta B_{rec_{ij}} = q \cdot g_1 \cdot p_{ij} \cdot \left[Eu_{ji}\left(q^1\right) - Eu_{ji}\left(q^0\right)\right] \quad (12)$$

$\Delta B_{rec_{ij}}$ = estimated bound for annual benefits from change from q^0 to q^1 due to the location specific recreation effects for market area j and property i

? = annualization factor

III. Data

Our analysis requires that three different types of information be combined consistently. The first involves information on the sales of private homes in Wake County, North Carolina. These data were obtained from the Wake County Revenue Department. This database includes detailed information on residential properties. However, the format for these data was often not compatible with economic analysis. A translation from administrative records to measures of structural features of the homes was an important first step in our research. For example, the county database has information on each home's floor plan. The pre-analysis of these records required calculating the number of squared feet in different uses in each home. The top panel of Table 1 provides definitions of variables derived from these sources. Most are self explanatory. A set of qualitative variables for the condition of the house were defined

[7] We could also consider how we would measure a bound for changes in site specific amenities. This process requires the definition of a distance equivalent change for the change in q.

$$\Delta B_{nam_{ij}} = q \cdot g_2 \cdot p_{ij} \cdot \left[q\left(d^1\right) - q\left(d^0\right)\right]$$

$\Delta B_{nam_{ij}}$ = bound for annual benefits from change from d^0 to d^1 *hypothesized to* capture the neighborhood amenity effects of the changes from q^0 to q^1

based on ratings of the physical condition of the structure, rating from A (the highest score) to D (the lowest score).[8]

The second set of information was derived from a mailed survey to homeowners. Using the records of home sales from 1992 to 2000, we selected owner-occupied properties with sales prices greater than $50,000. Our sampling plan took advantage of realtor defined sub-markets. There are nineteen zones identified by the Triangle Multiple Listing Service as relatively homogenous sub-markets.[9] These areas will be labeled as the MLS zones. Figure 1 displays a map of the county with the spatial boundaries for each zone. For the selection of our sample, these areas were combined into four larger contiguous zones (i.e., approximately dividing the county into four quadrants). 9,000 records were drawn randomly from the records satisfying our initial criteria. The resulting sampled units were then evaluated to assure a sufficient number of observations in each of the sub-hydrologic units identified in a detailed separate analysis of the watersheds in Wake County by a private consulting firm (see CH2MHill [2003]). The sub-areas defined for this assessment are given in Figure 2.[10] There are 81 sub-hydrologic units in the CH2MHill classification scheme. When the initial sample did not have 20 observations in a sub-hydrologic area, we evaluated the set of housing sales that remained after drawing our initial sample of 9,000. If there were sufficient remaining housing sales in the relevant zones, we randomly selected additional observations to raise the number in each area to 20. If there were an insufficient number of sales, we simply

---

[8] A very small number of sales were of houses rated E. These were combined with rating D before the sample was drawn.

[9] We analyzed the hedonic price function in two ways - as a single price equation for one equilibrium based on structural attributes, but with our index of area specific opportunities as a determinant of price, and alternatively as a price function with fixed effects for each sub-market. Then we evaluated the determinants of these fixed effects (see below).

[10] Because the hydrologic zones are generally smaller than the MLS zones, this restriction also assured reasonable sample sizes for each MLS zone. See table 1A in the Appendix.

selected all that met our criteria. Each owner's name and address was verified using the current Wake County Property tax records. Only observations where the sales record from our hedonic database could be cross-linked to the currently listed owners were included in the sample.

A mailed survey was designed to collect information about each homeowner's socio-economic characteristics, recreation behavior, and leisure time choices. One aspect of the design of the questionnaire involved collecting information about whether homeowners considered water-based recreation sites and their attributes in making their housing choices. To address this issue we conducted two focus groups.[11] These discussions lead to the definition of a new class of recreation trips – which we designate here as local outings. These trips are short excursions involving a few hours.

Surveys were mailed to 7,554 households with valid addresses where we also had complete sales and property characteristics. Two mailings and a reminder postcard were sent to each selected homeowner (i.e., following the Dillman [1978] format for mailed surveys). Our survey took place between May 2003 and September 2003. We realized a 32% response rate, based on completed valid responses in comparison to the mailing reaching the intended addresses.[12] Each survey packet contained the survey

[11] Two focus groups were conducted as part of the background research to develop the survey. The first took place July 23, 2002 with 10 homeowners. The years they lived in Raleigh ranged from 5 to 36 years. The second was October 9, 2002 with 14 individuals. Members of this group have lived in the area between 2 and 26 years. The focus groups identified local outings as the primary type of recreation that would be influential for selecting among neighborhoods in Wake County. Participants did not feel location would be important to trips that involved a longer time period.

[12] To gauge the potential for selection effects we used information from the 2000 Census at the block group level to estimate a grouped logit model with the fraction returning a questionnaire specified to be a function of the socio-economic characteristics of each block group. The results suggest areas with higher proportion of white residents, in areas with older homes, and with residents that lived a longer time in the area were more likely to return the questionnaire. There was some evidence that the response rates might be lower from high income areas. The full results (with *z* statistics in parentheses) are given as follows:

fraction responding =	1.724 percent white	+ 0.159 median number of rooms
	(6.73)	(1.94)

questionnaire, a letter, a map, and a legend for the recreation sites (as well as the opportunity to identify sites not listed on the map). Appendix A provides the survey assignments and the proportion returned by MLS zone.

The survey design allows each of these two databases (i.e. the residential housing sales data and the household survey) to be linked (via the latitude and longitude of each residence) to a set of geo-coded records developed for each of the over 200 recreation areas. These sites were identified in the survey. They are the sites listed by the survey respondents as the places for their recreation trips. The records for the housing sales, survey responses, and the locations, plus the travel time and distance to each recreation site, can also be linked to a separately developed database that is the third component of our analysis.

The last database includes records for water quality readings for the county. The water quality data combine twelve separate databases with technical indicators of water quality characteristics.[13] Our analysis in this paper is intended to be a first stage

---

+ 0.021 median house age	- 0.039 median amount of time in area
(3.83)	(-2.27)
+ 0.022 x 10^{-5} median house value	- 0.091 x 10^{-5} median income
(1.50)	(-1.45)
+ 33.976	
(1.28)	
Pseudo R^2 = 0.018	

[13] Two are chemical monitoring data obtained from the N.C. Department of Natural Resources. These include monthly readings form 1994 to 2000 for 61 variables. The definitions of the factors that are measured and the method used are documented based on available records. These reports were supplemented with the paper records required for major NPDES point sources. Nine variables were collected from the monthly reports of these sources for the Neuse River. Four types of biological databases are included. Single samples collected on benthic and habitat, characteristics in August 2001 by CH2MHill for Wake County, and periodic readings for the state benthic communities were collected by N.C. Division of Water Quality from 1982 to 2003 for the sites in the Neuse River Basin and from 1983 to 2001 for the Cape Fear River Basin. Chemical data for four variables describing water quality for major lakes in the Neuse and Cape Fear watersheds are available periodically from 1981 to 2002. Chemical data for the upper Neuse River Basin with 89 variables are reported monthly over the period 1990 to 2002. The U.S. Geological Survey (USGS) also report chemical and flow data for sites within the upper Neuse and Cape Fear basins monthly from 1989 to 2001. This database includes 33 variables. Chemical and flow data for

evaluation of the basic logic of the model. As a result, we focus on only two of the available variables – a measure of the percent of the land area in each MLS zone covered with impervious surface, and a qualitative variable recoding the CH2MHill rating of the sub-hydrologic units in the county.

IV. Results

A. Describing Local Recreation Choices: RUM Estimates

The first step in developing our index for the role of local recreation alternatives available to homeowners involves modeling local outings. As we noted, a simple random utility model is used to describe these choices. We develop separate models for each of the 19 housing market areas identified by the Multiple Listing Service. This strategy is possible because our survey elicits for each sampled homeowner a record of three types of recreation trips to water based recreation sites. Our questionnaire asks about the recreation trips taken during a seven month period from May through November 2002. The trips are distinguished as: short outings that involve less than four hours away from home; day outings involving a full day of activity but no overnight stay; and experiences that involve two day trips with an overnight stay. The number of each type of trip, the sites used, and activities undertaken are each recorded separately. Over two hundred locations were identified by the sample respondents. Each site was geo-located with a latitude and longitude. As described in the footnotes to Table 1, distance and travel time measures to every possible site were estimated for every sample respondent.

---

the lower Neuse River Basin are available in the LNBA database monthly from 1994 to 2002. Finally, the USGS flow data for upper Neuse River Basin was assembled monthly from 1990 to 2002. All these databases can be linked either through the latitude and longitude of the sampling location or other identifying information to our various geographic area definitions.

For the random utility models estimated to develop our index of recreation opportunities, we define a zone specific choice set with all the sites identified by homeowners in each MLS zone. Each random utility model provides the basis for an index of the local recreation alternatives homebuyers are assumed to consider in evaluating the selection of a residential location. We assume new buyers will focus on the recreation sites that current residents use. Each of the zone specific choice sets varies in size and composition. While our questionnaire did limit the space for reporting sites used to seven alternatives, none of the individuals identified more than 6 sites for local outings. The average number identified by a respondent who took local outings was about 2 sites for each zone. This count offers a potentially interesting way to consider the differences among the recreation trips in our survey. The count of sites an individual reports that she uses reflects both her desire for variety and the supply of recognized alternatives to meet each type of recreation.

While local outings are the focus of our recreation demand models, a comparison of the factors influencing the stated number of sites used for each type of recreation helps to confirm that people do consider these types of trips as distinct. Table 2 provides a simple multivariate analysis of the reported counts of the sites used for each type of recreation based on a Poisson regression model. The second column provides the results for local outings. Columns three and four report the findings for one day and two day trips respectively. Several socio-economic characteristics display different influences on the three types of trips. The most notable of these is income, which has a significant (with a p-value of 0.10) negative influence on the number of places respondents report for their local outings, but the opposite effect for longer trips. Age and boat ownership have consistent effects on all three types of recreation. Small children appear constraining for day trips but do not have an impact on the number of sites selected for other types of recreation. Other variables such as respondent reports of appreciable time limitations do not affect the count of sites listed but may well affect behavior in other ways. The distinctive roles for income, race, and small children in these summaries suggest people appear to evaluate the choice alternatives differently for each type of recreation.

Our simple random utility models for local outings follow the logic outlined in equation (8). Trips are assumed to be independent choices. Travel time was considered to be the primary "cost" of a local outing. We also add to this specification two measures of the quality of the watershed that includes the site. The first of these measures is the estimated percent of the land area covered with impervious surface. Schueler [1994] and Cappiella and Brown [2001] have suggested this measure can serve as an indicator to predict the negative effects of development-related changes in land cover on aquatic systems. In addition, we use an expert rating of each sub-hydrologic zone as a second indicator. More specifically, as we noted earlier, in 2003 a private consulting firm, CH2MHill, completed a commissioned study of Watershed Quality. Wake County had requested a study to evaluate the county's streams and watersheds as part of a planning process intended to balance economic development with natural resource conservation and environmental protection.

Three categories of information were assembled for their assessment: chemical data on stream quality and concentration of pollutants, biological data on the number and types of species sensitive to water quality, and physical characteristics related to habitat and geomorphology. Eight-one sub-hydrologic units were classified into healthy, impacted, and degraded. The breakdown is given as follows:

Rating	Number of Sub Hydrologic
Healthy	30
Impacted	38
Degraded	13

We coded a qualitative variable to distinguish sites in degraded hydrologic areas. All of the sites visited for local outings were either degraded or impacted.

Table 3 provides the estimated random utility models for six of the nineteen zones. In all of these cases, increases in travel time to reach a site reduced the likelihood of selecting it.[14] The signs for both the impervious surface measure and the qualitative variable for degraded conditions varied across models estimated for each MLS zones. In the case of the impervious surface measure, the majority of the estimated parameters were negative and most of these were significantly different from zero. The qualitative variable rating sub-hydrologic units (based on the CH2MHill evaluation) was less stable – with both positive and significant and negative and significant estimates. Our a priori interpretation of these variables implied that both would have negative effects on the likelihood of visiting the recreation sites in areas with these conditions. Nonetheless, it is important to acknowledge that both watershed quality measures refer to spatial zones that include the recreation sites. They are not specific indexes for each site.[15]

Despite the mixed record for the influence of these watershed measures on site choices, the overall effect of impervious surface on our index of water-based recreation

[14] For the remaining zones, only one case resulted in a positive estimate for the travel time parameter.

[15] In future research we plan to consider linking the available technical measures of water quality in our database to each site. However, it is also reasonable to ask how the people selecting these sites would know about these detailed measurements and use them to evaluate the water quality conditions. This issue will be considered in our further research with the Wake County Database.

opportunities provided by each neighborhood is consistent with *a priori* expectations. That is, when we consider the mix of sites selected by our sample respondents in each MLS zone and compute the average value for the expected maximum utility terms (i.e. equation (10)), the index declines with increases in the impervious surface in the MLS zone visited for short outings. Equation (13) provides a simple regression of the value of our index of opportunities on the average impervious surface in the zones with sites visited.

The numbers in parentheses below the estimated parameters are t-ratios.[16]

$$\underset{}{\overline{E}u_j} = \underset{(1.73)}{31.50} - \underset{(-1.85)}{2.57}\ \text{Percent Impervious Surface}_j \tag{13}$$

$$n = 19$$
$$R^2 = 0.17$$

The estimates for the expected maximum utility (or the average log sum), $\overline{E}u_j$, corresponds to the selections by respondents in each MLS zone, weighted by the parameters from the zone specific random utility model. The average measure for impervious surface considers the values for the MLS zones *visited* through the selection of sites for local recreation. It is a trip weighted average of these measures. This expression indicates that the overall pattern described with the index is what we would have expected. Recreation opportunities are given a lower (quality adjusted) “score” when there are higher proportions of the land areas in impervious surface in the locations of the sites visited. There was no significant association when the same analysis was

[16] This model is not intended as a test, since the dependent variable is defined using values of the independent variable from a set of RUM estimates. It is a convenient summary of the net outcomes of the reported choices in each MLS zone. The objective is to evaluate whether the recreation quantity index signals to property markets consistently the quality of the recreation sites being selected. In this case it describes whether increases in the weighted average value for the impervious surface measure are associated with declines in our quality adjusted index for recreation opportunities.

conducted using the average log sum and the average scores based on the CH2MHill rating.

B. Hedonic Property Value Estimates

Table 4 provides the estimates for our hedonic model, based on sales in 1998 and 1999 using a semi-log specification. The second column reports the estimated effects of structural characteristics along with two measures of water quality related effects. The first of these is our quality adjusted index of "value" of access to recreation sites for local outings, based on equation (10) and the 19 estimated random utility models. The second is an index of general water based amenities that are also hypothesized to be relevant for each neighborhood. It relies on the conventional logic that if a house is located on or near a lake this proximity may be an amenity for the residents, which may influence property values. To compute this measure, we used Wake County GIS Services to provide an Arcview shapefile of all lakes in the county. The distance of each house from all lakes was calculated and the distance to the nearest lake was determined. Since the amenity effect of lake proximity would decline rapidly with distance from the lake and would fall to zero at some distance, an index for lake proximity was developed. The

Lake Distance index = $\max\left\{1-\left(\frac{d}{d_{\max}}\right)^{\frac{1}{2}};0\right\}$, where d is the distance of the house from the nearest lake and $d_{\max}$ is the maximum distance where the lake has any effect on the house value. This index is between zero and one and is convex. As noted in table 1, a value of 2,640 feet (one-half mile) was used for $d_{\max}$. The third column reports the means for each of the conventional housing attributes as well as for the sales price (in the row corresponding to the intercept for the model).

Both measures of the effects of watershed related amenities are significant, positive determinants of property values. This result suggests that the effects of the quality adjusted recreation index can be distinguished from a more general index of the neighborhood related amenities provided by urban watersheds.[17] All of the other structural variables in the model (with the exception of an indicator variable for the presence of a swimming pool) are significant determinants of the sales prices. The only potentially implausible relationship implied by the estimates is for the measure of average commuting time. We expect that increases in commuting time to work associated with the different home sites would reduce property values. However, this measure could easily be serving as a proxy variable for the more rural areas in the county and, as a result, reflect the influence of rural amenities which would also imply greater distances from employment centers and longer average commutes.

Thus, the hedonic estimates provide strong confirmation for our efforts to distinguish the long and short run aspects of the influences amenities have on individual behavior. Our framework implies that a model that describes the role of housing choices as conditioning factors influencing short term recreation decisions addresses the "double

---

[17] Our quality adjusted index for the amount of each recreation is the average of the expected maximum utilities as defined in equation (10). Assigning this to all housing transactions based on their MLS zone might arguably introduce an errors-in-variables problem (see Moulton [1990]). To evaluate whether this interpretation affected our estimates for the role of $\hat{E}u$, we considered an alternative estimation strategy. We estimated fixed effects for each zone in the hedonic model and then used the estimated fixed effects in a feasible GLS (using the relevant partition matrix from the OLS variance covariance matrix for the covariance matrix, see Nevo [2001] as an example). The estimated effect for the recreation index is nearly identical to the one step hedonic findings (t-ratios are in parentheses)

$$\text{MLS\_Fixed\_effect} = \underset{(2297.6)}{10.881} + \underset{(32.271)}{0.004}\,\hat{E}u$$

counting" concerns raised by McConnell [1990]. Moreover, with information on recreation choices it is possible to consistently estimate the distinct roles for neighborhood amenities and the amenities conveyed through local recreation in an integrated framework.

C. A Policy Application

One important use of hedonic property value models is for estimating bounds for the tradeoffs homeowners would be willing to make to improve the amenities available in their neighborhoods. We can use this logic to evaluate the plausibility of our estimates for the effects of access to, as well as the quality of, local recreation sites. Equation (12) provides the algebraic description of the logic involved. To make the analysis tangible we selected a recent proposal to expand the capacity of a waste water treatment plant serving a growing community, Butner, NC, that is outside Wake County.[18] However, the change would influence important watersheds in the county. The expansion would increase the plant discharge from 5.5 to 7.5 million gallons daily. This increase implies that nitrogen loadings into a tributary of the Neuse River would double.[19] The Neuse Watershed is the most important in Wake County. This river also is the source for water to Falls Lake, one of the popular recreation sites in Wake County, and a drinking water source for homeowners in Raleigh and elsewhere in the county. The lake has already

[18] Our description is based on newspaper accounts of the proposal in *The Raleigh News and Observer*, August 5, 2004, August 7, 2004, and September 24, 2004.
[19] The proposed increased discharge from the Butner waste water treatment plant is possible under current regulations because the Butner facility purchased emission permits from the Bay River Metropolitan Sewage District near the mouth of the Neuse River. The emissions from the Bay River facility are, for practical purposes, directly into the Pamlico Sound at New Bern, N.C. The purchase of 6,113 pounds of this facility's permits translates into 61,130 pounds 200 miles up river because it is estimated that only 10 percent of the added nitrogen up river would reach the end of the Neuse. The permits are defined exclusively on the basis of nitrogen entering the estuary. They do not consider the intermediate effects of increased discharges on the river and ecosystem throughout the 200 mile stretch.

begun to experience water quality problems even without this expansion. The upper portion of the lake has measured concentrations of chlorophyll A, exceeding state standards. Chlorophyll A is related to algae blooms and water quality. Increased nutrients will accelerate these problems.

To illustrate how our linked model can be used to consider the effects of this change, we assume that granting the expansion permit would imply Falls Lake was no longer an attractive recreation site for local outings due to the continued degradation associated with the increased nitrogen loadings into the lake. To represent this change we removed Falls Lake from the choice set describing available sites in each of the 17 MLS zones where it was a choice alternative. This process allows us to compute the change in expected maximum utility, our quality-adjusted index of the "quantity" of local recreation opportunities available to each housing market. We then use the estimated hedonic price function to compute an upper bound for homeowners' annual willingness to pay to avoid this change. Our estimates use the adjusted predictions for the housing prices and a five percent rate to compute the annual estimate of the bound for the willingness to pay.[20]

Table 5 reports these estimates in the second column along with the proportionate change in the expected maximum utility (in the third column), the average sales prices for housing by MLS zone (in the sixth column), and some other information to gauge the importance of the Falls Lake site for the survey respondents in each MLS zone. These summary statistics are given in the last four columns. First, we list the total number of local outings reported to be taken by our survey respondents and the average per

[20] The adjusted price is an approximation to reduce the bias in predicting the price from a semi log model. For simplicity we assume housing is completely durable, so the annual value is the discount rate times the sales price.

respondent in the seven month period covered by our survey. To evaluate the potential importance of Falls Lake to these residents, we also computed the number of these outings that were to the Lake and the average outings per user. Economic importance is not exclusively associated with the count of trips. It will also depend on the alternatives available with comparable proximity and quality.

Comparison of the values measured for the loss together with the total outings versus the outings to Falls Lake confirms this conclusion. Some of the larger values arise when there are a number of outings to other sites, as in the case of MLS zones 2, 4, and 7. The Falls Lake site makes an important contribution to the quality adjusted index of the amount of recreation opportunities available in an area, thus relying on the pattern of use alone would be misleading. Of course, the largest values for MLS zone 14 (close to the Lake) arise where residents perceive few alternatives.

Finally for comparative purposes we report the average value for the change in per trip consumer surplus (also in 1998 dollars) due to the loss of Falls Lake as a choice alternative by MLS zone. This estimate is based on each zone's random utility model and the change in the expected maximum utility with and without Falls Lake in the choice set. There are two added steps required to compute it. First, the difference in the average log sums with and without Falls Lake is divided by the absolute magnitude of the parameter estimated for travel time. We could consider this ratio as expressing the willingness to avoid the loss, in time units – the amount of free time a person would give up rather than close Falls Lake from their choice set. To monetize this time, we make use of some related research with this same sample (see Palmquist, Phaneuf, and Smith [2004]). This work hypothesized that the opportunity cost of time varies based on the amount and timing of the time required for recreation. We use the time allocations of our survey respondents along with their willingness to pay to substitute market services for some home production to estimate this opportunity cost. Our analysis suggests the marginal opportunity cost varies with the amount of time required. For these computations we used the marginal value for a 4 hour trip and adjusted the estimated parameters for time costs. Using this average value by MLS zone (and given in column six) together with the willingness to give up time, it is possible to develop an approximate estimate of the per trip consumer surplus. If we scale this willingness to pay by the average number of outings taken by our sample respondents to all sites (given in column eight) we see the product is generally less than the long run value implied by the hedonic estimates. While there is no reason to expect the short run and long run estimates would be equal, there is clear consistency between the two. More specifically, the two methods are monetizing the same increment in the index for the change in recreation opportunities. The hedonic uses the long run market capitalization of these opportunities (in annualized terms) by the housing market. The monetizing of the same index uses another market – based on labor/leisure choices and time allocation choices when respondents were offered short run options for adjustment. In the absence of uncertainty and with limited adjustment costs, we could specify an envelope condition that would imply equality in these values.[21] The close correspondence for our approximation implies there is scope for using housing markets together with structural models of how ecosystem services contribute to people's activities in developing revealed preference estimates for fairly complex patterns of spatial effects on behavior, provided we can rely on people observing how these services contribute to the quality of their activities.

[21] This condition is what McConnell [1990] was implicitly describing.

V. Implications

Measuring people's valuation of water quality and watershed services with hedonic property value models has proved difficult. Leggett and Bockstael [2000] suggest that despite consumers' reports indicating they want to live near water resources for the recreational opportunities they offer, there are often few opportunities for analysts to observe sufficient local differences in recognizable water quality conditions to measure their effects. As a result, these authors highlight the distinction between the geographic extent of the housing market and the likely spatial variation in water quality conditions. To estimate consumers' responses to differences in the services provided by improved water related resources within a hedonic framework there must be sufficient variation in the measure hypothesized to characterize these services. Often this is not the case. Properties on a single lake are unlikely to experience markedly different water quality. Their analysis of the sales of waterfront properties on the western shore of the Chesapeake Bay was successful in estimating a water quality effect using a distance weighted average of and index for the bacterial contamination (i.e. the fecal coliform counts from 104 monitoring stations). The water quality measure exhibited sufficient spatial variation to evaluate its effect on coastal property values. Mahan et al. [2000] also found that proximity to streams, lakes and some types of wetlands increase property values in Portland. However, their efforts to estimate second stage inverse demand models were not successful. They also acknowledge the important role the spatial extent of the market plays in these types of analyses.

Our research suggests that there are several distinct roles for the services of environmental resources. A single proxy index is unlikely to be able to adequately reflect all of them. One of the first of these roles is as a neighborhood amenity. This contribution is the one most widely recognized in the hedonic literature. A second role often acknowledged in discussions of the importance of ecological services but with little specific discussion in the hedonic literature arises when their services make a supporting contribution to other activities. Some of these involve people and their outdoor recreation trips. Others involve related natural resources, such as groundwater, whose quality and recharge rate can be influenced by the characteristics of watersheds.

The spatial boundaries relevant for these various influences across different sets of activities need not be the same. Neighborhood amenity effects are likely to be associated with the immediate proximity of a house, as our index of access to close lakes implied. It is less clear how to characterize the roles for other influences. Most hedonic studies have relied on some distance based index. We have suggested an alternative approach.

Our framework considers the decisions used in revealed preference models applied to environmental services as alternative strategies to recover information about the importance of these services to people. Each describes a different choice margin. To integrate their results, the various choices must be described consistently. In this paper we used the long run/short run distinction to integrate local recreation choices with residential housing decisions.

Efforts to propose some type of integration are not new to non-market valuation. One was the basis for Cameron's [1992a, 1992b] proposal to use revealed preference behavior to impose “budget discipline” on the stated preference choices people make for the same resource. A proposed strategy for integration is also the basis for the maintained assumptions that Smith, Pattanayak, and Van Houtven [2002] use to calibrate preference functions for benefit transfers. In our case here, however, there is an important distinction. Revealed preference models are used to construct a quantity index that collapses the recreation opportunities available to those living in a neighborhood. This index is derived from a model of recreation demand. The model reduces the complexity of all the attributes and availability measures for the local recreation sites into a consistent quantity index. It also defines the spatial domain of influence through the choice set of recreation sites considered relevant for the model.

The equilibrium housing price will be influenced by this index because the opportunities differ across the neighborhoods comprising a housing market. McConnell [1990] describes this prospect as a potential source for double counting. He argues that property values capitalize the expected future values derived from the available recreation services due to a location. Our use of the expected value of the maximum utility available from a recreation choice set is consistent with his suggestion that it is not a large leap to propose that “…the present discounted value of pollution damage from an ex ante concept, containing valuation of expectations of future choices” (p. 126). The potential for connections does not stop here. Rather, our proposed logic offers the means to consider other watershed services, provided there is a basis for using current choice margins to describe how these services contribute to current decisions.

Our empirical example exploits prior information describing the types of recreation likely to be associated with choices among alternative housing neighborhoods.

The measure of these recreation alternatives in a location was a consistent and significant determinant of housing prices and the specification also controls for the effects of more general amenity effects of proximity to local water resources. We developed estimates for the value of avoiding the loss of a popular recreation site in the northern portion of Wake County using both the hedonic bounds and the random utility models. The results are consistent with interpreting the hedonic as ex ante bound for the incremental value of the expected future services from protecting the lake.

Table 1: Primary Variables for Empirical Analysis

Name	Definition
A. <u>Hedonic Variables</u>	
lprice	Natural log of sale price of property
baths	Number of bathrooms
regheatarea	Main heated living area in square feet
age	Age of structure, calculated as sale year-year built
acreage	Lot size in acres
sewer	Community sewer system
bsmtheat	Basement heated area in square feet
atticheat	Attic heated area in square feet
encporch	Enclosed porch area in square feet
scrporch	Screened porch area in square feet
opnporch	Open porch area in square feet
garage	Garage area in square feet
Deck	Deck area in square feet
fireplaces	Number of fireplaces
detgarage	Dummy variable indicating presence of detached garage
walldum1	Dummy variable indicating presence of brick walls
bsmtdum1	Dummy variable indicating presence of full basement
bsmtdum2	Dummy variable indicating presence of partial basement
floordum1	Dummy variable indicating presence of hardwood floors
poolres	Dummy variable indicating presence of residential swimming pool
condadum	Dummy variable indicating house is of condition A (highest)
condcdum	Dummy variable indicating house is of condition C
condddum	Dummy variable indicating house is of condition D
commuting time	Average travel time to work computed for workers 16 years and older by block group based on 2000 census
Lake Distance Index	this variable is measured in feet as the $\max\left[1-\left(\frac{d}{d_{\max}}\right)^{1/2},0\right]$ where d is the distance of each house to the nearest lake and $d_{\max}$ is the maximum distance, assumed to be ½ mile (2,640 feet)
B. <u>Recreation Variables</u>	
Travel time	Time in minutes for one way trips from respondent's home to recreation site[a]

[a] The travel time and travel distance between each survey respondent's house and each recreation site were calculated using the PCMiler software. PCMiler calculates distances between lat/long points along a road network, and then estimates travel times using speed limit information. It has been commonly used in travel cost models to calculate travel distances and times, however it is designed for the trucking industry.

Distance	One-way distance in miles from respondent's home to the recreation time[a]
C. Watershed Variables	
Percentage Impervious Surface[b]	Measure of fraction of land area in MLS zone covered with impervious surface
Sub Watershed Rating	Classification of 81 sub-hydrologic units in Wake County as healthy, impacted, or degraded, based on the CH2MHill evaluation of the state of the County's watersheds
D. Household Survey	
less high	qualitative variable = 1 if less than high school education
Finc	family income (in dollars)
male	qualitative variable = 1 if respondent is male
white	qualitative variable = 1 if respondent is white
age of respondent	age in years
children less than 6	number of children less than 6 years of age
time_limited	qualitative variable = 1 if respondent indicates leisure time is limited
boat_own	qualitative variable = 1 if respondent owns a boat

Thus one of PCMiler's drawbacks is that the road network it uses to calculate the times and distances is composed of roads that are accessible to trucks. The error in estimating travel times and distances using a network of major roads accessible to trucks is likely to be largest for the sites used for local outings.
To decrease the measurement error that might be introduced with PCMiler in these cases, an alternative strategy was developed using Arcview. Using a comprehensive road network including minor roads developed by "Tigerline" (Census 2000 TIGER/Line Data is provided by the U.S. Bureau of the Census) for Wake County, travel times and distances from survey households to local recreation sites were calculated within Arcview. One exception was the calculation of times and distances to Jordan Lake, a popular local recreation destination located just outside of Wake County. By calculating the travel time and distance to the County line, and the adding this time and distance to the PCMiler estimate from the county line to the site, a more accurate time and distance was generated to this recreation site. To determine if the other Arcview estimates were more accurate than the PCMiler estimates for the local recreation site, a sample of 20 households and 10 recreation sites were compared to estimates produced by Mapquest, an online service that also uses major and minor roads in their calculations. Based on Sum of Squared Errors, it appears that the Arcview estimates were more accurate than the PCMiler estimates for the local recreation sites. Thus we replaced the PCMiler times and distances with the Arcview times and distances for local recreation sites.

[b] To create a measure of percent imperviousness for other geographic areas in our study, we used the same procedure employed by CH2MHill. Land use types were classified into 17 classes. We used the CH2MHill estimates for percent impervious surface measures for each of the 17 land use classes. The amount of each land type in each area was then weighted by these percentages to measure the impervious surface for the geographic area of interest.

Table 2: Determinants of Count of Sites Used by Type of Recreation Trip[a]

Independent Variables	Local Outing	Day Trip	Two Day Trip
less high (= 1)	-0.142 (-0.40)	0.114 (0.25)	0.382 (0.85)
Finc	-0.067×10^{-6} (-1.94)	-0.022×10^{-6} (-0.47)	0.073×10^{-6} (2.10)
male (= 1)	-0.041 (-0.93)	0.033 (0.53)	-0.060 (-1.23)
white (= 1)	0.116 (1.64)	0.085 (0.85)	0.262 (3.07)
age of respondent	-0.013 (-5.18)	-0.013 (-3.75)	-0.010 (-3.65)
children less than 6	-0.023 (-0.80)	-0.144 (-3.20)	-0.014 (-0.45)
time_limited (= 1)	0.030 (0.57)	-0.009 (-0.13)	-0.029 (-0.50)
boat_own (= 1)	0.263 (4.80)	0.586 (8.49)	0.296 (5.11)
intercept	0.807 (5.93)	0.232 (1.22)	0.178 (1.19)
no. of observations	1572	1354	1641
pseudo R^2	0.013	0.028	0.015

[a] These estimates are based on a Poisson regression model with the number of recreation sites treated as a count variable. The numbers in parentheses are ratios for the estimated coefficients to their asymptotic standard errors.

Table 3: A Sample of Random Utility Models by MLS Zone

Independent Variables	MLS Zone [a]					
	1	5	7	14	15	18
Percent Impervious Surface	-0.035 (-3.71)	0.032 (4.97)	-0.306 (-26.27)	-0.028 (-1.11)	0.005 (0.69)	-0.215 (-7.57)
CH2MHill Rating = Degraded (=1, 0 otherwise)	0.773 (8.25)	0.333 (7.92)	3.406 (23.89)	-0.645 (-2.03)	-0.863 (-6.93)	2.882 (9.241)
Travel Time	-0.070 (-8.32)	-0.109 (-30.94)	-0.126 (-36.66)	-0.138 (-13.37)	-0.193 (-19.99)	-0.125 (-14.39)

[a] The numbers in parentheses are the ratios of the estimated parameters to its estimated asymptotic standard error for the null hypothesis of no association.

Table 4: Hedonic Property Value for Sales in 1998 and 1999

Independent Variables	Model[a]	Means[b]
Index of Recreation Access[c]	0.004 (28.56)	–
Lake Distance Index[d]	0.014 (2.57)	–
age	-0.002 (-17.54)	11.37 (15.06)
baths	0.036 (23.97)	2.46 (0.68)
acreage	0.042 (29.84)	0.45 (0.62)
regheatarea	0.039×10^{-2} (204.43)	1,914 (681.24)
detgarage	0.085 (18.83)	0.03 (0.17)
fireplaces	0.068 (29.16)	0.91 (0.34)
deck	0.019×10^{-2} (33.42)	159.35 (145.05)
sewer	0.013 (5.60)	0.83 (0.37)
floordum1	-0.015 (-4.35)	0.10 (0.30)
scrporch	0.034×10^{-2} (25.40)	16.78 (55.88)
atticheat	0.023×10^{-2} (42.96)	43.21 (142.27)
bsmtheat	0.058×10^{-3} (11.22)	48.39 (199.66)
garage	0.030×10^{-2} (69.80)	289.46 (248.82)
poolres	0.006 (0.76)	0.01 (0.09)
bsmtdum1	0.133 (30.93)	0.052 (0.221)
bsmtdum2	0.138 (35.70)	0.063 (0.243)

[a] The numbers in parentheses are t-ratios for the null hypothesis of no association.
[b] Numbers in parentheses are standard deviations.
[c] The Index of Recreation Access corresponds to the average values across properties sold for the log sum derived from the parameter estimates for the random utility model associated with each house's MLS zone.
[d] The Lake Distance Index is $\max\left[1-\left(d/2650\right)^{1/2};0\right]$ with d the distance from the home to the nearest lake.

walldum1	0.038 (14.22)	0.113 (0.317)
encproch	0.196×10^{-3} (7.32)	3.72 (28.11)
opnporch	0.169×10^{-3} (19.10)	68.46 (85.17)
condadum	0.231 (62.58)	0.06 (0.233)
condcdum	-0.139 (-28.22)	0.03 (0.158)
condddum	-0.310 (-19.09)	0.02×10^{-1} (0.041)
commuting time	0.005 (47.50)	28.61 (8.37)
Year of Sale = 1999	0.036 (24.22)	
Intercept	10.853 (2,224.10)	180,202[e] (75,564)
no. of observations	38,725	
R^2	0.861	

[e] The average value of the sales price.

Table 5: WTP Bounds for Removing a Recreation Site

MLS Zone	Hedonic Bound for WTP[a]	Proportionate Change in Recreation Index	Benefits – RUM per trip[b]	Marginal Value of Time (per hour)	Average Housing Price	Local Outings – All Areas		Falls Lake Outings	
						Total	Per User	Total	Per User
1	1.49	0.039	0.30	32.24	208,851	920	5.75	82	3.7
2	3.40	0.090	0.31	27.18	188,630	3,414	10.25	485	6.6
3	1.59	0.061	1.18	45.25	107,387	143	4.09	13	6.5
4	7.32	0.235	0.37	20.96	136,030	854	8.80	6	1.5
5	0.16	0.004	0.02	28.78	207,699	3,150	7.93	54	2.8
6	0.15	0.006	0.01	20.85	123,880	523	7.58	4	2
7	12.87	0.279	1.15	31.12	225,316	2,058	6.77	958	8.3
8	3.03	0.106	0.14	25.72	134,764	698	5.97	118	5.1
9	0.57	0.014	0.08	19.74	195,453	1,124	4.89	21	3.5
10	–	–	–	18.33	232,327	657	7.30	0	0
11	1.34	0.049	0.28	26.77	123,567	333	4.01	56	4.3
12	17.31	0.830	0.48	28.89	104,258	96	4.00	47	5.9
13	10.31	0.332	–[c]	15.52	123,211	58	2.64	14	2.3
14	58.86	1.606	3.86	19.95	177,824	310	4.25	217	5.7
15	0.06	0.002	0.005	32.57	174,766	869	6.30	3	1
16	2.14	0.069	0.57	26.53	138,287	366	3.62	6	2
17	–	–	–	20.00	155,304	142	4.58	0	0
18	0.41	0.012	0.03	20.02	157,528	401	4.66	10	1.7
21	1.81	0.056	1.09	30.99	148,560	383	4.30	168	4.8

[a] These estimates are in 1998 dollars. They use the predicted price and adjust for the bias in converting from the predicted $\ln p$ to a predicted price. $\hat{p} = \exp(\ln \hat{p}) \cdot (1 + \tfrac{1}{2}\mathrm{var}(\ln \hat{p}))^{-1}$ (see Kennedy[1983] for further details).

[b] Converted to 1998 dollars using the Consumer Price Index.

[c] The estimated parameter for time cost of travel was positive for this model. As the seventh column indicates, this MLS zone had the smallest number of local outings generated, with only 22 users.

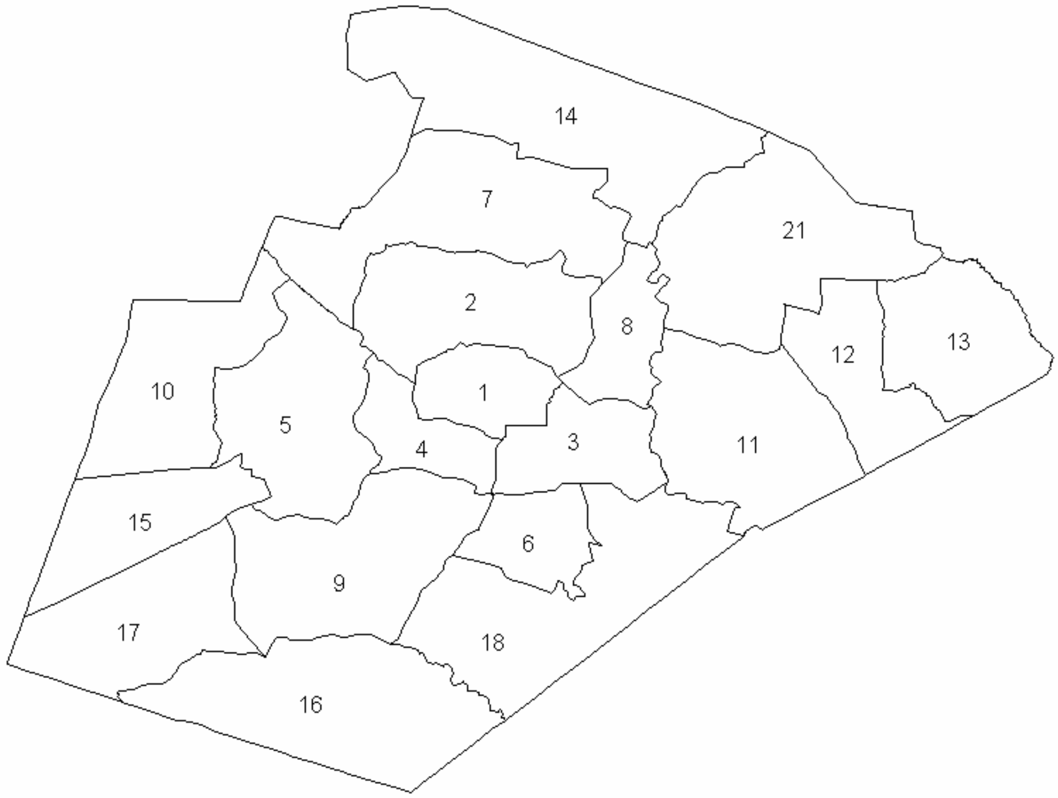


Figure 1: MLS Spatial Zones for Housing Submarkets in Wake County, NC

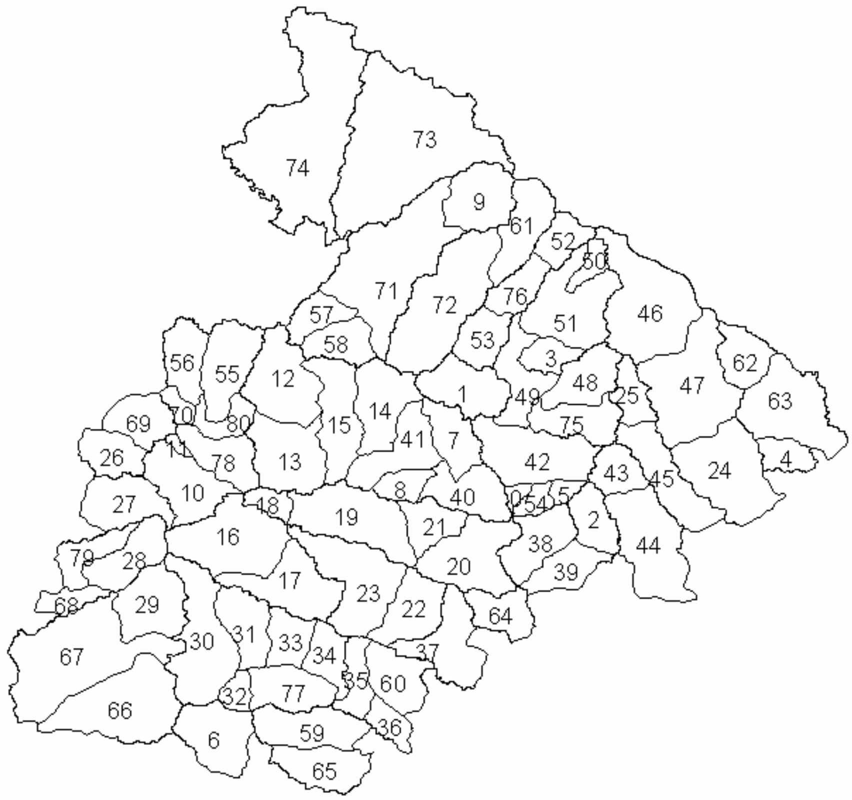


Figure 2: CH2MHill Zones for Disaggregated Spatial Units in Wake County, NC

References

Atasoy, Mary, Raymond B. Palmquist, and Daniel J. Phaneuf, 2003, "Land Use Patterns and Pollution in the Upper Neuse," presented at Water Resources Research Institute Annual Conference, Raleigh, April.

Bateman, Ian J., Matthew Cole, Phillip Cooper, Stavros Gerogiou, David Hadley and Gregory L. Poe, 2004, "On Visible Choice Sets and Scope Sensitivity," *Journal of Environmental Economics and Management*, 47(January): 71-93.

Cameron, Trudy Ann, 1992a, "Combining Contingent Valuation and Travel Cost Data for the Valuation of Non-market Goods," *Land Economics*, 68(3): 302-317.

Cameron, Trudy Ann, 1992b, "Nonuser Resource Values," *American Journal of Agricultural Economics*, 74(5): 1133-1137.

Cappiella, Karen and Kenneth Brown, 2001, *Impervious Cover and Land Use in the Chesapeake Bay Watershed*, report by the Center for Watershed Protection for U.S. EPA Chesapeake Bay Program, January.

CH2MHill Inc., 2003, "Wake County Final Plan," *Wake County Comprehensive Watershed Management Plan*, Charlotte, NC, February. (This document and other related documents can be found at http://projects.ch2m.com/WakeCounty).

Cropper, Maureen L., Leland B. Deck and Kenneth E. McConnell, 1988, "On The Choice of Functional Form for Hedonic Price Functions," *Review of Economics and Statistics*, 70(November): 668-675.

Dillman, Don A., 1978, *Mail and Telephone Surveys: The Total Design Method*, (New York: John Wiley & Sons).

Egan, Kevin J., Joseph A. Herriges, Catherine L. Kling, and John A. Downing, 2004, "Recreation Demand Using Physical Measures of Water Quality," Department of Economics, Iowa State University, Working paper, (August).

Farber, Stephen and Brian Griner, 2000, "Valuing Watershed Quality Improvements Using Conjoint Analysis," *Ecological Economics*, 34(1): 63-76.

Feenstra, Robert C., 1995, "Exact Hedonic Price Indexes," *Review of Economics and Statistics*, 77(4): 634-653.

Feitelson, E., 1992, "Consumer Preferences and Willingness to Pay for Water-Related Residences in Non-Urban Settings: A Vignette Analysis," *Regional Studies*, 26(1): 49-68.

Johnston, Robert J., Stephen K. Swallow and Thomas F. Weaver, 1999, "Estimating Willingness to Pay and Resource Tradeoffs with Different Payment Mechanisms: An Evaluation of a Funding Guarantee for Watershed Management," *Journal of Environmental Economics and Management*, 38(July): 97-120.

Kennedy, P.E., 1983, "Logarithmic Dependent Variables and Prediction Bias," *Oxford Bulletin of Economics and Statistics*, 45( ): 389-392.

Leggett, Christopher G. and Nancy E. Bockstael, 2000, "Evidence of the Effects of Water Quality on Residential Land Prices," *Journal of Environmental Economics and Management*, 39(2): 121-144.

Mahan, Brent L., Stephen Polasky, and Richard M. Adams, 2000, "Valuing Urban Wetlands: A Property Price Approach," *Land Economics*, 76(1): 100-113.

McConnell, K.E., 1990, "Double Counting in Hedonic and Travel Cost Models," *Land Economics*, 66(2): 121-127.

Moulton, Brent R., 1990, "An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables in Micro Units," *Review of Economics and Statistics*, (May): 334-338.

Nevo, Aviv, 2001, "Measuring Market Power in the Ready-to-Eat Cereal Industry," *Econometrica* 69 (2): 307-342.

Palmquist, Raymond, 2004, "Weak Complementarity, Path Independence, and the Willig Condition," *Journal of Environmental Economics and Management* (in press).

Palmquist, Raymond B., Daniel J. Phaneuf and V. Kerry Smith, 2004, "Differing Values of Time for Non-Market Valuation: A Theoretical and Empirical Comparison," Paper presented to American Agricultural Economics Association, Denver, Colorado, (August).

Parsons, George R., 1991, "A Note on Choice of Residential Location in Travel Cost Models," *Land Economics*, 67(3): 360-364.

Phaneuf, Daniel J., 2002, "A Random Utility Model for Total Maximum Daily Loads: Estimating the Benefits of Watershed-Based Ambient Water Quality Improvements," *Water Resources Research*, 38 (11): 36-1 – 36-11.

Pollak, Robert A., 1969, "Conditional Demand Functions and Consumption Theory," *Quarterly Journal of Economics*, 83 (February): 60-78.

Poor, P. Joan, Kevin J. Boyle, Laura O. Taylor, and Roy Bouchard, 2001, "Objective versus Subjective Measures of Water Clarity in Hedonic Property Value Models," *Land Economics*, 77(4): 482-493.

Schueler, T., 1994, "The Importance of Imperviousness," *Watershed Protection Techniques*, 1(3): 100-111.

Smith, V. Kerry, George L. Van Houtven and Subhrendu K. Pattanayak, 2002, "Benefit Transfer via Preference Calibration: Prudential Algebra for Policy," *Land Economics*, 78(1): 132-152.

Willig, Robert D., 1978, "Incremental Consumer's Surplus and Hedonic Price Adjustment," *Journal of Economic Theory*, 17: 227-253.

Woodard, Richard T. and Yong-Suhk Wui, 2001, "The Economic Value of Wetland Services: A Meta-Analysis," *Ecological Economics*, 37(May): 257-270.

Appendix A

Table 1A: Survey Assignments and Returns by MLS Zone

MLS Zone	Surveys Mailed[a]	Surveys Returned	Proportion Returned
1	358	107	0.299
2	1055	334	0.317
3	289	101	0.349
4	179	62	0.346
5	1401	430	0.307
6	281	87	0.310
7	840	260	0.310
8	481	149	0.309
9	525	162	0.323
10	334	108	0.342
11	284	97	0.361
12	97	35	0.457
13	81	37	0.306
14	222	68	0.352
15	270	95	0.296
16	274	81	0.417
17	48	20	0.265
18	230	61	0.334
21	305	102	0.317
Total	**7554**	**2396**	**0.317**[b]

[a] Errors in record keeping caused the version number of four surveys to be omitted from the tracking system. As a result, they are included here but not used in subsequent analysis.
[b] Proportion returned for the county as a whole.

Session III: Keeping Water Fresh: The Value of Improved Fresh Water Quality
Discussant Comments -- John Powers
October 26, 2004

Summary of Egan et al.

The purpose of the research is to provide information on the recreational value of water quality improvements as a function of detailed physical attributes of water bodies. The research supports Iowa's effort to comply with Clean Water Act requirement to develop TMDLs for impaired waters. The policy effort involves identifying priority waterbodies and strategies for allocating resources through the use of cost and benefit information on remediation efforts.

The research includes developing a recreation demand (travel cost) model of recreational lake usage in Iowa. Unique data collected by Iowa State University's Limnology Laboratory an extensive array of physical attributes, including Secchi depth, chlorophyll, 3 nitrogen measures, phosphorus, silicon, acidity (pH), alkalinity, and 2 suspended solids measures. The researchers are also collecting site and household characteristics data .

The authors use a mixed logit model that integrates site selection and participation decisions in a utility consistent framework. They estimate model specifications that differ in the numbers of physical water quality measures in order to test for the stability of parameter estimates.

The estimated parameters are generally of the expected sign, with water clarity being valued highly. Some variation in water color is acceptable, but high algae levels lead to a reduced number of trips taken.

The results indicate that policy makers can maximize benefits by spreading improvements across the state, and by improving a smaller number of lakes to high quality rather than raising a large number of lakes to average quality.

Comments

Overall, this is a nice paper, but it is only a small fraction of the bigger project. I like the idea of testing to see how recreation demand is affected by physical characteristics of water quality. The results suggest people know about and respond to <u>easily observed</u> characteristics, especially water clarity. But, the impact of nitrogen is less observable, and also very valuable, since it affects the nitrogen-phosphorous balance, and has impacts in estuaries.

Several questions for the researchers

How does limited information about water quality affect the welfare estimates? Does the valuation <u>methodology</u> affect your answer (e.g., SP rather than RP)? Does knowing the source of contamination affect "value"?

Summary of Smith et al.

The purpose of the research is primarily methodological. The authors examine choice margins using hedonic and recreation demand (travel cost) models through integrated estimation of hedonic property values (long run decisions) and recreation demand values (short run decisions). Expected recreation benefits are viewed as a (public) attribute of home location. The results are used to estimate the impact (lost water quality benefits) of recent proposal to expand capacity of wastewater treatment plant serving a growing community (Butner, NC). In this example, the authors estimate willingness to pay to avoid the adverse impact on recreation and drinking water in Wake County, NC of nitrogen loads into the Neuse River.

This study attempts to estimate choice margins across a larger set of alternatives, by using hedonic and travel cost methods in an integrated manner. This analysis involves using GIS-based models and data, socio-economic data, water quality measure, property sales, and recreation data for over 2,000 households. Several indexes are used in this study, including a Watershed Quality Index , which is used to summarizes effects of watershed quality measures on local recreation opportunities, a Recreation Quantity Index (Index of Recreational Opportunities), which is used to capture the expected benefits from recreation, and a Lake Distance Index, which is an index of lake proximity, accounting for distance of the house from the nearest lake, and the maximum distance from where the lake has any effect on house value.

Comments

I like the idea of integrating different sources and types of benefit information, although I am concerned about the complexity. I also think the use of the indexes is quite interesting, though I would like to see greater attention given to index structure and theoretic rationale. Finally, does it matter whether we measure from the household location to the resource location, or vice versa?

General comments

The "commodity" definition is important to benefit transfer so that apples-to-apples transfers are possible. If we think of an ecosystem production function, then we can obtain value estimates for ecosystem <u>outputs</u>, such as safe drinking water or safe water for swimming (e.g., CWA designated uses), or ecosystem <u>inputs</u>, such as biophysical characteristics (e.g., pollutant concentrations). What is/are the "policy-relevant" definition(s) of water quality? And are certain valuation methods are to different definitions?

Indexes are alluring but can be tricky. They can help facilitate analysis, and can help communicate complexity, but without a simple theoretical structure, they can also be easily criticized.

How do we reconcile these tensions? Benefit transfer is commonplace, as policy analysts at all levels of government look to the literature for benefits information. How do you (researchers) feel knowing that your published findings could be used to estimate the benefits of a policy beyond the immediate scope of your study (e.g., benefits of agricultural nutrient controls in New England, or Minnesota, or the whole US). For the researchers, how does it feel to know that your research findings may be used in a transfer? Also, how does the geographic scale of your work affect your current research? Could you shift your research into a regional or national scale?
How high are the transaction costs associated with multidisciplinary research?

Summary of the Q&A Discussion Following Session III (Part 1)

Steve Swallow (University of Rhode Island)
Directing his question to Joseph Herriges, Dr. Swallow stated that he noticed most, or perhaps all, of the water quality dimensions were linear. He said he was "just thinking about how a lake ecosystem works—maybe I should talk about nutrients, maybe I should talk about Secchi depths, whatever, but if you can see to the bottom of a lake, that's a lake that doesn't have a lot of nutrients in it." He commented that although that may be aesthetically pleasing, it's not necessarily good for fish and, therefore, might be affecting the "recreation quality." Dr. Swallow continued: "If you raise the Secchi depth up to zero, that means it's eutrophic—everything is growing, and it probably stinks, too." He closed by asking whether Dr. Herriges has "thought about trying to do some non-linearities where there might be a *peak* in the quality from the perspective of what humans are valuing but a difference from the peak in the quality from the perspective of a pristine ecosystem that some of your ecology friends might be focused on."

Joseph Herriges (Iowa State University)
Dr. Herriges explained that he didn't really have time to talk a lot about the specification search part of the study, but a lot of that came from talking with, in this case, the limnologist. He continued, " I showed you a real simple version of the model, but what we're doing in the specification search is looking over a variety of models with both linear and non-linear effects—non-linear effects in terms of Secchi depth and things like that—so we have looked at a whole range of different models and we have found non-linear effects in a number of the variables. In the specification stage, we're searching over both whether to include a variable in the model and also what non-linear form we have." Dr. Herriges stated that "one of the things coming out of this conference is that we need to go back and look at some more non-linearities in the process. The limnologist has been particularly helpful in pointing out which variables might be the ones we focus on because they have *physical* signs that people visiting the lake might see. So, that's why we had the six variables I showed you—those are the ones we focused on initially because the nutrients and so on have particular physical attributes that people can see." He concluded by reiterating that they "have all the other variables in and have looked at a lot of different non-linearities."

Steve Swallow
Dr. Swallow added, "It also might affect the difference you're seeing between different user groups—the people who get in the water versus the people who are on top of the water fishing."

Joseph Herriges
Dr. Herriges replied, "In fact, that's something we *haven't* done, which I think would be useful to do. We have not looked at segmenting the population. The problem there is that different user groups are somewhat endogenous—if you don't like certain types of water quality, you may not be a swimmer *because* you don't like the physical attributes, so there's a bit of a problem modeling what people choose to do."

David Widawsky (U.S. EPA/OPP)
Identifying himself as "both a producer and consumer of ecological benefits analysis," Dr. Widawsky said he wanted to bring the focus back to the subtitle of the workshop: Improving the Science Behind Policy Decisions. Referring to "the talks we heard just now and some of the talks we heard this morning," he stated "policy decisions are often presented as a choice between one set of biophysical properties and another set of biophysical properties. We know that in getting to that different set of biophysical properties, the real decision is not choosing that set of properties but choosing a set of land use decisions and behaviors that are *linked* to the properties and which we can value through the biophysical models that are kind of the *challenge*. As we heard this morning from Nicole and in the keynote address, the challenge is with respect to having an *integrated* model between an ecological assessment model, an ecological valuation model, and an economic model. My question is: To what degree do you gentlemen incorporate biophysical models to describe how all of this gets you to the sub-characterization of value and what challenges were expected getting to an integrated model, and . . . how would you address those challenges?"

Joseph Herriges
Dr. Herriges responded, "The quick answer is: We did not look at that." He continued, "What we're doing in our project, for example, is trying to look at the value that the households place in certain attributes of the lakes, certain water quality levels. I think the question you're addressing is that there's a cost associated with that. You have to understand that if you're really going to evaluate whether to adopt a [program] to try to get these lakes up to a given level of quality, we want to know the benefits of that, and that's really what our project is looking at. But, you also need to know the *costs* of doing that, so you need to be able to model the fate and transport of the various pollutants getting in, how different incentives might cause changes in land use and how those then, in turn, affect the water quality." Reiterating that that's a different issue outside the scope of their study, Dr. Herriges commented, "There is actually a project going on at Iowa State University in the Center for Agricultural and Rural Development trying to do exactly that—trying to pair up our work on getting at the benefits with their own work of trying to model the cost of achieving different levels of water quality through different incentives on land use and set aside and so on.

Kerry Smith (North Carolina State University)
Dr. Smith said, "I should say that I was, as usual, not very clear on what the benefit we measured was. The benefit measured, which I presented at the very end, was just the elimination of the site, in this case Falls Lake, from the choice set. Ray [Palmquist] and Dan [Phaneuf] have done some separate work that, as we develop this index function I'm talking about, would be capable of being used, but it's . . . sort of a reduced form model. What they've done is they've put their variety of different measures based on monitoring

data in the Neuse River watershed of ambient concentrations of different pollutants—nitrogen, phosphorus, and so forth—and then set up a spatial model that takes account of both the timing of the monitoring and the timing of the activities, and in this case it's changes in land cover and land use at points that are upstream of the places where the measurements are taken. Now, in principle, if we had those physical attributes that they are describing in the largely reduced form model, conveyed through our index, then it would be possible to make *somewhat* of a connection. The difficulty is that the closed loop . . . isn't in our model—the closed loop being: suppose we were to take this reduced form model that they've developed that looks at land cover changes and new development (new building permits, new land conversion, and so forth) and it takes that and it links it to total measured phosphorus or nitrogen or something else at a particular point in the river. That gets conveyed through our index up to our housing model, and we say "Okay, no problem, we're just going to put some limits on here—we'll refer to them as brand new versions or something else so it will *simulate* that effect in the reduced form model that they've got, then that will connect to our index, and we'll just value it in the Hedonic model. The problem is that the Hedonic equilibrium is different because it's restricting the nature of the land use that's associated with getting the outcome in the beginning of the model, so the feedback would be passively put in there.

So, the short answer that I should have said was: No, we didn't do that. Those of you who have listened to me so far today know that I *never* give *any* short answer to *any*thing."

Robert LaFrance (Connecticut Department of Environmental Protection)
Mr. LaFrance said, "I've listened to a lot of your academic discussions and I'm wondering: How do you guys relate to local and state officials, both those who are elected and those who are not? Maybe you can give me some sense of your interaction with them, because that's kind of where I'm at and I'm trying to take some of this and bring it back to my job."

Joseph Herriges
Dr. Herriges responded, "I'm not sure how to answer that question. This gets back to this whole issue about interdisciplinary research, too. There are interactions between ecologists and economists, and getting the communication between those two different disciplines *and* communicating with the local and state regulators in the process [is often difficult]. There are costs associated, but there are *huge* benefits as well. In our project the limnologist actually started this interaction by calling and saying that they were doing this extensive study and would like some economic numbers at the end—economists are used to being called in at the very end. Well, what's happened in the process of both of us talking to each other is that the project has evolved into something bigger and broader." He said this expansion of the project involved "bringing in local people and finding out what matters to them in terms of the lake—what changes they're looking at, their interest in local economic impact versus what economists would say in terms of changes in value, etc." Dr. Herriges summarized by saying, "Communication is

extremely important. We've learned a lot by talking to state regulators, and what matters to them is they want to know that people will actually *do* something as a result and that they'll contact their state legislator and there will be *action* coming out of this. So, learning how to communicate with each other is extremely important in this process.

Kerry Smith
Dr. Smith advised Mr. LaFrance to talk to his colleague Dan Phaneuf about that issue. "because he's really had much more experience, not only in the context of developing this model I refer to, but in the context of working with some folks at RTI (RTI International, Inc.) at integrating a watershed model with an economic model for a large local project." He went on to relate this story: "Many years ago I was asked to *pretend* I was an expert witness at a mock trial that took place in New York City—this was about twenty years ago—and the best way of characterizing *me* interacting with public officials was what was *said* after I pretended I was an expert witness and was supposed to be presenting *purely* the results of an economic model. A retired judge who was listening to this looked at the people who had hired me and said, "*Where* did you find *this* person?" That has often been the response I get."

Clay Ogg (U.S. EPA, National Center for Environmental Economics)
Dr. Ogg identified himself as "the Project Officer on the other project that you mentioned where they're looking at the production costs . . . and we did ask them if this cost analysis is directly linked to the lakes that you're looking at, and I think the answer was "No." . . . They did look at one lake though, and for the first lake that they analyzed I think there was a report that indicated you could actually take all the land out of agriculture and that the benefits would be sufficient to pay for that. But, if you're talking about making Iowa lakes look like Okoboji, I think you are talking about something fairly drastic there in terms of taking land out of agriculture. So, it might be useful at least to look at the size of the watershed you're talking about."

Joseph Herriges
Dr. Herriges admitted to not knowing exactly what project Dr. Ogg was speaking about, but said, "They're working on a number of projects, and some of them are very much at a smaller watershed level. The project I'm talking about actually is with the Iowa DNR (Department of Natural Resources), and I think it's a different project than the one you're referring to." He added, "I'm not on the project, so I can't tell you exactly what they're doing, but my understanding is that they're trying to give the state some information about the cost side of achieving some improvements in water quality. I don't know how *broad* it is, but that's the *kind* of thing you have to look at. We're trying to model the benefits, but if we're trying to achieve some of these improvements in water quality, you need to understand the costs and how that works."

END OF SESSION III (Part 1) Q&A

Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

PROCEEDINGS OF

SESSION III, PART 2: KEEPING WATER FRESH:
THE VALUE OF IMPROVED FRESH WATER QUALITY

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

October 26-27, 2004
Wyndham Washington Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Cynthia Morgan and the Project Officer, Ronald Wiley, for their guidance and assistance throughout this project.

DISCLAIMER

TABLE OF CONTENTS

Session III, Part 2: Keeping Water Fresh: The Value of Improved Fresh Water Quality

Valuation of Natural Resource Improvements in the Adirondacks

Spencer Banzhaf, Dallas Burtraw, David Evans, and Alan Krupnick*

Resources for the Future

October 2004

* Corresponding author. Resources for the Future, 1616 P Street NW, Washington, DC, 20036; krupnick@rff.org.

Valuation of Natural Resource Improvements in the Adirondacks

Spencer Banzhaf, Dallas Burtraw, David Evans, and Alan Krupnick

Resources for the Future

Abstract

For 20 years acid rain has been a central issue in the debate about clean air regulation, especially in New York State's Adirondack Park. Based on a contingent valuation survey of a random sample of New York residents, our study quantifies for the first time the total economic value of expected ecological improvements in the Park from likely policies. Our preferred estimates of the mean willingness to pay using the base case characterization of ecological improvements range from $48 to $107 per year per household in New York State. The alternative scope case yields mean WTP ranging from $54 to $159. Multiplying these population-weighted estimates by the approximate number of households in the state yields benefits ranging from about $336 million to $1.1 billion per year. The instrument passes an external scope test, a test of sensitivity to bid, and a test of sample selection.

Key words: Adirondacks Park, air pollution, contingent valuation, ecological values, New York, non-market valuation, scope test.

Valuation of Natural Resource Improvements in the Adirondacks

1. Introduction

For 20 years acid rain has been a central issue in the debate about clean air regulation and the controversy has centered on the Adirondack Park, which covers some six million acres in New York State. The park was prominent when Congress created the 1980 National Acid Precipitation Assessment Program (NAPAP), which coordinated the expenditure of roughly $500 million to study the effect of acid precipitation on the Adirondacks' ecosystem and other natural resources in the United States. The 1990 Clean Air Act amendments, an important legislative milestone in the protection of air quality, dedicated a separate title to the reduction of acid rain that initiated the well-known sulfur dioxide (SO_2) emission allowance-trading program. More recently, the Environmental Protection Agency (EPA) has cited the reduction in acid precipitation as a benefit of further reductions in SO_2 and nitrogen oxides (NO_X) in its support of the Bush administration's Clear Skies legislative initiative and its regulatory alternative, the Clean Air Interstate Rule. New York State justifies its own regulatory policies and lawsuits against utilities by emphasizing the benefits of reduced acid deposition in the Adirondacks.

Until now, all of these abatement initiatives have taken place in the absence of economic estimates of the total benefits that would result from improvements to the park's ecosystem.[1] In part, this mismatch is explained by the large health benefits that independently justify most policies that reduce acid rain precursors as in U.S. EPA 1999. But it has resulted primarily from an inadequate link between the ecological science and social science necessary to enable

[1] The NAPAP research effort did include a partial assessment of benefits, including an estimate of $4-15 million annual recreational fishing benefits in the Adirondacks, from a 50 percent reduction in acid deposition (NAPAP 1991). No study has ever attempted to estimate the *total* value of improvements in the Adirondacks.

economic valuation of the benefits of emission reductions. This mismatch has also resulted from a lack of information on the ecological effects of changes in emissions and deposition to support that linkage.

Accordingly, while analyzing the environmental pathways linking changes in emissions to economic benefits, Burtraw et al. (1998) identified the quantification of nonuse values as a key gap in the literature and thus a priority area for future research. Indeed, the need for improved estimates of nonuse benefits from ecosystem protection has arisen in many policy contexts. Consequently, the EPA and other agencies are placing increased emphasis on gathering this information, as seen for example in the recent formation of the EPA Science Advisory Board Committee on Valuing the Protection of Ecological Systems and Services.

This study seeks to fill this gap within the important context of air pollution policies by estimating the change in the total economic value (the sum of use and nonuse value) to New York State residents that would result from an improvement in the Adirondack Park ecosystem through further reductions in air pollution. Because stated preference is the only method capable of estimating nonuse values and because our research application focused on a total value rather than a value function of attributes, we employed a contingent valuation survey. The survey was administered both on the Internet and via mail, providing a comparison of mode of administration and an indirect test of convergent validity. While these different modes have their pros and cons, the key survey results are remarkably consistent across modes.

This survey was designed to meet or exceed the stringent protocols for stated preference surveys developed by the NOAA Panel on Contingent Valuation (1993) and the OMB (2003). One of these protocols stresses that the “commodity” being valued map closely to the underlying science. Following this guideline, we interviewed a number of top experts on ecological damages in the park and developed a summary of the science report (Cook et al, 2002).[2] The report serves as the foundation for the description of the park's condition as well as the commodity being valued, that is, the type and magnitude of improvements reasonably following further reductions of acid deposition precursors.

A major effort of our research was to accurately but meaningfully distill this information and convey it to a general audience. To this end, during development of the survey we convened 31 focus groups and conducted two major pretests to develop and extensively assess alternative text, debriefing questions, and graphics.

Our scientific review indicated that there remains much uncertainty about the future status of the park in the absence of intervention and about the benefits of intervention. Nonetheless, focus group results clearly indicated that credibility of the survey depended on respondents believing that scientists understand the problem and how to fix it. Consequently we developed two versions of the survey to span the range of opinion about the status of the park. We use the terms *base case* to refer to the survey that describes a constant baseline (in the absence of a policy intervention) paired with small ecosystem improvements (in the presence of an intervention) and *scope case* to refer to a gradually worsening baseline paired with larger ecosystem improvements. This design choice has the added advantage of permitting an external scope test of preferences, a key test of contingent valuation performance highlighted by the NOAA Panel. We find strong evidence that our instrument is in fact sensitive to scope.

A common criticism of contingent valuation is that the hypothetical nature of the exercise tends to yield overestimates of willingness to pay (WTP). In response, we typically followed a cautious or conservative approach when faced with questions of appropriate survey design by

[2] A draft of this report was peer-reviewed by field scientists, advocates, and staff at the New York Department of Environmental Conservation (NYDEC).

characterizing the science, presenting information, and applying statistical methods in ways that are expected to yield estimates likely to understate rather than overstate the true WTP for the improvements described.

Our preferred estimates of the mean WTP using the base case characterization of ecological improvements range from $48 to $107 per year per household in New York State. The alternative scope case scenario yields mean WTP ranging from $54 to $159 per year per household. Multiplying these population-weighted estimates by the approximate number of households in New York State yields benefits ranging from about $336 million to $1.1 billion per year.

The results of this study help complete the two-decade-long project of integrated assessment across natural and social sciences, resulting in economic estimates that can be used to guide policymaking to address the ecological effects of acid rain in North America. The above values exceed cost estimates of reducing SO_2 and NO_x emissions from power plants subject to the Clear Skies initiative if the cost share is determined according to the share of these emissions actually being deposited in the park.

2. From Science to Survey

Comprising both public and private lands, the Adirondack Park covers 20 percent of New York State, encompassing nearly three times the area of Yellowstone National Park. One-sixth of the park is designated as wilderness—85 percent of all wilderness area in the northeastern United States. The park has 2,769 lakes larger than 0.25 hectares, six major river basins, and the largest assemblage of old growth forests east of the Mississippi River. Thirty tree species, along with numerous wildflowers and a multitude of shrubs, herbs, and grasses, are native to the park. These attributes draw nine million visitors each year.

The Adirondacks' watersheds are particularly sensitive to potential acidification from atmospheric deposition of sulfates and nitrates, in part because they tend to have shallow soils and bedrock with low acid-neutralizing capacity. However, as is said in the survey, "[m]ost of the lakes affected by past air pollution are small; they are typically much smaller than Central Park in New York City. The large lakes that you may have heard of (such as Saranac Lake or Lake George) are much bigger than Central Park and are not lakes of concern."

Table 1 shows some of the conclusions reached in our analysis of the scientific research and how they translated into descriptions in the survey. Currently, a small fraction of the lakes in the park are acidic due to natural causes (roughly 10%), but most degradation is a result of acidification linked to emissions from power plants and other sources. About half of the lakes are degraded in quality, some of these without fish populations. The actual cause of declining populations of fish is often increased aluminum concentrations, a by-product of the process of acidification.

The future baseline for the park's ecosystem depends largely on nitrogen saturation. If a watershed becomes nitrogen saturated, then increased nitrogen deposition will lead to greater chronic acidification of the receiving water body. Significant reductions in SO_2 and NO_X emissions resulting from the 1990 Clean Air Act Amendments (CAAA) have led to some recovery of acid-neutralizing capacity and surface water pH in the Adirondacks, but not in proportion to the drop in emissions (Driscoll et al., 2001a; 2001b; 2003; Stoddard et al., 1999). Estimates of the time scale for reaching saturation vary considerably from watershed to watershed. Some may never become saturated at current or forecasted deposition levels; others may and would thus require further reductions in deposition for recovery.

This variability and underlying uncertainty implies a range for the future baseline of chronically acidic lakes (assuming constant future deposition) from great degradation to a modest improvement. Assuming full implementation of the 1990 CAAA and no further emission reductions, the share of lakes that are chronically acidic could rise from 19 percent in 1984 to 43 percent or more by 2040 with saturation at 50 years or fall to 11 percent or less by 2040 if saturation is never reached (EPA, 1995). Our response to this information was to develop base case and scope case alternatives.

We found widespread scientific consensus that acidification also has harmed forests (Driscoll et al., 2001a; 2001b; Lawrence, 2001). In particular, because acid deposition has been implicated in declines of high-elevation spruce stands, in the base case scenario respondents are told that the improvement program would yield small benefits to these stands. Moreover, there is mounting but as of yet not definitive evidence that damage to sugar maple and white ash stands also can be caused or exacerbated by acidification.

In the scope case scenario the described damage to the spruce stands is greater, damage to sugar maple and white ash is described, and it is stated that the stands are expected to decline in the future. Improvements from the current and future state of the forests also are more significant in the scope version of the survey.

There is also mounting evidence that acidification is affecting some bird populations. In the base case scenario, acidification is implicated in reduced, but stable, populations of the common loon and hooded merganser. The improvements to these species as a result of the policy intervention are characterized as minor in the base case scenario. In the scope case ecosystem acidification also is implicated in loss of nesting places and changes to songbird populations of wood thrush and tree swallow in the park. In the scope case, all four species are expected to gradually worsen without the policy intervention.

3. Description of Survey Instrument

To develop an estimate of societal WTP to avoid the effects of acidification, we employed a contingent valuation (CV) survey, an approach that has been used since the early 1960s (Davis, 1963) to determine both use and nonuse values and has been extensively examined (Mitchell and Carson, 1989; Haab and McConnell, 2002) in a wide variety of applications. Of the thousands of CV instruments administered to date, there is generally a handful of studies that are considered models. One relatively famous example is the application of the CV technique to estimate damages from the Exxon *Valdez* oil spill in Prince William Sound in 1989 (Carson et al., 2003). A later, widely known, and thorough application by the same team of researchers estimated damages from the Montrose Corporation's release of DDT and PCBs off the coast of Los Angeles (Carson et al., 1994). These studies served as models for the organization and treatment of information in our study provided below.[3] This information is followed by treatment of several thematic issues, which arose from our objective of developing a cautious, valid WTP estimate grounded in science and useful for policy.

Context

The introductory section of the survey is designed to place the proposal into a broad context of household and public decisionmaking and address the embedding problem, which is a tendency of respondents to expand the commodity definition to include many other things than

---

[3] A burgeoning literature on valuing ecosystems is increasingly able to inform policy but it is rarely capable of providing estimates of specific value that can be used in benefit–cost analysis (for example, Nunes et al., 2003; Simpson et al., 1996). In a limited application Morey and Rossman (2003) use stated preferenece methods to measure the value of delaying damage to cultural materials from acid deposition.

those intended to be valued (Kahneman and Knetsch, 1992). Respondents are helped to think about substitutes to the proposal without explicitly asking them to choose among different goods. The opening is austere, with the title “Policy Priorities Study: Adirondacks Version,” giving respondents the impression that there are many different versions of the survey addressing different issues and public policy priorities. Respondents are asked if they felt their income taxes are too high or low.

To encourage consideration of public goods trade-offs, subjects are asked to specify whether more or less state spending in various areas (such as crime prevention or providing and maintaining natural areas) is called for. They are explicitly reminded that spending increases or decreases may result in higher or lower taxes. Respondents are then told that their version of the survey deals with a tax-and-spending program to improve the health of lakes in the Adirondack Park, while other versions focus on such diverse topics as infant health care and fire protection.

Baseline

Subjects are next introduced to the Adirondack Park and educated about damages to the ecosystems of the park’s lakes with specific attention paid to their altered fish populations. We call the affected lakes the “lakes of concern,” a sterile term intended to discourage overly dire interpretations of their status.[4] We state that about half (1,500 lakes of approximately 3,000 total) are lakes of concern. We emphasize that these lakes are generally smaller and less well known than the large lakes, such as Saranac Lake or Lake George, that attract most of the park’s visitors. In the base case, the condition of forests and bird populations is also characterized. In

[4] Initially we defined lakes as “healthy,” “sick,” or “dead,” and found in focus groups that many subjects had graphic images of “dead” lakes and “sick” lakes and thought that a “dead” lake could not be recovered. We found that using the term “lakes of concern” did not create such a vivid mental image and allowed a more dispassionate description of the commodity. Similarly, we used sterile black-and-white pictures to introduce the affected animals.

the scope case more forest and more bird species are characterized as damaged. Subjects learn that the cause of these problems is acid deposition, acting directly and through aluminum leaching from the soil.

Respondents learn that acid deposition has slowed dramatically thanks to programs to reduce air pollution and that, in the base case, acid deposition is not expected to harm any additional lakes in the future, but nor will the lakes improve on their own. As seen in many polls (Bowman, 2004), in general people believe the environment is worsening over time. That view applied to the Adirondack Park would be erroneous, based on our understanding of the science. We appealed to the authority of scientists studying the lakes and the Environmental Protection Agency (as our focus groups indicate great trust in these groups) to refute this preconception. In the scope case we say that the lakes, forests, and bird populations will worsen slowly without intervention.

A potentially troublesome concern in creating the survey was that the respondents would associate human health damages with damage to the lakes. There are no direct human health hazards from contact with the affected lakes. To address this issue respondents are told that the acidity of the lakes is no more than that of orange juice, that they are safe for swimming, and that there are no health effects from eating affected fish. They are also told that there is no commercial market for these fish.

Scenario

A scenario for the improvement must be plausible to respondents but, as seen in the Montrose and Exxon *Valdez* surveys and many others, need not be a real scenario currently acted upon or even under consideration. What is important is that the improvement approach is credible, is a public good requiring payment by individuals and not so expensive or cheap to make cost an issue. A perfect scenario is transparent and uses a payment vehicle that avoids any bias in WTP responses. Telling the truth—that imposing reductions on power plants and other sources of air pollution is the best way to fix the problem—could very well lead to biased responses, which is what we found in initial focus group settings.

Our solution was to develop a fictional program that "scientists determined to be the safest and most practical" for improving the Adirondacks ecosystem, involving the application of a Norwegian technology to lime lakes (each year for ten years) and, in the scope case, forests by airplane. In fact, liming of lakes to reduce acidity on an individualized basis does occur, but it remains controversial and, to our knowledge, an application of the scale described in the survey has never been recommended. However, liming constitutes an active, public program that would require the collection of additional taxes—and, hence, the opportunity to elicit WTP.

The ten-year improvement period is probably in reality too short a time for the ecological improvement from reducing acidification precursors to be fully realized. We choose a ten-year horizon for benefits for two reasons. Practically, focus group participants equated long time frames with uncertainty of outcome, which reduced the perceived effectiveness of the intervention and thus biased WTP downward. Furthermore, emission reductions under Title IV of the Clean Air Act Amendments have shown a change from trend in the Adirondacks lakes in less than ten years since the program took force in 1995, so that important improvements could in fact be expected in this time frame (Driscoll et al., 2003).

Focus group responses pointed to distrust of the ability of New York State government to implement the program as described, and there was concern that the government would use the taxes raised for the program for other purposes. Consequently, we invoked "an independent Adirondacks Management Board of scientists, a representative from the U.S. Environmental

Protection Agency, and other experts" that would oversee the program. In focus group testing, this board appeared to deflect many of the concerns about management credibility.

In response to concerns that anglers will reap benefits and should pay their share of the costs of improvements, we said that, where necessary, the fish will be restocked using revenue from fish license fees. To fill out the scope case, we said that a tree-planting program would supplement the liming of the forest.

Commodity

The effects of this program, and the commodity to be valued, vary for the base and scope cases. In the base case, the improvement[5] is to 600 lakes of concern (out of 1,500), which will take place over a ten-year period, after which the lakes will be stocked with fish. Small improvements in the populations of two bird species and one tree species will also occur, limited to areas surrounding the affected lakes. In the scope case, improvement is to 900 lakes, plus two additional bird species and two additional tree species. The status of the lakes with and without the intervention is summarized in a pie graph and recapped in a summary table along with the baseline and changes to tree and bird populations. For the scope version, improvements to the forests are displayed using a pictograph with each square on a grid representing some number of trees of various species, and their health, as a portion of total forests in the park.

Payment Vehicle

[5] In early focus groups, we described the resource as being "restored," but found considerable evidence of loss aversion in voting decisions as many people felt that ethics demanded we "clean up our messes." We believed that, though such ethical perspectives are an important element of the policy debate, the issue is independent from a measure of the benefits from the particular resource. A cautious approach to valuing benefits required that we divorce stated WTP for the particular improvements from the general desire to rectify past harm. As a solution, we turned to "improvement" over "restored."

Respondents (speaking for their households) are then presented with an opportunity to pay increased taxes annually for ten years, if the majority of voters agree. To strengthen the certainty of the government's commitment, the funding instrument for the program is a revenue bond that must be paid off by the increased tax revenue. Prior to voting, respondents are presented a balanced list of three reasons they may want to vote for or against the program. They are also presented with "cheap talk" language that warns the respondent of a tendency by people to answer survey questions about WTP in a different way than they would behave in actual decisions and to try to consider their choice as though it was an actual decision.

Eliciting WTP

Finally, we elicit a vote in referendum format for or against the program, plus a single follow-up vote in referendum format, motivated by the idea that engineering costs are uncertain.

Based on the results of two pretests, we targeted initial annual payment (bid) levels at approximately the median and the 30th and 70th percentiles of the WTP distribution for the base case improvements. We also sought information in the right-hand tail given that estimates of mean WTP can be particularly sensitive to distributional assumptions in that region. Initial bids were set at $25, $90, $150, and $250. Follow-up bids, conditional on a "no" or "yes" response on the initial bid in the first vote were set at ($10, $50), ($50, $150), ($90, $250), and ($150, $350).[6] The first number in the follow-up bid is if they voted "no" initially and the second is if they voted "yes."

Debriefing

After they voted for the program, we asked participants several debriefing questions. The primary purposes of these questions were: (i) to solicit respondents' beliefs about the information

[6] In addition, one of the pretests, used in the final data analysis, had initial bids set at $35, $85, $150, and $200.

and improvement scenario they were provided; (ii) to give them some limited opportunities to revote when their beliefs were at odds with the survey's intent (if they believed there were health effects,[7] if they voted "no" only because New York State was responsible for implementing the improvement plan or if they voted "no" because they believed upwind electric utilities should pay); and (iii) to examine their more general attitudes and beliefs that might lead them to provide "nay-saying," or "yea-saying" responses (see below). We also asked demographic questions in this section, including one rarely asked about respondent's future family income. This question was asked because the payment was to be over a ten-year period. This variable turned out to be more significant than current income in explaining WTP.

After the demographic questions, at the end of the survey we inform respondents that the liming program is not being considered by the New York State government and is not feasible. Respondents are also told that these improvements would actually occur through further reductions in pollution and who the sponsors of the survey were.

Expansive Priors

One may reasonably ask why we bother to introduce the effects of the intervention on forests and birds in the base case if these endpoints do not improve significantly as a result of the intervention. Initially our approach was to simply limit the description of the damage to the aquatic ecosystem in the base case. However, we discovered in focus groups that omitting mention of forests and birds in the base case was inconsistent with respondents' prior beliefs. Because it was judged so unlikely that forests and birds were neither being currently damaged nor would be helped by an improvement plan, respondents substituted their own expansive

[7] 52 percent accepted that there were no human health effects, 38 percent thought that there may be minor health effects, and 10 percent thought there were important health effects. Of those who had voted for the program and thought there were health effects, about 12 percent changed their vote to "no" when asked to suppose there were no health effects.

priors, ascribing much broader and larger effects to our improvement plan than we intended or that the science can substantiate. There is some evidence that this substitution had the effect of actually making their WTP higher for the base case than for the scope case. Accordingly, we validated respondent priors by both narrowly identifying effects on forests and birds and describing their improvements as minor. In focus groups we found this change made the information treatment more credible, so that respondents suspended their priors and accepted our characterization.[8] A similar challenge was to make credible and certain the characterization of a constant future baseline and limited health effects, as discussed above.

Yea-saying and Warm Glow

One potential concern with contingent valuation is a presumed tendency of respondents to vote "yes" for programs in a pro forma way, perhaps out of a sense of obligation or desire to please the survey administrator, but in any case without truly registering the economic trade-offs involved and hence without truly revealing preferences. A special case is "warm glow," in which respondents value the giving per se as much as the commodity acquired (Andreoni, 1990). Including warm glow would overstate values for the actual commodity, in this case the Adirondacks.

As noted previously, the introductory pages of the survey are designed to make respondents immediately think about the opportunity cost of paying for the program, and before voting they were reminded of costs and other reasons to vote "no." In addition, we took pains to use line drawings and other design features to minimize embedding and to avoid emotional triggers. Also, we asked a series of debriefing questions that could be used to identify this type of vote. In particular, we asked respondents if they agreed that "costs should be a factor when

[8] Moreover, this nuance in fact made the scenario more consistent with the science than the simplistic no-terrestrial-effects description.

protecting the environment." Fully 75 percent of the respondents agreed that costs should be a factor, suggesting they believe in the trade-offs inherent in a willingness-to-pay exercise. Moreover, of the others, one-fifth exhibited implicit acceptance of the maxim when they switched their vote to "no" in the follow-up valuation question when the bid was changed.

Nay-saying

In contrast to yea-saying, nay-saying is a tendency for respondents to vote against a program for reasons that are extraneous to its benefits and costs. This includes respondents who reject the scenario or choice construct as presented or who use their vote to register some other protest. For example, some people vote against the program on the principle of limiting taxes or because they do not trust the New York State government to implement the program or because they don't think the program will work. Although our cautious approach made us more tolerant of nay-saying than yea-saying, we nevertheless designed the survey to limit and identify this phenomenon. About 79 percent of the sample agreed in principle that there are programs that could justify new taxes. But as with our debrief targeting warm glow, actions speak louder than words here, with almost half of the remaining 21 percent voting for the program and its tax increases at some bid level. Moreover, as discussed below we asked several debriefing questions on beliefs about the baseline and the feasibility of our program, with most respondents accepting the scenario.

4. Survey Protocol

The survey was administered by Knowledge Networks (KN) from August 2003 through February 2004 to residents of New York State. We selected this population for several reasons. First, New Yorkers are most likely to hold nonzero values for improvements to the Adirondacks. Second, designing an acceptable method of payment was easier if the sample were limited to

New York. Third, by ignoring people out of state we were being cautious in our total benefit estimates.

Table 2 summarizes the total sample, useful completions, and response rates for the different modes of survey administration. Results from a second pretest were included in the data analysis.[9] Response rates to KN's preselected panel were, as expected, quite high, ranging from 84 percent for the pretest to 74 percent for the final implementation. The group comprises 53 percent of our total completed surveys.

To boost the sample size provided by Knowledge Networks and to examine the potential sample selection caused by attrition in the KN panel, the survey was given to a group that had withdrawn from the panel. This version was administered over the Internet and, with the exception of some demographic debriefing questions, was the same as the version given to the panel. The response rate for this group was 14 percent and totals 16.8 percent of our completed surveys. Although this response rate seems low, it is not surprising from a group of subjects who had already declined participation in one venue.

As a formal test of mode of administration, as an additional check on the KN panel, and to further boost sample size, a final wave was mailed using a random-digit selection of telephone

[9] An initial pretest was omitted from the final analysis, as it was too different from the final instrument.

numbers that were in turn matched to available addresses. The response rate for the mail survey was 24 percent, and the group constitutes 31.3 percent of our completed surveys.[10]

Table 3 presents descriptive statistics of the demographics of each sample. It illustrates the difference among the samples and, where possible, compares them to the general population of New York State. While there are some differences across the samples (for example, the mail sample had the oldest average age, while the withdrawn sample had the youngest), in general they display fairly consistent attributes. On each measure, the samples are proximate to the characteristics of the general adult population in New York State.

5. Results

With the NOAA Panel protocols and OMB guidelines putting the burden of proof squarely onto the researchers to show that their results are valid, we start with showing the validity of our results before actually summarizing what they are.

Measures of Validity

We present three basic measures of validity: the external scope test, sensitivity of vote to bid, and construct validity, that is, the extent to which patterns in the data reflect common sense and expectations based on economic theory.

The external scope test examines whether two separate samples have different average WTP for differing scales of environmental improvements (Boyle et al., 1994). It is a test both of the

[10] Techniques used to induce response from respondents varied amongst the samples. Members of KN's panel received compensation equivalent to about $10 in Internet service in exchange for completing the survey while withdrawn and mail respondents received $10. In addition to these incentive payments, subjects received reminders to complete their surveys. Members of the panel received reminder e-mails encouraging completion of the survey. Members of the withdrawn and mail samples received follow-up phone calls and reminder letters. For the mail sample up to five attempts at person-to-person calls were made to contact the potential respondent to directly request that they take the survey.

subjects' comprehension of and attention to the scenario and vote, as well as warm glow and embedding, or what Mitchell and Carson (1989) call "part-whole bias." The scope test has been a major standard for contingent valuation since the NOAA Panel report.

A fundamental issue in designing a scope test is determining which dimensions of the resource or service to expand. For example, Boyle et al. (1994) failed to find sensitivity to the scope of a program to save migratory waterfowl from oiling themselves in dirty ponds. The scope was measured as a variation in the number of birds (in three different versions, 2,000, 20,000, or 200,000 birds would be saved respectively). Some have criticized this scope test on the grounds that the commodity is mistakenly defined: people might care more about the availability of the clean ponds themselves than the birds or perhaps measured birds in flocks rather than individuals or, again, in percentage terms rather than numbers. On the other hand, Carson et al. (1994) passed a test of scope when comparing a project that would improve the health of two fish species in Los Angeles Harbor to a project that would in addition improve the health of bald eagles and peregrine falcons. This approach to a scope test is in contrast open to the criticism that the scope of a commodity has not been measured at all, but rather an entirely new commodity that is more greatly valued than fish.

Our approach to the scope test attempted a compromise between the narrow more-individuals and the broad more-commodities approaches. We defined the resource to be scaled as the health of the Adirondack Park as a *system* of lakes, forests, and animals. Specifically, we varied the quantity of lakes improved (analogous to Boyle et al.) and also varied the number (and quantity, in percentage terms) of tree and bird species improved. Our results provide strong evidence of sensitivity to scope. Table 4 reports the share of "yes" votes at each bid level for the base and scope versions.

Several approaches can be used to test for scope sensitivity using these data. The most nonparametric and perhaps most persuasive is to test for differences in the mean share voting for the program at each bid level. P values for this chi-square test are provided in the final column of the table. As seen in the table, more respondents vote for the program under the scope scenario at each bid level, and the difference is statistically significant. Respondents are thus willing to pay more when they understand there will be greater improvements. In addition, estimates of mean WTP are higher for the scope version under a variety of model specifications (see the section on willingness to pay estimates below), and these differences are also statistically significant.

Finally, other results corroborate the interpretation that respondents were paying careful attention to the description of the resource. For example, when we asked whether respondents accepted our description of the baseline state of the Adirondack Park, in the base survey instrument 24 percent of the sample said that it was probably worse than we described it, compared to only 6 percent with the scope instrument, a statistically significant difference. Similarly, 15 percent of the sample thought that the survey was biased in favor of the program with the base instrument, but 27 percent thought so with the scope instrument. The relatively low numbers here overall are also evidence of content validity.

The second important statistical test is sensitivity to the level of the bid, that is, whether fewer respondents vote "yes" when the bid level is increased within each given scenario. In fact we find that responses are strongly statistically significant for both the base and scope versions (with the exception of those cells with few observations, accounted for by the pretest). Even including these cells, the difference is statistically significant according to a chi-squared test of the equality of means. Moreover, according to Kendall's tau test these differences are statistically ranked monotonically by bid, showing a consistent increase.

Figure 1 concisely illustrates the sensitivity to scope and bid, omitting the sparse cells from the pretest. Sensitivity to scope is indicated in each bid category by the higher percentage who voted "yes" in the scope scenario than the base scenario. Sensitivity to bid is indicated by the decline in the share of respondents willing to vote for the program as the initial bid level is increased, for both the base and scope scenarios.

The third set of construct validity tests verifies that the other patterns in the data conform to theory and common sense. We find that they generally do. Table 5 provides a representative regression output covering three types of variables: demographic, attitudinal, and the degree to which respondents accept the concepts in the survey and other information provided to them (protests or indications of yea- or nay-saying). Model 1 contains only demographical and attitudinal variables, model 3 contains only the protest variables, and model 2 contains both. Some of these variables may be considered endogenous, an issue we return to below in the discussion of willingness to pay.

Models 1 and 2 in the table show households with the highest incomes have the highest WTP, as expected. The poorest households are also more likely to vote for the proposal, presumably because they do not expect to have to pay for it, but the effect is not significant. Consistent with the permanent income hypothesis and with the fact that payment would occur over a ten-year period, those who expected their future income to be higher are willing to pay more than those who thought otherwise. Household size is also a consistently significant factor, with larger households less likely to vote for the program, although the effect is not significant. On the other hand, holding household size constant, households with more children are significantly more likely to vote for the program.[11] Other standard demographic variables (age, race, sex) are unsigned as hypotheses and were not considered in our analysis.

Measures of personal stake in the resource are also important. Households that frequently visit the park (more than ten times a year) are willing to pay more for the program than others who visit less frequently. In addition, those living farther from the park are willing to pay less, with WTP falling by about $0.08 per kilometer from the household's closest entrance (by road) to the park and with an elasticity of WTP to distance of about 0.4 when controlling for indicators of protests (model 2).[12] This information is important for this study because of the inferences one might make about WTP of households outside of New York. The finding is consistent with previous work (Johnson et al., 2001).

Regarding the effect of attitudes on voting, self-classified environmentalists are more likely to vote for the program, just as self-proclaimed conservatives and those who think taxes are too high are more likely to vote against. We also asked people in the beginning of the survey if they are interested in government spending more on nature and wildlife programs and on air and water pollution control programs, among other things. Those who favored more government spending on the environmental programs are more likely to vote for the program. In alternative models, we replaced these variables with indicators for those who describe themselves as "liberal" or "conservative," and find that the former are more likely to vote for the program while the latter are less likely to do so.

Willingness to Pay

---

[11] The model includes an indicator variable for the presence of children, plus a linear term for the number of children. The former is negative, but the latter is positive and offsets the former at two children.

[12] After conditioning on distance, those living within the park's boundaries do not appear to pay more than other households.

We designed our strategy for estimating willingness to pay to limit three potential sources of bias: the representativeness of the sample, anchoring in the follow-up vote on the program, and yea-saying or nay-saying votes.

The first potential source of bias is the possibility of an unrepresentative sample, especially for the KN panel of regular survey takers. To address this potential problem, first we weighted all responses by all observable demographics, including location of residence, to reflect the New York State population. To address unobservable factors, we included a random mail-based sample of the entire New York population as a check on the KN panel. After weighting the data to account for the differing demographics of the sample (see Table 3), we could not reject the hypothesis of equal WTP from the differing survey modes.

Furthermore, one of the advantages of the KN panel is that Knowledge Networks elicited initial background demographic and attitudinal questions for all its panel members. Thus, we have individual-level details about the nonrespondents. This information provides a unique opportunity to estimate sample-selection models against both those currently on the panel, but not completing our survey, and those who have dropped out of the panel over time. We estimate a Heckman sample selection model with a joint normal distribution between the unobserved component of responding to our survey (among all those ever on the KN panel) and the unobserved component of voting for the program. With this model, we cannot reject the hypothesis that the correlation is zero, again implying no differences among the samples.[13]

The second potential source of bias is the use of the follow-up dichotomous choice question, giving double-bounded rather than single-bounded data. Using double-bounded data

[13] The test is in the context of a model implying that WTP is lognormally distributed, one of the econometric models presented below.

provides gains in efficiency (Hanemann, Loomis, and Kanninen, 1991), but may induce bias if the WTP distributions differ across the two equations, for example because the new price in the follow-up question sends a signal about the program quality or suggests that a strategic game may be being played (see Haab and McConnell, 2002, for discussion). Estimating willingness to pay with a lognormal distribution and restricting a completely general binary probit model to be consistent with a single distribution (Cameron and Quiggin, 1994), we reject the hypothesis of identical distributions at the one percent level using a log-ratio test.[14] Although we cannot reject the hypothesis of constant median WTP, estimated mean WTP is lower using the double-bounded data, a typical finding. Still, as with others using dichotomous choice data, we prefer to make use of the additional efficiency afforded by the follow-up question. Moreover, any potential bias introduced by this approach is downward, which is consistent with our cautious philosophy.

The third type of potential bias is yea-saying or nay-saying. If these problems came undetected, they would contaminate the estimates of WTP for the intended commodity with values for other commodities. As discussed above, we attempted to identify such problems by probing people's beliefs about the scenario and their willingness, in principle, to make trade-offs between taxes and public goods. Table 6 summarizes the key probes and divides them into those tending to bias WTP upward (yea-saying) and downward (nay-saying). It also shows the share of respondents whose answers raised flags and our response. In some cases, when we identified

---

[14] However, employing a nonparametric test suggested by Haab and McConnell (2002), we find that, for those bid levels used both in initial votes and in follow-ups ($150 and $250), the percentage voting "yes" in the second vote, conditional on voting "yes" in the first vote, was higher than the unconditional percentage voting "yes" in the first vote. This finding is consistent with the existence of a single distribution, and so constitutes a failure to reject the hypothesis of a constant values across votes (compared to the alternative hypothesis of falling values in the follow up). Admittedly, this is a weak test.

problems (such as a belief that human health would be improved by the program), we asked respondents to hypothetically accept our premise and revote. If they did not change their vote, or in cases where we did not ask them to revote, we then have the opportunity to eliminate the respondents from the sample or to control for them econometrically. As discussed below, our results are robust to these differing treatments.

Using the full double-bounded data, we used standard methods for analyzing interval data (Hanemann, Loomis, and Kanninen, 1991; Haab and McConnell, 1997), and assume that the responses are distributed according to Weibull and lognormal distributions. These distributions imply that WTP is always positive. They generally provide similar estimates of the effect of covariates, but mean WTP is generally larger with the lognormal distribution because of a thicker right-hand tail.

We estimated population-weighted interval models of the WTP distribution, controlling for indicators of scenario or task rejection. In estimating WTP, we did not control for demographic and attitudinal variables, such as those in models 1 and 2 of Table 5, as these variables have no "right" answer and can simply be integrated over in computing mean WTP as long as they are properly weighted to reflect the New York population.

In order to control for yea-saying and nay-saying, we either dropped respondents or controlled for them econometrically. Model 3 in Table 5 presents the regression results for the all-econometric-control case using the lognormal distribution. Table 7 presents the full array of mean WTP estimates arising from different combinations of these two approaches (drops and controls) for the base case survey. Table 8 does the same for the scope case. Each cell contains estimates of the mean WTP for the lognormal and Weibull models. The columns represent adjustments made for nay-saying controls, while the rows represent adjustments made for yea-saying controls.

To decide which variables to target for dropping (instead of adjusting econometrically), we ran a series of regressions to determine which variables had the most important affect on WTP. For yea-saying, the most significant variables are the attitude that costs should not be a factor when protecting the environment and the belief that health effects are important; for nay-saying, the most important variables are the belief that taxes should not be raised under any circumstances and the belief that the liming program was not practical.

In the various treatments indicated in Tables 7 and 8 these variables are either dropped or else controlled for econometrically by calculating WTP from the estimated regression coefficients after redefining the targeted variable's value appropriately (for example, setting the "thought there were health effects" variable to zero). All other variables of concern listed in Table 6 were similarly controlled for econometrically.

Looking down the first column of data on Table 7, note how close the estimates are to one another, ranging from $58 to $80. This implies that the results are remarkably robust to various attempts to correct for warm glow and other yea-saying effects. The results appear to be less robust when adjusting solely for the nay-sayers in the first row of the table, but still fairly robust overall. As expected, the lognormal model produces substantially larger estimates than that of the Weibull model, although results based on the latter model are fairly similar.

The other rows and columns of this table provide results for various combinations of controls on the different groups of people in the sample. The diagonal is particularly important, as it represents a symmetric treatment of yea- and nay-sayers. Across all the cells with some form of control (either econometric controls or dropping specific variables) the results are quite close to one another, ranging from $156 to $266. This suggests that our estimates are quite robust to the choice of dropping or controlling econometrically for these responses. However, comparing the middle of the table with various choices of dropping or controlling econometrically to the first row and column, it is clear that our results are sensitive to treating various yea-sayers and nay-sayers in some form versus not at all. We tend to favor models with more controls, but a case could be made for omitting some controls if it is believed responses to the debriefs are endogenous with responses to the vote. In other words, after the vote, people might look for additional reasons to justify their vote when they respond to the debriefing questions.[15]

We consider the symmetric, all-econometric-controls option as our preferred model in Table 7 since it maintains the largest sample size and symmetrically controls for both yea-sayers and nay-sayers. The Weibull model gives an estimate of $159, while the lognormal model gives an estimate of $213. Turning to Table 8 for the scope case, the corresponding best estimates are $179 and $308 per household per year.

The range of results across the cells of the table, and between the Weibull and lognormal models, represents model uncertainty in the WTP estimates. The range between the base and scope estimates represents the scientific uncertainty about the baseline state of the Adirondacks and the effects of policy interventions. Each of these estimates is further subject to statistical uncertainty, as indicated in Figure 2. The figure reflects uncertainties in WTP from the regressions with only econometric controls and shows that statistical uncertainties are quite small for the Weibull model and considerably larger for the lognormal model. Ninety-five percent

[15] One might in particular accept respondents' statement that they would not have changed their vote if there were no health effects or even if New York State were not involved, obviating any need to control for those responses. Dropping those controls lowers estimates by about one-fourth and widens the differences between the base and scope cases.

confidence intervals for the latter are two to two-and-one-half times greater than the mean on the high side, compared to about a 25 percent confidence interval on the Weibull models.

An even more cautious approach, using the most conservative design, is to estimate the Turnbull lower bound (Carson et al. 1994, Haab and McConnell, 1998). This approach considers the WTP of each household to be the lower bound of each interval of data. For example, if a respondent answers “yes” to an initial bid of $25 and “no” to $50, this approach would interpret $25 to be the actual WTP. In fact it is the lower bound of the $25-to-$50 interval. Besides being unassailably cautious, this approach has the advantage of avoiding any distributional assumptions.[16]

Using the double-bounded referendum format, the Turnbull lower-bound estimates in the base case scenario yield an estimate of mean WTP of $53 per household using all the data and $46 per household dropping those who say costs should not be a factor, who believed there were significant health effects, or who thought taxes should not be raised for any reason. The Turnbull lower bound estimates of the mean WTP for the scope case are $155 and $111 per household respectively.

6. From Survey to Policy

The foregoing results, although they are weighted to represent the population of New York, lack three elements to make them policy relevant. The first is that they are developed from a particular temporal phasing of payments and benefits that is unique to the survey. Converting them to annualized benefits over an infinite time period would make them more generally useful. Second, they provide total values for improvements at the park. But in some applications it may

[16] Note that because it is a nonparametric estimator, the Turnbull lower bound cannot control for protest attitudes. Thus, respondents must be either maintained in the sample or dropped.

be important to have some idea of the use and nonuse value components. Third, as with any estimate of benefits, the question arises: are these big numbers or small numbers? That question is answered by comparing the estimates to a cost benchmark.

Discounting

The WTP estimates computed directly from responses as provided above are for payments over a ten-year period beginning immediately to obtain a stream of benefits that won't begin in full until the end of that ten years. For use in a benefit–cost analysis, we need to convert these estimates into an annualized infinite stream. Assuming benefits phase in linearly over ten years, the equation below provides this conversion:

$$\text{Annualization Factor} = \frac{\sum_{i=0}^{9} \delta^{i}}{\delta^{10} * \left(\frac{1}{1-\delta} \right) + \sum_{i=0}^{9} 0.1 i * \delta^{i}} = 10\text{r}$$

where $\delta = \frac{1}{1+r}$ and r is the discount rate.

Using the factor associated with a three percent discount rate, for instance, the $159 best Weibull estimate with economic controls for all yea-saying and nay-saying variables provided above is multiplied by 0.3, reducing WTP to $48 per year per household for a benefit phased in over ten years and continuing indefinitely. As an upper bracket on the range of values for the base case, we take the lognormal estimate of $213 times 0.5 (the factor associated with the five percent discount rate), for a WTP of $107. For the scope case we similarly take the estimates of $179 and $308 from the same cell, times the respective three and five percent adjustment factors, for a WTP range of $54 to $154.

Total Value versus Use and Nonuse Values

People who recreate in the Adirondacks hold use and nonuse values. People who do not recreate in the Adirondacks hold nonuse values. Thus, it is possible to get some insight into the subcategories of values by examining WTP for the two groups. To do this, we first regressed variables for frequency of use and the standard variable list against vote responses. We found that the only significant distinction was between those whose visit frequency is over ten times in the previous five years (23 percent of the sample) and those with less frequent visits (or no visits). Using this variable, we predicted WTP for the two groups and found that the frequent users had a WTP about 70 percent higher than that of the infrequent and nonusers, implying relatively large use values.

Are the Benefits Large?

Are our WTP estimates “big” numbers? First, note what is not included in these numbers that would be relevant to a formal benefit–cost analysis concerning reductions in acid deposition precursors. They omit benefits to residents of other states, be they users or nonusers of the Adirondack Park. Our results on the effect of location on WTP suggest that such benefits may be smaller per household than those enjoyed by New York State residents. They also exclude benefits to other ecological assets and those to other types of endpoints, most importantly the health effects related to fine particulate exposure.

Second, these numbers can be compared to a cost benchmark. EPA (2004) has estimated the costs of its Clear Skies proposal to utilities to be $4.3 billion in 2010, rising to $6.3 billion per year by 2020.[17] Clearly only a fraction of these costs should be attributable to improvements in the Adirondacks because only a fraction of utility emissions affects that region. Although there is no universally accepted way to make such allocations, a reasonable approach is to assign

---

[17] Clear Skies ultimately would lead to reductions of 75 percent in SO_2 and 65 percent in NO_x by sometime after 2020 when allowance banks are exhausted.

cost shares to each utility's in accordance with the fraction of their emissions falling in the Adirondacks. Using the TAF model (Bloyd et al., 1996) for the source-receptor relationships to do this and model runs that provide the costs by electricity-producing region, we find that on average, 2.3 percent of utility SO_2 emissions fall on the Adirondacks. Multiplying each region's share by their costs for implementing Clear Skies gives an estimate of $86 million in 2010 and $126 million in 2020 for costs attributable to Adirondack improvements. These cost estimates are significantly less than our estimates of the benefits.

7. Conclusions

This paper has presented the first-ever results for the total value of the ecological improvements to the Adirondack Park that might be expected from another round of reductions in air pollution emissions. These estimates matter because damage to the Adirondacks has been a focal point in the clean air debate for over 20 years. Further emissions reductions are being justified, in part, by how they will improve this unique resource. How much these improvements are worth to the public is important to understand.

Not surprisingly, there are a large number of results, reflecting uncertainties in the science, the underlying model of people's preferences for such improvements, normal statistical uncertainties, and a variety of assumptions. Because these results have policy significance, we work through these uncertainties and assumptions to provide a range of best estimates for use in the policy process. We adopt a cautious interpretation of the natural science and cautious design and analytical decisions to provide a value for an ecological outcome that scientists and economists can agree would be achieved at a *minimum* by policy proposals to reduce precursor emissions.

The resulting cautious, best defensible estimates of the mean WTP using the base case characterization of ecological improvements and adjusting for discount factors ranging from three to five percent range from $48 to $107 per year per household in New York State. The alternative scope case scenario yields mean WTP ranging from $54 to $159 per year per household. Multiplying these population-weighted estimates by the approximate number of households in New York State yields benefits ranging from about $336 million to $1.1 billion per year. Accounting for statistical uncertainties underlying these estimates could halve them or more than double them.

This study was designed to adhere closely to scientific information about the park and to build a bridge between the natural and social sciences that could allow people to meaningfully express a willingness to pay for ecological improvements in the Adirondacks. The methodology adheres to all the appropriate protocols suggested by the NOAA Panel and OMB and passes their suggested tests, most importantly the scope tests. As such our results are the culmination of over two decades of a major federal research effort and provides long-sought and valuable information about the benefits of air pollution policy.

References

American Association for Public Opinion Research. 2004. *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys*, Third Edition. Lenexa, Kansas: American Association for Public Opinion Research.

Andreoni, James. 1990. □Impure Altruism and Donations to Public Goods: A Theory of Warm Glow Giving.□ *Economic Journal* 100(401): 464-77.

Bowman, Karlyn. 2004. □Polls on the Environment.□ AEI Studies in Public Opinion http://www.aei.org/publications/pubID.14888/pub_detail.asp

Boyle, Kevin J., William H. Desvousges, F. Reed Johnson, Richard W. Dunford, and Sara P. Hudson, 1994. □An Investigation of Part-Whole Biases in Contingent Valuation Studies.□ *Journal of Environmental Economics and Management* 27(1): 64-83.

Bloyd, Cary., et al. *Tracking and Analysis Framework (TAF) Model Documentation and User's Guide*, 1996. Argonne National Laboratory, (December), ANL/DIS/TM-36.

Burtraw, Dallas, Alan J. Krupnick, Erin Mansur, David Austin, and Deidre Farrell, 1998. "The Costs and Benefits of Reducing Air Pollutants Related to Acid Rain,□ *Contemporary Economic Policy*, 16, (4), 379-400.

Cameron, T.A., and J. Quiggin, 1994. □Estimation Using Contingent Valuation Data from a 'Dichotomous Choice with Follow-Up' Questionnaire.□ *Journal of Environmental Economics and Management* 27: 218-34.

Carson, R. T., M. Hanemann, R. J. Kopp, J. A. Krosnick, S. Presser, P. A. Ruud, and V. K. Smith, 1994. *Prospective Interim Lost Use Value Due to DDT and PCB Contamination in Southern California*, Report to the National Oceanic and Atmospheric Administration. Natural Resource Damage Assessment, Inc. La Jolla, California.

Carson, R.T., R.C. Mitchell, M. Hanemann, R.J. Kopp, S. Presser, and P.A. Ruud, 2003. □Contingent Valuation and Lost Passive Use: Damages from the Exxon *Valdez* Oil Spill.□ Environmental and Resource Economics. July 2003, vol. 25, no. 3, pp. 257-286.

Cook, Joe, Anthony Paul, Terrell Stoessell, Dallas Burtraw, and Alan Krupnick. 2002. "Summary of the Science of Acidification in the Adirondack Park," Unpublished manuscript, Resources for the Future.

Cummings, Ronald G., and Laura O. Taylor, 1999. □Unbiased Value Estimates for Environmental Goods: A Cheap Talk Design for the Contingent Valuation Method,□ *American Economic Review* 89(3): 649-665.

Davis, R.K., 1963. The Value of Outdoor Recreation: An Economic Study of the Maine Woods. Dissertation, Harvard University.

Driscoll, Charles T., Kimberley M. Driscoll, Karen M. Roy, and Myron J. Mitchell, 2003. "Chemical Response of Lakes in the Adirondack Region of New York to Declines in Acidic Deposition," *Environmental Science & Technology*, 37(10): 2036-42.

Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eager, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001a. Acidic Deposition in the Northeastern United States: Sources and Inputs, Ecosystem Effects, and Management Strategies. *Bioscience* 51(3): 180-98.

______. 2001b. *Acid Rain Revisited: Advances in scientific understanding since the passage of the 1970 and 1990 Clean Air Act Amendments.* Hubbard Brook Research Foundation. Science Links Publication. Vol. 1, no. 1.

Haab, Timothy C., Kenneth E. McConnell. 1997. "Referendum Models and Negative Willingness to Pay: Alternative Solutions." *Journal of Environmental Economics and Management* 32: 251-270.

______. 1998. □Referendum Models and Economic Values: Theoretical, Intuitive, and Practical Bounds on Willingness to Pay.□ *Land Economics* 74: 216-29.

______. 2002. *Valuing Environmental and Natural Resources*. Cheltenham, UK: Edward Elgar.

Hanemann, W., J. Loomis, and B. Kanninen, 1991. □Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation,□ *American Journal of Agricultural Economics* 73: 1255-63.

Johnson, F. Reed, Richard W. Dunford, William H. Desvousges, and Melissa Ruby Banzhaf. 2001. □The Role of Knowledge in Assessing Nonuse Damages: A Case Study of the Lower Passaic River.□ *Growth and Change* 32: 43-68.

Kahneman, D., and J. Knetsch, 1992. “Valuing public goods: The purchase of moral satisfaction,” *Journal of Environmental Economics and Management*, 22: 57-70.

Lawrence, Greg. 2001. □Forest and Terrestrial Systems.□ In *Acid Rain: Are the Problems Solved?* (Conference Proceedings), ed. James C. White. Rochester:Center for Environmental Information Inc.

Mitchell, Robert Cameron, and Richard T. Carson. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method.* Washington, DC: Resources for the Future.

NOAA Panel on Contingent Valuation (Arrow, Kenneth, Robert Solow, Edward Leamer, Paul Portney, Roy Randner, and Howard Schuman), 1993. 15 CFR Chapter IX, Federal Register 58(10): 4601-4614.

Morey, Edward, and Kathleen Greer Rossman. 2003. “Using Stated-Preference Questions to Investigate Variations in Willingness to Pay for Preserving Marble Monuments: Classic Heterogeneity, Random Parameters, and Mixture Models,” *Journal of Cultural Economics,* Vol. 27 No. 3/4, (November 20), 205-229.

Nunes, Paulo A.L.D., Jeroen C.J.M van den Bergh, and Peter Nijkamp, 2003. *The Ecological Economics of Biodiversity,* Northampton MA: Edward Elgar.

Simpson, R. David, Roger A. Sedjo, and John W. Reid, 1996, “Valuing Biodiversity for Use in Pharmaceutical Research,” *Journal of Political Economy,* Vol. 101: 163-85.

Stoddard, J.L., et al. 1999. “Regional trends in aquatic recovery from acidification in North America and Europe,” *Nature* 401:575-578.

U.S. Environmental Protection Agency, 1995. *Acid Deposition Standard Feasibility Study: Report to Congress.* EPA 430-R-95-001a, October.

______. 1999. *The Benefits and Costs of the Clean Air Act, 1910 to 2010.* Report to Congress.

U.S. Office of Management and Budget, 2003. Regulatory Analysis. Circular A-4 (September 17).

U.S. National Acid Precipitation Assessment Program, 1991. *1990 Integrated Assessment Report.*

Table 1. Summary of the Science of Acid Precipitation at Adirondacks Park

Science	**Instrument**
Approximately 3,000 lakes, mostly small; half degraded or devoid of fish.	In description.
Fish decline attributable to acidification through aluminum mobilization; some from natural causes.	In description.
Effect on forests, but less well understood. Possible effect on birds.	Base case: Effect on one tree, two bird species. Scope case: Effect on three tree, four bird species.
1990 CAAA reductions leave stable ecological baseline or improving slightly; potential of nitrogen saturation.	Base case: Baseline not worsening, not improving. Scope case: Baseline worsening.
Uncertainty in time period for recovery; uncertain time period to nitrogen saturation.	Uncertainty excluded.
No health effects.	Explicitly addressed and excluded in instrument.
Expected changes from lower acidification include improvements in between 20% and 40% of lakes; small improvements in forests and bird populations.	Base case: 20% increase in lakes that support fish in ten years. Slight improvements to forests, birds. Scope case: 40% improvement in lakes that support fish in ten years; larger improvements in more types of forest and bird populations.

Table 2. Summary of Survey Administration

Administration	Mode	Versions	Surveyed	Useful Responses[†]	Response Rate	Share of Sample
Pretest KN Panel	Web TV/ Internet	Base	141[*]	118	84%	6.5%
Main KN Panel	Web TV/ Internet	Base and Scope	1,143[*]	841	74%	46.2%
KN Withdrawn	Internet	Base and Scope	2,120[*]	293	14%	16.8%
Mail	Paper	Base	2,372[††]	570	24%	31.3%
ALL		Total/Base/ Scope	5,776/4,150/1,626	1,822/1,254/568		

[*]To exhaust the New York residency on KN's panel certain households had multiple members surveyed. If a household had one or more surveys where there was a response to the first referenda question, the first member of the household that completed the survey was kept as part of the sample and the remaining members were not counted as surveyed. If there was no response from the household, only the member of the household first solicited to take the survey is retained in the calculation of response rates. Thus, the response rates should be viewed as a household response rate.

[†]Useful responses include those surveys where respondents answered at least the first referendum question and completed the survey in a reasonable amount of time. Respondents who indicated they had not realized that the payment was over a ten-year period were also excluded from being a useful response.

[††]3,905 mail surveys were distributed. The reported figure is adjusted for the number of addresses that were not English-speaking residences or were forwarded to addresses outside New York. The response rate for mail is calculated using "response rate one" (RR1) in American Association for Public Opinion Research (2004), defining cases with no answer during a fifth disposition reminder call as ineligible.

Table 3. Mean and Standard Deviation of Demographic and Attitudinal Questions, by Survey Wave and for New York Population

Variable Description	Panel (N=959)	Withdrawn (N=293)	Mail (N=570)	Total (N=1822)	New York State Adult Population†
Age in years	48.2 (14.3)	42.1 (13.1)	51.4 (15.1)	48.2 (14.7)	45.5
Female	58.2%	46.8%	41.4%	51.2%	52.7%
Nonwhite	22.8%	20.8%	12.4%	19.3%	32.1%
Household size	2.50 (1.43)	3.33 (1.35)	2.67 (1.72)	2.68 (1.54)	2.61
Number of children per HH	0.55 (0.99)	1.11 (1.10)	0.64 (1.13)	0.67 (1.07)	0.65
Annual household income*	$57,928 ($38,903)	$72,021 ($39,001)	$67,411 ($49,071)	$63,078 ($42,585)	$57,171
Expectation of income in five years					
Lower than current	55.0%	52.1%	57.1%	55.2%	N/A
Same as current	14.2%	10.2%	18.6%	15.0%	N/A
Higher than current	30.8%	37.7%	24.3%	29.9%	N/A
High school educated	96.4%	99.6%	96.3%	96.8%	79.1%
Heard of Adirondack Park	90.1%	91.1%	92.0%	90.8%	N/A
Distance (mi) to Park entrance	149.4 (63.3)	150.5 (61.0)	144.7 (64.0)	148.1 (63.2)	N/A
Reside in a metropolitan area	93.3%	94.5%	89.0%	92.2%	92.1%
NY resident 5+ years	96.2%	96.1%	97.0%	96.4%	91.8%
Paid NYS taxes last year	84.5%	91.5%	85.1%	87.0%	N/A
Environmentalist	12.3%	11.7%	22.0%	15.4%	N/A
Self-identified political persuasion					
Liberal	18.4%	17.6%	18.8%	18.5%	N/A
Moderate	67.0%	65.1%	61.5%	65.0%	N/A
Conservative	14.4%	17.3%	19.7%	16.5%	N/A

*Computed assuming each household is at the midpoint of its income range.
†Drawn from 2000 U.S. Census.

Table 4. Share Voting for Program by Bid and Scenario

First Vote Bid Level	Base Scenario	Scope Scenario	P-value
25	65.6% (291)	73.5% (147)	0.10
35*	44.8% (29)	-- (0)	--
85*	39.3% (11)	-- (0)	--
90	50.9% (275)	63.4% (142)	0.02
150	41.8% (316)	57.9% (140)	<0.01
200*	32.3% (10)	-- (0)	--
250	36.3% (289)	51.5% (134)	<0.01
P-value (chi-square)†	<0.01	<0.01	
P-value (Kendall's tau)†	0.03	0.04	

(Sample Size in Parentheses)

*Bid values were used in the second pretest only, so sample sizes are small.

†The chi-square test provides a test of simple joint inequality across bid levels; Kendall's tau is a stronger test of monotonic ordering.

Table 5. Log-Normal Econometric Models (Base Instrument)

Variable	Model 1	Model 2	Model 3
Constant	4.6277*** (5.53)	4.0116*** (5.23)	4.4076*** (20.08)
Sigma	1.5432 --	1.2737 --	1.3825 --
Income < \$20k	0.5221 (1.41)	0.3929 (1.53)	
Income \$20-35k	0.2331 (0.94)	0.1210 (0.54)	
Income \$35-50k	0.2464 (1.09)	0.2208 (1.10)	
Income >\$125k	0.5569** (2.41)	0.6611*** (2.90)	
Future income higher	0.2191** (2.32)	0.2267*** (2.81)	
Household size	-0.0849 -(0.87)	-0.1036 -(1.22)	
Presence of children (0/1)	-0.4767 -(1.41)	-0.5286* -(1.90)	
Number of children	0.2717* (1.73)	0.3491** (2.39)	
Female	-0.0688 -(0.38)	-0.1846 -(1.30)	
Black (Not Hispanic)	-0.2058 -(0.68)	-0.5227* -(1.93)	
Other (Not Hispanic)	0.0608 (0.16)	0.1080 (0.34)	
Hispanic	-0.3397 -(0.82)	-0.4557 -(1.50)	
Age	-0.0181 -(0.61)	0.0200 (0.75)	
Age^2	0.0002 (0.50)	-0.0002 -(0.58)	
Reduce spending on clean air & water	-0.7298 -(1.38)	-0.4684 -(1.08)	

Increase spending on clean air & water	0.9370*** (3.89)	0.3284 (1.53)	
Environmentalist	0.7453*** (3.83)	0.4484*** (2.57)	
Frequent visitor to park	0.4874** (2.35)	0.2903* (1.65)	
Live in park	-0.5603 -(1.21)	0.0027 (0.01)	
Distance to park (km)	-0.0019** -(2.01)	-0.0008 -(1.08)	
Protect environment at any cost (warm glow)		1.3655*** (7.34)	1.3915*** (7.22)
Health effects (minor)		0.5519*** (3.41)	0.7562*** (4.43)
Health effects (significant)		1.4671*** (4.87)	1.1737*** (3.12)
Future w/o liming is worse than survey depicts		0.2899 (1.63)	0.2939 (1.62)
Future w/o liming is better than survey depicts		-0.3603 -(1.18)	-0.1557 -(0.54)
Other animals effected		0.1029 (0.69)	0.0986 (0.63)
Didn’t pay taxes		0.3207 (1.32)	0.3112 (1.45)
Liming not practical		-1.1779*** -(4.24)	-1.4697*** -(4.63)
Not confident in NY State to admin. program		-0.4930*** -(3.56)	-0.5117*** -(3.23)
Don’t raise taxes for any reason		-0.2508 -(1.31)	-0.2225 -(1.18)
Vote doesn’t matter		-0.1460 -(1.00)	-0.0138 -(0.09)
Upwind polluters are at fault		-1.1976** -(2.40)	-1.8245*** -(2.71)
N	938	872	1056
Log Likelihood	-925.75	-678.10	-921.22

(Z-scores in parentheses.)

Table 6. Identification of Possible Yea-saying and Nay-saying Votes

Indicator	Share of Final Sample	Treatment
Yea-saying		
Costs should not be a factor	24.9%	Dropped or controlled.
Some health effects	38.1%	Given chance to revote. Others controlled.
Significant health effects	10.3%	Given chance to revote. Others dropped or controlled.
The future status of Adirondacks is worse than described	18.4%	Controlled.
Other animals are affected beyond those mentioned	58.5%	Controlled.
Does not pay taxes	13.0%	Dropped or controlled.
Nay-saying		
Taxes should not be raised for any reason	21.1%	Controlled.
The future status of Adirondacks is better than described	8.3%	Controlled.
Not confident in New York State government to run the liming program	37.1%	Given chance to revote. Others controlled.
Liming program not practical	15.0%	Dropped or controlled.
Voted against program solely because upwind polluters should reduce instead	19.1%	Controlled.

Table 7. Base Improvement: Mean WTP, By Yea-saying Controls, Nay-saying Controls, and Distributional Assumption (L=Lognormal, W=Weibull)*

		Nay-saying Controls									
		None		All econometric controls		Econometric controls, drop tax haters		Econometric controls, drop if tax hater AND lime rejector		Econometric controls, drop if tax hater OR lime rejector	
Distribution		L	W	L	W	L	W	L	W	L	W
Yea-saying Controls	None	324	180 N=1175	986	565 N=1099	817	505 N=884	1037	609 N=1024	721	441 N=795
	All econometric controls	66	58 N=1102	213	159 N=1056	203	159 N=848	223	173 N=983	201	156 N=763
	Econometric controls, drop warm glower	77	63 N=841	223	156 N=800	194	156 N=638				
	Econometric controls, drop if warm glower AND health embedder	67	58 N=1050	231	166 N=1004			238	180 N=932		
	Econometric controls, drop if warm glower OR health embedder	80	63 N=810	266	179 N=770					233	180 N=544

*N applies to both lognormal and Weibull distributions.

Table 8. Scope Improvement: Mean WTP, By Yea-saying Controls, Nay-saying Controls, and Distributional Assumption (L=Lognormal, W=Weibull)*

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="10">Nay-saying Controls</td></tr>
<tr><td colspan="2">None</td><td colspan="2">All econometric controls</td><td colspan="2">Econometric controls, drop tax haters</td><td colspan="2">Econometric controls, drop if tax hater AND lime rejector</td><td colspan="2">Econometric controls, drop if tax hater OR lime rejector</td></tr>
<tr><td colspan="2">Distribution</td><td>L</td><td>W</td><td>L</td><td>W</td><td>L</td><td>W</td><td>L</td><td>W</td><td>L</td><td>W</td></tr>
<tr><td rowspan="5">Yea-saying Controls</td><td>None</td><td>730</td><td>316
N=532</td><td>1791</td><td>841
N=515</td><td>2597</td><td>1962
N=424</td><td>1962</td><td>782
N=497</td><td>2921</td><td>866
N=388</td></tr>
<tr><td>All econometric controls</td><td>135</td><td>98
N=523</td><td>308</td><td>179
N=506</td><td>316</td><td>135
N=417</td><td>336</td><td>179
N=488</td><td>346</td><td>144
N=384</td></tr>
<tr><td>Econometric controls, drop warm glower</td><td>122</td><td>98
N=394</td><td>331</td><td>192
N=380</td><td>341</td><td>142
N=307</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Econometric controls, drop if warm glower AND health embedder</td><td>134</td><td>98
N=487</td><td>308</td><td>180
N=470</td><td></td><td></td><td>337</td><td>180
N=452</td><td></td><td></td></tr>
<tr><td>Econometric controls, drop if warm glower OR health embedder</td><td>123</td><td>99
N=359</td><td>332</td><td>188
N=346</td><td></td><td></td><td></td><td></td><td>384</td><td>155
N=252</td></tr>
</table>

*N applies to both lognormal and Weibull distributions.

Figure 1. Share Voting for Program by Bid and Scenario

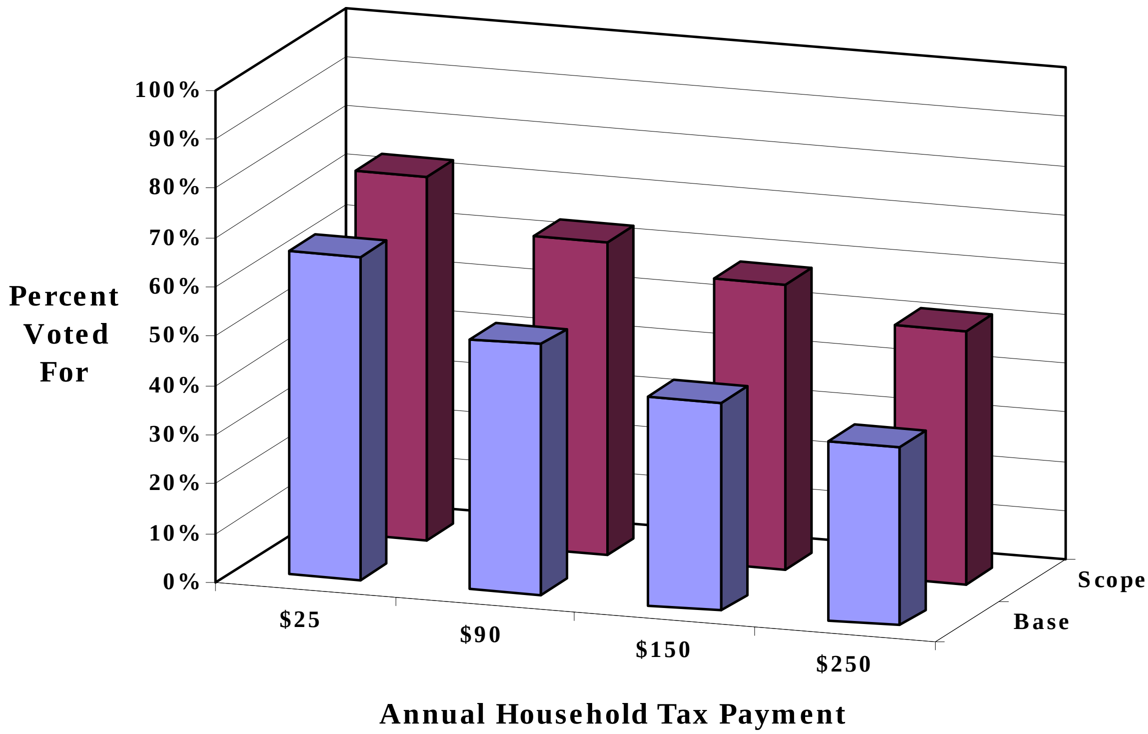
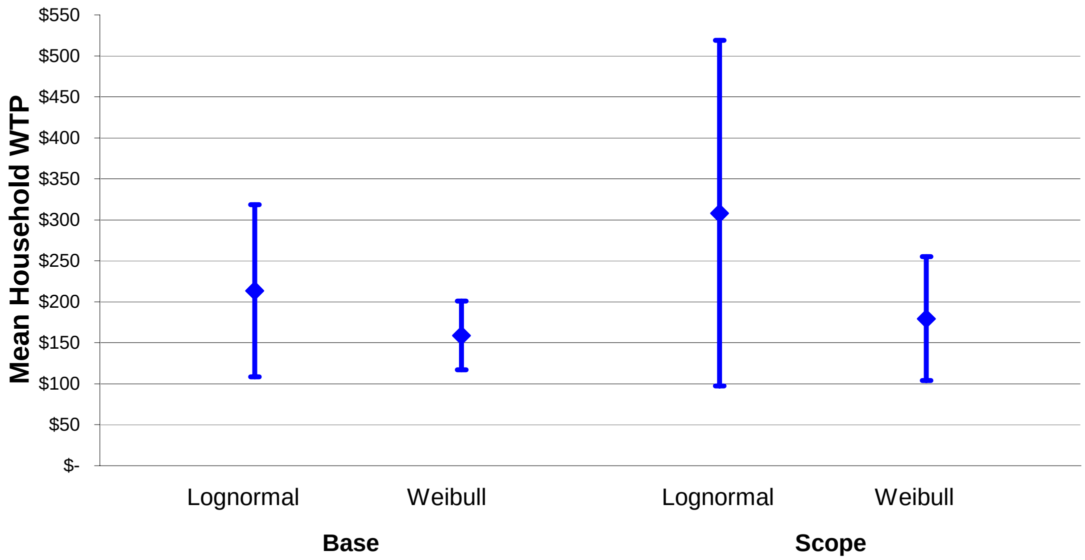
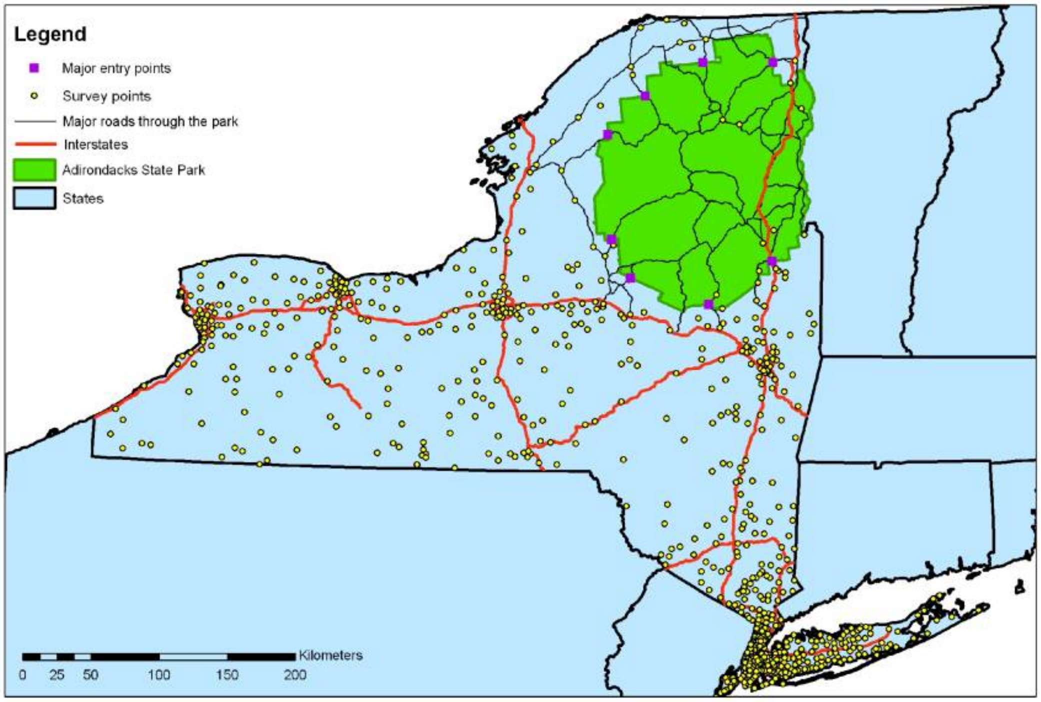


Figure 2. Model and Statistical Uncertainty of Mean WTP for All Econometric Models

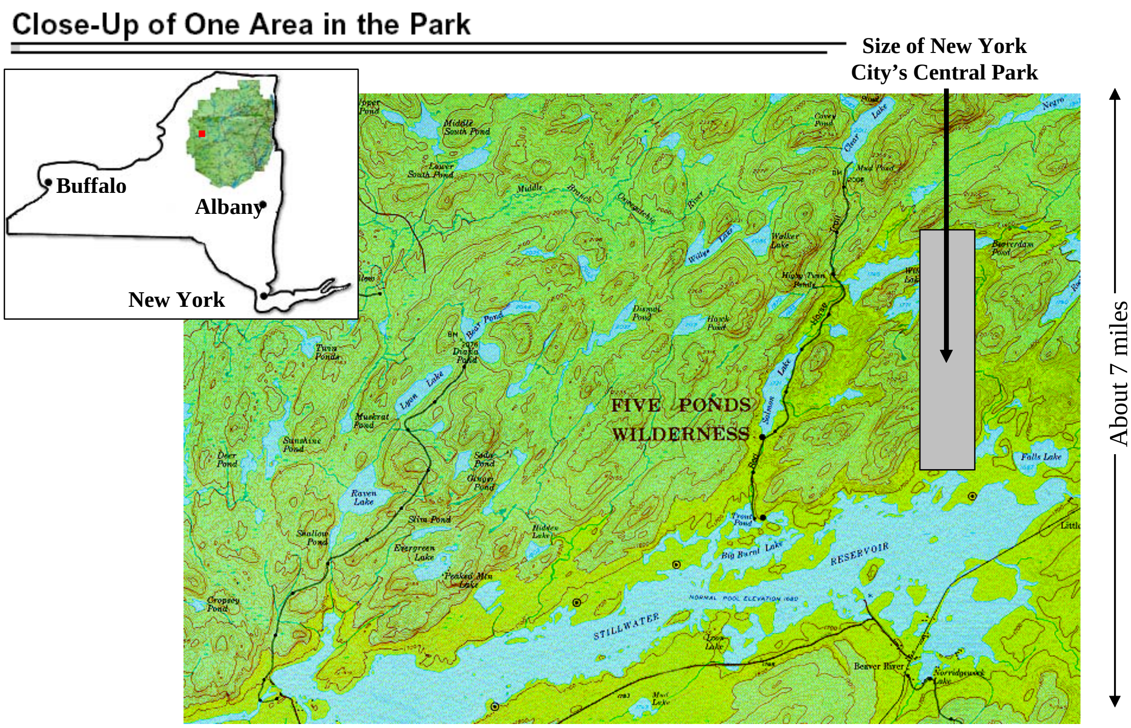


Appendix A: Geographic distribution of respondents within New York State.



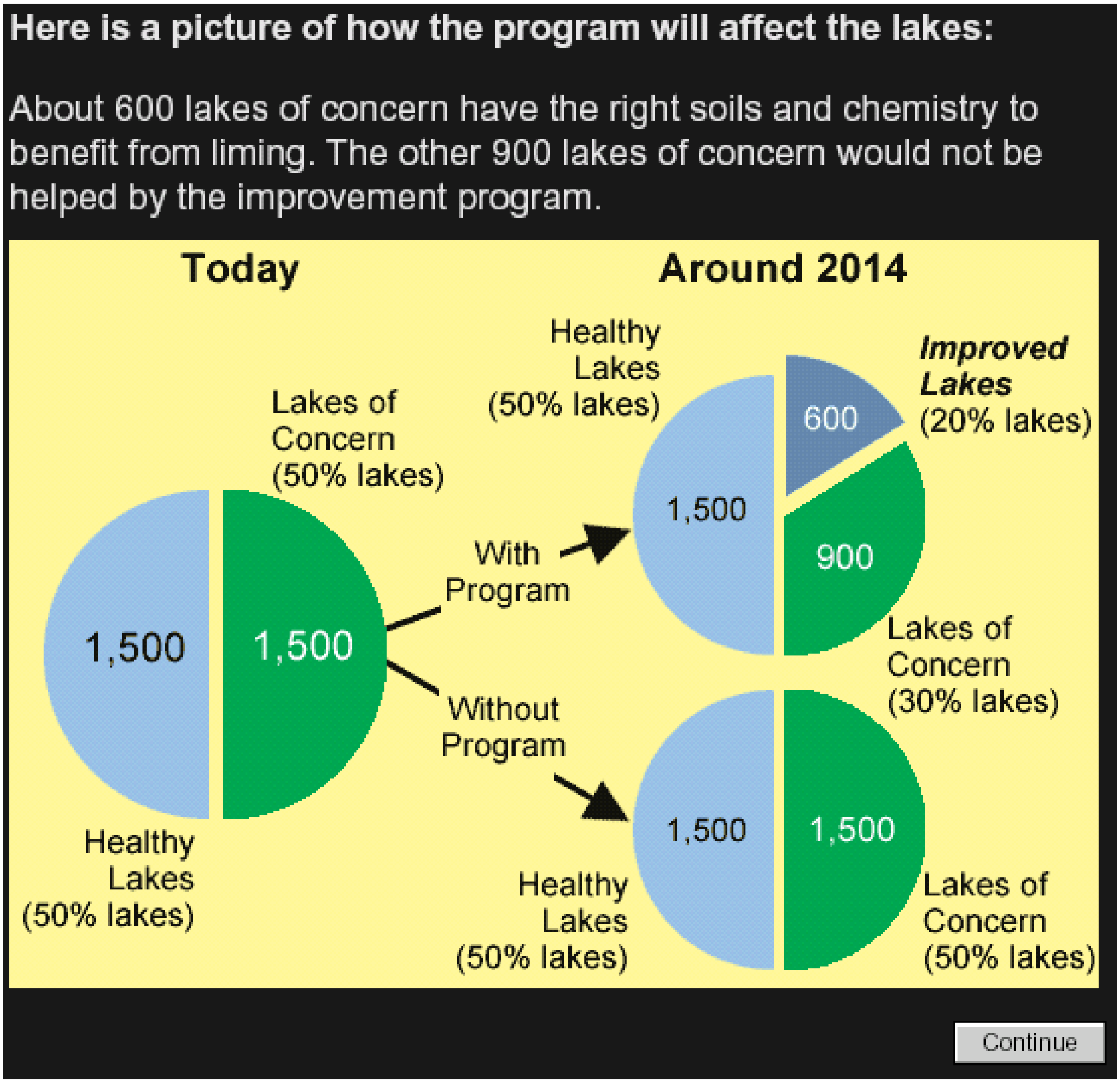
Appendix B: Screen and page captures from survey

Map illustration of size of affected lakes.

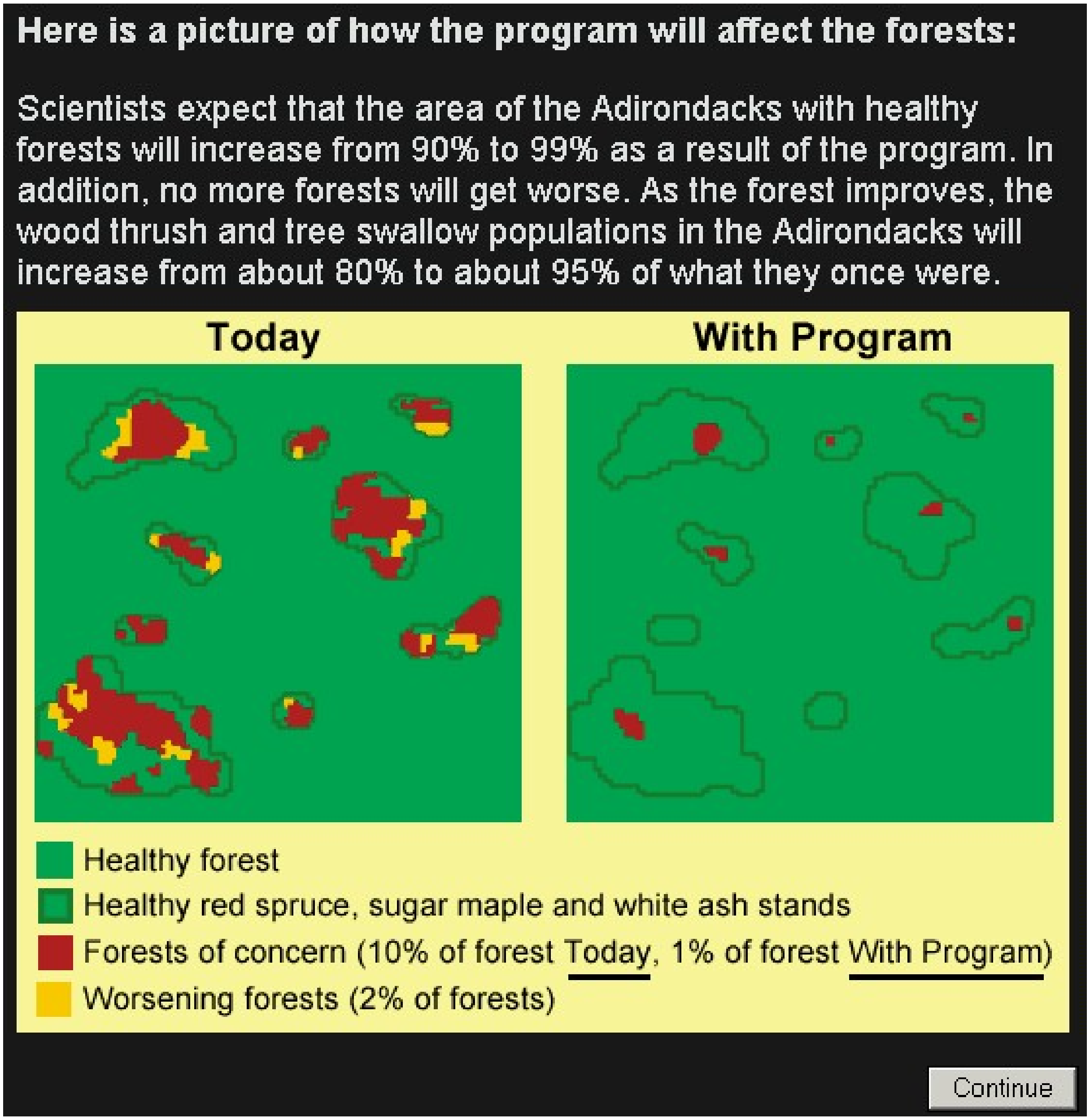


This map illustrates one small part of the Adirondack State Park. This part is located where the red dot is on the inset map. Most of the lakes affected by past air pollution are small; they are typically much smaller than Central Park in New York City. The large lakes that you may have heard of (such as Saranac Lake or Lake George) are much bigger than Central Park and <u>are not</u> lakes of concern.

Chart representing how the program will affect the lakes.



Representation of forest improvement



ISSN 1045-6333

HARVARD

JOHN M. OLIN CENTER FOR LAW, ECONOMICS, AND BUSINESS

THE VALUE OF REGIONAL
WATER QUALITY IMPROVEMENTS

W. Kip Viscusi
Joel Huber
Jason Bell

Discussion Paper No. 477

06/2004

Harvard Law School
Cambridge, MA 02138

JEL Codes: Q25, K32

The Value of Regional Water Quality Improvements

W. Kip Viscusi,* Joel Huber, and Jason Bell

Abstract

Four years ago, Magat, Huber, Viscusi, and Bell (2000) reported pretest results that introduced an iterative choice approach to valuing water quality improvements. This paper applies this approach to a nationally representative sample of over 1,000 respondents. We find that the method provides stable, policy relevant estimates of the amount people are willing to pay for improvements. Willingness to pay for a one percentage point improvement in water quality has a mean value of $23.17 with a median of $15, and appropriately increases with family income, age, education, and the likelihood of using lakes or rivers. In addition, the method passes an external scope test demonstrating that greater gains in the percent of water rated "good" increase the likelihood that the respondent will choose the alternative with better water quality. We tested the appropriateness of a national web-based panel of respondents and find that the Knowledge Networks sample does not fall prey to difficulties that could plague such panels. First, the sampled web-based panel matches United States demographics very well, and predictors of sample responsiveness, such as the likelihood to take a long time to respond to the survey, have minimal impact on the critical estimates of the value of good water. Second, the results are quite insensitive to doubly censored regression that accounts for the portion of respondents who indicated an unboundedly high or low estimate for the value of cleaner lakes and rivers. Finally, the stability of the benefit values is further demonstrated by the selection-corrected estimates that adjust for people invited to participate but who did not successfully complete the survey.

Keywords: water quality, environmental benefits, survey, contingent valuation

---

* Cogan Professor of Law and Economics, Harvard Law School, Hauser 302, Cambridge, MA 02138
ph: (617) 496-0019 kip@law.harvard.edu

This research was supported by EPA Cooperative Agreement R-827423-01-4 with Harvard University. Viscusi's research is also supported by the Harvard Olin Center for Law, Economics and Business. Helpful comments were provided by Dr. Alan Carlin, John Powers and Mahesh Podar.

The Value of Regional Water Quality Improvements

W. Kip Viscusi, Joel Huber, and Jason Bell

1. Introduction

The economic benefit of water quality improvements is society's willingness to pay for increases in water quality. Early measures of water quality were derived from travel cost values of recreational benefits[1]. Subsequent benefit assessments, which remain in use in some policy applications, consist of analyzing the value of improvements in the water's ranking on a water quality ladder.[2] This unidimensional water quality index assumes that there is a hierarchy of quality levels in terms of whether the water is drinkable, swimmable, fishable, or boatable. Thus, water that is drinkable also meets acceptability criteria for all lower ranked uses. Unfortunately, this hierarchical characterization is problematic, as these categories of uses do not reflect our current scientific understanding of the empirical ordering of water quality. That is, if one examines the pattern of quality levels across states, there is almost no evidence of such a hierarchy.[3] The focus of the survey results reported here is on people's willingness to pay for water that is rated "good" based on an overall index, developed by the U.S. Environmental Protection Agency (EPA), that initially merges benefits with respect to fishing, swimming, and the quality of the aquatic environment. An additional survey component makes it possible to

---

[1] See Berkman and Viscusi (1973).
[2] Mitchell and Carson (1989) and Carson and Mitchell (1993) provide benefit assessments using this approach, which was consistent with the previous scientific literature at that time. A different perspective is provided by Smith and Desvousges (1986).
[3] Examples of these differences using data from EPA's National Water Quality Inventory appear in Magat, Huber, Viscusi, and Bell (2000), pp. 10-11.

separate the component values.[4] The survey results reported here will focus on the overall water quality valuation component.[5]

This paper expands and tests the methodology developed by Magat, Huber, Viscusi, and Bell (2000), where water quality values are derived from hypothetical market choices. These values are based on simple choices between regions that differ on water quality and cost of living. A series of such choices yield bounds on the value of water quality improvements for each individual. The method has the advantage of generating estimates of the private value of improvements in water quality from a simple understandable task.

This paper discusses econometric stability of these estimates as well as some reliability and sampling questions that arise in this use of iterative choice to assess private values. The study is based on over 1,000 new surveys implemented through web-based interviewing. Generally, we find that water quality valuations follow expected economic patterns: factors such as income, education, and visits to lakes or rivers are appropriately related to the value of water quality. Further, a scope test indicates greater valuations for larger changes in water quality gains, increasing confidence in the metric quality of the results. We assess the reliability of this approach by testing for the stability of the results given different econometric assumptions, with particular focus on those responses for which the dollar value of water quality could only be bounded on one side.

A second important improvement in this study is the use of a national web-based panel rather than the recruitment to regional central sites or mall intercepts used in the Magat *et al.* (2000) study. The use of respondent panels for policy has emerged as a response to increasing difficulty and expense attached to recruiting probability-based random samples. It is

[4] See Magat, Huber, Viscusi, and Bell (2000).
[5] The attributes of good water quality will be addressed in a separate survey to be administered by the authors in 2004.

fundamentally an empirical question whether a panel-based sampling approach will produce acceptable results. We find that the demographic characteristics of the final sample closely correspond to that of the target universe of U.S. adults. Additionally, we show that that the results are not affected by factors that might distinguish between those who take the survey against those who do not. Finally, a sample selection procedure adjusts the water quality valuations for the probability that a panel member will not take or successfully complete the survey. These estimates differed little from the unadjusted means, providing assurance that they are relatively independent of possible panel selection biases.

Section 2 describes the overall study design, the survey methodology and the iterative choice method for generating values for improvements in water quality. Section 3 explores the logical adequacy of the results, including an exploration of consistency tests for the responses as well as the variation of the valuation responses conditioned on demographics. Section 4 provides tests of survey and sample validity. The survey was internet-based, using the Knowledge Networks panel. We examine the extent to which attrition bias from the panel and other aspects of this survey mode influence the water quality values. As indicated in the concluding Section 5, the results are quite robust and meet a wide variety of tests for rationality and consistency.

2. Study Design

The survey used a computer-based methodology and was administered to a representative national sample.[6] The average respondent completed the survey in 25 minutes. The instrument initially acquainted the respondent with the meaning of regional differences in lake and river water rated of good quality and differences in annual cost of living. This introductory section

[6] While our survey uses an iterative choice format, it is related to contingent valuation surveys, though it uses a different survey approach. For discussions of contingent valuation, see among others Bishop and Heberlein (1990), Fischhoff and Furby (1998), and Mitchell and Carson (1989), and Schkade and Payne (1986).

establishes the cognitive groundwork for the respondents so that a choice between regions differing in these aspects can be reliably answered.

Introductory section in the survey

The key valuation task involves choices between regions differing in their levels of water quality and the annual cost of living. A critical part of the method involves introductory sections that encourage the respondent to think about these tradeoffs. This process begins with some very general questions to encourage the respondent to think about the value of freshwater bodies. It also elicits information on the frequency of visits to lakes and rivers as well as related activities, such as boating, fishing, or swimming. The primary reason for asking about usage is to encourage respondents to think about why they might value differences in water quality. However, it may also be the case that respondents reporting greater usage of lakes and rivers have higher valuations of improvements in the quality of those water bodies.

Immediately following the introduction to water usage, the survey explains the meaning of cost of living and elicits the respondent's level of concern with an annual increase in cost of living of $200. Respondents then respond to a question that tests comprehension involving a simple choice between two regions, identical except that one is more expensive. The few respondents who chose the more expensive location are provided a brief educational module before being asked to proceed.

Next, respondents are introduced to the criteria that define what it means for water quality to be "good." Consistent with definitions used by EPA's National Water Quality Inventory, the survey provides the following definition:

> The government rates water quality as either
> * Good, or
> * Not Good.

> Water quality is Good if the water in a lake or river is safe for all uses. Water quality is Not Good if a lake or river is polluted or unsafe to use.
>
> More specifically, water quality is Good if the lake or river
> * Is a safe place to swim,
> * Fish in it are safe to eat, and
> * Supports many plants, fish, and other aquatic life.
>
> Water quality is Not Good if the lake or river
> * Is an unsafe place to swim due to pollution,
> * Has fish that are unsafe to eat, or
> * Supports only a small number of plants, fish, and other aquatic life.

The survey then explicitly excludes drinking water from the valuation task.

Once familiar with the concepts of water quality and cost of living, these contexts are framed within context of a region, defined as "within a 2-hour drive or so of your home, in other words, within 100 miles." A 100 mile radius is appropriate because it reflects a reasonable 2-hour drive for the recreational use of bodies of water, and about 80 percent of all recreational visits for lakes, rivers, and streams are within such a radius.[7] This text explanation of region contrasts with the method reported in Magat et al. (2000) where respondents viewed pictorial representations of the region size. However, our pretest interviews indicated that the 100-mile region radius could be well understood when described through the text used.

After they learned about water quality and the region, respondents received a warm-up choice. In this case they were asked to choose between two regions that differed in the percentage of water bodies with quality rated good. Respondents who preferred the region with a lower percent of lakes and rivers rated good received a brief interactive tutorial on the meaning of the benefit measure and the error in their response.

<u>Key Valuation Choice Task</u>

[7] Data generated by the EPA NCEE Office for this study indicate that 77.9% of boating visits, 78.1% of fishing visits, and 76.9% of swimming recreational visits are within a 100 mile radius. Calculations were made by Jared Creason of NCEE using the 1996 National Survey on Recreation and Environment.

Once respondents learn about water quality, cost of living and their application to a region, they are ready for the iterative choice questions. This key valuation task is designed to elicit the respondent's tradeoff between water quality and cost of living in choices between different regions. These regions are "the same in all other ways, including the number of lakes and rivers near your home." As a final warm-up question respondents are asked to make a choice where one alternative dominated another on both cost of living and water quality. That is, they choose between two regions, where one region had more quality lakes and rivers and lower cost of living. Respondents who erred received a remedial tutorial that reviewed the nature of the choice being made.

The critical choice questions take the form shown in Figure 1. It is noteworthy that the task itself is not complex, which past evidence suggests should enhance the validity of the survey approach.[8] We will also present a series of rationality tests of the survey responses as validity checks of the methodology.

If a respondent was indifferent in the initial choice presented in Figure 1, then the iterative choice process is complete, yielding a cost of living willingness to pay value for the illustrated choice of ($300-$100) / (60%-40%) = $10 per 1 percent improvement in water quality. A choice of either alternative led to successive choices that terminated either at indifference or a narrowly bounded value estimate. Specifically, if we let C_i be the cost of living in region i, i=1,2; and let G_i be the percent of water in region i rated good, then the value V of water quality benefits is given by

$$V = (C_2 - C_1) / (G_2 - G_1).$$

[8] DeShazo and Fermo (2002) show that complex choice sets can pose difficulties with respect to respondents' ability to process the choices and give consistent responses.

Figure 2 displays the logic of the iterative choice questions. The program iterates choices, each time degrading the desirable aspect of the last alternative chosen until the selection reverses. For example, a respondent preferring the lower cost region on the initial question in Figure 1 then considers the same pairwise choice, except the cost of living in that region is raised. Continued preference for the lower cost region leads to continued increases in the cost of living in the chosen region until the respondent faces a dominated choice in which the regions have the same cost of living but differ only in terms of water quality. Similarly, continued preference for the higher quality region leads to continued reductions in the water quality of the chosen region until the regions have the same water quality but differ only in cost of living. This series of questions permits a bounded estimate value of water quality improvements for all respondents except for those at the corners of the decision tree. For these corner respondents, we analyze their results in two ways. First, for those respondents who choose the non-dominated region, we estimate the value as twice the maximum observed dollar value for water improvements for those with very high and halved it for those with very low values of water quality. Second, we used more appropriate econometric treatment for those respondents based on censored regression methods, as described in Section 3.

As another check of rationality, for respondents who reach a corner boundary of the tree indicating zero value for money or good water, the survey brings this decision to the respondent's attention, offers a chance to reconsider, and then inquires regarding the reason for their choice. The analysis deals with the 6% who indicated that they would still choose the dominated alternative or had no preference by dropping them from the initial analysis and by treating as non-respondents in the Heckman adjustment for selection bias.

The survey also ends with a number of additional sections, such as a brief series of demographic questions and whether the respondent had difficulty understanding any part of the survey.

This process of elaborate training before the choice questions is one we have used a similar formulation in a wide variety of other environmental risk contexts. We have found that with sufficient grounding, the tradeoff against cost of living can be well understood.[9] We deliberately framed the choice as one between regions similar to but abstracted from the region where the person now lives. This abstraction is one that we believe contributes to the stability, validity and actionability of the results. In terms of stability, not having to focus on a particular body of water conditioned on the location of one's home discourages inferences about one's particular circumstance that may or may not apply to a particular change in the percent of good water quality in a region. In terms of validity, the survey focuses on a free market choice that has minimal social consequences—whether one buys in region A or B primarily influences one's own utility. These market choices contrast with referenda where one's vote can affect the welfare of others, confounding the results with an array of conflicting forces including altruism, confidence in the efficacy government action, willingness to impose costs on others, and attitudes about taxation to fund such referenda. Finally, the results are actionable in helping to establish a general social metric for policy decisions across regions. The projected dollar value for changes in water quality can be related to general citizen characteristics such as age, income and education. These values can be applied using census data to evaluate a broad range of options that affect the quality of water.

<u>Experimental conditions</u>

[9] The first of these many studies is Magat, Viscusi, and Huber (1988).

In order to test the robustness of the results to different versions of the questionnaire, randomly identified groups received alternative versions. These tests permit an assessment of the effects of anchoring and the initial range of the alternatives in the initial trade off.

Our study tests for anchoring influence by manipulating the presence of an external norm for water quality. Approximately half the respondents received information that the national average of water quality was rated 65% Good, whereas the other respondents received no national information. Being told the US 65% value may increase the sensitivity to water quality, since there is now an anchor that helps respondents value of the water percent amounts provided.

Second, the value of a given change in percent good may itself be affected by the range of percent good and dollars in the initial choice. For example, if the first choice is between a gain of 20% good in return for $400 in cost of living (e.g., $20 for one percentage point), then respondents may reasonably use that information to assume that, say, $15 is a good price to pay for one percentage point gain. By contrast, if the initial choice pits a 20% gain against $200, ($10 per one percentage point), then the $15 seems relatively high. This inference is understandable if one takes the Gricean (1975) assumption that the initial choices provided in such questionnaires are reasonable. To test the impact of the initial range we altered the initial range in cost of living to be either $200, $300 or $500, and the range of the gain in percent good to be either 20, 30 or 40 percentage points. This test is whether the initial choice is appropriately sensitive to ranges, as required for appropriate sensitivity to scope.

3. Valuation of Water Quality Improvements

In reporting our results we first give the mean and distribution of our unit water quality benefit measure, the dollar value of a one percentage point change in water quality. Then, to validate the results, we regress these valuation measures against respondent characteristics to demonstrate that the kinds of respondents expected to have higher or lower valuations indeed have them. To show that these results are meaningful for policy, we demonstrate that the initial choice is appropriately sensitive to scope. That is, the choice of the region with better water quality increases with its advantage in percent good, and goes down with its disadvantage in cost of living.

Overall Benefit Values

The benefit value measures how much of an increase in the annual cost of living respondents are willing to incur for each percentage point improvement of water rated good. For each respondent, this value V is calculated at the point of indifference between two regions or the average V where a finite bound can be estimated. The mean value of V for a 1 percent improvement in water quality is $23.17 per year, with a standard error of the mean of 0.79, based on 1,103 respondents.[10] The median water quality benefit value V is $15, which indicates that the benefit distribution is skewed with a large upper right tail. It is reassuring to note that these summary statistics correspond well to a mean of $22.40 and median of $12 reported by Magat et al. (2000).

There was a substantial variability in water quality values across people. Respondents at the 25th percentile registered a value of $6.25 per unit improvement in water quality, as compared to $15 at the median and $30 at the 75th percentile. The disparity between the valuation at the 10th percentile value of $1.92 and the 90th percentile value of $75 indicates substantial heterogeneity in the value respondents place on clean lakes, rivers, and streams.

Validity Tests

[10] Carson and Mitchell (1993) examined willingness to pay for national water quality and estimated that people would pay $242 in 1990 dollars (or $315 in 2003 dollars) annually to improve from a baseline of non-boatable to nationally swimmable.

Two validity tests provide evidence of the meaningfulness of the estimated water quality values. The first test requires that the individual estimates of water quality value differ across respondents in ways predicted by economic theory. The second validity assessment is an across person test requiring respondents to be sensitive to the scope of differences in cost of living and water quality provided.

Consider first the relationship between generated values and respondent characteristics. The Magat *et al.* (2000) survey found very weak relationships between valuations and demographic characteristics. The current results are far more substantial, perhaps due to a sample almost three times as large and because of better survey implementation. The dependent variable for analysis is the log of respondent's unit water quality benefit value, V. The log transformation is used because it has the effect of making the right-skewed distribution of V approximately normal.

Table 1 presents two sets of regression results for the log value of V, the unit value of water quality. The first column presents the OLS estimates, while the second column of results presents the censored Tobit regressions. Survey respondents consistently choose the low priced or high quality option eventually reach or the corner maxima or minima in the iterative choices shown in Figure 2. The censored regression in effect combines the information from the respondents who hit the upper or lower limits with conventional regression results for the bounded respondents. Thus, the censored regression coefficients makes the best prediction taking into account the fact that the survey truncates the distribution of possible responses at both the high and low end of the distribution of water quality values. The Tobit estimates in Table 1 are remarkably similar to the OLS estimates.

The statistically significant explanatory variables all have coefficients that one would expect. The coefficient of .17 for log income indicates that water quality is a normal good, with valuations increasing by 17% for a doubling in income. Individual education is likely to be a proxy for lifetime wealth. Better educated respondents exhibit a higher value for good water quality, controlling for current income levels and personal characteristics. Older respondents likewise indicate a higher valuation of water quality that is consistent with life cycle changes in wealth.

Two variables that should reflect whether a respondent is likely to have particularly strong preferences for good water quality are whether the respondent is a member of an environmental organization or has visited a lake or river in the last 12 months.[11] The coefficients of the environmental group membership and environmental activities variables were almost identical in magnitude, with each increasing the value of water quality by around 28%. The significant positive influence on benefit values of visits to lakes and rivers accords with previous research by Cameron and Englin (1997) showing that respondent experience with the good being valued raises the valuation amounts. After accounting for the influence of the environmental variables and demographic effect such as income and education, variables pertaining to region, race, and gender were not significant on an individual basis.

Whether the respondent was told the percentage of water in the country rated good did not have a statistically significant effect on valuations. The sub-sample that was given information pertaining to this possible anchor exhibited no difference in their valuation amounts. This result indicates that the respondents focused on the difference between the alternatives in the choice set, rather than on the presence of an external reference point.

---

[11] The particular environmental organizations listed in the survey for possible membership were the following: Environmental Defense Fund, Greenpeace, National Audabon Society, National Wildlife Federation, Nature Conservancy, Natural Resources Defense Council, and Sierra Club.

External Scope Tests

The second validity assessment is an external scope test. The scope test is important in establishing context that the estimates of V were a meaningful quantitative, valuation metric.[12] If respondents are willing to incur the same cost of living increase for a 20 percentage point change in water quality as a 40 percentage point change, then all one is measuring is a general attitude towards water quality over cost of living, such as "warm glow" effects. The test we report is across respondents, a stronger test than a within subject test.

This test is possible because we altered the initial range of water quality ranges and the cost of living across respondents. In particular, one of the alternatives in the initial choice was either 20, 30, or 40 percentage points in good water quality higher than the other, and the difference in cost of living was either $200, $300 or $400 per year.[13] To demonstrate appropriate sensitivity to the scope of the choice, respondents' initial choices should favor the region with higher water quality when its gain in water quality is greater. Similarly, respondents should favor the region with lower cost of living when its gain in living expense is greater. Table 2 displays a logistic regression predicting initial choice as a function of initial ranges and the demographic variables used to predict the final valuation amounts for the regressions in Table 1. The variables pertaining to each of the scope tests are significant and in the expected direction. Increasing the water quality difference or decreasing the cost of living difference makes one more likely to choose the alternative with higher water quality. Further, the characteristics that predict the initial choice for the regressions in Table 2 parallel those predicting the final tradeoff reflected in the regressions in Table 1, with choice of the high water quality option increasing

[12] For a detailed review of scope tests and the ability of contingent valuation studies to pass scope tests, see Smith and Osborne (1996).
[13] We also altered the average levels of water quality to see if response depended on these. Those analyses are available on a working paper: "Coping with the Contingency of Valuation: Range and Anchoring Effects in Choice Valuation Experiments," Huber, Viscusi and Bell (2004).

with age, income, education and the environmental preference variables such as visits to lakes and rivers or membership in environmental organizations.

4. Evaluation of the Panel Sample

Sample Characteristics

The sample used for the study came from the Knowledge Networks (Menlo Park, CA, www.knowledgenetworks.com) panel. Researchers on environmental benefits valuations have increased their use of internet panels, so that the performance of this survey approach has broad implications beyond our particular study.[14] The Knowledge Networks sample consists of a national sample of households recruited by random-digit dialing, who either have been provided internet access through their own computer or are given a WebTV console. The underlying Knowledge Networks sample has been selected to be broadly representative of the U.S. population.[15]

Table 3 compares the sample characteristics of those who completed the survey and with the 2001 U.S. adult population. The survey population closely mirrors the U.S. Census distribution. One might have hypothesized that people willing to be surveyed would be better educated, underrepresented at the extremes of income, and younger than the general population. However, there are no major discrepancies between the sample mix for our study and the population. While some differences are statistically significant, including the percentage of respondents age 64 and over and the representation of some income groups, these differences are not consequential. For example, 11 percent of the sample is age 64-74 compared to a national average 9 percent, and 21.1 percent of the sample have household income in the $50,000-

[14] Other researchers using the Knowledge Networks sample have included Krupnick et al. (2002), Berrens et al. (2004), and DeShazo and Cameron (2004).
[15] Ongoing research by Trudy Cameron and J.R. De Shazo has examined the representativeness of this sample and has developed a selection correction to account for differences from U.S. Census averages.

$74,999 range, as compared to the national average of 18.9 percent. Differences such as these are to be expected, both because of the stochastic nature of the sampling process as well as the fact that there is not an exact match up for the 2001 Census time period and the more recent sampling period. Overall, the sample tracks the U.S. population remarkably well.

Sample Validity Tests

Because the survey was administered via the internet using an existing panel of respondents, we undertook a series of validity tests specifically determining whether their panel membership influenced the valuation results. To the best of our knowledge, these are the first such tests to have been undertaken for this sampling methodology. We tested the panel influences of four variables on the regression analysis of the determinants of the value of water quality benefits. Table 4 reports these regression results in which these panel variables first are added to our earlier analysis shown in Table 1 and then are included without these variables.

The first variable is whether the respondent stopped the survey and then continued the survey at a later time. Conceivably, such respondents might be less engaged in the survey task. However, there was no significant effect of this variable on benefit values.

The second variable of interest is the time the respondent has been a member of the Knowledge Network panel. Length of time in the panel may affect attentiveness to surveys and potentially could be correlated with other personal characteristics that influence water quality valuations. The estimates in Table 4 fail to indicate any significant influence of this variable either.

Third, the number of days the respondent took to complete the survey after being offered the opportunity to participate could reflect a lack of interest in the survey topic or in taking surveys generally. Nevertheless, there is no significant effect of this variable on benefit valuations in either of the equations estimated in Table 4

The final survey methodology variable tested is whether the respondent subsequently quit the panel either immediately after the invitation for this survey or at any later time until May 2004, when data for this variable were collected. Such respondents could be less interested in taking surveys and might have different valuations. However, this variable was also not statistically significant in the water quality valuation equations.

Overall, there is no indication that any of these key aspects of the panel methodology bias the survey responses. In addition to the general match of our respondents to the U.S. population, we also examined whether these four variables reflecting the methodology had any influence on the probability that the respondent failed to pass the consistency test with respect to the benefit valuations. There were no significant effects of any of the Knowledge Networks panel variables so that there is no evidence that national performance of the survey task is importantly influenced by any of these variables.

Selection Effects

Although the sample is nationally representative and had a high overall response rate, it is useful to test for possible selection biases arising from panel members who were invited to participate but did not successfully complete the survey. Of 1,587 panel members invited to take the survey, 74% of respondents chose to participate. Of the 1,174 participants, three respondents did not complete the portion of the survey that elicits water quality value. Finally, 6% of participants completed the survey but were dropped because they chose the dominated alternative and continued with that choice even after being so informed. Therefore, 1,103 of 1,587 invitees consistently completed the water quality valuation portion of the survey. For the selection correction for bias, we used variables for which we had the values for non-respondents as well as survey respondents. This data is routinely collected by Knowledge Networks on its panel members. Thus, an additional advantage of such panels is that there is information available to analyze who chose not to take the survey after being offered the chance to do so.

To predict participation, we identified a number of variables that significantly affected survey completion. In particular, we found that being African American or Hispanic was negatively associated with completing the survey, as was household size. We also constructed two health-related stress dummy variables. The first stress variable was for individuals who reported that they had a high stress level. The high stress variable indicated respondents who reported more “stress, strain, or pressure” than usual “during the past few months.” The second stress variable was for people who failed to respond to the stress information question. Each of these variables was negatively related to the probability of taking the survey but not significantly related to the water quality valuation amount V, thus achieving the appropriate identification.

Table 5 reports the selection equation and the selection-corrected regression of the log value of water quality. The threshold empirical issue is whether there are any statistically significant selection effects. As the chi-squared statistic reported at the bottom of Table 5 indicates, one cannot reject the hypothesis that there is no significant effect of sample selection on our empirical estimates. Thus, the empirical estimates are not biased in any statistically significant way by the self-selection of respondents in the Knowledge Networks sample who chose to complete the survey and did so successfully.

Given this absence of statistically significant selection effects, it is not surprising that the selection-corrected estimates closely parallel our earlier estimates. Water quality values increase with income levels, age, and education, as before. The race variable has become significant, but this effect may have been due in part to the omission of the environmental group membership and water recreation use variables from the equation, since they were not available for non-respondents.

Similar stability in the results is implied by an examination of the extent to which the estimates of the dollar value of water quality changes with the selection adjustment. Using the parameter estimates of the selection-corrected regression, we estimated the log value of a one percent improvement in water quality. The average log value then decreased by 4.5% and the antilog by 11.1% compared to corresponding estimates using parameters from the ordinary least squares regression. These differences are well within sample variability and thus are not statistically significant. More important, these results indicate that the estimates are not substantively different even after careful adjustment for sample selection.

5. Conclusions

The survey results presented here passed a variety of consistency tests and rationality checks. These tests included dominance tests as part of the iterative choice process and external scope tests across respondents. In addition, the internet-based methodology itself was tested with respect to a variety of potential sources of bias, such as sample attrition, and these panel characteristics had no significant effect on the results.

It is appropriate to speculate on why these results are much stronger than those reported in Magat et al. (1988). The earlier study produced similar aggregate values, but the covariates with water quality value were largely insignificant, and a scope test was not even attempted. The Magat et al (1988) study had less than half the number of respondents, but the main differences are methodological. In the current study, greater effort was placed on preparing the respondent to make the trade-off between water quality and cost of living. Three warm up questions involving dominated choices provided easy ways to understand the choice task, and for the relatively low percent of respondents who ‘failed’ those questions, provided a way to communicate the importance of their answers.

Working with a panel had several advantages. First, since our survey design involved the use of a computer-based sample, the Knowledge Networks panel yielded a more representative sample of survey participants than other survey methods such as those used by Magat et al. (2000) in which a group of subjects contacted by phone came to a central location to take the survey. Second, respondents in the panel are accustomed to taking surveys, so they are not confused by the process. Third, and most important, because there are data on those who declined to take the survey, it is possible to estimate the impact of that self-selection on our results. In this case, that self-selection had minimal effect on our estimates. However, that result strictly applies only to our focal question about the value of water quality. The real value of panels is that they contain the information that permits an assessment of the impact of respondent selection mechanism that will certainly be an even greater problem in the future.

The practical benefit of these results is that they provide unit water quality benefit values that can be matched to existing EPA measures of water quality to provide an assessment of benefits of water quality programs. Good water quality has a unit value of $23 per percentage point increase in water quality. This value is dependent on variables such as income, education, and personal use of lakes and rivers in the expected fashion. To value water quality improvements, one can use these values in conjunction with results that break down the benefits in terms of benefits for the components of water quality—fishing, swimming, and health of the aquatic environment— to gauge the economic benefit of an improvement project to the affected local population.

References

Berkman, Richard and W. Kip Viscusi. (1973). *Damming the West*. New York: Grossman Publishers.

Berrens, Robert P., Alok K. Bohara, Hank C. Jenkins-Smith, Carol L. Silva, and David L. Weimer. (2004). "Information and Effort in Contingent Valuation Surveys: Application to Global Climate Change Using National Internet Samples," *Journal of Environmental Economics and Management*, 47(2), 331-363.

Bishop, Richard C. and Michael P. Welsh. (1992). "Existence Values in Benefit-Cost Analysis and Damage Assessment," *Land Economics*, 68(4), 405-417.

Bishop, Richard C. and Thomas A. Heberlein. (1990). "The Contingent Valuation Method." In Rebecca L. Johnson and Gary V. Johnson (eds.), *Economic Valuation of Natural Resources: Issues, Theory, and Applications.* Social Behavior and Natural Resources Series. Boulder: Westview Press.

Cameron, Trudy, and Jeffrey Englin. (1997). "Respondent Experience and Contingent Valuation of Environmental Goods," *Journal of Environmental Economics and Management*, 33(3), 296-313.

Carson, Richard T. and Mitchell, Robert Cameron. (1993). "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Quality Water," *Water Resources Research*, 29(7), 2445-2454.

DeShazo, J.R., and German Fermo. (2002). "Designing Choice Sets for Stated Preference Methods: The Effects of Complexity on Choice Consistency," *Journal of Environmental Economics and Management*, 44(1), 123-143.

DeShazo, J.R., and Trudy Cameron. (2004). “Moving Beyond the Value of a Statistical Life: A New Theoretical and Empirical Analysis.” Paper presented at 2004 AEA meetings.

Fischhoff, Baruch and Lita Furby. (1988). “Measuring Values: A Conceptual Framework for Interpreting Transactions with Special Reference to Contingent Valuation of Visibility,” *Journal of Risk and Uncertainty*, 1(2), 147-184.

Grice, H.P. (1975) “Logic and Conversation” In PCole and J.P. Forgas (eds.) *Syntax and Semantics: 3. Speech Acts (*p. 41-58*),* New York, Academic Press.

Huber, Joel, W. Kip Viscusi, and Jason B. Bell. (2004). “Coping with the Contingency of Valuation: Range and Anchoring Effects in Choice Valuation Experiments,” Working Paper, Fuqua School of Business, Duke University.

Kahneman, Daniel and Amos Tveski (1979) “Prospect Theory: An Analysis of Decision under Risk,” *Econometrica, 47*, 263-291.

Krupnick, Alan, Anna Alberini, Maureen Cropper, Nathalie Simon, Bernie O’Brien, Ron Goeree, and Martin Heintzelman. (2002). “Age, Health and Willingness to Pay for Mortality Risk Reductions: A Contingent Valuation Survey of Ontario Residents,” *Journal of Risk and Uncertainty*, 24(2), 161-186.

Magat, Wesley A., Joel Huber, W. Kip Viscusi, and Jason Bell. (2000). “An Iterative Choice Approach to Valuing Clean Lakes, Rivers and Streams.” *Journal of Risk and Uncertainty*, 21:1, 7-43.

Magat, Wesley A., W. Kip Viscusi, and Joel Huber. (1988). “Paired Comparison and Contingent Valuation Approaches to Morbidity Risk Valuation,” *Journal of Environmental Economics and Management*, 15, 395-411.

Mitchell, Robert Cameron and Richard T. Carson. (1989). *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington: Resources for the Future.

Schkade, David A. and John W. Payne. (1993). "Where Do the Numbers Come from? How People Respond to Contingent Valuation Questions." In Jerry A. Hausman (ed.), *Contingent Valuation: A Critical Assessment*. New York: North-Holland, 271-293.

Smith, V. Kerry, and William H. Desvousges. (1986). *Measuring Water Quality Benefits*. Boston: Kluwer Academic Publishers.

Smith, V. Kerry, and Laura L. Osborne. (1996). "Do Contingent Valuation Estimates Pass a 'Scope' Test? A Meta-Analysis," *Journal of Environmental Economics and Management*, 31(3), 287-301.

United States Environmental Protection Agency. (1994). *National Water Quality Inventory, 1992 Report to Congress*, EPA 841-R-94-001.

Figure 1
Sample Private Water Quality Benefit Question

We would like to ask you some more questions like these. However, in these questions, one region will have a lower annual cost of living and the other will have higher water quality. **Remember that the national average for water quality is 65% Good.**			
	Region 1	Region 2	
Increase in Annual Cost Of Living	**$100** More Expensive	**$300** More Expensive	
Percent of Lake Acres and River Miles With Good Water Quality	**40%** Good Water Quality	**60%** Good Water Quality	
Which Region Would you Prefer?	Region 1 *	Region 2 *	No Preference *

Figure 2
Survey Decision Tree

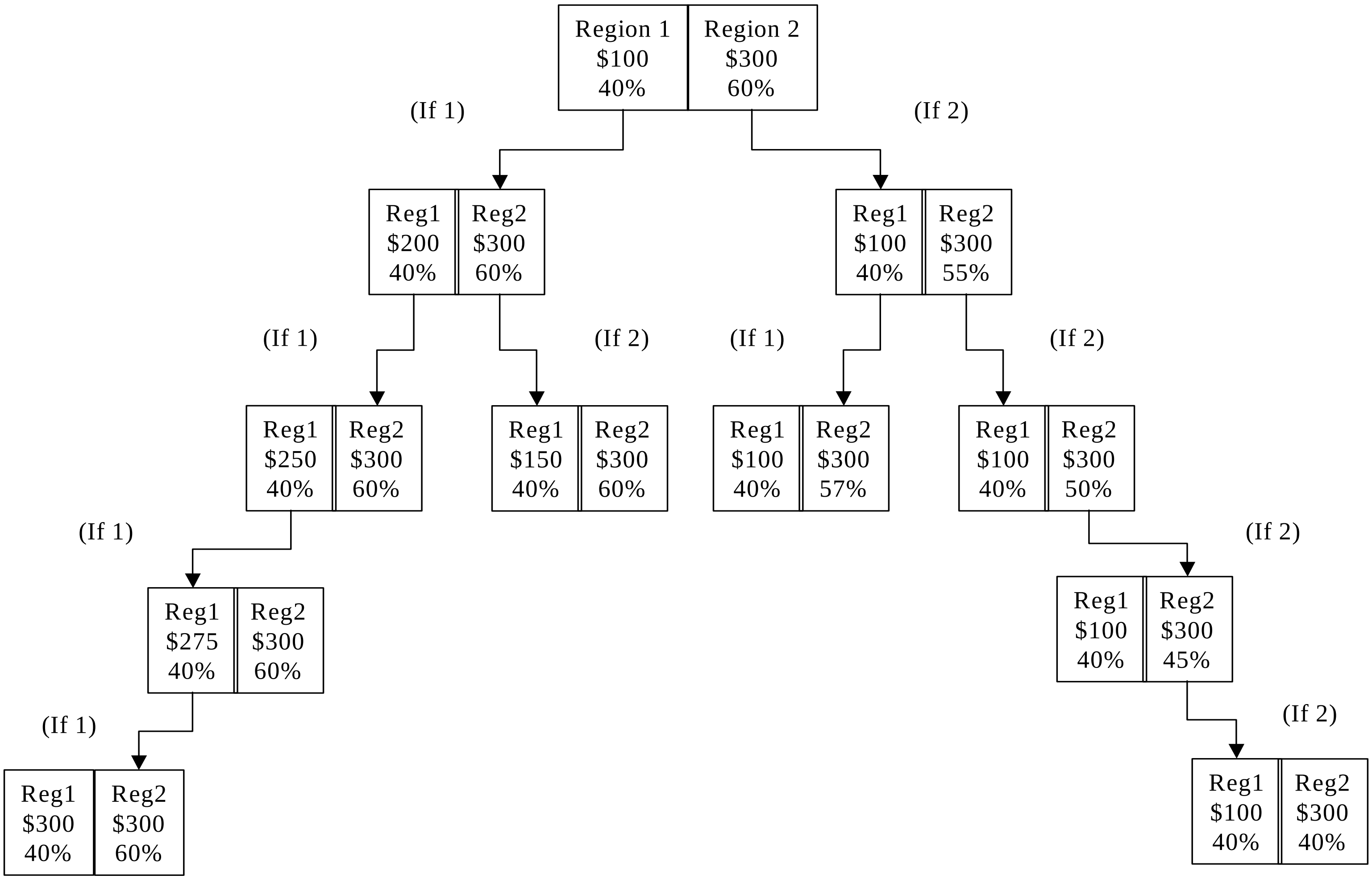


Table 1
Regression Estimates for Log of Unit Water Quality Benefit Value

	Log (Unit Value for Good Water Quality)			
	OLS		Censored	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Log (Income)	0.1668***	0.0480	0.1687***	0.0484
Years of education	0.0409***	0.0151	0.0423***	0.0153
Age	0.0115***	0.0023	0.0119***	0.0023
Environmental organization membership	0.2843	0.1734	0.3140*	0.1773
Visited a lake or river, last 12 months	0.2822***	0.0778	0.2839***	0.0784
Told national water quality	0.0966	0.0728	0.0955	0.0734
Race: Black	-0.1403	0.1109	-0.1404	0.1117
Race: Non-black, Non-white	-0.0661	0.1637	-0.0844	0.1642
Hispanic	0.1415	0.1223	0.1325	0.1232
Gender: Female	0.0166	0.0727	0.0169	0.0733
Household size	-0.0093	0.0291	-0.0099	0.0293
Region: Northeast	-0.0271	0.1126	-0.0333	0.1134
Region: South	-0.0765	0.0955	-0.0814	0.0962
Region: West	-0.0997	0.1096	-0.0980	0.1107
Intercept	-0.4646	0.5243	-0.5031	0.5282
Adjusted R^2	0.0614		0.0251	

Notes: * significant at the .10 level, ** significant at the .05 level, *** significant at the .01 level, all two-tailed tests.

Table 2
Scope Test: Demonstrating the Impact of
Water Quality and Cost of Living Range on Initial Choice

	Respondent Chose the Higher Water Quality Region in First Choice	
Variable	Coefficient	Standard Error
Logistic Regression		
Initial Cost of Living Range	-0.00161**	0.00072
Initial Water Quality Range	0.0180**	0.00751
Log (Income)	0.2904***	0.0847
Years of education	0.0620**	0.0269
Age	0.0196***	0.00404
Environmental organization membership	0.6427**	0.3420
Visited a lake or river, last 12 months	0.4445***	0.1357
Told national water quality	0.0642	0.1338
Race: Black	-0.0249	0.1933
Race: Non-black, Non-white	-0.1145	0.2846
Hispanic	0.2827	0.2154
Gender: Female	0.0574	0.1277
Household size	-0.0543	0.0508
Region: Northeast	0.0322	0.1999
Region: South	-0.1125	0.1679
Region: West	-0.1526	0.1927
Intercept	-4.6635***	0.9745
	c = 0.654	

Notes: * significant at the .10 level, ** significant at the .05 level, *** significant at the .01 level, all two-tailed tests.

Table 3
Comparison of Knowledge Networks Sample to the National Adult Population[1]

Demographic Variable	Survey Participants Percent	US Adult Population Percent
Employment Status (16 years or older)		
Employed	65.1	66.9
Age		
18-24	13.1	13.0
25-34	19.1	18.8
35-44	20.2	21.2
45-54	19.1	18.5
55-64	12.2	11.9
64-74	11.0*	8.6
75+	5.4*	7.9
Educational Attainment		
Less than HS	17.0	15.9
HS Diploma or higher	60.0	58.5
Bachelor or higher	23.0*	25.6
Race / Ethnicity		
White	81.5	82.3
Black/African-American	13.1	11.8
American Indian or Alaska Native	1.0	0.9
Asian/Pacific Islander	3.1*	4.1
Other	1.3	1.0
Race / Ethnicity of Household		
Hispanic	11.1	11.4
Gender		
Male	51.0	48.3
Female	49.0	51.7
Marital Status (2000)		
Married	61.4	59.5
Single (never married)	23.5	23.9
Divorced	9.0	9.8
Widowed	4.1*	6.8
Household Income (2000)		
Less than $15,000	13.2*	16.0
$15,000 to $24,999	11.3	13.4

$25,000 to $34,999	13.4	12.5
$35,000 to $49,999	18.9*	15.5
$50,000 to $74,999	21.1*	18.9
$75,000 or more	22.2	23.8

Statistical Abstract of the United States, 2002. 2001 adult population (18 years+), unless otherwise noted.
* The 95% Confidence Interval for survey participants does not include mean adult US population for this demographic variable.

Table 4
Validity Tests Based on Censored Regression of Log of Unit Water Quality Benefit Values

	Log (Unit Value for Good Water Quality)			
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Log (Income)	0.1710***	0.0487	--	--
Years of education	0.0421***	0.0153	--	--
Age	0.0119***	0.0024	--	--
Environmental organization membership	0.3165*	0.1776	--	--
Visited a lake or river, last 12 months	0.2787***	0.0787	--	--
Told national water quality	0.0966	0.0736	--	--
Race: Black	-0.1362	0.1129	--	--
Race: Non-black, Non-white	-0.0876	0.1643	--	--
Hispanic	0.1326	0.1237	--	--
Gender: Female	0.0150	0.0734	--	--
Household size	-0.0086	0.0295	--	--
Region: Northeast	-0.0381	0.11406	--	--
Region: South	-0.0873	0.0971	--	--
Region: West	-0.1024	0.1119	--	--
Respondent stopped and continued survey later	-0.006	0.1467	0.0233	0.1517
Time as panel member, in months	-0.0021	0.0032	0.0023	0.0032
Days from invitation to completion	-0.0013	0.0023	-0.0039	0.0024
Has panel member quit panel	-0.0131	0.0789	-0.1006	0.0803
Intercept	-0.4561	0.5326	2.5538***	0.0950
Adjusted R^2	0.0254		0.0017	

Notes: * significant at the .10 level, ** significant at the .05 level, *** significant at the .01 level, all two-tailed tests.

Table 5
Log Unit Water Quality Value Regression Results Controlling for Selection Effects

Variable	Coefficient	Standard Error
Regression Model for Log of Value		
Log (Income)	0.1701***	0.0480
Years of education	0.0447***	0.0150
Age	0.0122***	0.0023
Race: Black	-0.2391**	0.1119
Race: Non-black, Non-white	-0.0919	0.1637
Hispanic	0.0446	0.1241
Gender: Female	0.0106	0.0727
Household size	-0.0195	0.0303
Region: Northeast	-0.0561	0.1124
Region: South	-0.1059	0.0951
Region: West	-0.1297	0.1094
Intercept	-0.3666	0.5243
Participation Equation		
High Stress level	-0.1929***	0.0749
Stress Data Unavailable	-1.4668***	0.1133
Race: Black	-0.2364**	0.0968
Hispanic	-0.3511***	0.1013
Household size	-0.1178***	0.0246
Intercept	1.2453***	0.0930

LR test of indep. eqns. (rho = 0): chi2(1) = 2.46 Prob > chi2 = 0.1164

Notes: * significant at the .10 level, ** significant at the .05 level, *** significant at the .01 level, all two-tailed tests.

A Consistent Framework for Valuation of Wetland Ecosystem Services Using Discrete Choice Methods

J. Walter Milon,* David Scrogin* and John F. Weishampel**

*Department of Economics, **Department of Biology and Geospatial Analysis & Modeling of Ecological Systems Lab
University of Central Florida
Orlando, FL

Goal and Approach

- The overall goal is to develop and test a consistent framework to estimate wetland services values.
- Our approach uses a joint modeling strategy to integrate revealed preferences (RP) from a discrete choice model of the housing market and stated preferences (SP) from a choice model for wetland ecosystem services.
- The analysis will be based on a comprehensive database from a stratified sample of residential property owners in three Metropolitan Statistical Areas (MSAs) in Central Florida.

Objectives

- 1) To estimate the demand for proximity to wetlands and other water resources using discrete choice and hedonic pricing models of residential property values.
- 2) To estimate the demand for ecosystem services from different types of wetlands that are not in proximity to residential property using a stated choice survey.
- 3) To develop and test a combined discrete choice model from the RP and SP data to produce a general valuation function for wetland ecosystem services.
- 4) To estimate the implicit prices of wetland services in mitigation banking markets.

Conceptual Framework

- Assume that housing and environmental protection are separable so an individual *n* maximizes the utility function:

  $U_n(X,Z;S)$

  subject to $M = P_X X + P_Z Z$

  where U is utility, X is a vector of housing attributes, Z is a vector of environmental services associated with wetland resources, S is a vector of observed individual characteristics, M is income, P_X is a vector of prices for housing attributes and P_Z is a vector of prices for environmental services.

- Wetland services are public goods so P_Z must be revealed through direct elicitation but some services may be packaged with housing units.

Conceptual Framework: Housing

- Discrete housing choice model:

  $$U_n = V_n\,(X_{A1}\,,\, X_{A2}\,,\, \ldots\,,\, X_{Al}\,,\, P_A) + \varepsilon_n$$

  where A_l represents attributes of the A^{th} alternative housing bundle from the choice set K.
- The probability that individual *n* chooses housing unit *A* is given by:

  $$\pi_{\mathrm{An}} = exp\,(\lambda^1 V_{An}) \,/\, \textstyle\sum_{B\in K} exp\,(\lambda^1 V_{Bn})$$

  where λ^1 is a scale parameter.

Conceptual Framework: Ecosystem

- Discrete stated choice model:

  $$U_n = V_n(Z_{C1}\,,\, Z_{C2}\,,\, \ldots\,,\, Z_{Cl}\,,\, P_C)$$

  where the C_l attributes represent specific wetland services such as size, type, habitat quality, and groundwater recharge and P_C is a cost associated with the C^{th} wetland alternative from choice set *E*.
- The probability that individual *n* chooses wetland services package *C* is given by:

  $$\pi_{\mathrm{Cn}} = exp\,(\lambda^2 V_{Cn}) \,/\, \textstyle\sum_{D\in E} exp\,(\lambda^2 V_{Dn})$$

  where λ^2 is a scale parameter.

Consistency Tests

- To empirically investigate the consistency of the housing and wetland services choices, we employ the likelihood ratio test:

  $$-2[(L^{A} + L^{C}) - L^{Joint}].$$

- Other tests will be used to evaluate the effects of treatments used in the stated choice experiments.

Treatment Effects

- Evaluate the effects of information on preferences and task complexity using a 3 x 2 block design. We contrast choice task complexity, choices involving partial sets of wetland attributes *vs* choices involving a full set of attributes, with the format for the provision of information, text description *vs* spatial description. Motivation for full/partial attribute design is the legal context for determining mitigation.

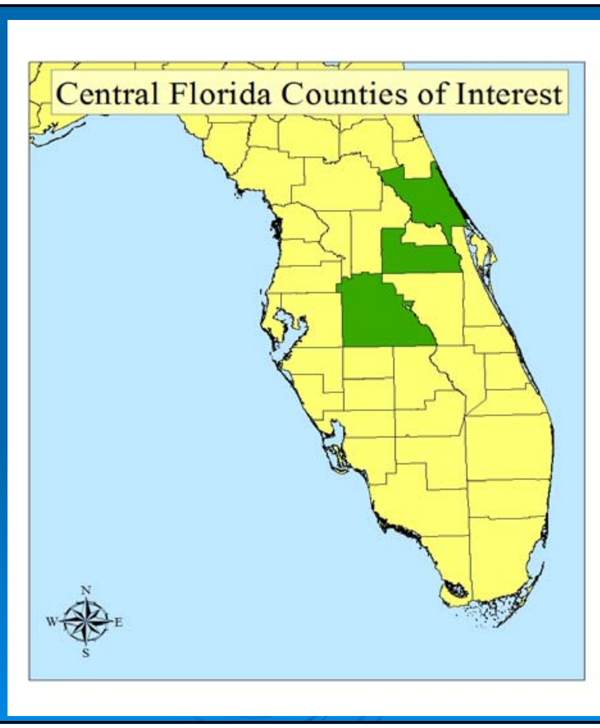
	Spatial Description	Text Description
Full Attributes		
Partial Attributes A		
Partial Attributes B		

Application

- Single family residential housing data will be collected from county tax appraisers in three Metropolitan Statistical Areas (MSAs) in Central Florida: Daytona Beach, Lakeland-Winter Haven and Orlando representing over 2.6 million people.
- From housing sales during the 2002 – 2004 period, develop a proportionally weighted sample of 1200 purchasers across the three MSAs.
- The sample of 1200 housing buyers will be contacted to participate in the stated choice wetlands survey. We anticipate a 50 percent response rate (600 property owners) to participate in interview surveys that will be conducted at a central location within each MSA.

Application

- GIS analysis will be used to identify the neighborhood and ecosystem attributes associated with each housing parcel.
- For the stated choice analysis, select a stratified random sample of wetland sites based on three stratification criteria: type of freshwater wetland, site acreage, and whether the wetland is connected to or isolated from surface waters. Sites will be from the land area containing the 3 MSAs.
- Each site selected will be profiled using GIS analysis to identify attributes of the site; these profiles will be 'ground-truthed' with site visits and additional information from wetland specialists in regional and state environmental agencies.

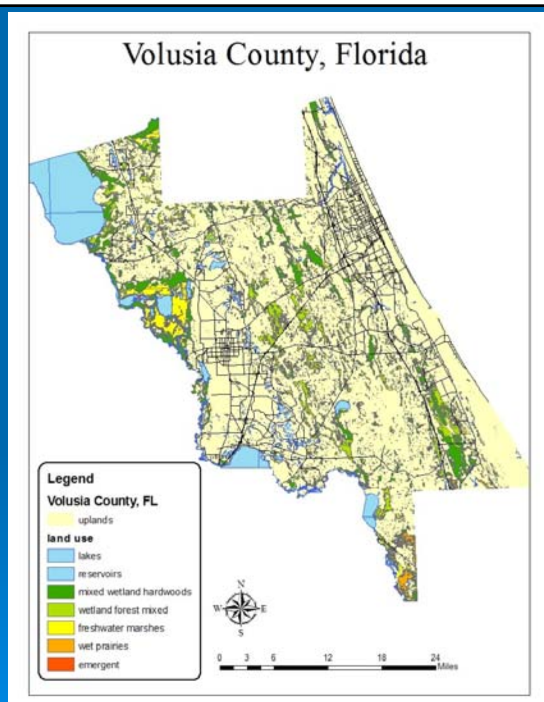


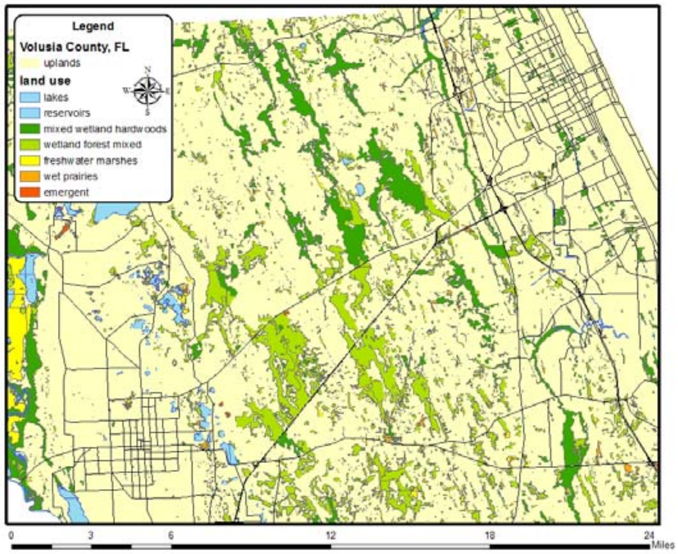
Land Use Coverage

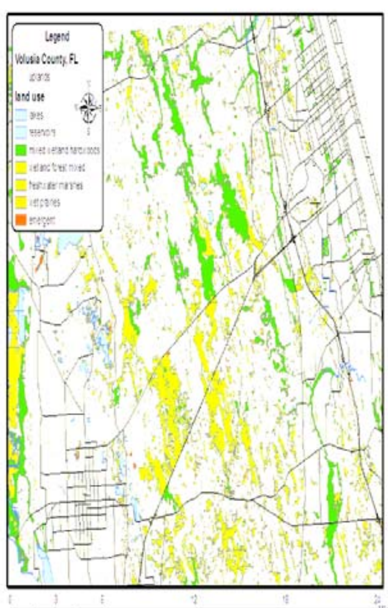
LAND USE	Percent Cover		
	Orange	Polk	Volusia
URBAN & BUILT-UP	17.3%	33.2%	12.3%
AGRICULTURE	9.1%	31.8%	6.0%
RANGELAND	5.7%	5.7%	4.1%
UPLAND FOREST	6.2%	5.8%	23.3%
WATER	21.1%	4.6%	19.4%
WETLANDS	36.8%	17.9%	33.3%
BARREN LAND	1.6%	0.1%	0.3%
TRANS & UTIL	2.2%	0.8%	1.2%

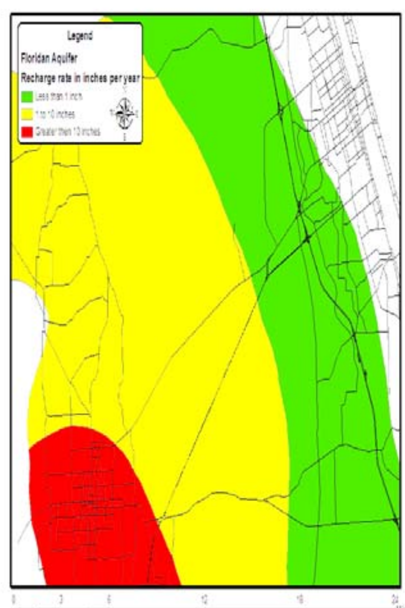
Wetland Coverage

WETLAND TYPES	Percent Cover		
	Orange	Polk	Volusia
Mixed Hardwoods	17.2%	43.5%	37.2%
Mixed Cypress/Forest	14.8%	35.2%	39.0%
Freshwater Marshes	62.5%	16.2%	9.8%
Wet Prairies	1.2%	3.9%	3.1%
Emergent Vegetation	4.2%	1.1%	10.8%




Legend
Volusia County, FL
uplands
land use
lakes
reservoirs
mixed wetland hardwoods
wetland forest mixed
freshwater marshes
wet prairies
emergent
0
3
6
12
18
24
Miles


Legend
Volusia County, FL
land use


Legend
Floridan Aquifer
Recharge rate in inches per year

Comments on:

Valuation of Natural Resource Improvements in the Adirondacks
Spencer Banzhaf, Dallas Burtraw, David Evans and Alan Krupnick

and

The Value of regional Water Quality Improvements
Kip Viscusi, Jason Bell and Joel Huber

By:

Kevin J. Boyle
Distinguished Maine professor
University of Maine

October 26, 2004

Introduction

These two papers make a nice comparison of applied studies on the benefits of improved surface water quality. My comments will address several key features in the design and implementation of stated-preference studies. I will discuss how each study addressed these specific design issues. The studies hereafter will be referred to as the Banzhaf and Viscusi studies, respectively.

Geographic Scope of Application

The Banzhaf study focuses on a specific region, the Adirondacks in New York, while the Viscusi study is designed to develop a national water quality value. These applications represent the two extremes of the spectrum in applied valuation studies. Regional studies for a specific application allow the design of precise and specific valuation scenarios, which most practitioners, I believe, would agree lead to better estimates of value in terms of validity and reliability. National value estimates are needed by U.S. EPA for RIAs of national policies. The question in my mind is whether the Viscusi study in the quest for a national value for policy results in value estimates that have very little empirical credibility. On the other hand, the Banzhaf value estimate has little relevance for national policy.

In other words, the Banzhaf says something very specific about benefits of a particular policy in a specific area, but has little to offer for national policy. The Viscusi study purports to comment on a general policy, but has little to say about any specific policy or regional application. Both types of value are needed. EPA does need estimates of value to address national policy initiatives. In application of policy EPA leaves states and/or regions with considerable latitude regarding how policies will be implemented. A national policy may overestimate or underestimate regional benefits, and more refined value estimates are needed to consider how and to what extent a policy should be implemented in a specific region.

The revealed-preference studies presented earlier in this session, Egan et al. and Smith et al., present a promising approach to addressing this dichotomy of policy needs that improves on the approaches in the Banzhaf and Viscusi studies. The Egan and Smith studies use aquatic ecosystem attributes that define the quality of anthropocentric uses. This type of attribute design provides flexibility in the computation of value estimates for national policy and for regional variations in the implementation of a national policy. Moreover, the results from these types of revealed preference studies could be used to design choice studies similar to the Viscusi study that would provide more credible estimates of value for both national and regional benefit calculations.

What is Being Valued?

This issue is related to my discussion above. The Banzhaf study substantially attempted to link the valuation scenario to bio-physical information on the quality change that would arise from a policy to improve surface water. However, the actual link is not as clear as it could be. Two suggestions arise here. First, a clearer link could be developed by a more formal presentation of an economic model that links the policy change to the design of the valuation scenario, to data analyses, and to interpretation of the statistical estimates. Second, as noted above, an attribute-based design of the scenario would have made the bio-physical link clear in the valuation questions and would have made it explicit in the econometric model used to analyze the valuation responses. This would not only have improved the value estimates for application sin the Adirondacks, but would have improved the transferability of the values estimates to other regions or for use in national p[policy.

The Viscusi study valued “good” water quality. Admittedly these investigators were constrained by EPA’s decision to defined water quality categories. However, given the experience of this research team one might expect a more creative design that might allow for the estimation of more credible estimates of value while developing a mapping that would allow the value estimates to be applied to EPA’s categories for policy analyses.

If I take the title of this workshop literally, “*Improving the Valuation of Ecological Benefits,*” then it seems imperative that EPA consider the support of developing more complex valuation approaches and empirical applications the link policy effects on ecosystem services to changes in economic value. As stated, in the preceding section, the Egan and Smith studies are a substantial step in this direction for revealed-preference applications, which have important implications for the design of stated-preference studies.

Framing of the Valuation Question

I think it is appropriate that both studies used a total economic value approach to estimate values. I think the value estimated in the Banzhaf study is clear and could be improve with a more explicit model that is carried though the empirical analysis.

The Viscusi study used a unique in interesting experimental choice to elicit values; the choice of a move to a new area. I have two concerns. First, respondents were not given a chance to say that they would not move, i.e., they are not in the market. Second, I do not know what economic concept of value they estimated. Some of the use value captured in a hedonic model would be included, and perhaps some recreation value of being closer to higher quality water bodies. I think that some nonuse value might be captured through the use of a higher cost of living as the payment vehicle. It does not appear that this framing of the valuation question captured all of respondents' recreation and nonuse values. This leaves the question of how much of national benefits are captured in the Viscusi study and how can other values estimated be included in the calculation of aggregate benefits without encountering substantial double-counting problems.

Internet Surveys

Both studies used an internet survey mode and investigated aspects of the validity of this mode, which is appropriate given the convenience and expanding use of internet surveys. The finding by Banzhaf that there is no difference between the value estimate between an internet survey and a mail survey is an important contribution to the literature.

The Viscusi study considered other the effects on aspects of respondents' actual participation in the internet survey on value estimates. No statistically-significant effects were identified, but the internet response features considered appear to be exogenous to valuation responses and it is not surprising that not significant effects were identified. I think it would be more interesting to consider data on time spent reading the valuation scenario and answering the choice questions, which may be more likely to be indicative of the difficulty of the exercise and effort that respondents invested in answering the valuation questions. Having said this, it is still good that the Viscusi study took these other internet survey response features off the list of concerns for future studies.

Educating Respondents

Both studies indicated that time was taken in the administration of the survey to educate respondents who had difficulty with the valuation tasks. Neither study fully documented what was done to educate respondents and how this influenced value estimates. This leaves a number of questions in my mind. Did these efforts keep people in the sample that might otherwise not have completed the survey? Did these efforts make these people statistically similar to other respondents in terms of their valuation responses? If valuation responses do differ, how so?

Econometric Analysis

Both studies are disappointing in their econometric analysis. Neither study has an empirical specification that is linked to a theoretical model, nor both studies have specifications that are not consistent with utility, e.g., including both bid amounts and income as separate linear arguments.

Tests of scope in both studies focused on valuation responses that include both use and nonuse values. I think the literature is clear that stated preference studies demonstrate scope for use values, while the real issue is in the estimation of nonuse values. The question is whether the use value component of the value estimate is driving the confirmation of scope in both studies. The Banzhaf study has the potential to address this issue by segmenting the sample to those who are not users and testing this group of responses for sensitivity to scope.

Usefulness of Value Estimates for Policy

The effects of public policy on aquatic ecosystems are highly uncertain. Both studies assumed this uncertainty away in the design of their studies. The Banzhaf study claimed to address uncertainty by using two scenarios. This split design does not address uncertainty as it simply give values for to different policy outcomes. Valuation studies that effectively value aquatic ecosystems need to include stronger links to ecosystem attributes in the design of valuation scenarios, and explicitly include physical and biological uncertainties into the scenario designs.

Summary of the Q&A Discussion Following Session III (Part 2)

Bill Mates (New Jersey Department of Environmental Protection)
Saying that he was not an economist or statistician but "might be in the position of *hiring* an economist or statistician," Mr. Mates addressed the three presenters: "*All* of your approaches are very well done and very persuasive, but the question I would like to ask each of you is "Where do you think your *own* approach is the best, and where might you be willing to admit that one of the other two approaches was superior?" In other words, what circumstances would lead to one approach versus another?"

Walter Milon (University of Central Florida)
Dr. Milon responded, "Well, if I'm in EPA's Office of Water, I would probably love Joel's [Huber] work, and I suspect that's, hopefully, what the fundamental orientation is. If I'm at the state level and I'm worried about wetland conversion decisions and policy choices about how we set up conversion ratios, public buyout programs, the set of ecosystem services that we would want to protect for the public, then I think we need the more detailed information. As laborious as it may be, I think you have to go that route. I personally think, as was said here earlier, you need to tailor the methods to the specific policy question."

Spencer Banzhaf (Resources for the Future)
Dr. Banzhaf said, "I would say something similar, or at least something that" gets back to the point made at "the beginning of these comments, which is the tradeoff between saying a lot about nothing versus saying a little bit about everything. That's really the tradeoff, so if it's a very specific policy question that one has *or* if shedding light on one specific region is enough to address the question, then that would be the way to go, but if you went . . . big . . . you could answer a host of questions."

Joel Huber (Duke University)
Dr. Huber added, "Basically, many of these signals are political ones, and for that we need the details. As an analogy, some of us *do* vote for President on the basis of what our party is, but most of us think about the individuals, and to assume that people do otherwise would be wrong. So, at best, the approach that we have is a good first pass, but it abstracts from *everything* that most of us hold *dear*, so in *no* sense am I saying this is true. The utilities are a fiction anyway, but ours are *true* fictions---theirs are *partial* fictions." (laughter)

Nancy Bockstael (University of Maryland)
Addressing her comment to Joel Huber, Dr. Bockstael asked, "Did you at any point try to get at, through focus groups or anything else, what people are thinking when they're answering these questions? I ask that because I can imagine that people—well, neither cost of living nor environmental quality drops from the sky. Presumably, people (some people, at least) think about a process by which some areas become higher in

environmental quality, some areas become higher in cost of living or whatever. Are they reading more into these questions and voting for more than they might get?

Joel Huber
Dr. Huber replied, "Right—there's the tendency to try to sort of make sense of it. The reason I actually asked you all to make the choice was it's about as deep as that—and you found you *could* make the choice, and if it were a real choice, could you make it?—yes, you probably could. Would you make the same choice every time?—no, probably not. Are you affected by anything around you?—yes. And then the question *we* asked: Is there any stability to what comes out?—and the answer is yes. *That* was the hard part, and it took a number of years to get it right. So, there's not *much* there—but it's enough.

Nancy Bockstael
Dr. Bockstael countered, "I have to ask: Is stability a good thing here? I don't know."

Joel Huber
Dr. Huber expounded, "Well, let me go back to the political issue. Part of the reason we have this is because we *need* to value things, and the solution I give is not a great solution, which is start with 50/50, but it does solve the problem of stopping anyone from entering bias into the mix. I'm a researcher—I can make the thing *very* biased—and this stops that, eliminates that."

Kerry Smith (North Carolina State University)
Dr. Smith said, "One of the issues that separates, invariably, economists and ecologists when they try to look at problems is that ecologists typically apply the risk at a spatial dimension. They're always *grounded* in a location and the characteristics of that location and a configuration, as Geof (Heal) said, of services that come as a consequence of those characteristics and resources and so forth. One of the advantages of your approach, Joel (Huber), from the perspective of the EPA's Office of Water, is that it *isn't* that way—it's much more compatible with the way in which economists like to think of things—away from space, away from locations, and you can *abstract* from all of that and get to a market, even though you don't define where it is. Do you see in the experience that you've had any *hope* that we could get to the point where we could do that with ecological services? I'm not sure, so I'm wondering—based on your experience not only in *this* study but in other studies, is that something we should aspire to" or not?

Joel Huber
Dr. Huber responded, ". . . the value for life, which we use. It's a number, and there's been some agreement on it, and it's very useful. Is it *the* value for life?—absolutely not. Does it apply to each person?—absolutely not. Is it useful for policy?—yes. Policy is way worse off if they don't have *some* number. What bothers me, and the reason I'm willing to put in as much as we put into this is: You've *got* to have a consistent number out there if you want to do consistent policy. And the number is pretty good. It's not

truth, but it's pretty good, and it's stable, and it will resist other people trying to say: Let's try a different way of getting at it. So, in that sense, it's a reasonable way to deal with this. But, for *most* cases, it would be a first pass, or if you have to do it quickly, you could use it."

Spencer Banzhaf

Dr. Banzhaf stated, "One of the other tradeoffs between the specific versus the generic approaches is what people are bringing to the task if it's a stated preference model. Things really are embedded in nature in various places. . . . In our case, it really is true in the Adirondacks that if you change water quality, you're going to change some other parts of the ecosystem, so these things really *are* embedded. We found that if we left that *out* and people were educated too well in high school, they embedded it themselves. We could, in some ways, make a concession to that, since it was really true, and it's actually easier to value a multiple than to try to divide things up and separate them piece by piece. What you lose when you go to the *generic* approach is the ability to control for that . . ."

Stephen Swallow (University of Rhode Island)

Responding first to Dr. Bockstael's statement about "whether environmental quality drops out of the sky," Dr. Swallow asserted, "In the Adirondacks, it does." (laughter) He continued, "Actually, I like the validity of the checks you did on the plausibility of that, but it still disturbs me that you're saying it's an unrealistic policy . . . On one hand I'm willing to go for that as a practical matter of the dirty work of policy analysis. On the other hand, I wonder if we could explore it even further, although you explored it pretty well."

Addressing a different issue, Dr. Swallow said, "This morning Nancy (Bockstael) said a whole lot of things that were absolutely right about the income point and evaluating . . .being careful about . . . welfare analysis." He said he was "encouraged with the sessions today to see that we're *not* getting caught entirely in what could become intellectual paralysis. We *need* to get some answers, and maybe *some* number is better than *no* number, and sometimes you need to check and be careful about what that number is. I like what Joel's doing because it *is* a step forward on what's really a dirty problem—when you get into policy" on an international scale or on a small, local scale, "you find out that when they get some information from several of these approaches, there's a lot of value to that information . . . "

"My final comment is that we've talked a bunch today about production functions and linking production functions, and I think that we've forgotten one type of production function . . . household production. Looking back at Joe Herriges' presentation on the Iowa lake water quality, I think that the trip behavior that people were exhibiting would have accounted for how the lakes interact with their household production. But, I wonder whether in some of the stated preference studies we focus a little too heavily on the production from the ecology side of “How do we get from water quality to recreation days?” Yet, there’s still the respondent who has his or her own production function that we haven’t necessarily tried to start to quantify.”

END OF SESSION III (Part 2) Q&A

Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

PROCEEDINGS OF

SESSION IV: TALES OF OTTERS, EAGLES, AND OWLS: VALUING WILDLIFE HEALTH AND BIODIVERSITY

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

October 26-27, 2004
Wyndham Washington Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Cynthia Morgan and the Project Officer, Ronald Wiley, for their guidance and assistance throughout this project.

DISCLAIMER

These proceedings are being distributed in the interest of increasing public understanding and knowledge of the issues discussed at the workshop and have been prepared independently of the workshop. Although the proceedings have been funded in part by the United States Environmental Protection Agency under Contract No. 68-W-01-055 to Alpha-Gamma Technologies, Inc., the contents of this document may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

TABLE OF CONTENTS

Contingent Valuation for Ecological and Noncancer Effects within an Integrated Human Health and Ecological Risk Assessment Model

James Hammitt and Katherine von Stackelberg
Harvard Center for Risk Analysis, 718 Huntington Avenue, Boston, MA 02115

Objectives:

The objective of this research is to contribute to the understanding of practical and credible approaches for estimating the benefits and costs of environmental policies and to improve decisionmaking regarding environmental issues. Our approach is to develop an integrated human health and ecological risk model using data from a case study, which also incorporates economic information from two contingent valuation surveys. The case study focuses on potential human health and ecological receptor exposure to polychlorinated biphenyl (PCB) compounds via fish ingestion. The risk model integrates the results of two contingent valuation (CV) surveys to quantify the benefit of potential risk reductions under assumed exposure conditions using a publicly available database. The integrated model uses the results of a web-based contingent valuation questionnaire to estimate willingness-to-pay of the general public to reduce potential risks associated with exposure to PCBs. These risks include reproductive effects in birds and mammals and developmental effects in children exposed *in utero*. The integrated risk model can be used to evaluate the economic role ecological and noncancer human health outcomes play under specific exposure conditions. The contingent valuation surveys are designed to inform the growing literature on the value individuals place on the ecological and noncancer benefits of risk reductions.

During the past year, we focused on working through methodological issues related to survey development. We also conducted an extensive literature search and evaluated this literature on the potential effects of exposure to PCBs in order to develop dose response models for developmental noncancer effects in humans and reproductive effects to ecological receptors. These dose response models provide the basis for the relevant endpoints used in survey development. Finally, we developed an Excel-based two-dimensional Monte Carlo modeling framework to predict dietary exposures to human and ecological receptors. We integrated the dietary exposure model with the dose response models to obtain probabilistic estimates of potential risks.

Potential Effects of PCBs

We have conducted an extensive literature search on the potential effects of PCBs in both humans and animals, focusing specifically on potential developmental effects in humans and reproductive effects in wildlife. This information is used to develop the specific endpoints for valuation within the CV survey, and to develop dose-response models for the integrated risk assessment.

Ecological Endpoints

Typical responses to PCB exposure in animals include wasting syndrome, hepatotoxicity, immunotoxicity, neurotoxicity, reproductive and developmental effects, gastrointestinal effects, respiratory effects, dermal toxicity, and mutagenic and carcinogenic effects. Some of these effects are manifested through endocrine disruption.

PCBs are typically present in the environment as complex mixtures. These mixtures consist of discrete PCB molecules that are individually referred to as PCB congeners. PCB congeners are often introduced into the environment as commercial mixtures known as Aroclors. PCB toxicity varies significantly among different congeners and is dependent on a number of factors. Two significant factors relate to the chemical structure of the PCB congener, including the degree of chlorination and the position of the chlorines on the biphenyl structure (Safe *et al.* , 1985a). In general, higher chlorine content typically results in higher toxicity, and PCB congeners that are chlorinated in the *ortho* position are typically less toxic than congeners chlorinated in the *meta* and *para* positions. Metabolic activation is believed to be the major process contributing to PCB toxicity.

Reproductive effects tend to be the most sensitive endpoint for animals exposed to PCBs. Indeed, toxicity studies in vertebrates indicate a relationship between PCB exposure, as demonstrated by AHH induction, and functions that are mediated by the endocrine system, such as reproductive success. A possible explanation for the relationship between AHH activity and reproductive success may be due to a potential interference from the P450-dependent MFO with the ability of this class of P450 proteins to regulate sex steroids. In fact, the induction of cytochrome P450 isozymes from PCB exposure has been shown to alter patterns of steroid metabolism (Spies *et al.*, 1990).

Historically, the most common approach for assessing the ecological impact of PCBs has involved estimating exposure and effects in terms of totals or Aroclor mixtures. It is important to note that, since different PCB congeners may be metabolized at different rates through various enzymatic mechanisms, when subjected to processes of environmental degradation and mixing, the identity of Aroclor mixtures is altered (McFarland and Clarke, 1989). Therefore, depending on the extent of breakdown, the environmental composition of PCBs may be significantly different from the original Aroclor mixture. Furthermore, commercial Aroclor mixtures used in laboratory toxicity studies may not represent true environmental exposure to this Aroclor. Thus, there are considerable uncertainties associated with estimating the ecological effects of PCBs in terms of total PCBs or Aroclors.

Ecological risk assessments follow an established framework in which there are assessment and measurement endpoints (EPA, 1993). Assessment endpoints represent that which is being protected, for example, protection and sustainability of wildlife populations. There are one or more measurement endpoints, which are the specific ways in which impacts on the assessment endpoints will be evaluated. For example, one of the associated measurement endpoints for that assessment endpoint might include comparing predicted doses to the selected species with doses from the toxicological literature associated with specific effects. Assessment endpoints are broadly defined while measurements endpoints are the specific analyses that will quantify potential impacts.

There are two distinct ways in which potential impacts to an ecosystem can be evaluated within a risk assessment context. The first focuses the analysis on a single species designed to represent high-end exposure and sensitivity. A set of representative receptors is selected that serve as proxies for the many species that the ecosystem supports. Potential impacts are evaluated by developing dose-response models, generally from laboratory data, to predict outcomes. The very simplest analysis involves developing a toxicity reference value (TRV) against which to compare exposures at the site. This deterministic analysis can be expanded to include a joint probability model that quantifies the probability of an increasing magnitude of effect using the dose-response model for a single species (e.g., reduction in fecundity), or one can model the probability of exceeding a threshold value. Under this representative receptor approach, a valuation for a single "high-profile" species will implicitly value those aspects of the ecosystem that support the species (Loomis and White, 1996). Management actions are designed to reduce risks for the presumed highest risk species. The corresponding valuation asks respondents about their willingness to pay to reduce the probability of an effect on a single species.

The second approach is slightly different. Rather than relying on a single dose-response relationship for one species, the analysis relies on species sensitivity distributions. These distributions quantify the probability of the proportion of species that will be affected (e.g., there is a 20% probability that 80% of the species will experience adverse reproductive effects). Under this approach, the analysis does not focus on one particular species but rather considers the probability of impacting multiple species. Both approaches are used in this analysis (and both kinds of endpoints valued in the survey).

In both cases, the exposure model incorporates a probabilistic bioaccumulation model to describe uptake of PCBs into the aquatic food web based on a model developed for the Hudson River RI/FS (EPA, 2000a; 2000b). Both benthic and pelagic invertebrates, aquatic vegetation and fish are consumed by ecological receptors. Risks are described across an increasing magnitude of effect (e.g., there is a 50% chance of an 80% reduction in fecundity) or across an increasing percentage of species (e.g., there is a 50% chance that 80% of the species will experience adverse reproductive effects).

The individual species of concern in this analysis is the bald eagle *(Haliaeetus leucocephalus*). We selected this receptor for modeling because:

- It is one of the most important receptors in the Hudson River RI/FS, which provides the exposure estimates;
- It consumes a variety of fish and fish-eating organisms;
- It only produces one or two nestlings per year;
- It is a threatened species.

Several field studies were identified that examined the effects of PCBs in eggs of bald eagles, but not dietary doses. Clark et al. (1998) presented information on concentrations of total PCBs (range = 20 to 54 mg/kg egg) and TEQs in eggs from two sites in New Jersey where reproductive failures have occurred, but the data could not be used to develop dose-response relationships. Studies by Wiemeyer et al. (1984, 1993) reported adverse effects on mean 5-year production in bald eagle with egg concentrations greater than 3.0 mg PCBs/kg egg. Wiemeyer et al. (1993) studied bald eagle production over a long time period (i.e., 5- year intervals from 1969 through 1984), and examined production rates in the field. However, significant intercorrelation of many contaminants made it difficult to determine which contaminants caused the adverse effects (Wiemeyer, 1993), thus, it is not possible to estimate individual dose-response relationships.

We are using a laboratory study by Dahlgren *et al.* (1972) as the basis for the individual dose-response modeling in this analysis. These authors found significantly reduced ($p<0.01$) egg production by hens that had been fed Aroclor 1254 for a period of 16 weeks. Egg production by hens fed PCBs at the lowest observed adverse effect level was 32-97% that of control hens. The Aroclor 1254 was administered weekly in capsules into the esophagus. A Generalized Linear Modeling (GLM) framework is used with a log link function and Poisson error distribution to estimate the dose-response relationship (Moore et al., 1999; EPA, 2000b).

The species sensitivity distribution (SSD) approach uses the distribution of effects concentrations for all species. Just as typical dose-response curves can be used to estimate the probability of effects for an individual species, the SSD can be used to estimate the probability of effects on a species or the probability of effects across species. We are relying on an SSD developed by Suter (2003), based on the survival and development of avian embryos and chicks. These effects were chosen because of data availability, comparability among studies and the clear relevance of reproductive success to avian populations. That report focuses on the potential effects of the dioxin-like congeners.

SSDs may be used quantitatively to estimate the proportion of a taxon (e.g., herons), trophic group (e.g., piscivorous birds) or community that will be affected by an exposure (Suter, 2003). This is equivalent to using a conventional dose-response function to estimate the proportion of a population that will be affected. It requires fitting some function to the SSD so that, as in other exposure-response models, the response can be estimated from the exposure level. The most common functions are the log normal or its linearized version the log probit and the log logistic or its linearized version the log logit, depending on how the outcomes are expressed (e.g., continuous versus dichotomous). The use of tested species to represent communities relies on the assumption that the tested species are an unbiased sample of the community. Test species are not chosen randomly, but, since species sensitivities are not known prior to testing, there is no reason to expect that the selection is biased.

Human Health Endpoints

The weight-of-evidence for a relationship between *in utero* polychlorinated biphenyl (PCB) exposure and developmental outcomes has been well established and continues to grow (Schantz et al., 2003). However, as with most epidemiological studies, discrepancies exist among measures of exposure and the strength of the relationships between the measures of exposure and developmental outcomes. Some of those discrepancies are attributable to differences in analytical methods, particularly in older studies (Longnecker et al., 2003) that had higher detection levels and less sophisticated quantitation techniques.

The primary difficulty in quantifying the relationship between dietary levels of PCBs associated with developmental effects based on epidemiological studies is in the lack of an association between exposure metrics and outcomes. Ingestion of food is likely the most significant exposure pathway (Longnecker et al., 2003; Laden et al., 2000). However, the studies that show significant associations between PCB exposure expressed as cord blood, maternal serum or breast milk concentrations and developmental outcomes in children (ranging in age from birth to 11 years) typically show little or no correlation between those metrics and seafood or other dietary item consumption (Schell et al., 2001;).

It is not a goal of the analysis to develop a definitive dose response model for potential developmental effects. Therefore, we selected data from one cohort specifically which has been well-documented in the literature, follows a cohort whose exposure is specifically tied to fish ingestion, and for which the evidence of *in utero* exposure is greatest. In addition, this cohort has been followed for 11 years with documented effects still at this age, as opposed to other studies which only have a few years worth of followup.

The Michigan Cohort: this cohort was recruited through four maternity hospitals in western Michigan from 1980 to 1981. Two hundred and forty two mothers who had at consumed more than 12 kg of Lake Michigan fish during the previous six years and 71 mothers who had not eaten any Lake Michigan fish participated in the study. The authors assessed prenatal exposure using umbilical cord serum collected at delivery, and maternal serum and breast milk collected shortly after delivery. Testing thus far has been conducted on the newborns, at 4 years, and at 11 years.

Newborn testing was conducted on 242 exposed and 71 control infants. Behavioral outcomes were assessed using the Brazelton neonatal Scale (NBAS), which showed that the most highly exposed infants were more likely than controls to be classified as “worrisome” (Jacobson et al., 1984). The four-year followup collected data from two separate visits – the first at four years and the second three months later. During the first visit, 236 exposed and 87 unexposed children were evaluated using the McCarthy Scales of Children’s Abilities, while the second visit involved a series of reaction time tests (Jacobson et al., 1990). Both visits involved extensive discussions with the mother, including completing the Peabody Picture Vocabulary Test-Revised and Buss and Plomin Emotionality Activity Sociability Temperament Survey for Children. The three ratings were transformed into standard scores and summed to provide a composite measure of activity, what was then standardized to a mean of zero and a standard deviation of one. The 11-year sample evaluated 178 children tested using the Wechsler Intelligence Scale for Children-Revised (WISC-R).

We are relying on the data presented in Jacobson et al. (2000), which presents a linear relationship between lipid-normalized breast milk concentration of PCBs and outcomes.

SURVEY DEVELOPMENT

We completed a pre-test version of the survey (see Appendix A). The survey is divided into two parts. In the first part, half the respondents see questions related to ecological effects first, and the other half see questions with human health effects. The second part asks for the total amount that a household would be willing to pay for the combined health and ecological benefits of PCB removal.

Environmental effects can be broadly categorized in one of two ways: a small probability of a fairly dramatic outcome (e.g., risk of developing a serious illness or cancer food poisoning, etc.), or a relatively large probability of a very small effect. There are a number of studies that have evaluated willingness to pay of the first category. This study is designed to evaluate willingness to pay for a very small effect (in humans) that occurs with a fairly large probability (50% chance if exposed). The ecological effect (e.g., reproductive impairment) occurs with a relatively high probability and is considered a large effect, but of course does not impact humans directly. For that outcome, we are interested in how people perceive environmental threats to ecological resources, what they might be willing to pay to reduce that threat, and how those results can be incorporated into a specific regulatory context – namely, risk assessment.

The human health component of the survey asks respondents about two potential developmental endpoints associated with PCB exposures: a probability of a 6 point reduction in IQ and a probability of a 7-month deficit in reading comprehension. The survey asks about a 50% risk of these endpoints decreasing to either 10% or 25%. The ecological endpoints include a probability of reproductive effects in eagles such that the ability of the population to sustain itself would be severely compromised, and a probability of an effect on 25% of the species (using a species sensitivity distribution). The ecological endpoints correspond to the two different management alternatives that are currently used in typical ecological risk assessments. The risk of adverse effects in eagles is 20% decreasing to 10% or 5%.

Willingness to pay is elicited using a double-bounded dichotomous choice format. Respondents are presented with an initial bid randomized from a bid vector ranging from $25 to $400. If the respondents agree to the initial bid, they are presented with a bid that is double the first bid (if they agree to $400 initially, then they are asked if they would be willing to pay at $800). If respondents do not agree to the initial bid, then they are presented with a bid that is half as much ($10 if they did not agree to $25 initially). The survey is currently undergoing pretest and depending on those results, the bid vector may be adjusted for the final survey.

We are interested in evaluating differences in willingness to pay values and predictors for ecological versus noncancer outcomes, both in relative and absolute terms. Respondents are asked about one set of effects (either human or ecological), and then asked the total amount they would be willing to pay for both sets of risk reductions. Because of potential embedding and ordering effects, there may inconsistencies in responses. Ideally, we would like to have the same respondents provide values for both sets of endpoints. However, it is difficult for people to disaggregate their willingness to pay. Respondents may not be willing to pay any additional amount for an additional benefit (e.g., under the first willingness to pay question, the PCBs will have been removed, therefore, both sets of benefits will occur regardless of any additional money that is spent). We could split the survey and administer it to half the respondents, or take the entire survey and administer it to all respondents. We chose the latter design, since ideally we are interested in evaluating risks of small, noncancer effects in humans versus ecological effects in addition to determining willingness to pay for each endpoint separately.

We have conducted several informal focus groups and discovered that among respondents who are not involved with environmental issues in some way (e.g., work for an environmental company or are involved in local or national environmental groups), there was greater skepticism about the potential effects of PCBs on ecological receptors relative to human receptors. That is, people readily accepted the concept that PCBs could cause developmental delays in children exposed *in utero*, but required greater justification for potential effects to ecological receptors, and, additionally, required greater assurances that the proposed cleanup would actually achieve the stated risk reduction.

Current Status

The survey is programmed and undergoing final edits for pretest. We anticipate going into pretest the week of October 18 and administering the final survey two weeks after that. The current survey is attached as Appendix A.

RISK MODELING

The risk models use the data presented earlier to develop dose-response relationships, which are combined with exposure data from the Hudson River case study to predict the probability of an increasing magnitude of effect.

Human Health Model

The dose of PCBs via fish ingestion is most simply modeled using a first-order uptake model assuming distributions for percent absorbed, lipid content, and elimination half-life.

First order uptake is given as:

$$C_{ms} = \frac{f * ADD * t^{1/2}}{\ln(2)} \qquad (1)$$

where:

C_{ms} = concentration in maternal serum (mg/kg)
f = fraction absorbed (0.5 – 0.9)
ADD = average daily dose (mg/kg-day)
$t^{½}$ = elimination half life (considered constant during lifetime) 7.5 years

Because PCBs are lipophilic and partition into the organic fraction of the environmental media they are in, the concentration of PCBs in breast milk is related to the concentration in serum through lipid content. Thus, the predictions for serum concentration are normalized for the overall tissue lipid content in pregnant women (Kopp-Hoolihan, 1999)

$$C_{LN} = \frac{C_{ms}}{L_b} \quad (2)$$

C_{LN} = mg PCB per kg lipid
C_{ms} = concentration in maternal serum (mg/kg)
L_b = lipid content of all tissues (fraction body fat)

The maternal average daily dose (ADD) is given as:

$$ADD = \frac{IR * C_{fish} *}{BW} \quad (30$$

ADD = average daily dose from fish consumption (mg/kg-day)
IR = ingestion rate (kg/day)
C_{fish} = concentration in fish (mg/kg)
BW = body weight (kg)

TABLE 1: Modeling Parameters

Parameter	Units	Variable or Uncertain	Distribution	Reference
Ingestion rate	kg/day	Variable and uncertain	From Hudson River RI/FS	EPA,
Body weight	kg	variable	Normal (64.8, 7.8)	Kopp-Hoolihan, 1999
PCB concentration in fish	mg/kg	uncertain	Lognormal (depends on scenario)	modeled
Fraction absorbed	fraction	uncertain	Uniform (0.5, 0.9)	assumption
$t^{½}$ (half-life)	1/year	uncertain	7.5	WHO
Total body fat	fraction	variable	Normal (31, 5.5)	Kopp-Hoolihan, 1999

The model uses two-dimensional Latin Hypercube to sample from each of the input distributions. It is iterative in that it first fixes all uncertain parameters, then runs an inner "variability" loop in which it samples from the variable distributions, and then returns to the outer loop to run another set of uncertain parameters.

Ecological Risk Model

The first ecological risk model quantifies the probability that a particular fraction of the eagle population will experience a particular effect (*e.g.,* 10% probability that there will be a 50% reduction in fecundity in the eagle population). The potential for population-level effects is evaluated by convolving the dose-response functions (based on Dahlgren et al., 1972) with cumulative distributions of exposure estimated using data from the Hudson River (EPA, 2000b). The second risk model quantifies the probability that a fraction of the species will experience a particular effects (*e.g.,* 10% probability that 50% of the species will experience egg death).

In both cases, the dose-response functions are obtained by fitting a probit or logit model to appropriate toxicity data. The probit model takes the following form:

$$P(d) = \frac{1}{\sqrt{2\pi}\log\sigma_g} * \int_{-\infty}^{\log d} \exp\left\{-\tfrac{1}{2}\left(\frac{x-\log d_{50}}{\log\sigma_g}\right)^2\right\}dx \qquad (4)$$

where:

d_{50} = median or geometric mean; dose at which 50% of the population responds
σ_g = geometric standard deviation; a measure of dispersion of the responses

The inverse of the cumulative probability of effect corresponding to these concentrations is obtained by using the NORMSINV function in Excel. This function provides the inverse of the standard normal cumulative distribution assuming a mean of 0 and a standard deviation of 1. The log-transformed concentration is thus linearly related to the inverse of the cumulative probability of effect. These points are then used to derive a linear relationship that follows the general form:

$$\Phi^{-1}(Y) = \beta_0 + \beta_1 X \qquad (5)$$

where:

Φ^{-1} = inverse of the normal cumulative probability (z) function (NORMSINV)
Y = probability of response
β_0 = intercept ($-d_{50}/\sigma_g$)
β_1 = slope of the line ($1/\sigma_g$)
X = log (concentration in mg/kg)

The following procedure is used to compare the cumulative exposure distributions with the dose response curves. First, Monte Carlo exposure models are used to generate the cumulative frequency of predicted dietary doses for each receptor. Output concentrations are log-transformed, and the associated cumulative frequencies, expressed as fractions, are transformed by the inverse of the normal cumulative distribution. The log-transformed Monte Carlo concentrations and the transformed cumulative frequencies yield straight lines when plotted against each other. The parameters of these regressions are used to obtain the cumulative frequency for the specified doses in the dose-response curves from the literature. The resulting curves can then be compared directly by plotting the probability of exccedence on the y-axis (obtained from the cumulative distribution of exposure) and the percent reduction in fecundity on the x-axis (obtained from the dose-response curves from the literature).

This estimate takes the following form substituting concentration *c* for dose *d*:

$$R = \int_{-\infty}^{\infty} P(c)\phi(c)dc \qquad (6)$$

where:

ϕ = the lognormal probability density function
R = risk

At each log concentration, a probability of effect is estimated from the probit model and a frequency of occurrence is estimated from the lognormally distributed body burdens. This model has been developed and applied in several site-specific applications (EPA, 2000b; Moore et al., 1999).

NEXT STEPS

We plan to derive willingness to pay estimates for the specified outcomes from the survey data. We also plan to incorporate the willingness to pay estimates into the risk assessment model to quantify the benefits of risk reductions using actual data from the Hudson River RI/FS. Management decisions have already been made for this site, therefore, it is used strictly for demonstration purposes.

We will also evaluate differences in willingness to pay between the human health and ecological endpoints. The risk model can also be used to estimate the probability of developing cancer and these results compared to the noncancer and ecological results. The exposure and risk models are largely complete and were used to derive the specific risk reductions that are the focus of the contingent valuation survey.

REFERENCES

Andrle, R.F. and J.R. Carroll (Editors). 1988. The Atlas of Breeding Birds in New York State. Cornell University Press. Ithaca, New York. 551 pp.

Clark, K. E., L. J. Niles, and W. Stansley. 1998. Environmental contaminants associated with reproductive failure in bald eagle (*Haliaeetus leucocephalus*) eggs in New Jersey. *Bulletin of Environmental Contamination and Toxicology*. 61:247-254.

Dunning, J.B. Jr. 1993. CRC Handbook of Avian Body Masses. CRC Press. Ann Arbor Michigan. 371 pp.

Elliott, J.E., R.J. Norstrom, A. Lorenzen, L.E. Hart, H. Philibert, S.W. Kennedy, J.J. Stegeman, G.D. Bellward, and K.M. Cheng. 1996. Biological effects of polychlorinated bibenzo-p-dioxins, dibenzofurans, and biphenyls in bald eagle (*Haliaeetus leucocephalus*) chicks. *Environmental Toxicology and Chemistry* Vol. 1(5):782-793.

(EPA) United States Environmental Protection Agency. 1993a. Wildlife Exposure Factors Handbook. Volume I of II. USEPA Office of Research and Development. Washington, D.C. EPA/600/R-93/187a.

(EPA) United States Environmental Protection Agency. 1993b. Wildlife Exposure Factors Handbook. Volume II of II. USEPA Office of Research and Development. Washington, D.C. EPA/600/R-93/187b.

(EPA) United States Environmental Protection Agency. 2000b. Further Site Characterization and Analysis, Volume 2E - Revised Baseline Ecological Risk Assessment (ERA), Hudson River PCBs Reassessment RI/FS. Prepared for USEPA Region 2 and USACE, Kansas City District by Menzie-Cura & Associates, Inc. and TAMS Consultants, Inc., August 1999.

Jacobson, J.L., Jacobson, S.W., Schwartz, P.M., Fein, G.G., and J.K. Dowler. 1984. Prenatal exposure to an environmental toxin: A test of the multiple effects model. *Developmental Pyschology* 20(4):523-532.

Jacobson, S.W., Fein, G.G., Jacobson, J.L., Schwartz, P.M., and J.K. Dowler. 1985. The effect of intrauterine PCB exposure on visual recognition memory. *Child Dev* 56:853-860.

Jacobson, J.L., S.W. Jacobson and H.E.B. Humphrey. 1990a. Effects of in utero exposure to polychlorinated-biphenyls and related contaminants on cognitive functioning in young children. *J. Pediatr* 116(1):38-45.

Jacobson, J.L., S.W. Jacobson and H.E.B. Humphrey. 1990b. Effects of exposure to PCBs and related compounds on growth and activity in children. *Neurotoxicol Teratol* 12:319-326.

Jacobson, J.L., S.W. Jacobson. 1996a. Intellectual impairment in children exposed to polychlorinated biphenyls in utero. *N Engl J Med* 335(11):783-789.

Jacobson, J.L., S.W. Jacobson. 1996b. Sources and implications of interstudy and interindividual variability in the developmental neurotoxicity of PCBs. *Neurotoxicol Teratol* 18(3):257-264.

Jacobson, J.L., S.W. Jacobson. 1997. Evidence of PCBs as neurodevelopmental toxicants in humans. *Neurotoxicology* 18(2):415-424.

Jacobson, J.L., Janisse, J., Banerjee, M., Jester, J., Jacobson, S.W., and J.W. Ager. 2002. A benchmark dose analysis of prenatal exposure to polychlorinated biphenyls. *Environ Health Perspect* 110(4):393-398.

Kopp-Hoolihan, L.E., M.D. van Loan, W.W. Wong, and J.C. King. 1999. Far mass deposition during pregnancy using a four-component model. *J Appl Ph*ysiol 87(1):196-202.

Laden, F., Neas., L.M., Spiegelman, D., Hankinson, S.E., Willett, W.C., Ireland, K., Wolff, M.S. and D.J. Hunter. 1999. Predictors of plasma concentrations of DDE and PCBs in a group of U.S. women. Environmental Health Perspectives 109(1):

Longnecker, M.P., Wolff, M.S., Gladen, B.C., Brock, J.W., Grandjean, P., Jacobson, J.L., Korrick, S.A., Rogan, W.J., Weisglas-Kuperus, N., Hertz-Picciotto, I., Ayotte, P., Stewart, P., Winneke, G., Charles, M.J., Jacobson, S.W., Dewailly, E., Boersma, E.R., Altshul, L.M., Heinzow, B., Pagano, J.J. and A.A. Jensen. 2003. Comparison of polychlorinated biphenyl levels across studies of human neurodevelopment. *Environ Health Perspect* 111(1):65-70.

Moore, D.R.J., Sample, B.E., Suter, G.W., Parkhurst, B.R. and R.S. Teed. 1999. A probabilstic risk assessment of the effects of methylmercury and PCBs on mink and kingfishers along East Fork Poplar Creek, Oak Ridge, Tennessee, USA. *Environ. Tox. Chem.* 18(12):2941-2953.

Schantz, S.L., Wiholm, J.J. and D.C. Rice. 2003. Effects of PCB exposure on neuropsychological function in children. *Environ Health Perspect* 111(3):357-376.

Schell, J.D. Jr., Budinsky, R.A., and M.J. Wernke. 2001. PCBs and neurodevelopmental effects in Michigan children: An evaluation of exposure and dose characterization. *Reg Tox Pharm* 33:300-312.

Todd, C. S., Young, L. S., Owen, R.B., Jr. et al. 1982. Food habits of bald eagles in Maine. *J Wildl Manage* 46: 636-645.

Wiemeyer, S.N., T.G. Lamont, C.M. Bunck, C.R. Sindelar, F.J. Gramlich, J.D. Fraser, and M.A. Byrd. 1984. Organochlorine pesticide, polychlorobiphenyl, and mercury residues in bald eagle eggs- 1969-79- and their relationships to shell thinning and reproduction. *Arch Environ Contam Toxicol* 13: 529-549.

Wiemeyer, S.N., C.M. Bunck, and C.J. Stafford. 1993. Environmental contaminants in bald eagle eggs – 1980-84- and further interpretations of relationships to productivity and shell thickness. *Arch Environ Contam Toxicol* 24:213-227.

PCB Exposure Valuation Survey

September 2004

– Study Details –

Note: This page may be removed when the questionnaire is sent to the client. However, it must exist in the version sent to Operations.

SNO	**7960**
Survey Name	**Willingness to Pay for Noncancer Developmental and Ecological Effects Pretest**
Client Name	**Harvard University**
Great Plains Project Number	**K0499**
Project Director Name	**Stefan Subias**
Team/Area Name	**TM Dennis**

Sample Criteria	**General population adults**
Samvar	**Standard demos only.**
Specified Pre-coding Required	**No**
Timing Template Required	**Yes**
Multi-Media	**Images**
Incentive	**No**
Disposition Information (Provide exact descriptions with reference to question numbers and answer list responses for all groups that daily counts are desired)	

Note: The change request log can be deleted, if you do not require it.

Change Request Log (Operations Please Disregard) Note: Do not change Question numbers after Version 1; to add new question, use alpha characters (e.g., 3a, 3b, 3c)					
Author	Ver-sion	Description of Change (Q#, plus change)	Approval Name	Date Apprv'd	Com-pleted (Y/N)

Willingness to Pay for Noncancer Developmental and Ecological Effects Pretest

September 2004

– Questionnaire –

NOTE TO SCRIPTER: RANDOMIZE SECTIONS B/C AND D SO THAT HALF SEE B/C FIRST AND HALF SEE D FIRST.

[DISPLAY]
We are conducting this survey to get your opinion on issues such as education, crime, and the environment facing people in your state. The study will provide information so that State policy makers can understand how people like you feel about these issues.

A. INTRODUCTORY QUESTIONS

NOTE TO SCRIPTER: I CONVERTED THE 3-POINT SCALES IN A1 AND A2 INTO 5-POINT ONES—THIS IS HARD TO SEE IN THE TRACKED CHANGES.

[GRID – SP BY ROW]

A1. There are many issues that require resources facing residents in your State. Some of them may be important for you personally and others may not. Please identify whether the listed issue is not important, somewhat important, or very important to you personally:

	Not Important		Somewhat Important		Very Important

Reducing crime
Cleaning up the environment
Improving education
Protecting State waterways
Reducing State taxes
Reducing air pollution
Improving library services
Providing more security at public events

[GRID – SP BY ROW]

A2. Your State government must allocate financial resources among many different programs. Below you will see a list of different programs. For each one, please indicate whether the amount of money being spent should be reduced, stay the same, or increased, keeping in mind that overall expenditures cannot be increased without an increase in revenue:

	Reduced A Lot	Reduced A Little	Stay the Same	Increased A Little	Increased A Lot

Public transportation in metropolitan areas
Providing homeless shelters
Protecting endangered wildlife
Increased funds for education
Building new prisons
Updating water treatment facilities

Maintaining the court system
Increasing security around public buildings

[DISPLAY]
Every year, the State must decide how to allocate money for the State budget. Sometimes new programs are proposed, and the State is interested in knowing how taxpayers feel about these programs in order to decide whether they should be funded or not. Surveys like this are used to explore how people like you feel about the various programs that the State can spend money on in the coming year. Everyone feels differently, and it's important to hear from as many people as possible in order to capture all the different points of view.

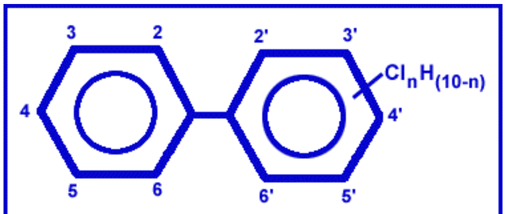
This survey is asking specifically about a program involving the potential effects of chemicals in the environment on both humans and animals. The next part of this survey will provide some background information on the situation and the potential effects of these chemicals. After that, the survey will ask you whether you think anything should be done about the situation. Finally, we are interested in knowing why you feel the way you do.

[DISPLAY]
Studies have shown that babies developing in the womb (fetuses) are affected later in life by some chemicals found in fish and other foods that are eaten by their mothers. Developing fetuses are exposed to the same things as their mothers – but because they are so small, and their organs are still developing, even very small amounts of substances that have little or no effect on the mother can have a big impact on a developing fetus. The effects, typically different kinds of developmental delays, can be observed even in small infants. Scientists have studied the issue, and have determined that the trouble is a result of being exposed to a specific chemical that is found in the sediment (dirt) of several rivers, streams, and lakes in your State. Scientists representing the State, Federal government, and academic institutions have spent years studying this issue. They agree that the known deposits of a specific chemical in the riverbeds bears some responsibility in causing these reproductive effects. The chemical is called polychlorinated biphenyls, or PCBs.

[SP]
A3. PCBs are chemicals that were developed in the early 1940's for electrical transformers and for other industrial purposes. They were an ideal insulating fluid because they are not flammable. Have you ever heard of PCBs?

Yes 1
No 2
Not Sure 3

[DISPLAY]

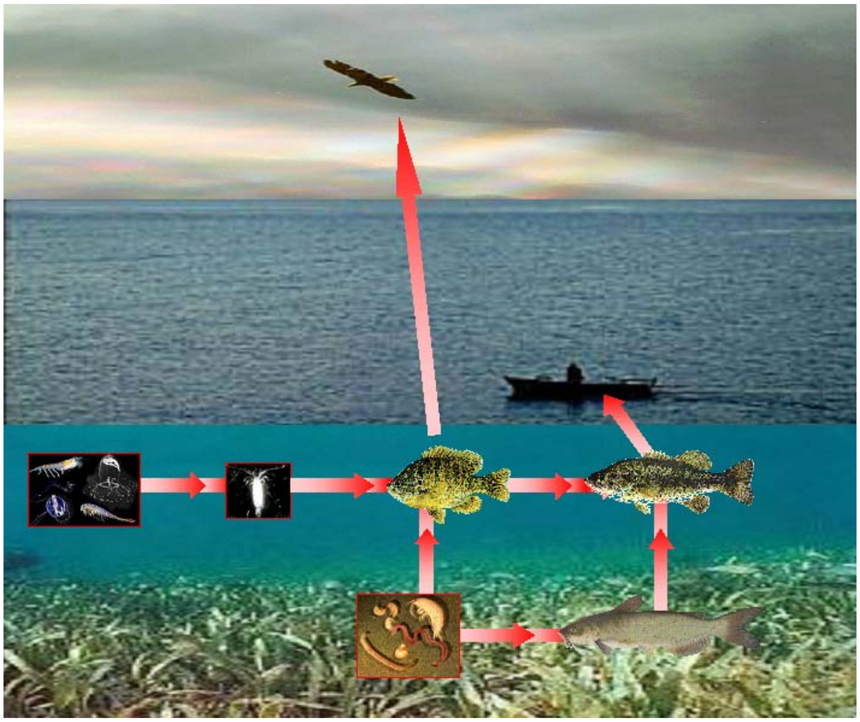


Polychlorinated Biphenyl (PCB)

Up until the early 1970's, people didn't realize that PCBs could affect fish, wildlife, and humans. Several companies that manufactured electrical transformers, or provided other industrial services, were located on different rivers in the State. Some of these companies are out of business now, but in the 1940's, 50's and 60's, they were allowed to discharge PCBs with other wastes from their manufacturing processes. Even though there have been no new PCBs discharged into rivers in at least 20 years, the amounts that were historically released continue to affect wildlife in the State. PCBs are very oily and do not dissolve in water. Once they are in water, they fall to the bottom of the river and remain in the sediment. Sediment, which is just sand and dirt at the bottom of the river, is very stable, except when there is a big storm. As a result, there are layers and layers of sediment containing PCBs.

[DISPLAY]

INSERT FOODWEB GRAPHIC HERE WITH AUDIO.



As this graphic shows, insects and shellfish living in the sediment absorb PCBs and transfer them to fish. Animals, including humans, eat the fish and in this way PCBs accumulate through the food web. You may have heard of fish consumption advisories in your State. These are due to PCBs as well as other chemicals.

The State is proposing to either clean up or remove the contaminated sediment from the river to make sure that humans and wildlife are no longer exposed. If the sediments are not cleaned up, they will continue to be a source of PCBs to the system.

[DISPLAY]
Eventually, PCBs in the sediments will grow less and less due to natural causes. New, clean sediment will deposit over the dirty sediment over a period of many years. The insects, as they continue to work the sediment, will eventually release or use up much of what is there. Scientists using models developed just for this system have shown that PCBs in the sediment will decrease to levels that aren't expected to have effects on animals and humans in approximately 100 years. A clean up remedy, such as dredging, is expected to take one year, will decrease these levels immediately after the clean up is completed. It will still take a few years for the species to recover, but they will not be exposed to any new PCBs during that time.

In order to pay for this cleanup, the State is proposing a one-time additional amount on next year's state income tax. Only this one time payment is required and the money will go into a special fund just for this purpose. There are lots of reasons why you might vote for or against such a program.

B. QUESTIONS RELATED TO HUMAN RECEPTOR EXPOSURE TO POLYCHLORINATED BIPHENYLS

PROGRAMMING NOTES:

SHOW "READ AT 7 MONTHS BELOW GRADE LEVEL" OR "EXPERIENCE A 6 POINT DECREASE IN IQ AS MEASURED BY STANDARD IQ TESTS" RANDOMLY; 50% SEE ONE AND 50% SEE THE OTHER. PLEASE CREATE A DATA-ONLY VARIABLE INDICATING WHICH STATEMENT WAS SHOWN.

SHOW "25%" AND "10%" RANDOMLY; 50% SEE ONE AND 50% SEE THE OTHER. PLEASE CREATE A DATA-ONLY VARIABLE INDICATING WHICH PERCENTAGE WAS SHOWN.

[DISPLAY]
Studies involving children exposed *in utero* to PCBs have shown that these children perform less well on a variety of developmental tests. For a unit exposure, IQ can decrease by six points, the average decrease in reading comprehension is 7 months, children perform less well on mathematical and quantitative tests. The chemical doesn't cause the exact same effects in every child, but it does cause some effect in every child. One specific effect that regulators are worried about is the evidence that exposure to PCBs causes decreases in reading comprehension below levels considered normal in school-age children. There is a 50% chance that children exposed to PCBs in this area will **[READ AT 7 MONTHS BELOW GRADE LEVEL /EXPERIENCE A 6 POINT DECREASE IN IQ AS MEASURED BY STANDARD IQ TESTS]**. If the sediments are removed and the river is cleaned up, scientists estimate that the risk will decrease to **[25% / 10%]**. There will always be some small chance of effects because the sediments can't be 100% cleaned up.

NOTE TO SCRIPTER: RANDOMLY SELECT THE VALUE FOR COST_H FROM THE FOLLOWING CHOICES: $25, $50, $100, $200, $400, $800; EACH VALUE SHOULD BE ASSIGNED FOR APPROXIMATELY 16.7% OF THE RESPONDENTS (I.E., 100/6). PLEASE CREATE A DATA-ONLY VARIABLE INDICATING WHICH VALUE WAS CHOSEN.

PLEASE MAKE THE HIGHEST BID FOR PEOPLE ASSIGNED TO THE $800 CATEGORY EQUAL TO $1000.
PLEASE MAKE THE LOWEST BID FOR PEOPLE ASSIGNED TO THE $25 CATEGORY EQUAL TO $10.

[SP]

B1. The State estimates that this program will cost $**[COST_H]**. Your household would pay this one time tax on next year's income tax and the money would go into a special fund set up to clean up the river. There will be a referendum to decide whether the river will be cleaned up and how much the one-time tax should be. If the election were being held today and the total cost would be a one time additional tax of $**[COST_H]**, would you vote for or against it?

For 1
Against 2

PROMPT ONCE.
SHOW B2 IF B1 = "FOR".
FOR B2, CREATE A DATA-ONLY VARIABLE INDICATING WHAT BID HIGHER THAN COST_H WAS SELECTED.

[SP]

B2. $**[COST_H]** represents the best estimate of the engineering costs. It could be that the cost to each household would be as high as $**[NEXT BID UP FROM [COST_H]** instead of $**[COST_H]**. If this was the case, and the one time tax would be $**[NEXT BID UP FROM [COST_H]]**, would you vote for or against it?

For 1
Against 2

SHOW B3 IF B1 = "AGAINST" OR SKIPPED.
FOR B3, CREATE A DATA-ONLY VARIABLE INDICATING WHAT BID LOWER THAN COST_H WAS SELECTED.

[SP]

B3. $**[COST_H]** represents the best estimate of the engineering costs. It could be that the cost to each household would be lower and would only be $**[NEXT BID LOWER THAN [COST_H]]** instead of $**[COST_H]**. If this was the case, and the one time tax would be $**[NEXT LOWER BID THAN [COST-H]]**, would you vote for or against it?

For 1
Against... 2

SHOW B4 IF B2 = "AGAINST" OR SKIPPED OR B3 = "AGAINST" OR SKIPPED.

[MP]

B4. The State is interested in knowing why you would vote against the program. There are lots of different reasons why you might vote against the program, like it just isn't worth that much money, or it would be difficult for your household to pay that much even though you support the program. Or there might be some other reason.

Isn't worth the money 1
Difficult for my household to pay 2
Don't believe the cleanup would work 3
Some other reason, please specify: ______ 4

SHOW B5 AND B6 IF B1, B2 OR B3 = "FOR".

[SP]

B5. People have lots of different reasons for voting for the program. Could you briefly describe why you would be willing to pay for it?

I'm worried about the potential risks to unborn babies 1
I support a cleanup no matter what 2
Some other reason, please specify: ______ 3

[SP]

B6. Thinking back on your responses, how confident would you say you are in your willingness to pay on a scale of 1 to 5 where 1 is "Not confident at all" and 5 is "Very confident"?

Not confident at all				Very confident
1	2	3	4	5

C. QUESTIONS RELATED TO QALYS

[SP]

C1. Now we're going to ask a slightly different question. Assume for a moment that your child was exposed to PCBs and has a slight reading comprehension deficit. Further assume there is a treatment available to remedy the impairment, but that it comes with a very small chance of dying as a result of the treatment. Would you accept a risk of death of 10 in 100,000 for your child to cure the deficit for the rest of the child's life (assuming all other risks remain the same)? This is also randomized – respondents see either 10 in 100,000 or 1 in 100,000 and then half that or double that for C2 and C3 respectively depending on whether they answered no or yes, respectively

Yes 1
No 2

[SP]

C2. If the risk of death was only 5 in 100,000, would you take the treatment?

Yes 1
No 2

[SP]

C3. If the risk of death was as high as 20 in 100,000, would you take the treatment?

Yes 1
No 2

D. QUESTIONS RELATED TO EAGLE RECEPTOR EXPOSURE TO POLYCHLORINATED BIPHENYLS

[DISPLAY]

PCBs can have effects on the environment and the birds and mammals that use the environment. This part of the survey is to find out whether you would be willing to pay an additional tax for the additional benefit of protecting ecological receptors like eagles. Many years ago, eagles were in danger of becoming extinct. Now, they are successfully hatching young and maintaining their populations in some places in the United States. But that is not the case along several waterways in this State. Studies have shown that eagles are sensitive to chemicals in the environment, particularly ones like PCBs that build up in the food chain. Sensitive receptors like eagles will show effects at lower concentrations than humans. As exposure to PCBs increases, there is an increase in the probability of a decline in reproductive capability. Scientists aren't sure what probability of a decline in reproductive capability leads to extinction, but any decline is likely to have a noticeable effect in the population of a species like an eagle, which only produce one or two young per year and which have small populations to begin with.

PROGRAMMING NOTES:

PLEASE SHOW ONE OF THE NEXT TWO DISPLAY SCREENS RANDOMLY; 50% SEE ONE VERSION, 50% SEE THE OTHER. PLEASE CREATE A DATA-ONLY VARIABLE INDICATING WHICH SCREEN WAS SHOWN.

IN THE FIRST DISPLAY SCREEN, PLEASE SHOW "10%" AND "5%" RANDOMLY; 50% SEE ONE AND 50% SEE THE OTHER. PLEASE CREATE A DATA-ONLY VARIABLE INDICATING WHICH PERCENTAGE WAS SHOWN.

IN THE SECOND DISPLAY SCREEN, PLEASE SHOW "25%" AND "10%" RANDOMLY; 50% SEE ONE AND 50% SEE THE OTHER. PLEASE CREATE A DATA-ONLY VARIABLE INDICATING WHICH PERCENTAGE WAS SHOWN.

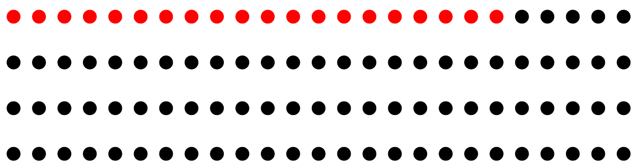
[DISPLAY]

Because of exposure to PCBs, scientists have estimated there is a 20% chance that eagles will experience a decline in reproductive capability that could impact the population.

If the sediments are removed and the river is cleaned up, scientists estimate that the risk decreases to **[10% / 5%]**.

Each dot below represents one eagle: The red dots represent the eagles that will not be able to reproduce.

[SHOW IMAGE WITH 20 RED DOTS.]

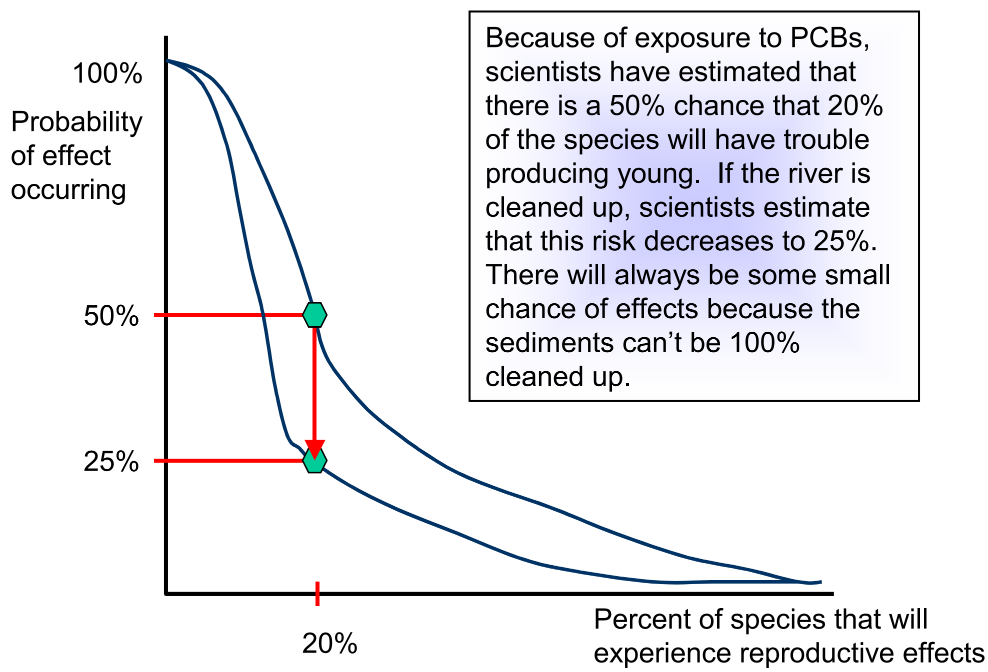


If the river is cleaned, scientists predict that **[10 / 5]** eagles will have trouble reproducing. There will always be some chance of effects because the sediments can't be 100% cleaned up.

[SHOW IMAGE WITH 10 OR 5 RED DOTS DEPENDING ON CONDITION SELECTED.]

[DISPLAY]

INSERT RISK GRAPHIC HERE.



NOTE TO SCRIPTER: RANDOMLY SELECT THE VALUE FOR COST_E FROM THE FOLLOWING CHOICES: $25, $50, $100, $200, $400, $800; EACH VALUE SHOULD BE ASSIGNED FOR APPROXIMATELY 16.7% OF THE RESPONDENTS (I.E., 100/6). PLEASE CREATE A DATA-ONLY VARIABLE INDICATING WHICH VALUE WAS CHOSEN.

ALSO NOTE THAT FOLLOWUP ITEMS USE THE NEXT HIGHEST/LOWEST BID.

IMPORTANT: THE FIRST BID THAT IS SELECTED HERE SHOULD CORRESPOND TO COST_H THAT WAS AGREED TO EARLIER. IF THE RESPONDENT SAID YES TO BOTH BIDS IN B, THEN COST_E = NEXT HIGHEST BID AMOUNT. IF RESPONDENT SAID YES THEN NO, COST_E = TO

LAST (REJECTED) BID AMOUNT FROM B. IF RESPONDENT SAID NO, THEN COST_E IS RANDOMLY SELECTED FROM THE FULL BID VECTOR.

PLEASE MAKE THE HIGHEST BID FOR PEOPLE ASSIGNED TO THE $800 CATEGORY EQUAL TO $1000. PLEASE MAKE THE LOWEST BID FOR PEOPLE ASSIGNED TO THE $25 CATEGORY EQUAL TO $10.

[SP]

D1. The State estimates that this program will cost each household $**[COST_E]**. Your household would pay this one time tax on next year's income tax and the money would go into a special fund set up to clean up the river. There will be a referendum to decide whether the river will be cleaned up and how much the one-time tax should be. If the election were being held today and the total cost would be a one time additional tax of $**[COST_E]**, would you vote for or against it?

For 1
Against.................................... 2

PROMPT ONCE.

SHOW D2 IF D1 = "FOR".

[SP]

D2. $**[COST_E]** represents the best estimate of the engineering costs. It could be that the cost to each household would be as high as $**[NEXT BID UP FROM [COST_E]]** instead of $**[COST_E]**. If this was the case, and the one time tax would be $**[NEXT BID UP FROM [COST_E]]**, would you vote for or against it?

For 1
Against.................................... 2

SHOW D3 IF D1 = "AGAINST" OR SKIPPED.

[SP]

D3. $**[COST_E]** represents the best estimate of the engineering costs. It could be that the cost to each household would be lower and would only be $**[NEXT BID DOWN FROM COST_E]** instead of $**[COST_E]**. If this was the case, and the one time tax would be $**[NEXT BID DOWN FROM [COST_E]]**, would you vote for or against it?

For 1
Against.................................... 2

SHOW D4 IF D2 = "AGAINST" OR SKIPPED OR D3 = "AGAINST" OR SKIPPED.

[MP]

D4. The State is interested in knowing why you would vote against the program. There are lots of different reasons why you might vote against the program, like it just isn't worth that much money, or it would be difficult for your household to pay that much even though you support the program, or you are opposed to dredging as an alternative. Or there might be some other reason.

Isn't worth the money 1

Difficult for my household to pay 2
Don't believe the cleanup would work 3
Some other reason, please specify: _______ 4

SHOW D5 AND D6 IF D1, D2 OR D3 = "FOR".

[SP]

D5. People have lots of different reasons for voting for the program. Could you briefly describe why you would be willing to pay for it?

I'm worried about the eagles 1
I support a cleanup no matter what 2
Some other reason, please specify: _______ 3

[SP]

D6. Thinking back on your responses, how confident would you say you are in your willingness to pay on a scale of 1 to 5 where 1 is "Not confident at all" and 5 is "Very confident"?

Not confident at all				Very confident
1	2	3	4	5

E. QUESTIONS RELATED TO MOTIVATION

[DISPLAY]

It is important for regulators to know how you came to your decision.

[SP]

E1. How concerned are you about chemicals in the environment?

Not at all concerned.. 1
Somewhat concerned....................................... 2
Quite concerned 3
Very concerned 4

[SP]

E2. How concerned are you about PCBs in the environment?

Not at all concerned.. 1
Somewhat concerned....................................... 2
Quite concerned 3
Very concerned 4

[SP]

E3. Do you believe that PCBs could cause the reproduction problems in eagles?

Yes 1
No 2
Not Sure 3

[SP]

E4. Do you believe that PCBs could cause developmental delays in young children exposed in the womb?

Yes 1
No 2
Not Sure 3

[SP]

E5. Did you feel like the survey pushed you to vote a particular way or did you feel like you really made up your own mind based on the best available information?

Pushed to vote for it 1
Pushed to vote against it 2
Made up my own mind 3
Not Sure 4

[LARGE TEXT BOX]

E6. What is it about the survey that made you feel that way?

[SP]

E7. Thinking back on all the information, would you say the reproduction problems facing eagles in this state are…

Not serious at all 1
Somewhat serious 2
Very serious 3
Extremely serious 4
Not sure 5

[SP]

E8. Thinking back on all the information, would you say the risks facing unborn babies due to exposure to PCBs in this state are…

Not serious at all 1
Somewhat serious 2
Very serious 3
Extremely serious 4
Not sure 5

F. QUESTIONS RELATED TO RECREATIONAL ACTIVITIES

[SP]

F1. How often do you personally watch television programs about wildlife?

Never	1
Rarely	2
Sometimes	3
Often	4
All the time	5

[SP]

F2. Do you live near a river, lake or stream?

Yes	1
No	2

[SP]

F3. How often does your family spend time near a river, lake or stream?

Never	1
Rarely	2
Sometimes	3
Often	4
All the time	5

[SP]

F4. How often do people in your household eat fish?

Never	1
A few times a year	2
A few times a month	3
Every week	4

[GRID – SP BY ROW]

G2. You receive a lot of information from a lot of different sources. In general, how much confidence do you have in information you obtain from:

	No Confidence	Some Confidence	A Lot of Confidence

Federal government
Scientists who work for industry
Scientists who work for universities
Television media
Internet sources **[NO SELECTION FOR THIS HEADER ITEM]**
  Government web sites
  Commercial web sites
  Non profit web sites
  Academic web sites
Print media (newspapers, magazines)

Joint Determination in a General Equilibrium Ecology/Economy Model*

David Finnoff
dfinnoff@bus.ucf.edu

John Tschirhart
jtsch@uwyo.edu

Department of Economics and Finance
Department 3985 • 162 Ross Hall
University of Wyoming
Laramie, WY 82071

October 2004

*To be presented at the EPA Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions - A STAR Progress Review Workshop. This research is supported by the U.S. Environmental Protection Agency grant # RD-83081901-0.

1. Introduction

This work is part of the ongoing effort by economists and ecologists to better integrate their disciplines in order to improve policymaking. The motivation for the work is the realization that all economic activity ultimately depends on the natural resource base and the ecosystems contained therein, but the extent to which the base is tapped has limits (Arrow, et al., 1995). By some accounts the limits have been reached and a depleted resource base is having negative impacts on living standards (Norgaard 1994). Monitoring depletion and predicting future resource limits requires a better understanding of the interplay between the ecology of natural systems and economic activity (Nordhaus and Kokkelenberg, 1999). The objective here is to develop a method to better capture the interplay. The method is useful for addressing the numerous conflicts that arise when economic development and environmental conservation appear at odds. Familiar examples include logging, harvesting wildlife, preservation of biodiversity (Weitzman, 1993) and endangered species (Shogren and Tschirhart, 2000), bioprospecting (Simpson, Sedjo and Reid, 1996), and, more generally, conserving the essential human services supplied by natural environments (Daily, 1997).

In many economic papers that examine biological renewable resources, logistic growth functions are employed to capture the resources' characteristics. Usually, a single growth function is employed to study one species, thereby omitting the other species in the community. Occasionally, two or three species are studied in a predator-prey relationship, or, as in Brander and Taylor (1998), humans are the predator. The point is that in all this work entire communities are reduced to one or two species, and a few parameters must summarize the numerous interactions that occur in real ecosystems. Moreover, the logistic growth functions depend on entire species' populations and as such they take a macro view in which species interactions, if present at all, are at an aggregated level.

An alternative is to model many interacting species in food webs and to do this at the micro level so that individual organism behavior yields community populations. Of course, modeling a community with many species is a challenge because everything depends on everything else (Amir, 1979; Crocker and Tschirhart, 1992). Economists face a similar challenge in modeling an economy in which everything depends on everything else. Economists address the challenge by developing computable general equilibrium (CGE) models, and this is the tack taken here. By exploiting the three themes fundamental to economics - rational behavior, efficiency and equilibrium, a general equilibrium model of an ecosystem is built. The general equilibrium ecosystem model (GEEM) is then tied to a general equilibrium of an economy to examine the ecosystem/economy interplay.

GEEM is a new adaptive approach that appeals to the oft-made analogies between economies and ecosystems in both the economic and ecological literatures (Tschirhart, 2000, 2002, 2004).[1] Like CGE models that rely on micro foundations of individual consumer and firm behavior to drive the macro outcomes, the individual plant and animal behavior in GEEM appeals to the micro principle that success depends on their energy utilization, and this drives the ecological macro outcomes (i.e., population changes). Population updating uses general equilibrium results from individual plant and animal net energy optimization aggregated to species levels, similar to how CGE economic models start with individual consumer and firm demands and supplies and aggregates them to market levels.

In this paper, CGE/GEEM is applied to the Alaskan economy that is linked via its fishing and tourism industries to an eight species marine ecosystem that includes an endangered species. The fisheries sector is modeled as a regulated open access fishery (Homans and Wilen, 1997) but is significantly modified to be compatible with the general equilibrium framework. Each general

[1] However, the similarities only go so far and there are features in GEEM that are not found in economic models (Tschirhart, 2003). For example, predators and prey do not engage in voluntary exchange, but in biomass transfers.

equilibrium calculation corresponds to one year, but the fishing season is considerably shorter than one year. The fishing off season is explicitly modeled by allowing for fishing factors to receive rents in season that carry them through the off season, and by including in welfare the off-season leisure enjoyed by unemployed fishery labor.

Results from the linked models include period-by-period gross state product, prices and quantities for final goods and factors in the economy, and predator/prey biomass consumption, energy prices, and species populations in the ecosystem. In addition, welfare comparisons of alternative fishing regulations are presented. Welfare is increased with mandatory reductions in fish harvests to protect the endangered Steller sea lions that feed on fish for two main reasons. First, and as expected, capital and labor move from the regulated open access fishery sector to other sectors where they both earn more on an annual basis, and second, the tourism industry grows owing to increased numbers of marine mammals.

In what follows a brief description of GEEM for the marine ecosystem is provided. This is followed by a presentation of how the fishery is merged into the CGE model and what welfare measure may be appropriate for the linked systems.

2 The Ecology Model

GEEM is applied here to an oft studied marine ecosystem comprising Alaska's Aleutian Islands (AI) and the Eastern Bering Sea (EBS). The ecosystem is represented by the food web in Figure 1. All energy in the system originates from the sun and is turned into biomass through plant photosynthesis. Photosynthesis is carried out in the AI by individuals of various species of algae, or kelp, and in the EBS by individuals of various species of phytoplankton. All individual animals in the system depend either directly or indirectly on the kelp and phytoplankton plant species. In the EBS, zooplankton prey on phytoplankton and are prey for pollock. The pollock are a groundfish that support a very large fishery. Steller sea lions, an endangered species, prey on pollock, while killer whales prey on the sea lions. In the AI, killer whales also prey on sea otter that in turn prey on sea urchin that in turn prey on kelp.

In GEEM, demand and supplies are developed somewhat similarly to CGE. Species are analogous to industries, and individual plants and animals are analogous to firms. Plants and animals are assumed to behave as if they maximize their net energy flows. Where perfectly competitive firms sell outputs and buy inputs taking market-determined prices as signals, plants and animals transfer biomass from prey to predators taking 'energy prices' as signals. (Plants can be thought of as preying on the sun.) An energy price is the energy a predator loses to the atmosphere when searching for, capturing and handling prey. A key difference between economic markets and ecological transfers, however, is that in the latter the prey does not receive this energy price. Therefore, the biomass transfer is not a market because there is no exchange (Tschirhart, 2003). Nevertheless, predators' demands and preys' supplies are functions of the energy prices.

A brief sketch of GEEM is provided here, but for details see Finnoff and Tschirhart (2003, 2004). The three basic equations that comprise GEEM are given by (2.1) – (2.3). The first equation is a general expression for the net energy flow through a representative animal from species i.

$$R_i = \sum_{j=1}^{i-1}[e_j - e_{ij}]x_{ij} - \sum_{k=i+1}^{m} e_i[1 + t_i e_{ki}]y_{ik} - f^i(\sum_{j=1}^{i-1} x_{ij}) - \beta_i \quad (2.1)$$

$$N_i x_{ij}(\boldsymbol{e}_i) = N_j y_{ji}(\boldsymbol{x}_j(\boldsymbol{e}_j)) \quad (2.2)$$

$$N_i^{t+1} = N_i^t + N_i^t\left[\frac{1}{s_i}(R_i(\cdot) + v_i) - \frac{1}{s_i}\right] \quad (2.3)$$

R_i is in power units (e.g., Watts or kilocalories/time).[2] The species in (2.1) are arranged so that members of species i prey on organisms in lower numbered species and are preyed on by

[2] According to Herendeen (1991) energy is the most frequently chosen maximand in ecological maximization models, and energy per time maximization as adopted here originates with Hannon (1973) and expanded to multiple

members of higher numbered species. The first term on the right side is the inflow of energy from members of prey species (including plants) to the representative individual of species i. The choice variables or demands, x_{ij}, are the biomasses (in kilograms/time) transferred from the member of species j to the member of species i, e_j are the energies embodied in a unit of biomass (e.g., in kilocalories/ kilogram) from a member of species j, and e_{ij} are the energies the member of species i must spend to locate, capture and handle units of biomass of species j. These latter energies are the energy prices. There is one price for each biomass transfer between a predator and prey species. As in economic CGE models, the prices play a central role in each individual's maximization problem, because an individual's choice of prey will depend on the relative energy prices it pays. Individuals are assumed to be price takers: they have no control over the energy price paid to capture prey, because each is only one among many individuals in a predator species capturing one of many individuals in a prey species.

The second term is the outflow of energy to animals of species k that prey on i. The e_i is the embodied energy in a unit of biomass from the representative individual of species i, and y_{ik} is the biomass supplied by i to k. The term in brackets is the energy the individual uses in attempts to avoid being preyed upon. It is assumed to be a linear function of the energy its predators use in capture attempts: the more energy predators expend, the more energy the individual expends escaping. t_i is a tax on the individual because it loses energy above what it loses owing to being captured. The third and fourth terms in (2.1) represent respiration energy lost to the atmosphere which is divided into a variable component, $f^i(\cdot)$, that depends on energy intake and includes feces, reproduction, defending territory, etc., and a fixed component, β_i, that is basal metabolism.

Time in the Alaskan model is divided into yearly reproductive periods. Each year a

species in Crocker and Tschirhart (1992) and to the individual level in Tschirhart (2000). Energy per time is also the general equilibrium is determined wherein the populations of all species are constant, each plant and animal is maximizing its net energy (using the derivatives of (2.1) for first-order conditions), and aggregate demand equals aggregate supply between each predator and prey species. For each price that equates a demand and supply transfer there is an equilibrium equation given by (2.2). Each plant and animal is assumed to be representative individuals from its species; therefore, the demand and supply sums are obtained by multiplying the representative individual's demands and supplies by the species populations given by the N terms.

A representative plant or animal and its species may have positive, zero or negative net energy in equilibrium. Positive (zero, negative) net energy is associated with greater (constant, lesser) fitness and an increasing (constant, decreasing) population between periods. (The analogy in a competitive economy is the number of firms in an industry changes according to the sign of profits.) Net energies, therefore, are the source of dynamic adjustments. If the period-by-period adjustments drive the net energies to zero, the system is moving to stable populations and a steady state. The predator/prey responses to changing energy prices tend to move the system to steady state.

The adjustment equation for the i^{th} species is given by (2.3) where $R_i(\cdot) = R_i(x_{ij}; \boldsymbol{N}^t)$ is the optimum net energy obtained by substituting the optimum demands and supplies as functions of energy prices into objective function (2.1). $\boldsymbol{N}^t$ is a vector of all species' populations and it appears in $R_i(\cdot)$ to indicate that net energies in time period t depend on all populations in time period t. In the steady state, $R_i(\cdot) = 0$. Also, s_i is the lifespan of the representative individual, v_i is the variable respiration, v_i^{ss} is the steady-state variable respiration, and N_i^{ss} is the species steady-state population. The first and second terms in brackets in (2.3) are the birth and death rates. Expression (2.3) reduces to the steady state if $R_i(\cdot) = 0$ (in which case $v_i = v_i^{ss}$ and $N_i^t = N_i^{ss}$).

---

individual's objective in the extensive optimum foraging literature (e.g., Stephens and Krebs 1986).

Because the biomass demands depend on the period t populations of all species, the population adjustment for species i depends on the populations of all other species. In addition, out of steady state $R_i(\cdot)$ and v_i change across periods. These changes distinguish the GEEM approach from most all ecological dynamic population models, because the latter rely on fixed parameters in the adjustment equations that do not respond to changing ecosystem conditions.

3 The Economy Model

The CGE model pioneered by Ballard et al. (1985) and applied in the OECD GREEN model (Burniaux et al, 1991) is most appropriate for linking with GEEM. The approach Ballard et al. developed may be termed "myopically dynamic," because it consists of a sequence of static optimizations and resulting equilibria connected through the evolution of factor stocks and household savings. Households are intertemporal optimizers whose savings decisions are based on myopic expectations over future prices.

The economy is modeled as having three production sectors: the fishery F, recreation and tourism R, and composite goods C.[3] The fishery is modeled as a single, vertically integrated industry consisting of catcher vessels, catcher processors and, motherships and inshore processors. Recreation and tourism represents the Census Bureau's classification of Wildlife Related Recreation, and composite goods are a catch all for the residual private industries in Alaska. Profit-maximizing, price-taking firms employ harvests of pollock in the fishery, non-consumptive use of marine mammals (Steller sea lions, killer whales and sea otter) in recreation, and capital and labor in all sectors, to produce their outputs in a continuous, nonreversible, and bounded process. Outputs from the fishery, recreation, and composite goods are sold in regional markets and exported out of the region, while regional production is differentiated from imports

[3] The sector and regional profiles follow the Steller Sea Lion Supplemental Environmental Impact Statement (SEIS, U.S. Department of Commerce, 1991).

for fish and composite goods following Armington (1969). Capital K and labor L are homogeneous and defined in service units per period. They are also perfectly mobile between sectors and between periods, but not within periods which is pertinent for the fishery. Sector i factor employment levels are given by K_i and L_i ($i = F, R, C$).

The linkage between the fishery and the ecosystem is presented in detail. The treatment of the tourism industry that depends on the marine mammals, the households, the composite goods, and trade and price relationships are presented in detail in Finnoff and Tschirhart (2004).

3.1 Fishery Incorporating a fishery into a CGE framework raises issues that require two modifications to the standard fishery models. First, where most of the fishery literature employs effort as the single human factor of production, capital and labor must be included in CGE so that the fishery interacts with other sectors. Second, the non-fishery sectors hire capital and labor in service units per year, but in the fishery factors are employed considerably less than one year and may earn rents.

Expressions (3.1) – (3.4) summarize production in the fishery sector:[4]

$$TAC_t = a + bN_4^{0,t} \tag{3.1}$$

$$H_F = d_F T^{a_F} N_4 \tag{3.2}$$

$$\text{minimize} \quad \hat{w}L_F + \hat{r}K_F \quad \text{subject to} \quad T = d_F^m L_F^{a_F^m} K_F^{(1-a_F^m)} \tag{3.3}$$

Equation (3.1) introduces government into the model in the form of a fishery manager. Homans and Wilen (HW, 1997) developed a model of a regulated open-access fishery to reflect that fishery managers set total allowable catch, TAC, and fishing season length, T. The heavily-regulated Alaskan pollock fishery fits this institutional arrangement. To mesh an HW type model with the CGE framework, the fishery manager chooses period t's TAC according to (3.1) where N_4 is the population of pollock. No harvests are allowed whenever the actual biomass is less than the minimum level set by the manager. For given *TAC* and technology, the season length is determined from the aggregate harvest function in (3.2), where a_F and d_F are parameters and H_F is aggregate harvest. The industry is assumed to harvest up to their limit so that $H_F = TAC$.

The season length is the time needed to land the *TAC* given the fish stock and is increasing in *TAC* (Homans and Wilen, 1997). Following the fishery manager's choices for *TAC* and *T*, the industry is assumed to minimize the cost of harvesting according to (3.3) by employing capital and labor to work time *T*. The production function exhibits constant returns to scale, $a^m{}_F$, and $d^m{}_F$ are parameters, and $\hat{w}$ and $\hat{r}$ are the fishery wage and rental rate of capital that may diverge from the market wage and rental rate in other sectors. The associated cost function is linearly homogenous in time, allowing the total costs of harvesting to be written as $C(\hat{w},\hat{r})T$. This setup with the industry choosing *K* and *L* for a given season length incorporates the two modifications defined above.

The divergence of fishery factor prices from market factor prices in the other sectors arises from the restricted season length and is an important feature of the model. Entry is assumed to dissipate all rents in open access models. But these are partial equilibrium models and factors are either not defined over time or if they are defined, they are instantaneous rates or daily rates as in Clark (1976). What these factors are doing off season is not an issue, because there is no off season in the models. In the CGE setting where all other sectors are operating year round, the fishery experiences an off season during which factors are either unemployed or employed elsewhere, often outside the region. In reality, unemployment is common and it may be either voluntary, or involuntary owing to factor immobility between seasons.[5] In either case,

---

[4] We are indebted to Robert Deacon for his invaluable input in the development of this section.

[5] The Alaskan Department of Labor and Workforce Development provides information about fishing jobs in Alaska on various websites (e.g., http://www.labor.state.ak.us/esd_alaska_jobs/careerstreams.htm). The job descriptions suggest that workers can save money, and pay can be substantial if the fishing is good. College students are encouraged to apply and then return to college in the off season. Boyce (2004) examines rents in fisheries and assumes that fishing inputs cannot be redeployed during the off season.

rational factors may demand higher than market payments in season in anticipation of being unemployed off season. If they do, seasonal factor payments will not be driven down to market levels in season, leaving positive seasonal rents. One might argue that these above market payments are not really rents, because they are merely covering the opportunity costs of factors in the off season. This is certainly not true for voluntary unemployment because the factors are enjoying leisure. But even for involuntarily unemployment, rational factors will anticipate some transition time before reemployment, and will enjoy rents if the transition time is equal to or less than what they anticipate.

Let W and R be the market determined factor prices for labor and capital in other sectors. Because labor and capital are defined in service units per year, W and R are annual payments. Let $\beta \in (0, 1)$ be the percent of the year the fishery is active so that market factor prices in the fishery are $\beta\, W$ and $\beta\, R$. If there are intra-seasonal rents in the fishery, they must be reflected in factor prices that deviate from these market prices such that $C(W\beta, R\beta) < C(\hat{w}, \hat{r})$. Assuming any rents impact labor and capital uniformly and linearly, let δ be a rent divergence term so that the factor prices in the fishery are:

$$\hat{w} = \beta\, \delta\, W \quad \text{and} \quad \hat{r} = \beta\, \delta\, R$$

$$\text{where } \delta = 1 \Rightarrow \text{ no rents and } \delta > 1 \Rightarrow \text{ positive rents.}^{6} \qquad (3.4)$$

In developing the simulation model the available data provides estimates for β and δ. But the data is inadequate to determine whether factors were voluntarily or involuntarily unemployed or whether they were reemployed during the off season. Therefore, the assumption made here is that labor is voluntarily unemployed, i.e., enjoying leisure, and capital is idle or employed outside the Alaskan economy. Labor's leisure time in the off season will be accounted for in

[6] Factor price distortions commonly enter the CGE literature in the form of taxes (Harberger, 1974, Shoven and Whalley, 1976, Ballard et al., 1985, and Bovenberg and Goulder 1996). The divergences here are not distortions in the usual sense: β is merely an accounting adjustment to correct for a shorter work year, and a $\delta > 1$ may be welfare enhancing since some positive rents are desirable.

welfare measures below.

Equilibrium for the industry is given by a pseudo zero-profit condition that allows for intra-season rents:

$$\pi_F = P_F H_F - C(\beta\delta W, \beta\delta R)T = 0 \qquad (3.5)$$

In this representation, the total factor payments over the season equal the total revenue divided by the season length, or an average revenue per time. An exogenous increase in *TAC or* H_F increases season length for a given fish stock and δ falls to maintain equality in (3.5). Intuitively, the longer season implies less off-season time for the factors, and they require less rent in season to get through the off season. To summarize, after the fishery manager sets *TAC* by (3.1) and *T* by (3.2), the factor demands and the rent divergence δ are determined by (3.3) and (3.5).

3.2 Equilibrium and Dynamics The economic system is in equilibrium when households and firms optimize, there exists a set of prices and level of output at which all firms break-even, Walras Law holds, and all markets clear. Incomes are derived through a two-stage process. Regional households are endowed with labor ω_L^{AK} and capital ω_K^{AK}. While foreign value added expenditures (from foreign factor employment in the fishery) accumulate elsewhere, regional value added expenditures flow first to factor "institutions", and then redistributed to households. We close the model through the region's current account and savings investment balance. Economic dynamics are recursive, consistent with the evolution of species populations. Given myopic expectations, the time path of the economy is represented by a sequence of competitive equilibria, one for each period. The periods are linked through factor accumulation, where savings in each period (and therefore regional investment $\mathbf{I}_t$) expand the capital service endowment for the subsequent period, and the effective labor force grows at an exogenous rate. If the capital stock grows at the same rate as the effective labor force, the economy is on a balanced growth path; however, balanced growth is not a feature of the linked model, because species populations cannot grow continually.

3.3 Welfare Measures The welfare impacts of alternative policies are evaluated in terms of modified Hicksian equivalent variational measures similar to those developed in Ballard et al. Each policy change leads to changes across prices and income in relation to a reference/benchmark sequence of business as usual. Let the Hicksian expenditure function associated with consumption in period t be given by $M_t(.)$. Vectors of prices in any period t of the reference scenario b or policy alternate a are given by $\underline{P}^b{}_t$ and $\underline{P}^a{}_t$, with corresponding indirect utility functions $V^b{}_t$ and $V^a{}_t$. In the results we employ annual equivalent variations $EV_t = M_t(\underline{P}_t^b, V_t^a) - M_t(\underline{P}_t^b, V_t^b)$ [7] to calculate welfare changes for any single period across policy scenarios. Cumulative aggregate (or multi-market) welfare measures are found using discounted summations of EV_t (P_{EV}) which is possible as the measure is based upon a common baseline price vector. Future welfare changes are discounted both by consumers' rate of time preference and by the human population growth rate. Also, given the exogenous time horizon a termination term is added to account for welfare impacts after the final period T. In this we assume that by T the economy is close to a steady state.

4. Model Specification

4.1 Ecological Specification and Data In applying GEEM to the Alaskan ecosystem, ecological studies of the Alaskan and other ecosystems were used. Time series of pollock biomass estimates exists for the period 1966 through 1997, and the rest of the data are from 1966 or interpolated to that date. Data were obtained for plant and animal populations, benchmark plant biomasses and animal biomass demands, and parameters that include embodied energies, basal metabolisms, and plant and animal weights and lifespans. Sources include numerous

---

[7] Defined as the difference between initial expenditure and that expenditure necessary to achieve the post-policy level of satisfaction at initial prices.

National Marine Fisheries Service publications and ecological journal articles. Details on data sources can be found in Finnoff and Tschirhart (2003).

Using this data, calibration yielded estimates for parameters in the plant and animal respiration and supply functions (Finnoff and Tschirhart, 2003). Calibration consists of simultaneously solving for each species the net energy expressions set to zero, first-order conditions or the derivatives of the net energy expressions set to zero, and the equilibrium conditions.

4.2 Economic Specification and Data In a similar fashion as with the ecosystem model, the economic specification is based on a chosen benchmark year, and the data were used in calibrations to estimate parameters. The benchmark dataset constructed in the analysis is shown in Table 1 where all values are in millions of dollars. The data sources include reports from the U.S. Department of Commerce, Bureau of Census, Bureau of Labor Statistics, the Alaskan Bureau of Economic Analysis, and others. Details on data sources are in Finnoff and Tschirhart (2004).

5. Policy Analysis

The NMFS in 2001 issued a Supplemental Environmental Impact Statement (SEIS) containing alternative management strategies that specify various pollock catch limits and no fishing zones to protect both the sea lions and the fishery. Using the linked CGE models, the effects of the management strategies on economic welfare are examined, and then the linked model is compared to a business-as-usual model that does not account for economy/ecosystem interactions.

The management strategies are differentiated here by the regulator's choice of *b* in the quota function (3.1). Holding $N_4^{\min}$ constant, *b* is varied by 30% and 170% of its 1997 harvest levels. (Numerous other harvest levels were examined but not reported. The 30% (170%) results are indicative of all runs below (above) the benchmark harvest.) All general equilibrium calculations and population updates were made with the nonlinear programming software package GAMS. The calculations consist of four steps: 1) Given current species populations, a GEEM equilibrium is found, determining species net energies, energy prices, biomass demands and supplies. 2) Given current species populations, the fishing manager determines the *TAC* (that is adjusted in separate scenarios by the two percentages above). 3) Given current species populations and capital and labor endowments, a CGE is found, delivering prices, fish harvests and other outputs, incomes, investment, savings, factor employment and the rent divergence, δ. 4) In the ecosystem, given the findings from step 1) and the *TAC* from step 2), the species populations are updated. In the economy, given current endowments and the findings form step 3), factor endowments are updated. The updated populations and endowments from steps 3) and 4) are then used to start the next period by retuning to step 1). The steps are repeated each period of the time horizon across each trade elasticity specification.

A benchmark scenario is initiated using the 1997 benchmark dataset, then simulated for 50 and 100 years.[8] Given natural resource stocks (species populations) whose growth is limited by biological carrying capacities, balanced growth is not a feature of the benchmark scenario. This is a departure from Ballard et al. or numerous other applications, where balanced growth is characterized by all quantities increasing by the same rate and constant relative prices. In the benchmark scenario, all quantities evolve at a constant rate, but the rate may vary over sectors owing to the reliance of the fishery and recreation sectors on biological natural resource inputs. Further, given heterogeneous growth of the natural resources, benchmark relative prices do not remain constant.

[8] Sequence lengths of 100 years and a discount rate of 4% were chosen as representative for Federal projects.

5.1 Ecosystem Impacts The impacts on populations of pollock, sea lions, sea otter and killer whales for the 30% and 170% management strategies are shown in Figure 2. Predicted populations (given actual harvests) prior to the 1997 calibration year and projections beyond 1997 are displayed. All populations move to new steady states, in as little as 10 years for phytoplankton (not shown) but as many as 30 years for killer whales. Phytoplankton are short-lived (less than one year) and reproduce rapidly, whereas killer whales are long-lived (twenty years) and reproduce slowly.[9] Reduced pollock harvests (30%) result in long-term increases in phytoplankton, sea urchins, sea lions and killer whales, and long-term decreases in zooplankton, kelp, and sea otters. The recreation sector will benefit from more sea lions and killer whales, but will be hurt by fewer sea otter.

To appreciate the general equilibrium nature of the population changes, consider the 170% harvests in some detail. The immediate affect of the higher harvest is to lower the pollock population. In the subsequent period the lower population increases the energy price sea lions pay to capture pollock and the sea lion demand for pollock decreases. Sea lion net energy decreases as a result and their population falls. These changes work their way up the food web as the killer whale population reacts in the same way to the fall in sea lions as the sea lion population reacted to the fall in pollock. The further up the food web from pollock, the less pronounced the impact. Where pollock populations fall by about 24%, sea lion and killer whale populations fall by about 13% and 9%, respectively.

5.2 Economic Impacts – Following changes in fishing policies, there occur many simultaneous changes in prices, incomes and profits. We can trace the flows of outputs, capital and labor between industries and between domestic and foreign sectors. More detail is in Finnoff and Tschirhart (2004). Here we concentrate on welfare impacts. The welfare impacts of

[9] Average lifespan enters into the population update equation, (2.9), similar to the way the less tangible species growth rates enters into the often-used but simplistic logistic update equation; thus, the lifespans are important in

alternative management strategies are quantified as discussed in Section 3.4. Welfare changes (from the reference) presented in Table 2 are the present value of the cumulative sum of equivalent variations P_{EV}[10] over 50 and 100 year planning horizons. For both horizons, leisure accruing to regional labor in the fishery during the off-season was valued at full, three quarters and half the wage rate. Under both horizons and across leisure values, decreasing the quota always results in cumulative aggregate welfare gains (P_{EV}). The longer the horizon and the greater the leisure values, the smaller the gains. For brevity, in the following discussion we focus on the30% reduced quota, noting that the 170% increased quota produces opposite results.

Figure 3 is helpful in understanding the fishery's contribution to the welfare changes. Starting from a steady state, T^0 is the season length and the average revenue per time from (3.5) is downward sloping as shown by the solid line. At T^0 factor payments are $C(\hat{w}^0,\hat{r}^0)$ which exceeds market-based factor payments $C(W,R)$ owing to rents. In the next period the fishery manager lowers the harvests and because the fish stock has not changed, the season length falls to T^1. The shorter season means less labor and capital in the fishery, but these remaining factors enjoy higher rents ($C(\hat{w}^1,\hat{r}^1)-C(W,R)$) per time employed as δ adjusts upward. As explained above, for labor the shorter season results in fewer fishery workers who enjoy higher rents per time worked and greater off-season leisure, while the workers who leave the fishery are employed at market wages in other sectors for the full year with no leisure.

In the second period the fish population is greater and the price of fish is higher because of the reduced harvest strategy. Both changes cause the average revenue curve to shift upward. The fishery manager sets a greater *TAC* by (3.1) because of the greater fish population, and the

determining whether population oscillations occur and how quickly populations will converge to steady state.

[10] In the absence of balanced growth in the reference sequence, we deflate all prices to 1997 levels using a modified Laspeyres formula $CPI_t=\left[\sum P_tQ_0 / \sum P_0Q_0\right]*100$ where CPI_t is the price index in period t, P_t current price of each commodity, Q_0 is the market quantity of each commodity in the baseline period (1997) and P_0 is the price of each

season length increases to T^2 although it is less than the initial season length. δ adjusts downward and rents fall to $C(\hat{w}^2,\hat{r}^2)-C(W,R)$. Some workers now return to the fishery from the other sectors, leaving their full-year market wages for higher part-year wages and leisure. In addition, because the fish population is greater, the fishery factors are more productive. Over the remainder of the planning horizons, the season lengths remain between T^0 and T^1 and the rents remain between the initial low value and the second period high value.

In a demonstration exercise, we quantify those portions of welfare changes attributable only to changes in ecosystem populations. The simulations were rerun with marine mammal inputs to recreation held at their reference sequence levels across the two *TAC* strategies. The portion of welfare change attributable to changes in marine mammals can then be inferred as the difference in periodic equivalent variations between the simulations with and without the impacts fishing has on the food web.[11] The ecosystem valuations for alternative quota rule are displayed in Table 3. While the magnitudes of the ecosystem valuations are small due to assumptions made in parameterizing the model, they are consistent for increases or decreases in ecosystem inputs. They loosely indicate the direct value to the economic system of marginal changes in ecosystem quality. Each one percent annual improvement in ecosystem quality in relation to the reference is worth roughly $110,000. Further, these values demonstrate that under a reduced *TAC*, if these ecosystem values were to be ignored the welfare impacts will be understated. Increased quota rules will result in overstated welfare benefits

6. Conclusion

We demonstrate that Steller sea lion recovery measures via alternative pollock quotas have consequences throughout the ecosystem and economy owing to the joint determination of

---

commodity in the baseline period. This follows the same general fashion of the BLS Consumer and Producer Price indices important variables. Quota changes cause altered levels of all ecosystem populations, economic factor reallocation, changes in all regional prices, incomes, demands, outputs, imports, exports, and differential rates of factor accumulation. Without a jointly- determined analysis, the benefits from a reduced quota accruing to the ecosystem inputs would be understated as would the costs of a slower growing capital stock. The mediating behavior of each system to shocks arising from the other is important for policy analysis.

Of the eight species modeled, four are used directly in the economy either as consumption goods (fish) or non consumption goods (marine mammals). Nevertheless, all species matter for the economy because the other four species are used indirectly as support for ecosystem functions. A portion of the regional welfare gains from reduced quotas follow from an economy relying less on resource extraction and more on resource non extraction. This result is consistent with a report from the Panel on Integrated Environmental and Economic Accounting which states: “economic research indicates that many renewable resources, especially in the public domain, are today more valuable as sources of environmental service flows than as sources of marketed commodities.” (Nordhaus and Kokkelenberg, 1999, p. 177)

Our reported welfare impacts of alternative fishing policies may be understated for three reasons. First, all species apart from pollock are at or close to a steady state in 1997. Changing pollock harvests, therefore, result in relatively small changes in other species. Second, the three marine mammals are assumed to be a small fraction of Alaska's ecological systems inputs to the economy. Third, non-use values associated with the ecosystem (e.g., existence values) are not considered. Turcin and Giraud (2001) conducted a willingness to pay survey that asked how much households were willing to pay for continuing the Federal Steller Sea Lion Recovery Program. They found Alaskan households willing to pay in total $25 million, and extrapolating

[11] Values attributable to ecosystem inputs were found as $EV^{L}_{t} - EV^{NL}_{t}$ where *L* refers to ecosystem impacts (or

to U.S. households the figure is $8 billion. Interestingly, household in the area of Alaska that contains critical habitat for the sea lions were willing to pay considerably less and in some cases negative amounts. These results do not indicate the existence value for changes in the sea lion populations, but they do suggest that the value may be substantial

Extensions of this work will include enlarging the community of species by admitting other harvested fish species (Pacific cod and herring), whale species (blue and sperm) and another marine mammal (Northern fur seal). This will allow for more testing of ecological hypotheses concerning how the economy and human actions impact the ecosystem. In addition, more economic sectors will be added by using IMPLAN data for the Alaskan economy.

CGE models are useful in judging alternative economic policies for their effects on resource allocation and on the distribution of net benefits. The objective of linking GEEM to CGE is to account for resource allocation in ecosystems as well so that the scope of policies that can be judged is broadened. While the economic and ecological underpinnings of this linked approach can be extended and improved in many ways, CGE/GEEM is a step toward integrating disciplines with common structures and goals.

linkages) being accounted for, and *NL* not accounted for (not linked).

References

Amir, S. 1979. “Economic Interpretations of Equilibrium Concepts in Ecological Systems,” *Journal of Social Biological Structures*, 2, 293-314.

Armington, P., 1969. "A Theory of Demand for Products Distinguished by Place of Production," *IMF Staff Papers*, 16, 159-178.

Arrow, K., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C. S. Holling, B.-O. Jansson, S. Levin, K.-G. Maeler, C. Perrings and D. Pimentel. 1995. “Economic Growth, Carrying Capacity and the Environment.”*Science*,268, April,520-21.

Ballard, C. L., D. Fullerton, J. B. Shoven, and J. Whalley, 1985. *A General Equilibrium Model for Tax Policy Evaluation*, The University of Chicago Press, Chicago.

Boyce, John R. 2004. Instrument choice in a fishery. *Journal of Environmental Economics and Management*, 47, 183-206.

Bovenberg, A. L. and L. H. Goulder, 1996. “Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analyses,” *American Economic Review*, **86**(4), 985-100.

Burniaux, J.M., J.P. Martin, G. Nicoletti and J.O. Martin, 1991. "A Multi-region Dynamic General Equilibrium Model for Quantifying the Costs of Curbing CO_2 emissions: A Technical Manual," *OECD Dept. of Economics and Statistics Working Paper # 104,* OECD.

Clark, C. W. 1976. *Mathematical Bioeconomics: The Optimal Management of RenewableResources*. 2nd ed. (1990) New York: Wiley.

Crocker, T.D. and J. Tschirhart, 1992. “Ecosystems, Externalities and Economies,” *Environmental and Resource Economics*, 2, 551-567.

Daily, G.C. 1997. *Nature's Services*, ed. G.C. Daily, Washington, D.C.: Island Press.

Finnoff, D., and J. Tschirhart, 2003. " Protecting an Endangered Species while Harvesting Its Prey in a General Equilibrium Ecosystem Model," *Land Economics*, 79, 160-180.

Finnoff, D., and J. Tschirhart, 2004. Linking Dynamic Economic and Ecological General Equilibrium Models. Working paper, University of Wyoming.

Hannon, B. 1973. "The Structure Of Ecosystems." *Journal of Theoretical Biology* 41: 535-546.

Harberger, A.C. 1974. *Taxation and Welfare*. Chicago: University of Chicago Press.

Herendeen, R. 1991. "Do Economic-Like Principles Predict Ecosystem Behavior Under Changing Resource Constraints?" In *Theoretical Studies Ecosystems: The Network Perspective*. eds. T. Burns and M. Higashi. New York: Cambridge University Press.

Homans, F.R. and J.E.Wilen, 1997. "A model of regulated open access resource use," *Journal of Environmental Economics and Management*, 32, 1-21.

Nordhaus, William D. and Edward C. Kokkelenberg, eds. 1999. *Nature's Numbers*, Washington, D.C.: National Academy Press.

SEIS (Supplemental Environmental Impact Statement). 2001. *Steller Sea Lion Protection Measures in the Federal Groundfish Fisheries off Alaska*. NMFS, Alaskan Region.

Shogren, J. F. and J. Tschirhart. 2000. *Protecting Endangered Species in the United States: Biological Needs, Political Realities, Economic Choices.* New York: Cambridge Un. Press.

Shoven, J.B., and J. Whalley. 1992. *Applying General Equilibrium*. Cambridge: Cambridge University Press.

Simpson, R. David, Roger A. Sedjo and John W. Reid. 1996. "Valuing Biodiversity for Use in Pharmaceutical Research." *Journal of Political Economy*, 104, 163-185.

Stephens, D.W. and J.R. Krebs. 1986. *Foraging Theory*. Princeton: Princeton University Press.

Tschirhart, J. 2000. "General Equilibrium of an Ecosystem." *J. Theoretical Biology,* 203: 13-32.

Tschirhart, J. 2002. "Resource Competition Among Plants: From Optimizing Individuals To Community Structure." *Ecological Modelling* 148: 191-212.

Tschirhart, J. 2003. "Ecological Transfers Parallel Economic Markets in a General Equilibrium Ecosystem Model." *Journal of Bioeconomics*, 5, 193-214.

Tschirhart, J. 2004. "A New Adaptive System Approach to Predator-prey Modeling" *Ecological Modelling,* 176, 255-276.

Weitzman, M. L. 1993. "What to Preserve? An Application of Diversity Theory to Crane Conservation," *Quarterly Journal of Economics*, CVIII, 157-183.

Table 1 Value of Benchmark Variables, in Million $

Variable	Value	Definition	Variable	Value	Definition
K_F	365.608	Fishery Capital	ω_K^{AK}	11263.681	Regional Capital Endowment
L_F	293.567	Fishery Labor	$\omega_K^{ш}$	307.325	Foreign Capital
$Q^M{}_F$	0.244	Fish Imports	ω_L^{AK}	9625.415	Regional Labor Endowment
Q_F	659.420	Aggregate Fish Output	$\omega_L^{ш}$	190.064	Foreign Labor
K_R	894.368	Recreation Capital	$C^T{}_{AF}$	24.443	Household Fish Demand
L_R	766.398	Recreation Labor	$C^T{}_R$	737.244	Household Recreation Demand
Q_R	1660.766	Aggregate Recreation Output	$C^T{}_{AC}$	19925.646	Household Composite Goods Demand
K_C	10311.029	Composite Goods Capital	S	201.764	Household Savings
L_C	8755.514	Composite Goods Labor	I_F	7.638	Fishery Investment
$Q^M{}_C$	10938.005	Composite Goods Imports	I_R	15.554	Recreation Investment
Q_C	30004.549	Aggregate Composite Goods Output	I_C	178.572	Composite Goods Investment
$X^D{}_F$	32.080	Regional Fishery Demand	$X^E{}_F$	627.340	Fish Exports
$X^D{}_R$	752.798	Regional Recreation Demand	$X^E{}_R$	907.968	Recreation Exports
$X^D{}_C$	20104.217	Regional Composite Goods Demand	$X^E{}_C$	9900.331	Composite Goods Exports

Table 2 Discounted Cumulative Welfare Impacts

Welfare Measure	Value of Leisure	Quota Rule	**50 Year Horizon (Million 1997 $)**	**100 Year Horizon (Million 1997 $)**
P_{EV}	100% Wage	30%	$1,117.77	$1,210.54
		170%	-$7,811.23	-$8,665.10
	75% Wage	30%	$1,530.77	$1,674.54
		170%	-$7,334.98	-$8,129.02
	50% Wage	30%	$1,943.77	$2,138.54
		170%	-$6,858.73	-$7,592.94

Table 3. Ecosystem Valuation Per Percentage Change in Ecosystem Inputs:

Welfare Measure	Value of Leisure	Quota Rule	**Average Annual Welfare Change Per 1 % Change in Ecosystem Inputs: Linked Model – Non-Linked(1997 $)**
EV_t	100%	30%	$109,626.43
		170%	$114,458.27
	75%	30%	$109,677.71
		170%	$114,493.98
	50%	30%	$109,728.99
		170%	$114,529.69

Figure 1 Economy Ecosystem Interaction

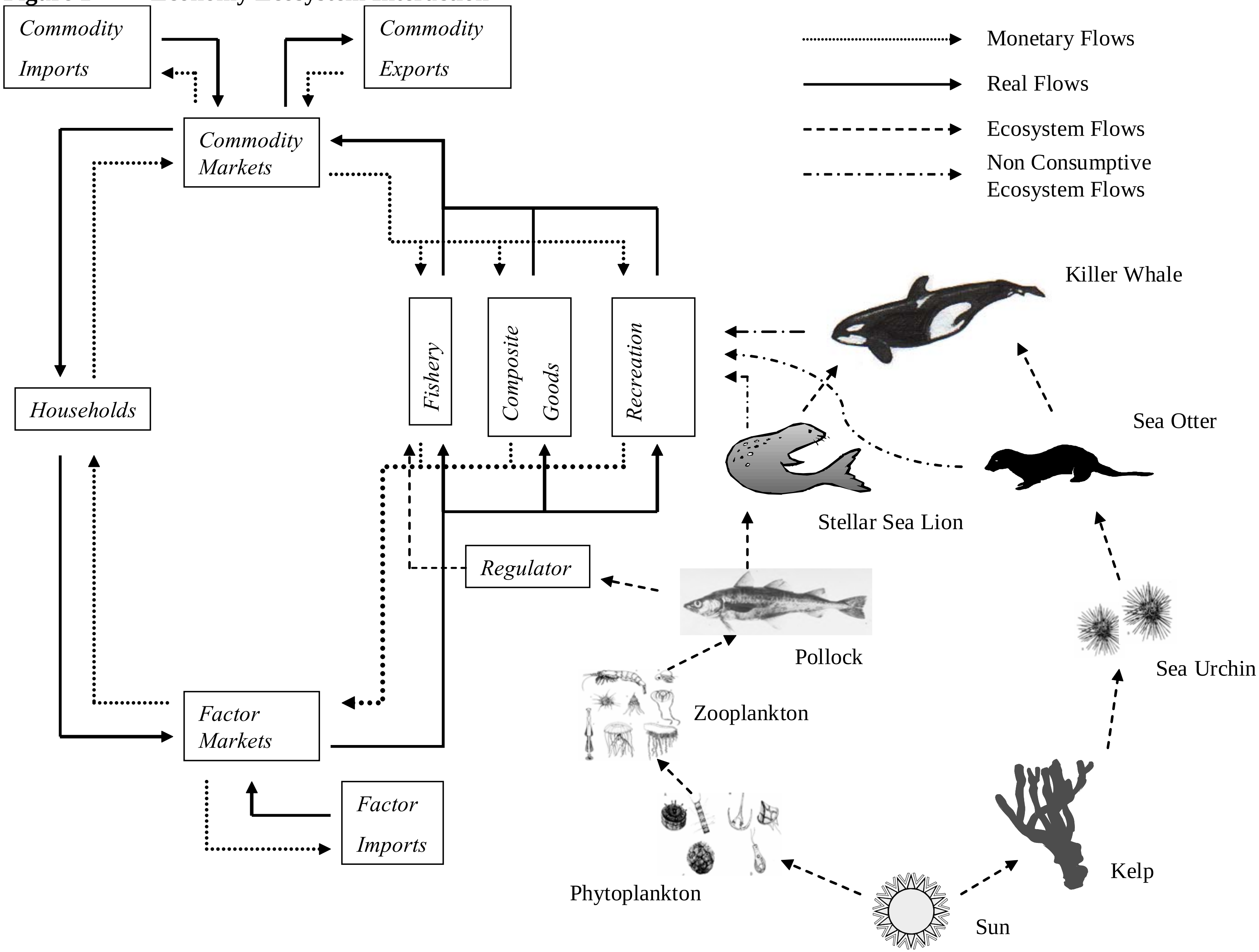
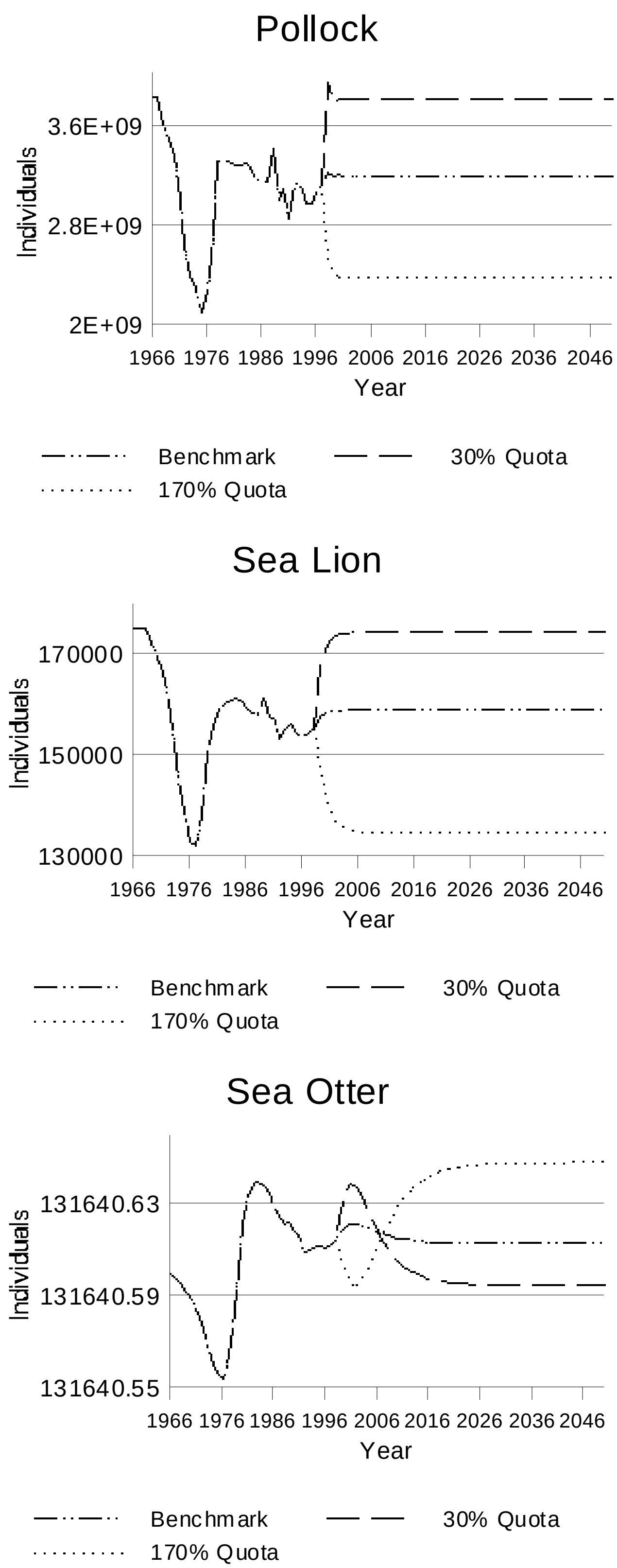
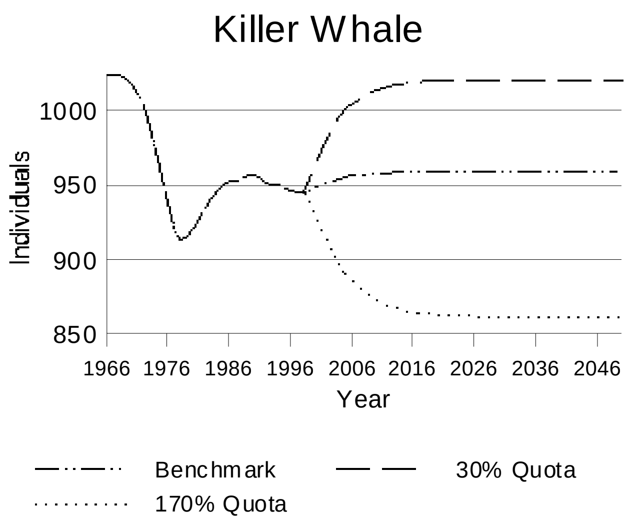


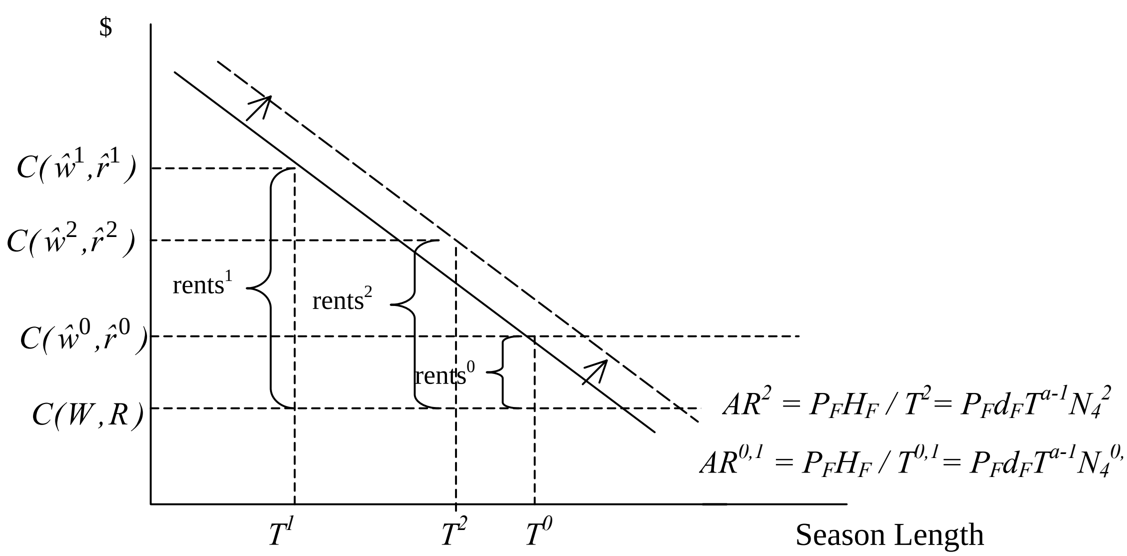
Figure 2 Ecosystem Populations





Killer Whale
Individuals
1000
950
900
850
1966 1976 1986 1996 2006 2016 2026 2036 2046
Year
Benchmark
30% Quota
170% Quota

Figure 3 Fishery Intra-season Rents



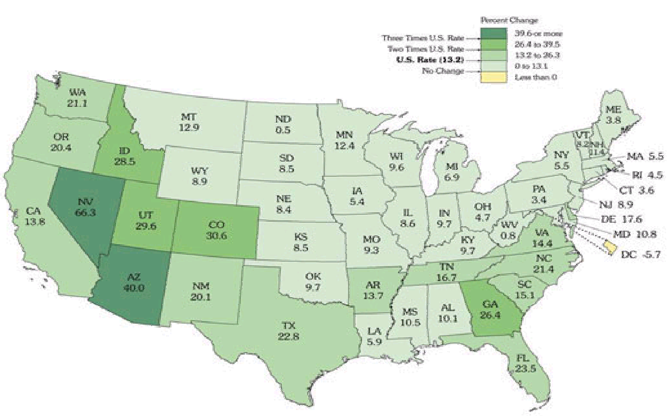
Integrated Modeling and Ecological Valuation

David Brookshire (PI)
Julie Stromberg (Co-PI)
Arriana Brand, Janie Chermak
Bonnie Colby, Mark Dixon, David Goodrich
John Loomis, Thomas Maddock
Holly Richter, Steven Stewart (Co-PI)
Jennifer Thacher

The University of New Mexico

Demographic Changes: Population Has Grown Fastest in the West, Particularly in the "Public Land States"

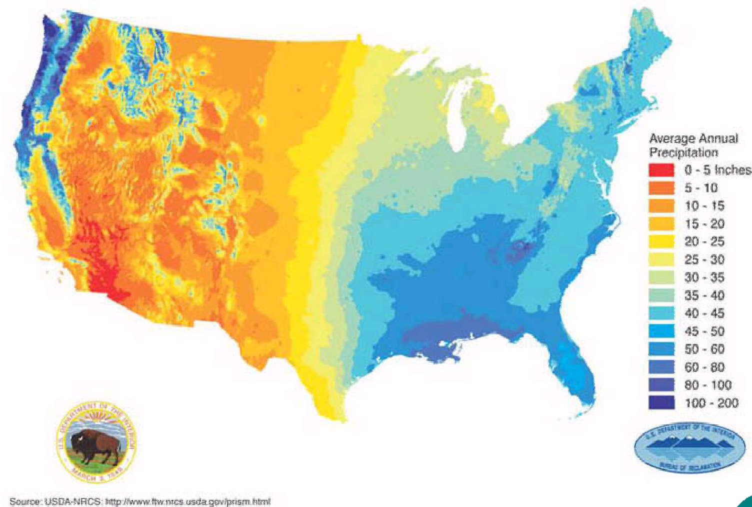
Percent Change in Resident Population for the 48 States and the District of Columbia: 1990 to 2000



- Darker areas denote faster growth rates.
- Nevada (66%) and Arizona (40%) lead the nation.
- Intermountain states average about 30%.

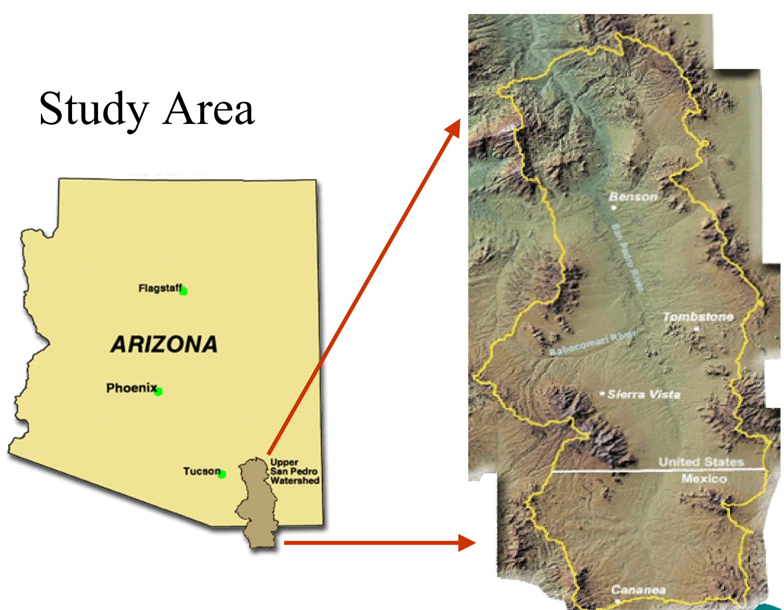
The University of New Mexico

Average Inches of Annual Precipitation in the United States 1961-1990



The University of New Mexico

Study Area



The University of New Mexico

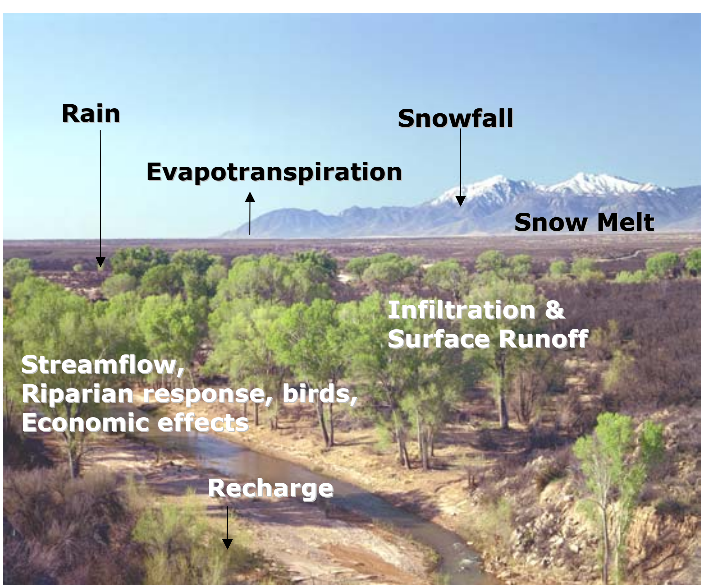
Study Areas

San Pedro
River Region

Bosque Del Apache
National Wildlife Refuge

The University of New Mexico

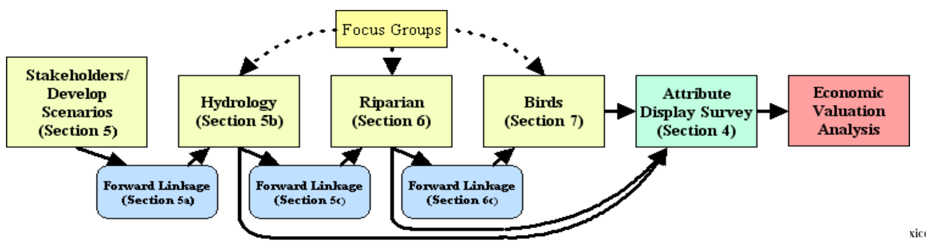
SAHRA/UA/UNM Research



The University of New Mexico

Objectives

- Integrate a hydrologic, vegetation, avian and economic models into an integrated framework
- Couple natural science information with socio-behavioral information to better understanding of both intra-site and inter-site data transfer functions
- Determine the value of changes in ecological systems caused by changes in hydrological profiles
- Introduce the non-market derived demand for water into an integrated demand management framework



Scenarios And Study Framework

- 2-anthropogenic and 2-climatic
- Use two stated preference techniques for valuation
  - Contingent valuation and choice models
- 3 information gradients
  - Fully integrated science models
  - 2 Transferable indexes
- 2 test sites through an internet-based visualization survey
- San Pedro River and Rio Grande

The University of New Mexico

Rio Grande

San Pedro

Alternative Sites to Bosque Del Apache

Alternative Sites:

- Rio Grande Nature Center - Albuquerque
- Randal Davey Nature Center – Santa Fe
- Riverside Nature Center - Farmington
- The Nature Conservancy's Bear Mountain Lodge – Silver City
- Guadalupe Canyon – Douglas, AZ
- McKitrrick Canyon - Carlsbad

Site Attributes:

- Riparian areas without the extensive wetland influence
- Gila, Animas and McKitrrick Creek are un-damned
- All have similar issues with urban competition for water
- Lower visitation

The University of New Mexico

Why Two Study Sites?
Issues Of Transferability

•Don’t always have the ability to collect original data.

–Timeframe

–Lacking of basic science

•Cost of a primary studies (both economic and scientific) may be greater than value added from improved accuracy.

The University of New Mexico

Data Transfer Issues

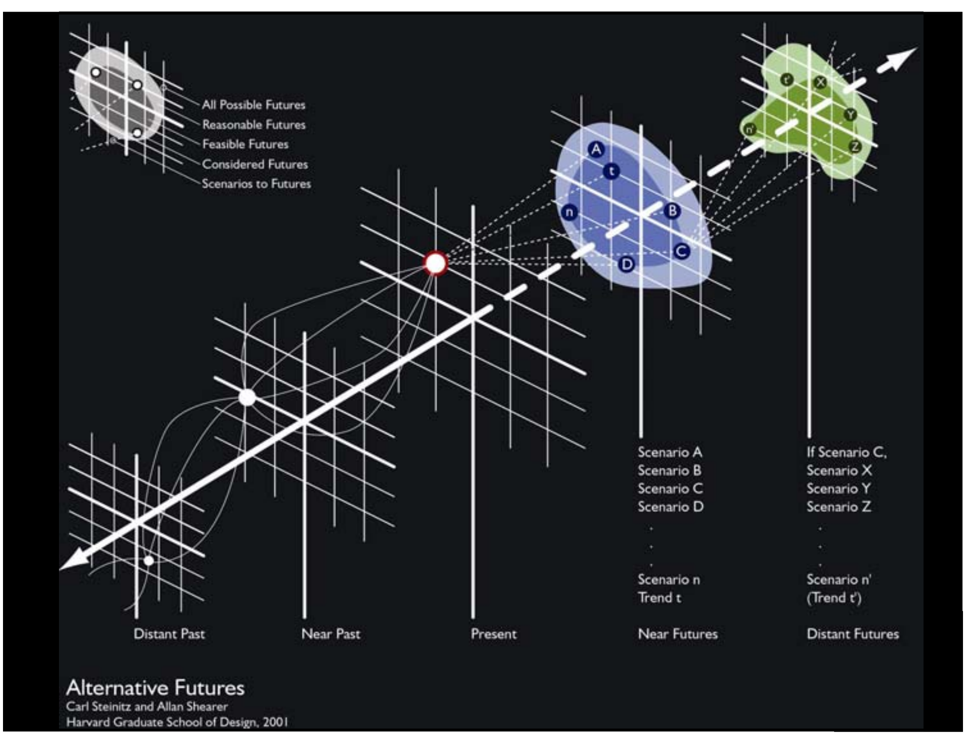
- What is the information we take from other disciplines in our economic analysis?
- Does this information itself rely on some type of transfer?
- What predefined conditions, if any, is the policy analyst to assume?

The University of New Mexico

Alternative Futures Study

- Explores how urban growth and change in the rapidly developing Upper San Pedro Basin might influence the hydrology and biodiversity of the area.
- Evaluation of individual scenarios from the present time (1997-2000) to 20 years in the future (2020).
- Provides information to stakeholders in the area regarding issues and planning choices, and their possible consequences.
- Alternative Futures study conducted by Department of Defense, Desert Research Institute, Harvard Graduate School of Design, IMADES, and The University of Arizona.

The University of New Mexico



The Alternative Futures

◦ **PLANS** -- based on interpretation of the current Arizona and Sonora plans, and a forecast population of 95,000 in 2020 in the Arizona portion of the study area.

° **CONSTRAINED --** assumes lower than forecast population growth in Arizona. Development is concentrated in existing developed areas.

° **OPEN --** assumes higher than forecast population growth in Arizona, with major reductions of development control. Sonora remains as forecast.

The University of New Mexico

Focus Groups

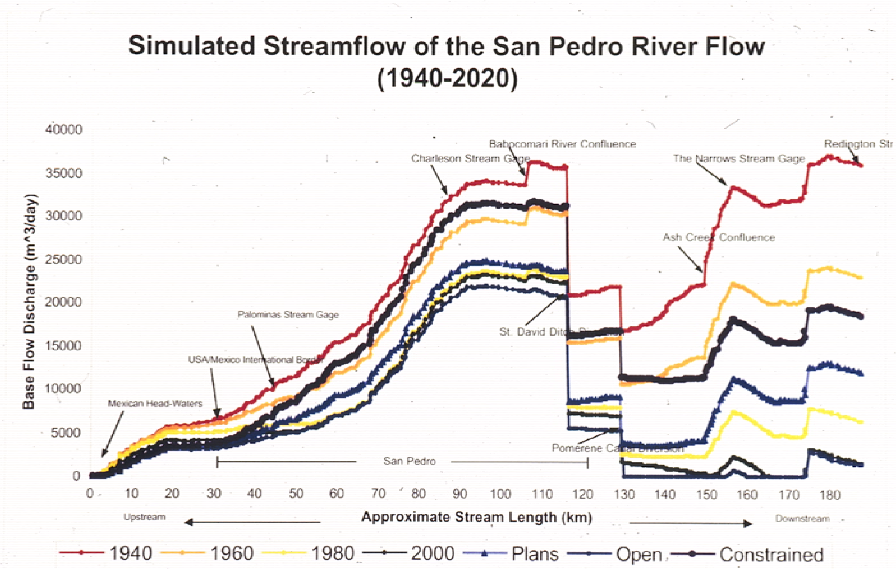
- Unique aspect of this study
- Necessary to bridge the gap between the specialized science of scientists and general knowledge/perception of public
- Groups will help determine what information is collected and how that correlates with water management changes
- Groups will identify important attributes
  - Those will be measured by natural scientists and included in the choice model

The University of New Mexico

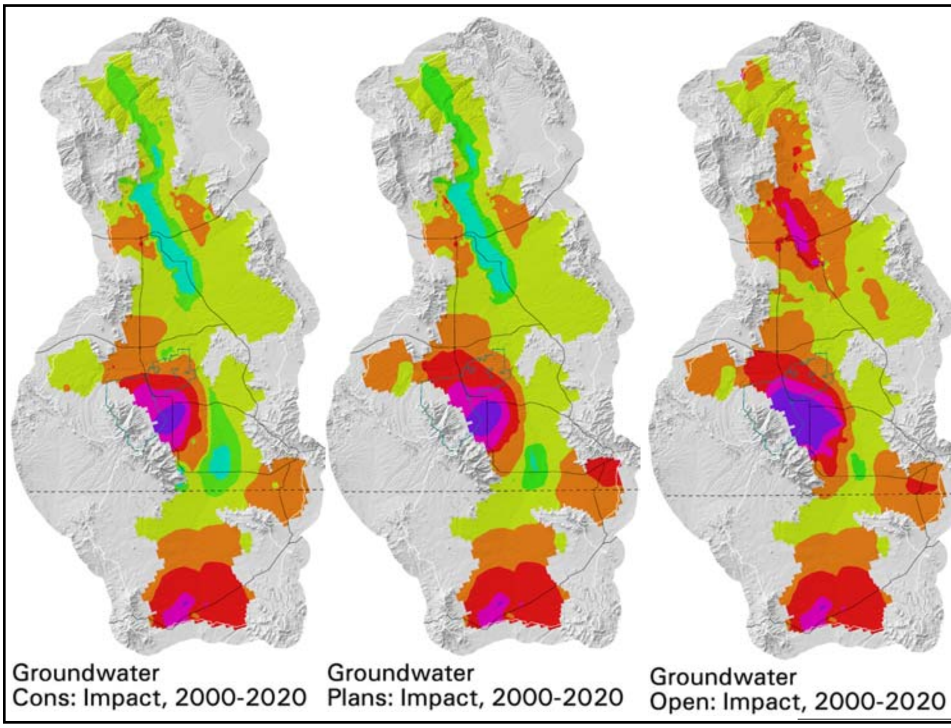
Valuation and Visualization Projections

- Web-enabled science-based Economic Valuation and Visualization System (EVVS)
  - Geographic information technologies
    - Geo-databases
  - Geographic information system (GIS)
  - Internet-enabled mapping technologies
  - Integrating technologies

The University of New Mexico



The University of New Mexico



Two Stated-Preference Methods

- Choice models (CM)
- Dichotomous choice contingent valuation models (CVM)
- We will examine:
  - Convergent validity for single attribute and policy (multiple attribute)
  - Valuation across methods
  - Conduct traditional tests of scope and embedding
  - Examine differences between on-site and Internet survey formats

The University of New Mexico

Treatments

Sample Size	Model	Internet	In Person	Total Surveys
San Pedro				
	IM CM	300	100	400
	Index CM	150	50	200
	Trad CM	150	50	200
San Pedro				
	IM CM	600	200	800
	Index CM	300	100	400
	Trad CM	300	100	400
Bosque Del Apache				
(Or Similar Site)	IM CM	150	50	200
	Index CM	150	50	200
	Totals	2100	700	2800

IM – Integrated Model

CM- Choice Model

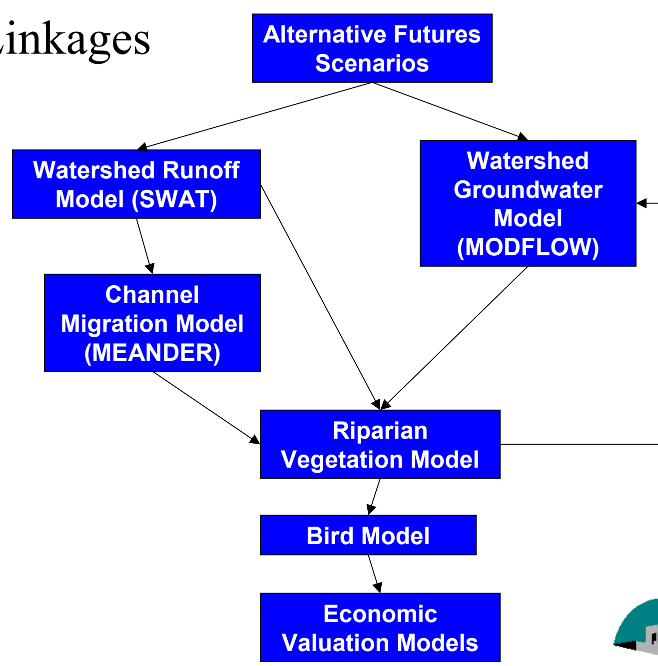
Trad – Traditional Model – (Not Significantly Anchored In Science)

Index- "Off The Shelf" Scientific Information

CVM – Contingent Valuation

The University of New Mexico

Model Linkages



The University of New Mexico

Hydrology Component

- Analysis of anthropogenic and climate changes in San Pedro River Region
- Alternative Futures Study (AFS)
- Hydrological Models
  - GIS-Based Modflow
  - Water Runoff
  - Penman-Monteith Riparian Evapotranspiration

The University of New Mexico

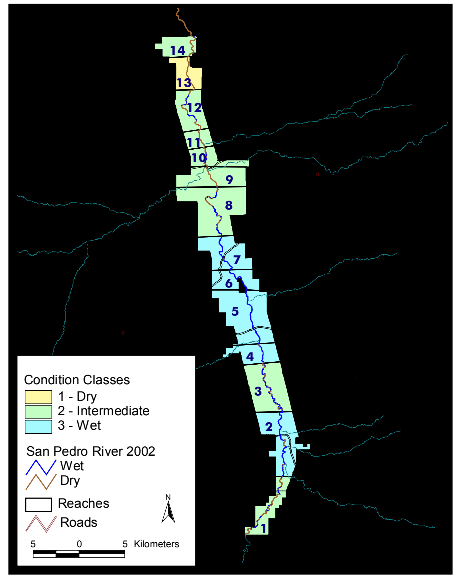
Riparian Component

- How changes in surface flow and ground water levels effect
  - Riparian vegetation distribution
  - Composition
  - Structure
- Use existing information and backward linkages to:
  - Identify relationships
  - Develop reach-scale indices
  - Model finer-scale, patch level riparian vegetation change in response to scenarios

The University of New Mexico

Coarse-scale Vegetation Modeling

- Divided river into 14 reaches based on physical characteristics
- Determined relationships between vegetation traits (e.g., cottonwood vs. tamarisk abundance) and site hydrology
- Classified reaches into 3 condition classes (dry, intermediate, wet) based on vegetation traits (bioindicators) indicative of site hydrology
- Will project reach-scale vegetation changes based on changes in condition class under alternative futures



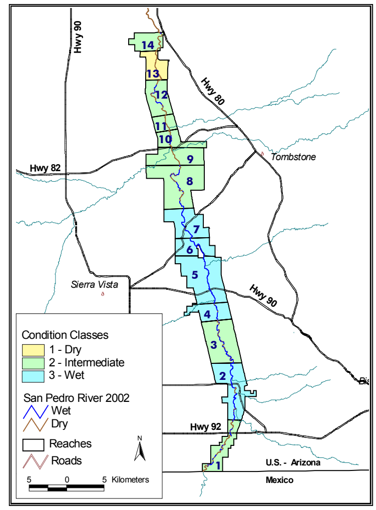
Bird Component

- Objective
  - To determine the impact of vegetation changes on bird populations and communities for differing type of reaches of the SPR
  - Provide characteristics of bird abundance, productivity, richness, and diversity

The University of New Mexico

Coarse-Scale Bird Modeling

- Classified bird sampling locations by 3 condition classes (following Stromberg et al.) and 5 habitats (cottonwood, mesquite, salt cedar, grassland, and desert scrub).
- Quantified avian abundance, nest success, and species richness as a function of habitat / condition class.
- Can project habitat/condition class changes affecting birds under alternative futures.



The University of New Mexico

Major Issues

1. How do individuals value marginal changes in indices of ecosystem health and can such indices be used as proxies for specific benefits?
2. Which benefits contribute most directly to human well-being, what are their relative values, and what are the most efficient methods of valuing them?
3. What is the tradeoff between the accuracy associated with more detailed benefit transfers and the more costly information necessary to provide them?
4. To what extent can simpler “reduced form” transfer functions mitigate inaccuracies?

The University of New Mexico

Expected Results For Determining Derived Demand For Water

- A fully integrated valuation framework using the best science and alternative valuation methods.
- Methodological insights into non-market valuation techniques.
- Alternative data transfer functions that rely upon alternative information gradients.
- Non-market water demand valuation functions for integrated modeling.

The University of New Mexico

Thank You

Comments on the Papers by Finoff and Tschirhart and Hammitt and von Stackelberg

R. David Simpson
NCEE

A good place to start my discussion of these innovative and stimulating contributions may be by repeating the commonplace observation that economics and ecology both stem from the same Greek root: *oikos*, meaning house or household. Ecology is the study of "nature's household"; economics, that of the society's. Before Ernst Häckel coined the term *oecologie* in 1869, though, the disciplines were even more closely tied in their terminology. The natural historian Gilbert White wrote in 1789 that " . . . nature, who is a great economist, converts the recreation of one animal to the support of another!" and "The most insignificant insects and reptiles are of much more consequence, and have much more influence in the Economy [of] nature, than the incurious are aware of".

Contacts between the disciplines continued. Charles Darwin credited his reading of Thomas Malthus's *Essay on Population* for providing the insight that motivates the "survival of the fittest" in *The Origin of Species*, while Karl Marx is said to have intended to dedicate one of the volumes of *Das Kapital* to Darwin—at least until Engels persuaded him to identify a less bourgeois inspiration.

Cross-fertilization continued into the next century, including John Maynard-Smith's application of game theory in the spirit of John von Neuman and Oskar Morgenstern and John Nash to animal behavior, and Richard Nelson and Sidney Winter's explorations of evolutionary principles in economics.

So, the first of the papers I discuss has a long list of illustrious antecedents—and in whose distinguished company, I would venture to say, it is not misplaced. David Finoff and John Tschirhart's work is insightful and innovative. If I ask some questions and note some possible limitations in what follows, my remarks are intended in no way to temper my general impression that their work is original and valuable.

I must confess that while reading a paper combining fundamental principles of general equilibrium analysis with an application to large Alaskan marine mammals my imagination began to work overtime (see figures 1a and 1b). As it did, though, perhaps the couplet I composed captured some essential element of Finoff and Tschirhart's analysis:

The time has come, the Walras said, to speak of new devices
For getting rich, by sparing fish, when Joules mark their prices

Figure 1a
Marie-Ésprit Léon Walras
1834-1910

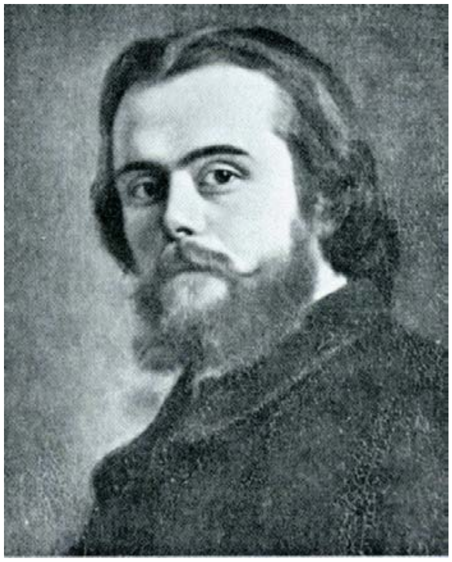
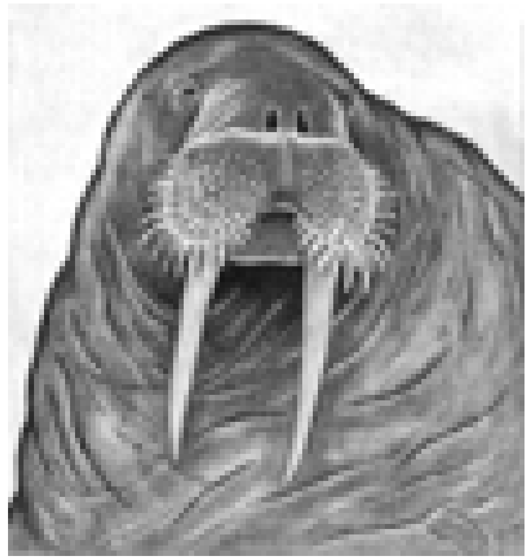


Figure 1b
Odobenus Romarus
The Pacific Walrus



While I do think it's ingenious to think of the ecological "prices" of fish and other marine organisms being calibrated in Joules, I do have some nagging doubts about the procedure. I might express the first by asking "Are *we* likely to be any better at doing *their* stuff than *they* are at doing *ours*?" The "we" and the "they" are, respectively, economists and ecologists. While I've discussed some of the overlaps between the fields in my opening remarks, some recent forays by ecologists into economics have not been met with favor by many economists. A 1997 effort by Robert Costanza and numerous coauthors was roundly criticized for confusing marginal and average notions, failing to appreciate the limitations of ability to pay on willingness to pay, and as Michael Toman famously remarked, offering "A serious underestimate of infinity." A generation later the ecologist Howard Odum proposed measuring the value of ecosystem services by the energy required to perform them. This proposal betrays, as Partha Dasgupta has noted, an apparent want of familiarity with Paul Samuelson's nonsubstitution theorem. The nonsubstitution theorem demonstrates that reducing values to a common metric reflecting the contribution of any single input is, in general, impossible.

I'm also a little concerned with an attempt to describe the functioning of one complex system—a marine ecosystem—by analogy to another—a general competitive equilibrium—when students of the former have already developed an elaborate description of at least some of its mechanics. I'm referring to the evolutionary paradigm in which the fit survive and replicate themselves. I'll also note in passing that it's always seemed to me that evolutionary arguments in economics founder on the absence of a mechanism of inheritance. There is no, or at best a very poor, analog in economics to the role of genetics in biology.

Having expressed my doubts about Finoff and Tschirhart's use of energy as if it were the objective of a biological system, I should also say that they have certainly not fabricated it from whole cloth. The authors include many citations to biologists who have made similar assumptions, and note especially that it's a staple of the "optimal foraging literature" that describes creatures' feeding habits and the tradeoffs they make between gathering food and risking predation while doing so. Nor, I should add, do Finoff and Tschirhart fall into Odum's error of supposing that values can be represented by equivalent energy *inputs*; in Finoff and Tschirhart, energy is the objective to be maximized, not the fundamental unit of account in which all inputs and outputs are to be measured.[1]

Still, I can't help hearing my mother's voice saying "Eat your vegetables!" What I mean is that a balanced diet requires a mixture of foods; choosing our own diets to maximize solely calories within linear budget constraints would have us subsisting solely on lard, albeit, presumably, not for long before our arteries clogged. In short, and in economic terms, Finoff and Tschirhart ask us to suppose that "biological production functions" exhibit straight-line isoquants whose slopes are determined entirely by relative calorie contents of available food sources. This may be a reasonable approximation, but I guess I'd be more comfortable if I felt I knew the biology a little better.

I have another concern with Finoff and Tschirhart's analysis, although I suspect that it revolves around little more than an expositional suggestion to clarify the notion in their paper. The classic proof of general competitive equilibrium in economics demonstrates that *there exists a set of prices* at which all supplies and demands balance. The limitations of this theorem are well known. It is silent on how these prices are determined. What happens if there is some departure from such prices? My understanding is that the question has never adequately been resolved, but most of the economics profession believes that the intuitive notions that prices go up when demand exceeds supply and decline otherwise provide a workable depiction of the process of reaching equilibrium. Is there a similar process driving convergence to ecological equilibrium in Finoff and Tschirhart's work? "Prices" are determined by energy content, and so it is not clear how these prices would adjust to clear the "markets" for species. Presumably the energy cost of seeking a certain prey decreases in that species abundance, but I'd like to see more explanation of this.

One mechanism for equilibration is apparent: species that acquire more energy through preying on others than they expend in predation or lose by becoming prey themselves thrive. In this respect, population growth is to positive net energy flux as industrial entry is to supernormal profits. Processes of industrial entry may not be wholly adequate for eliminating supernormal profits when barriers exist to entry, however. I'm curious as to whether similar concerns might apply in the biological model.

---

[1] Somewhat ironically, and wholly by coincidence, between the time I presented my oral comments at the workshop and writing them up now I picked up a copy of Robert Nadeau's recent book *The Wealth of Nature*. Nadeau, following Philip Mirowski, develops the thesis that neoclassical economics is modeled on 19th century physics. In Nadeau and Mirowski's view, neoclassical economists did little save relabel the variables in models of physics, and the analogy between utility and energy in their respective disciplines is exact. Without commenting as to the validity of his critique, I'll simply say that Nadeau might find it ironic to see economists now structuring a model of biology in which energy is now the analog to utility.

My remarks thus far have largely focused on the question of whether the net energy flux Finoff and Tschirhart use to motivate their model is the “right” objective. This is a relative matter, though. “Right” for what? I can see several potential purposes:

- Describing population dynamics.
- Calculating and explaining the relative abundance of species.
- Developing real-world policy advice.

It seems that, in order adequately to serve the last of these purposes, the model would have to be fairly closely calibrated to biological data and demonstrate an ability closely to explain and predict them. It is no criticism of a model of so complex a phenomenon to suggest that the model has not yet done this. It’s a very, very hard problem!

Thus, I don’t think Finoff and Tschirhart’s contribution is sufficiently refined as yet to form the basis for concise policy guidance. I might also note in passing that various elements of the problem over and above the fundamental biology make the analysis even more difficult. Consider, for example, fisheries policy: to what combination of political and social factors do regulators respond, and how effective are their regulations? These considerations make the development of policy advice even more complicated.

As another example of policy interactions, Finoff and Tschirhart note that fishermen may earn quasi-rents in that their labor is seasonal. It’s difficult, then, to know how to evaluate their earnings and opportunity costs of time. As a personal aside, I grew up in a small fishing town on Puget Sound in Washington State. The area had been settled at the turn of the 19th century by Serbo-Croatian immigrants whose descendents resembled professional basketball player Vlade Divac in appearance, stature, and, in some instances, athletic ability. One guy who was a few years older than me—and whom we all envied greatly—spent his summers fishing in the Gulf of Alaska. This paid him well enough that he drove an expensive sports car. He attended college, on a basketball scholarship, through the other seasons. The rumor around town was that he was also collecting unemployment benefits since he was unable to fish during basketball season but he was, or so he claimed, prepared to quit school and the team if he could find employment. So, the interaction between labor and fishery policies might affect results as well! To be fair, Finoff and Tschirhart demonstrate that their results are not sensitive to wage rate assumptions. Still, any number of interrelated policy interactions might affect the analysis. The collective uncertainties introduced at all the many stages of the analysis might be enough to propagate cumulative errors large enough to preclude precise policy guidance.

If Finoff and Tschirhart’s analysis is not (yet) well enough grounded to provide concise policy advice, what are its chief merits? I think they lie in providing a concise and thought-provoking paradigm for thinking about interrelated social and ecological systems. Whether or not a biological approach modeled after economic equilibrium is accurate, there’s tremendous value simply in communicating the possibility of approaching problems in this way and providing concrete instances of parallels and differences between biological and social systems.

Another virtue of Finoff and Tschirhart's approach may be that it facilitates "informationally dense," for want of a better term, interpretations of a system's state. Economists often make much of the informational role of prices: they tell us everything we need to know about preferences, costs of production, future prospects, etc. The "energy prices" of Finoff and Tschirhart's model may perform a similar role of describing the state of the biological system. Another analogy comes to mind. Whether or not a particular animal is eaten by another is, of course, a random event, and can't be accurately predicted. Yet on the aggregate level we should be able to say something about general patterns of predation and their consequences for relative abundance. Just as the logistic model of infection generates aggregate regularities from a host of individually stochastic events, the Finoff and Tschirhart paper may usefully reduce complex stochastic phenomena to the compact summary statistics of "prices".

Let me conclude my discussion of Finoff and Tschirhart with one final reservation, however. The paper is concerned with what I might describe as "most-of-the-time" behavior on a path toward a steady-state equilibrium. Our greatest social concern with biological systems often involves rare stochastic events, however. How vulnerable are such systems to climate change? To invasive species? It is, of course, difficult to predict the response to an unpredictable shock, but another useful direction for research might be to consider the "resilience"—to borrow a loaded term from the ecological literature—of such systems.

The paper by James Hammitt and Katarina von Stackelberg takes up some similarly complex issues of ecological and economic interactions using a very different set of tools. I might also note that, because Hammitt and von Stackelberg have only been working on a difficult problem for a limited time, the paper I had to review is still preliminary and incomplete.[2] I will, then, be commenting on their procedures rather than their results.

My first comment is simply to re-emphasize that Hammitt and von Stackelberg are discussing extremely difficult issues. What are the effects of PCB contamination on human health and ecosystem functioning, and how do people form values regarding these effects? If, as Hammitt and von Stackelberg propose, such values are to be elicited by asking stated preference questions, the questions will necessarily be very complex.

The authors are off to an impressive start in formulating the questions. I've never read a paper that discusses, within the span of a few pages, concepts as variesd as "PCB congenors . . . chloronated in the *ortho* . . . *meta* and *para* positions"; " . . . the induction of cytochrome P450 enzymes . . ."and "the McCarthy Scales of Children's Abilities, . . . the Peabody Picture Vocabulary Test-Revised and Buss and Plomin Emotionality Activity Sociability Temperament Survey for Children . . . and the Wechsler Intelligence Scale for Children-Revised (WISC-R)"! This breadth of coverage is both impressive to the reader and challenging for the authors. They will need to knit together the analysis in such a way as to make it cogent to people who are not experts in all fields (who include

[2] I might also note that the project reported at the workshop by David Brookshire was still too recent for there to have been any written material for me to review.

just about everyone except the authors), as well as to reduce these issues to terms that will be comprehensible to their stated preference survey respondents.

While it may always be implicit, perhaps I should mention explicitly before what I say next that "the opinions expressed here are those of the discussant and not necessarily those of the Agency . . . " It seems to me that two questions can be asked of any exercise in valuation, and of stated preference approaches in particular.

1. Are the specific answers generated useful for making policy? And
2. Are we learning more about the validity, reliability, and transferability of the methods employed?

It is difficult to see how one can posit a positive answer to the first without presenting more evidence as to the second.

From this perspective, Hammitt and von Stackelberg are building in interesting and useful tests. By approaching the same phenomenon of PCB contamination from a variety of angles, they are building in cross-checks as to the validity of each. Of particular interest may be their proposal to alternate the order in which they ask questions concerning human health and ecological effects. *In theory* it shouldn't matter if a respondent is asked first about one and then the other, or if the order is reversed. It will be interesting to see if this novel twist on the "embedding" question yields the anticipated result.[3]

It's interesting to see researchers grappling with such challenging questions. One way of thinking about the types of things that Hammitt and von Stackelberg are considering is that they're exploring public attitudes toward experience goods with which people have little or any experience. The severe health consequences of PCB exposure will, for most of us, be encountered once in our lifetimes and at the end of our lives at that. The ecological consequences of PCB are even further from the realm of things with which most people have had any experience.

I'm reminded of something I've heard Dan Bromley say—though I should caution that I can't claim to be quoting exactly, but rather, to the best of my recollection: "If you think prices come from markets, you probably believe milk comes from plastic bottles." I think what he means by this is that the properties we attribute to prices—and some economists assert attributes of foresight and rationality that border on the magical—arise in institutional and cognitive circumstances that have often evolved over long periods of time. What does it mean to be eliciting "prices" respondents profess to be willing to pay absent the trappings of a market? I have no answer to propose, but suspect that we might better inform and refine our attempts at valuation if we could incorporate into our analysis an understanding of what motivates the formation of markets and what we can infer from their absence.

---

[3] I continue to be somewhat surprised that the consistency tests proposed by Peter Diamond in his 1996 *Journal of Environmental Economics and Management* seem to have attracted as little attention as they have.

EPA Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions – A STAR Progress Review Workshop.

Session IV

Juha Siikamäki
Fellow, Resources for the Future

Discussion of two presentations:

"Joint Determination in General Equilibrium Ecology/Economy Model"
by David Finnoff and John Tschirhart and

"Contingent Valuation for Ecological and Non-Cancer Effects within an Integrated Human Health and Ecological Risk Assessment Model"
by James Hammitt and Katherine von Stackelberg.

==

"Joint Determination in General Equilibrium Ecology/Economy Model"

This paper by David Finnoff and John Tschirhart is part of their research program, in which the authors have developed a joint ecology/economy general equilibrium framework. This modeling framework suggests concepts to modeling ecology/economy interactions, which makes the research effort particularly challenging and ambitious.

The economic component of the joint equilibrium framework by Finnoff and Tschirhart comprises a standard computable equilibrium model of the economic sector, in this case, the fishing industry. The ecological component (GEEM, general equilibrium ecosystem model) of the framework extends the economic equilibrium model to modeling ecosystems. While the economic model comprises individual agents (consumers and firms), which maximize their objective functions (utility, profit), the ecosystem model comprises different species, which maximize their net energy intake. Ecosystems are organized as hierarchical food webs, which are assumed to transfer energy between different trophic levels via "energy markets," conceptually much the same way as goods and the factors of production are transferred within the economy. Each period, all energy markets are required to clear, bringing the ecosystem to equilibrium.

My discussion highlights the ecological modeling tradition[1] and makes an attempt to place the research by Finnoff and Tschirhart into a larger context. I will discuss different ecological modeling approaches by focusing on their origins.

Most mathematical models in ecology relevant to the Finnoff and Tschirhart paper are *population-level* models. The first such models were introduced well before ecology became an established discipline. Malthus' prediction of the human population growth introduced an exponential growth model in the late 1700s. A few decades later in the 1830s, Verhulst incorporated a carrying capacity constraint in the exponential growth model and thereby formulated the widely used logistic growth model, which has an S-shaped population growth curve. In the 1920s and '30s, physicists Lotka and Volterra developed sophisticated mathematical models of, among other things, species competition and predator-prey interactions. These models, as well as the host-parasite models by Nicholson and Bailey (1935), are still some of the fundamental mathematical models in ecology. The approach taken by Lotka and Volterra influenced economics (for example, Samuelson notes their work in the introduction of his

[1] See, for example, Begon et al. 1996, Edelstein-Keshet 1988, Real et al. 1991.

textbook), and their models of competition were also introduced to economics. May (1976 and elsewhere) demonstrated that simple deterministic models could drive complicated and even chaotic behavior, with completely different outcomes driven by slight differences in initial conditions and population parameters. Current themes in population ecology involve developing complex dynamic models, in particular, meta-population models (Hanski 1999).

Individual-level ecological models relevant to the Finnoff-Tschirhart paper deal with optimal foraging behavior. These models draw directly from economics and explain animals' strategies to exploit resources most efficiently. MacArthur and Pianka (1966) first adapted the economic model to a patch choice problem, proposing that foraging decisions are based on the relative benefits and costs of foraging on alternative patches. A rich consequent literature on foraging behavior has thereafter addressed time spent foraging on each patch, nutritional constraints, learning and memory, risk and stochastic factors, as well as fitness and the genetic base of behavior, and other factors. Central to the foraging studies is the assumed relationship between the behavior of organisms and their net energy intake. Optimal foraging studies often view organism's rate of energy intake as the proxy of evolutionary fitness.

The concept of *ecosystem*, which was introduced by Tansley (1935) and Lindeman (1942), emphasizes that biotic community is not differentiated from its abiotic environment and used the term "ecosystem" to denote the biological community integrated with the abiotic environment. Ecosystem is viewed as the fundamental ecological unit, and organisms within an ecosystem may be grouped into a series of discrete trophic levels. The key processes structuring ecosystems across spatial and temporal scales are tested and discussed, for example, by Holling (1992) and Holling et al. (1995).

I will now proceed to discussing the paper by Finnoff and Tschirhart.

The ecological scales of GEEM and research questions

The suitable model type and its complexity depend on the research question. In this case, the modeling effort seeks to identify prices and quantities of final goods and the factors of production, predator and prey biomass consumption, and species populations in the ecosystem. The ecological questions are, therefore, population-level questions. However, the GEEM is an individual-level model, which is aggregated to the ecosystem level by employing representative organisms/animals (the ecological counterparts of representative consumer/firm). Alternatively, one could combine the economic model with a mainstream dynamic population model from ecology. Multi-species dynamic models are demanding, but using numerical simulation models and software may facilitate complex modeling efforts. The question then becomes which modeling approach is more useful and accurate: the joint ecology/economy equilibrium model or a "mainstream" bioeconomic model (see, e.g., Clark 1990, Sanchirico and Wilen 2001).

Since an altogether new modeling approach is being introduced, it would be valuable to see a comparison of alternative modeling approaches applied to the same problem. Different models could be compared relative to their predictive power. Such a comparison would help determine which types of modeling efforts the GEEM is suitable for, and on the other hand, which modeling may be best carried out by using mainstream bioeconomic models.

Data needs

The data requirements of the GEEM differ from bioeconomic models. Therefore, it would be useful to assess the GEEM also from the perspective of data requirements and quality. Some questions used in assessing the model could be: What are the minimum data requirements for implementing the GEEM and how reliable are these data relative to data used in bioeconomic models? What are the possible gains or losses in modeling accuracy associated with data sources and quality?

Ecosystem equilibrium

The GEEM is an equilibrium model, which clears all energy markets every period. In the long run, the ecosystem directs itself towards the steady state. Ecological systems, however, are often perplexed by non-linearity, complex feedback loops, and multiple or no equilibrium. An application, which would examine how to modify the GEEM to handle these issues, would be welcome.

Spatial scale

The relevant spatial scale may vary among different trophic levels, and depend, on the mobility of different species or other factors. For example, sea urchins, sea otters, and killer whales each operate at different spatial scales. The GEEM may be modified to account for varying spatial scales, perhaps by viewing different meta-populations as separate "species" in the same trophic level. On the other hand, meta-population models in ecology have been developed specifically for handling spatially differentiated populations.

"Contingent Valuation for Ecological and Non-Cancer Effects within an Integrated Human Health and Ecological Risk Assessment Model"

This paper by James Hammitt and Katherine von Stackelberg describes a research project for valuing the ecological and human health effects of PCB contamination. Their research is currently ongoing, with the survey involved nearly ready to be launched. My comments that follow address mostly general issues related to the valuation of ecological and human health risks.

Hammitt and von Stackelberg use a dichotomous choice contingent valuation method for the valuation of both ecological and health endpoints of PCB contamination. The ecological endpoints involve two alternative valuation endpoints: the effects of PCB contamination on a high-profile species (bald eagle) versus its effects on a group of species (species sensitivity distribution). The human health endpoints consist the effects of PCB on developmental outcomes (IQ, reading comprehension). The exposure pathway causing the adverse effects is the ingestion of fish.

Non-market valuation studies typically do not address uncertainties inherent in the evaluated policy outcomes. Several factors contribute to this tendency. First, uncertainties often stem from very complex relationships and scientific phenomena, which are complicated to communicate effectively to survey respondents. Second, the expression of uncertainties as probabilities has been a long-standing challenge in stated preference surveys (Hammitt and Graham 1999). Third, uncertainties in policy outcomes can cause respondents to question the scientific credibility of the scenarios presented to them.

Hammitt and von Stackelberg address the uncertainty of ecological outcomes by using the species sensitivity distribution (SSD) approach to describe the distribution of reproductive effects of PCB contamination for all species. The ecological basis of the SSD approach is appealing, but the involved graphs are cognitively challenging. It will be interesting to see how well using the SSD works in the valuation context. The survey also uses graphs with colored dots for intuitively easy illustrations of the risk probabilities.

The survey will help estimate the value per statistical life (VSL) for children, which is an important research question for which practically no information currently exists. Children are especially sensitive to the effects of pollution and estimating VSL for children would therefore be an important contribution and useful in policy evaluations.

Willingness to pay for both ecological and human health risk reductions will be determined by respondents' risks perceptions, which, in turn, will reflect information available to the respondents both in the survey and prior to it. Therefore, it would be interesting if the survey could collect information on the actual risk perceptions of the respondents. Quantitative measures of the perceived risks may be hard to attain, but the survey could collect data on at least the extent of ecological and human health effects respondents consider in answering the valuation questions.

References

Begon, M., J.L. Harper, and C. R. Towsend, (1996). *Ecology: Individual, Populations, and Communities,* Blackwell Science, Third Edition, p. 1068.

Clark, C. W. (1990), Mathematical Bioeconomics: the Optimal Management of Renewable Resources, Second Edition, John Wiley & Sons.

Edelstein-Keshet, L. (1998). *Mathematical Models in Biology,* McGraw Hill, p. 586.

Hanski, I., (1999). *Metapopulation Ecology*, Oxford University Press, p. 313.

Hammitt, J.K. and J.D. Graham, (1999). Willingness to Pay for Health Protection: Inadequate Sensitivity to Probability? *Journal of Risk and Uncertainty* 18(1): 33-62.

Holling, C.S., (1992). Cross-Scale Morphology, Geometry and Dynamics of Ecosystems. *Ecological Monographs.* 62(4):447-502.

Holling, C.S., D.W. Schindler, B. W. Walker, and J. Roughgarden, (1995). Biodiversity in the Functioning of Ecosystems: An Ecological Synthesis. In: Perrings, C. K-G Mäler, C. Folke, C. S. Holling, B-O. Jansson, *Biodiversity Loss, Economic and Ecological Issues,* Cambridge University Press.

Lindemann, R. L., (1942). The Trophic-Dynamic Aspect of Ecology, *Ecology* 23:399-418.

Lotka, A.J., (1925). *Elements of Physical Biology.* Baltimore: Williams and Wilkins.

MacArthur, R. H. and E. R. Pianka, (1966). On Optimal Use of a Patchy Environment, *The American Naturalist* 100: 603-09.

May, R. M., (1976). Simple Mathematical Models with Very Complicated Dynamics, *Nature*, 269, 471-477.

Nicholson, A. J. and Bailey, V. A., (1935). The Balance of Animal Populations, Part 1, Proceedings of Zoological Society of London, 3:551-598.

Real, L. A. and J. H. Brown, editors, (1991). Foundations of Ecology, Ecological Society of America.

Sanchirico, J. N., and Wilen J. E. Bioeconomics of Spatial Exploitation in a Patchy Environment, *Journal of Environmental Economics and Management,* 37: 129-150

Tansley, A. G., (1935). The Use and Abuse of Vegetational Concepts and Terms, *Ecology* 16: 284-307.

Volterra, V., (1926). Fluctuations in Abundance of a Species Considered Mathematically, *Nature* 118:558-60.

Summary of the Q&A Discussion Following Session IV

Amy Ando (University of Illinois at Urbana-Champaign)
Directing her comment to David Brookshire, Dr. Ando said, "Yesterday, Nancy Bockstael made the astute observation that individual decisions, in your case water use—people watering their bluegrass—*don't* tend to feedback directly to them. It seems to me that the *main* method of feedback in your case will be policy—changes in water prices or rules that you can't have bluegrass or at least can't water it. Are you planning on having policy be endogenous in your study?"

Turning to John Tschirhart and David Finnoff and saying that her comment related to a few of the points made by the discussants, Dr. Ando said, "Let me make a quick analogy to economics. It may be profit-maximizing for a farmer to adopt a new cost-saving technology, but if all the farmers adopt the cost-saving technology, the supply curve shifts down and the price falls. I think you had *at least two* such micro but then macro feedback [options] and I can't tell from a 25-minute talk whether you're accounting for them. One, as David mentions, is energy prices. If a seal lion avoids being eaten, that's good for the sea lion—the population rises—but that lowers the energy cost (energy price) of eating a sea lion, so the killer whales may move more to prey upon sea lions. The second one I was thinking about—again, both of your discussants alluded to this, is fitness. Why on earth did we reintroduce wolves into vast parts of the continental U.S.? One argument was that it actually benefits prey populations and improves their fitness. So, if a sea lion avoids being preyed upon, that's good for the sea lion but may be *bad* for the population, because maybe it was a crummy, unfit sea lion that ought to have been eaten anyways. And, do we really want to get rid of all the killer whales? One argument against that might be that it would reduce the fitness of the two prey populations. That may be a hard thing to have data for, but I'm wondering if you can address those kinds of issues."

David Brookshire (University of New Mexico)
Dr. Brookshire first explained that he didn't have a paper prepared for the workshop because his funding came in just a couple of months ago. He then responded to the question by saying, "Nancy's point of view is very interesting. Actually, I see it a little differently than she does. I think at the individual level we don't get feedback on our decisions. Actually, it's not even on our radar—let me give you an example: If you take a 10-minute shower thirty times in Albuquerque using a 2.5-gallon-per-minute shower head (that's a water saver), as a commodity charge that would cost you $1.09. This is spare change in the parking lot." Referring to the decision process involved in pricing water in the West, he went on to say that this level of individual water use is "*not* on our radar, so to speak. However, *collectively*, it *is* on our radar. And this is where you have your stakeholder groups, and again, for instance, if I may use my hometown of Albuquerque, we're very conscious of the fact (and most people actually know this, believe it or not) that we're mining ground water at a rate of approximately 70,000 acre feet per year and that we'll have a short fall in the year 2035. We are *compounding daily* the problem with the collective implications. So, on the one hand, at the individual level

we don't get the signals that we as economists would like people to be seeing. Actually, we're doing some work on experimental estimation of what will happen in terms of urban demand at higher price levels, using both a lab and the water bills for every household in Albuquerque for the last seven years. . . . So, we'll have some idea how people would respond *if* the prices were higher, but if you look at the literature, you don't see that anywhere—you see the traditional administrative cost prices."

Addressing Dr. Ando's question more directly, Dr. Brookshire continued, "In terms of the policy being endogenous, I don't know. I don't know exactly how we're going to do some of this. We have an upcoming meeting with the San Pedro Partnership. To some extent, we have to work with our local folks. How they want us to bring forth the Harvard study and other kinds of things remains to be seen at this point. It's a possibility—it's a good thought—but that's all I can leave you with at this point."

David Finnoff (University of Wyoming)
Dr. Finnoff responded to Dr. Ando by saying, "By the example that you used, let's say we were to cull killer whales. That would lower the predation of the sea lions, and with less predation the population would increase," which would result in increased intraspecies competition among sea lions for *their* food supply. He concluded by saying, "So as the population goes up, the price rises and demand will eventually go down, so you'll have a population growth, but that will then be limited by this intraspecies competition. It's the way that we treat our ecosystem exchanges (or "transfers," as we call them) that allows these threads to be captured."

John Tschirhart (University of Wyoming)
Dr. Tschirhart stated, "We don't make any welfare judgments about what's good or bad with respect to the ecosystem, whether it's good to have this many more sea lions or something like that, other than how it might affect the economy. In fact, we start off with calibrating the ecosystem without any humans whatsoever and call that the natural, steady state. Then we introduce the economy—the economy is not self standing; the economy cannot survive without the ecosystem, because in this case you need the food, whereas the ecosystem does very well without humans." (scattered laughter)

Dan Phaneuf (North Carolina State University)
Posing his question to David Finnoff and John Tschirhart, Dr. Phaneuf said, "The economic general equilibrium model is apparently aspatial, correct?—it assumes that there's perfect integration of markets across space and it abstracts away from the notion that there might be differences across landscape. I thought I'd mention that . . . the ecosystem general equilibrium model is also aspatial in the way you've thought about it thus far, and I think that that's a necessary condition for what you're looking at. I'm wondering what you *lose* from going in that direction. In the economic general equilibrium model we have a good sense of what we'd lose, and we're usually willing to assume that there's the kind of arbitrage that sort of makes prices the same across space. Is that going to be a reasonable assumption in what you guys are looking at, and if not, what are we losing because of that?"

David Finnoff
Dr. Finnoff responded, "Well, we have a little of space, in the sense that we have two legs of the food web in different regions, but *within* those regions, we model" those with no concept of space. In a project I'm working on with Kerry (Smith) right now we are adding space, and so migration" between regions .

Dan Phaneuf
Dr. Phaneuf stated that he saw similar problems between Finnoff and Tschirhart's work and Smith's study in dealing with the space issue. He characterized Finnoff and Tschirhart's work as "using more careful structural modeling that abstracts more from space."

David Finnoff
Dr. Finnoff added, that this relates to the question regarding "whether we're trying to run two kinds of modeling frameworks in a parallel fashion to answer the same kind of question." He said it always comes down to looking at what a potential model "brings to the table that a standard macro population dynamic model doesn't, and vice versa."

John Tschirhart
Dr. Tschirhart clarified, "Basically, you could have killer whales feeding in two different areas, and which area are they going to go to?—They're going to go to where the prices are lower, and when they move from one area to another, they're going to cause those prices to increase and then there's a tendency to move back to the first place." So, there is interaction through price with regards to space.

Nancy Bockstael (University of Maryland)
Offering a follow-up comment on Amy Ando and David Brookshire's exchange, Dr. Bockstael stated, "Actually the system I was talking about yesterday is one in which there *isn't* that strong public feedback. It's where residential development is putting a lot of pressure along the East Coast—water quality, stream ecology, and such—but there isn't any *sense* of that and it's not affecting the housing market *except* to the extent that it *induces* policy responses in some *feeble* effort to reconfigure how the land use changes."

Dr. Bockstael continued, "Concerning your point about policy being endogenous, it seems to me that in *that* context policy *is* endogenous, but there's a long lag. It is such a long lag that it almost doesn't pay to view it as endogenous *except* to the extent that all of the ecologists want to spew out these scenarios over 50 years." She went on to state that these extended projections are senseless exercises because "the structure is going to change in the system so much because of the induced policy changes" that we can't anticipate all the effects and ramifications. She concluded by saying that this is a big difference between the ecologists and economists, who "understand that there will *indeed* be induced policy changes but who really aren't sure what form they would take."

Amy Ando
Dr. Ando commented to David Brookshire: "Considering your idea that people have a collective sense of "Yes, we're drawing down the water"—in a public choice model, that feeds into a policy change. So, I think that these are not entirely different things."

Nancy Bockstael
Addressing John Tschirhart, Dr. Bockstael stated, "It seems to me in my encounters with ecologists that there's a lot of resistance to belief in the equilibrium. I may be wrong, but that's the way I feel. Loosely speaking, when we're thinking about equilibrium . . . we're thinking about it in two ways, really: There's sort of a *market* equilibrium—prices adjust to equate supply and demand . . . but then there's this *steady state* equilibrium in a dynamic system. That's the more interesting part, I think, about the equilibrium in your model—that you're *thinking* in terms of steady state. My sense is that ecologists would say, "Well, we never get there, so why even talk about it?" But shocks aren't infrequent—they're very frequent, and they're environmental shocks. I wonder if you've encountered that criticism and whether there's a way to think about this issue in a way that would be more pleasing to ecologists in terms of introducing random shocks so that you don't have this steady state equilibrium that you characterize in the system."

John Tschirhart
Dr. Tschirhart answered, "Yes, we definitely have gone into that. They don't talk about general equilibrium, of course—they talk about steady states, and they have gone away from the steady state type idea in more recent times. But, we have another model, for example, in which we have just plants. Modeling plants without animals is okay because that's where it all starts. What we do, very simply, is we have temperature as the random variable, so the system is constantly being jostled from heading toward one steady state to another. That seems somewhat satisfying, so we *are* trying to bring that into account."

Stephen Swallow (University of Rhode Island)
Also addressing David Finnoff and John Tschirhart, Dr. Swallow commented, "When I looked at your paper in the Journal of Biological Theory a while ago, I had some questions about capturing the *intra*specific competition for prey and I wondered whether you were capturing *inter*specific data. As an analogy, when you have a lot of firms, they are all competing for the same labor pool, whereas in the ecology model you showed us today it appeared that the consumers of prey were competing "within their own industry" for that prey, but not necessarily between the two species for the same prey. As you go to looking at a larger number of species, I imagine that an extra level of detail would enter in." He closed by asking whether the researchers had "any insights as to whether that's actually going to be a significant problem in your next modeling step and, if it is, how you might handle it."

John Tschirhart
Dr. Tschirhart replied, “That’s a really good observation—we’ve thought about doing it both ways. The issue would be, for instance, if you have, as we do in our expanded model,” a predator preying not just on one but on two species. He stated that this raises the issue of deciding whether it’s one market—in which the predator is paying one price for the two different species—or two markets. Dr. Tschirhart clarified that “in economics, it would be just one market—one price for both.” He added, “We didn’t do that because it just seemed to work better in the simulations to have separate markets between each pair of species, but it’s a good question.” He acknowledged, though, that it would be reasonable to make it one price because the price is actually measured “per kilogram of fish flesh,” thereby eliminating any species size differential that would influence species-specific prices. Dr. Tschirhart closed by saying that they are continuing to look at both options and haven’t determined yet which is preferable. He added that they hadn’t yet talked to ecologists about the details of this issue because ecologists “are so unused to seeing this whole methodology that getting down to those kinds of details just hasn’t happened yet.”

Kerry Smith (North Carolina State University)
Dr. Smith commented, “We didn’t get much of a look at the utility function on the economic part of the model and this is sort of a detailed question: Is the value derived from recognition separable or non-separable from the quantity and type of species of fish? In other words, what I’m looking for is a feedback effect, such that the rate of leisure choice associated with looking is influenced by the availability of these species to look at.” He said when you put that feedback back in, “you get a couple of different loops in the model that connect the economic structure with the biological structure.”

David Finnoff
Dr. Finnoff responded, “No, it’s not like that right now. . . . Essentially, this was our test model . . . One thing I’d like to say, though, is that our leisure choice is essentially regulator determined in this model.”

Will Wheeler (U.S. EPA/NCER)
Dr. Wheeler said he didn’t have a question but wanted to clarify something for the audience, and he commented, “It’s part of the STAR Grant policy that all grantees come in once a year to present their work and we have violated that policy. That’s why when we have a conference on ecovaluation, we have all our ecovalution grantees come in. That’s why, although David’s grant was just awarded this year, we still had to make him come in so we don’t violate our policy quite so bad as we have. Actually, the other two grantees work began only last year, so that’s why we’re seeing work in progress—we’re still trying to tweak everything. We appreciate everyone’s work.

Bob Reilly (Virginia Commonwealth University)
Dr. Reilly stated, "I'm still a little bit troubled with these energy prices in the general equilibrium model. It seems to me that the way things are at the moment these prices are just market-clearing prices affecting differences in excess demand. In point of fact, really, these energies are functional relationships. Some of them are easily movable, possibly, and others move as a result of density interactions in the species. It's nothing like moving the market-clearing prices in the economic market. It's hard for me to believe that an ecologist is going to sign off on this kind of a view of moving energy prices when they are very well aware what it takes to handle and absorb this energy price is very different from the movement of an energy price when in fact you have to worry about spatial issues and search costs and a lot of things that appear to be central in this problem. . . . Those relationships are difficult to nail down and the literature is very poor on how does energy cost vary as a result of density effects. As far as I know, there's not a lot of good development literature there. . . .

David Finnoff
Dr. Finnoff answered by saying, "I definitely agree. One thing in our model is that our respiration function is a physiological function that really governs the transfer of energy into heat production and whatnot. So, a lot of what you're talking about takes place within our respiration function itself. What we think is unique about this energy price rate is that the system together helps determine outcomes—and not just a functional relationship for one species to another, but there's something that's endogenous to the interactions of all these individuals. That's really what we add to the table here, because there are input-output kinds of models in ecology. But, we think that this system-wide interaction is important and that's what these prices are allowing us to bring to the table."

David Brookshire
Dr. Brookshire said, "I can't let this issue on policies go. . . .This is like saying, "let the market do it. What market? What does it look like?"—these kinds of things. We use the phrase "heterogeneous preferences" in economics. That takes on *real* meaning when we look at water issues in the West—line everybody up and you'll get 2x number of ideas. So, when we talk about policies, we're really talking about *chipping* at the market, and Nancy (Bockstael) alluded to that." He used an example of putting in low-flow toilets only to discover that everyone then double-flushes and water consumption goes up—or installing low-flow shower heads, and then everybody takes longer showers. Dr. Brookshire went on to say that "we haven't really come up with a set of systematic policies that account for the human behavior side of this issue. We would like to see prices raised, which is a popular and unpopular thing to say, depending on who you speak with. Our typical policies are short-term: we ration; we jawbone through conservation; we don't raise prices, even though we should—the reason I gave you that commodity chart is to give you a clue as to just how cheap it really is. So, it's not clear what to do in the San Pedro area. In fact, it is *very clear* that if you go to the San Pedro area and you ask, "What should be the water policy?" you will get *multiple* answers, and that's why it's so difficult and why the San Pedro Partnership exists."

Dr. Brookshire said that they are looking for "some guidance from this group" (the San Pedro Partnership) because they "need some anchor so that we're not discredited for "inventing" things, if you will—we're going to have to get some buy-in. But to think that there's going to be *a* water policy for the San Pedro region is mythical" and he said this is true for the West, in general.

In closing, Dr. Brookshire commented, "The *one* area that we are making progress in is what we all know as "water banking"—the institution of re-allocating water on a spatial and temporal basis, where we don't actually have to trade the property rights and so don't run into adjudication problems. We are making progress in getting *better use* of what we have through these institutions, and various states are interested. That's one of the *few* kind of global policies that everybody seems to be *at least* willing to talk about."

END OF SESSION IV Q&A

Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

PROCEEDINGS OF

SESSION V: CONSERVATION AND URBAN GROWTH: FINDING THE BALANCE

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

October 26-27, 2004
Wyndham Washington Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Cynthia Morgan and the Project Officer, Ronald Wiley, for their guidance and assistance throughout this project.

DISCLAIMER

These proceedings are being distributed in the interest of increasing public understanding and knowledge of the issues discussed at the workshop and have been prepared independently of the workshop. Although the proceedings have been funded in part by the United States Environmental Protection Agency under Contract No. 68-W-01-055 to Alpha-Gamma Technologies, Inc., the contents of this document may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

TABLE OF CONTENTS

Session V: Conservation and Urban Growth: Finding the Balance

Applying Economic and Ecological Principles to Identify Conservation Reserves for Vernal Pools with Residential Development

By

Dana Marie Bauer,* Yong Jiang,* Stephen K. Swallow,* Peter Paton,** Dennis Skidds**

*Department of Environmental and Natural Resource Economics
**Department of Natural Resources Science
University of Rhode Island
Kingston, RI 02881

Keywords: open space, metapopulations, amphibian, reserve design, land conservation, wetland

Residential development or exurban development in rural communities is a common cause of fragmentation of ecological habitats at a landscape scale. Existing wetlands protection regulations commonly protect wetlands from direct development, sometimes extending protection to include a buffer zone around delineated wetland, but without sufficient ecological consideration of the linkage between wetland habitat patches and the matrix of uplands. Such regulatory approaches may doom some species, such as metapopulations of amphibians, to localized extinction, because the common approach preserves breeding habitat without preserving sufficient habitat critical to species life-stages outside the breeding season. In a separate literature, scientists, often involving economists, have been developing methods for selecting lands for priority protection relative to objectives focused broadly on conservation of biological diversity. Many of these studies have focused on identifying sites, and networks of conservation reserves, that protect a target number of endangered or sensitive species at least cost. However, the many of these studies have not incorporated ecological processes and resulting spatial linkages that may influence the long-term sustainability of biological diversity in the conservation reserves.

This presentation will consider amphibian metapopulation dynamics as a indicator of or proxy for ecosystem integrity. (Metapopulations are populations of a species that are comprised of many subpopulations that exist separate habitat patches, but which must exchange breeders in order to sustain the overall population. Subpopulations in habitat patches my become extinct and the patches may be recolonized from other subpopulations.) The analyses discussed will use concepts from production theory (the production function) and opportunity costs of development to identify optimal land conservation reserves, and intensity of residential development. The research uses the framework of the Hanski-Ovaskainen spatially explicit form of Levins' metapopulation model to identify an objective for ecological quality, which is then maximized subject to a cost constraint. One aspect of the study places the framework in a theoretically complete context, with applications requiring either detailed data or transfer of key parameters from existing literature; this portion of the study may be better suited for developing intuitive guidance for policy. An alternative portion of the study uses relatively easily obtained biological data to develop a proxy for metapopulation production to establish spatially explicit priorities for land conservation suitable for policy in real watersheds. Analyses include variation in the opportunity cost of land development, distance between habitat patches, and size of subpopulations in habitat patches, as well as the role of the matrix of undeveloped land around habitat patches.

OVERVIEW:

The paper consists of two parts. In the first part, we present a simple land use model constrained by an ecological goal to protect amphibian populations in the face of development. The empirical simulation is based on a relatively complete ecological production function relating amphibian populations to protection of habitat patches and the matrix of land surrounding these patches through a jurisdiction. The approach facilitates a preliminary assessment of actual wetland protection policies, some proposed policies promoted by conservation groups in some states, and some alternatives to these proposals. The results presented remain based on basic assumptions and substantial simplifications from the actual heterogeneity that exists in terms of the value of land for either ecological purposes or for development. It is indicative of the types of analysis to be done as the project continues. The perspective of this approach is expected to be most suitable to establishing uniform policies (regulations or incentive-based policies to be evaluated in future work) that would apply across a jurisdiction.

The second part of the paper considers the question of balancing ecological conservation and development from the perspective of identifying a land conservation network that would obtain an optimum performance on ecological criteria subject to the cost of preserving land. Land preservation could be interpreted as the purchase of land or development rights, and its cost is therefore equivalent to the foregone value of development opportunities on land that is preserved. This part of the paper develops a model for the ecological performance of a land conservation reserve that can be based on relatively easily available biological data while also recognizing some of the major biological-behavioral processes that affect the ability of a species to survive across a landscape in the long term. The application uses data on egg-mass counts as a proxy for population estimates of amphibians breeding in vernal pools (seasonally-flooded wetlands), and uses this proxy to represent key features of a metapopulation model that would be applied by ecologists to model amphibian populations. Results represent a novel approach to incorporating bioprocess-based elements of spatial factors into the selection of a conservation lands network. The approach could support planning by municiple or regional officials to identify land parcels to target for conservation, while allowing residential development to proceed elsewhere.

PART One: Economic Consequences of Conserving Amphibian Metapopulations within Areas of Urban Sprawl

INTRODUCTION

Development in rural fringe communities is occurring in a random and sprawling fashion, potentially damaging healthy ecosystems (Heimlich and Anderson 2001; Daniels 1999). Environmental impacts of development include loss, degradation, and fragmentation of wildlife habitat, increased air and water pollution, increased soil erosion, and decreased aesthetic appeal of the landscape (Johnson 2001). Current land use policies rarely incorporate features of landscape-scale ecosystem health (Burke and Gibbons 1995; Miltner, White, and Yoder 2004; Willson and Dorcas 2003). For example, wetland policies focus on protection of individual wetlands, but at the same time provide incentives for higher-intensity development of upland habitat (Hardie et al. 2000; Swallow 1994; Semlitsch 1998; Semlitsch and Bodie 2003). Many wetland species, such as pond-breeding amphibians, spend much of their life histories in these upland habitats either over-wintering or dispersing to other wetland habitats (Semlitsch 2000). Development of upland areas decreases the long-term viability of these species by reducing the quantity and quality of upland habitat and decreasing dispersal success (Arnold and Gibbons 1996; Lehtinen, Galatowitsch, and Tester 1999; Vos et al. 2001; Vos and Chardon 1998; Woodford and Meyer 2003). Development affects amphibians, in particular, by destroying upland habitat, changing the hydroperiod of the pond, adding pollutants to both wetland and upland environments, and creating barriers to dispersal (Woodford and Meyer 2003).

This paper investigates the long-term ecological impacts of development in exurban communities using pond-breeding amphibians as indicators of ecosystem health. Amphibians are good indicators of ecological stress due to roads and other forms of urbanization (Lofvenhaft, Runborg, and Sjogren-Gulve 2003; Trombulak and Frissell 2000; Woodford and Meyer 2003). Amphibians are also considered to be particularly good ecological indicators for wetland ecosystems (Keddy, Lee, and Wisheu 1993; Hecnar and M'Closkey 1996). Several characteristics of amphibians make them good indicators of ecosystem health. First, they are extremely sensitive to changes in their environments (Vitt et al. 1990; Welsh and Droege 2001; Welsh and Ollivier 1998). The skin of amphibians at all life-history stages is permeable to water and thus many types of pollutants. Eggs are covered by a thin layer of gelatinous material so they are directly exposed to the aquatic environment and adults of many species spend their lives physically against mud, sand, or leaf litter. Second, amphibians are central to many wetland ecosystems with their relatively high position in the food chain and biomass that often exceeds that of all other vertebrates combined (Welsh and Droege 2001). Third, pond-breeding amphibians are thought to exist in metapopulations, where each pond has its own local population but dispersal of individuals between ponds occurs annually and is critical to sustaining the overall population (Marsh and Trenham 2001). For example, although adult wood frogs are incredibly site-faithful, approximately 18% of juvenile wood frogs leave their natal pond and disperse across the landscape to settle in another pond (Berven and Grudzien 1990). Fourth, many amphibian species are common and widespread (Calhoun and Klemens 2002). The persistence of common species across the landscape are considered by some to be more crucial to ecosystem health (King 1993).

This paper develops an empirically-based conceptual model that combines economic and ecological principles to determine the optimal allocation of land between development and preservation uses and then compares the optimal solution to specific land allocations resulting from current and alternative land use policies. Results show that current regulations protecting only the aquatic environment ultimately lead to extinction of amphibian metapopulations in areas of urban sprawl. Land use policies such as environmental impact fees, transferable development rights (TDRs), or cluster developments may be better alternatives.

METAPOPULATION THEORY

Natural landscapes are patchy, with each patch supporting different types of flora and fauna. Human activities such as building construction or timber harvesting contribute additional levels of fragmentation to natural environments. Metapopulations consist of groups of local subpopulations distributed throughout a patchy environment, with each subpopulation occupying its own patch (Hanski 1999). Local subpopulations exchange individuals through a dispersal process whereby a small number of individuals leave the patch and join a new subpopulation. Local subpopulations can go extinct and patches can be re-colonized without threatening the overall viability of the entire metapopulation. The status of species in a regional context may be determined more by metapopulation dynamics than by local birth and death processes (Hecnar and M'Closkey 1996).

Amphibian spatial dynamics resemble classical metapopulation models, in which subpopulations in breeding ponds blink in and out of existence and extinction and colonization rates are functions of pond size and spatial arrangement in addition to species-specific characteristics (Marsh and Trenham 2001; Green 2003). This "ponds-as-patches" view of metapopulation dynamics has been used in many prior amphibian studies and is used here (Carlson and

Edenhamn 2000; Gill 1978; Pope, Fahrig, and Merriam 2000; Sjogren-Gulve 1994; Vos, Ter Braak, and Nieuwenhuizen 2000).

The Classical Levins Model

The classical Levins metapopulation model views a metapopulation as a population of local populations inhabiting an infinite number of identical patches (Hanski 1999; Levins 1969, 1970). All patches are the same size, the same quality, and equally connected to all other patches. Colonization is not affected by the distance between patches. The Levins model is an occupancy model, based on presence or absence of the species, rather than a count model, based on number of individuals. The model assumes that local patch dynamics can be ignored. The Levins metapopulation model, given by

$$dP/dt = cP(1-P) - eP,$$

measures the rate of change in "metapopulation size", where P is the fraction of patches that are occupied at time t and c and e are species-specific colonization and extinction rate parameters, respectively. The colonization and extinction rates can be estimated with time-series occupancy data. For example, the colonization rate can be calculated as the ratio of the number of years the species was absent but present the next year to the total number of years the species was absent (Gilpin and Diamond 1981). The extinction rate can be calculated in a similar manner. Metapopulation persistence occurs when there is a balance between local extinctions and recolonizations. The steady-state equilibrium value of patch occupancy is given by

$$P^* = 1 - e/c.$$

If $e/c > 1$, the metapopulation goes extinct.

A Spatially-Realistic Model

A spatially-realistic metapopulation model developed by Ilkka Hanski and others extends the Levins model by allowing patch areas and distances between ponds to vary according to a realistic landscape structure (Hanski 1999; Hanski and Gyllenberg 1997; Hanski and Ovaskainen 2000; Moilanen and Hanski 1998; Moilanen and Nieminen 2002; Ovaskainen 2003; Ovaskainen and Hanski 2003, 2001; Hanski and Ovaskainen 2003). In this finite-patch metapopulation model, the change in probability that any given patch is occupied is a function of local colonization and extinction rates that are different for each patch. It has been observed that in comparing different connectivity measures in their ability to predict colonization events, the best and most consistent performance is found for a measure that takes into account the size of the focal patch and the sizes of and distances to all potential source populations (Moilanen and Nieminen 2002). In the spatially-realistic model, the rate of change in the probability of patch i being occupied, dP_i/dt, is given by a system of N equations for a network of N patches:

$$dP_i/dt = C_i\,(P)(1-P_i) - E_i(P)P_i\,, \qquad i=1,\ldots,N$$

where colonization and extinction rates are a function of P, which is the vector of the N occupancy probabilities. The equilibrium probability of occupancy, P_i^*, also called the "incidence" of the species in patch i, depends on the probability of persistence in all other patches (Hanski 1994, 1999):

$$P_i^* = C_i / (C_i + E_i)$$

The colonization rate of patch i, C_i, is function of the N patch areas, A_i, and the spatial location of patch i within the network given by the dispersal kernal, $f(d_{ij})$:

$$C_i = c\,A_i \sum A_j\,P_j\,f(d_{ij}) \text{ for all } j\neq i$$

where the dispersal kernal f(.) accounts for the effect that increasing distance d_{ij} between habitat patches i and j reduces the rate of recolonization of patch i from patch j when j is occupied. The patch-specific colonization rate can be interpreted as the sum of contributions toward colonization from each of the other N-1 patches:

$$c_{ij} = c\ A_i\ A_j\ f(d_{ij}) \text{ for all } i \neq j.$$

The exponential form of the dispersal kernel, $f(d_{ij}) = \exp(-\alpha d_{ij})$, is commonly used and indicates that the greater the distance between two patches, the smaller the contribution to re-colonization. The parameter, α, reflects the dispersal ability of the focal species ($1/\alpha$ is the average migration distance). The probability of colonization C_i increases with more patches, larger patch sizes, and shorter distances between patches.

The extinction rate of patch i, E_i, is a function of the area of patch i and the species-specific extinction rate:

$$E_i = e/A_i.$$

Extinction rates vary as an inverse function of area, because larger patches usually mean larger local populations and risks of extinction tend to decrease with larger local populations (Gilpin and Diamond 1976).

An NxN landscape structure matrix, L, is derived from the previous colonization and extinction equations where each element of the matrix is a function of patch areas and the dispersal kernel:

$$L_{ij} = (e/c)\ (c_{ij}/E_i) = A_i^{ex} \cdot A_i^{im} \cdot A_j^{em} \cdot e^{-\alpha dij} \qquad \text{for } i \neq j$$

$$L_{ij} = 0 \qquad \text{for } i=j$$

Each element gives the contribution that patch j makes to the colonization rate of patch i when patch i is empty, multiplied by the expected lifetime of patch i when it is occupied (Ovaskainen and Hanski 2003).

Patch areas are scaled by extinction, immigration, and emigration factors (ex, im, and em) that are specific to the focal species (Hanski and Ovaskainen 2003). Empirical studies have shown these parameters to vary widely, from a minimum of 0.05 to a maximum of 2.30 [(Ovaskainen 2002) pg. 428-430]. For a "typical" metapopulation, the sum of the three scaling factors would fall between 1.0 and 2.0 [(Ovaskainen 2002) p. 430]. The model used in the conceptual framework developed here expands the dispersal kernel to reflect the additional barriers to dispersal that result from development:

$$L_{ij} = A_i^{ex} \cdot A_i^{im} \cdot A_j^{em} \cdot (1 - B_{ij}) \cdot e^{-\alpha dij}$$

where the barrier to dispersal between any two patches, B_{ij}, is a function of the percentage of land that is developed. Thus, the greater the barrier between two patches, the smaller the contribution of those patches towards long-term persistence of the species.

From the probability of occupancy and the landscape matrix, two constructs for comparing or ranking different landscapes can be derived (Hanski and Ovaskainen 2000; Ovaskainen and Hanski 2003, 2001). The metapopulation persistence capacity, or metapopulation capacity for short, is a measure of the landscape's ability to support a viable metapopulation over the long term. It is similar to the carrying capacity in a single-population model. It takes into account both the quantity of habitat available and the spatial configuration of the habitat patch network. A species is predicted to persist in a landscape if the metapopulation capacity of that landscape is greater than a critical threshold determined by characteristics of the focal species. The larger the metapopulation capacity the greater the long-term probability of persistence. Therefore, the metapopulation capacity can be used to rank different landscapes in terms of their capacity to support viable metapopulations. It is possible to calculate how the metapopulation capacity is changed by removing habitat fragments from or adding new habitat fragments to specific spatial locations. It is also possible to calculate the effect on metapopulation capacity caused by increasing or decreasing patch areas. Increases in the number or areas of patches results in an increase in the metapopulation capacity, while an increase in the distances between patches results in a decrease in the metapopulation capacity.

Mathematically, the metapopulation capacity, K, is the leading eigenvalue of the non-negative landscape matrix, L (Hanski and Ovaskainen 2000; Ovaskainen and Hanski 2001). Metapopulation capacities can be considered as simple sums of the contributions from individual patches, given by the elements of the leading eigenvector. Habitat destruction, habitat deterioration, and increased dispersal barriers all lower the metapopulation capacity of the patch network. The effect of gradual habitat deterioration or gradual increases in dispersal barriers is given by the derivative of K with respect to patch attributes and may be evaluated by sensitivity analysis (Ovaskainen and Hanski 2003, 2001). In contrast, destruction of entire patches leads to a rank modification of matrix L, the effect of which on K may be derived from eigenvector-eigenvalue relations (Ovaskainen 2003). Metapopulation capacity defines the threshold condition for long-term metapopulation persistence as:

$$K > \delta = e/c.$$

The second theoretical construct developed from the spatially-realistic metapopulation model, the “size” of a metapopulation, S, is a measure of the “average” patch occupancy (Ovaskainen and Hanski 2003). It's value reflects the rarity or commonness of the species in the given patch network. Metapopulation size, given by

$$S = 1 - (\delta / K),$$

shows a direct relationship between the metapopulation capacity of a particular habitat patch network and the metapopulation size. The larger the metapopulation capacity, the larger the metapopulation size. Values of metapopulation size range between 0 and 1, with values closer to zero corresponding to rare species and values closer to 1 corresponding to common species. The choice in a particular analysis between metapopulation capacity and metapopulation size depends on the question being asked (Ovaskainen and Hanski 2003).

LAND ALLOCATION MODEL

A simplistic land allocation model would attempt to maximize the sum of benefits from both development and preservation land uses. In this type of model, the optimal quantity of land allocated to each land use is determined by equating the marginal benefits. A number of approaches have been used to incorporate ecological "values" into economic analyses. For example, hedonic housing studies, recreational travel-cost models, and contingent valuation surveys have been used to estimate values of non-market public goods such as open space (Bates and Santerre 2001; Geoghegan 2002; Irwin 2002; Johnston et al. 2001; Lutzenhiser and Netusil 2001; Rosenberger and Loomis 1999). Unfortunately, attempts to quantify the entire economic value of ecosystem services are often difficult to acquire or, when obtained, are unreliable or met with substantial controversy (Swallow 1996; Toman 1998; Berrens 1996). Because of the difficulty in fully measuring all the non-market benefits of ecosystem health, an alternative "safe minimum standard" (SMS) approach may be used (Bishop 1978; Randall and Farmer 1995;

Ciriacy-Wantrup 1952; Farmer and Randall 1998). With the SMS approach, a government agency, on behalf of society and based on recommendations from the EPA and other scientific advisory boards, establishes a standard or constraint that guarantees a particular level of safety. For example, an SMS approach is used by the Clean Water and Clean Air Acts, whereby various pollutants are not allowed to exceed given levels. As society increases its understanding of ecological processes and environmental conditions, standards are modified (strengthened or relaxed) to reflect this new information.

One way of modeling a safe minimum standard is through the use of an ecological constraint. Ecological constraints have been used in the modeling of both renewable and non-renewable resources (Albers 1996; Marshall, Homans, and Haight 2000; Roan and Martin 1996; Yang et al. 2003). Albers presents a model for economic management of tropical forests that uses ecological constraints to reflect the spatial interactions across forest plots and the irreversibility of some forest land uses. The explicit recognition of the varied uses of forested land, spatial interdependence, irreversibility, and uncertainty leads to optimal patterns that have different structures and more forested area that those recommended by traditional models lacking an ecological constraint. Roan and Martin model mineral production and waste reclamation as joint products subject to the traditional ore depletion constraint and an ecosystem constraint that limits the amount of water pollution released. Reclamation is identified as the creation of additional "environmental slack" or expansion of the capacity of the waste pile under the ecosystem constraint. Results indicate that the mine will lose rent on the mineral product as the shadow price of environmental slack increases. Yang et al. developed an integrated framework of economic, environmental and GIS modeling to study cost-effective retirement of cropland to reduce sediment loading of local rivers by a set amount. The analysis suggests that program costs are minimized when the abatement standard is set for the region rather than uniformly for individual watersheds. Marshall et al. modeled warbler population dynamics as a function of timber rotation length to find the rotation age that attains a predetermined critical population size at the end of the management time horizon. Management cost is calculated as the opportunity cost of not harvesting timber at the profit maximizing rotation length. Because different management strategies were associated with different costs and with different outcome extinction probabilities, it was possible to construct a marginal cost curve for the probability of species survival. Results show that the desirable combination of management tools depends on the safety margin (SMS) selected. In each of the above studies, the ecological constraint provided insights that weren't available from the corresponding traditional model without the constraint.

This study uses an optimization model that maximizes the benefits of residential development subject to a series of constraints, including an SMS-type ecological constraint:

$$\text{Maximize } V(\mathbf{Q}) = R \bullet (Q_l + \sum Q_i)$$

$$\text{Subject to } \quad Q_i \leq A_{i0}$$

$$Q_l \leq L_0$$

$$\text{and } \quad S \geq S_{min}$$

The benefits from development, $V(\mathbf{Q})$, are calculated by multiplying the land rent associated with residential development, R, by the sum of the number of acres developed in each patch, Q_i, plus the number of acres developed in the intervening landscape, Q_l. Land is assumed to be homogeneous from the perspective of the developer and the subsequent home-buyer, therefore the per-acre land rent is the same for all acres. The scale of analysis used here assumes that land values are constant and determined exogeneously. Development is assumed to be irreversible, thus undeveloped land can be viewed conceptually as a non-renewable resource. The first two constraints on the system represent this finite quantity of land, and we set the total available land to 10,000 acres (corresponding approximately to a single jurisdiction in our case study below). It is not possible to develop more land than what is originally available, A_{i0} in patch i and L_0 in the intervening landscape. The third constraint is the ecological constraint. It states that the metapopulation size, S, (described in the previous section) cannot fall below the minimum level set by society, S_{min}. It is expected that this third constraint drives the system and that as long as the minimum size is set at a level high enough to prevent metapopulation extinction, some amount of land will be preserved. Metapopulation size, S, was chosen over metapopulation capacity, K, because it provides a better comparison measure for common species used as indicators of ecosystem health.

DATA AND ANALYSIS

Vernal pool and other landscape data from the Rhode Island Geographic Information System (RIGIS) were used to establish a realistic landscape structure for the application. Analysis was based on data from the Wood-Pawcatuck watershed in western Rhode Island which included a GIS coverage of all vernal pools in the watershed mapped from aerial photographs with additional field data provided from local ecologists (Paton 2004). A 10,000-acre parcel of land was selected from the middle of the watershed because it contained areas of both high and low densities of pond occurrences and there were no major barriers to dispersal (Figure 1). For each of the 123 ponds in the parcel, pond area (range 0.0065 to 10.34 acres ; mean = .5; median =.14) and distance to each of the other 122 ponds (range <30m to >8km; mean ~= median = 2.8km) was obtained. From this data, an initial landscape structure matrix, L_0, was generated using a pond-as-patch approach for determining habitat patches. The initial patch area, A_{i0}, includes the area of the pond itself as well as a 750-foot buffer of upland habitat. Habitat quality is assumed to be homogeneous and the initial landscape is completely undeveloped.

Land value data was provided by local tax assessors for towns in the Wood-Pawcatuck watershed. An ordinary least squares (OLS) regression was estimated using a log-log functional form with per-acre land value as the dependent variable and size of the parcel as the dependent variable (R^2=0.96). Linear and log-linear functional forms were also tried but did not perform as well as the log-log model. A land rent value of $640 per acre was determined by entering the largest parcel size (150 acres) into the estimated equation.

Optimization of the model was performed using MATLAB. Appropriate species-specific parameter values were taken from the literature: δ=1.2, α=1000m, ex=im=em=0.5 (Berven and Grudzien 1990; Hanski and Ovaskainen 2003; Marsh and Trenham 2001; Ovaskainen 2002).[1] A series of "optimal" land use allocations was produced by varying the ecological constraint parameter, S_{min}, over its entire range (0.0-1.00). The term "optimal" refers to the solution from the optimization program and is indicative of the best we could do in a perfect world, with perfect information, and no transaction costs. The optimization assumes that all developed

[1] Amphibian-specific parameter values for area scaling factors were difficult to find in the literature, so values were extrapolated from those of other species. Sensitivity analysis performed on these parameters did not change the qualitative results.

parcels are one acre and that the entire parcel gets developed. Thus, developed parcels are removed from their respective patches or intervening landscape and added to the corresponding barrier. The opportunity costs are calculated as the foregone benefits associated with those acres, out of the total 10,000 acres, that cannot be developed in order to achieve the safe minimum standard. The opportunity cost can be viewed as an indication of the level of opposition that developers will exert on town officials if new conservation policies are put in place.

The "optimal" solution set is compared to a variety of policy alternatives (Table 1). The first three policy alternatives reflect current regulations. In Rhode Island, for example, only the vernal pool itself is protected. Development is allowed right up to the pool's high water mark. Other states' regulations protect a small buffer or envelope around the pool. Note that C2 uses 2-acre development which reduces the barrier effect on dispersal by 50%. All other policy alternatives assume 1-acre development. The fourth policy, G for "guidelines" is based on the best development practices put forth by the Wildlife Conservation Society (Calhoun and Klemens 2002). According to these guidelines, the pool and envelope (100-ft buffer) are completely protected. In addition, 75% of the critical habitat (100-750 feet from pool edge) is protected. Policies P1, P2, and P3 are modified versions of the vernal pool guidelines that allow more development of critical habitat, but in the case of P3 protect a portion of the intervening landscape. Policy 0 protects all 10,000 acres in the study area. For each policy, the amount of land that must be preserved is determined and then the opportunity cost in terms of foregone development benefits is calculated. The corresponding metapopulation size, S, for each policy alternative is also calculated.

RESULTS

Results from the series of optimizations are shown in Figure 2, which plots the opportunity costs of foregone development (in $millions) against the metapopulation size, S_{min}.[2] The curve represents the tradeoff between the economic benefits of residential development and the ecological benefits of land preservation. The key result is that it is possible to achieve a relatively high metapopulation size at a relatively minimal cost. A 90% average probability of occupancy can be achieved at a cost in terms of foregone development of less than $0.5 million. These low costs are possible because the optimization eliminates small, isolated patches and large "empty" landscapes first. This is consistent with one study that showed 89% of the variability in dispersal success can be accounted for by differences in the size and isolation of forest patches, with closer and larger patches having significantly greater exchange of dispersing organisms (Gustafson and Gardner 1996). In addition, the "optimal" solution does not prohibit the complete destruction of patch. Opportunity costs rise exponentially in order to increase metapopulation size from 0.95 to 0.99 as it becomes necessary to preserve more and more habitat patches.

Figure 3 shows the opportunity costs and metapopulation size corresponding to the various policy alternatives. Current regulations (C1, C2, and E) fall to the far left of the graph. In the policies protecting the pool-only (C1) and the pool plus a small buffer (E), the metapopulation size falls below zero. Thus, with current regulations, amphibian metapopulations will eventually go extinct. The policy protecting the pool-only with 2-acre development (C2) increases the metapopulation size to 31% average probability of occupancy because of the lower dispersal

[2] The x-axis contains values of S_{min} from 0.65 to 1.0 in order to emphasize the policy-relevant portion of the graph, since our goal was to keep a common species common. The curve extends to the left downwards towards zero. In fact, it is possible to go beyond a metapopulation size of 0, which is interpreted as the entire metapopulation going extinct.

barrier, but still not very high and not likely to receive support from conservationists. At the other extreme, the no development policy (0) achieves a metapopulation size of .998 or a 99.8% average probability of occupancy. However, the opportunity cost of achieving this goal is \$6.4 million.

The recommended guidelines protecting 75% of critical habitat, G, achieve a very high metapopulation size (0.99), but at a cost of close to \$2 million. Comparing this to the "optimal" solution, we could get the same level of long-term metapopulation persistence at less cost or, alternatively, we could achieve a higher level of persistence at the same cost. Comparing the guidelines, G, to policy P1 that allows 50% of the critical habitat to be developed, we are still able to achieve a relatively high metapopulation size (0.97) but at a cost savings of \$600,000 (\$1.8m - \$1.2m). Policy P2, that allows 75% of the critical habitat to be developed, results in a metapopulation size of 0.89 at an even lower opportunity cost of \$680,000.

Consideration of Figure 3 can provide some insight to further policy implications. First, environmental managers (or, say, town planners and land trust officials) could consider results such as those in Figure 3 to identify opportunities to improve either the ecological outcomes anticipated in the long term at a given cost of foregone development or to improve (reduce) the cost of foregone development that leads to a particular ecological outcome. Optimizing policy design (such as Table 1) in a manner that moves a policy outcome horizontally or vertically in Figure 3 would improve economic effectiveness. Certainly, since current regulations in the study area will largely fail to maintain species persistence in the long term, a change to a policy such as P2 (Table 1, Figure 3) could provide some degree of success in ecological criteria without a massive increase in cost (foregone development opportunity). Also, it is clear that policy P1 dominates policy P3 in the study area, because P1 is better in terms of both cost and ecological outcome. Moving diagonally down and to the right in the figure improves economic effectiveness of wetland policy. Second, comparisons of policies P1, P2, and P3 may shed light on how different policy elements will influence the cost-outcome relationship. Both P1 and P3 may be seen as nesting P2 within themselves. While P2 and P3 both protect 25% of critical habitat, P3 also protects 25% of the surrounding matrix. The improved ecological outcome of P3 comes at a cost of approximately one million in additional losses of development opportunities. Relative to P2, P1 does nothing more to protect the surrounding habitat matrix but P1 does increase the protection of the critical habitat zones to 50%. These comparisons suggest that policy involves a balance between protection of the habitat zones and protection of the surrounding matrix, with particular outcomes for this study area. However, in general, these factors may be affected by such considerations as the definition of the critical habitat zone and the natural distribution of habitat sites across the landscape. For example, with policy G (75% protection of critical habitat zones), a very high level of metapopulation size is maintained, but at about $700,000 additional cost relative to P1. However, if habitat sites were more widely dispersed through the study area, matrix lands between habitat sites may become more of a limiting factor. Indeed, some preliminary analyses not reported here shows that the definition of critical habitat, as consisting of 750 meters around the vernal pool, results in substantial overlap of habitat sites, leaving relatively little land in the classification of matrix between habitat sites. A reduction in the critical habitat size could cause matrix lands to play a more substantial role in the relative merits of alternative policies, such that policies that protect more matrix lands may dominate some policies focused on critical habitat zones. Thus, the present results should be taken only as illustrations.

SUMMARY AND FUTURE DIRECTIONS

The results of this study show that the current regulatory environment will eventually lead to extinction of amphibian metapopulations that are currently common species throughout the landscape. In addition, the recommended vernal pool guidelines (policy G, Table 1, Figure 3) maintain a high level of amphibian metapopulation persistence, and thus ecosystem health, but are costly to society as a whole. Future analyses may evaluate the potential for alternative policies, including market-based or incentive-based policies, to improve outcomes in terms of either cost or ecological results.

The land allocation framework developed here was presented in its most simplistic implementation where land is homogeneous from both the perspective of residential land development and the perspective of amphibian habitat quality. The model can easily be adapted to incorporate a variety of extensions. For example, heterogeneous quality of land from the developers perspective can be captured in the objective function by including two or more types of benefits based on a Ricardian land rent model. Different levels of habitat quality can also be included in a spatially realistic metapopulation model by modifying the effect of patch areas on the metapopulation capacity and metapopulation size by incorporating a habitat quality index (Moilanen and Hanski 1998). A metapopulation study of the butterfly *Speyeria nokomis apacheana* showed that neither occupancy nor turnover patterns were best modeled as functions of patch area or isolation (Fleishman et al. 2002). Instead, other measures of habitat quality explained the most variance in occupancy and turnover.

Further analysis of initial conditions, model parameters, and functional forms will provide additional insights into the optimal allocation of land between development and preservation. The analysis performed here starts with a pristine (i.e., totally undeveloped) landscape. Further analysis could investigate initial conditions where development has already taken some of the high-quality development land. With the exception of policy alternative C2, the model presented here assumes 1-acre development where the entire acre becomes impervious surface and development is evenly distributed throughout a given patch. An investigation of more robust dispersal barrier functions may be warranted. The analysis presented here focused on the establishment of a healthy ecosystem as indicated by long-term persistence of a common species. The model could also be used to identify the cost-effective reserve network for an endangered species.

The issue of determining the appropriate scale of analysis for guaranteeing healthy ecosystems "across the landscape" remains open. The "optimal" solution for the 10,000-acre parcel achieves a large metapopulation (S=0.95) by preserving two relatively small sections (areas with lots of well connected large patches) of the entire landscape. Because of the use of amphibians as the indicator species (short dispersal, large number of connected patches), a better method might be to use a two-stage approach where the first stage assesses metapopulation size, S, on a smaller scale (e.g., 1000 acres) and the second stage assessed the connectivity between 1000-acre sections.

Finally, this entire analysis was conducted using a static optimization model. For certain landscape scales, that incorporate the entire regional land market, land rents will increase over time. Thus, a dynamic analysis may be appropriate for determining the optimal allocation of land for an entire region.

References

Albers, Heidi J. 1996. Modeling ecological constraints on tropical forest management: spatial interdepence, irreversibility, and uncertainty. *Journal of Environmental Economics and Management* 30:73-94.

Arnold, Chester L., and C. James Gibbons. 1996. Impervious surface coverage: The emergence of a key environmental indicator. *Journal of the American Planning Association* 62 (2):243-258.

Bates, Laurie J., and Rexford E. Santerre. 2001. The public demand for open space: the case of Connecticut communities. *Journal of Urban Economics* 50:97-111.

Berrens, Robert P. 1996. The safe minimum standard approach: an alternative to measuring non-use values for environmental assets. In *Forestry, Economics and the Environment*, edited by W. L. Adamowicz, P. Boxall, M. K. Luckert, W. E. Phillips and W. A. White. Wallingford, UK: CAB International.

Berven, Keith A., and Thaddeus A. Grudzien. 1990. Dispersal in the wood frog (rana sylvatica): implications for genetic population structure. *Evolution* 44 (8):2047-2056.

Bishop, Richard C. 1978. Endangered species and uncertainty: the economics of a safe minimum standard. *American Journal of Agricultural Economics* 60:10-18.

Burke, Vincent J., and J. Whitfield Gibbons. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina bay. *Conservation Biology* 9 (6):1365-1369.

Calhoun, Aram J. K., and Michael W. Klemens. 2002. Best development practices: Conserving pool-breeding amphibians in residential and commercial developments in the northeastern United States. Bronx, NY: Metropolitan Conservation Alliance, Wildlife Conservation Society.

Carlson, Allan, and Per Edenhamn. 2000. Extinction dynamics and the regional persistence of a tree frog metapopulation. *Proceedings of the Royal Society fo London B* 267:1311-1313.

Ciriacy-Wantrup, Siegfried V. 1952. A safe minimum standard as an objective of conservation policy. In *Resource Conservation: Economics and Policy*. Berkeley: University of California Press.

Daniels, Tom. 1999. *When City and Country Collide: Managing Growth in the Metropolitan Fringe*. Washington, D.C.: Island Press.

Farmer, Michael C., and Alan Randall. 1998. The rationality of a safe minimum standard. *Land Economics* 74 (3):287-302.

Fleishman, Erica, Chris Ray, Per Sjogren-Gulve, Carol L. Boggs, and Dennis D. Murphy. 2002. Assessing the roles of patch quality, area, and isloation in predicting metapopulation dynamics. *Conservation Biology* 16 (3):706-716.

Geoghegan, Jacqueline. 2002. The value of open spaces in residential land use. *Land Use Policy* 19:91-98.

Gill, Douglas E. 1978. The metapopulation ecology of the red-spotted newt, *notophthalmus viridescens* (rafinesque). *Ecological Monographs* 48 (2):145-166.

Gilpin, Michael E., and Jared M. Diamond. 1976. Calculation of immigration and extinction curves from the species-area-distance relation. *Proceedings of the National Academy of Sciences USA* 73 (11):4130-4134.

———. 1981. Immigration and extinction probabilities for individual species: relation to incidence functions and species colonization curves. *Proceedings of the National Academy of Sciences USA* 78 (1):392-396.
Green, David M. 2003. The ecology of extinction: population fluctuation and decline in amphibians. *Biological Conservation* 111 (3):331-343.
Gustafson, Eric J., and Robert H. Gardner. 1996. The effect of landscape heterogeneity on the probability of patch colonization. *Ecology* 77 (1):94-107.
Hanski, Ilkka. 1994. A practical model of metapopulation dynamics. *Journal of Animal Ecology* 63:151-162.
———. 1999. *Metapopulation Ecology*, *Oxford Series in Ecology and Evolution*. New York: Oxford University Press.
Hanski, Ilkka, and Mats Gyllenberg. 1997. Uniting two general patterns in the distribution of species. *Science* 275 (5298):397-400.
Hanski, Ilkka, and Otso Ovaskainen. 2000. The metapopulation capacity of a fragmented landscape. *Nature* 404:755-758.
———. 2003. Metapopulation theory for fragmented landscapes. *Theoretical Population Biology* 64 (1):119-127.
Hardie, Ian W., Peter J. Parks, Peter Gottlieb, and David N. Wear. 2000. Responsiveness of rural and urban land uses to land rent determinants in the U.S. South. *Land Economics* 76 (4):659-673.
Hecnar, Stephen J., and Robert T. M'Closkey. 1996. Regional dynamics and the status of amphibians. *Ecology* 77 (7):2091-2097.
Heimlich, Ralph E., and William D. Anderson. 2001. Development at the Urban Fringe and Beyond: Impacts on Agriculture and Rural Land. Washington, D.C.: Economic Research Service, U.S. Department of Agriculture.
Irwin, Elena G. 2002. The effects of open space on residential property values. *Land Economics* 78 (4):465-480.
Johnson, Michael P. 2001. Environmental impacts of urban sprawl: a survey of the literature and proposed research agenda. *Environment and Planning A* 33:717-735.
Johnston, Robert J., James J. Opaluch, Thomas A. Gigalunas, and Marisa J. Mazzotta. 2001. Estimating amenity benefits of coastal farmland. *Growth and Change* 32:305-325.
Keddy, Paul A., Harold T. Lee, and Irene C. Wisheu. 1993. Choosing indicators of ecosystem integrity: Wetlands as a model system. In *Ecological Integrity and the Management of Ecosystems*, edited by S. Woodley, J. Kay and G. Francis. Delray Beach, FL: St. Lucie Press.
King, Anthony W. 1993. Considerations of scale and hierarchy. In *Ecological Integrity and the Management of Ecosystems*, edited by S. Woodley, J. Kay and G. Francis. Delray Beach, FL: St. Lucie Press.
Lehtinen, Richard M., Susan M. Galatowitsch, and John R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. *Wetlands* 19 (1):1-12.
Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. *Bulletin of the Entomological Society of America* 15 (1):237-240.
———. 1970. Extinction. *Lecture Notes in Mathematics* 2:75-107.
Lofvenhaft, Katarina, Siv Runborg, and Per Sjogren-Gulve. 2003. Biotope patterns and amphibian distribution as assessment tools in urban landscape planning. *Landscape and Urban Planning* 68 (4):403-427.

Lutzenhiser, Margo, and Noelwah R. Netusil. 2001. The effect of open space on a home's sale price. *Contemporary Economic Policy* 19 (3):291-298.
Marsh, David M., and Peter C. Trenham. 2001. Metapopulation dynamics and amphibian conservation. *Conservation Biology* 15 (1):40-49.
Marshall, Elizabeth, Frances Homans, and Robert Haight. 2000. Exploring strategies for improving the cost effectiveness of endangered species management: the Kirtland's Warbler as a case study. *Land Economics* 76 (3):462-473.
Miltner, Robert J., Dale White, and Chris Yoder. 2004. The biotic integrity of streams in urban and suburbanizing landscapes. *Landscape and Urban Planning* 69 (1):87-100.
Moilanen, Atte, and Ilkka Hanski. 1998. Metapopulation dynamics: Effects of habitat quality and landscape structure. *Ecology* 79 (7):2503-2515.
Moilanen, Atte, and Nieminen. 2002. Simple connectivity measures in spatial ecology. *Ecology* 84 (4):1131-1145.
Ovaskainen, Otso. 2002. Long-term persistence of species and the SLOSS problem. *Journal of Theoretical Biology* 218 (4):419-433.
———. 2003. Habitat destruction, habitat restoration and eigenvector-eigenvalue relations. *Mathematical Biosciences* 181 (2):165-176.
Ovaskainen, Otso, and Ilkka Hanski. 2001. Spatially structured metapopulation models: global and local assessment of metapopulation capacity. *Theoretical Population Biology* 60 (4):281-302.
———. 2003. How much does an individual habitat fragment contribute to metapopulation dynamics and persistence? *Theoretical Population Biology* 64 (4):481-495.
Paton, Peter W. C. 2004. Personal communication on RIGIS vernal pool data.
Pope, Shealagh E., Lenore Fahrig, and H. Gray Merriam. 2000. Landscape complementation and metapopulation effects on leopard frog populations. *Ecology* 81 (9):2498-2508.
Randall, Alan, and Michael C. Farmer. 1995. Benefits, costs, and the safe minimum standard of conservation. In *The Handbook of Enviromental Economics*, edited by D. W. Bromley. Oxford: Blackwell Publishers.
Roan, Philip F., and Wade E. Martin. 1996. Optimal production and reclamation at a mine site with an ecosystem constraint. *Journal of Environmental Economics and Management* 30:186-198.
Rosenberger, Randall S., and John B. Loomis. 1999. The value of ranch open space to tourists: combining observed and contingent behaviour data. *Growth and Change* 30:366-383.
Semlitsch, Raymond D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamandars. *Conservation Biology* 12 (5):1113-1119.
———. 2000. Principles for management of aquatic-breeding amphibians. *Journal of Wildlife Management* 64 (3):615-631.
Semlitsch, Raymond D., and J. Russell Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology* 17 (5):1219-1228.
Sjogren-Gulve, Per. 1994. Distribution and extinction patterns within a northern metapopulation of the pool frog, *rana lessonae*. *Ecology* 75 (5):1357-1367.
Swallow, Stephen K. 1994. Renewable and nonrenewable resource theory applied to coastal agricultural, forest, wetland, and fishery linkages. *Marine Resource Economics* 9 (4):291-310.

———. 1996. Economic issues in ecosystem management: an introduction and overview. *Agricultural and Resource Economics Review* 25 (2):83-100.
Toman, Michael A. 1998. Why not to calculate the value of the world's ecosystem services and natural capital. *Ecological Economics* 25:57-60.
Trombulak, Stephen C., and Christopher A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14 (1):18-30.
Vitt, Laurie J., Janalee P. Caldwell, Henry M. Wilbur, and David C. Smith. 1990. Amphibians as harbingers of decay. *BioScience* 40 (6):418.
Vos, Claire C., A. G. Antonisse-deJong, P. W. Goedhart, and M. J. M. Smulders. 2001. Genetic similarity as a measure for connectivity between fragmented populations of the moor frog (*Rana arvalis*). *Heredity* 86:598-608.
Vos, Claire C., and J. P. Chardon. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog *Rana arvalis*. *Journal of Animal Ecology* 35:44-56.
Vos, Claire C., Cajo J. F. Ter Braak, and Wim Nieuwenhuizen. 2000. Incidence function modelling and conservation of the tree frog *hyla arborea* in the Netherlands. *Ecological Bulletins* 48:165-180.
Welsh, Hartwell H., and Sam Droege. 2001. A case for using plethodontid salamanders for monitoring biodiversity and ecosystem integrity of North American forests. *Conservation Biology* 15 (3):558-569.
Welsh, Hartwell H., and Lisa M. Ollivier. 1998. Stream amphibians as indicators of ecosystem stress: A case study from California's redwoods. *Ecological Applications* 8 (4):1118-1132.
Willson, John D., and Michael E. Dorcas. 2003. Effects of habitat disturbance on stream salamanders: implications for buffer zones and watershed management. *Conservation Biology* 17 (3):763-771.
Woodford, James E., and Michael W. Meyer. 2003. Impact of lakeshore development on green frog abundance. *Biological Conservation* 110:277-284.
Yang, Wanhong, Madhu Khanna, Richard Farnsworth, and Hayri Onal. 2003. Integrating economic, environmental and GIS modeling to target cost effective land retirement in multiple watersheds. *Ecological Economics* 46:249-267.

TABLE 1. Descriptions of Policy Alternatives

Policy Alternative	Description[1]
Current 1 (C1)	Current wetland policy that protects the area of the pool only
Current 2 (C2)	Same as C1 except developed parcels are two acres
Envelope (E)	Protect vernal pool plus 100-foot buffer (envelope)
Guidelines (G)	Protect vernal pool plus 100-foot buffer plus 75% of critical habitat;[2] recommended vernal pool guidelines[3]
New Policy 1 (P1)	Protect vernal pool plus 100-foot buffer plus 50% of critical habitat
New Policy 2 (P2)	Protect vernal pool plus 100-foot buffer plus 25% of critical habitat
New Policy 3 (P3)	Protect vernal pool plus 100-foot buffer plus 25% of critical habitat plus 25% of intervening landscape matrix
No Development (0)	Protect all vernal pools plus 100-foot buffer plus 100% critical habitat plus 100% of intervening landscape

[1]Unless otherwise noted, all policies assumed all developed parcels were one acre.
[2]Critical habitat is defined as an outer buffer 100-750 feet from pool edge.
[3]Vernal pool guidelines (Calhoun and Klemens 2002).

Figure 1. Study area: 123-pond network within 10,000 acres of landscape matrix.

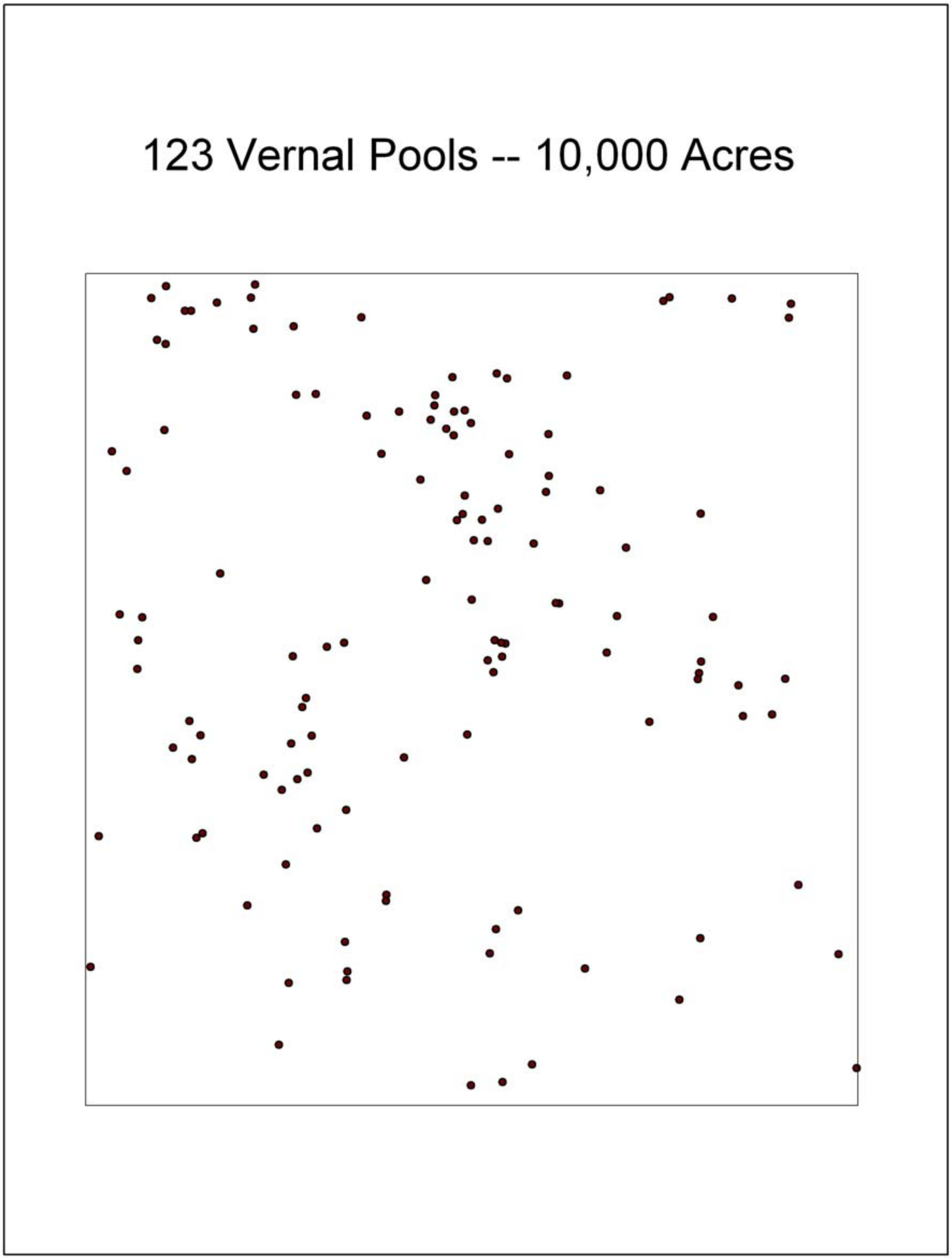


Figure 2. Optimization results. The foregone benefits of development (i.e., the opportunity costs of restricting development) increase as the level of the metapopulation size is increased.

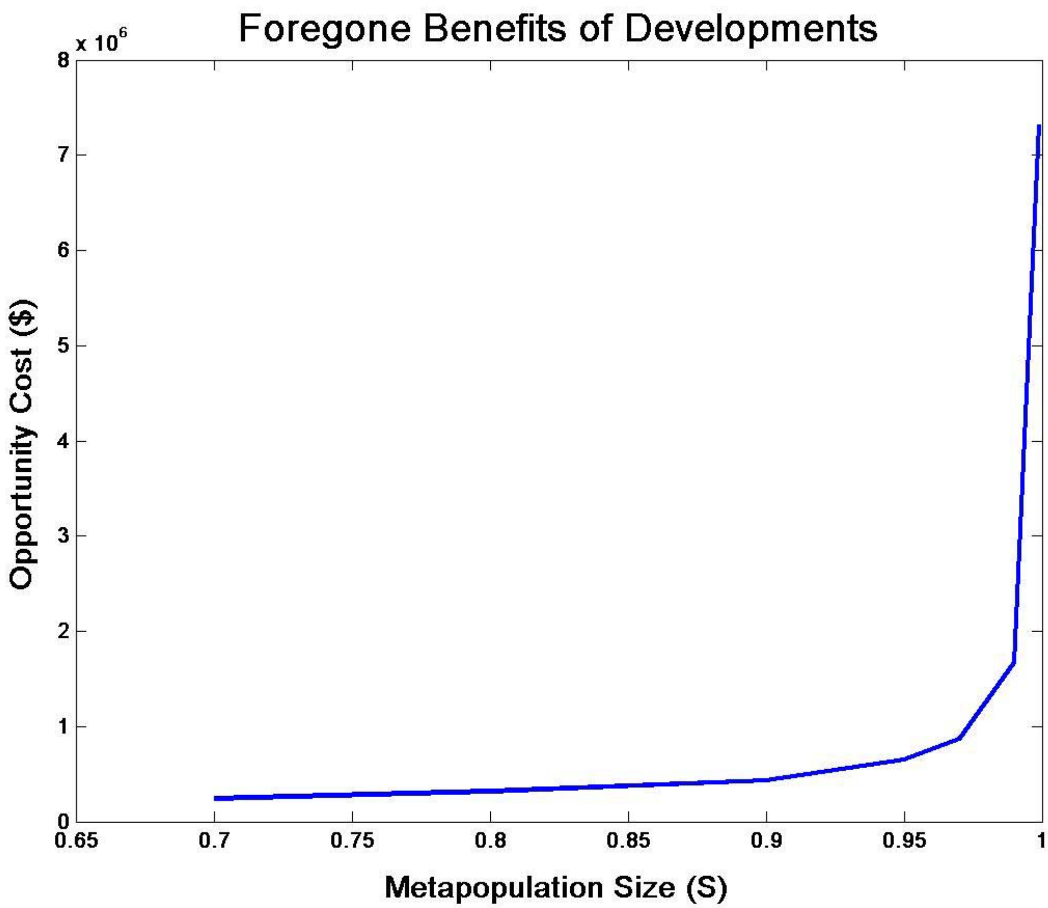
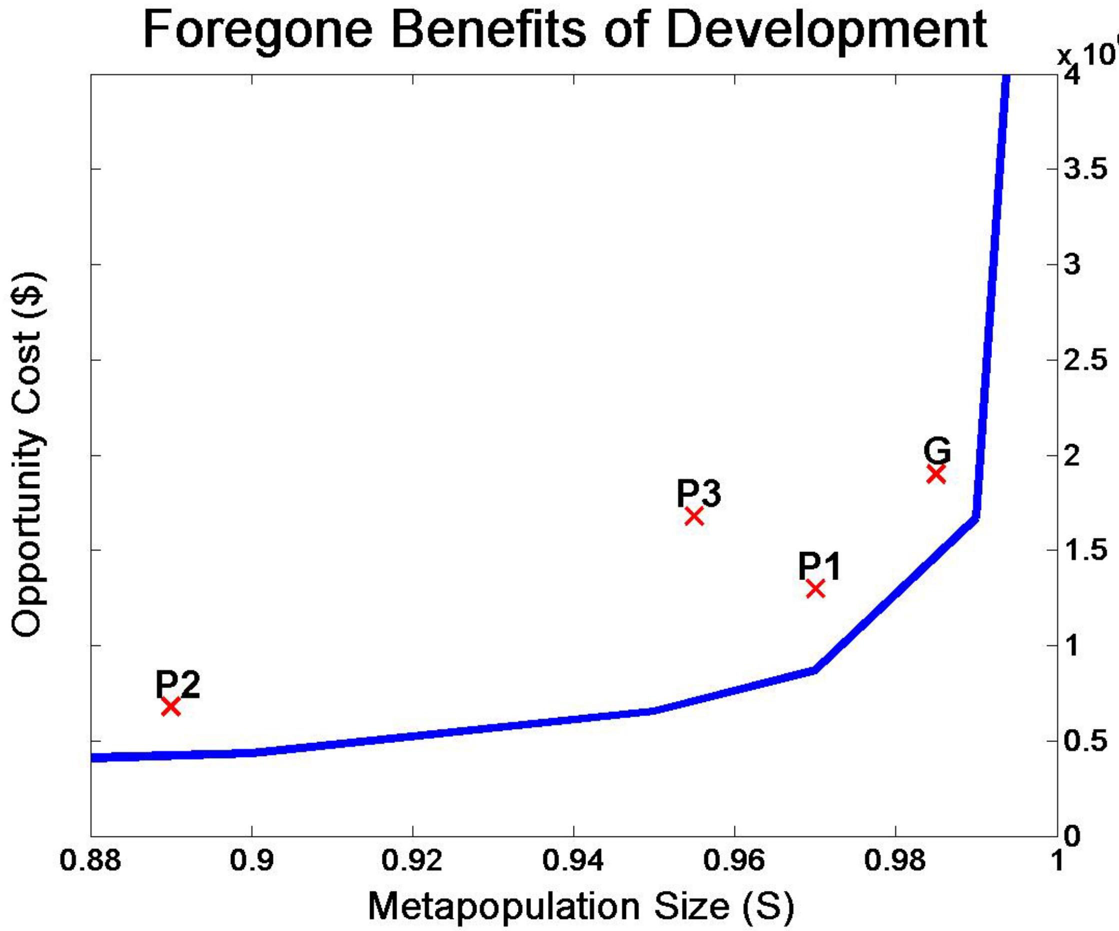


Figure 3. Comparison of the opportunity costs corresponding to various policy alternatives versus the optimal solution set.



PART Two: Bioprocess-based Spatial Modeling of Reserve Network Design: An Integer Programming Approach

A common, even leading, cause of biodiversity loss is habitat loss and fragmentation. A growing literature concerns methods by which to identify priority lands for purchase and preservation as a conservation reserve, particularly by identifying lands that currently support species and that may be purchased or conserved at low cost (Ando et al. 1998, Polasky et al. 2000; Possingham et al. 2000). Economists have used an index of species diversity or species presence to identify a measure of ecological contribution from preserving a land parcel and have minimized the cost of achieving a target level of that index. However, many of these analyses have not considered the spatial relationship among lands conserved, nor the ecological role that this spatial relationship implies for land parcels preserved. As a result, many of the reserve designs show a high degree of fragmentation or disconnection between the land parcels targeted for conservation (Possignham et al. 2000; McDonnell et al. 2002).

Some recent analyses consider spatial relationships (Williams 1998; Williams and ReVelle 1998; Possingham et al. 2000; Briers 2002; McDonnell et al. 2002; Nalle et al. 2002b; Onal and Briers 2002, 2003). Yet these studies have generally not emphasized the ecological mechanisms whereby spatial linkages among land parcels affect the level achieved relative to a measure of ecological quality. These studies have also been limited by computational techniques, particularly when the ecological index considered is non-linear. A combination of heuristic methods and optimization methods have been presented in the literature (Kirkpatrick 1983; Margules et al. 1988; Nicholls and Margules 1993; Underhill 1994; Church et al. 1996; Pressey et al. 1996, 1997; Pressey

2002; Rodrigues and Gaston 2002). Optimization models may not be practical to solve at a large scale using available solution methods. Heuristic methods may be used to solve problems at a larger scale, using a measure of an ecological quality index that is logically, but imperfectly, correlated with the actual index decision makers might target. While optimization methods may be used to obtain a truly optimal solution over a restricted problem, heuristic methods may not produce an optimal (e.g., minimum cost) solution but can address a less restricted scope of the problem (often a larger geographic area).

This second portion of the research (Part Two of this paper) strives to develop a bioprocess-based method for selecting land for conservation reserves, considering not only the spatial relationship among land parcels but also the ecological role of land in that spatial relationship. We are developing an optimization approach that may be solved with available methods, but which may not be subject to the restrictions expected by previous practitioners when optimizing a non-linear index of ecological quality. In particular, we are developing methods that use a linearization that accurately reflects the ecological index that one would prefer to optimize directly, and this linearization permits use of existing integer-program optimization routines. The research is motivated by conservation of amphibian metapopulations in the Wood-Pawcatuck Rivers watershed of southwestern Rhode Island and southeastern Connecticut, particularly amphibians which depend on seasonally flooded wetlands (vernal pools) for breeding sites.

Overview of Ecological Concepts of Reserve Design

Part One of this paper provided a review of a spatially explicit metapopulation models from ecological theory. That theory notes that a population of some species may depend on subpopulations residing within habitat patches. These subpopulations may occasionally go extinct and the corresponding habitat patch may be recolonized by dispersal of individuals, from the remaining occupied patches, across a matrix of inter-patch land. Patches with higher population size may be more likely to contribute immigrants (or re-colonizers) to other patches, and patches are more likely to receive immigrants from patches that are closer rather than farther away. A group of subpopulations that interact in this way to maintain an overall population is called a metapopulation.

Based on these fundamental relationships, the research proceeds by developing a model of the probability that the overall population of an amphibian species goes extinct. This model depends on the probability that a patch is occupied or, if unoccupied, the probability that the patch is re-colonized. We then develop a simulation model that minimizes the probability that the species goes extinct from within the lands designated for a conservation reserve, as constrained by a budget for the cost of purchasing or preserving land in the reserve. We omit the equations that describe this probability here, but Table 1 is indicative of the factors that the project includes.

Three versions of this model (cf. Figure 1) are being developed and examined with respect to the watershed in southwestern Rhode Island (Figure 2). All versions use integer programming and a linearized version of an index for the probability that the overall population goes extinct within a conservation reserve network. In Version One, individual ponds (vernal pools or habitat patches) are chosen for preservation and their contribution to the index of extinction probability is calculated. By construction, this contribution reduces the extinction probability index only if a pond is preserved within a biologically relevant neighborhood of another pond that is also being preserved. This neighborhood is defined as two kilometers, based on literature pertaining to the dispersal distances witnessed for the study species (wood frogs or spotted salamanders). This first version assumes matrix land between ponds will remain permeable to dispersal of migrant individuals in the metapopulation. In Version Two, preservation of a pond only reduces the probability of population extinction if that pond is connected to at least one other pond by a preserved corridor of land. In this version, the budget constraint includes the opportunity cost of purchasing land around the pond sites plus the corridor between pond sites (habitat patches). Habitat patches are connected to at least one other patch, but not necessarily to all other patches. The contribution that preserved patches make to reducing the index of extinction probability is defined to be higher when the preserved ponds are connected by a preserved corridor, as compared to version one when the patches are not required to be connected by a preserved corridor.

Version Three of the model is an intermediate case. In Version Three, preserved patches do reduce the index for probability of metapopulation extinction if patches are preserved with or without preservation of the intervening corridor. This reduction in the index requires preservation of at least one other patch within 2 kilometers but without an intervening corridor, or it requires preservation of one other patch along with the intervening corridor. In this third version of the model, isolated patches may be preserved with or without corridors, but preservation of the corridor between two (or more) patches increases the contribution of these patches to reducing the index of the probability of metapopulation extinction within the conservation reserve relative to the contribution of patches that are not interconnected by preserved corridors.

In all cases, the index of the probability of metapopulation extinction is adjusted for a measure of quality of a habitat patch, as represented by an estimate of the subpopulation size for that patch. This measure of habitat quality or subpopulation size is equal to the number of egg-masses estimated at the pond site for that species. This egg-mass count is representative of the number of adult breeding females of the study species (Crouch and Paton 2000; Paton, unpubl. data).

Overview of Empirical Application

We applied the model to a subset of vernal pool habitat patches within the watershed of southwestern Rhode Island; the subset consisted of 39 ponds. The three versions of the model were solved by integer programming using GAMS 20.7. Figure 3 shows the results of the network design models based on a $10,000,000 budget applied to the land around these 39 ponds. Land values were derived from tax assessor records for the towns in the watershed and assigned to cells within a 1 ha grid. Skidds (2004) provides details.

Results in Figure 3 show that the Version One results in conservation of several clusters of habitat patches dispersed across the landscape. In Version Two, the additional requirement to preserve connecting corridors with ponds causes a reduction of the number of habitat patches preserved and yields a smaller number of clusters of preserved pond sites. Version Three leads to preservation of a few additional habitat patches in exchange for not connecting all ponds to at least one other pond by a preserved corridor. Table 2 shows that Version One preserved the most patches (29) while Version Two preserved the fewest (12, all with at least one preserved corridor) and Version Three preserved the next fewest (15).

Concluding Notes

This preliminary research demonstrates that it may be feasible to explicitly consider the ecological role of spatial connections (corridors) between preserved habitat patches using an index of the probability that key species persist within a conservation reserve network. The various versions of the model rely, to different degrees, on the assumption that matrix lands intervening between habitat patches remain permeable to migrants that could recolonize patches following extinction of the subpopulation within a patch. Ecological research is critical to calibrating this assumption; that is, ecological research is needed to shed light on how various types and intensities of development will change the permeability of unpreserved matrix lands to metapopulation persistence. Such research will aid in developing a better representation of the probability of metapopulation persistence in an index that can be built on relatively easily available biological data (egg-mass counts in this case). Calibrating the components of the index of metapopulation extinction (or persistence) will allow decision-makers (watershed managers) to better evaluate the likely impact of tradeoffs between preserving habitat patches with and without preserving intervening corridors. From our preliminary models, the basic models seem to offer a practical approach by which local or regional decisionmakers could identify priority lands for conservation and then develop, purchase, regulatory, or incentive-based policies that encourage land conservation and development consistent with maintaining an identified conservation reserve.

References and Literature Cited

Ando, Amy, Camm, Jeffrey, Polasky, Stephen, and Andrew Solow, 1998, Species Distributions, Land Values, and Efficient Conservation, *Science* 279: 2126-28.

Briers, Robert A., 2002, Incorporating Connectivity into Reserve Selection Procedures, *Biological Conservation* 103: 77-83.

Crouch, W. B. III, and P. W. C. Paton. 2000. Using egg mass counts to monitor wood frog populations. *Wildlife Society Bulletin* 28:895-901.
Diamond, J.M., 1975, the Island Dilemma: Lessons of Modern Biogeographic Studies for the Design of Natural Reserves, *Biological Conservation* 7: 129-146.
Flint, R. F. 1971. Glacial and Quaternary Geology. John Wiley and Sons, New York, NY, USA.
Gonzalez, A., Lawton, J.H., Gilbert, F.S., Blackburn, T.M., and I. Evans-Freke, 1998, Metapopulation Dynamics, Abundance, and Distribution in a Microecosystem, *Science* 281: 2045-47.
Gosselink, J.G. et al. 1990, Landscape Conservation in a Forested Wetland Watershed, *BioScience* 40: 588-600.
Hanski, I., 1994, A Practical Model of Metapopulation Dynamics, *Journal of Animal Ecology* 63: 151-62.
Joly, P., Morand, C., and A. Cohas, 2003, Habitat Fragmentation and Amphibian Conservation: Building a Tool for Assessing Landscape Matrix Connectivity, *Biologies* 326: 132-139.
Kindvall, O., 1999, Dispersal in a Metapopulation of a Bush Cricket, Metrioptera Bicolor (Orthoptera: Tettigoniidae), *Journal of Animal Ecology* 68: 172-85.
Kirkpatrick, J.B., 1983, An Iterative Method for Establishing Priorities for Selection of Nature Reserves: An Example from Tasmania, *Biological Conservation* 25: 127-134.
Mann, C.C. and M.L. Plummer, 1995, Are Wildlife Corridors on the Right Path? *Science* 270: 1428-30.
Margules, C.R., Nicholls, A.O., and R.L. Pressey, 1988, Selecting Networks to Maximize Biological Diversity, *Biological Conservation* 43: 63-76.
Margules, C.R. and R.L. Pressey, 2000, Systematic Conservation Planning, *Nature* 405: 243-53.
McDonnell, Mark D., Possingham, Hugh P., Ball, Ian R., and Elizabeth A. Cousins, 2002, Mathematical Methods for Spatially Cohesive Reserve Design, *Environmental Modeling and Assessment* 7: 107-114.
Moilanen, A. and M. Nieminen, 2002, Simple Connectivity Measures in Spatial Ecology, *Ecology* 83(4): 1131-45.
Mwalyosi, R.B., 1991, Ecological Evaluation for Wildlife Corridors and Buffer Zones for Lake Manyara National Park, Tanzania and Its Immediate Environment, *Biological Conservation* 57: 171-186.
Nalle, Darek J. Arthur, Jeffrey L., and John Sessions, 2002, Designing Compact and Contiguous Reserve Networks with a Hybrid Heuristic Algorithm, *Forest Science* 48(1): 59-68.
Nicholls, A.O. and C.R. Margules, 1993, An Upgraded Reserve Selection Algorithm, *Biological Conservation* 64: 165-169.
Nicholls, A.O., 1998, Integrating Population Abundance, Dynamics and Distribution into Broad Scale Priority Setting, in: Mace, G.M., Balmford, A. and J.R. Ginsberg (eds), Conservation in a Changing World: Integrating Processes into Priorities for Action, Cambridge Univ. Press, 251-272.
Onal, Hayri and Robert A. Briers, 2002, Incorporating Spatial Criteria in Optimum Reserve Network Selection, *Proc. R. Soc. Lond. B* 269: 2437-2441.

Onal, Hayri and Robert A. Briers, 2003, Selection of a Minimum-boundary Reserve Network Using Integer Programming, *Proc. of Royal Society of London B* 270: 1487-1491.

Onal, Hayri and R.A. Briers, 2004, Designing a Conservation Reserve Network with Minimal Fragmentation: A Linear Integer Programming Approach, working paper.

Pelletier, J.D., 2000, Model Assessment of the Optimal Design of Nature Reserves for Maximizing Species Longevity, *Journal of Theoretical Biology* 202: 25-32.

Polasky, Stephen, Camm, Jeffrey D., and Brian Garber-Yonts, 2001, Selecting Biological Reserves Cost-Effectively: an Application to Terrestrial Vertebrate Conservation in Oregon, *Land Economics* 77(1): 68-78.

Possingham, Hugh, Ball, Ian, and Sandy Andelman, 2000, Mathematical Methods for Identifying Representative Reserve Networks, in: Quantitative Method for Conservation Biology, Ferson, S. and Burgman, M.(eds), Springer-Verlag, New York.

Pressey, R.L. and R.M. Cowling, 2001, Reserve Selection Algorithms and the Real World, *Conservation Biology* 15: 275-77.

Pressey, R.L., Possingham, H.P., and C.R. Margules, 1996, Optimality in Reserve Selection Algorithms: When does It Matter and How Much? *Biological Conservation* 76: 259-267.

Pressey, R.L., Possingham, H.P., and R.J. Day, 1997, Effectiveness of Alternative Heuristic Algorithms for Identifying Indicative Minimum Requirements for Conservation Reserves, *Biological Conservation* 80: 207-219.

Rodrigues, Ana S., Cerdeira, J. Orestes, and Kevin J. Gaston, 2000, Flexibility, Efficiency, and Accountability: Adapting Reserve Selection Algorithms to More Complex Conservation Problems, *Ecography* 23: 565-574.

Rodrigues, Ana S. and Kevin J. Gaston, 2002, Optimization in Reserve Selection Procedures — Why Not? *Biological Conservation* 107: 123-129.

Sessions, J., 1992, Solving for Habitat Connections as a Steiner Network Problem, *Forest Science* 38(1): 203-207.

Shafer, C.L., 1995, Values and Shortcomings of Small Reserves, *BioScience* 45: 80-88.

Shaw, M.W., 1994a, Modeling Stochastic Process in Plant Pathology, *Annual Review of Phytopathology* 32: 523-44.

Shaw, M.W., 1994b, Simulation of Population Expansion and Spatial Pattern When Individual Dispersal Distributions Do Not Decline Exponentially with Distance. *Proceedings of the Royal Society of London*, Series B 259: 243-48.

Simberloff, D.S. and L.G. Abele, 1982, Refuge Design and Island Biogeographic Theory: Effects of Fragmentation, *American Naturalist* 120: 41-50.

Simberloff, D.S. and N. Gotelli, 1984, Effects of Insularization on Plant Species Richness in the Pairie-Forest Ecotone, *Biological Conservation* 29: 27-46.

Skidds, D.E., 2004, Vernal Pool Amphibian Habitat Conservation in the Pawcatuck River Watershed of Southern Rhode Island, unpublished paper.

Soule, M.E., 1991, Conservation: Tactics for a Constant Crisis, *Science* 253: 744-50.

Soule, M. and D. Simberloff, 1986, What Do Genetics and Ecology Tell Us about the Design of Nature Reserves? *Biological Conservation* 35: 19-40.

Underhill, L.G., 1994, Optimal and Suboptimal Reserve Selection Algorithms, *Biological*

Conservation 70: 85-87.
Wiens, J.A., 1996, Wildlife in Pathy Environment: Metapopulations, Mosaics, and Management, in: D.R. McCullough (eds), Metapopulations and Wildlife Conservation, pp. 53-84, Island Press, Washington, D.C.
Wiens, J.A., 1997, Metapopulation Dynamics and Lanscape Ecology, in: I. Hanski and M.E. Gilpin (eds), Metapopulation Biology: Ecology, Genetics, and Evolution, pp. 43-62, Academic Press, San Diego.
Wilcove, D.S. and R.M. May, 1986, National Park Boundaries and Ecological Realities, *Nature* 324: 206-207.
Williams, Justin C. and Charles S. ReVelle, 1998, Reserve Assemblage of Critical Areas: A Zero-one Programming Approach, *European Journal of Operations Research* 104: 497-509.
Williams, Justin C., ReVelle, Charles S., and Simon A. Levin, 2004, Using Mathematical Optimization Models to Design Nature Reserves, *Front. Ecol. Environ.* 2(2): 98-105.
With, K.A., 2002, Using Percolation Theory to Assess Landscape Connectivity and Effects of Habitat Fragmentation. in: K.J. Gutzwiller (eds), Applying Landscape Ecology in Biological Conservation, pp. 105-130, Springer-Verlag, New York.

Table 1. Definition of Model Variables and Parameters

Model Variables and Parameters	Definition
Decision variables	
t_{ij}	status of vernal pool i and j, 1 indicating both selected, 0 otherwise
z_{ij}	status of corridor connection between pond i and j, 1 indicating being selected, 0 otherwise
x_i	status of pond i, 1 indicating being selected, 0 other wise
Model parameters	
N_i	set of potential source ponds of pond i, defined by distance
p_{ij}	probability of migration of amphibian from pond j to pond i with corridor connection
p_{ij}'	probability of migration of amphibian from pond j to

	pond i without corridor connection
α	dispersal parameter
d_{ij}	distance between pond i and j, km
m_i	egg mass count in pond i
B	Budget line

Table 2. Comparison of Reserve Networks under Alternative Models

	Model 1.	Model 2.	Model 3.
Vernal pools	29	12	15
Corridor connection	0	10	9
Extinction probability	3.11×10^{-7}	2.13×10^{-19}	6.61×10^{-20}

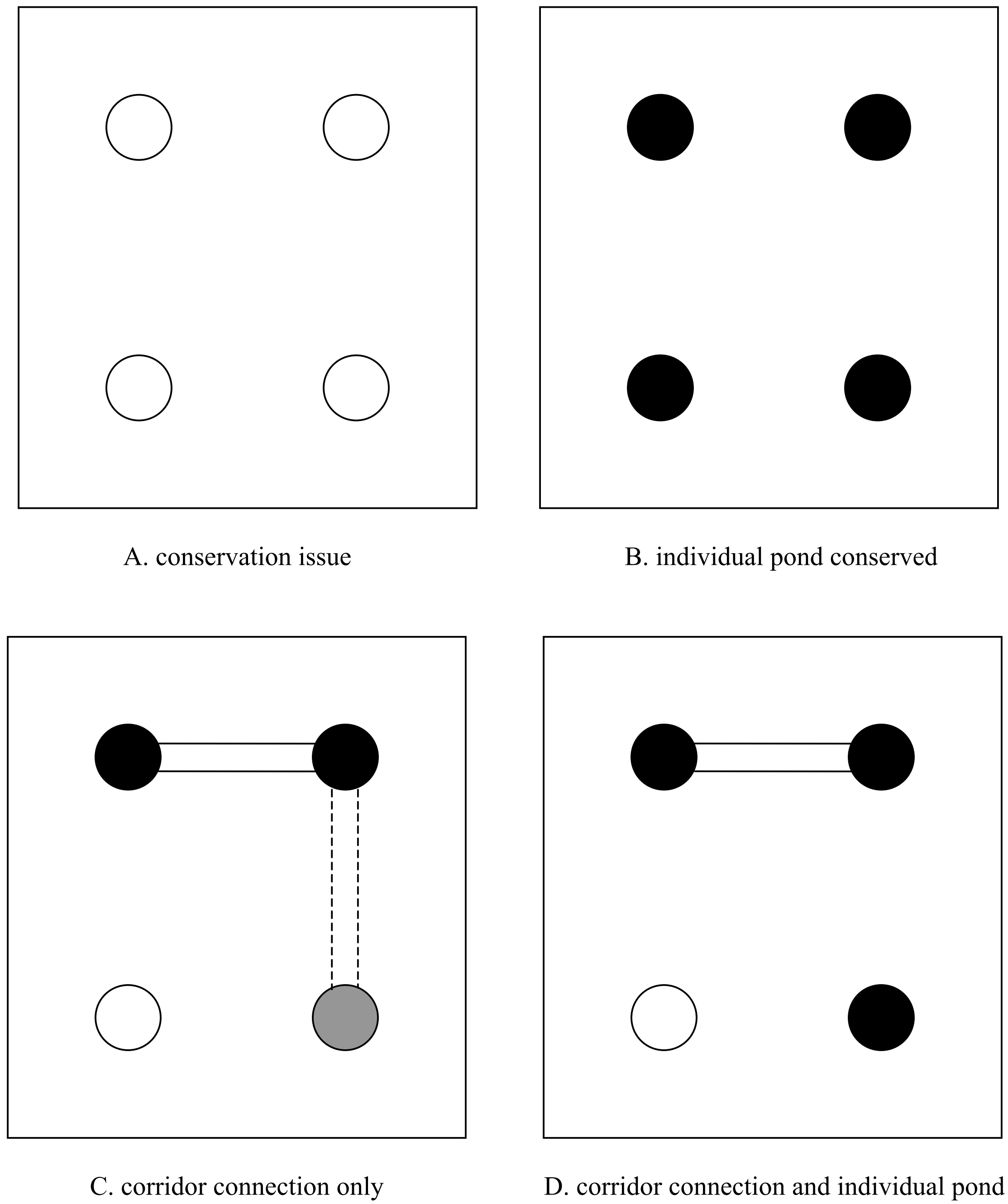


Figure 1. Reserve Network under Alternative Conservation Strategies: Panel A presents the conservation issue; Panel B demonstrates the reserve system by selecting individual pond; Panel C demonstrates the reserve system by selecting habitat corridor, where the dot line and gray circle means the budget is not enough to fully cover their cost; Panel D demonstrates the case with individual pond and corridor.

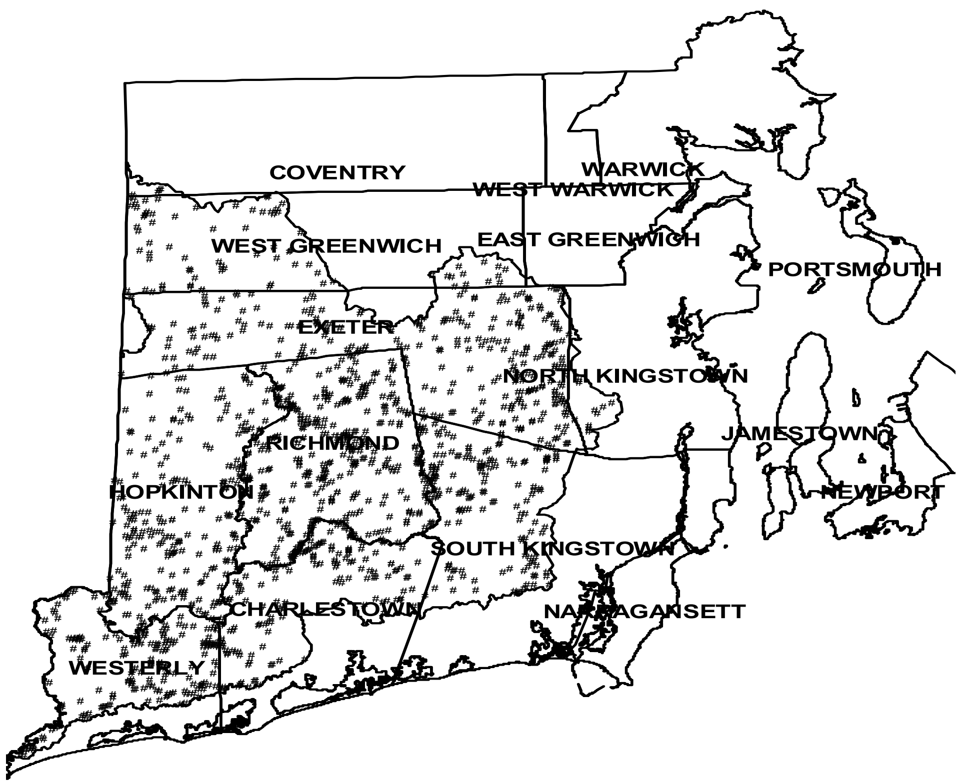
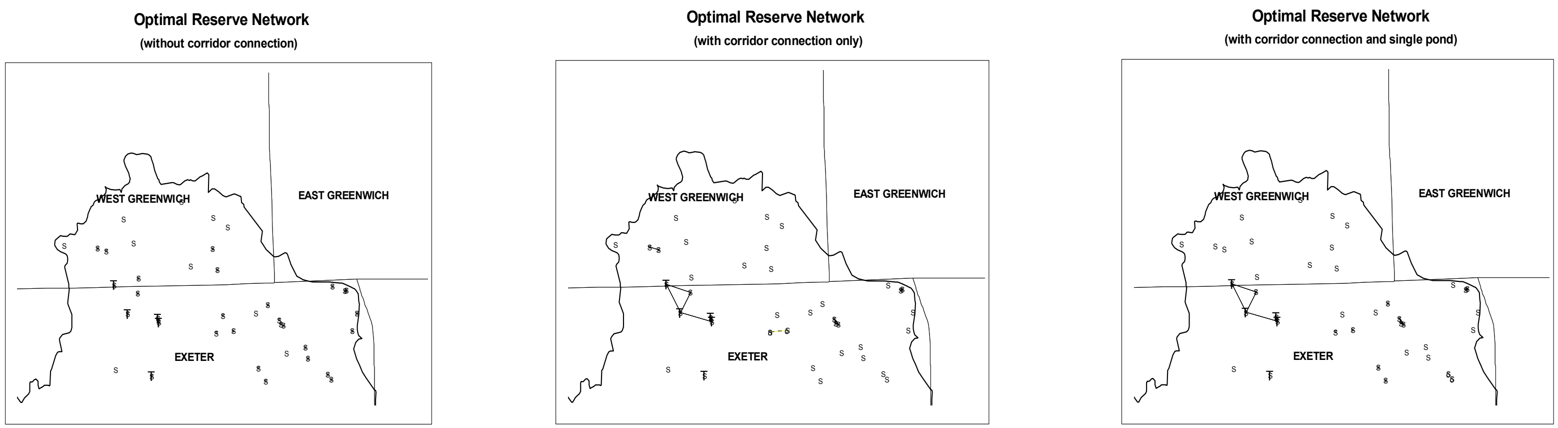


Figure 2. the Pawcatuck Watershed Area of Rhode Island



A. B. C.

Figure 3. Comparison of the Reserve Networks under Alternative Models with A Budget of 10 Million Dollars

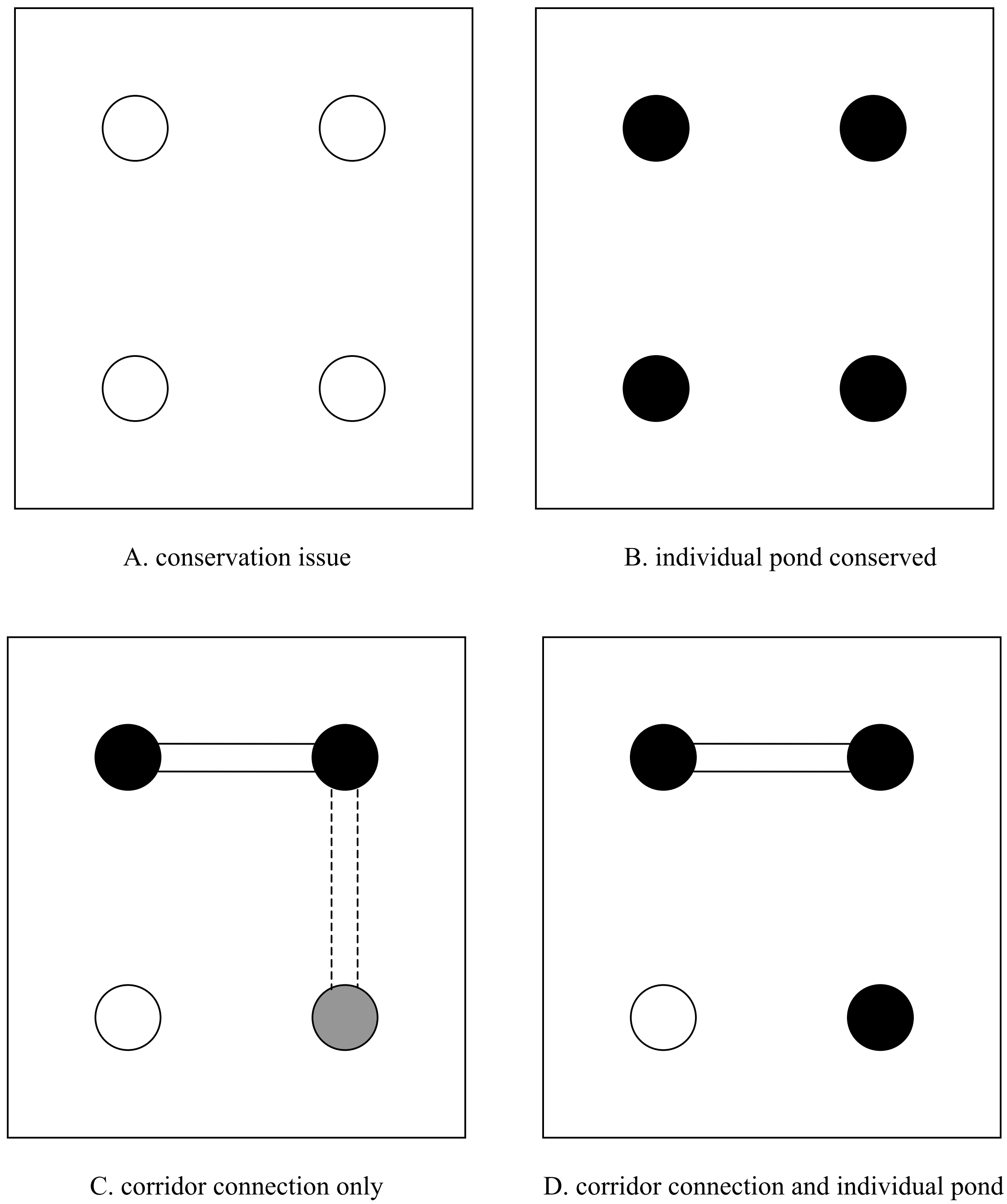


Figure 1. Reserve Network under Alternative Conservation Strategies: Panel A presents the conservation issue; Panel B demonstrates the reserve system by selecting individual pond; Panel C demonstrates the reserve system by selecting habitat corridor, where the dot line and gray circle means the budget is not enough to fully cover their cost; Panel D demonstrates the case with individual pond and corridor.

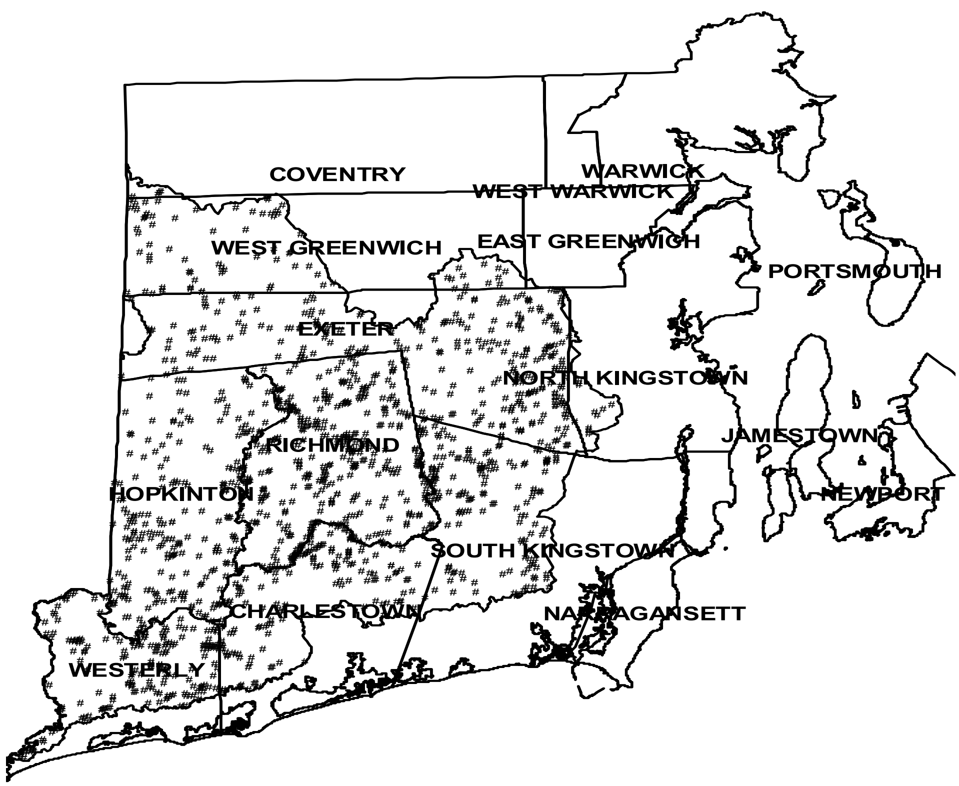
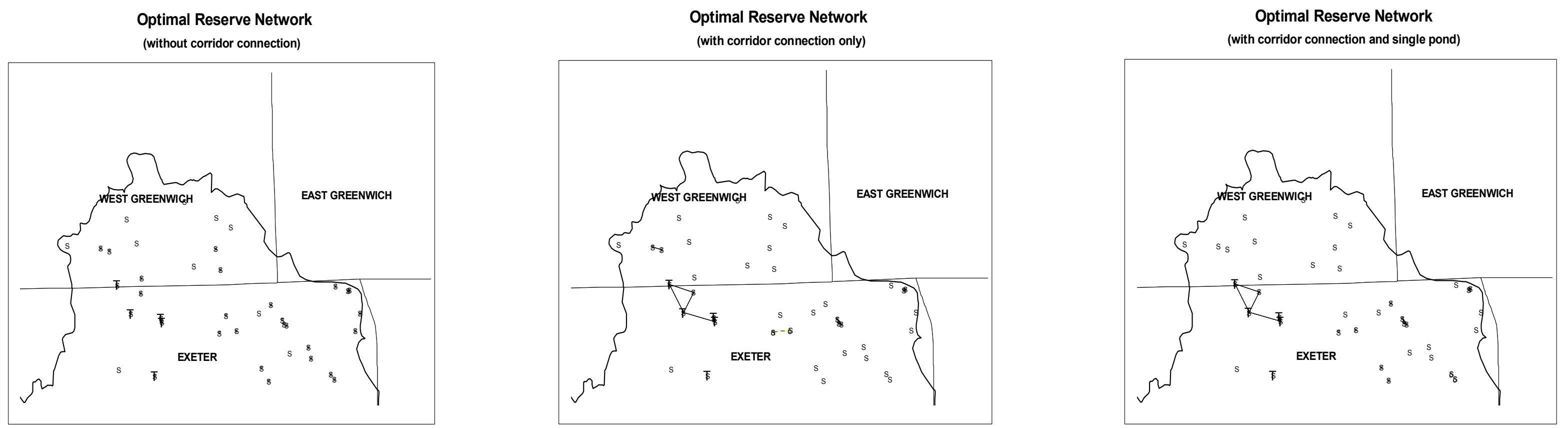


Figure 2. the Pawcatuck Watershed Area of Rhode Island



A. B. C.

Figure 3. Comparison of the Reserve Networks under Alternative Models with A Budget of 10 Million Dollars

Spatial Analysis of Private Land Conservation Behavior

Heidi J. Albers* and Amy W. Ando**

*Associate Professor
Dept. of Forest Resources
College of Forestry
Oregon State University
Corvallis, OR 97331

**Assistant Professor
Dept. of Ag. and Consumer Economics
Univ. of Illinois Urbana-Champaign
Urbana, IL 61801

We gratefully acknowledge major funding from the National Science Foundation. This material is also based in part upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Project No. ILLU 05-0305. We thank our excellent research assistants, Mike Batz, Xiaoxuan Chen, and Kenny Gillingham, while taking full responsibility for any mistakes and misstatements that lie within.

I. Introduction

Protected lands provide important conservation benefits in the U.S. — public goods ranging from species protection to water quality maintenance to recreation. Although state and federal governments manage public lands to provide these benefits, private land trusts augment the supply of benefits by conserving other land. By 1998, at least 1,211 land trusts were operating in the U.S. (LTA, 1998), where a land trust is defined as a non-profit private organization actively engaged in land conservation activity. The acreage of land protected by such groups tripled in the 1990s.

The existing constellation of lands protected by governments may not contain the most valuable land for providing conservation services (Scott, Abbitt, and Groves, 2001). Gap analysis—a technique used by conservation biologists to assess reserve systems—for various regions of the U.S. finds glaring differences between the location of species and threatened ecosystems and the location of conserved land (Hoctor, Carr, and Zwick, 2000; Wright, Scott, Mann, and Murray, 2001). In addition, the production of many types of conservation benefits, including both watershed and species protection, contains thresholds of land below which only limited benefits accrue but the tendency of governments to overdisperse their conservation spending can mean that those thresholds are not met (Wu and Boggess, 1999). Only limited expansion of federal protected areas is likely; hence, private land conservation agents have an important role to play in rationalizing the nation's network of protected lands.

Despite the growing importance of private land trusts in the provision of these valuable public goods, few economic analyses (see literature section below) have examined either individual land trust decisions or the cumulative effect of land conservation by the uncoordinated activities of many public organizations and private trusts. In non-economic analysis, authors describe the failure of focused local land trusts to provide regional or cross-jurisdictional conservation benefits (Goldsmith, 2001). This local focus and lack of coordination across trusts has become a serious enough problem to give rise to organizations that facilitate coordination across trusts (Maine Land Trust Network, 2002; Goldsmith, 2002; Bay Lands Center, 2002). Albers and Ando's (2002) economic analysis of the structure of the land conservation industry revealed that whether land trusts incorporate information about other land conservation activities into decisions is important for the provision of a socially desirable level of conservation benefits. However, land-trust decision making processes are complex and poorly understood.

It is difficult to control, predict, and even describe an effective state-wide conservation strategy when the efforts that comprise that conservation are made independently by distinct organizations. If, for example, a state government engaged in a major land-conservation initiative, we do not know how private trusts would react. Economic theory about government activities might suggest that such government conservation could displace some or all land conservation by private trusts through "crowding-out." But, because conservation benefits are a function of cumulative amounts of land and its configuration, perhaps government land conservation could act as a "seed" and "crowd-in" private land conservation activities. This project seeks to develop some understanding of how public and private conservation agents interact and the consequences of different modes of interaction in order to elucidate the potential impact of various policies to promote private land conservation. Though the discipline of economics is ideally suited for modeling and understanding this kind of inter-agent interaction, little rigorous scholarly analysis exists within economics to shed light on this important mechanism for providing valuable public goods.

To fill the gaps in our current understanding of private conservation, we are engaged in a body of research which examines the actions and decisions of private land trusts with a focus on their consideration of the land conservation actions of other land conservation actors. In our project, we will characterize land trust decisions with models and data. We will explore the extent to which land trusts make decisions based on information about the actions of other land conservation actors, and examine the impact of information exchange and coordination among diverse land trusts and between trusts and government. On the policy front, we will identify the role of government protected lands in encouraging or discouraging private land conservation, and explore policy options such as providing information and facilitating coordination across land trusts to encourage socially-preferred patterns of land trust activity.

This paper provides a background in the literature for our work, and sets out a general modeling framework for the research. We report on preliminary results from simulation and econometric exercises that are being conducted as parts of this multi-faceted research project. We conclude with observations regarding the status of the work to date, and expectations for future efforts.

II. Literature and Background

There is a now-classic literature on the impact that the public provision of public goods may have on related levels of private provision. This literature focuses largely on the potential for and extent of "crowding out" of private provision by public spending (e.g. Andreoni, 1989; Kingma, 1989). More recent work by Andreoni (1998) does point to the potential for government grants to "seed in" private contributions when charitable groups have fixed costs. However, papers in this literature have not considered the case of public goods for which spatial externalities are likely to be important.

The social benefits of open, protected, and managed lands are public goods with complex spatial features. While conservation has not been modeled in the public-good provision framework, there is a sizable literature analyzing land use patterns: studies of tropical deforestation (Chomitz and Gray, 1996; Nelson and Hellerstein, 1997; Cropper et al, 2001), participation in farmland preservation programs (Lynch and Lovell, 2003), and land-development patterns (Irwin, 2002; Irwin and Bockstael, 2002; Bell and Irwin, 2002). These studies provide some insight into landowner decision making. However, they have focused on decisions made by private agents to maximize individual utility. Any analysis of land retirement choices aimed at providing public goods such as biodiversity must be qualitatively different, for those benefits depend differently on the spatial pattern of land uses.

Swallow et al. (1997) and Swallow, et al. (1990) were early advocates of the notion that the impact of land use decisions hinge critically on the precise configuration of land uses in the landscape. Albers (1996) develops a model of tropical land management in which certain uses create adjacency values and certain spatial patterns of uses interact with the flows of benefits over time. MacFarlane (1998) points out that because of spatial externalities, agri-environmental policies could yield greater benefits if they were designed to consider the landscapes produced by such policies rather than focusing on individual farms.

The reserve-site selection literature began to model the optimal choice of protected lands when the benefits of protecting one parcel depend on exactly which other parcels have been protected (Ando et al. 1998; ReVelle, Williams, and Boland, 2002). However, these papers provide normative guidance for a single hypothetical social planner. In reality, conservation networks emerge from land-use choices made by many agents.

Only recently have scholars begun to develop frameworks for analyzing conservation outcomes and policy when multiple decision makers exert spatially-explicit externalities on each other. Bergeron and Polasky (2000) show that when land-use decisions made by multiple landowners contribute to a species' survival or downfall, conservation efforts may be inadequate or excessive relative to the social optimum. Experimental work by Parkhurst et al. (2002) suggests that when benefits depend on the configuration of the entire network of conserved lands, the total benefits yielded by voluntary conservation networks may be increased by offering agglomeration bonuses to private landowners. Several new papers allied with urban and regional economics have modeled equilibrium urban development in settings with multiple agents and spatial externalities (Marshall, 2004; Tajibaeva, Haight, and Polasky, 2003; Turner, forthcoming). The agents modeled in these papers, however, do not have public-good provision as an objective.

Very few papers have studied the behavior of the collection of conservation agents which actually exists in the U.S. Albers and Ando (2003) showed potentially desirable patterns in land-trust proliferation. There are more trusts in states where net benefits of conservation are higher, and fewer where the need for coordination might be high relative to the benefits of niche diversification. The results of that paper also left behind a puzzle: at the state level, there are more trusts where there is more public conservation. This paper seeks to explore the relationship between public and private conservation at a finer level of spatial detail.

Work in progress by Parker and Thurman (2004) conducts a panel-data analysis of county-level conservation acreage, and find evidence that increased government conservation in a county tends to crowd out private conservation in that same county. Their work has the advantage of panel data, and considers land enrolled in CRP and WRP as well as public lands which are in permanent protected status. However, they do not have spatial data on the location of the private protected lands, which complicates their econometric efforts.

To address the gaps in the literature, we model behavior by multiple agents who aim for public good provision in a setting where private and total benefits depend on the spatial configuration of all parcels protected in the landscape. This pursuit yields a framework for simulations in which government provision may crowd private conservation either in or out, and the resulting pattern may or may not demonstrate spatial agglomeration. Empirically, we use township-level spatial data on the location of private and public lands in several states to explore the spatial relationships that exist among protected lands, and to cast light on which of the scenarios we model seems most likely to obtain in the real world.

III. Framework

The fundamental perspective of the modeling framework employed in both the simulation and empirical work discussed here is that land trusts make decisions about the location and amount of land to conserve by solving a constrained optimization problem to maximize their net benefits subject to budget constraints. At least two characteristics of land conservation differentiate this problem from other such optimization problems. First, the benefits from conservation are a function of the total amount of land conserved, rather than solely a function of the amount of land the individual trust conserves. Second, the benefits from conservation are a function of the spatial configuration of land conserved, rather than solely a function of the total land area conserved. Both of these characteristics imply that to maximize net conservation benefits, the trust must consider the conservation actions of other trusts and the government in choosing how much and where to conserve.

A. Benefits

Because the benefits from conserved land are public goods, each conservation actor receives benefits from all conserved land, not just from land they conserve themselves. The shape of the benefit function from all conserved land can take a variety of forms. In a standard example, the marginal value of an acre of one type of land declines as the amount of that land type that is conserved increases. In some cases such as watershed and habitat protection, however, the conservation benefit function contains thresholds, which implies ranges of increasing marginal benefits to land conservation in the same area (Wu and Boggess, 1999). Furthermore, in a wildlife example, the marginal value of a small piece of forest may be very high if that plot provides a corridor for wildlife to travel between two larger conserved areas but that same piece of forest may provide few benefits if the other areas are not conserved. Because conserved parcels create "spillover" benefits when appropriately paired, the production of conservation benefits is a function of bundles of land parcels rather than of the sum of benefits from individual parcels (Albers 1996; Swallow, *et al.* 1990). In this framework, as in Albers and Ando (2003), a land trust decides whether to purchase a particular plot based on the costs and benefits of that parcel but the benefits generated by that parcel are a function of the amount and pattern of land conservation overall.

B. Actors

In the framework developed here, conservation actors (government or land trusts) may differ from each other in how they value conserved land. For example, some actors may place a high value on creating contiguous conservation land for species protection while other actors more highly value conservation land that creates local open space. Even though each actor may have their own benefit function to determine the level of benefits they receive from a particular pattern/amount of conserved land, however, each actor receives benefits from all protected land rather than simply from the land that they conserve. The individual actor incurs the costs of the conservation activities that it undertakes but receives benefits, according to their specific benefit function, from those activities *and* all other conservation activities.

Because of this structure to conservation benefits, and based on observations of land trust activities, the modeling framework employed here assumes that individual land trusts do not make their conservation decisions in a vacuum. Trusts consider what conservation activities the government and other trusts have taken or are planning to take when they make decisions about their own conservation activities. The individual actor's decision, then, is to maximize the net benefits of conservation when conservation benefits are generated by their actions and the actions of others, incurring the costs of their own conservation, and subject to a budget constraint.

Because many actors are operating at the same time in the same general location, we posit a game structure to the interaction of actors and their decisions. In this framework, we can consider cases in which one actor (perhaps the government) undertakes actions first and the other actors make decisions based on the first actor's decisions such as in a sequential move Stackelberg equilibrium game. Similarly, all actors may make decisions at the same time with some information about what the other actors are doing, such as in a simultaneous move game resulting in a Nash equilibrium.

Our framework, then, is quite general and parsimonious. The shape of the benefit functions for each conservation actor and the size of their budget constraint will contribute to the resulting pattern of land conservation and the total conservation benefits provided.

IV. Simulation Analysis

A. Structure

The first set of simulations explore the patterns and amount of land conserved by two conservation actors who choose discrete land parcels to conserve from a line of 7 parcels. The two actors face the same cost function for conservation but have potentially different benefit functions and budget constraints. The cost function is simply:

$$C(X_i) = \beta x_i \qquad (1)$$

where x_i is the number of parcels that that individual actor *i* conserves and X_i is the set of conserved plots for actor *i*.

For our benchmark case and for most of the analysis here, the parcels are identical in their potential contribution to conservation benefits. In our preliminary analysis, the benefits functions have two components. First, the trust values benefits from *total* land conserved according to the simple function:

$$B_i(X_i + X_{-i}) = (X_i + X_{-i})^{\alpha_i} \qquad (2)$$

When α_i is less than one, the actor *i* receives diminishing marginal benefits from total area of conserved land. When α_i is greater than one, the actor receives increasing marginal benefits from total area of conserved land. The latter case may prove particularly relevant when there are thresholds within the benefits function, such as occur in watershed protection and in avian habitat protection.

Second, as a first step toward capturing benefits that derive from the spatial configuration of plots, each trust may have a positive, negative, or zero value for adjacencies between conserved plots. In this preliminary analysis, the pattern of conservation generates an adjacency value for each border with conservation land on both sides. (In future work, we will include more sophisticated configuration values such as those that differentiate between two groups of two plots and one plot removed from a group of three plots.) The total benefits to trust i from a pattern of conservation include both the benefits from total area conserved and the additional adjacency value, γ_i, for each of j relevant borders:

$$B_i(X_i + X_{-i}) = (X_i + X_{-i})^{\alpha_i} + \gamma_i j \tag{3}$$

For each of a range of sets of parameters that describe the benefits and costs, we explore and compare several types of interactions between actors: completely cooperative (social optimum); full-information, noncooperative, sequential move and simultaneous move games; and no-information, noncooperative, sequential move and simultaneous move outcomes. By comparing the pattern and values that arise from the social planner's decisions to those from various sets of independent agents, the simulations will reveal the settings in which a "free market" of conservation agents may or may not lead to a pattern of conservation with a high level of total social benefit. In future work, we will run simulations to mimic potential policies to increase the provision of conservation benefits. One such policy is the use of public conservation land to "seed" land trust activity in an area. Another policy to consider is the role of the government in providing information and assistance in the coordination of land trust activities. The simulation analysis will reveal the settings in which these policies are likely to encourage socially beneficial private land trust activity in addition to settings in which the conservation by private trusts must be augmented directly by public land conservation to achieve the socially-preferred outcome.

A MatLab program solves this game/decision model over a line of parcels for a range of conservation actor types, interaction types, and costs/benefit parameters. The results discussed below use two conservation actors (hereafter land trust 1, LT1, and land trust 2, LT2) and 7 parcels in a line. The model computes the equilibria for a sequential game in which LT1 is the Stackelberg leader-trust and LT2 is the follower-trust, and then uses the same code, switching trust parameters, to compute the equilibria for a sequential game in which LT2 leads. The Nash equilibria for a simultaneous move game are computed from the two sets of best responses of the follower trusts from each sequential game. The social planner problem is solved by giving one trust all of the funding and the social benefit function and picking the highest net valued pattern using the same code but having no reaction from a second trust.

The model first creates a set of all possible patterns of parcel conservation for both trusts. For each pattern, for each trust, costs, benefits, and net costs are computed; if costs to either trust exceed budget constraints, the pattern is removed from consideration as a possible equilibrium. For each possible pattern of LT1 conservation, LT2 determines its best response pattern by maximizing net benefits; LT2 may have multiple choices of patterns that provide the same maximum level of benefits. LT1 then maximizes benefits over all of its possible choices and for each of LT2's best responses to these choices; each pattern that maximizes benefits for LT1 is an equilibrium. The model then repeats this process, with trusts switching lead, to determine equilibria for LT2 as leader. To compute Nash equilibria for a simultaneous move game, the model uses LT2's best response patterns from the LT1 leader case, and LT1's best response patterns from the LT2 leader case. If a particular pattern of LT1 and LT2 moves satisfies both best response patterns for the individual trusts, it is a spatial Nash equilibrium to the simultaneous move game. For all cases, the program records the resulting pattern of conservation and the level of benefits and costs each actor incurs. In most cases we consider the government to be LT1, with their benefit function representing that of society.

B. Preliminary Simulation Results

1. Crowding In and Out in Total Area Conserved

As a first case, when neither trust has any value for spatial adjacency, the shape of the benefit functions from total area conserved determines whether government conservation crowds in or crowds out private conservation (see Table 2). To determine whether there is crowding in or out in total land conserved, we begin with the equilibrium from a game with one set of parameter values and then compare it to the equilibrium from a game in which the government has a larger budget and conserves more (for the same parameter values).

As expected, when both conservation actors have a benefit function that exhibits diminishing marginal benefits, $\alpha<1$, an increase in the amount of land conserved by one actor crowds out conservation by the other actor. For example, in a simultaneous move game with a budget constraint of 1 unit (while LT2 has 3 units to spend) and set 1 of parameter values, LT1 conserves 1 parcel and land trust 2 conserves 3 parcels with 140 Nash equilibria all achieving the same level of benefits for both trusts. If the budget for LT1 increases to 2 units with the set 1 parameter values, LT1 conserves only 2 parcels and LT 2 conserves 2 parcels with 140 equal-valued Nash equilibria. LT2 chooses to conserve fewer parcels in the second case because the marginal benefit of that parcel is now smaller because LT1 is conserving additional parcels; LT2’s conservation is crowded out by LT1’s conservation. The sequential move game with either LT1 or LT2 as the leader produces the same level of benefits and the same amount of crowding out. The social planner, however, responds to increases in its budget but conserving more parcels than are conserved in the noncooperative game of the two trusts because no crowding out occurs.

With the same parameters and costs as in set 1 above but using a benefit function that exhibits increasing marginal benefits, $\alpha>1$, demonstrates the opposite situation. In this case, at the lower budget constraint for LT1, LT1 conserves 0 parcels and LT2 conserves 0 parcels in the simultaneous move and sequential move Nash equilibria. The social planner, however, conserves 2 parcels in this case. The uncoordinated actions of the two trusts create an outcome that isn’t close to the socially preferred level of conservation. In this case, the marginal benefits of conservation do not outweigh the costs for LT2 and LT1 has too small a budget to conserve. When LT1’s budget constraint is loosened, for the simultaneous and sequential move games, LT1 conserves 1 parcel. This extra conservation from LT1 raises the marginal benefits of conservation enough that now LT2 spends its entire budget on conservation. This case results in

42 possible Nash equilibria with 2.2974 net benefits generated. If LT1, the government, provides enough conservation, it can induce crowding in of private conservation in the case of increasing marginal benefits to conservation and the two actors together create the socially optimal (equivalent to the social planner's) level of conservation.

In both sets of cases, no one values the spatial configuration of conservation and the result is a large number of equilibria that all generate the same net benefits. Some of the equilibria have scattered parcels while others have groups of contiguous plots but the actors do not distinguish between these patterns.

2. Spatial Agglomeration

To understand the impact of benefits from spatial configuration, we begin by examining the patterns and benefits that two conservation actors produce when at least one of them has a positive value for each adjacency between conserved parcels.

a. Diminishing Marginal Benefits (Tables 3-5).

In the cases without spatial adjacency values described above, increased conservation activity by one actor crowds out activity by the other actor. Similarly, in a scenario in which LT1 has a positive adjacency value but LT2 has a zero adjacency value, increases in LT1's budget still imply that LT2 conserves fewer parcels through crowding out (Table 3). In this case, however, as LT1 takes on more of the conservation, the pattern of conservation becomes increasingly contiguous; LT1 values adjacency and generates patterns of conservation with more agglomeration. In the simultaneous move game, in the low budget case, LT1 conserves 1 of the total 4 conserved parcels and can only guarantee one adjacency per equilibrium. At higher budgets, LT1 conserves more parcels while LT2 conserves fewer parcels but LT1 increasingly controls the number of adjacencies. In all simultaneous move games, the equilibrium never has an LT1 parcel that is not adjacent to another conserved parcel. In the sequential move game with LT1 as the leader, however, LT1 "moves" and LT2's response only leads to adjacencies some fraction of the time. LT1 sees lower benefits on average because LT2 can generate some low valued equilibria without adjacencies. In this parameterization, LT1 gets a particularly bad equilibrium in which no adjacencies are created 2 percent of the time and receives a particularly good equilibrium with 3 adjacencies in 14 percent of the possible equilibria. In contrast, when LT2 is the leader of a sequential move game, LT1 can always guarantee at least one adjacency and so the worst equilibria are not as low valued as in the LT1 leader case and the results are the same as those in the simultaneous move case. Because LT1 is the only actor who values adjacency, when its budget increases or it has a chance to react to the other actor's actions, LT1 uses that additional control to generate spatial adjacencies.

If LT1 represents the government in this case, then losses associated with the crowding out of private conservation (by LT2) are partially offset by creating more highly valued *patterns* of conservation. In this scenario, the government is better off when it is not the leader and either follows or participates in a simultaneous move game. Still, the inability to coordinate across actors is costly. A social planner conserves more plots as the budget increases and generates more adjacencies and thus higher benefits.

If both actors have a positive value for adjacency, the outcome of any game (simultaneous or sequential with either actor leading) creates as many adjacencies as possible (Table 4). In fact, if the adjacency value is large enough relative to the level of marginal net benefits, that value can slow or stop crowding out of one actor's conservation when the other increases their level of conservation. The adjacency value is potentially large enough to offset the diminishing marginal benefits, over some range. This scenario suggests that considering the relationship between marginal benefits and a spatial adjacency value would be useful in determining the correct size for an agglomeration bonus (Parkhurst, *et al.*, 2002).

If LT1 has a positive adjacency value and LT2 has a negative adjacency value, the two actors' aims are at odds and pure strategy equilibria can be difficult to find (Table 5). For our baseline parameters, no simultaneous move pure strategy Nash equilibria exist. When LT1 is the Stackelberg leader, the situation is even more extreme than in the case of LT2 having no value for adjacency. In this case, LT2 will only conserve parcels that are located away from other parcels. At low budgets for LT1, 4 parcels are conserved in equilibrium with LT1 conserving only 1 of those and the equilibrium patterns of conservation contain no adjacencies. When LT2 is the leader and LT1 has a low budget, LT1 conserves 1 parcel and always places it adjacent to one of LT2's 3 parcels to generate equilibria that have one adjacency. However, when LT1's budget increases to the point that it can conserve 2 parcels, LT2 conserves no parcels and the equilibria contain only LT1's 2 adjacent parcels. Although the other results here suggest that LT1's increased conservation would crowd out one parcel of LT2's conservation, in this parameterization, the negative value of adjacency for LT2 is significant enough to reduce total conservation by crowding out in total area and is an example of "spatial crowding out."

b. Increasing Marginal Benefits (Tables 6-8)

The case of increasing marginal benefits and no spatial adjacency values, described above, demonstrated that for some parameter values, one actors' conservation can create a seed effect that induces more conservation by the other actor. Adding a positive value to adjacency can provide extra incentive for that crowding-in in total area, in addition to creating an incentive for spatial agglomeration.

For the case of LT1 with a positive value for adjacency and LT2 with a zero value, the adjacency value creates an incentive for LT1 to conserve more parcels, located next to each other, than without that value (Table 6). This additional conservation by LT1 implies that there are more cases in which LT2's conservation will be crowded in when LT1 values adjacency. Again, the two actors generate the highest benefits when LT2 is the Stackelberg leader or in the simultaneous move game because LT1 can locate its parcels to generate adjacencies in equilibrium. For example, the social planner or coordinated activities of the two trusts generates 3 adjacencies while the simultaneous move and LT2 leader games generate 2.4 adjacencies on average (forming 3 adjacencies in 42.1% of equilibria) while LT1 as the leader forms 2.1 adjacencies on average (3 adjacencies in 25 % of equilibria and 1 adjacency in 15% of equilibria). Both the average benefits over equilibria and the "worst case scenario" equilibrium are higher when LT1 can respond rather than lead in picking parcels.

The situation in which both actors have a positive value for adjacency leads to the same pattern of all parcels located adjacent to each other in the sequential move games and with a social planner (Table 7). In our parameterization, all game structures lead to 4 conserved parcels but the simultaneous move game has lower valued equilibria that contain gaps between 2 pairs of adjacent parcels in 25 % of the equilibria. Benefits are higher for both trusts and for society when the trusts' actions are coordinated or sequential. Compared to a case of the same values with both actors having a zero value for adjacency, more conservation takes place, because it is more highly valued with the adjacency value, and the patterns in equilibrium contain more contiguous conserved parcels.

If LT1 has a positive value for adjacency but LT2 has a negative value for adjacency, again, pure strategy equilibria to simultaneous move games are difficult to find (Table 8). The sequential move games give an advantage to the follower because that actor can exercise control over whether to generate adjacencies or not. LT2's negative value for adjacency can offset the tendency of LT1's conservation to crowd-in LT2 activity, especially when much of the line of parcels is conserved. Whether crowding-in in total area conserved occurs reflects the relative value of the marginal benefits of parcels versus the adjacency "cost" and whether there are available parcels on the line that allow for no adjacencies to be created when LT2's conservation is crowded in.

3. Special Cases/Future Work

Many conservation organizations argue for conservation to follow priorities beginning with the parcels that generate the highest benefits or "hotspots." Economists counter that groups of parcels that generate the highest *net* benefits are preferred to a pure hotspot analysis and reserve site selection researchers argue that the best sequence of purchases is not necessarily "hotspots first." To think about how hotspots might affect the outcome of the uncoordinated activities of two conservation actors, we increase the benefits from one plot (while maintaining the cost equal to that of the other parcels) and examine the equilibrium patterns of conservation that result. One example looks at the case of increasing marginal benefits in which the marginal benefits of conservation do not exceed the costs for LT2 on the "normal" plots at low levels of conservation and in which both actors have a small positive value on adjacency (Table 9). If LT1 is the Stackelberg leader, the equilibria involve LT1 conserving a parcel adjacent to the hotspot and leaving LT2 to conserve the hotspot itself. (At higher budgets for LT1, LT1 conserves other parcels adjacent to each other but always leaves LT2 to conserve the hotspot.) Within the range of values in this parameterization, LT2's costs are not outweighed by any parcel's benefits other than those of the hotspot and LT2 does not conserve at all if the hotspot is unavailable. When LT2 is the Stackelberg leader, LT2 leaves all the conservation to LT1, who then chooses to conserve the hotspot (and, depending on the budget, perhaps other adjacent parcels). The simultaneous move game results in a low valued equilibrium with only the one hotspot parcel conserved by LT1 and no conservation by LT2 in one-third of the equilibria and a higher valued situation in the remaining equilibria in which LT2 conserves the hotspot and LT1 conserves an adjacent plot. Even in the case of LT2 having a negative adjacency value, the size of the hotspot benefits can be large enough to induce LT2 to conserve the hotspot (in half of the simultaneous move equilibria and in the LT1 as Stackelberg leader equilibria) regardless of LT1's decision to create adjacencies with that plot.

Expanding from this hotspot work, we plan to use this framework to examine a range of issues in land conservation: filling spatial gaps; creating wildlife corridors; heterogeneous land; forming decisions based on a geographic focus; and other niche conservation goals. In addition, we will further investigate the role of information in decisions and the types of interactions amongst a diverse set of land conservation actors. We will examine policy scenarios to determine how the setting (both benefits/ecology and the conservation "industry" structure) contributes to policy decisions about spatially strategic land conservation, agglomeration bonuses, and the potential for institutions to coordinate the activities of conservation actors.

C. Discussion

The modeling and simulation work thus far has focused on developing a framework for examining the interaction of conservation actors. As expected, the framework demonstrates that both crowding in and crowding out of private conservation by conservation by government or other land trusts are possible, depending on the structure of the underlying benefits function. The crowding in case may be of particular interest in land conservation because of the many examples in which conservation benefits exhibit increasing marginal benefits over a relevant range.

Incorporating a simple spatial value, a bonus for adjacency between conserved plots, identifies two ways in which spatial benefits contribute to conservation patterns. First, as long as neither actor has a negative value for adjacency, this value leads to land conservation patterns with more spatial agglomeration than other cases. How much spatial agglomeration we see depends on the structure of the interaction between the trusts and whether they both value adjacency. In our cases thus far, all parcels are equally valued and so a tiny positive spatial adjacency value creates agglomeration. Second, the adjacency value makes conservation more valuable and can offset crowding out and create crowding in at lower parcel-benefit levels. When one trust's actions create opportunities for the other trust to capture spatial adjacency values, we not only see patterns of agglomeration but we see crowding-in in total area conserved. This type of crowding in – derived from a spatial value rather than the shape of the benefit function over total area – is somewhat unique to land conservation and potentially useful in establishing policy.

V. Empirical Analysis

For our empirical analysis of private conservation, we will use data on the amount and patterns of land conservation in two[1] states that differ markedly in their ecological characteristics, land-use patterns, amount of land trust activity, and amount of government protected land.

We explore these data sets to find evidence of the manner in which private conservation decisions are affected by public land conservation. Do private conservation agents respond to the amount of previously-protected government land in their decision-making process? Does government conservation stimulate or stifle nearby private conservation? Is there any evidence that private conservation is clustered (perhaps to provide benefits more cost-effectively), or are private lands scattered across the landscape?

[1] The research will soon include an analysis of California as well, bringing the number of states analyzed up to three.

Our analyses permit a comparison across two different states of the interactions of public and private land conservation decisions. Based on the models developed in Albers and Ando (2002) and in this paper, we might expect to see different types and degrees of interaction between private and public land conservation agents because of differences in the conservation benefits provided by land in each state.

A. Model

Our empirical analysis is grounded in the conceptual framework set forth in section III of this paper. Because the vast majority of permanently-protected government land was in conservation status before the private conservation movement gained strength, we take government protected areas as exogenous and fixed, and treat private conservation as the dependent variable of our analysis. We examine the extent to which private conservation in a township is positively or negatively correlated with the amount of government protected areas in that township and in the areas that surround it. We also investigate whether the current network of private protected areas is agglomerated in space.

There are multiple private agents making conservation choices in the landscape. Hence, we are interested in the extent to which the number of acres of privately protected land in a given township is correlated, positively or negatively, with the acres of privately protected land in the townships that surround it. If such mutual relationships exist, we can model private conservation acreage as a spatial reaction function (as in Brueckner (1998)):

$$Y_i = \phi \sum_{j \neq i} w_{ij} Y_j + X_i \beta + \varepsilon_i \tag{4}$$

where Y_i is private conservation acreage in township i, and the w_{ij} are weights that aggregate conservation acreages in townships other than i into a single "neighboring protected acreage" variable which has a scalar coefficient φ. That coefficient is the slope of a township's reaction function. The vector X_i contains other important characteristics of the township that influence the private conservation agents' choice of acreage, the vector β contains coefficients on those variables, and ε_i is the error term (assumed to be normally distributed, homoscedastic, and independent across observations.)

This equation can be written in matrix form as

$$Y = \phi WY + X\beta + \varepsilon \tag{5}$$

where W is the spatial weights matrix. The coefficients of this equation are estimated in a spatial autoregressive econometric model commonly referred to as a spatial-lag model (as in Anselin, 1988).

In this autoregressive model, all of the characteristics of a township's neighbors have an influence on its private conservation acreage. For example, if townships A and B are neighbors, the amount of government conservation in township B affects private conservation in township

A through its impact on the amount of private conservation in township B itself. In some of our specifications, we include a variable which is "acres of government conservation in neighboring townships."[2] This permits the possibility that government conservation influences private conservation in neighboring townships, even if private conservation in neighboring towns is otherwise mutually uncorrelated.

B. Data and Methods

We divide each state into townships[3] and calculate the amount of land protected in each township by government and private conservation agents. Almost all townships in Massachusetts have at least some protected land of both types, so we are able to use the standard linear spatial-econometric techniques. Many townships in Illinois have no privately protected lands. We will eventually use a spatial tobit to deal with the left-truncation of this dependent variable; since that model is not readily available in pre-programmed form, we use the standard model in this preliminary report. We estimate a spatial lag model on these data, and use the results to test two null hypotheses: amounts of private and public land within a township are not statistically correlated, and private conservation in a given township is not affected by conservation levels in neighboring townships.

The spatial unit of analysis is the township. There are 351 townships in Massachusetts, and 1433 townships in Illinois. Because our data source for Illinois township boundaries had some of the townships subdivided, we have 1691 spatial units in Illinois. "Neighbors" are formally defined as first-order queen (in other words, all townships that touch the boundary of a given township in any direction). Hence, the weight matrix W has diagonal elements equal to zero, and off-diagonal elements w_{ij} equal to 1 if township j borders township i, and 0 otherwise.

Our primary sources for Illinois data are the Illinois Department of Natural Resources (IDNR) and the Illinois State Geological Survey (ISGS). The IDNR data identifies private land registered in protection with the Illinois Nature Preserves Commission. The ISGS data shows protected areas owned by local, state and federal government. The two data layers are combined to create a map of protected land in the state of Illinois. Many of the data layers for the independent variables come from these two agencies as well.

For the state of Massachusetts, we use data developed and provided by the Massachusetts Geographic Information System (MassGIS). The "Protected and Recreational Open Space" data layer shows boundaries of conservation lands and outdoor recreational facilities. Relevant information about each parcel includes ownership, level of protection, public accessibility, assessor's map and lot numbers, and related legal interests held on the land, including conservation restrictions. We use information about the polygons to categorize each area as either privately or publicly protected. The MassGIS website was our source for many of the independent variables as well.

---

[2] This created by pre-multiplying the vector of "acres publicly preserved" by the spatial weights matrix, W.

[3] When we add California to our research, we will use 7.5 minute USGS quadrangles of similar size to the townships in IL and MA since CA does not have townships. There are 3049 such quads in the state.

Private protected acreage is illustrated in Figure 1 and the independent variables used in the analyses are summarized in Tables 10 and 11. The independent variables (elements of matrix X) include socioeconomic variables (income, education, population) to proxy for the demand for private conservation acreage. We include characteristics of the land or township that influence the marginal product of that land in providing benefits. The number of endangered species is correlated with biodiversity potential. Proximity to the nearest major urban center acts as a proxy for recreational demand. The area of surface water is correlated with the value of protected land in providing water quality, erosion control, and aesthetic benefits. The cost of land is correlated both with the cost of setting it in conservation status and with the probability that the land will be developed if it is not protected. Population density is also correlated with the degree of conversion threat faced by open lands. The coefficient of variation (standard deviation divided by mean) of elevation is included as a proxy for recreation potential and aesthetic value. We include variables that capture the amount of land that falls into each of a number of land-cover categories: farmland, forest, agriculture, wetland, "open urban," and developed. Some land-cover types might be more valued as conservation targets. Large amounts of developed land may act both to limit the acreage of private conservation possible and to stimulate the intensity of demand for protecting the open space that remains.

MassGIS maintains data showing which areas are characterized as being "priority habitat" for threatened species; we use acreage of such habitat as a proxy for the value of land in providing biodiversity benefits. We have just obtained data on the location of endangered species in Illinois, and will be using that data to proxy for the same thing in future drafts of this work.

The current regressions do not include any variables which can control for local variation in environmental ideology. In later drafts, we will be using precinct-level voting data to control for that source of variation in demand for private land conservation.

C. Results

Tables 12 and 13 present preliminary results for the analyses of private conservation acreage by township in Illinois and Massachusetts. The model fit is better in Massachusetts than in Illinois; the fit may be improved for Illinois once we are able to employ spatial tobit methodology. [4]

In both states, there is a positive spatial lag in private protected areas; more acres are protected by private agents in a township if the surrounding townships have extensive private reserves. This finding is consistent with a story in which the equilibrium of private conservation choices leads to spatial agglomeration in the network of private protected areas; this occurs most in our simulations when there increasing marginal benefits to conservation, and positive values associated with adjacency. The coefficients are similar in magnitude in the two states' regressions, even though the states and the groups of conservation actors that work in them are very different.

[4] Non-spatial analyses were performed on the Illinois data. We ran both OLS and tobit regressions, and found that the results were qualitatively similar. There is hope then that the spatial tobit results will not vary much from the results reported here.

This finding could be an artifact of spatial correlation in unobserved variables which drive private conservation choices. However, we have controlled for many socio-economic and physical characteristics of the land across space. We will continue to add explanatory variables and explore the functional specification of the analyses to further reduce concerns about omitted variables and misspecification leading to spurious findings of spatial correlation.

While private conservation may crowd other private conservation into surrounding townships, we find that the coefficient on government protected land is negative in both regressions; there is less private protected land in townships which have a large acreage of public reserves. The effect is much larger in Massachusetts than in Illinois; however, in each state the coefficient is statistically significantly smaller (in absolute magnitude) than 1. We find (in regressions not reported here) that a variable capturing "neighbors' public protected areas" has no significant correlation with private conservation in a township. The nature of the spatial lag model is such that neighboring public protected areas have an indirect negative effect on private conservation in a township by reducing private conservation in the neighboring townships. However, the absence of a direct effect means that the impact of public protected areas on private conservation is greatest in the township where the public reserve is located.

At first blush, then, it appears that government conservation crowds out private conservation. However, we note that publicly owned land is, by definition, not available as a target for acquisition by private land conservation groups. Hence, it may be that the small size of the negative coefficients, particularly in Illinois, is actually evidence of some kind of a spatial seeding effect. We will refine the specification of these regressions in order to clarify the impact of public lands on private conservation.

Other variables are significant in these regressions as well. There is more private conservation in parts of Illinois with greater variation in elevation, more forest, and more wetlands. This is consistent with the fact that such areas are likely to yield relatively high conservation benefits in terms of species conservation and recreational enjoyment.

Population density is negatively correlated with private conservation in Illinois, but there is more conservation in areas where land values are high. These seem like contradictory findings, because both variables act as proxies for the opportunity cost of the land and the degree of conversion threat to unprotected land. We will enrich the specifications of these variables (adding population growth to the regression, exploring nonlinear functional forms, including interaction terms with proximity to urban areas) to improve the coherence of the story revealed by the results.

In Massachusetts, there is more private conservation in areas with large amounts of agriculture, forest, and priority habitat for threatened wildlife. It is interesting that agriculture was not significantly correlated with conservation efforts in Illinois. This contrast in the results for the two states may reflect the fact that Massachusetts is a more heavily developed state than Illinois, and agriculture provides aesthetic landscape benefits that may be more highly valued on the margin in the Northeast than in the Midwest. There is also more private conservation in Massachusetts townships that have relatively large acreage of open urban land; such areas have high marginal recreational value as protected urban open space.

VI. Conclusion

This research is in preliminary stages, but already begins to make contributions to our understanding of private land conservation behavior. The econometric work will be refined, but it seems likely that we will continue to find that there is spatial agglomeration in private conservation activity, and there are hints that we may find that government conservation has some kind of seeding effect on the choices made by private agents. These findings are consistent with the simulation results of scenarios in which there are increasing returns to scale and positive benefits associated with having connected reserves. These are precisely the scenarios in which there is the greatest potential for government policy to increase total social welfare in the conservation arena.

Even just using the results of these simple linear simulation models, a number of important points can be made. First, if the incentives or benefit functions for the land conservation actors do not closely align, the conservation outcome of their uncoordinated activities creates lower total benefits, less conservation, and less agglomeration than is socially desirable. Second, a government conservation actor who ignores the potential activities of private conservation actors makes decisions that lead to less conservation and less beneficial patterns of conservation than a government who considers the actions of private actors in making its conservation choices. Third, in land conservation when spatial adjacencies matter differently to two conservation actors, the actor who can wait and react to the other actor's decisions has an advantage in creating its preferred pattern of conservation. Fourth, spatial agglomeration bonus policies can have a large impact on both the pattern and amount of conservation. Fifth, in some cases, a government decision to conserve parcels other than a "hotspot" can induce private conservation of that parcel and lead to higher levels of social benefits.

These findings, especially the last two, have important policy implications. As we continue our research, we will focus on extensions that provide even more direct guidance to the government and private officials who are responsible for choosing which lands to add to their portfolios of protected areas, and to the decision makers in a position to set forth policies to influence private conservation activities.

References

Albers, H. J. 1996. “Modeling Ecological Constraints on Tropical Forest Management: Spatial Interdependence, Irreversibility and Uncertainty.” *Journal of Environmental Economics and Management* 30(1): 73-94.

Albers, H. J. and A. W. Ando. 2003. “Could State-Level Variation in the Number of Land Trusts Make Economic Sense?” *Land Economics* 79(3): 311-327.

Andreoni, J. 1989. “Giving with Impure Altruism: Applications to Charity and Ricardian Equivalence.” *Journal of Political Economy* 97: 1447-58.

Andreoni, J. 1998. “Toward a Theory of Charitable Fundraising.” *Journal of Political Economy* 106(6): 1186-1213.

Anselin, L. 1988. *Spatial Econometrics: Methods and Models.* Studies in Operational Regional Science Series. London: Kluwer Academic.

Bay Lands Center. 2002. Ba*y Lands Center Homepage*. http://www.savebuzzrdsbay.org/baylandsmap.html. [3/02]

Bell, K. P. and E. G. Irwin. 2002. “Spatially Explicit Micro-level Modelling of Land Use Change at the Rural-Urban Interface.” *Agricultural Economics* 27(3): 217-32.

Bergeron, N. and S. Polasky. 2000. “Species Conservation with Multiple Landowners.” Unpublished manuscript, University of Minnesota.

Bruekner, J. 1998. “Testing for Strategic Interaction among Local Governments: The Case of Growth Controls.” *Journal of Urban Economics* 44(3): 438-67.

Chomitz, K., and D. Gray. 1996. “Roads, Land Use, and Deforestation: A Spatial Model Applied to Belize.” *World Bank Economic Review* 10(3): 487–512.

Cropper, M., C. Griffiths, and M. Muthukumara. 2001. “Predicting the Location of Deforestation: The Role of Roads and Protected Areas in North Thailand.” *Land Economics* 77(2): 172–186.

Goldsmith, E. 2001. *Beyond Municipal Boundaries: Designing a Regional Land Conservation Strategy in Washington County, Rhode Island*. Brown University: Providence, RI. http://www.envstudies.brown.edu/thesis/2001/goldsmith/writeup/dreamweaver/index.html. [3/02]

Hoctor, T. S., M. H. Carr, and P. D. Zwick. 2000. “Identifying a Linked Reserve System Using a Regional Landscape Approach: The Florida Ecological Network.” *Conservation Biology* 14(4): 984-1000.

Irwin, E. G. 2002. "The Effects of Open Space on Residential Property Values." *Land Economics* 78: 465-80.

Irwin, E. G. and N. E. Bockstael. 2002. "Interacting Agents, Spatial Externalities, and the Evolution of Residential Land Use Patterns." *Journal of Economic Geography* 2: 31-54.

Kingma, B. R. 1989. "An Accurate Measurement of the Crowd-Out Effect, Income Effect, and Price Effect for Charitable Contributions." *Journal of Political Economy* 97(5):1197-1207.

Lynch, L. and S. J. Lovell. 2003. "Combining Spatial and Survey Data to Explain Participation in Agricultural Land Preservation Programs." *Land Economics* 79(2): 259-76.

MacFarlane, R. 1998. Implementing Agri-environment Policy: A Landscape Ecology Perspective." *Journal of Environmental Planning and Management* 41(5): 575-96.

Maine Land Trust Network. 2002. *About MLTN*. http://www.mltn.org/about_mltn.html. [3/02]

Marshall, E. 2004. "Open-Space Amenities, Interacting Agents, and Equilibrium Landscape Structure." *Land Economics* 80(2):272-293.

Nelson, G. C., and D. Hellerstein. 1997. "Do Roads Cause Deforestation? Using Satellite Images in Econometric Analysis of Land Use." *American Journal of Agricultural Economics* 79(1): 80–88.

Parker, N. and W. Thurman. 2004. "Crowding out Open Space: Federal Land Programs and their Effects on Land Trust Activity." Unpublished manuscript.

Parkhurst, G. M., J. Shogren, C. Bastian, P. Kivi, J. Donner, and R. B. W. Smith. 2002. "Agglomeration Bonus: An Incentive Mechanism to Reunite Fragmented Habitat for Biodiversity Conservation." *Ecological Economics* 41(2): 305-28.

ReVelle, C. S., J. C. Williams, and J. J. Boland. 2002. "Counterpart Models in Facility Location Science and Reserve Selection Science." *Environmental Modeling and Assessment* 7:71-80.

Scott, J. M., R. J. F. Abbitt, and C.R. Groves. 2001. "What Are We Protecting? The United States Conservation Portfolio." *Conservation Biology in Practice* 2: 18-19.

Swallow, S. K., P. J. Parks and D. N. Wear. 1990. "Policy Relevant Nonconvexities in the Production of Multiple Forest Benefits." *Journal of Environmental Economics and Management* 19(3): 281-296.

Swallow, S., P. Talukdar, and D. Wear. 1997. "Spatial and Temporal Specialization in Forest Ecosystem Management under Sole Ownership." *American Journal of Agricultural Economics* 79(1): 311-327.

Tajibaeva, L., R. Haight, and S. Polasky. 2003. "A Discrete Space Urban Model with Environmental Amenities." Unpublished manuscript, University of Minnesota. Available at http://www.apec.umn.edu/faculty/spolasky/Working%20Papers.htm.

Turner, M. Forthcoming. "Landscape Preferences and Patterns of Residential Location." *Journal of Urban Economics*.

Wu, J. and W. G. Boggess. 1999. "The Optimal Allocation of Conservation Funds." *Journal of Environmental Economics and Management* 38(3):302-21.

Table 1: Baseline Trust Parameters

Parameter	Increasing Marginal Benefits			Decreasing Marginal Benefits		
	Low Budget	Mid Budget	High Budget	Low Budget	Mid Budget	High Budget
α_1	3	3	3	0.96	0.96	0.96
α_2	1.5	1.5	1.5	0.91	0.91	0.91
β	2.4	2.4	2.4	0.8	0.8	0.8
$Budget_1$ (parcels)	1	2	3	1	2	3
$Budget_2$ (parcels)	2	2	2	3	3	3

In following tables "Number of equilibria" counts the number of "nontrivial equilibria." That is, the equilibrium of 0000000 is not counted.

Table 2: Crowding In and Out in Total Area Conserved

	Increasing Marginal Benefits			Decreasing Marginal Benefits			
	Low Budget	Mid Budget	High Budget	Low Budget	Mid Budget	High Budget	Very High Budget*
LT1 Leader							
Number of equilibria	0.00	210.00	210.00	140.00	140.00	140.00	140.00
Ave total parcels conserved	0.00	4.00	5.00	4.00	4.00	4.00	4.00
Ave LT1 parcels conserved	0.00	2.00	3.00	1.00	1.00	1.00	1.00
Ave total adjacencies	0.00	1.71	2.86	1.71	1.71	1.71	1.71
Ave LT1 net benefit	0.00	59.20	117.80	2.98	2.98	2.98	2.98
Ave LT2 net benefit	0.00	3.20	6.38	1.13	1.13	1.13	1.13
Ave social benefit	0.00	64.00	125.00	3.78	3.78	3.78	3.78
Max LT1 net ben (fraction)	0 (0)	59.2 (1)	117.8 (1)	2.98 (1)	2.98 (1)	2.98 (1)	2.98 (1)
Min LT1 net ben (fract.)	0 (0)	59.2 (1)	117.8 (1)	2.98 (1)	2.98 (1)	2.98 (1)	2.98 (1)
Max LT2 net ben (fract.)	0 (0)	3.2 (1)	6.4 (1)	1.13 (1)	1.13 (1)	1.13 (1)	1.13 (1)
Min LT2 net ben (fract.)	0 (0)	3.2 (1)	6.4 (1)	1.13 (1)	1.13 (1)	1.13 (1)	1.13 (1)
LT2 Leader							
Number of equilibria	42.00	210.00	210.00	140.00	210.00	140.00	35.00
Ave total parcels conserved	2.00	4.00	5.00	4.00	4.00	4.00	4.00
Ave LT1 parcels conserved	1.00	2.00	3.00	1.00	2.00	3.00	4.00
Ave total adjacencies	0.29	1.71	2.86	1.71	1.71	1.71	1.71
Ave LT1 net benefit	5.60	59.20	117.80	2.98	2.18	1.38	0.58
Ave LT2 net benefit	0.43	3.20	6.38	1.13	1.93	2.73	3.53
Ave social benefit	8.00	64.00	125.00	3.78	3.78	3.78	3.78
Max LT1 net ben (fract.)	5.6 (1)	59.2 (1)	117.8 (1)	2.98 (1)	2.18 (1)	1.38 (1)	0.58 (1)
Min LT1 net ben (fract.)	5.6 (1)	59.2 (1)	117.8 (1)	2.98 (1)	2.18 (1)	1.38 (1)	0.58 (1)
Max LT2 net ben (fract.)	0.43 (1)	3.2 (1)	6.4 (1)	1.13 (1)	1.93 (1)	2.73 (1)	3.53 (1)
Min LT2 net ben (fract.)	0.43 (1)	3.2 (1)	6.4 (1)	1.13 (1)	1.93 (1)	2.73 (1)	3.53 (1)
Simultaneous							
Number of equilibria	0.00	210.00	210.00	140.00	210.00	140.00	35.00
Ave total parcels conserved	0.00	4.00	5.00	4.00	4.00	4.00	4.00
Ave LT1 parcels conserved	0.00	2.00	3.00	1.00	2.00	3.00	4.00
Ave total adjacencies	0.00	1.71	2.86	1.71	1.71	1.71	1.71
Ave LT1 net benefit	0.00	59.20	117.80	2.98	2.18	1.38	0.58
Ave LT2 net benefit	0.00	3.20	6.38	1.13	1.93	2.73	3.53
Ave social benefit	0.00	64.00	125.00	3.78	3.78	3.78	3.78
Max LT1 net ben (fract.)	0 (0)	59.2 (1)	117.8 (1)	2.98 (1)	2.18 (1)	1.38 (1)	0.58 (1)
Min LT1 net ben (fract.)	0 (0)	59.2 (1)	117.8 (1)	2.98 (1)	2.18 (1)	1.38 (1)	0.58 (1)
Max LT2 net ben (fract.)	0 (0)	3.2 (1)	6.4 (1)	1.13 (1)	1.93 (1)	2.73 (1)	3.53 (1)
Min LT2 net ben (fract.)	0 (0)	3.2 (1)	6.4 (1)	1.13 (1)	1.93 (1)	2.73 (1)	3.53 (1)
Social Planner							
Total parcels conserved	3.00	4.00	5.00	4.00	5.00	6.00	7.00
Total adjacencies	0.86	1.71	2.86	1.71	2.86	4.29	6.00
Net benefit	19.80	54.40	113.00	0.58	0.69	0.79	0.88
Social benefit	27.00	64.00	125.00	3.78	4.69	5.59	6.48

* $Budget_1$ =4 parcels, $Budget_2$ = 3 parcels

Note: for increasing marginal benefits, crowding in happens between budget low and mid, but not between budgets mid and high. For decreasing marginal benefits, crowding out happens at each budget level.

Table 3: DECREASING Stackelberg: LT1 (+) adjacency, LT2 0 adjacency value

	Small Adjacency Value ($\gamma_1 = 0.1$, $\gamma_2 = 0$)			Large Adjacency Value ($\gamma_1 = 1$, $\gamma_2 = 0$)		
	Low Budget	Mid Budget	High Budget	Low Budget	Mid Budget	High Budget
LT1 Leader						
Number of equilibria	100.00	100.00	100.00	100.00	100.00	100.00
Ave total parcels conserved	4.00	4.00	4.00	4.00	4.00	4.00
Ave LT1 parcels conserved	1.00	1.00	1.00	1.00	1.00	1.00
Ave total adjacencies	1.80	1.80	1.80	1.80	1.80	1.80
Ave LT1 net benefit	3.16	3.16	3.16	4.78	4.78	4.78
Ave LT2 net benefit	1.13	1.13	1.13	1.13	1.13	1.13
Ave social benefit	3.96	3.96	3.96	5.58	5.58	5.58
Max LT1 net ben (fract.)	3.28 (0.14)	3.28 (0.14)	3.28 (0.14)	5.98 (0.14)	5.98 (0.14)	5.98 (0.14)
Min LT1 net ben (fract.)	2.98 (0.02)	2.98 (0.02)	2.98 (0.02)	2.98 (0.02)	2.98 (0.02)	2.98 (0.02)
Max LT2 net ben (fract.)	1.13 (1)	1.13 (1)	1.13 (1)	1.13 (1)	1.13 (1)	1.13 (1)
Min LT2 net ben (fract.)	1.13 (1)	1.13 (1)	1.13 (1)	1.13 (1)	1.13 (1)	1.13 (1)
LT2 Leader						
Number of equilibria	68.00	57.00	16.00	68.00	57.00	16.00
Ave total parcels conserved	4.00	4.00	4.00	4.00	4.00	4.00
Ave LT1 parcels conserved	1.00	2.00	3.00	1.00	2.00	3.00
Ave total adjacencies	2.18	2.42	3.00	2.18	2.42	3.00
Ave LT1 net benefit	3.20	2.43	1.68	5.16	4.61	4.38
Ave LT2 net benefit	1.13	1.93	2.73	1.13	1.93	2.73
Ave social benefit	4.00	4.03	4.08	5.96	6.21	6.78
Max LT1 net ben (fract.)	3.28 (0.24)	2.48 (0.42)	1.68 (1)	5.98 (0.24)	5.18 (0.42)	4.38 (1)
Min LT1 net ben (fract.)	3.08 (0.06)	2.38 (0.58)	1.68 (1)	3.98 (0.06)	4.18 (0.58)	4.38 (1)
Max LT2 net ben (fract.)	1.13 (1)	1.93 (1)	2.73 (1)	1.13 (1)	1.93 (1)	2.73 (1)
Min LT2 net ben (fract.)	1.13 (1)	1.93 (1)	2.73 (1)	1.13 (1)	1.93 (1)	2.73 (1)
Simultaneous						
Number of equilibria	68.00	57.00	16.00	68.00	57.00	16.00
Ave total parcels conserved	4.00	4.00	4.00	4.00	4.00	4.00
Ave LT1 parcels conserved	1.00	2.00	3.00	1.00	2.00	3.00
Ave total adjacencies	2.18	2.42	3.00	2.18	2.42	3.00
Ave LT1 net benefit	3.20	2.43	1.68	5.16	4.61	4.38
Ave LT2 net benefit	1.13	1.93	2.73	1.13	1.93	2.73
Ave social benefit	4.00	4.03	4.08	5.96	6.21	6.78
Max LT1 net ben (fract.)	3.28 (0.24)	2.48 (0.42)	1.68 (1)	5.98 (0.24)	5.18 (0.42)	4.38 (1)
Min LT1 net ben (fract.)	3.08 (0.06)	2.38 (0.58)	1.68 (1)	3.98 (0.06)	4.18 (0.58)	4.38 (1)
Max LT2 net ben (fract.)	1.13 (1)	1.93 (1)	2.73 (1)	1.13 (1)	1.93 (1)	2.73 (1)
Min LT2 net ben (fract.)	1.13 (1)	1.93 (1)	2.73 (1)	1.13 (1)	1.93 (1)	2.73 (1)
Social Planner						
Total parcels conserved	4.00	5.00	6.00	4.00	5.00	6.00
Total adjacencies	3.00	4.00	5.00	3.00	4.00	5.00
Net benefit	0.88	1.09	1.29	3.58	4.69	5.79
Social benefit	4.08	5.09	6.09	6.78	8.69	10.59

Notes: When LT1 leads, it chooses not to crowd LT2. Since LT2 wants 3 parcels and doesn't care which location, LT1 has such high expected adjacencies even if LT2 is random that the extra certainty of choosing adjacencies isn't worth the additional cost to LT1. Increasing adjacency value has no effect on patterns, but does increase benefits.

Table 4: DECREASING Marginal Benefits: LT1 (+) adj, LT2 (+) adj ($\gamma_1 = 0.1$, $\gamma_2 = 0.1$)

	Baseline Parameters			Steeper LT2 ($\alpha_2 = 0.85$)		
	Low Budget	Mid Budget	High Budget	Low Budget	Mid Budget	High Budget
LT1 Leader						
Number of equilibria	16.00	30.00	40.00	16.00	3.00	8.00
Ave total parcels conserved	4.00	5.00	6.00	4.00	5.00	6.00
Ave LT1 parcels conserved	1.00	2.00	3.00	1.00	2.00	3.00
Ave total adjacencies	3.00	4.00	5.00	3.00	4.00	5.00
Ave LT1 net benefit	3.28	3.49	3.69	3.28	3.49	3.69
Ave LT2 net benefit	1.43	2.33	3.21	1.15	1.93	2.69
Ave social benefit	4.08	5.09	6.09	4.08	5.09	6.09
Max LT1 net ben (fract.)	3.28 (1)	3.49 (1)	3.69 (1)	3.28 (1)	3.49 (1)	3.69 (1)
Min LT1 net ben (fract.)	3.28 (1)	3.49 (1)	3.69 (1)	3.28 (1)	3.49 (1)	3.69 (1)
Max LT2 net ben (fract.)	1.43 (1)	2.33 (1)	3.21 (1)	1.15 (1)	1.93 (1)	2.69 (1)
Min LT2 net ben (fract.)	1.43 (1)	2.33 (1)	3.21 (1)	1.15 (1)	1.93 (1)	2.69 (1)
LT2 Leader						
Number of equilibria	16.00	30.00	40.00	16.00	24.00	16.00
Ave total parcels conserved	4.00	5.00	6.00	4.00	4.00	4.00
Ave LT1 parcels conserved	1.00	2.00	3.00	1.00	2.00	3.00
Ave total adjacencies	3.00	4.00	5.00	3.00	3.00	3.00
Ave LT1 net benefit	3.28	3.49	3.69	3.28	2.48	1.68
Ave LT2 net benefit	1.43	2.33	3.21	1.15	1.95	2.75
Ave social benefit	4.08	5.09	6.09	4.08	4.08	4.08
Max LT1 net ben (fract.)	3.28 (1)	3.49 (1)	3.69 (1)	3.28 (1)	2.48 (1)	1.68 (1)
Min LT1 net ben (fract.)	3.28 (1)	3.49 (1)	3.69 (1)	3.28 (1)	2.48 (1)	1.68 (1)
Max LT2 net ben (fract.)	1.43 (1)	2.33 (1)	3.21 (1)	1.15 (1)	1.95 (1)	2.75 (1)
Min LT2 net ben (fract.)	1.43 (1)	2.33 (1)	3.21 (1)	1.15 (1)	1.95 (1)	2.75 (1)
Simultaneous						
Number of equilibria	16.00	34.00	40.00	16.00	30.00	33.00
Ave total parcels conserved	4.00	5.00	6.00	4.00	4.10	4.76
Ave LT1 parcels conserved	1.00	2.00	3.00	1.00	2.01	3.09
Ave total adjacencies	3.00	3.88	5.00	3.00	3.00	3.76
Ave LT1 net benefit	3.28	3.48	3.69	3.28	2.57	2.44
Ave LT2 net benefit	1.43	2.31	3.21	1.15	1.94	2.73
Ave social benefit	4.08	5.08	6.09	4.08	4.17	4.84
Max LT1 net ben (fract.)	3.28 (1)	3.49 (0.88)	3.69 (1)	3.28 (1)	3.49 (0.10)	3.69 (0.24)
Min LT1 net ben (fract.)	3.28 (1)	3.39 (0.12)	3.69 (1)	3.28 (1)	2.38 (0.10)	1.68 (0.48)
Max LT2 net ben (fract.)	1.43 (1)	2.33 (0.88)	3.21 (1)	1.15 (1)	1.95 (0.80)	2.75 (0.48)
Min LT2 net ben (fract.)	1.43 (1)	2.23 (0.12)	3.21 (1)	1.15 (1)	1.85 (0.10)	2.69 (0.24)
Social Planner						
Total parcels conserved	4.00	5.00	6.00	4.00	5.00	6.00
Total adjacencies	3.00	4.00	5.00	3.00	4.00	5.00
Net benefit	0.88	1.09	1.29	0.88	1.09	1.29
Social benefit	4.08	5.09	6.09	4.08	5.09	6.09

Notes: Using the baseline parameters, there is no crowding out of LT2. The extra bonus of adjacencies to LT2 overcomes its decreasing marginal benefits. The runs to the right show that for steeper decreasing marginal benefits for LT2, the adjacency value no longer prevents crowding out. That is, (+) adjacency values offset decreasing marginal benefits.

Table 5: DECREASING Marginal Benefits: LT1 (+) adj, LT2 (-) adj ($\gamma_1 = 0.1$, $\gamma_2 = -0.1$)

	Baseline Parameters			Shallower LT2 (α_2 = 0.96)		
	Low Budget	Mid Budget	High Budget	Low Budget	Mid Budget	High Budget
LT1 Leader						
Number of equilibria	4.00	4.00	4.00	20.00	35.00	35.00
Ave total parcels conserved	4.00	4.00	4.00	4.00	5.00	5.00
Ave LT1 parcels conserved	1.00	1.00	1.00	1.00	2.00	2.00
Ave total adjacencies	0.00	0.00	0.00	1.00	2.00	2.00
Ave LT1 net benefit	2.98	2.98	2.98	3.08	3.29	3.29
Ave LT2 net benefit	1.13	1.13	1.13	1.28	2.09	2.09
Ave social benefit	3.78	3.78	3.78	3.88	4.89	4.89
Max LT1 net ben (fract.)	2.98 (1)	2.98 (1)	2.98 (1)	3.08 (1)	3.29 (1)	3.29 (1)
Min LT1 net ben (fract.)	2.98 (1)	2.98 (1)	2.98 (1)	3.08 (1)	3.29 (1)	3.29 (1)
Max LT2 net ben (fract.)	1.13 (1)	1.13 (1)	1.13 (1)	1.28 (1)	2.09 (1)	2.09 (1)
Min LT2 net ben (fract.)	1.13 (1)	1.13 (1)	1.13 (1)	1.28 (1)	2.09 (1)	2.09 (1)
LT2 Leader						
Number of equilibria	4.00	6.00	5.00	4.00	48.00	18.00
Ave total parcels conserved	4.00	2.00	3.00	4.00	5.00	5.00
Ave LT1 parcels conserved	1.00	2.00	3.00	1.00	2.00	3.00
Ave total adjacencies	1.00	1.00	2.00	1.00	3.00	3.00
Ave LT1 net benefit	3.08	0.45	0.67	3.08	3.39	2.59
Ave LT2 net benefit	1.03	1.78	2.52	1.28	1.99	2.79
Ave social benefit	3.88	2.05	3.07	3.88	4.99	4.99
Max LT1 net ben (fract.)	3.08 (1)	0.45 (1)	0.67 (1)	3.08 (1)	3.39 (1)	2.59 (1)
Min LT1 net ben (fract.)	3.08 (1)	0.45 (1)	0.67 (1)	3.08 (1)	3.39 (1)	2.59 (1)
Max LT2 net ben (fract.)	1.03 (1)	1.78 (1)	2.52 (1)	1.28 (1)	1.99 (1)	2.79 (1)
Min LT2 net ben (fract.)	1.03 (1)	1.78 (1)	2.52 (1)	1.28 (1)	1.99 (1)	2.79 (1)
Simultaneous						
Number of equilibria	0.00	0.00	0.00	2.00	0.00	6.00
Ave total parcels conserved	0.00	0.00	0.00	4.00	0.00	5.00
Ave LT1 parcels conserved	0.00	0.00	0.00	1.00	0.00	3.00
Ave total adjacencies	0.00	0.00	0.00	1.00	0.00	3.00
Ave LT1 net benefit	0.00	0.00	0.00	3.08	0.00	2.59
Ave LT2 net benefit	0.00	0.00	0.00	1.28	0.00	2.79
Ave social benefit	0.00	0.00	0.00	3.88	0.00	4.99
Max LT1 net ben (fract.)	0 (0)	0 (0)	0 (0)	3.08 (1)	0 (0)	2.59 (1)
Min LT1 net ben (fract.)	0 (0)	0 (0)	0 (0)	3.08 (1)	0 (0)	2.59 (1)
Max LT2 net ben (fract.)	0 (0)	0 (0)	0 (0)	1.28 (1)	0 (0)	2.79 (1)
Min LT2 net ben (fract.)	0 (0)	0 (0)	0 (0)	1.28 (1)	0 (0)	2.79 (1)
Social Planner						
Total parcels conserved	4.00	5.00	6.00	4.00	5.00	6.00
Total adjacencies	3.00	4.00	5.00	3.00	4.00	5.00
Net benefit	0.88	1.09	1.29	0.88	1.09	1.29
Social benefit	4.08	5.09	6.09	4.08	5.09	6.09

Notes: With baseline, no Nash equilibrium. The negative adjacency value for LT2 drops its benefit curve too low to conserve at all. Competing adjacency preferences make it difficult to find equilibria for simultaneous game. Runs to the right increase the benefit curve for LT2, offsetting negative adjacency values on total parcels, but strange, erratic equilibria result. As budget1 goes from 1 to 2 to 3, parcels conserved in the simultaneous game are (1,3), (0,0), and (3,2).

Table 6: INCREASING Marginal Benefits: LT1 (+) adj, LT2 0 adj

	Small Adjacency Value ($\gamma_1 = 0.1$, $\gamma_2 = 0$)			Large Adjacency Value ($\gamma_1 = 1$, $\gamma_2 = 0$)		
	Low Budget	Mid Budget	High Budget	Low Budget	Mid Budget	High Budget
LT1 Leader						
Number of equilibria	0.00	40.00	18.00	0.00	40.00	18.00
Ave total parcels conserved	0.00	4.00	5.00	0.00	4.00	5.00
Ave LT1 parcels conserved	0.00	2.00	3.00	0.00	2.00	3.00
Ave total adjacencies	0.00	2.10	3.33	0.00	2.10	3.33
Ave LT1 net benefit	0.00	59.41	118.13	0.00	61.30	121.13
Ave LT2 net benefit	0.00	3.20	6.38	0.00	3.20	6.38
Ave social benefit	0.00	64.21	125.33	0.00	66.10	128.33
Max LT1 net ben (fract.)	0 (0)	59.5 (0.25)	118.2 (0.39)	0 (0)	62.2 (0.25)	121.8 (0.39)
Min LT1 net ben (fract.)	0 (0)	59.3 (0.15)	118.0 (0.06)	0 (0)	60.2 (0.15)	119.8 (0.06)
Max LT2 net ben (fract.)	0 (0)	3.2 (1)	6.3803 (1)	0 (0)	3.2 (1)	6.3803 (1)
Min LT2 net ben (fract.)	0 (0)	3.2 (1)	6.3803 (1)	0 (0)	3.2 (1)	6.3803 (1)
LT2 Leader						
Number of equilibria	12.00	57.00	48.00	12.00	57.00	48.00
Ave total parcels conserved	2.00	4.00	5.00	2.00	4.00	5.00
Ave LT1 parcels conserved	1.00	2.00	3.00	1.00	2.00	3.00
Ave total adjacencies	1.00	2.42	3.63	1.00	2.42	3.63
Ave LT1 net benefit	5.70	59.44	118.16	6.60	61.62	121.43
Ave LT2 net benefit	0.43	3.20	6.38	0.43	3.20	6.38
Ave social benefit	8.10	64.24	125.36	9.00	66.42	128.63
Max LT1 net ben (fract.)	5.7 (1)	59.5 (0.42)	118.2 (0.63)	6.6 (1)	62.2 (0.42)	121.8 (0.63)
Min LT1 net ben (fract.)	5.7 (1)	59.4 (0.58)	118.1 (0.38)	6.6 (1)	61.2 (0.58)	120.8 (0.38)
Max LT2 net ben (fract.)	0.43 (1)	3.2 (1)	6.3803 (1)	0.43 (1)	3.2 (1)	6.3803 (1)
Min LT2 net ben (fract.)	0.43 (1)	3.2 (1)	6.3803 (1)	0.43 (1)	3.2 (1)	6.3803 (1)
Simultaneous						
Number of equilibria	0.00	57.00	48.00	0.00	57.00	48.00
Ave total parcels conserved	0.00	4.00	5.00	0.00	4.00	5.00
Ave LT1 parcels conserved	0.00	2.00	3.00	0.00	2.00	3.00
Ave total adjacencies	0.00	2.42	3.63	0.00	2.42	3.63
Ave LT1 net benefit	0.00	59.44	118.16	0.00	61.62	121.43
Ave LT2 net benefit	0.00	3.20	6.38	0.00	3.20	6.38
Ave social benefit	0.00	64.24	125.36	0.00	66.42	128.63
Max LT1 net ben (fract.)	0 (0)	59.5 (0.42)	118.2 (0.63)	0 (0)	62.2 (0.42)	121.8 (0.63)
Min LT1 net ben (fract.)	0 (0)	59.4 (0.58)	118.1 (0.38)	0 (0)	61.2 (0.58)	120.8 (0.38)
Max LT2 net ben (fract.)	0 (0)	3.2 (1)	6.3803 (1)	0 (0)	3.2 (1)	6.3803 (1)
Min LT2 net ben (fract.)	0 (0)	3.2 (1)	6.3803 (1)	0 (0)	3.2 (1)	6.3803 (1)
Social Planner						
Total parcels conserved	3.00	4.00	5.00	3.00	4.00	5.00
Total adjacencies	2.00	3.00	4.00	2.00	3.00	4.00
Net benefit	20.00	54.70	113.40	21.80	57.40	117.00
Social benefit	27.20	64.30	125.40	29.00	67.00	129.00

Note: (+) LT1 adjacency values change agglomeration patterns but not overall crowding in. large adjacency values don't affect patterns - they only increase benefits for LT1.

Table 7: INCREASING Marginal Benefits: LT1 (+) adj, LT2 (+) adj

	Small Adjacency Values ($\gamma_1 = 0.1$, $\gamma_2 = 0.1$)			Large Adjacency Values ($\gamma_1 = 1$, $\gamma_2 = 1$)			
	Low Budget	Mid Budget	High Budget	Very Low Budget*	Low Budget	Mid Budget	High Budget
LT1 Leader							
Number of equilibria	0.00	24.00	30.00	0.00	15.00	24.00	30.00
Ave total parcels conserved	0.00	4.00	5.00	0.00	3.00	4.00	5.00
Ave LT1 parcels conserved	0.00	2.00	3.00	0.00	1.00	2.00	3.00
Ave total adjacencies	0.00	3.00	4.00	0.00	2.00	3.00	4.00
Ave LT1 net benefit	0.00	59.50	118.20	0.00	26.60	62.20	121.80
Ave LT2 net benefit	0.00	3.50	6.78	0.00	2.40	6.20	10.38
Ave social benefit	0.00	64.30	125.40	0.00	29.00	67.00	129.00
Max LT1 net ben (fract.)	0 (0)	59.5 (1)	118.2 (1)	0 (0)	26.6 (1)	62.2 (1)	121.8 (1)
Min LT1 net ben (fract.)	0 (0)	59.5 (1)	118.2 (1)	0 (0)	26.6 (1)	62.2 (1)	121.8 (1)
Max LT2 net ben (fract.)	0 (0)	3.5 (1)	6.8 (1)	0 (0)	2.4 (1)	6.2 (1)	10.4 (1)
Min LT2 net ben (fract.)	0 (0)	3.5 (1)	6.8 (1)	0 (0)	2.4 (1)	6.2 (1)	10.4 (1)
LT2 Leader							
Number of equilibria	15.00	24.00	30.00	0.00	15.00	24.00	30.00
Ave total parcels conserved	3.00	4.00	5.00	0.00	3.00	4.00	5.00
Ave LT1 parcels conserved	1.00	2.00	3.00	0.00	1.00	2.00	3.00
Ave total adjacencies	2.00	3.00	4.00	0.00	2.00	3.00	4.00
Ave LT1 net benefit	24.80	59.50	118.20	0.00	26.60	62.20	121.80
Ave LT2 net benefit	0.60	3.50	6.78	0.00	2.40	6.20	10.38
Ave social benefit	27.20	64.30	125.40	0.00	29.00	67.00	129.00
Max LT1 net ben (fract.)	24.8 (1)	59.5 (1)	118.2 (1)	0 (0)	26.6 (1)	62.2 (1)	121.8 (1)
Min LT1 net ben (fract.)	24.8 (1)	59.5 (1)	118.2 (1)	0 (0)	26.6 (1)	62.2 (1)	121.8 (1)
Max LT2 net ben (fract.)	0.6 (1)	3.5 (1)	6.8 (1)	0 (0)	2.4 (1)	6.2 (1)	10.4 (1)
Min LT2 net ben (fract.)	0.6 (1)	3.5 (1)	6.8 (1)	0 (0)	2.4 (1)	6.2 (1)	10.4 (1)
Simultaneous							
Number of equilibria	0.00	32.00	34.00	0.00	15.00	32.00	34.00
Ave total parcels conserved	0.00	4.00	5.00	0.00	3.00	4.00	5.00
Ave LT1 parcels conserved	0.00	2.00	3.00	0.00	1.00	2.00	3.00
Ave total adjacencies	0.00	2.75	3.88	0.00	2.00	2.75	3.88
Ave LT1 net benefit	0.00	59.48	118.19	0.00	26.60	61.95	121.68
Ave LT2 net benefit	0.00	3.48	6.77	0.00	2.40	5.95	10.26
Ave social benefit	0.00	64.28	125.39	0.00	29.00	66.75	128.88
Max LT1 net ben (fract.)	0 (0)	59.5 (0.75)	118.2 (0.88)	0 (0)	26.6 (1)	62.2 (0.75)	121.8 (0.88)
Min LT1 net ben (fract.)	0 (0)	59.4 (0.25)	118.1 (0.12)	0 (0)	26.6 (1)	61.2 (0.25)	120.8 (0.12)
Max LT2 net ben (fract.)	0 (0)	3.5 (0.75)	6.8 (0.88)	0 (0)	2.4 (1)	6.2 (0.75)	10.4 (0.88)
Min LT2 net ben (fract.)	0 (0)	3.4 (0.25)	6.7 (0.12)	0 (0)	2.4 (1)	5.2 (0.25)	9.4 (0.12)
Social Planner							
Total parcels conserved	3.00	4.00	5.00	2.00	3.00	4.00	5.00
Total adjacencies	2.00	3.00	4.00	1.00	2.00	3.00	4.00
Net benefit	20.00	54.70	113.40	4.20	21.80	57.40	117.00
Social benefit	27.20	64.30	125.40	9.00	29.00	67.00	129.00

* Budget_1 = 0 parcels, Budget_2 = 2 parcels. Note: Small adjacency values are similar to the results from the LT1 (+) and LT2 (0) case; change agglomeration patterns even further, but no change to overall crowding in. Large adjacency values (especially for LT2) do affect crowding-in (CI). CI occurs at lower budget/parcel conservation for LT1.

Table 8: INCREASING marginal benefits: LT1 (+) adj, LT2 (-) adj

	Small Adjacency Values (γ_1 = 0.1, γ_2 = -0.1)			Large Adjacency Values (γ_1 = 1, γ_2 = -1)		
	Low Budget	Mid Budget	High Budget	Low Budget	Mid Budget	High Budget
LT1 Leader						
Number of equilibria	0.00	50.00	18.00	0.00	12.00	3.00
Ave total parcels conserved	0.00	4.00	5.00	0.00	4.00	5.00
Ave LT1 parcels conserved	0.00	2.00	3.00	0.00	2.00	3.00
Ave total adjacencies	0.00	1.00	3.00	0.00	1.00	2.00
Ave LT1 net benefit	0.00	59.30	118.10	0.00	60.20	119.80
Ave LT2 net benefit	0.00	3.10	6.08	0.00	2.20	4.38
Ave social benefit	0.00	64.10	125.30	0.00	65.00	127.00
Max LT1 net ben (fract.)	0 (0)	59.3 (1)	118.1 (1)	0 (0)	60.2 (1)	119.8 (1)
Min LT1 net ben (fract.)	0 (0)	59.3 (1)	118.1 (1)	0 (0)	60.2 (1)	119.8 (1)
Max LT2 net ben (fract.)	0 (0)	3.1 (1)	6.1 (1)	0 (0)	2.2 (1)	4.4 (1)
Min LT2 net ben (fract.)	0 (0)	3.1 (1)	6.1 (1)	0 (0)	2.2 (1)	4.4 (1)
LT2 Leader						
Number of equilibria	12.00	33.00	18.00	0.00	6.00	18.00
Ave total parcels conserved	2.00	4.00	5.00	0.00	2.00	5.00
Ave LT1 parcels conserved	1.00	2.00	3.00	0.00	2.00	3.00
Ave total adjacencies	1.00	2.00	3.00	0.00	1.00	3.00
Ave LT1 net benefit	5.70	59.40	118.10	0.00	4.20	120.80
Ave LT2 net benefit	0.33	3.00	6.08	0.00	1.83	3.38
Ave social benefit	8.10	64.20	125.30	0.00	9.00	128.00
Max LT1 net ben (fract.)	5.7 (1)	59.4 (1)	118.1 (1)	0 (0)	4.2 (1)	120.8 (1)
Min LT1 net ben (fract.)	5.7 (1)	59.4 (1)	118.1 (1)	0 (0)	4.2 (1)	120.8 (1)
Max LT2 net ben (fract.)	0.3 (1)	3 (1)	6.1(1)	0 (0)	1.8 (1)	3.4 (1)
Min LT2 net ben (fract.)	0.3 (1)	3 (1)	6.1(1)	0 (0)	1.8 (1)	3.4 (1)
Simultaneous						
Number of equilibria	0.00	0.00	6.00	0.00	0.00	0.00
Ave total parcels conserved	0.00	0.00	5.00	0.00	0.00	0.00
Ave LT1 parcels conserved	0.00	0.00	3.00	0.00	0.00	0.00
Ave total adjacencies	0.00	0.00	3.00	0.00	0.00	0.00
Ave LT1 net benefit	0.00	0.00	118.10	0.00	0.00	0.00
Ave LT2 net benefit	0.00	0.00	6.08	0.00	0.00	0.00
Ave social benefit	0.00	0.00	125.30	0.00	0.00	0.00
Max LT1 net ben (fract.)	0 (0)	0 (0)	118.1 (1)	0 (0)	0 (0)	0 (0)
Min LT1 net ben (fract.)	0 (0)	0 (0)	118.1 (1)	0 (0)	0 (0)	0 (0)
Max LT2 net ben (fract.)	0 (0)	0 (0)	6.1 (1)	0 (0)	0 (0)	0 (0)
Min LT2 net ben (fract.)	0 (0)	0 (0)	6.1 (1)	0 (0)	0 (0)	0 (0)
Social Planner						
Total parcels conserved	3.00	4.00	5.00	3.00	4.00	5.00
Total adjacencies	2.00	3.00	4.00	2.00	3.00	4.00
Net benefit	20.00	54.70	113.40	21.80	57.40	117.00
Social benefit	27.20	64.30	125.40	29.00	67.00	129.00

Note: small (-) adjacency values prevent crowding in of LT2 until budget1 reaches high (rather than mid). Large (-) adjacency values prevent LT2 from crowding in at all.

Table 9: Hot Spots

	Low Budget, (+) Adj Values ($\gamma 1$ = 0.1, $\gamma 2$ = 0.1)	Mid Budget, (+) Adj Values ($\gamma 1$ = 0.1, $\gamma 2$ = 0.1)	Mid Budget, Mixed Adj Values ($\gamma 1$ = 0.1, $\gamma 2$ = -1.1)
LT1 Leader			
Number of equilibria	2.00	3.00	2.00
Ave total parcels conserved	2.00	3.00	3.00
Ave LT1 parcels conserved	1.00	2.00	2.00
Ave total adjacencies	1.00	2.00	2.00
Ave LT1 net benefit	24.70	59.40	59.40
Ave LT2 net benefit	1.87	3.86	1.46
Ave social benefit	27.10	64.20	64.20
Max LT1 net ben (fract)	24.7 (1)	59.4 (1)	59.4 (1)
Min LT1 net ben (fract)	24.7 (1)	59.4 (1)	59.4 (1)
Max LT2 net ben (fract)	1.87 (1)	3.86 (1)	1.46 (1)
Min LT2 net ben (fract)	1.87 (1)	3.86 (1)	1.46 (1)
LT2 Leader			
Number of equilibria	1.00	2.00	2.00
Ave total parcels conserved	1.00	2.00	2.00
Ave LT1 parcels conserved	1.00	2.00	2.00
Ave total adjacencies	0.00	1.00	1.00
Ave LT1 net benefit	5.60	22.30	22.30
Ave LT2 net benefit	2.46	4.27	3.07
Ave social benefit	8.00	27.10	27.10
Max LT1 net ben (fract)	5.6 (1)	22.3 (1)	22.3 (1)
Min LT1 net ben (fract)	5.6 (1)	22.3 (1)	22.3 (1)
Max LT2 net ben (fract)	2.46 (1)	4.27 (1)	3.07 (1)
Min LT2 net ben (fract)	2.46 (1)	4.27 (1)	3.07 (1)
Simultaneous			
Number of equilibria	3.00	5.00	4.00
Ave total parcels conserved	1.67	2.60	2.50
Ave LT1 parcels conserved	1.11	2.08	2.08
Ave total adjacencies	0.67	1.60	1.50
Ave LT1 net benefit	18.33	44.56	40.85
Ave LT2 net benefit	2.07	4.03	2.27
Ave social benefit	20.73	49.36	45.65
Max LT1 net ben (fract)	24.7 (0.67)	59.4 (0.6)	59.4 (0.5)
Min LT1 net ben (fract)	5.6 (0.33)	22.3 (0.4)	22.3 (0.5)
Max LT2 net ben (fract)	2.46 (0.33)	4.27 (0.4)	3.07 (0.5)
Min LT2 net ben (fract)	1.87 (0.67)	3.86 (0.6)	1.46 (0.5)
Social Planner			
Total parcels conserved	3.00	4.00	4.00
Total adjacencies	2.00	3.00	3.00
Net benefit	57.00	115.70	115.70
Social benefit	64.20	125.30	125.30

Notes: In low budget case, LT1 conserves 1 and LT2 conserves 2 - in mid budget, LT1 conserves 2 and LT2 conserves 1. No major differences except fraction of equilibria in which LT2 does not conserve is 1/3 in column 1 & 2/5 in column 2. Paragraph in text refers to column 1.

Table 10: Summary Statistics of Variables in Illinois

Variable Name	Mean	S.D.	Min.	Max.
Privately protected areas (acres)	45.38	287.92	0	9397.73
Publicly protected areas (acres)	489.1	2368.37	0	23366
Population density (population/acre, year 2000)	0.4466	1.545	0	23.09
Median household income ($, year 2000)	44,592	12,697	7.21	146,551
High school graduates as % of people over age 25 (%, year 2000)	38.2	7.6	5.8	64.2
College graduates as % of people over age 25 (%, year 2000)	10.4	5.5	0.4	40.6
Elevation heterogeneity (standard deviation of elevation / mean elevation)	0.058	0.042	0.001	0.277
Cost of land ($/acre)	1651	1090	624	6141
Mean distance from municipal boundaries (miles)	3.62	1.018	0	28.8
Area of surface water (acres)	867	17,349	0	570,600
Area of agricultural land (acres)	16,272	8,067	0	54,156
Area of forest (acres)	2,454	2,968	0	46,211
Area of urban land (acres)	1,376	4,433	1.12	138,200
Area of wetland (acres)	836	1,095	0	11,339

Table 11: Summary Statistics of Variables in Massachusetts

Variable Name	Mean	S.D.	Min.	Max.
Privately protected areas (acres)	1,664	2,045	0	11,815
Publicly protected areas (acres)	2,810	2,891	4.49	21,856
Population density (population/acre, year 2000)	1.92	3.58	0	29.25
Median household income ($, year 2000)	63,014	19,656	29,861	160,084
High school graduates as % of people over age 25 (%, year 2000)	26	9.9	0	46
College graduates as % of people over age 25 (%, year 2000)	20	8.6	0	44
Elevation heterogeneity (standard deviation of elevation / mean elevation)	0.374	0.234	0.071	1.182
Cost of land ($/acre)	6,803	5,119	0	42,565
Mean distance from municipal boundaries (miles)	2.97	3.6	0	19.7
Area of surface water (acres)	543	850	6.67	9,210
Area of agricultural land (acres)	1,013	1,142	0	7,372
Area of forest (acres)	8,422	6,607	0	40,837
Area of open urban land (acres)	433	478	1.78	5,649
Area of wetland (acres)	451	557	0	4,970
Area of priority habitat (acres)	2,390	3,377	0	28,974

Table 12: Results of Spatial-Lag Econometric Estimation for Illinois

Variable	Coef.	S. E.	Significance
Neighbors' private protected area	.33	.035	***
Publicly protected land	-.0069	.0032	**
Population density	-16.5	6.82	**
Median income	-.00030	.00088	
High school	-111.02	119.6	
College	-127.7	196.9	
Elevation heterogeneity	439.5	212.5	**
Cost of land	.052	.013	**
Distance to city	-4.16	3.58	
Surface water area	-.00028	.00044	
Agriculture	$-1.6\ e^{-5}$	.001	
Forest	.0048	.0028	*
Developed land	.00099	.0018	
Wetland	.040	.0067	*
Constant	-34.1	62.6	
N	1691		
R^2	.13		
Log-likelihood	-11905.8		

Notes:

1) The dependent variable is the number of acres of privately protected land in a township.

2) *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

Table 13: Results of Spatial-Lag Model for Massachusetts

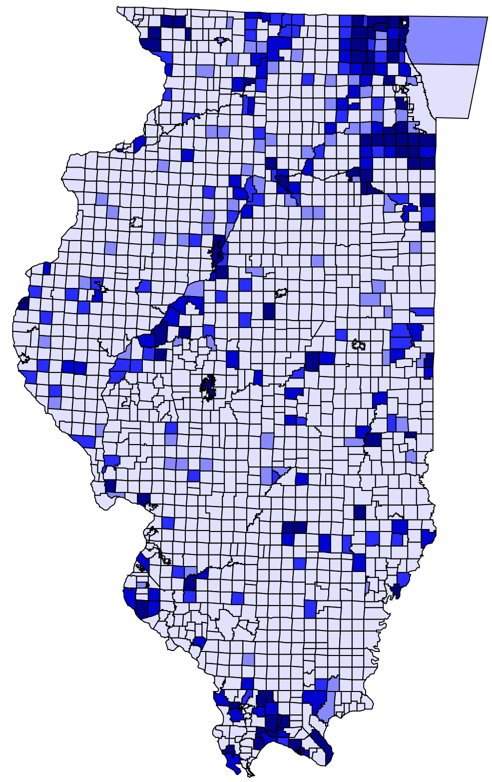
Variable	Coef.	S. E.	Significance
Neighbors' private protected area	.24	.060	***
Publicly protected land	-.27	.048	***
Population density	21.2	30.8	
Median income	.00022	.0071	
High school	-2051.3	1032.6	**
College	2172.7	14706	
Elevation heterogeneity	432.4	485.1	
Cost of land	.0013	.0211	
Distance to city	21.7	30.4	
Surface water area	-.14	.12	
Agriculture	.32	.090	***
Forest	.20	.025	***
Open urban land	.36	.19	*
Wetland	.18	.17	
Priority habitat	.13	.033	***
Constant	-662.0	709.1	
N	351		
R^2	.49		
Log-likelihood	-3062.68		

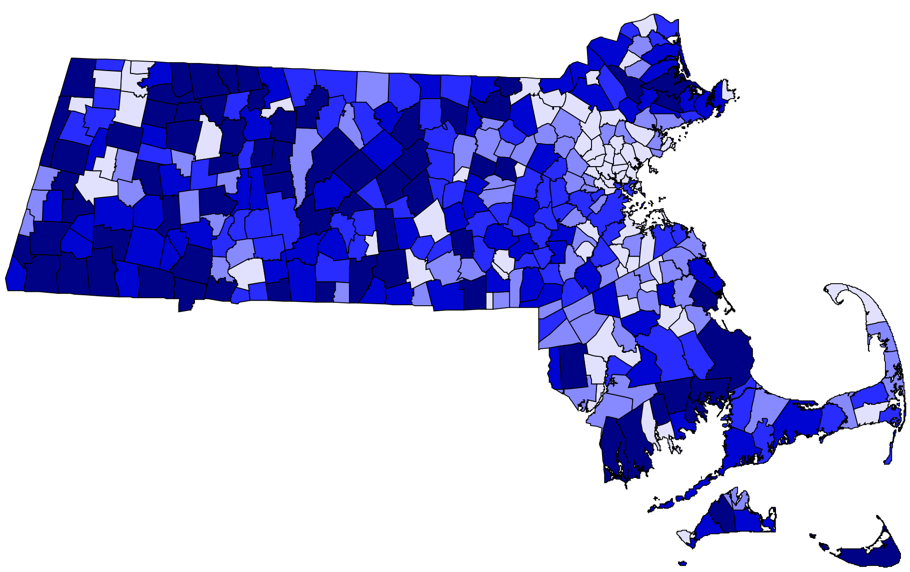
Notes:

1) The dependent variable is the number of acres of privately protected land in a township.

2) *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

Figure 1: Private Protected Areas in Illinois and Massachusetts





Note: Townships are shaded in increasing order of quintiles. The bottom quintile in Illinois is equal to zero acreage.

Pixels in place of parcels: Modeling urban growth using information derived from satellite imagery

Rich Iovanna & Colin Vance
USEPA, National Center for Environmental Economics &
German Aerospace Center, Institute of Transportation Research

Pixels in place of parcels: Modeling urban growth using information derived from satellite imagery

Introduction

Over the past two decades, the conversion of farm and forestlands on city fringes throughout the United States has continued unabated, with the urbanized area expanding from approximately 51 to 76 million acres between 1982 and 1997 (Fulton et al, 2001). While partly reflecting growing prosperity and preferences for increased living space, this trend has raised concerns on several fronts. Through its strong association to the increase in impervious surfaces, expansion of the urban frontier degrades and fragments natural habitats, contributes to poor air quality through increased reliance on vehicle travel, and disrupts a multitude of ecosystem services such as aquifer recharge and nutrient cycling. Such disruptions can impose significant costs on municipalities, including damage from flooding, higher medical costs for air quality-related illnesses, and increased expenditures for the provision of public services and infrastructure. Social and aesthetic costs may further compound these ecological and health impacts. The movement of populations away from central city areas has been argued to not only contribute to urban blight (Jargowsky, 2001), but also to a loss of cultural heritage as farmland and forest is replaced by what is often a pattern of helter-skelter development characterized by strip malls, office parks and disconnected residential communities (Kunstler, 1994).

To the extent that development decisions create landscape mosaics that alter ecological function and constrain the choice set of future land-use alternatives, efforts to understand urban expansion have the potential to contribute greatly to land-use planning and environmental policy processes. Models that are fine scale and spatially explicit are particularly meaningful because ecologists and allied disciplines perceive an intimate connection between the provision of habitat and other services by ecosystems and the pattern of the landscape mosaic in which the ecosystems function. Complex landscape patterns attributable to development disproportionately impact the environment by fragmenting ecosystems and increasing the ratio of edge to interior extent. Similarly, where development takes place (location in the watershed and proximity to water bodies), rather than how much, is of paramount importance when considering how development stresses aquatic ecosystems.

Attention toward the fine scale and spatial explicitness is noticeable in the recent economics literature, with a recurring theme being how the spatial configuration of land use, by virtue of its association to both accessibility and spatially determined externalities, is itself an important determinant of conversion of open space to developed uses. In recent years, an increasing number of studies have combined principles from landscape ecology with spatial-econometric methods to account for how human decision-making, ecosystem function, and their interaction effect landscape changes across different spatial scales (e.g. Turner, Wear and Flamm, 1996; Geoghegan, Wainger and Bockstael, 1997; Kline, Moses and Alig, 2001; Irwin and Bockstael, 2002). Pioneering work in this area was undertaken by Geoghegan, Wainger and Bockstael (1997), who capture externality effects on land values by including explanatory variables measuring landscape diversity and fragmentation in a cross-sectional hedonic regression. Subsequent work by Irwin and Bockstael (2002) adds a temporal dimension by specifying the Cox proportional hazards model to examine the influence of spatially determined spillover effects on the likelihood of land-use conversion. They capture spillover effects by including a spatial explanatory variable that measures the percent of land already developed in a roughly one-mile radius surrounding the parcel, but, unlike Geoghegan, Waigner, and Bockstael, they include no control for the extent to which this development is fragmented.

Motivated by the hypothesis that "urban spatial structure is determined by interdependencies among spatially distributed agents," our efforts take as their point of departure the work of Irwin and Bockstael (2002: 32). While the present paper further explores the role of landscape pattern in land-use change, we decouple our exploration from reliance on parcel-level data. By focusing on a consistent and finer unit of observation (a 60 X 60-meter satellite pixel), we develop a model that ventures beyond Irwin and Bockstael's ability to predict where development may occur, to both where and by how much.[1] Significantly, the structural equations we develop indicate that neither price nor lot size data are required for our modeling approach. A further implication is that the effect of variables measuring pixel-level amenities on the likelihood of conversion is an empirical question, the sign of which cannot be hypothesized a priori.

From a dynamic profit- and consumer surplus-maximizing framework we derive an empirical model to identify the determinants of land conversion from commodity-based to urban uses across a 25,900 square kilometer swath in central North Carolina, an area that has undergone extensive change over the last two decades. The data we use to estimate the model come primarily from five satellite images spanning the years 1976-2001. Using 60 X 60-meter satellite pixels as the unit of observation, we subsequently test for the significance of these factors with a complementary log-log model derived from the proportional-hazards specification.

The model estimated has several distinguishing features: Unlike the Cox model, which conditions out the parameters corresponding to the dynamics of the process being modeled, the complementary log-log specification affords great flexibility for parameterizing the effect of time. Because the data are observed at a very fine level of spatial resolution, we can additionally relax the assumption commonly invoked in land-use shares models that all change occurs at the rural urban interface (Hardie *et al*., 2000). Finally, the model includes a broad array of time-varying covariates that measure the land allocation response to site, locational, and pattern attributes associated with each pixel.

Our empirical results confirm the hypothesis that pixel-level characteristics – particularly what surrounds a pixel – have a major influence on the likelihood of its conversion. We also find that the omission of landscape pattern variables can lead to biased inferences regarding the influence of other covariates, such as proximity to road and urban centers, which are commonly identified as important determinants of land-use change. Finally, we uncover some counterintuitive results with respect to the effects of amenities on the hazard of conversion, results that are suggested by our theoretical model to be attributed to trade-offs between plot quality and plot size in the market for undeveloped land.

The Study Region

The study region straddles portions of the Piedmont and the Inner Coastal Plane of North Carolina, two distinct physiogeographic zones that cut diagonally north-south across the state (Figure 1). Across the state as a whole, hardwoods cover more than half of the timberland acreage, while pine stands and oak-pine stands account for the remaining 33 and 14 percent, respectively (Brown, 1993; Brownlow, Lineback and DeHart, 2000). Centuries of human occupation have fragmented these forests into a patchwork that now includes croplands, fields in varying stages of abandonment, and, increasingly, built-up areas.

INSERT FIGURE 1 HERE.

North Carolina is widely regarded as a state in which inefficiencies in land allocation are leading to excessively costly expansion of the built environment. A highly publicized report recently released from Smart Growth America (Ewing, Pendall and Chen, 2003) ranked Greensboro and Raleigh-Durham as second and third among a listing of 83 U.S. cities in which the spread of development far outpaces population growth. In Raleigh, for example, the population increased by 32 percent between 1990 and 1996, while its urbanized land area increased nearly twofold (Sierra Club, 1998).

Historical accounts suggest that the foundations for the sprawling patterns observed in these and other North Carolina cities can be traced back to the 1880s, when a low-density urban landscape emerged as a result of the proliferation of tobacco factories and textile mills (Orr and Stuart, 2000; Ingals, 2000). These employment centers spawned a dispersed network of small towns across the state that today serve as bedroom communities for regional metropolitan centers. By 1900 there were 177 mills in the state, with over 90% of them in the Piedmont (Ingals, 2000). To connect these emergent centers of economic activity, major investments in road infrastructure were undertaken with the result that by the early 1920s there were over 5,500 miles of roads paved linking county seats (Ingals, 2000). These developments ushered in a transition from an economy based largely on agriculture to one based on the service sector and on manufacturing, with heavy reliance on the forest-products sector.

Although the state remains a major producer of tobacco, sweet potatoes, and hog products, the area under agriculture has declined drastically since its peak in the early 1900s (Lilly, 1998). The area under commercial timberland, by contrast, has remained relatively stable, peaking in the early 1970s at 20.13 million acres and then dropping back down to approach the 1938 level of 18.1 million acres by 1990 (Brown, 1993). Nevertheless, a recent U.S. Forest Service report projected that North Carolina will lose 30% of its privately owned, natural forest by 2040, with the Interstate 85 corridor extending southward from Raleigh-Durham designated as a "hotspot" of forest loss due to continuing urbanization (Prestemon and Abt, 2002; Wear and Greis, 2002).

Formalization

Responding to concern about the rate and extent of land-use change requires understanding the causes, timing and location of land-use change. If we know why and when pressures to develop increase for a given tract, we will be in a better position to evaluate where significant ecological consequences are likely to occur as well as the merit of conservation responses. The decision to convert depends on a complex multiplicity of factors, including the market value of output from the land in alternative uses, expectations about the future use of neighboring lands, and the surrounding composition of land ownership. Following the work of Capozza an Helsley (1989) and Boscolo, Kerr, Pfaff, and Sanchez (1998), the theoretical approach taken here attempts to structure this complexity by assuming that a unit of land (referred to hereafter as a 'pixel' to keep this discussion consistent with the data we ultimately use) will be converted if the net present discounted benefits of doing so are greater than the net present discounted benefits of leaving the land under its present use. In other words, the land manager converts pixel i in period T to maximize the following objective function:

$$(1) \quad Max_T \sum_{t=0}^{T} A_{it}\delta^t + \sum_{t=T}^{\infty} D_{it}\delta^t - C_T\delta^T ,$$

where

A_{it} is the return derived from a commodity-based use of the pixel in period t, i.e., the agricultural or forestry rent;

D_i is the return to development in period t, i.e., the development rent;

C_T is the cost associated with conversion; and

δ is the discount rate, 1/(1+r).

Assuming irreversibility of the conversion process, there are two necessary conditions for conversion to take place: The first is that the discounted stream of returns derived from conversion are greater than that of leaving the plot in its present use, net of the one-time conversion costs:

$$(2) \quad \sum_{t=0}^{\infty} (D_{it} - A_{it})\delta^t - C_T > 0 .$$

The operative condition, however, is one that would be met well after that specified by equation (2). Conversion will occur when the development rent just equals the opportunity cost, *OC,* of developing that period as opposed to the next. Assuming development rents are rising over time and conversion costs are declining, it is more profitable to the land owner to defer development for at least another period before time T.[2] After T, the landowner loses money every period that development is deferred. More formally, a developed pixel is one in which

$$(3) \quad D_{it} \geq OC_{it} = A_{it} + (C_{it} - \delta C_{it+1}).$$

If the development rent in period t exceeds the sum of agricultural rent and the cost savings from deferring development, which relates to downward trend in costs as well as the fact that costs are discounted an additional period, the pixel has already been developed. With equality, time *T* is when conversion actually takes place. Equation 3 indicates and Figure 2 depicts how higher development rents hasten conversion, while higher agricultural rents, conversion costs, and the rate of decline in costs defer conversion for one pixel relative to another.[3]

INSERT FIGURE 2 HERE

To account for unobserved idiosyncratic factors associated with pixel *i* at time *t*, we add an error term to equation (3) such that the greater it is, ceteris paribus, the less likely is conversion. If we further specify ε^* as the amount that makes (3) an equality, then we find the likelihood of conversion at time t to simply be the cumulative density of ε evaluated at ε^*. In other words, if the error for pixel *i* at time *t* is less than or equal ε^*, conversion occurs.

(4) $D_{it} \geq OC_{it} = A_{it} + \left(C_{it} - \delta C_{it+1}\right) + \varepsilon_{it}$.

We can also depict the relationship between a pixel's development rent and opportunity cost in a manner that makes explicit the contribution of factors affecting opportunity cost, both known and unknown. The former comprises those exogenous factors of which the researcher is aware, including agricultural prices and agronomic characteristics. Assuming for simplicity's sake that the vector of known supply-side factors, X, is adequately represented by a single indicator, we can describe a single-pixel analogue of a supply curve for pixels based on a pixel's opportunity cost CDF in a given period. Depicted in Figure 3, the position of this curve is determined by X, while the distribution of ε determines its general shape.

INSERT FIGURE 3 HERE

At equilibrium, the total amount of conversion (in terms of pixels) that occurs in a market or region must equal the summation across all pixels of conversion likelihoods:

(5) $\sum_i P_{OC}^*\left(D_V, X\right) = TotDevt$

where

P_{OC} is the cumulative density of operating cost, and

TotDevt is the overall areal extent of conversion.

We have shown thus far how the likelihood of conversion is simply determined the comparison of development returns with opportunity costs. Before moving onto an empirical model that estimates the likelihood of conversion, however, we must somehow deal not only with the fact that the likelihood of conversion and development returns are jointly determined, but also with the absence of price data for precisely the tracts in which we are interested, which precludes recourse to modeling via simultaneous equations approach. To overcome this problem, we explicitly consider an individual's residential choice.[4]

A pertinent abstraction of the individual's site selection process has them essentially viewing from above the region they plan on living and considering where best to situate their lot. They behold in their region undeveloped patches of varying levels of appeal (i.e., the patches' quality varies), each of which a potential location for their new lot. A patch's quality results from a vector of demand-side factors, denoted *V,* that individuals deem important, e.g., proximity to water, proximity to the urban core, the landscape pattern of neighboring land, etc. We assume that this vector, too, contains one element indicative of overall quality.[5] In Figure 4, quality is portrayed in a hypothetical region by color: the deeper the green, the higher the quality of a patch. In addition to having discretion over where their new lot will be, these individuals also determine how big a lot to carve out of the open space. Conceivable plots are portrayed by the rectangular polygons.

INSERT FIGURE 4 HERE

The utility provided by the lot depends on both its size and the quality of the land on which it resides. Development rents – or per pixel rental prices from the demand-side perspective – will vary according to quality and the individual's desired lot size for a particular quality level is determined by the first order condition equating marginal WTP with this price:[6]

$$(6)\quad D_V = \frac{\partial WTP(V,S)}{\partial S} \forall V \, ,$$

where

WTP is the willingness to pay for a lot, and

S is the size of a lot.

Critically, pixel rental prices across quality levels adjust to ensure that the consumer surplus the individual garners from a lot is the same regardless of the quality level. Expressed mathematically, we have

$$(7)\quad WTP(V,S) - D_A S = CS \forall V .$$

It is relatively easy to see how a lot conceived on a relatively unappealing patch could be larger than that on an amenity-laden patch: the pixel rental price for the former will be low enough for one to carve out a larger lot size, compensating for the relatively low quality. At market equilibrium, individuals will be indifferent to all quality-quantity combinations in their choice set of potential lots. We can see the quality-quantity tradeoff in Figure 4, where the lots in patches of higher quality are smaller (holding incomes constant).

The relationship between quality and quantity can also be depicted graphically, as in Figure 5. The solid lines represent equilibrium pixel rental prices and lot sizes at low and high quality levels; they are demand curves. The dotted line represents pixel rental price and lot size combinations holding *CS* constant so the points of intersection illustrate the tradeoff that may exist in the choice set between quality and quantity at market clearing prices. The areas bounded by the two solid lines and their respective pixel rental prices (indicated by the points of intersection) – reflecting surplus – are equal.

INSERT FIGURE 5 HERE

By incorporating the foregoing into Equation 5, we now express the total number of pixels converted in terms of integration over the joint density of *V* and *X:*

$$(8)\quad \sum_i P^*_{OC}\left(D_V, X\right) = I \cdot \int_V \int_X \left[g(V,X) \cdot P^*_{OC}\left(D_V\left(V, CS\right), X\right)\right] dXdV$$

where

I is the total number of undeveloped pixels in a region, i.e., areal extent of the region.

$g(V,X)$ is the joint probability density function for V and X.

By dividing the likelihood of conversion for a pixel with V and X characteristics by the equilibrium lot size (itself a function of V and CS) for such a pixel type, we have an expression equal to the total number of lots sought over the entire market, considered as given:

$$(9)\quad I \cdot \int_V \int_X g(V,X) \frac{P^*_{OC}(D(V,CS),X)}{S(V,CS)} dXdV = TotLots$$

With the distribution for demand and supply-side factors, along with the number of lots sought known, this equation condition could be solved for CS.

Stepping back to focus on the landscape change process has involved combining into a single framework decisions about where and how much to develop. The resulting equilibrium condition implies that lot size and price information are not required for estimation of pixel conversion probabilities. Apparent in the numerator of the expression, V and X are the relevant covariates. The CS solving Equation 9 is actually irrelevant, as it is a market-level value that is constant across all pixels in a given market and for a given time interval. As such, its effect on the likelihood of conversion will manifest for all pixels in a constant term or set of fixed effects.

For land-use change and other phenomena, timing is a critical aspect of interest. Given that conversion is the consequence of continuous processes and may occur at any point in time during the period under observation, the appropriate means by which to estimate parameters that affect all observations in a consistent manner is by recourse to duration – or survival – modeling. Rather than modeling the direct influence of a covariate on conversion probabilities, duration models are concerned with the hazard rate underlying the probabilities, i.e., the instantaneous risk that pixel i is cleared in period t conditional on not having been converted before t.[7] While conventional methods such as linear or logistic regression have been applied in these contexts, they are ill-equipped to handle the features that often characterize duration data, including time-varying explanatory variables and censoring or truncation of the dependent variable.[8]

As our study data are interval censored, meaning that each observation's survival time is known only to fall somewhere between two dates, the dependent variable assumes a value of one if a conversion occurs over an interval between the dates and zero otherwise. To reconcile the temporal continuity of the conversion process being modeled with this coarseness in the measurement of timing, we specify a complementary log-log duration model. By doing so, the relationship between our V and X covariates and the probability that opportunity costs are low enough for conversion to occur is

$$(10) \qquad P_{OC} = 1 - e^{-h},$$

where

$$(11) \qquad h = e^{\alpha + \beta V + \beta X \ldots}.$$

The complementary log-log model is a discrete analogue to Cox's proportional hazards model, a highly flexible specification that is estimated using partial likelihood methods. Two major advantages the models share are that they readily accommodate time-varying covariates and require no assumptions on the functional form of the baseline hazard rate or on the factors that may change this rate over time. This enables attention to be focused specifically on the effect of the covariates on the relative risk of a transition. Additionally, and as the name implies, the coefficients estimated by these proportional hazards models have a relative risk interpretation. Unlike the Cox model, the complementary log-log model is estimated using maximum likelihood, allowing one to readily generate estimates for the effect of time on the odds of a transition (See Allison, 1995 for further discussion).

Data and Methods

The Dependent Variable

The econometric model presented in this paper is estimated using a time series of five classified Thematic Mapper (TM) and Landsat Multispectral Scanner (MSS) satellite images over central North Carolina for the years 1976, 1980, 1986, 1993 and 2001.[9] The process of imagery classification was preceded by the standard pre-processing activities, including geometric correction, spectral-spatial clustering, and radiometric normalization. Classification then proceeded according to a hybrid change detection methodology combining radiometric and categorical change techniques on a pixel-by-pixel basis. This procedure produced four land cover classes: forest, non-forest vegetation, impervious surface, and water. From these classes, we generated a binary dependent variable equaling 1 if a conversion from forest or non-forest vegetation to impervious surface occurred between two dates and 0 otherwise.[10] Conversions to water were treated as censored, while pixels whose classification in the first year (1976) was either water or impervious surface were eliminated from the data. Transitions between forest and non-forest vegetation were also treated as censored as these may be attributable more to forest rotations than permanent conversion from one land cover to another. After overlaying two GIS layers of tenure data from ESRI (2000) and the North Carolina Department of Parks and Recreation (2003), those pixels falling under public ownership (e.g. national, state, and municipal parks) were also eliminated.

Upon classifying the imagery, a systematic sample of pixels was drawn that provided 65,991 pixels for model estimation. The grid pattern across the satellite scene was such that roughly 1.2 kilometers separated each pixel from their nearest neighbors. Systematic sampling is a commonly applied technique to handle spatial correlation of unobserved variables that affect the probability of conversion (Turner, Wear, and Flamm, 1996; Cropper, Puri and Griffiths, 2001; Kline, Moses and Alig, 2001). The consequences of spatial autocorrelation include inefficient but asymptotically unbiased estimates. However, in cases in which the unobservable variables are spatially correlated with the included explanatory variables, the coefficient estimates on the included variables will additionally be biased (Irwin and Bockstael, 2001). A major source of spatial autocorrelation arises from multiple observations falling under common landowners (Kline, Moses and Alig, 2001). Given that the average size of private forest ownership in North Carolina is 9.7 hectares (Powell et al., 1992), while the average farm size is approximately 75 hectares (U.S. Census of Agriculture, 1997), 1.2 kilometer pixel separation in our sample was deemed an adequate distance to sufficiently reduce the likelihood of this occurring.[11, 12]

The Explanatory Variables

Several static and time-varying covariates are included in the model, the values for which correspond to the start year of the interval given by the dates of the satellite imagery. The suite of variables specified captures both site and locational attributes that are hypothesized to affect the likelihood of land-use conversion. Table 1 presents descriptive statistics and the units of measurement for each variable.

INSERT TABLE 1 HERE

To capture the influence of what Healy (1985) has termed juxtaposition effects – or "spatially bounded externalities that affect adjoining or nearby land" (Alig and Healy, 1987: 225) – we derived four time-varying window-based metrics from the imagery that measure the landscape configuration surrounding a pixel. The first is the percent of the area within a window of approximately two square kilometers that is classified as impervious (inner_imperv). The size of the window is admittedly arbitrary, yet also based both on best professional judgment of a typical developer's spatial frame of reference and on previous studies that have found window-sizes of similar magnitude to capture spatial externalities (Geoghegan, Waigner, and Bockstael, 1997; Fleming, 1999; Irwin and Bockstael, 2002). The second metric complements the first, and is the percent impervious in a region between the aforementioned window and another with sides double the size of the first (outer_imperv). Thus, the metrics are non-overlapping, with outer_imperv relating to a region that rings inner_imperv's.

Interestingly, the fact that we explore the potential for spatial externalities using the amount of development within windows around a pixel, as opposed to a measure of how things look around the perimeter of the lot within which the developed pixel would reside, is not a cause for concern. Given that the parcel – like the pixel – must be in an undeveloped state in the data upon which the metrics are based means that the two calculations lead to the same result. As can be seen in Figure 6, the amount of impervious surface within the windows is the same whether or not one considers the lot, since it cannot contribute to that amount.

The two additional window metrics are based solely on the smaller window and are the percent of area classified as water (p_water) and a fragmentation metric (frag). We use a formulation developed by Frohn (1998), which is defined as $Frag_{it} = \frac{m_{it}}{n * \lambda}$, where *i* denotes the pixel, *t* denotes the date of the image, *m* is the total number of patches in the window, *n* is the total number of pixels in the window, and λ is a scaling constant equal to the area of the pixel.[13] Because *n* and λ are constants in our data, the metric essentially reduces to a count of patches.[14] Hence, as the landscape becomes more fragmented, frag increases.

In addition to the window-based metrics, time-varying proximity-based metrics are also included in the specification. The first is the Euclidean distance to the nearest primary road (road_dist).[15] The second is the Euclidean distance to the nearest woodchip mill (chipmill_dist), which is a potentially important cost attribute of forestry operations.[16] The third proximity metric (city_dist), a measure of the influence of market proximity, gives the Euclidean distance to the nearest city with a population of over 50,000 (i.e., Charlotte, Durham, Fayetteville, Greensboro, Raleigh, and Winston-Salem).

Another five variables are included in the model that do not change with time: elevation (elev), slope, and dummy variables indicating forested pixels (forest), wetlands (wetland), and whether either public lands (nearpub) are within a mile of the pixel, or whether hazardous waste sites are (nearhaz).[17]

Varying by county and time interval, a returns to agriculture metric is also in the model and assumed exogenous (ag_returns). This metric is calculated as county total farm receipts less costs, divided by farm acreage in the county. This metric was associated with even forested pixels: as we found agricultural returns to exceed forestry returns in all cases, we assumed that agricultural production to be the relevant alternative use for land vis-à-vis development.

Finally, we include a set of county dummies representing the 31 counties in the region, as well as a dummy for each market—time interval combination (markets in our dataset are assumed to be the Metropolitan Statistical Areas (MSAs) for Charlotte, Durham, Fayetteville, Greensboro, Raleigh, and Winston-Salem). The former serve to limit omitted variable effects arising from county-level differences in governance, zoning, and other factors that may be fixed over time. The latter are a consequence of the formalization as per the discussion relating to Equation 9. Each pixel in our sample was assigned to a market based upon the population weighted distance from each to that pixel.

Results

Table 2 presents results of two complementary log-log models of the determinants of increases in impervious surface. The second model is distinguished from the first by its inclusion of the window-based metrics. In both models, the distance measures and the measures of surrounding impervious surface are transformed as logarithms to allow for attenuated effects of these variables with increases in their magnitude. Although interpretation of the coefficient estimates from the complementary log-log model is complicated by the log-odds transformation of the dependent variable, we can readily calculate their "risk ratio," which also is their marginal effect. In the case of the linear (logged) continuous covariates, the risk ratio is interpreted as the percent change in the hazard rate from a unit (percentage) increase in the covariate. These values are obtained by subtracting one from e^{β} and multiplying the resulting value by 100 in the case of the linear covariates, and by one in the case of the logged covariates. For the dichotomous variables, the percent change in the hazard rate when the variable equals one is again 100 times e^{β}-1(Allison, 1995).

INSERT TABLE 2 HERE

While Models 1 and 2 are both highly significant, with chi square values of 1846 and 2707, respectively, a likelihood ratio test of the null-restrictions imposed by Model 1 on the effects of the window based metrics suggests that it be rejected in favor of Model 2. The chi square value of the test is 860 with four degrees of freedom, providing clear-cut evidence that the metrics improve the fit of the model. As an additional gauge of the predictive performance of the two models, we calculated Goodman and Kruskal's gamma (Goodman and Kruskal, 1954, 1959 and 1963), a non-parametric, symmetric metric that is based on the difference between concordant (C) and discordant (D) pairs of predicted and actual values of the dependent variable as a percentage of all pairs ignoring ties. Gamma is computed as $(C – D)/(C + D)$, and can be interpreted as the contribution of the independent variables in reducing the errors of predicting the rank of the dependent variable. The value of gamma calculated from the constrained model is 0.838, while that of the unconstrained model is 0.923. The improvement in the predictive ability of the model with the inclusion of the window metrics is thus considerable, reducing the fraction of uncertainty remaining in the constrained model by 52 percent.

With respect to the statistical significance and magnitude of the coefficient estimates on the window metrics, the strongest result is seen for the inner ring metric, a 1% increase in which induces a 1.18 percent increase in the hazard of conversion. The coefficient of the outer ring metric is also positive and significant but of considerably lower magnitude, increasing the hazard by 0.16 percent. It is notable that Irwin and Bockstael (2002) obtain contrary findings on similarly constructed variables measuring the percent of developed area in two non-overlapping rings surrounding a plot. Their study focuses on explaining leap-frog development of land parcels limited to areas on the urban fringe, and they interpret the negative coefficients as representing 'repelling effects'. Our attempt to replicate their result by limiting the sample to pixels located beyond 10, 15, and 20 kilometer gradients of the nearest city of greater the 25,000 found the positive and significant parameter estimate on the outer ring variable to be robust. [18]

Increases in fragmentation, as measured by frag, decrease the hazard of conversion, though the estimate is just within the range of significance at the 10% level. Increases in the percent of water surface area, by contrast, have a positive effect that is just out of the range of significance. The former result may reflect disamenities associated with development on highly fragmented land immediately surrounding the pixel, while the latter result is a likely consequence of the positive spillovers generated by hydrological resources for both residential and industrial uses.

Beyond improving the fit of the model, the inclusion of the window metrics produces some noteworthy discrepancies with respect to the sign, significance and magnitude of the remaining covariates. Elevation and the dummy indicating proximity to public lands, both significant and positive in Model 1, are insignificant in Model 2. The negative and significant coefficient on distance to road decreases by over threefold in Model 2, while the coefficient on the variable measuring the distance to the nearest large city reverses its sign from negative to positive. The former result is consistent with the intuition that decreasing primary road proximity discourages peripheral location through increases in accessibility costs per kilometer. However, the latter finding of a positive effect of distance to the nearest city in Model 2 contradicts the conventional expectation that the value of land in developed use is a positive function of spatial proximity to city centers. One plausible explanation for this finding is omitted variables bias: It may be that what is most relevant to development potential is the existence of suitable infrastructure, something better captured by the percent impervious metrics, than by the proximity to some city center.

This result also serves to highlight the trade-off between lot size and pixel quality that underpins the theoretical model outlined above. While decreased pixel quality, as measured here by decreased proximity to the urban center, is expected to reduce the hazard of conversion, this effect may be countered by a market equilibrium in which lower quality pixels are compensated by larger lot sizes. These countervailing effects preclude hypothesizing the sign of the variable a priori. Thus, Model 2's positive signing of the distance measure could also reflect the dominance of size effects, which results in larger lots and hence a higher hazard of conversion.

A final notable discrepancy between the two models is the sign reversal on the dummy variable indicating proximity to a hazardous waste site, which is positive in Model 1 and negative in Model 2. Specifically, the estimate from Model 2 suggests that the hazard of conversion for pixels located within a mile of a hazardous waste site 82 percent of the hazard for pixels located beyond a mile of such sites. The counterintuitive sign on this variable in Model 1 likely reflects an upward bias imparted from the combined influence of the uniformly positive influences of inner_imperv and outer_imper on the hazard of conversion together with the positive correlations between these variables and the hazardous waste site dummy (which Spearman's rank correlation tests support at the 99% level).

The remaining variables across the two models are largely in agreement. While the coefficients of the 27 county dummies in the model are not shown in the table, using a chi-square test of their joint significance we cannot reject the hypothesis at the 1% level that all of these coefficients are zero in both models. Likewise, joint tests of the MSA-year interactions are found to be statistically significant at the 1% level. The return to agricultural land uses, while having the expected negative sign, is insignificant in both models. Turning to the pixel attributes, Model 2 indicates that the hazard of conversion for pixels identified as wetlands is 55 percent of the hazard for those pixels not having this attribute, which is slightly higher than the magnitude estimated in Model 1. These findings are consistent with the hypothesis of higher conversion and opportunity costs associated with pixels under mature or ecologically important vegetation. The two remaining pixel attributes – the forest dummy and slope – are insignificant in both models.

Finally, the negative coefficient on the chipmill_dist variable is noteworthy given a continuing controversy over the socioeconomic and ecological impacts of satellite chip mills in the state. Between 1980 and 1998 the number of such mills in this region increased from two to 18, a trend that many perceive as hastening environmental degradation and biodiversity loss through the promotion of clear-cutting on non-industrial woodlots and monoculture tree farms.[19] While not illuminating the question of clear-cutting, the result obtained in Models I and II indicate that closer proximity to chip mills does serve to increase the hazard that land is converted from forest to urbanized use. The small magnitude of the coefficient estimate, however, suggests that the economic significance of the mills for conversion may be minimal.

Discussion and Conclusion

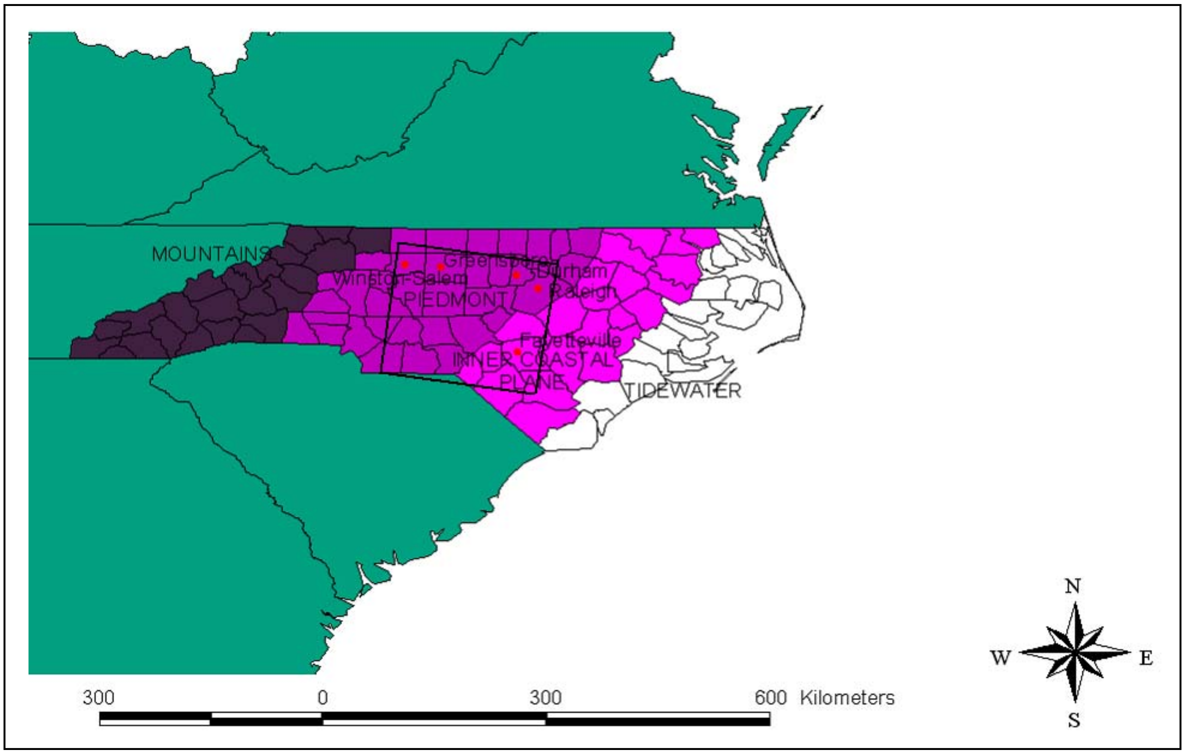
This paper began with a theoretical model of land use change that takes into consideration both the supply and demand sides of the market for undeveloped tracts. One of the most salient results to emerge from the model is that data on parcel boundaries, lot size, and prices are not required for the estimation of conversion probabilities, as these factors are absent from the derived equilibrium condition. While such factors may play a role in land use conversions, their effects play out at the market level and can hence be captured in the model through the inclusion of fixed effects and time-market interaction terms. A second important conclusion is that it is impossible to sign the effects of landscape amenities on the hazard of conversion; to the extent that disamenities are compensated in equilibrium by larger lot sizes, they may have the effect of actually increasing the probability that land is converted.

Based on the theoretical framework, the paper then presented an application of a hazard model as a means of analyzing the effects of static and time-varying socioeconomic and ecological covariates on the conditional risk that land is converted for developed use. By specifying the complementary log-log derivation of the proportional hazards model, we employed a methodology for modeling a continuous time process – the conversion of land to impervious surface – using discrete time satellite data. Our analysis confirmed several findings uncovered elsewhere in the literature, including significant impacts of ecological attributes and road proximity on the likelihood of conversion. As in the works of Geoghegan, Wainger, and Bockstael (1997) and Irwin and Bockstael (2002), we additionally find support for the hypothesis that spatial interactions, as measured by the window metrics describing the landscape pattern, are important determinants of the land conversion process. Unlike Irwin and Bockstael, however, we find no support for repelling effects; contrasting with their study, the two variables employed here measuring the percent of impervious surface surrounding the pixel both have positive impacts.[20]

Our result may be attributed to the dispersed pattern of urban development, organized around mill towns that emerged in North Carolina at the turn of the century. To the extent that a leap frog pattern of development was already established at this time, subsequent development occurring at the end of the century may have been driven largely by urbanization economies arising from city size itself. Our result may also indicate simply that the repelling effect does not operate at a macro enough scale to be evinced by a covariate like inner_imperv, but rather at finer resolution that has implications for development patterns in a locale irrespective of its overall density of development.

There are several possible extensions for using the empirical model estimated in this paper to explore the issue of urbanization. Among the most promising would involve exploiting the model's flexibility in incorporating the effects of time on the hazard of conversion (Allison, 1995). Rather than specifying time dummies, as done here, this could involve including a trend variable measuring the time elapsed since some starting date of interest, such as a change in tenure or the transfer of land ownership (see e.g. Vance and Geoghegan, 2002). Such an approach would enable experimentation with different functional forms of the baseline hazard, including the inclusion of squared and higher order trend terms to allow for non-linearities in the hazard rate, and would provide a basis for simulating future landscape patterns under alternative policy scenarios.

Figure 1: The study region boundaries and physio-geographic zones of North Carolina



Source: Adapted from T.E. Stear, "Population Distribution," pp.30-51, in *North Carolina's Changing Population* (University of North Carolina, Carolina Population Center, 1973).

Figure 2: Time paths for development rent and opportunity costs

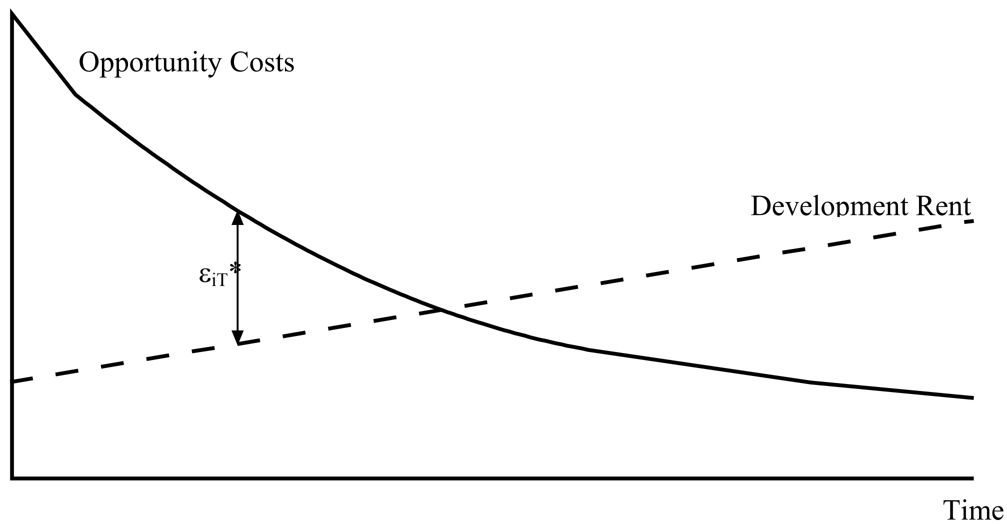


Figure 3: Given the equilibrium price of pixels of quality, *V,* the likelihood of conversion depends on supply side characteristics

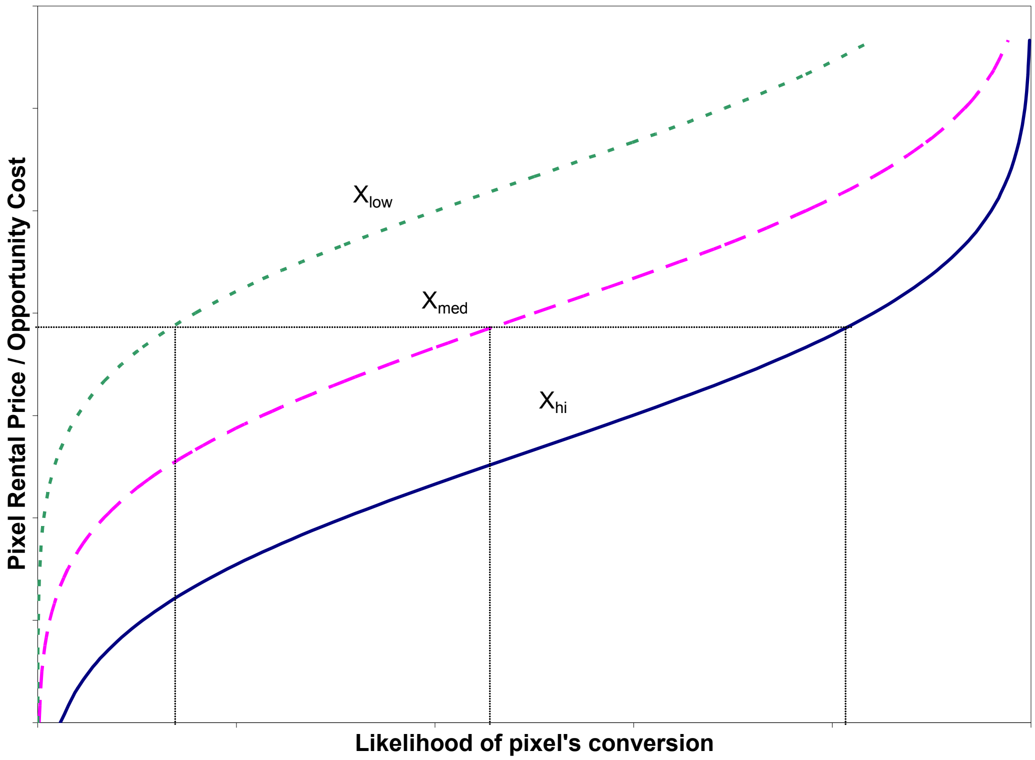


Figure 4: Landscape mosaic illustrating patches of varying quality and potential lot choices

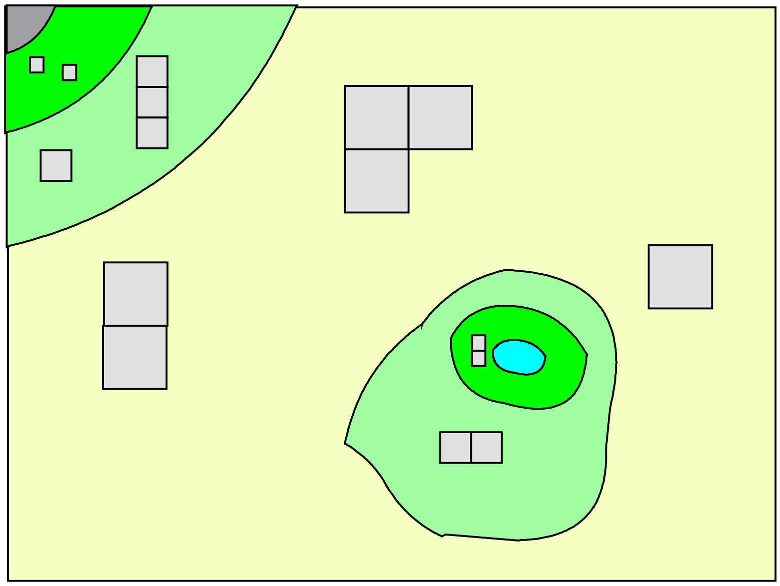


Figure 5: All lots at equilibrium, varying by size and quality, provide the same consumer surplus

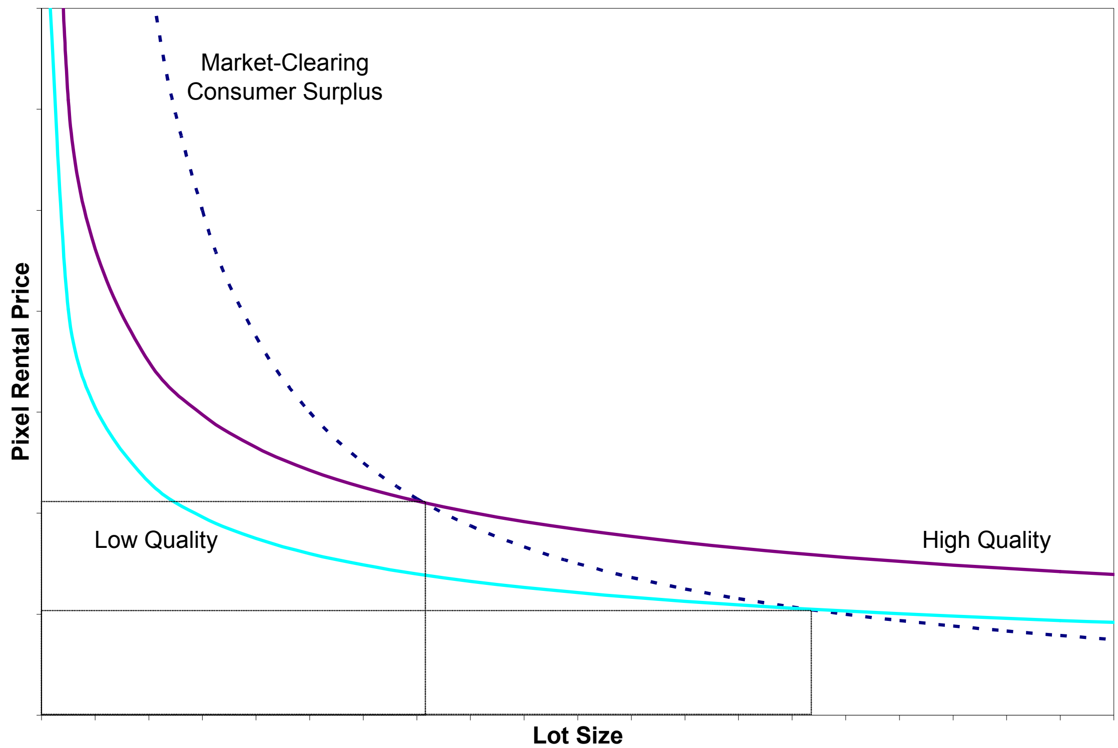


Figure 6: Equivalence between % impervious for a given pixel and an associated lot

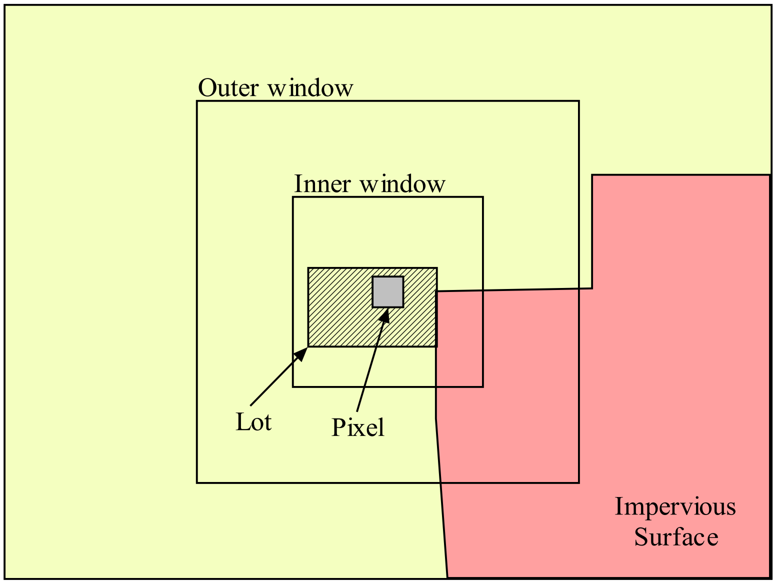


Table 1: Descriptive statistics

Variable name	**Units**	**Mean**	**Standard deviation**
dep. var. (1=conversion)	0,1	0.01	0.10
forest	0,1	0.63	0.48
wetland	0,1	0.12	0.32
slope	degrees	0.60	1.19
elev	meters	137.18	65.81
ag_returns	$1000/acre	0.10	0.12
chipmill_dist	kilometers	63.74	44.56
pub_dum	0,1	0.09	0.28
city_dist	kilometers	42.35	20.07
road_dist	kilometers	1.41	1.32
nearhaz	0,1	0.05	0.21
inner_imperv	percent	1.69	6.26
outer_imperv	percent	2.02	6.47
percent_water	percent	0.51	3.05
frag	index	9.60	6.40

Table 2: Complementary log-log model of the hazard of conversion to impervious surface

	Model I		Model II	
	Coef. est.	% Chg	Coef. est.	% Chg
forest	0.035	3.562	-0.282	-24.573
	(0.856)		(0.140)	
wetland	-0.716	-51.130	-0.595	-44.844
	(0.000)		(0.003)	
slope	0.031	3.149	0.374	45.354
	(0.453)		(0.386)	
elev	0.006	0.602	-0.001	-0.100
	(0.001)		(0.738)	
ag_returns	-1.371	-74.615	-1.635	-81.269
	(0.200)		(0.122)	
chipmill_dist	-0.007	-0.007	-0.005	-0.005
	(0.000)		(0.005)	
nearpub	0.612	84.412	0.006	0.602
	(0.000)		(0.956)	
city_dist	-0.560	-0.429	0.188	0.207
	(0.000)		(0.020)	
road_dist	-0.650	-0.478	-0.158	-0.146
	(0.000)		(0.002)	
nearhaz	0.610	84.043	-0.200	-18.127
	(0.000)		(0.053)	
inner_imperv			0.770	1.159
			(0.000)	
outer_imperv			0.105	0.111
			(0.051)	
pcnt_water			0.027	2.737
			(0.116)	
frag			-0.010	-0.981
			(0.095)	
intercept	-4.854		-5.520	
	(0.000)		(0.000)	
chi^2 county dummies (27)	138		65	
	(0.000)		(0.000)	
chi^2 MSA-year interactions (23)	196		185	
	(0.000)		(0.000)	
LR chi^2 (60, 64)	1846		2707	
	(0.000)		(0.000)	
n_obs	65991		65991	

p-values in parentheses

References

Alig, R. and R. Healy. 1987. "Urban and Built-Up Area Changes in the United States: An Empirical Investigation of Determinants," *Land Economics* 63(3): 215-226.

Allison, P. D., 1995. *Survival Analysis Using the SAS System: A Practical Guide.* Carey: SAS Institute Inc.

Bobyarchick, A.R. and J.A. Diener. 2000. "Land Regions and Geology," in: Orr, D.M. Jr. And A.W. Stuart (eds.), *The North Carolina Atlas: Portrait for a New Century.* Chapel Hill: The University of North Carolina Press.

Bollen, K.A. 1996. "An Alternative Two Stage Least Squares (2SLS) Estimator for Latent Variable Equations," *Psychometrika* 61: 109-121.

Boscolo, M., S. Kerr, A. Pfaff, and A. Sanchez. 1998. "What Role for Tropical Forests in Climate Change Mitigation? The Case of Costa Rica," Paper prepared for the HIID/INCAE/BCIE Central America Project.

Brown, M.J. 1993. *North Carolina's Forests, 1990*. USDA Forest Service Technical Report. Asheville, N.C.: USFS.

Brownlow, B., N. Lineback, J. DeHart. 2000. "Forest Sector Strategies," in Lineback, N. (ed.), *North Carolina's Sensible Greenhouse Gas Reduction Strategies*. Report of the Department of Geography and Planning, Appalachian State University.

Capozza, D. R., and R. W. Helsley. 1990. "The Fundamental of Land Price and Urban Growth," *Journal of Urban Economics* 26: 295-306.

Cooper, A.W. 2000. "Vegetation," in: Orr, D.M. Jr. And A.W. Stuart (eds.), *The North Carolina Atlas: Portrait for a New Century.* Chapel Hill: The University of North Carolina Press.

Cropper, M., J. Puri and C. Griffiths. 2001. "Predicting the Location of Deforestation," *Land Economics* 77: 172-186.

Environmental Systems Research Institute, Inc. (ESRI). 2000. U.S. National Atlas Federal and Indian Land Areas, ESRI Data & Maps 2000 (CD 2).

Environmental Systems Research Institute, Inc. (ESRI). 2000. U.S. GDT Park Landmarks, ESRI Data & Maps 2000 (CD 3).

Environmental Systems Research Institute, Inc. (ESRI). 2000. Census 2000 TIGER/ Line Data, http://www.esri.com/data/download/census2000_tigerline/, retrieved March 2003.

Ewing, R., R. Pendall and D. Chen. 2003. "Measuring Sprawl and Its Impact," http://www.smartgrowthamerica.com/sprawlindex/MeasuringSprawl.PDF, retrieved February 2003.

Fleming, M. 1999. "Growth Controls and Fragment Suburban Development: The Effect on Land Values," *Geographic Information Sciences* 5(2): 154-162.

Freddie Mac. CMHPI Data, http://www.freddiemac.com/finance/cmhpi/#new, retrieved January 2003.

Frohn, R.C. 1998. *Remote Sensing for landscape Ecology: New Metric Indicators for Monitoring, Modeling, and Assessment of Ecosystems*. Boca Raton: CRC Press LLC.

Fulton, W., R. Pendall, M. Nguyen and A. Harrison. 2001. "Who Sprawls Most? How Growth Patterns Differ Across the U.S." Center on Urban & Metropolitan Policy, The Brookings Institution.

Gallagher, R. 1968. *Information Theory and Reliable Communication*. New York: John Wiley & Sons.

Geoghegan, J., S. Cortina Villar, P. Klepeis, P. Macario Mendoza, Y. Ogneva-Himmelberger, R. R. Chowdhury, B. L. Turner, II, and C. Vance. 2001. "Modeling Tropical Deforestation in the Southern Yucatan Peninsular Region: Comparing Survey and Satellite Data." *Agriculture, Ecosystems, and Environment* 84(1-3): 25-46, 2001.

Geoghegan, J., L.A. Wainger, and N.E. Bockstael. 1997. "Spatial landscape indices in a hedonic framework: an ecological economics analysis using GIS," *Ecological Economics* 23: 251-264.

Goodman, L. and W.H. Kruskal. 1954. "Measures for association for cross-classification I," *Journal of the American Statistical Association* 49: 732-764.

Goodman, L. and W.H. Kruskal. 1959. "Measures for association for cross-classification II," *Journal of the American Statistical Association* 54: 123-163.

Goodman, L. and W.H. Kruskal. 1963. "Measures for association for cross-classification III," *Journal of the American Statistical Association* 58: 310-364.

Hardie, I.W., P. Parks, P. Gottlieb, D. Wear. 2000. "Responsiveness of Rural and Urban Land Uses to Land Rent Determinants in the U.S. South," *Land Economics* 76(4): 659-673.

Hauser, J.R. 1978. "Testing the Accuracy, Usefulness, and Significance of Probabilistic Choice Models: An Information-Theoretic Approach," *Operations Research* 26(3): 406-421.

Haynes, K.E. and A.S. Fotheringham. 1984. *Gravity and Spatial Interaction Models*. Beverly Hills: Sage Publications.

Healy, R.G. 1985. "Population Growth in the U.S. South: Implications for Agricultural and Forestry Land Supply," *Rural Development Perspectives* 2(1): 27-30.

Hosmer, D. and S. Lemeshow. 1999. *Applied Survival Analysis: Regression Modeling of Time to Event Data*. New York: John Wiley and Sons, Inc.

Ingalls, G.L. 2000. "Urbanization," in: Orr, D.M. Jr. And A.W. Stuart (eds.), *The North Carolina Atlas: Portrait for a New Century.* Chapel Hill: The University of North Carolina Press.

Irwin, E.G. and N.E. Bockstael. 2001. "The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space on Residential Property Values," *American Journal of Agricultural Economics* 83: 699-705.

Irwin, E.G. and N.E. Bockstael. 2002. “Interacting Agents, Spatial Externalities, and the Endogenous Evolution of Residential Land Use Pattern,” *Journal of Economic Geography* 2: 31-54.

Jargowsky, P.A. 2001. “Sprawl, Concentration of Poverty, and Urban Inequality,” in: Squires, G. (ed.), *Urban Sprawl: Causes, Consequences & Policy Responses*. Washington D.C.: Urban Institute Press.

Kline, J.D., A. Moses, and R.J. Alig. 2001. “Integrating Urbanization into Landscape-level Ecological Assessments,” *Ecosystems* 4: 3-18.

Kunstler, J.H. 1994. *The Geography of Nowhere : The Rise and Decline of America's Man-Made Landscape.* New York: Touchstone Books.

Lee, M. 1998. “Off-farm Labor Supply and Various Related Aspects of Resource Allocation by Agricultural Households,” Ph.D. diss.Falkultät für Agrarwissenschaften der Georg-August-Universität Göttingen,.

Lichtenberg, E. 1989. “Land quality, irrigation development, and cropping patterns in the northern High Plains,” *American Journal of Agricultural Economics* 71: 187-201.

Lilly, J.P. 1998. “North Carolina Agricultural History,” North Carolina Department of Agricultural and Consumer Services, http://www.ncagr.com/stats/history/history.htm, retrieved February 2003.

North Carolina Division of Parks & Recreation, Resource Management Program, http://www.ncsparks.net.

North Carolina Corporate Geographic Database Data Layers. http://cgia.cgia.state.nc.us/cgdb/catalog.html

Orr, D.M. Jr. And A.W. Stuart (eds.). 2000. *The North Carolina Atlas: Portrait for a New Century.* Chapel Hill: The University of North Carolina Press.

Plantinga, A.J., T. Mauldin, and D.J. Miller. 1999. “An Econometric Analysis of the Costs of Sequestering Carbon in Forests,” *American Journal of Agricultural Economics* 81: 812-824.

Powell, D.S., J.L. Taulkner, D.R. Darr, Z. Zhu, D. MacCleery. 1992. "Forest Resources of the United States," USDA Forest Service, Gen. Technical Report RM-234.

Prestemon, J.P. and R.C. Abt. 2002. “Chapter 13: Timber Products Supply and Demand,” *The Southern Forest Resource Assessment*. USDA Forest Service.

Prestemon, J., J. Pye, D. Butry, and D. Stratton. Economic Research Unit, USDA Forest Service. “Locations of Southern Wood Chip Mills for 2000,” http://www.srs.fs.usda.gov/econ/data/mills/chip2000.htm, retrieved April 2003.

Saloner, G. and A. Shepard. 1995. “Adoption of Technologies with Network Effects: An Empirical Examination of the Adoption of Automated Teller Machines,” *Rand Journal of Economics* 26(3): 479-501.

Schaberg, R., F.W. Cubbage, and D.D. Richter. 2000. "Trends in North Carolina Timber Product Outputs, and the Prevalence of Wood Chip Mills," paper prepared for the study on: Economic and Ecological Impacts Associated with Wood Chip Production in North Carolina.

Shi, Yue Jin, T. T. Phipps and D. Colyer. 1997. "Agricultural Land Values under Urbanizing Influences," *Land Economics* 73(1): 90-100.

Sierra Club. 1998. "1998 Sierra Club Sprawl Report: 30 Most Sprawl-Threatened Cities," http://www.sierraclub.org/sprawl/report98/raleigh.asp, retrieved January 2003.

Stavins, R.N. and A.B. Jaffe. 1990. "Unintended Impacts of Public Investments on Private Decisions: The Depletion of Forested Wetlands," *American Economic Review* 80: 337-352.

Stear, T.E. 1973. "Population Distribution," in: *North Carolina's Changing Population* University of North Carolina, Carolina Population Center.

Thiel, H. 1967. *Economics and Information Theory*. North-Holland: Amsterdam.

Turner, M.G., D.N. Wear and R.O. Flamm. 1996. "Land Ownership and Land-Cover Change in the Southern Appalachian Highlands and the Olympic Peninsula," *Ecological Applications* 6(4): 1150-1172.

U.S. Census of Agriculture. 1997.

USDA National Resources Conservation Service. Land Capability Classes, http://soils.usda.gov/soil_survey/main.htm, retrieved January 2003.

U.S. Department of Commerce, Bureau of the Census, County and City Data Books 1982, 1987, 1992, 1994, 2000.

USGS. EROS Data Center. National Land Cover Data 1992, http://edc.usgs.gov/products/landcover/nlcd.html, retrieved January 2003.

Vance, C. and J. Geoghegan. 2002. "Temporal and spatial modelling of tropical deforestation: A survival analysis linking satellite and household survey data," *Agricultural Economics* 27: 317-332.

Wear, D.N. and P. Bolstad. 1998. "Land-use Changes in Southern Appalachian Landscapes: Spatial Analysis and Forecast Evaluation," *Ecosystems* 1: 575-594.

Wear, D.N. and J.G. Greis. 2002. *The Southern Forest Resource Assessment Summary Report*. USDA Forest Service Southern Research Station.

[1] Irwin and Bockstael focus on which open-space tracts will be subdivided. In the sense that these tracts can be of any size over five acres, their model does not predict the magnitude of conversion.
[2] If non-decreasing rents over time seems a doubtful assumption, a weaker one can be employed to an equivalent effect, namely that the change in the present value of a one-time return (selling, rather than renting, the pixel) may be employed to similar effect, i.e., $\sum_{t=\tau}^{\infty} D_{it}\delta^{t-\tau} - \delta\left(\sum_{t=\tau+1}^{\infty} D_{it}\delta^{t-\tau+1}\right) \geq 0 \forall \tau \geq T$.
[3] Note, too, that this formulation ensures that the change in returns due to conversion exceeds total costs. This is evident if we simplify Equation (3) and examine the extreme case in which both C and net returns are constant from time T. Equation (3) becomes $(D-A)_{it} / 1-\delta \geq C_{it}$, illustrating how discounted net returns must exceed conversion costs.
[4] Our focus exclusively on residential development is based on the assumption the majority of transitions to industrial or commercial uses occur on already developed lands rather than on the undeveloped tracts that comprise our data.
[5] In actuality, the vectors X and V may overlap in terms of the metrics they include.
[6] While we have assumed homogenous preferences for this exposition, an analogous result is attained when preferences vary within a region due to, say, the income distribution.
[7] It bears pointing out that the hazard rate itself is not a probability, but rather a measurement of the number of events per unit interval of time, where an event is defined as some discrete transition across states.
[8] Truncation and censoring are pervasive features of duration data, resulting respectively from the data selection process inherent in the study design or from observation-specific random features that make observations on survival time incomplete (Hosmer and Lemeshow, 1999).
[9] The images are taken from the northern half of path 16, row 36 and the southern half of path 16, row 35 of the Landsat satellite orbit. Data for the years 1976 and 1980 were derived from the MSS imaging system, while the TM imaging system was the data source for the years 1986, 1993, and 2001. Because TM and MSS data have different spatial resolutions – 58 X 79 meters for MSS and 30 X 30 meters for TM – the data was spatially degraded to a 60 X 60 meter resolution for consistency.
[10] Impervious surface includes paved surfaces, structures, and medium to high-density residential areas.
[11] We also experimented with samples having 2.4 km separation between the pixels (n=15,623) and obtained similar model results with respect to the statistical significance and magnitude of the coefficient estimates.
[12] Another problem that models such as ours face is that of endogeneity bias: since it works in both directions, the influence on a pixel's land cover of adjacent pixels' land covers leads to association among the error terms. We circumvent this problem in two ways: through our modeling of the hazard of conversion to an impervious surface, rather than simply the likelihood a pixel covered by impervious surfaces, and through judicious use of systematic sampling.
[13] Frohn (1998) suggests that unlike conventional measures of fragmentation, his metric allows comparisons of landscape fragmentation across images having different spatial resolutions, raster orientations, and numbers of land cover classes.
[14] The metric does not assume only integer values because of the GIS algorithm used to calculate it.
[15] Dis_road is based primarily on the road network available from ESRI, but was modified using image interpretation of Landsat data to reflect the conditions existing at the beginning of each interval.
[16] The distance to the nearest chipmill was obtained by overlaying a GIS layer of woodchip mill locations and their establishment dates that is available from Prestemon, Pye, Butry, and Stratton (2003) of the Economic Research Unit of the USDA's Forest Service. To limit the effect of this variable on forested pixels, we interact it with the forest dummy.
[17] The measures of elevation, slope and the forest dummy were derived directly from the satellite imagery. Soil quality data was taken from the Land Capability Classes of the USDA Soil Conservation Service, which indicates the soil's suitability for agriculture. The wetland category was derived from the 1992 land use and land cover data from the EROS Data Center of the USGS. Data on the location of public lands were derived from the above referenced shapefiles produced by ESRI and the North Carolina Department

of Parks and Recreation. The hazardous waste site data was obtained from the North Carolina Corporate Geographic Database Data Layers.

[18] As Irwin and Bockstael point out (and Geoghegan, Waigner and Bockstael confirm empirically), the direction of landscape pattern effects may vary over different window sizes, a possibility that data constraints precluded us from pursuing.

[19] These concerns prompted Governor Hunt to commission a study by Schaberg, Cubbage and Richter. (2000) on the ecological and economic impacts of the mills. Although the report found that the mills increase the incentive to clear cut and raised the possibility of increased forest fragmentation and truck traffic in areas around the mills, it stated that the mills are not expected to significantly shorten timber rotations barring changes in the historical structure of timber product prices (p. v).

[20] A possible explanation for this discrepancy is that our results suffer from positive biases imparted by omitted variables. As Irwin and Bockstael note, such biases may emerge from positive spatial autocorrelation among unobserved factors such as topography, school quality, and tax policy. Indeed, they assert that because the net effect of this bias is positive, the estimated effect of their impervious surface measures, which they refer to as the *interaction effects*, will bind the true effect from above. They use this reasoning as an identification strategy, arguing that if "the estimated effect is negative, then it must hold that the 'true' interaction effect is negative for at least some range of the sample and over some interval of time (p. 43)."

One weakness with this reasoning is that it rests entirely upon positive spatial autocorrelation among unobserved factors, which is argued to necessarily impart an upward bias on variables that are included in the model. There is no justification for this expectation, even on net. The direction of the bias from an omitted variable, x, will be largely determined by two factors, the sign of its correlation with the included variable, and the sign of the coefficient estimate of x upon including it in the model. The direction of the overall bias will depend on the combined influence of all relevant variables omitted from the model. In fact, several of the omitted variables that Irwin and Bockstael themselves cite as important (p. 42-43) may very well impart a bias opposite to the direction required for their identification strategy to be valid. Hazardous waste sites are an example: It is plausible, and confirmed in the present study, that the correlation between the incidence of hazardous waste sites and the percent of impervious surface is positive, while the effect of hazardous waste sites on the likelihood of conversion for residential development is negative. It can be readily demonstrated empirically that the bias imparted on the interaction term from omitting the hazardous waste site is negative, thereby undermining the identification strategy that motivates their approach. We thus do not share Irwin and Bockstael's confidence that a negative effect on the interaction terms ensures that the true effect is negative over some range. Omitted variables could impart either a negative or positive bias, and it is not possible to identify *a priori* the overall direction of this bias with any certitude.

Discussant Comments on Presentations in "Conservation and Urban Growth."

Sabrina Lovell, PhD. US EPA, National Center for Environmental Economics.
October 27, 2004.

Good afternoon. First, I'd like to say thank you to our three presenters for attending today's workshop and sharing the results of their research with us. My goal today is to discuss the policy relevance of the three presentations in this session and the general importance of research on land use and habitat conservation.

The research by Iovanna and Vance focuses on the factors influencing transition from rural to urban uses, by developing a model that identifies the likelihood of conversion from forest and agricultural lands to developed uses. According to the Census Bureau, urban areas in the US more than doubled from 1960 to 1990, and grew at about 1 million acres per year during that time. Although developed land only accounts for about 3% of all US land area, and therefore, is still a small proportion of our land base, the patterns and rates of urban growth can have negative consequences (Heimlich and Anderson, 2001). These include disruption of ecological processes, loss of habitat, higher costs of community services, and a loss of rural amenities such as open space and scenic beauty. As a result of these potential negative impacts, it is important that society understands the factors leading to urbanization and particularly their interactions. The research by Iovanna and Vance specifically accounts for landscape pattern and changes in that pattern over time and space, and gives us a better understanding of how interactions in these patterns can influence the amount and location of development. Their model uses data over 2.5 decades and thereby accounts for long-term changes in land use. This is important because land use transitions are often slow and cumulative. As a result of these subtle changes, the real underlying patterns of change are often not apparent when looking at only one or a few years of data as are used in other land use research papers. I found their use of satellite pixel, rather than parcel level data, to provide an alternative way to analyze land use when parcel level data is unavailable. However, I wonder whether or not satellite data at the pixel level is really a viable and cost-effective alternative for most researchers. If not, I would like to pose the question whether or not the model could be adjusted to use datasets of land cover and land use that are at a larger scale than either the pixel or parcel level. I would also suggest that they include more discussion about the pros and cons of parcel versus pixel level data.

In terms of the policy relevance of this type of conversion model, the results could be used to simulate future development patterns based on different policy scenarios, such as building of new roads, and then the results could be linked to other environmental modeling efforts. The first example that comes to mind is the impacts of different land use patterns on air emissions. EPA has put out guidance on how States can use land use strategies and development decisions to help meet their air quality planning requirements, and how to account for air quality impacts of such decisions and strategies. A model such as the one developed by Iovanna and Vance could be used to predict different development patterns and then based on such patterns, air emissions models could generate potential air quality impacts.

Another way in which I see this type of model providing a contribution is to an Alternative Futures Analysis (AFA). AFA is an environmental assessment approach that provides a suite of alternative scenarios for the future land use in an area, as developed by multiple concerned stakeholders. These scenarios are expressed as maps of future land use patterns in an area, and then the potential effects of alternative scenarios on such things as wildlife populations, water supply and quality, open space, and agriculture are assessed. It provides communities with a clear picture of the consequences of many different potential development decisions. EPA has sponsored a few such exercises, including one in the Willamette River watershed in Oregon. Typically, however, these analyses use very simplistic and deterministic economic factors to predict future growth if any are used at all. The relevance of the hazard model developed by Iovanna and Vance is that it accounts for multiple factors driving conversion to urban uses, in a more rigorous economic framework. Such a model would be better able to capture the complexity associated with actual urbanization and could improve AFA modeling.

Whereas the Iovanna and Vance research looks at the factors influencing conversion to developed uses, the research by Albers and Ando looks instead at the issue of land preservation. Land preservation is an important public issue as evidenced by the fact that 76 % of 801 non-federal ballot measures to protect land have passed in the last 6 years and generated $24 billion in funds (Land Trust Alliance, 2004). The research presented today seeks to understand the nature of interactions between private land trusts and government agencies and the impacts on the environment based on different levels of cooperation. In their paper, they model the government's conservation actions as exogenous to the land trust. However, it is often the case that the government works together with a land trust to preserve an area, rather than each acting independently as in the current model. For example, the former Mt Tom Ski area in western Massachusetts was preserved in 2002 by a partnership between a land trust, two government agencies, and another charity (Land Trust Alliance, 2004). One suggestion I have for expansion of the model is to explicitly account for this potential scenario and to compare the results with those where the government acts independently. Another suggestion is to explicitly incorporate the actions and responses of developers into their model. The actions of developers influence what land is in the most danger of being converted, and is often one of the criteria land trusts use for choosing which parcels to protect. Finally, I think the authors should consider how both the pattern and amount of land available for protection is affected when land owners donate lands. In this case, the land trust is not choosing which lands to purchase, as in their model, but only whether or not to accept the donation.

Like the other two papers in this session, there is a spatial dimension to the model that provides for a more realistic analysis. In particular, I liked the way the authors incorporated the idea that benefits depend on the spatial pattern of all lands protected and that benefits may not be a linear function of amount conserved. This acknowledgement of the ecological implications and interconnections of different preserved areas is increasing in policy work related to habitat preservation, and I'm glad to see it accounted for in this model. One of the potential policy applications I can see arising out of this research is that the model could be used for analyzing the benefits of preserving a network of avian reserves. Cooperation among states, and between the US, Canada, and Central and South American countries for setting aside migratory bird habitat would be an excellent application of this type of model.

The paper by Bauer et al. on different potential patterns of vernal pool preservation relative to residential development provides an excellent example of an integrated ecological-economic model. As we heard yesterday, EPA's Ecological Benefits Assessment Strategic Plan (EBASP) calls for more research that integrates the two disciplines. I also found the particular application used here to have significant policy relevance in that it focused on amphibians. Across the globe, amphibians are experiencing a precipitous decline. In the United States, there are 292 species, 21 of which are endangered or threatened (USFWS, 2004). Responding to this concern, the federal government has a new national program to research and monitor the state of amphibians, and devotes $4 million a year to identify threats to amphibians nationwide. Habitat destruction poses one of the biggest challenges for their conservation, and research such as that presented here can help us understand how best to address that challenge. In addition, while in discussions to develop EPA's EBASP, amphibians where often overlooked when it came to both ecological risk assessment and economic valuation and this study provides a first step to correcting that gap.

The importance of accounting for species dispersal and connectivity of habitat for species preservation as discussed in this paper is a good example of the point made in the Albers and Ando paper that benefits of preservation depend on the pattern and total amount of land preserved. The use of different types of habitat by amphibians, here wetlands and upland areas, is just one example of the importance of preserving a variety habitats for different life-stages or activities of wildlife. Another application of this model could be for preservation of habitat for songbirds that often use different habitats for feeding, nesting, and migrating. Habitat fragmentation, particularly for birds dependent on forest for their primary habitat, is thought to be a big reason for the declines we are now seeing in many songbird species. One question that arises in transferring this type of model to another species, is the data requirements - how detailed does the information have to be to widely apply a model such as this to different areas or species?

The three presentations we just heard offer different but complementary approaches to understanding the complex issues involved with land use and land conservation. Land use patterns and development from rural to urban uses are indeed complex and the impacts of land use decisions have wide spread and important consequences for both people and the environment. The research just presented describing the factors influencing land use change, the impact of interactions between different conservation organizations on conservation outcomes, and the potential impacts on ecological resources of different patterns of development, is therefore critical to helping understand the complex tradeoffs between the many alternative land use choices.

References:

Heimlich, R.E. and W.D. Anderson. Development at the Urban Fringe and Beyond. US Department of Agriculture. Agricultural Economic Report Number 803. June 2001.

Land Trust Alliance. http://www.lta.org

US Fish and Wildlife Service. http://endangered.fws.gov/wildlife.html#Species

Discussant Comments: "Conservation and Urban Growth: Finding the Balance"

Andrew J. Plantinga
Associate Professor
Department of Agricultural and Resource Economics
Oregon State University
Corvallis, OR 97331
plantinga@oregonstate.edu

The first two papers, by Bauer et al. and Albers and Ando, explicitly consider the designation of land for conservation uses. The Bauer et al. paper focuses on designating habitat for amphibians and places particular emphasis on modeling ecological relationships. In this paper, the decision-maker is a social planner. In contrast, Albers and Ando consider the provision of conservation land by the private sector. The paper focuses on modeling the strategic behavior of land trusts and exploring their interaction with a government conservation agency. The last paper, by Iovanna and Vance, presents an econometric analysis of private land development decisions. The focus of the paper is on estimation with high resolution spatial data and measuring the effects of spatial measures of development patterns on land conversion decisions. To some degree, all of the papers present preliminary work. Therefore, my comments will focus on the methodologies employed, rather than on specific results.

The paper by Bauer et al. has two parts. The first presents a land allocation model constrained to protect amphibian populations from adverse effects of development. The second is concerned with identifying a reserve network to minimize the probability of extinction subject to a budget constraint on the total foregone value of developed land. This research has several strengths. It integrates ecological and economic modeling in logical ways. The ecology component is a finite-patch metapopulation model, which accounts for the spatial arrangement of patches. This seems to be an appropriate framework to study amphibians. Finally, the authors draw on data from an actual landscape to develop the simulation and optimization models.

In the first part of the paper, the ecological model includes land development as a barrier to dispersal between any two patches. The more development that occurs between two patches, the smaller is the contribution of those patches to the long-term persistence of the species. A refinement of the model could allow for different types of development. More intensive developed uses, such as roads, are likely to be a greater barrier to dispersal than less intensive development, such as low-density residential housing. This may allow the authors to consider a larger, and more realistic, set of policies. Rather than only evaluating preservation policies, they may be able to consider policies that allow only certain types of development. Zoning policies that restrict intensive development, but allow residential housing, for example, may be relevant alternatives.

Another refinement should address an inconsistency between the initial landscape used in the simulations and the method by which land values are measured. Data on land values and lot sizes are assembled from local tax assessments. A simple regression model is estimated and used to derive the per-acre value of land for use in the simulations. These data on land values are conditioned on the current landscape, reflecting such factors as the existing road network. However, in the simulations, the initial landscape is assumed to be completely undeveloped. The first step in addressing this inconsistency might be to re-estimate the land value model with distance to roads as a regressor and to include the current road network in the initial landscape. This should help to make the cost estimates presented in the results section more meaningful. However, it raises other challenges, such as needing to account for the barriers to dispersal posed by the existing road network.

The authors compare the costs of current policies to a reference case corresponding to the optimal solution. The current policies are representative of existing policy approaches. The reference case assumes that the planner operates free of transactions or information costs. For a given metapopulation size, Figure 3 shows the divergence between the costs of the current policies and the reference case. Future work might investigate the costs of implementing each of these policies, accounting for transactions, measurement, and monitoring costs. This would permit an evaluation of whether the optimal solution is truly the least-cost approach. Because implementation costs are likely to be highest with the reference case, current policies may be more efficient. Plantinga and Ahn (2002) and Antle et al. (2003) analyze implementation costs for land-use and carbon sequestration policies.

In the second part of the paper, the authors evaluate three methods for conserving habitat for amphibians: conserving ponds, conserving corridors between ponds, and conserving both ponds and corridors. The authors should clarify what the conservation of corridors between ponds entails. First, if the land between ponds is already developed, then in many cases it will be infeasible to acquire and restore the land for use as habitat. Consider the cases of land currently used for roads or residential housing. Second, if the land is not developed, then why is conservation necessary? Might the land remain in the undeveloped state? If so, should the opportunity costs of conservation be zero?

The paper by Albers and Ando presents theoretical and empirical analyses of private land trust decisions. This paper addresses the interesting and policy-relevant issue of coordination between private conservation groups and public sector conservation agencies. The theoretical model involves two land trusts (one of which could be the government) deciding which parcels to conserve. The set-up is seven parcels arranged in a line, land trusts with inter-related benefit functions, spatial externalities (negative or positive) between adjacent parcels, and competition for parcels in the manner of Cournot duopolists or a Stackleberg leader and follower. The decision by the authors to specify a discrete state space (land parcels) means that only numerical solutions can be found. In my view, it would be preferable to specify a simpler model with a continuous state space that permits analytical solutions.[1] The structure of the land trust model has analogues in the industrial organization literature. For example, product differentiation models involve Cournot competition over where firms locate in product space. This competition gives rise to location externalities similar to the spatial externality in the present model. Other relevant models include those concerned with network externalities and product space location. One technical point is that early models in the industrial organization literature represented locations along a line, but it was found that the existence of equilibria is influenced by the endpoints. Circle models (e.g., Salop, 1979) were developed to avoid this problem.

The structure of the theoretical model requires that land trusts conserve parcels in the same geographic area. An empirically-relevant alternative is for land trusts to operate independently. According to the Land Trust Alliance, local and regional land trusts conserve 6.2 million acres of land in the U.S., which represents less than 0.5% of the U.S. private rural land base. The authors might define their benchmark case as one in which the land trusts do not compete. This raises the issue of how to specify the benefit functions when land trusts operate independently. If the benefits from conservation are pure public goods, then the functions might still be inter-related, though the spatial externalities would not be present.

In the theoretical model, land prices are assumed to be exogenous, suggesting that land is competitively supplied. However, if a set of parcels provides unique conservation values, then landowners may be in a position to extract the rents that, in the current formulation of the model,

[1] If simulations are used, my view is that the results would be more interesting and relevant if the authors use an actual landscape, as in the Bauer et al. paper, or at least a more realistic landscape.

accrue to the land trusts. That is, one can envision agents having market power on the supply side of the market, as well as on the demand side.

The second part of the Albers and Ando paper presents empirical models of land trust acquisition in Massachusetts and Illinois. The dependent variable is the number of privately protected acres in a township and regressors include the area of protected land in neighboring townships, the area of publicly protected land, and sociodemographic and physiographic characteristics of townships. Because townships differ in size, the variables measured in acre units should be expressed as shares (i.e., normalized on total township area). A more fundamental issue is whether the dependent variable should be defined in terms of townships. If the purpose of the empirical exercise is to test the implications of the theoretical model, in which the decision-making unit is the land trust, then ideally the dependent variable would be defined in the same way. This point is obviously moot if there is a one-to-one correspondence between townships and land trusts. If this is not the case,[2] there may be problems with interpreting the results. The authors find that that the acres of privately protected land in neighboring townships have a positive effect on the dependent variable. This is not necessarily evidence that land trusts are coordinating their activities. Township boundaries may simply cut across the holdings of a single land trust.

This result that land trust acres are affected by neighboring land trust acres has another plausible interpretation. Presumably, land trusts will want to preserve lands that have not been developed for urban uses or, in some cases, agricultural uses. We might then ask: why have these lands remained undeveloped? One answer is that these lands were never profitable to develop. Characteristics of such lands include inaccessibility or topography that limit the

[2] The Nature Conservancy, which is an international land trust, protects 76,000 and 22,000 acres of land in Illinois and Massachusetts, respectively.

productivity of the land for agriculture. Lands with these characteristics are often clustered spatially. For example, lands unproductive for agriculture are often found in upland or unglaciated areas. The spatial pattern of federal lands in the western U.S. corresponds strongly to the distribution of unproductive lands.

A final point relates to the exogeneity of certain regressors. It is not difficult to imagine that population, the number of endangered species, and the cost of land could be endogenous to the amount of privately protected land. The authors should consider testing for the exogeneity of these variables (e.g., Hausman 1978).

The paper by Iovanna and Vance begins with a theoretical model of private land-use decisions that informs the development of an empirical model of land development. My general comment on the theoretical model is that it should be worked out in full so that all of the derivations and assumptions are transparent. Currently, the model is a mix of equations, graphs, and verbal arguments. A main purpose of the theoretical model is to justify replacing development rents, which the authors do not observe at the pixel level, with site-specific characteristics. The authors invoke an equilibrium argument: in a spatial market equilibrium, prices for developed land will have adjusted so that individuals are indifferent to the available set of residential lots. Because in equilibrium the demand for lots equals the supply of lots, the equilibrium price for developed land can be expressed as a reduced-form function of exogenous demand- and supply-side factors, which include site-specific attributes.

This spatial equilibrium framework underlies hedonic property value studies and urban spatial models. Consider, for example, the closed-city model of Capozza and Helsley (1989). The equilibrium price of developed land is given by equation 17. As shown, it depends on exogenous model parameters, the distance of a particular parcel to the CBD, *z*, and the location of the city boundary relative to the central business district (CBD), $\bar{z}(t)$.[3] Thus, the equilibrium price depends on a single site-specific attribute, z, and on time. The dependence on time comes through the exogenous population level, $N(t)$, which affects the position of the city boundary according to equation 11. If the population level is constant, then the boundary is fixed and the city does not grow. If the population level increases, then the city grows as development rents at the boundary of the city rise above the exogenous agricultural rent (equation 14 and section IV). Two points deserve emphasis. First, if population is constant, the equilibrium price of developed land varies spatially according to a single site-specific attribute (location), and is constant over time. Second, in order for land development to occur in equilibrium, there must be a change in an exogenous factor such as population.

Iovanna and Vance also model equilibrium land development. The question raised by the foregoing discussion is: what exogenous factors are changing that result in land development? Many of the variables in the empirical model are constant over time. Variables that are not constant may not change enough to explain a large portion of the development (e.g., agricultural returns, chipmill distance) or are not exogenous from a regional perspective (i.e., spatial variables that are a function of development within the region). The authors should work to reconcile the empirical model with an equilibrium model of land development. One approach would be to specify the empirical model in terms of changes in site-specific attributes, rather than start-of-period levels.

The authors estimate their model with high-resolution (60 meter) pixel data. Modeling land-use decisions with these data poses a number of challenges, not least of which is managing such as a large amount of information. The authors are to be commended for going beyond

[3] Note that future increases in development rents (the last term in equation 17) are a function of the city boundary location, $\bar{z}(t)$, by equation 13.

descriptive analysis and taking on the difficult task of estimation. In this regard, the chief advantage of these data—relative to plot data or aggregate data—is that it allows spatial processes to be modelled explicitly. The authors include three spatial metrics to explain land development: two measure the density of development around each pixel (inner_imperv, outer_imperv) and one measures the fragmentation of development (contagion).

The results indicate that the spatial metrics are important determinants of development. However, it is difficult to know how to interpret their effects. First, all impervious surfaces are classified as developed land. As such, the data does not distinguish between development for residential housing and development for commercial or industrial uses. One can imagine that residential development decisions are affected by development patterns, but why would it affect other types of development? Even if most development is for residential uses, the same value of a spatial metric could indicate very different types of development. For example, fragmented development could correspond to an appealing wealthy neighborhood with low housing densities, or to unappealing low-density commercial development. Second, the development density measures may just be picking up effects of omitted variables. Many factors that explain past development decisions are likely to explain current development decisions. For example, the extent of the transportation network (e.g., road density, not just the distance to the nearest road) is likely to matter. Because no road density variable is included, its influence may be coming through the development density variable. Third, and related to the second point, the density measures cause identification problems for variables that do not change over time. For example, suppose the elevation of a pixel is the same (or similar to) the elevation of surrounding pixels included in the density metrics. Then, the effect of elevation is not identified because it affects past and current development.[4]

For modeling land-use decisions, plot and aggregate data have several advantages relative to pixel data. At the current time, these data provide much broader coverage. For example, the National Resources Inventory (NRI) contains 1 million plots spread across the continental U.S. Because these data are collected through on-the-ground inventories, the NRI provides a wealth of plot information (e.g., detailed land use, land quality). The broader geographic coverage is advantageous because it allows the modeler to take advantage of spatial variation in economic variables. For example, economic returns to forestry vary spatially because climatic differences affect which tree species are dominant. One of the important uses of land-use models is for policy analysis. Particularly for economists, it is valuable to include economic policy levers like net returns in the model so that market-based incentives can be analyzed (see, for example, Plantinga and Ahn 2002).

References

Antle, J., S. Capalbo, S. Mooney, E. Elliott, and K. Paustian. 2003. Spatial Heterogeneity, Contract Design, and the Efficiency of Carbon Sequestration Policies for Agriculture. *Journal of Environmental Economics and Management* 46(2):231-50.

Capozza, D.R., and R.W. Helsley. 1989. The Fundamentals of Land Prices and Urban Growth. *Journal of Urban Economics* 26:295-306.

Hausman, J.A. 1978. Specificiation Tests in Econometrics. *Econometrica* 46:1251-72.

Plantinga, A.J., and S. Ahn. 2002. Efficient Policies for Environmental Protection: An Econometric Analysis of Incentives for Land Conversion and Retention. *Journal of Agricultural and Resource Economics* 27(1):128-45.

[4] Consider what happens to the elevation variable as we move from Model I to Model II. Its coefficient changes from being highly significant to being highly insignificant.

Salop, S.C. 1979. Monopolistic Competition with Outside Goods. *The Bell Journal of Economics* 10:141-56.

Summary of the Q&A Discussion Following Session V

Nancy Bockstael (University of Maryland)
Directing her comment to Rich Iovanna, Dr. Bockstael asked for clarification as to how he measured his dependent variable.

Richard Iovanna (U.S. EPA, NCEE)
Mr. Iovanna responded, "It's a binary variable that's "1" if over an interval of time, say 1976 to1980, a pixel went from being . . . primarily agricultural uses to an impervious surface."

Nancy Bockstael
Dr. Bockstael questioned Mr. Iovanna further, asking if the variable was related to "some percentage of impervious surface" or whether there was just "one measure per pixel—and that's either impervious or not."

Richard Iovanna
Mr. Iovanna answered, "It's the latter. At this level of resolution, it's quite a research challenge to go beyond whether or not that's clearly classified as one or the other."

Nancy Bockstael
Dr. Bockstael continued with "just a few comments, and you'll probably be able to resolve these, but my experience dealing with parcel-level data and struggling with it leads me to ask. First of all, I think that the size of development is considerably larger than one of your pixels, if I'm doing my multiplication and division right, at least in Maryland. Since there are economies of scale in development, it seems to me that you *always* have difficulties if you don't have observations at the *decision* level. What *looks* like a surrounding land use effect may *really* be just the effect of the same decision because the decision is overlapping your unit of observation—so that the pixel next door is getting developed either concurrently or in the next wave of development. So, I'm always reluctant to interpret the neighboring land use having an effect on the current pixel if it's based on pixel-level rather than parcel-level data."

She continued by questioning the resolution capability of the LANDSAT data that remote sensing experts use, stating, "We actually had a project with NASA to try to figure out whether the remote sensing people could pick up low-density residential use—lots that are 2 acres or more. Something like 80 or 90 percent of the land that's been developed in the last 10 years has been 2-acre or larger lots. They *can't* do it. . . . and we had very accurate data on certain places in Maryland about *exactly* what's going on. We even matched it out against the actual houses from tax maps, and they basically gave up on that part of the project. So, despite what remote sensing people will *say* about some of the LANDSAT data, I would ask them whether or not they're *sure* that they're picking up low-density residential, which is such an important part of development these days. Also, I would question whether you could go back in time and get anything like that very accurately, because the accuracy of LANDSAT data has been increasing over the last 25 years. I wonder, also, whether there are situations in which you might actually be "picking up" the *resolution* of stuff that happened a long time ago, but you're just seeing it now because of the changing technology in LANDSAT data."

Dr. Bockstael concluded by adding "One other thing: You mentioned that you sort of assume this relationship between size of the parcel and value. However, if you introduce regulations like minimum lot size, which is a *common* zoning regulation in Maryland . . . Trying to keep developers from developing, we make the minimum lot size larger and larger, and if you do that, then it introduces distortion into that relationship. Since I haven't seen the data, I'm not absolutely certain how you would introduce the typical land-use regulations into your model. Over the 25 years, I don't see anything [in your model] that would reflect any *changes* in land-use regulations over that time, and I would expect that there *would* have been. So, if there's no place in which to pull strings on regulation, you may not be able to answer the policy questions that you'd like."

Richard Iovanna
Mr. Iovanna responded by saying, "With regard to your last question, I think you're absolutely right—at this stage of the game, we intended to pick up a lot of those influences simply with the fixed effects, and we are planning to revisit that issue as soon as we can find the data. What I find particularly interesting is the impact of minimum lot size and how that could be, if possible, incorporated into our model, which is right now at a pretty high level of abstraction."

He continued, "With regard to the low-density residential, you're absolutely right—that's been an issue sitting in the back of our minds since we received the data from the contractors, who initially assured us that things could be sliced ten different ways. When we finally received the product, they sheepishly admitted that with low-density residential, given the fact that there are laws and the fact that much of it will be under tree cover, it often looks like forest."

David Martin (Davidson College)
Addressing Heidi Albers and Amy Ando, Dr. Martin said, "With respect to Andrew's (Plantinga) comment about land trusts competing, they also compete with foundation grants. So, it's not just land prices . . . I was on the board of directors of a land trust, and it wasn't always clear to me whether we were better off *cooperating* with another land trust or *competing* for a particular grant—there's that budget constraint issue as well."

Speaking to "both Stephen (Swallow) and Amy (Ando)," Dr. Martin stated, "My other career is as a local elected official, so I'm wondering about your welfare functions for a decision maker. For example, I care about frogs and affordable housing. From my perspective, how do we achieve that balance of getting frogs *and* affordable housing? I guess I'm seeing in your model that if the decision maker likes frogs, this is the best thing to do, but what happens if the decision maker likes more than one thing that affect the conservation? So, if I like affordable housing, I may like to have more houses, higher density, and what not. In your case, Amy, when I buy public land, what kind of uses do I use that land for—do I put in soccer fields or hiking trails? Or do I put soccer fields in the middle and have the edges for the hiking trail and then let the land trust conserve the land right next to the hiking trails? What I'm encouraging is a richer consideration in terms of the decision maker."

Dr. Martin closed with a personal anecdote, saying, "I found it easier to get re-elected because people will have moved to my community because they liked high taxes and open space, and they moved elsewhere if they liked asphalt and low taxes. In the dynamics of this, it was easier for me to support environmentally friendly things."

Stephen Swallow (University of Rhode Island)
Dr. Swallow responded that the issue of affordable housing is "kind of on my radar screen. My understanding is that certainly at state levels, and, I believe at the federal level also, the requirement, so to speak, for affordable housing trumps everything. In fact, in Massachusetts and Rhode Island I've been hearing environmental horror stories . . . where a developer can come in, and if he's having trouble getting a proposal through" for a development involving $250,000 houses, all he has to do is say that he'll do affordable housing and "everything's out the window. There are situations developing, at least in Massachusetts, where those buildings are going next to the wetlands, and they're nicely mosquito-infested" with all the attendant disease possibilities. Dr. Swallow closed by saying, "It's certainly beyond what I'm getting to, but I wanted to take the time to say that I think there's some bad policy there."

Amy Ando (University of Illinois at Urbana-Champaign)
Dr. Ando replied, "Our model doesn't have endogenous budgets. There are some in the literature where fundraising is endogenous and land trusts might differentiate each other in order to facilitate fundraising. So, if we take Andrew's (Plantinga) suggestion of developing an integral model, we might go that route. . . . We certainly do not have a government objective function that is as complicated as the one you just described—government has an arbitrarily chosen objective function. If you model the social planner, the social planner maximizes total net benefits (total benefits minus total costs)—it's pretty simple. I have a feeling that making it more complicated will have to wait until the next round of research."

Stephen Swallow
Dr. Swallow added, "Let me be a little less dismissive: Clearly, in principle, you could add another constraint and deal with that, among some other things like that."

John Tschirhart (University of Wyoming)
Dr. Tschirhart addressed Amy Ando, saying, "You mentioned that there are conditions under which hot spots may not be the best places to preserve—I was wondering what those conditions might be. Also, you've worked in the past on explaining government decisions about endangered species and so forth." With all the elections around the

country, Dr. Tschirhart said he wondered what the characteristics are of the local governments at the county and city level who are deciding on passing taxes in support of environmental/ecological programs.

Addressing Stephen Swallow, Dr. Tschirhart asked, “Who owns these vernal pools, and if they’re preserved would there be public access or are they so small that no one really wants to visit them anyway?” He closed by saying, “Also, I was wondering if you could explain to me why the toads on my property are declining precipitously over the last ten years.”

Amy Ando
Dr. Ando said, “You know, it’s funny—I do a lot of work on political economy and the behavior of government agents and here I am cranking out papers in which our government doesn’t behave in anything like an interesting or realistic manner. . . . Thank you, John, for reminding me of that stuff—it’s certainly something that it would be good to be thinking about more actively as we proceed. Right now we don’t have plans to model government behavior in a more realistic way, but maybe we should.”

Heidi Albers (Oregon State University)
Responding with what she classified as a “quick answer on that hot spot thing,” Dr. Albers said, “We’re just starting to develop that, but one example where the government might *leave* the hot spot unprotected is when the land trust perhaps has a lower marginal value for protection. So, if the government comes in and protects the hot spot, then they [the land trust] might not protect anything, but if the government comes in and protects something else *instead*, then the marginal value of protecting the hot spot is still high enough for them to come in—so you get a larger amount of area, overall, conserved, including the hot spot.”

Stephen Swallow
Dr. Swallow commented, “I think what may not have come through in the presentation is that we’re using the amphibians as an indicator of trying to keep a functioning ecosystem across the landscape. If we can keep the amphibians functioning, then there’s hopefully going to be room for many other species, including birds. What I had in mind with preservation, if you link this with the land trust unit . . . Rhode Island has more municipal land trusts, which are town agencies, than probably any other state in the country despite the fact that we are only slightly larger than Yosemite. If the land trusts are going to own the land, they’re *probably* going to be involved with providing some public access when it can be managed in conjunction with ecological attributes.”

He continued, “I want to point out one thing related to Amy’s talk: The grant application process that many of these land trusts face I think actually *causes* the land trusts to *alter* their objectives. So, a lot of times, you might be picking up the objectives of the funding agency.”

Susan Durden (U.S. Army Corps of Engineers, Institute of Water Resources)

Addressing a brief comment to Amy Ando, Ms. Durden stated, “I’m pretty familiar with townships in Illinois, and I *think* that Massachusetts townships are probably more analogous to counties in Illinois because at the [Illinois] township government level, there’s not a lot of activity other than clearing the snow off of the roads.”

Continuing with a second comment directed at Dr. Ando, Ms. Durden said, “This was bothering me a little bit in some of the papers, and you said something that reminded me of it: When you were talking about the econometric models (and I’m a great fan of using real logic and looking at the outputs and seeing if they make sense), you mentioned that the government investment went up and the private investment in conserving land went up, and just as an aside you said, “well, there were some problems with the econometrics as if the observation didn’t make any sense. I may have misunderstood that, because I certainly didn’t take in the whole paper, but it concerns me that in some cases we may have an idea that this or that would make sense or would not make sense. I would think particularly in Illinois there would be a lot of reasons that might explain what you observed—the younger farmers who are taking over from older farmers might be more inclined to convert lands, or people contributing money could indicate simply that the economy is good. Again, I may not have gotten it right, but I think it’s important to realize that those two could move together rather than necessarily moving in opposite directions.”

Amy Ando
Responding first to the township comment, Dr. Ando said, “Yes, they are *totally* different. We used them because they are a nice size. We wanted a spatial unit of observation that wasn’t too big and that wasn’t too small. In California, we ended up using quadrangles because California doesn’t have townships and their counties are too big. But, you’re absolutely right—they are *not* functionally similar” and we will try hard to emphasize that in Massachusetts the townships merely provided convenient boundaries for our study. Ms. Ando also said that they also benefited from the “wonderful coincidence” that in Massachusetts, voting data are also essentially gathered at the township level.

Dr. Ando presented the following clarification to address the second point that was made: “The comment that I made about a paper that had analyzed potential crowding out having some econometric problems—the particular issue is that they didn’t have spatial data on the locations of private protected areas. All they knew was how much land was protected by different land trusts but not *where*. Since many land trusts operate in multiple counties, these authors were struggling with this econometric difficulty of how to cope with the lack of spatial data in their data set. They have a panel and we don’t, so in that sense their work has an advantage over ours. I actually think that in a year or so, there will be two papers in the literature, ours and theirs, . . . approaching a similar question from very different points of view with very different data, and it will be very interesting.”

Dr. Ando closed by stating, “We’re not making any assumptions about whether public and private protected areas are likely to be positively related or correlated—we’ll let the data tell us what they say.”

Nancy Bockstael
Saying that her comment was actually a follow-up on this last question, Dr. Bockstael stated that “. . . preservation decisions are simple sorts of things, and we’ve been dealing with this as a supply and demand issue, basically. The landowner has to decide his reservation price, so there’s this wide range in this market. Now, if one’s willingness to sell development rights, which is what we’re talking about, is affected at all by how many people around them are also selling development rights, then it seems to me that that side of the model has to be dealt with if you’re going to deduce anything from the results and looking at outcomes. One of the problems with the literature in this area is that we analyze the outcomes, and half the papers analyze the outcomes as though it’s the result of people’s willingness to preserve their land, and the other half analyze the output as though it’s the agency’s decisions as to what to purchase, when in fact it’s the interaction of the two. We have found, at least in the agricultural preservation area, a landowner’s reservation price is definitely affected by how many people around him are willing to preserve—the property preserved is a lot more valuable if other people are preserving, whether it’s agriculture or if it’s for a state kind of effect. If the development happens all around you, you wish you really hadn’t sold at the development price because the value of the property isn’t as high—and I’m saying that in analyzing the output, you’d have to separate that out in order to make deductions about the interactions with the government policy.”

Amy Ando
Dr. Ando replied, “Thank you—that’s a very good observation, and I’m sitting here thinking about scale. The story I was just telling was a story at the landowner level or parcel level, . . . and you would end up with clusters *because* of that just because reservation prices depend on what’s going on around you, so either you end up with everybody selling or nobody. I don’t know whether a similar story translates when your unit of observation is a town—is much larger . . .”

Nancy Bockstael
Dr. Bockstael interrupted, saying, “Well, I’m not sure how big the townships are—if nothing else, it will induce spatial autocorrelation, because anybody around you obviously is affected by people around them—just something to think about.”

Kerry Smith (North Carolina State University)
Dr. Smith commented, “I just want to put in a plug for Andy’s (Plantinga) comment about structural modeling. There’s a fellow by the name of Randy Walsh at Colorado who has been using this in assorted models to look at an interaction between *public*

choices and *private* choices where there may be substitutes and complements. So, you locate government space or you protect areas, and the private undeveloped land may actually become developed in communities as a consequence of those decisions, so it's not just the interaction between land trusts—it's the interaction between the land trusts and other *private* decisions that influences the outcomes. Now, he's [Walsh] been able to solve that in a framework that allows you to look at Nash equilibrium and a variety of other things. Now, you could take that and extend it a little bit, using some of the median voter models from public economics and think about the decision process of local governments or another kind of framework that would describe land trusts' decisions. It would require a structural model for each of the agents participating in the model, in the supposed market, and what it *would* do is give you the ability to look more specifically at *how* those decisions influence prices. There are certainly easier models than the one he's working with—there's stuff in the public economics literature using some of the random utility models that we heard about for recreation yesterday. So, it would be worth looking at."

END OF SESSION V Q&A

Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

PROCEEDINGS OF

SESSION VI: METHODOLOGICAL ADVANCES IN STATED PREFERENCE VALUATION

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

October 26-27, 2004
Wyndham Washington Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Cynthia Morgan and the Project Officer, Ronald Wiley, for their guidance and assistance throughout this project.

DISCLAIMER

These proceedings are being distributed in the interest of increasing public understanding and knowledge of the issues discussed at the workshop and have been prepared independently of the workshop. Although the proceedings have been funded in part by the United States Environmental Protection Agency under Contract No. 68-W-01-055 to Alpha-Gamma Technologies, Inc., the contents of this document may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

TABLE OF CONTENTS

Session VI: Methodological Advances in Stated Preference Valuation

Embedding in the Stated-Preference Methods
By
Michael Hanemann, University of California, Berkeley
Jeff Lazo, National Center for Atmospheric Research

(Summary of Dr. Hanemann's presentation)

Dr. Hanemann began by stating that the reason he and his colleague focused their attention on embedding is that he believes "embedding is one of the most serious issues that remains not satisfactorily resolved in contingent evaluation, and it's a major focus of the critics." He continued, "This research wants to try and come to grips with what is causing embedding, whether these causes operate in market valuation as opposed to non-market valuation, whether they occur in stated preference based on conjoint analysis, and lastly, what can be done to deal with embedding in stated preference generally."

Stating that different terminologies are often used, Dr. Hanemann went on to clarify the meaning of the term "embedding" as he uses it. He stated that embedding involves three elements: (1) insensitivity to scope, so that a larger item is not valued more than a smaller item; (2) sub-additivity, meaning that the value of a set of items is less than the sum of the values of the items individually, and (3) order effects—the order in which an item is valued affects its value. He said that he believes "one can write down utility functions which explain all three effects in terms of diminishing marginal rate of substitution, income effects, and substitution effects."

Referring to a formula with variables representing public goods and income, Dr. Hanemann said he thinks "something like this can represent mental accounting; that is, mental accounting can be expressed as a form of utility function. He continued, "What I want to stress here is that I don't think the economic structure of preferences is all that's going on with embedding, and I want to focus on other features, such as features of the questionnaire and features of the elicitation format, but also, more basically, features of how people think and make judgments about items." Dr. Hanemann explained that the methodology of the research is to replicate some of the existing studies in the literature, using the same sort of setting and the same survey mode while at the same time adding features to the survey which are designed to explore some of the hypotheses that focus on the three items he identified.

Starting off by looking at scope effects, Dr. Hanemann asked, "Why might somebody give you the same willingness to pay for a larger item as for a smaller item?" He suggested five possible explanations: (1) The survey is flawed and doesn't really capture what the person feels. (2) The person doesn't see the larger item as any better than the smaller item. (3) The person feels that if he pays for the smaller item, he actually gets the effect of the larger item anyways, so there's no point in offering more money. (4) The person feels that the larger item isn't feasible, and therefore pointless. (5) The person thinks that the larger item actually only *costs* the same. He stated, "To explore these explanations, one needs to incorporate what are called manipulation checks, that is, questions in the survey or "think-alouds" or verbal protocols to get at what the respondent was thinking of. We focus on monetary valuation and get anomalous results, and we feel that's because of a flawed elicitation of monetary valuation. However, it *may not* be flawed—it may simply be that these other things are going on, but we don't normally look for them. So, the focus of the research and the replication that I'm conducting is to investigate these other explanations. Of 60 or 80 scope studies, there are only 4 or 5 that I've seen that do this. A very nice recent one is coming out shortly in the Journal of Environmental Economics and Management by Heberlein, Bishop, and Schaefer. They express that conventional economists look at economic scope, what they call an affective scope and cognitive scope, and they get at these things by asking a series of questions—this is what I was referring to as manipulation checks. For instance, in a question to evaluate wolves, they ask, "How important are wolves to you, personally? –Not at all important—Somewhat important—Etc." Or: "In valuing a population of 800 wolves versus a population of 300 wolves in northern Wisconsin, how would you rate a population of 800 wolves? –Extremely bad—Somewhat bad—Bad—Neither bad nor good—Etc."

Dr. Hanemann revealed that "what they find when they use these manipulation checks is that they line up with the monetary valuation. When respondents *like* the larger item more, they give it a higher value. Sometimes the respondents like the smaller item more, and then they value that item accordingly compared to the larger item." Providing another example, which he said "is not widely reported in the study that Bill Desvouges, Kevin Boyle, et al. did on birds" Dr. Hanemann said that there was actually a manipulation check in the survey. He stated, "Remember, the focus was on covering waste oil holding ponds on the flyway to protect birds from being killed—2,000 birds—20,000 birds—200,000 birds. The researchers posed the question: Covering waste oil ponds will not significantly affect populations—Strongly agree?—Agree?—Neither agree nor disagree?—Etc. There was the same sentiment. That is, most people felt that this didn't make a big difference. So, it's not surprising to me that they then found no difference in monetary value between those items."

Moving on to the issue of feasibility, Dr. Hanemann cited Baruch Fischoff's paper in which he looked at willingness to pay for pollution cleanup along variable segments of the Susquehanna River. Dr. Hanemann focused on some debriefing questions that were not used in the study's data analysis but that were reported. Fischoff found that in a post-survey phone interview people remembered poorly how many miles of the river were to be cleaned up, but the people who thought there were more miles had a higher willingness to pay. Dr. Hanemann summarized, "In other words, some of the noise in the willingness to pay responses seems to correlate with noise in what the size of the commodity was. Also, a significant fraction of people didn't think that a thousand miles could be cleaned up, and again that appears to have influenced their responses."

Dr. Hanemann went on to note that "most of these studies use the open-ended format—how much are you willing to pay?—and that introduces additional complications because in addition to valuing the item, people don't want to pay more than their fair share and they don't want to pay more than the item costs. In this context, one issue is maybe a larger item will involve more people, and the cost per household for the larger item may not be any greater than the cost per household for the smaller item." He cited some evidence from a phone survey he had done in Ohio regarding river cleanup in which he found that willingness to pay is correlated with cost, and cost doesn't vary with scope. He said, "What we are finding is that things that ought to correlate, rationally, with the willingness to pay also don't vary with scope. So, the focus of this research is to replicate some of the scope studies but to add these questions to see if this holds in some of those studies."

Saying he wanted to relate all of this to the literature on market research, Dr. Hanemann cited "a very interesting series of papers by Chris Hsee at Chicago, who has worked on what he calls joint versus separate evaluation." He said that in implementing the strategy, you first describe a market goods item to someone and then ask, "How much would you pay for this?" Another group of people is asked the same question regarding a different item. A third group is then asked to evaluate the two items together, so you achieve both separate and joint evaluation. Dr. Hanemann said that Hsee's premise is that "assessing an item in isolation is more difficult than assessing two or more items together, and because of this difficulty, people adopt different response or judgment strategies in assessing a single item in separate evaluation than in joint evaluation." He stated that Hsee frames his comparison "in terms of evaluability: When assessing an item in *isolation*, the judgment is influenced more by attributes that are easy to evaluate, even if they are less important than other attributes which are hard to evaluate." However, when people assess two or more items together, it is easier to compare the attributes—one against the other—and more weight is placed on the more important attributes. Through your choice of things, you can therefore switch the ranking of the choice of items.

To illustrate the point, Dr. Hanemann cited one of Hsee's examples concerning the purchase of a music dictionary as a gift for a friend. Given the choice between a dictionary with 20,000 entries that has a torn cover and a dictionary in perfect condition but with only 10,000 entries, he revealed that in isolation people chose the smaller dictionary more often, but when they used joint evaluation people chose the larger dictionary more often and tended to overlook the blemish. Dr. Hanemann said that studies from the environmental literature show the same thing. He went on to reiterate the widely recognized "greater difficulty of doing separate evaluation as opposed to joint evaluation."

Dr. Hanemann said Hsee also points out "the link to another concept in psychological theory called norm theory: when evaluating an item in a separate evaluation, people think about the larger category to which they think the item belongs and then they compare it to the norm for that category. In *joint* evaluation they compare the two items as opposed to comparing each item with the norm from an imagined category." He said he stresses this point because he thinks that "*all* cognition is relative, not absolute, and the norm theory suggests that if I don't give you a standard of comparison but instead just ask you to evaluate a single item, you *invent* a standard of comparison." This ends up being "more noisy" because it's not controlled by the researcher.

"Here are the implications. I see this as essentially the same phenomenon as what some have termed coherent arbitrariness. As I said, cognition is relative to something—to a norm—and that something affects the evaluation. It makes evaluation in isolation noisy, or arbitrary, but I think it's arbitrary within some range." Dr. Hanemann said the important thing, he believes, is that "this applies not just to the monetary evaluation (expressed willingness to pay) but to all dimensions of liking and judgment for an item. So, again, the aim is to test this by replicating some studies. I also think mathematically you would say that separate evaluation involves an element of noise, and then there's less noise or less uncertainty when a second item is considered, and so one could write down some mathematical formalisms."

Dr. Hanemann continued, "This also relates to some recent work by Ian Bateman that was published this year looking at order effects—looking at the evaluation of multiple items and comparing what he calls step-wise versus advanced-disclosure designs." He explained, "With step-wise you get to see one item and you are asked to evaluate that. Then you get to see another item, a subset or something—then you get to see another item—but each time you value an item before knowing what else is coming. With full disclosure, on the other hand, you're shown everything—it's laid out before any of the valuation questions are asked." Dr. Hanemann stated, "What Ian (Bateman) finds is that the order effects appear very regularly with the step-wise design and go away with the advanced disclosure. How does this relate? I think this is like the distinction between separate evaluation and joint evaluation—it's the same type of phenomenon. It's not limited in any way to non-market goods, and it's not a feature of monetary evaluation as opposed to other dimensions of evaluation, and I think it moves things around much more than the economic formalisms of income effects and substitution effects."

"So, what I'm doing is replicating Ian Bateman's work, comparing step-wise with advanced disclosure, but also measuring not just monetary evaluation but other dimensions of liking and valuation for the goods in non-monetary terms and seeing if they have order effects in one treatment and not in the other treatment."

"If there is a difference between separate evaluation, thinking of items in isolation, versus thinking of them together, the question arises: Which is better?" Dr. Hanemann stated that "the NOAA panel argued strongly for separate evaluation for external tests of scope, not internal tests of scope." He added, "One reading of Hsee's work is that the external tests of scope, the separate, are much more noisy. They're rooted less securely. In a sense, they go *against* how human cognition works, and in fact, what happens is a person *invents* something with which to contrast or compare the item being evaluated."

Dr. Hanemann noted that "Hsee says in a recent paper that this also explains the difference that's been observed between predicted utility and experienced utility, because when I ask you to predict your behavior or your choice, that's like a joint evaluation because you imagine several outcomes and you compare them. But what actually happens in life is you choose one of them (or one of them gets chosen) and you experience that—you decide to move to the West Coast, for example—and then three years later you're asked how did you like it. That's more like separate evaluation; you experienced one thing and you didn't experience anything else, and he argues that separate evaluation may be more realistic for assessing actual experienced utility."

Dr. Hanemann continued, "My inclination is to prefer joint evaluation, *but*—this is the point I want to emphasize—it seems to me that joint evaluation is susceptible to the same underlying forces. Now, I just said that in joint evaluation you have contrast, but the contrast is influenced by the particular items that are involved in that contrast. If you had other items the assessment might have come out differently, and there is in fact a large literature in market research on, for example, the number of alternatives, the variety of alternatives, the number of different attributes or dimensions on each alternative, a range of values." He went on to offer this example: "Joel (Huber) and a colleague did a beautiful work on decoy effects in asymmetric dominance. You choose between A and B. Then I add an item C, which is actually *dominated* by A or B but shifts your choice between A or B because it makes one of the items look better. Why? Because you're evaluating attributes of a particular item relative to the range of attributes in the choice set. It's the same sort of cognitive imperatives potentially affecting joint evaluation, and Ian (Bateman) has a CV study showing the presence of decoy effects in multi-item evaluation."

In closing, Dr. Hanemann said, "I want to end with two points. First, one of the criticisms of non-market valuation relative to market valuation is that you tell me you would pay so much for this particular item, but there are other items out there—there are other brands, etc. How much would you pay for the other items and does it add up? A major difference with public goods is there's not a set of other items. If I ask you to value a particular flavor and brand of yogurt, we both know you can walk down the road to the supermarket where there's a whole shelf of other brands of yogurt. If I ask you to value a program to protect frogs in a particular part of Rhode Island—well, it's true that you could have programs to protect other creatures in other parts of New England, but the point is there's no reason to believe that anybody's planning to do anything about other creatures in Massachusetts or any place else—it's not *obvious* that these other public goods are out there. . . . So, one issue is what people think are the other items when you ask them about a public good. With market goods, you know what's in the supermarket—you don't need to ask them."

"I'm anticipating possible conclusions, but I haven't reached them. The surveys that we're doing now are meant to add features which test the speculations I've told you about. If they come out, this might be an assessment of embedding effects—that in some sense, joint evaluation with advanced disclosure is preferred, and that means that order effects can be controlled, and I think the scoping sensitivity gets controlled also and becomes less of an issue. The remaining issue, which is incorrigible, is that in any sort of joint evaluation the results are sensitive to the set of designs, and we need to think of ways of standardizing this or controlling this—we can't escape it, but we could perhaps agree on a protocol for doing this so we bring this effect under control."

"Thank you."

EPA Agreement Number: R830820
Title: Experimental Tests of Provisions Rules in Conjoint Analysis for Environmental Valuation
Investigators: Laura Taylor, Mark Morrison and Kevin Boyle
Institution: Georgia State University

In recent years there has been a movement away from using contingent valuation to estimate non-use values towards using various forms of conjoint analysis. Conjoint analysis is becoming the technique of choice in major government sponsored valuation exercises both in the US and abroad. This movement in part reflects concerns about possible biases associated with contingent valuation that are *assumed* to be less prevalent in conjoint analysis (Hanley, et al 1998).

An important part of the contingent valuation literature was the development of an incentive compatible provision rule that is made explicit to survey respondents (Arrow, et al, 1993). With conjoint analysis applications, however, respondents are simply asked to reveal their preferences through various evaluation tasks. Studies will describe a payment mechanism (such as a tax-price or a user-fee), however the actual rule used to determine which of the options presented in the survey will be the option that is implemented, if any at all (the provision rule) is left unspecified.

This study investigates the impacts of provision rules within conjoint choice questionnaires. Using both private and public goods, we collect conjoint choice data using three different provision rules and ten different treatments. First, we use an incentive-compatible, individual provision rule (IPR) involving real payments and purchase. We then conduct a treatment using an individual provision rule, but with hypothetical payment. Next, we use a group provision rule (GPR) in which the option that receives the greatest support in the survey is the option that is actually provided to every subject, regardless if this was his or her preferred option. This provision rule is *not* incentive compatible, but important to understand as it mimics the likely *inferred* provision rule in past conjoint surveys valuing public goods. Lastly, we conduct treatments where no provision rule (NPR) is described to subjects. This treatment is consistent with all previous conjoint applications for environmental valuation. Because no provision rule is specified, this treatment can not be conducted in an actual-payment scenario --

only hypothetical surveys can be conducted.

The treatments we conduct allow us to (1) examine the differences in choices due to hypothetical versus real-payments (i.e., explore hypothetical bias), an issue that has received considerable attention in the contingent valuation literature, (2) examine the effects of moving away from incentive compatibility toward mechanisms that are more realistic (but not incentive compatible) for conjoint exercises valuing public goods, and (3) examine whether the results from the treatment with no decision rule (NPR) converges on the results from the incentive compatible decision rule (IPR) or the group decision rule (GPR).

Preliminary results, based on nearly 2,000 subjects indicate that provision rules have important effects on the responses to choice surveys. Results indicate that in surveys using private goods, subjects opt to purchase the private good more often when either the non-incentive compatible group-provision rule is described (GPR), or when no provision rule is described (NPR). Results from surveys using a public good as the object of choice indicate a similar pattern. In particular, conditional logit and random parameter logit models indicate that the provision rule treatment affected the marginal values subjects revealed in the surveys. Subjects were significantly less responsive to price in both the GPR and NPR treatments as compared to the IPR treatment.

Lastly, preliminary results comparing the results from the IPR treatment in which payments are hypothetical with the IPR treatment in which subjects actually pay for the good and receive it as a result of their decisions in the choice survey, indicate significant differences in behavior between these two treatments. Interestingly, while it is clear that subjects "opt out" of the market more frequently when actual payments could result from their decisions, there may not be significant differences in the subjects' responsiveness to prices across the two treatments. However, these results are very preliminary in nature at this time.

Internet-Based Stated Choice Experiments in Ecosystem Mitigation: Methods to Control Decision Heuristics and Biases

John P. Hoehn,
Department of Agricultural Economics

Frank Lupi,
Department of Agricultural Economics and
Department of Fisheries and Wildlife

and

Michael D. Kaplowitz,
Department of Community,
Agriculture, Recreation and Resource Studies

Michigan State University
East Lansing, MI 48824

Acknowledgments

The reported research was supported, in part, by the: U.S. Environmental Protection Agency, Science to Achieve Results (STAR) Grant #R827922; the Michigan Sea Grant Program; and the Michigan Great Lakes Protection Fund. All opinions expressed and errors herein are the authors' alone.

November 12, 2004

Abstract

Internet-Based Stated Choice Experiments in Ecosystem Mitigation:
Methods to Control Decision Heuristics and Biases

John P. Hoehn, Frank Lupi, and Michael D. Kaplowitz.
Michigan State University

The research developed internet-based stated choice questionnaires to evaluate wetland ecosystem mitigation and restoration. The goals were to estimate the in-kind values of ecosystem attributes and test hypotheses about the performance of the questionnaires. A key question was whether the ecosystem information and program descriptions were sufficiently detailed to meet the informational needs of respondents, without overwhelming them with too much information. Behavioral research shows that respondents' decisions are inconsistent and biased when confronted with too much information. The research used a multistage design process to reduce the informational and choice complexity perceived by respondents. The final questionnaire presented ecosystem information in a tabular format that enabled respondents to easily identify the choice attributes and to compare attribute levels and qualities across wetland pairs. A text format was developed as a control to determine the degree that the tabular format controlled decision heuristics and biases.

Results indicated that the tabular format was successful in simplifying a complex choice without eliminating relevant information. In-kind values estimated with the tabular data were consistent with intuition and statistically significant. In contrast, text format responses were insensitive to high quality wetlands and highly sensitive to poor quality wetlands, as expected when loss aversion biases are present. Text responses were also more variable than the tabular responses. The results suggest that a systematic questionnaire design process reduces the subjective complexity of ecosystem choices without reducing the objective quality of information.

Internet-Based Stated Choice Experiments in Ecosystem Mitigation:

Methods to Control Decision Heuristics and Biases

Wetland ecosystems are regulated under an array of Federal and state regulations. The goal of many state regulations is similar to the Federal objective of "no net loss" of wetlands (National Research Council 2001). To avoid a net loss of wetland services, Federal and state regulations may require mitigation for activities that impair or destroy wetlands. Mitigation raises the issue of determining what and how much should be done to offset the loss or impairment of a wetland. One way that losses are offset is by restoring wetlands in locations near a destroyed or impaired wetland. The amounts and types of restoration are typically determined on ecological grounds. However, a purely ecological assessment may not adequately address wetland attributes that are valued by human beings. If the latter values are overlooked, a net economic loss may be incurred despite the no-net-loss goal.

Previous research shows that the ecological qualities of wetlands are indeed valued by ordinary citizens (Heimlich et al. 1998; Kosz 1996; Phillips, Haney, and Adamowicz 1993; Stevens, Benin, and Larson 1995). Both use and nonuse values are recognized as important to the economic value of wetlands (Woodward and Wui 2001). Previous research is less clear about the values of specific wetland attributes and qualities, such as wildlife habitat or access for recreation by the public. Reported research tends to focus "on the question of 'what *is* the value' and not enough on *what*, in particular, people value" (Swallow, 1998, p. 17).

Identifying the relevant wetland ecosystem attributes is important for both policy and valuation. Wetlands are complex ecosystems that may be evaluated in different ways. Different technical approaches characterize wetlands using different metrics and different attributes, such as hydrogeomorphic types, wetland functions, wetland processes, and ecological values (National

Research Council 2001). No net loss policies may mistakenly result in real and costly losses when wetland policies ignore economically important attributes, or use metrics that are only partially correlated with attributes that are valued by the general public.

Identifying the subset of economically relevant attributes is also important to the reliability of stated choice experiments. Recent experiments show that choice complexity reduces the consistency of stated choices, and increases the variance of stated choice results (Breffle and Rowe 2002; DeShazo and Fermo 2002; Swait and Adamowicz 2001). Including irrelevant attributes and ill-defined attributes makes stated choices unduly complex. Such complex information sets are likely to increase the variance of responses and reduce the statistical significance of estimated values.

Behavioral research also indicates that complexity increases the respondents' use of simplifying decision heuristics (Payne, Bettman, and Schkade 1999). Loss aversion is one of the common decision heuristics recorded in behavioral research (Kahneman 2003; McFadden 1999). Faced with a complex decision involving both losses and gains, loss-avoiding respondents make decisions that myopically avoid losses, and fail to account for gains. Loss-avoiding respondents tend to focus only on the potential losses and ignore potential gains. Such complexity-induced heuristics are likely to result in severely biased value estimates to the extent they are evoked by unnecessarily complex stated choice experiments.

The research reported below developed and tested internet-based questionnaires as a means of eliciting in-kind values for wetland mitigation from members of the general public. The questionnaire design drew on behavioral research for strategies to reduce the choice complexity perceived by respondents. These strategies were incorporated into a four-stage questionnaire design process. Focus groups were used to identify the wetland attributes that were most salient to respondents. Group and individual interviews were used next to test alternative information and choice formats. Verbal protocol analysis was employed to identify questionnaire content and attributes that were confusing or misleading to respondents. The final questionnaire presented ecosystem information in a tabular format that made it easy for respondents to identify choice attributes and to compare attribute levels across wetland pairs. A conventional text format was developed as a control to determine the degree that the tabular format controlled decision heuristics and biases.

Data from the tabular and text formats was used to estimate a mitigation equation that gave the acreage of a restored wetland necessary to compensate respondents for the loss of an existing wetland. The amount of restored acreage was conditioned on the acreage of the destroyed wetland, the quality differences between the two wetlands, and the demographic characteristics of respondents. With the data from the text format, the estimated in-kind values were consistent with uncontrolled loss aversion bias. Text format responses were highly sensitive to poor quality wetlands and insensitive to both wetland size and high quality wetlands. In contrast, tabular responses were sensitive to wetland size, low quality wetlands, and high quality wetlands. The tabular format appeared to facilitate informed and balanced tradeoffs.

Economic Model of Mitigation Choices

Wetland mitigation compensates for the loss of wetland services with the restoration of wetland services in a different location. As such, wetland mitigation offers a natural setting for eliciting pair-wise stated choices between a restored and drained wetland. An individual may be asked whether a restored wetland of a given acreage and quality is sufficient to compensate for the loss of a destroyed wetland of a given acreage and quality. This section presents a utility theoretic framework for such choices and derives the in-kind values associated with wetland acreage and wetland ecosystem qualities.

Stated preference techniques are widely applied in market research (Louviere 1991), transportation economics (Bates 2000), development economics (Rubey and Lupi 1997), and environmental economics (Adamowicz et al. 1998; Boxall et al. 1996; Mackenzie 1993; Opaluch et al. 1993; Swallow et al. 1998). Stated choices are usually estimated within a random utility formulation. In this analysis, we derive a choice model based on offered restoration versus a desired amount of utility compensating restoration.

The analysis begins with the preferences of a respondent drawn from the general public. The respondent has preferences over wetland size and wetland qualities that are conditioned on the respondent's demographic characteristics. These preferences are summarized by a utility function,

(1) $$u = u(x,q,c)$$

defined on wetland acreage, x, a K-element vector denoting the quality of wetland services, q, and a N-element vector of individual respondent characteristics, c.

Consider the loss of a wetland that is d acres in size with qualities q_d. The amount of restored acreage, m, with qualities q_m, that compensates for the loss of d with qualities q_d is

(2) $$u(m,q_m,c) = u(d,q_d,c)$$

Equation (2) states the amount of compensatory restoration, m, as an implicit function of lost wetland acreage, lost and restored wetland service qualities, and individual respondent characteristics.

A compensatory mitigation equation is derived by inverting the left-hand side of equation (2) about the amount of restored acreage,

(3) $$m = u^{-1}(q_m, c, u(q_d, d))$$

Equation (3) may be rewritten as a mitigation function,

(4) $$m = m(d, q_m, q_d, c)$$

Equation (4) is similar to an income compensation function (Chipman and Moore 1980) except that the mitigation compensation function is denominated in restored acreage rather than income. The mitigation equation states the amount of quality adjusted restored acreage required to compensate for the loss of an existing wetland of a given size and quality.

The mitigation function is approximated with a linear function of destroyed wetland acreage, the difference between the qualities of the restored and destroyed wetland, respondent demographic characteristics, and a stochastic term,

(5) $$m = \beta_0 + \beta_d d + \sum_{k=1}^{K} \beta_k \Delta q_k + \sum_{n=1}^{N} \gamma_n c_n + \epsilon$$

where β_0 is an intercept coefficient, β_d is the coefficient of the acreage of the destroyed wetland, d; β_k is the coefficient of the difference between the restored and destroyed wetland in the kth wetland quality, Δq_k; γ_n is the coefficient of the *n*th respondent characteristic, c_n, such as income level or having never visited a wetland; and ϵ is a stochastic error term. The stochastic term, ϵ, represents random choice effects that are unobserved by the researcher.

The stated choice experiments present respondents with a pair of wetlands, the restored wetland with its quality attributes, and the destroyed wetland with its quality attributes. The respondent can either accept or reject the restored wetland as compensation for the loss. A respondent accepts the restored wetland as compensation if the size of the restored wetland is greater than the compensating mitigation described by equation (5), given the size of the destroyed wetland, the quality differences between the restored and destroyed wetland, and individual characteristics. A respondent rejects the restored wetland as compensation if the size of the restored wetland is less than the compensatory mitigation described by equation (5).

Given the stochastic term in equation (5), a respondent's decision is not known with certainty by a researcher. However, the probability that an individual accepts restored acreage w with qualities q_w is

$$\begin{aligned} Prob[\text{accept } w \mid d, q_d, q_w] &= Pr(w > m \mid d, q_d, q_w) \\ &= Pr(w > \beta_0 + \beta_d d + \sum_{k=1}^{K} \beta_k \Delta q_k + \sum_{n=1}^{N} \gamma_n c_n + \epsilon) \\ &= Pr(w - \beta_0 - \beta_d d - \sum_{k=1}^{K} \beta_k \Delta q_k - \sum_{n=1}^{N} \gamma_n c_n > \epsilon) \end{aligned} \tag{6}$$

When the stochastic term, ϵ, is an independently distributed normal random variable, the probability of accepting the offered restored wetland is

$$(7) \qquad Prob[\text{accept } w \mid d, q_d, q_w] = \Phi[(w - \beta_0 - \beta_d d - \sum_{k=1}^{K} \beta_k \Delta q_k - \sum_{n=1}^{N} \gamma_n c_n)/\sigma_\epsilon]$$

where $\Phi(\cdot)$ is the standard normal cumulative density and σ_ϵ is the standard deviation of the stochastic term ϵ. Equation (7) describes a model similar to ordinary probit. However, in the ordinary probit model, the standard deviation σ_ϵ is not identified and the variable coefficients are identified only to a scale factor. In equation (7), the coefficient of restored acreage is one, so the coefficient of restored acreage estimated by an ordinary probit is $1/\sigma_\epsilon$ (Cameron and James 1987). Thus, the form of the mitigation equation identifies σ_ϵ and the other coefficients of the mitigation equation. The mitigation coefficients may be estimated as simple ratios of the probit coefficients and standard errors may be computed using a Wald procedure (Greene 2000).

In stated choice, it is convenient to elicit multiple choices from the same respondent. In this case, responses may not be independent due to the possibility that a respondent's choices may vary in a systematic manner. Butler and Moffitt (1982) show that equation (7) may be rewritten conditionally on a random respondent effect u,

$$(8) \; Prob[\text{accept } w \mid d, q_d, q_m, u] = \Phi[(w - \beta_0 - \beta_d d - \sum_{k=1}^{K} \beta_k \Delta q_k - \sum_{n=1}^{N} \gamma_n c_n + \sigma_u \nu)/\sigma_\epsilon]$$

where σ_u is the standard deviation of the random individual effect, ν is the standard unit normal random variable, $\nu = \mu/\sigma_u$, and σ_ϵ is the standard deviation of the cross-section stochastic term, ϵ, representing unobserved and independently distributed choice effects.

Equation (8) is a density function conditioned on the random variable ν representing the individual effect. The random effects probit model is derived by setting up the likelihood equation for the ordinary probit and computing the expectation of the likelihood equation with respect to ν. The expected likelihood equation is then evaluated by Gaussian quadrature to obtain maximum likelihood estimates of the coefficients and standard deviations (Butler and Moffitt 1982).

Stated Choice Questionnaire

The purpose of the questionnaire design process was to develop questionnaires that accurately describe wetland qualities and choices to respondents, while controlling the perceived complexity of wetland information and tradeoffs. Previous research shows that such complexity can introduce inconsistencies across stated choices (Breffle and Rowe 2002; DeShazo and Fermo 2002; Swait and Adamowicz 2001) and potentially lead to characteristic biases due to loss aversion and other decision heuristics (Kahneman 2003; McFadden 1999).

Stated choice research tends to treat complexity as an objective phenomenon (Breffle and Rowe 2002; DeShazo and Fermo 2002; Swait and Adamowicz 2001), but behavioral research indicates that it is subjective and conditioned on the structure of a particular informational treatment (Carlson, Chandler, and Sweller 2003; Ganier, Gombert, and Fayol 2000; Simon 1974). An informational treatment may focus on relevant information or it may force a reader to sort through relevant and irrelevant data. Focusing on the important and salient features reduces the number of features to be evaluated by respondents and thereby reduces one aspect of complexity. In addition, the same information may be presented in complex or simple ways. For example, the structure of human memory appears to make it easier for people to remember more information when it is presented with both text and graphical representations than when it is presented solely as text (Luck and Vogel 1997).

The research used the four-stage process described in Figure 1 to build the lessons of behavioral and cognitive research into a stated choice questionnaire. The objective of the first stage of the process was to determine the types of information that respondents find most relevant to mitigation choices. The first stage examined the general public's knowledge about wetlands, their experience with wetlands, and the priorities they placed on protecting and managing specific wetland qualities and services.

Data for the first stage analysis was obtained in focus group discussions. Participants were recruited using telephone numbers drawn randomly from the Lansing-area phone book. Respondents were asked whether they could attend a discussion group concerning 'critical policy issues'. Respondents were selected so that the mix of focus group participants was representative of the demographic characteristics of mid-Michigan. Focus group discussions were guided by trained moderators using a written discussion guide. The discussion guide began by eliciting top environmental concerns, and then probing these concerns to assess their connections with aquatic and wetland ecosystems. The discussion guide gradually probed the topic of wetlands and elicited respondents' baseline knowledge and experience with wetlands. The last segment of the discussion guide presented a wetland mitigation case and asked respondents to evaluate the case in terms of the adequacy of compensatory mitigation.

Results from the first stage group discussions were used to construct alternative information and choice formats. The alternative formats varied in three dimensions. The first dimension was the way the formats used hierarchical taxonomies to categorize wetland attributes. Behavioral research shows that information is readily assimilated and used when it is organized in subjectively meaningful categories or chunks (Gobet et al. 2001; Simon 1974). For instance, it is more difficult to recall the letters *BMICSIACB* than when they are arranged in as the chunks *IBM-CIA-CBS* (Bettman, Payne, and Staelin 1987). Similarly, wetland species may be chunked into taxonomic categories, such as wading birds, song birds, and amphibians. A format that divides species into species categories and lists specific species within that category is likely to appear less complicated to respondents than a format that simply lists individual species. Such a hierarchical listing may also appeal jointly to non-expert respondents and lay experts. Non-expert respondents may focus on the species categories while lay experts may find the sets of specific species meaningful to their evaluations and choices.

The second dimension that varied across the alternative formats was the way that the restored and destroyed wetlands were presented. For instance, the information about each of the two wetlands may be presented sequentially on separate pages or on the same page. Tabular designs may array wetland attribute information in corresponding columns to facilitate comparisons across the destroyed and restored wetlands. Previous research indicates that tabular designs reduce the perceived task complexity and reduce the amount of time needed for task completion (Carlson, Chandler, and Sweller 2003; Ganier, Gombert, and Fayol 2000).

The third dimension was a method of describing quality changes across wetlands. Focus group respondents tended to describe wetland experiences in terms of what they saw as they drove by or walked through wetlands. These comments suggested that metrics based on transect sampling may be a meaningful way to represent quality differences between wetlands. Transect sampling plots a path through a given area and counts all the features of interest along that path within a given time (Buckland et al. 1993). A wetland visitor might be thought of as conducting an informal transect where the quality of the wetland ecosystem influences the chance of seeing different categories of species, so one of the quality indicators evaluated was based on the chance that a lay visitor might see certain species during a visit to the wetland.

The second stage of the questionnaire design process evaluated the alternative information treatments in group and individual interviews. Participants for the group and individual sessions were drawn from the Lansing area through random selection using a local telephone directory. The interviews were divided into interview and debriefing segments. During the interview segment, respondents completed one of the alternative questionnaires. The debriefing segment began once the questionnaires were completed. The debriefing segment was led by a trained moderator who followed a written discussion guide. The guide asked respondents to discuss how they understood the tasks required by different parts of a questionnaire, examined any difficulties that respondents had in completing a questionnaire, and ended with a short quiz to assess respondents' comprehension of the questionnaire.

The debriefing interviews identified one questionnaire design as superior to the others. The questionnaire used hierarchical categories, a tabular layout, and placed the qualities of the drained and restored wetlands in adjacent columns on a single page of the questionnaire. Respondents using this format made specific and repeated references to wetland qualities during the debriefings. No specific quality seemed to dominate their recollections. Rather, respondents seemed to have balanced and nuanced perceptions of the wetland attributes being compared. The tabular format appeared to facilitate choice-related comparisons and tradeoffs across the two wetlands. Several respondents commented that the choices were almost “too easy,” despite the fact that the choices involved nine attributes, three possible quality levels for each attribute, and two wetlands.

The third stage of the questionnaire design process used individual pretest interviews to test and revise the prototype questionnaire. Pretest respondents were again drawn from the Lansing, MI area using a random selection method based on area telephone books. Participants were paid an honorarium to attend the pretest at a specified day and time on the Michigan State University campus. Pretest interviews were divided into questionnaire self-administration and debriefing segments. In the survey self-administration segment, each participant completed a prototype questionnaire. Once the questionnaire was complete, the respondent was guided to a private office for an in-depth debriefing interview.

Debriefing interviews followed a detailed written debriefing guide. The guide began by asking a respondent to recall and describe their thoughts as he or she completed particular segments of the questionnaire. Additional questions focused on how and whether the respondent understood the information and choice segments of a questionnaire. The debriefing ended with several knowledge-based questions to determine whether respondents understood important aspects of the questionnaire and choice question. Debriefing data were used to revise the prototype questionnaire, with the resulting revised questionnaires subjected to further testing.

The final stage of the design process programmed the questionnaire for use on the internet. The programming was done to preserve the appearance of a paper questionnaire as much as possible. The draft internet questionnaire was pretested over the internet with respondents from the Lansing area, primarily to test the technical characteristics of the questionnaire. Respondents were recruited through random identification from telephone records and paid an honorarium to complete the questionnaire and debriefing interview. Respondents used a variety of operating systems, e-mail systems, web browsers, computer displays, and different internet service providers. Despite the wide range of situations, relatively few problems arose with the web-based questionnaire. The minor problems that did arise were readily remedied by some minor reprogramming.

The final questionnaire focused on a subset of wetland attributes and presented these attributes in a tabular design. Attributes were selected for inclusion based on the data obtained in the qualitative research and pretesting. Attributes included wetland size, type of vegetative cover, accessibility by the general public, and suitability as habitats for plant and animal species. Vegetative cover was categorized as marsh, wooded wetland, or a mix of both marsh and wooded wetland.

Figure 2 shows a portion of the final tabular information format included in the final questionnaire. The tabular form arrayed the relevant wetland choice information in two adjacent columns, one for each wetland under consideration. Wetland habitats were described in five dimensions; habitat quality for amphibians and reptiles, habitat quality for small mammals, habitat quality for song birds, habitat quality for wading birds, and habitat quality for wild flowers.

Each type of habitat was described with a rating of poor, good, or excellent based on the transect sampling concept discussed above. Habitat quality ratings were provided for both the drained and restored wetlands. A narrative box at the bottom on the table explained each of the quality ratings. The ratings were based on what a visitor was likely to see during a visit to the wetland. A poor rating was indicated by "--" and was defined as a wetland habitat that supported "these species in very small numbers...[so] a trained observer is *unlikely to find any* of these species." A "good" rating meant that the wetland habitat supported "these species in average numbers...[so] a casual observer is likely to see a few of these species." An "excellent" rating meant that the wetland habitat supported "these species in better than average numbers...[so] a casual observer is very *likely to see a variety* of these species."

Internet-Based Stated Choice Experiments

The objective of the internet experiment was to test the performance of the developed questionnaire. The hypothesis was that the tabular format reduced complexity and encouraged reasoned decisions informed by a balanced view of all wetland attributes. To test the hypothesis, an experimental control was developed based on a text version of the information format. The text version contained information that was objectively identical to the tabular questionnaire. The only difference between the tabular and text questionnaires was that the text format used sentences to convey the information about wetland attributes and qualities. Figure 3 gives an example of the text format.

Two empirical consequences were expected if the tabular format reduced the complexity perceived by respondents. First, prior research showed that reduced complexity increases the choice consistency and reduces the variance of choice responses (Breffle and Rowe 2002; DeShazo and Fermo 2002; Swait and Adamowicz 2001). In the present case, reducing perceived complexity should result in greater consistency and smaller standard deviations for both the cross-section effect, ϵ, and the respondent effect, ν. Thus, the estimated standard deviations for the tabular format data, σ_ϵ and σ_ν, should be smaller than the estimated standard deviations for the text format data.

Second, behavioral research indicates that complexity leads to increases in the use of decision heuristics and biases (Payne, Bettman, and Schkade 1999). Viscusi and Magat (1987) found that text formats had less impact on risk avoidance behavior and willingness to pay than tabular formats. Psychological research stresses that cognitive constraints lead to characteristic biases when dealing with complicated decisions (Kahneman 2003; Payne, Bettman, and Schkade 1999). Loss aversion is one characteristic and common decision bias (Kahneman, Knetsch, and Thaler 1991; McFadden 1999). With loss aversion, respondents overweight losses and underweight gains.

With complex wetland choices, it was hypothesized that loss aversion would lead respondents to overweight wetlands with poor quality attributes and underweight wetlands with excellent quality attributes. As a result, a mitigation equation estimated with the text data was expected to have larger coefficients for variables indicating poor quality than a mitigation equation estimated with the tabular data. In contrast, a mitigation equation estimated with text data would be expected to have smaller coefficients for variables indicating excellent quality. The text coefficients for variables indicating excellent quality may be ignored by respondents, with the result that their coefficients may not be statistically different from zero. In contrast, the statistical significance of the coefficients estimated with tabular data is likely to be more evenly distributed across poor and excellent quality indicators.

Data to estimate the mitigation equations and test these empirical hypotheses was collected in a large-scale internet experiment with Michigan residents. Access to a panel of potential web-based respondents was purchased from Survey Sampling International (SSI), a commercial provider of sampling frames and databases. The SSI panel is a self-selected sample of potential respondents with known demographic characteristics.

The web-based experiment was implemented in multiple stages beginning in October and ending in December, 2003. E-mail invitations to 16,936 members of the SSI panel, resulted in 3,420 clicks on a welcome page to the web-based questionnaire. From the welcome page, 25 percent of respondents were randomly assigned to the text format. In all, 2,689 respondents began the first page of the questionnaire. Usable questionnaires with at least one completed mitigation choice and complete demographic information numbered 1,326. This was 8 percent of the number of e-mail invitations and 40 percent of those visiting the welcome page. Eight percent is a midrange rate for recent internet experiments (Berrens et al. 2002).

Results

The tabular and text formats yielded two sets of data suitable for an analysis of mitigation choices and values. The data pertaining to the tabular format were the preferred, core data set, since the tabular design was subject to the full iterative design process. The purpose of the text format data was to provide a baseline for evaluating the performance of the tabular design. By hypothesis, the text format leads to (1) more inconsistency in stated choices and (2) cognitive biases that overweight losses in wetland qualities and underweight gains in wetland quality.

The text and tabular data contained three types of variables. First, there were the wetland choice variables. Respondents were given five mitigation scenarios and were asked to determine whether the restored wetland was sufficient to offset the loss of a drained wetland. Hence, each individual recorded accept or reject choices for up to five restoration scenarios. Second, there were the variables that described the acreage and qualities of both the drained and restored wetlands. Third, there were demographic variables for each respondent.

Table 1 lists demographic characteristics for respondents to the tabular and text versions of the questionnaire. There were 937 respondents to the tabular version and 363 respondents to the text version who had responses complete enough to the used in the choice analysis. The choice analysis required complete responses for the variables listed in Table 1.

Mean levels of income, education, age, and gender were similar for respondents to both the tabular and text versions. One exception was for the age of respondents where the text data set contained about 8 percent more respondents who were over 65 years of age. The mean income level for respondents to both versions was about the same as the 2002 Census mean for the State of Michigan. Respondents to the questionnaires were somewhat more schooled with some college study and were more likely to be female and over 65.[1] Finally, 15 percent of the respondents in each sample had never visited a wetland.

The tabular and text data was used to estimate a mitigation equation (5) using the random effects probability model of equation (8). Table 2 lists the general characteristics of the two estimated equations. The data included 4,685 choices from the 963 respondents who used the tabular format and 1,811 choices from the 363 respondents who used the text format. The tabular and text equations performed about equally well in predicting both yes and no responses.

The tabular and text equations are noticeably different in the standard deviations for both the cross-sectional and respondent effects. The standard deviations for the text data are more than twice the size of those for the tabular data. The third column shows that the differences between the two sets of standard deviations are statistically different from zero at the 90 percent level of significant. These results indicate that respondents make more consistent choices with the tabular questionnaire format than the text questionnaire format. The tabular format appears to be successful in reducing perceived complexity, at least as indicated by the variability of choices.

---

[1]The sample selection procedures were intended to be weighted by the Census proportions for males and females in the 2000 Census. However, an error occurred in subcontractor's sample selection process during the waves 1 and 2 of the experiment. The error was corrected for waves 3 to 6 and the sample size was increased to meet the demographic criteria for the initial sample design.

Table 3 lists the wetland attributes and demographic variables used to estimate the mitigation equation coefficients. Wetland size was one of the variables and ranged from 5 to 19 acres for the drained wetlands and from 4 to 48 acres for the restored wetlands. Other wetland characteristics were described as categorical variables. The drained and restored wetlands (a) allowed access by the public, denoted by a "yes," (b) allowed access to the pubic with developed trails, denoted by "yes-trails," or (c) made no provision for public access, denoted by "no." The type of wetland was either a marsh, a wooded wetland, or a mixture of marsh and woodlands.

The changes in wetland characteristics variables, Δx_{gi}, were transformations of the data in the questionnaires. The change in access variable indicated whether there was a change in public access in the restored wetland relative to the drained wetland. The change in access variable was given a value of 1 if the restored wetland allowed public access while the drained wetland did not. Change in access was -1 if the restored wetland did not provide for public access while the drained wetland did provide for public access. In other cases, change in access was set to 0.

The change in wetland type variable was a simple, unsigned dummy variable. It was given a value of 1 if there was a change in wetland type between the restored and drained wetlands and set to 0 if there was no change in type.

The changes in wetland habitat variables were computed from dummy variables representing the poor and excellent categories. The first step was to assign a dummy variable for each of the poor and excellent quality levels of the drained and restored wetlands. Each of the "poor" dummy variables was given a value of 1 if a particular habitat category was poor in quality, and was set to zero otherwise. Each of the "excellent" dummy variables was given a value of 1 if a particular habitat quality was excellent in quality, and was set to zero otherwise. Dummy variables were created for the “poor” and “good” variables for four habitats (reptiles/amphibians, song birds, wading birds, and wild flowers) and both wetlands, so there were 8 initial dummy variables for quality. The habitat dimension for small animals was kept constant across the choice experiments, so no dummy was created to indicate the quality of habitat for small animals.[2]

The second step in computing the habitat change variables was to compute the difference in the habitat dummy variables between the restored and drained wetlands. For instance, the change in poor dummies for reptiles/amphibians was the difference between (a) the poor reptiles/amphibians dummy for the restored wetland and (b) the poor reptiles/amphibians dummy for the drained wetland. A value of 1 for the latter variable meant that the reptiles/amphibian habitat was poor for the restored wetland and not poor for the drained wetland. A value of -1 meant that the reptiles/amphibian habitat was not poor in the restored wetland and poor in the drained wetland. A value of 0 meant no change in the habitat quality for the reptiles/amphibians habitat across the two wetlands. Similar habitat change variables were computed for computed for the poor and excellent dummies variables for each of the 4 habitat categories, resulting in 4 variables to reflect changes in poor quality habitat and 4 variables to reflect changes in excellent quality habitat.

The demographic characteristics variables were simple levels or categorical dummy variables. Income was measured in thousands of dollars. The remainder of the respondent variables were categorical dummy variables, taking the value of 1 if the respondent had the characteristic, and taking the value of 0 otherwise.

---

[2]The small animals habitat quality was kept constant across the two wetlands to reduce the size of the experimental design. Because the small animals are generalists, this type of habitat was not thought to vary across substantially across the common wetlands under consideration, and the other habitat categories were sufficient to demonstrate the role of habitat quality with respect to respondents’ preferences.

Table 3 displays the estimated mitigation coefficients for the tabular and text equations. The second and third columns list the estimated normalized coefficients for the tabular and text data. The final column lists the differences between the coefficients of the tabular and text coefficients. The coefficients for the tabular equation have plausible signs and are mostly statistically different from zero at the 95 percent level. The normalized coefficient for drained acreage is equal to 1.42. A acreage coefficient equal 1 would mean that restored wetland acreage is a very close substitute for drained acreage. However, the coefficient is 42 percent larger than one and statistically different from 1 at the 95 percent level. The coefficient implies that the mean respondent requires compensation of 1.42 restored acres for each acre of drained wetland, even when the two wetlands are otherwise identical in access, wetland type, and habitat quality.

The premium of 42 percent on the drained wetland acreage is similar to Mullarkey's finding that natural wetlands are more valuable than restored wetlands (Mullarkey 1997). However, Mullarkey found a much larger premium on dollar value of natural wetlands, perhaps due to unaddressed differences in wetland qualities.

Public access and wetland type also have a significant impact on the amount of mitigation acreage that compensates for loss of the drained wetland. The public access coefficient indicates that providing public access reduces the compensating number of mitigated acres by 5.76 acres. A change in wetland type increases the compensating amount of mitigation by 4.69 acres.

The change in habitat variables are all significantly different from zero for the tabular data and have algebraic signs consistent with intuition. Reductions in habitat qualities from good to poor require additional acreage to offset the loss in quality. A change in a reptile/amphibian habitat from good to poor requires 8.19 additional restored acres to offset the loss of quality. A reduction in a wild flower habitat from good to poor requires 2.33 acres of additional restored acreage.

Improvements in habitat quality relative to the drained wetland reduce the amount of restored acreage required for mitigation. A change from a good wading bird habitat in the drained wetland to an excellent habitat in the restored wetland reduces the number of restored acres by 5.09 acres. An improvement from a poor habitat in the drained wetland to an excellent habitat in the restored wetland is assessed by summing the appropriate coefficients. For instance, for song birds, a change from poor to excellent reduces the number of restored acres by 6.56 plus 3.80, an overall reduction of 10.36 acres.

Several demographic characteristics affect the level of mitigation that compensates for wetland loss. Increases in respondents' income and schooling tend to reduce the size of compensatory mitigation projects. Having visited a wetland at some point in the past also leads to reductions in the amount of compensating mitigation acres. The latter variable is interesting since it indicates that individuals who have some experience with common wetlands are more inclined to accept the replacement of existing wetlands with restored wetlands.

The notable feature of the text coefficients is the large size of the poor quality habitat coefficients and the small size of the excellent quality habitat indicators. Respondents who were randomly given the text-based choice question require more acreage compensation for loss in quality than the respondents who were randomly selected to receive the tabular-based choice question. Alternatively, for improvements in restored habitat quality relative to the drained wetland, text respondents behave in just the opposite fashion; they underweight improvements.

The final column of Table 3 shows that these asymmetries are statistically significant for each of the poor habitat coefficients and are significant as a group for the excellent habitat coefficients. The results suggest that relative to the tabular format the text respondents fell prey to decisions biases that have been noted by psychologists: respondents tend to overweight losses and underweight gains. The tabular questionnaire appears unaffected by such biases. Coefficient estimates are relatively precise and the differences between coefficients seem reasonable and consistent with intuition. The iterative design process appears successful in deriving a questionnaire that supported balanced, reasoned decisions for rather complex mitigation choices.

The strong asymmetry in the resulting data from the text choice questionnaire also appears in estimating mitigation acreage requirements. Suppose one is considering mitigation for the drainage of a 20-acre wetland with good habitat quality in each of the four habitat categories. Consider two restoration projects: the first involves restoration that results in all four habitat qualities being in poor condition, and the second involves restoration that results in all four habitat qualities being in excellent condition. In the first case, the mitigation equation estimated with the tabular data requires 49 acres of restored wetland acres as compensation, but the equation estimated with the text data requires 106 acres of restored wetland as compensation. Conversely, in the second case involving restoration with excellent habitat quality, computing compensating restoration acreage with the tabular equation requires 11 acres of compensation while the text equation requires 28 acres as compensation.

The mitigation examples highlight the differences between the text and tabular data, and the hypothesized superiority of the tabular questionnaire. With the text questionnaire, respondents appear to overweight losses in habitat quality and underweight gains. The underweighting of gains is rather extreme, since the individual habitat coefficients for improvements are small in size and statistically indistinguishable from zero. In contrast, the tabular data results in coefficients that are economically significant, statistically different from zero, much more balanced in their assessment of wetland gains and losses, and accord with the respondent feedback from the focus groups and pretest interviews.

Conclusion

The research demonstrates that stated choice experiments with complex ecosystems are feasible for the general public. Careful research on baseline knowledge and systematic pretesting appear essential for obtaining reasonable, unbiased stated choice results. The tabular questionnaire format that resulted from a four-stage design procedure appeared to perform well. The research also used a simple text-based information treatment as an example of the type of questionnaire that might be developed without the iterative questionnaire design process. The simple text-based questionnaire revealed the kinds of asymmetric biases anticipated on the basis of recent psychological and economic research (McFadden 2001). The text-based descriptions resulted in losses in ecosystem quality being overweighted and gains in quality being underweighted relative to those estimated using the tabular format. Thus, while ecosystem choices may be complex enough to strain respondents' decision capacities, systematic questionnaire development seems able to help researchers arrive at formats that reduce or eliminate the impact of characteristic biases on the estimated values.

The results demonstrate that wetland qualities and services are valued by members of the general public. From qualitative research, wetland habitats for small animals, birds, and special plants were found to be of special interest and value to respondents (Hoehn, Lupi, and Kaplowitz 2003; Kaplowitz, Lupi, and Hoehn 2004). Respondents had direct experience with the latter types of wetland habitats and saw them as directly impacted by mitigation activities. The importance of habitat quality emerged consistently at all stages of the research including the initial focus groups, the pretest phase, and the web-experiments. This finding is similar to other recent research on wetland ecosystems (Azevedo, Herriges, and King 2000; Johnston et al. 2002; Stevens, Benin, and Larson 1995; Swallow et al. 1998).

Two aspects of the research need to be kept in mind in interpreting the results. First, respondents to both the qualitative and quantitative research were drawn from residents of Michigan. Michigan's climate is characteristic of the humid north-central portion of the United States. Wetlands are a common landscape feature, so Michigan residents may have more experience with wetlands than those in other parts of the United States, especially those living in arid regions. Second, while the study provides estimates of how to adjust mitigation ratios to account for differences in habitat quality, it should be considered a first step. The objective of this research was not to estimate values representing a particular population, but to develop and evaluate stated choice valuation methods and procedures. Further research is needed to implement the developed procedures in a statistically representative sample. Third, the wetlands considered here were common types which are regularly subject to permit actions in Michigan. The study results do not apply to rare wetlands, rare habitats, or rare species. Likewise, in the wetland choices studied here, respondents were explicitly asked to hold other functions of wetlands constant.

References

Adamowicz, W., P. Boxall, J. Louviere, J. Swait, and M. Williams. 1998. Stated Preference Methods for Valuing Environmental Amenities. In *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the U.S., E.C., and Developing Countries*, edited by I. Batemen and K. Willis. Oxford: Oxford University Press.

Azevedo, Christopher, Joseph A. Herriges, and Catherine L. King. 2000. Iowa Wetlands: Perceptions and Values. Ames: Center for Agricultural and Rural Development Iowa State University.

Bates, John. 2000. History of Demand Modelling. In *Handbook of Transport Modelling*, edited by D. A. Hensher and K. J. Button. Handbooks in Transport, vol. 1. Amsterdam; New York and Oxford: Elsevier Science Pergamon.

Berrens, R.P., A.K. Bohara, H.C. Jenkins-Smith, C.L. Silva, and D.L. Weimer. 2002. Information and Effort in Contingent Valuation Surveys: Application to Global Climate Change Using National Internet Samples. *Journal of Environmental Economics and Management* 47:331-363.

Bettman, J.R., J.W. Payne, and R. Staelin. 1987. Cognitive Considerations in Presenting Risk Information. In *Learning About Risk*, edited by K. W. Viscusi and W. A. Magat. Cambridge, MA: Harvard University Press.

Boxall, P., W. Adamowicz, J. Swait, M. Williams, and J. Louviere. 1996. A Comparison of Stated Preference Methods for Environmental Valuation. *Ecological Economics* 18:243-253.

Breffle, W.S., and R.D. Rowe. 2002. Comparing Choice Question Formats for Evaluating Natural Resource Tradeoffs. *Land Economics* 78 (2):298-314.

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L Laake. 1993. *Distance Sampling: Estimating Abundance of Biological Populations*. London: Chapman and Hall.

Butler, J.S., and Robert Moffitt. 1982. A Computationally Efficient Quadrature Procedure for the One-Factor Multinomial Probit Model. *Econometrica* 50 (3):761-764.

Cameron, T.A., and M.D. James. 1987. Efficient Estimation Methods for 'Closed-Ended' Contingent Valuation Surveys. *Review of Economics and Statistics* 69:269-276.

Carlson, R., P. Chandler, and J. Sweller. 2003. Learning and Understanding Science Instructional Material. *Journal of Educational Psychology* 95 (3):629-640.

Chipman, J.S., and J.C. Moore. 1980. Compensating Variation, Consumer's Surplus, and Welfare. *American Economic Review* 70 (5):933-949.

DeShazo, J.R., and G. Fermo. 2002. Designing Choice Sets for Stated Preference Methods: The Effects of Complexity on Choice Consistency. *Journal of Environmental Economics and Management* 44:123-143.

Ganier, F., J.E. Gombert, and M. Fayol. 2000. The Effects of Instructional Formats on Procedural Learning when Using Technical Documents. *Travail Humain* 63 (2):121-152.

Gobet, F., P.C.R. Lane, S. Croker, P.C-H. Cheng, G. Jones, I. Oliver, and J.M. Pine. 2001. Chunking Mechanisms in Human Learning. *Trends in Cognitive Sciences* 5 (6):236-243.

Greene, W.H. 2000. *Econometric Analysis*. 4th ed. Upper Saddle River, NJ: Prentice-Hall.

Heimlich, Ralph E., Keith D. Wiebe, Roger Claassen, Dwight Gadsby, and Robert M. House. 1998. Wetlands and Agriculture: Private Interests and Public Benefits. Washington, D.C.: Resource Economics Division, Economic Research Service, U.S. Department of Agriculture.

Hoehn, J.P., F. Lupi, and M.D. Kaplowitz. 2003. Untying a Lancastrian Bundle: Valuing Ecosystems and Ecosystem Services for Wetland Mitigation. *Journal of Environmental Management* 68:263-272.

Johnston, Robert J., Gisele Magnusson, Marisa J. Mazzotta, and James J. Opaluch. 2002. The Economics of Wetland Ecosystem Restoration and Mitigation: Combining Economic and Ecological Indicators to Prioritize Salt Marsh Restoration Actions. *Am J Agricultural Economics* 84 (5):1362-1370.

Kahneman, D., J.L. Knetsch, and R.H. Thaler. 1991. Anomalies the Endowment Effect, Loss Aversion, and Status Quo Bias. *Journal of Economic Perspectives* 5 (1):193-206.

Kahneman, Daniel. 2003. Maps of Bounded Rationality: Psychology for Behavioral Economics. *American Economic Review* 93 (5):1449-1475.

Kaplowitz, Michael D., Frank Lupi, and John P. Hoehn. 2004. Multiple-Methods for Developing and Evaluating a Stated Preference Survey to Value Wetland Ecosystems. In *Methods for Testing and Evaluating Survey Questionnaires*, edited by S. Presser, J. M. Rothgeb, M. P. Couper, J. T. Lessler, E. Martin, J. Martin and E. Singer. New York: John Wiley and Sons.

Kosz, Michael. 1996. Valuing Riverside Wetlands: The Case of the "Donau-Allen" National Park. *Ecological Economics* 16:109-127.

Louviere, J. J. 1991. Experimental Choice Analysis: Introduction and Overview. *Journal of Business Research* 23:291-297.

Luck, S.J., and E.K. Vogel. 1997. The Capacity of Visual Working Memory for Features and Conjunctions. *Nature* 390 (6657):279-281.

Mackenzie, J. 1993. A Comparison of Contingent Preference Models. *American Journal of Agricultural Economics* 75:593-603.

McFadden, Daniel. 1999. Rationality for Economists? *Journal of Risk and Uncertainty* 19 (1-3):73-105.

McFadden, Daniel. 2001. Economic Choices. *American Economic Review* 91 (3):351-378.

Mullarkey, Daniel J. 1997. Contingent Valuation of Wetlands: Testing Sensitivity to Scope. Dissertation, Agricultural and Applied Economics, University of Wisconsin, Madison, WI.

National Research Council. 2001. *Compensating for Wetland Losses under the Clean Water Act*. Washington, DC: National Academy Press.

Opaluch, J. J., S. Swallow, T. Weaver, C. Wessels, and D. Wichlens. 1993. Evaluating Impacts from Noxious Waste Facilities: Including Public Preferences in Current Siting Mechanisms. *Journal of Environmental Economics and Management* 24:41-59.

Payne, J.W., J.R. Bettman, and D.A. Schkade. 1999. Measuring Constructed Preferences: Towards a Building Code. *Journal of Risk and Uncertainty* 19 (1-3):243-70.

Phillips, W. E., T. J. Haney, and W. L. Adamowicz. 1993. An Economic Analysis of Wildlife Habitat Preservation in Alberta. *Canadian Journal of Agricultural Economics* 41 (4):411-418.

Rubey, L, and F. Lupi. 1997. Predicting the Effects of Market Reform in Zimbabwe: A Stated Preference Approach. *American Journal of Agricultural Economics* 78:89-99.

Simon, H.A. 1974. How Big Is a Chunk? *Science* 183:482-488.

Stevens, Thomas H., Samuel Benin, and Joseph S. Larson. 1995. Public Attitudes and Economic Values for Wetland Preservation in New England. *Wetlands* 15:226-231.

Swait, J., and W. Adamowicz. 2001. Choice Environment, Market Complexity, and Consumer Behavior: A Theoretical and Empirical Approach for Incorporating Decision Complexity into

Models of Consumer Choice. *Organizational Behavior and Human Decision Processes* 86 (2):141-167.

Swallow, S., M. Spencer, C. Miller, P. Paton, R. Deegen, L. Whinstanley, and J. Shogren. 1998. Methods and Applications for Ecosystem Valuation: A Collage. In *Proceedings of the first Workshop in the Environmental Policy and Economics Workshop Series*, edited by B. Kanninen. Washington, D.C.: Office of Research and Development and Office of Policy, U.S. Environmental Protection Agency.

Viscusi, W. Kip, and Wesley A. Magat. 1987. *Learning about Risk*. Cambridge, MA: Harvard University Press.

Woodward, R.T., and Y-S. Wui. 2001. The Economic Value of Wetland Services: A Meta-Analysis. *Ecological Economics* 37:157-270.

Figure 1. Four Stage Questionnaire Design Process

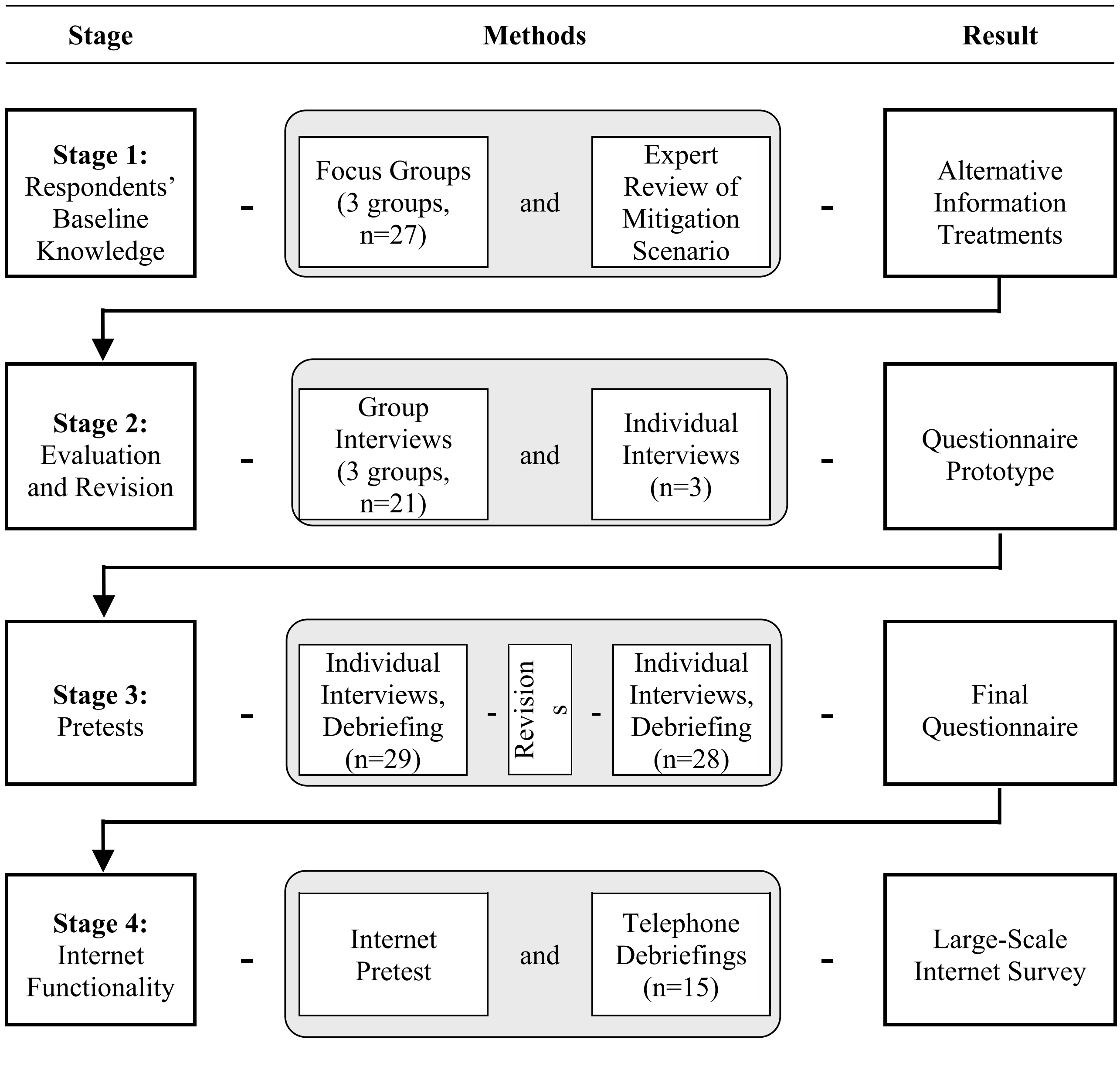


Figure 2. Tabular Choice Format

Wetlands Scorecard #1
How do the Drained and Restored Wetlands Compare?

	Wetland Choice #1	
Wetland Features	**Drained Wetland**	**Restored Wetland**
Is it marsh, wooded, or a mix of march and woods?	Wooded	Mixed
How large is it?	14 acres	23 acres
Is it open to public?	Yes	No
Are there trails and nature signs?	No	No
How good is the habitat for different species?		
Amphibians and reptiles like frogs and turtles	Excellent	--
Small animals like raccoon, opossum, and fox	Good	Good
Songbirds like warblers, waxing, and vireo	--	Good
Wading birds like sandpiper, heron, or crane	--	Good
Wild flowers?	Good	--

Figure 3. Text Choice Format

Wetlands Scorecard #1
How do the Drained and Restored Wetlands Compare?

Wetland Choice #1

Drained Wetland

The drained wetland is 14 acres in size. It is a wooded wetland. It is open to the public. It has no trails or nature signs. This wetland is excellent habitat for amphibians. Small animals such as raccoon, opossum, and fox have good habitat in this wetland. The habitat is poor for warblers, waxwing, vireo, and other songbirds. It is poor habitat for wading birds such as cranes, heron, and sandpipers. The growing conditions for wild flowers are good.

Restored Wetland

The restored wetland is 23 acres in size. It is a mix of marsh and wooded wetland. It is not open to the public. It has no trails or nature signs. This wetland is poor habitat for amphibians. Small animals such as racoon, opossum, and fox have good habitat in this wetland. The habitat is good for warblers, waxwing, vireo, and other songbirds. It is good habitat for wading birds such as cranes, heron, and sandpipers. The growing conditions for wild flowers are poor.

Table 1. Respondent Characteristics

Variable	Tabular	Text	Michigan, Census 2000
Households	937	363	3.8 million
Income ($1,000)	54.4	54.1	57.4
Some college	79%	79%	52%
18 to 25 years	8%	8%	9%
Over 65 years	38%	47%	12%
Female	56%	60%	49%
Never visited a wetland	15%	15%	-

Table 2. General Properties of the Tabular and Text Mitigation Equation Estimates

Variable	Tabular[a]	Text[a]	Difference: Text-Tabular
No of observations	4685	1811	2874
Correct predictions of yes responses (%)	63	64	-1
Correct predictions of no responses (%)	64	65	-1
Log-likelihood	-2814	-1151	--
Cross-sectional effects, standard deviation (σ_ϵ)	22.3 (1.64)	49.8 (15.33)	27.5 (15.42)
Respondent effects, standard deviation (σ_u)	17.0 (1.25)	40.1 (12.37)	23.1 (12.43)

a.. Asymptotic standard errors are given in parentheses.

Table 3. Coefficient Estimates for the Tabular and Text Mitigation Equations

Variable	Tabular[a]	Text[a]	Difference: Text-Tabular[a]
Acreage of drained wetland	1.42 (0.19)	0.99 (0.68)	-0.42 (0.70)
Change in public access	-5.76 (1.01)	-9.76 (4.00)	-3.99 (.412)
Change in wetland type	4.69 (1.14)	1.81 (4.18)	-2.86 (4.33)
Change in poor habitat			
Reptiles/amphibians	8.19 (1.17)	23.46 (8.10)	15.3* (8.98)
Wading birds	5.76 (1.14)	21.11 (7.53)	15.3 * (7.62)
Song birds	6.56 (1.16)	21.33 (7.12)	14.8* (7.21)
Wild flowers	2.33 (1.14)	12.51 (5.41)	10.2* (5.53)
Change in excellent habitat			
Reptiles/amphibians	-4.76 (0.76)	1.00 (3.27)	5.8* (3.35)
Wading birds	-5.09 (0.74)	-1.12 (3.19)	4.0* (3.28)
Song birds	-3.80 (0.76)	-1.76 (3.10)	2.0* (3.19)
Wild flowers	-1.94 (0.73)	-3.44 (3.12)	-1.50* (3.21)
Income ($1,000s)	-0.06 (0.02)	-0.03 (0.07)	0.03 (0.06)
Some college	-4.25 (1.83)	3.91 (7.49)	8.16 (7.71)
18 to 25 years of age	2.53 (2.70)	3.35 (9.62)	0.82 (10.0)
65 years of age and over	0.41 (3.17)	-3.29 (12.65)	-3.70 (13.05)

Table 3. Coefficient Estimates for the Tabular and Text Mitigation Equations

Variable	Tabular[a]	Text[a]	Difference: Text-Tabular[a]
Female	-2.9 (1.54)	0.59 (5.76)	3.50 (5.96)
Never visited a wetland	8.26 (2.14)	-0.54 (7.92)	-8.80 (8.21)
Intercept	4.75 (2.94)	6.68 (11.27)	1.93 (11.65)

a.. Asymptotic standard errors are given in parentheses. A "*" indicates that the habitat quality coefficients are significantly different from zero when evaluated as a group of coefficients.

Discussion

Session VI: Methodological Advances in Stated Preference Valuation

Joseph Cooper

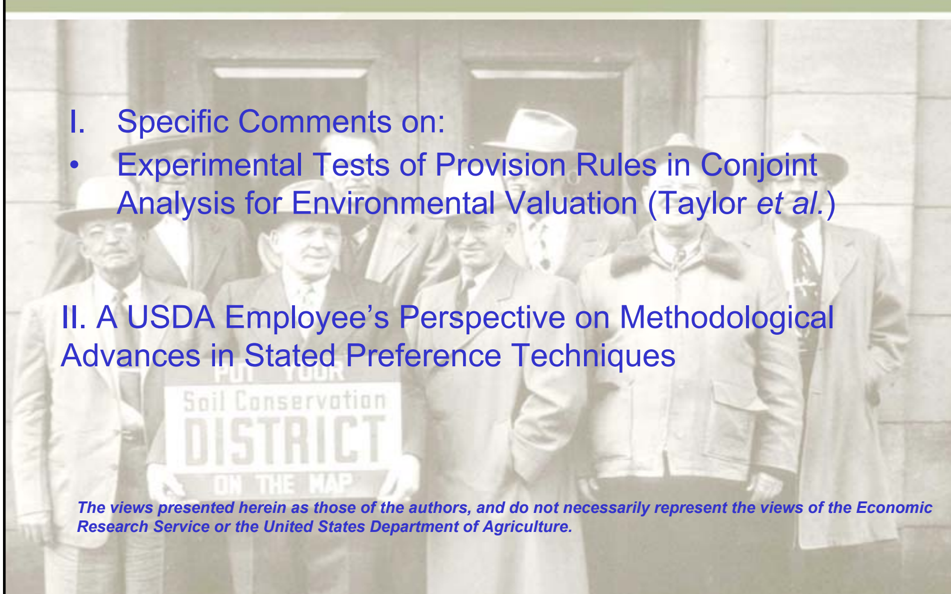
Economic Research Service – USDA

US EPA NCEE Workshop

Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions"

Washington, DC Oct 26-27, 2004

Overview



I. Specific Comments on:

- Experimental Tests of Provision Rules in Conjoint Analysis for Environmental Valuation (Taylor *et al.*)

II. A USDA Employee's Perspective on Methodological Advances in Stated Preference Techniques

The views presented herein as those of the authors, and do not necessarily represent the views of the Economic Research Service or the United States Department of Agriculture.

I. Comments on Taylor *et al.*

At least two sources of incentive incompatibility associated with conjoint surveys:

1) Incentive incompatibility due to exclusion of an explicit provision rule
   - This source of incentive incompatibility is the focus of Taylor et al.
   - This is also an issue with dichotomous choice reference surveys

2) Incentive incompatibility of referendums with three or more choices (or treatments)

I. Comments on Taylor *et al.*

With regards point 2),

Gibbard-Satterwait Theorem

An election mechanism for 3 or more alternatives which is:

- Unanimous
- Strategy proof

is a dictatorship.

Other election methods are not incentive compatible

I. Comments on Taylor *et al.*

General Question for Conjoint Analysis:

What is the potential response bias associated with 3 or more alternatives inherent in the voting mechanism itself?

I. Comment on Hoehn *et al.*

Comparison of the tabular choice (fig. 2) to the text choice format (fig.3):

- The text choice format has quality rankings of “Poor”, “good”, and “excellent.”
- The tabular choice format has quality rankings of “--”, “good”, and “excellent.”
- Substituting “--” for “poor” in tabular choice format would seem to limit comparability of the two formats.

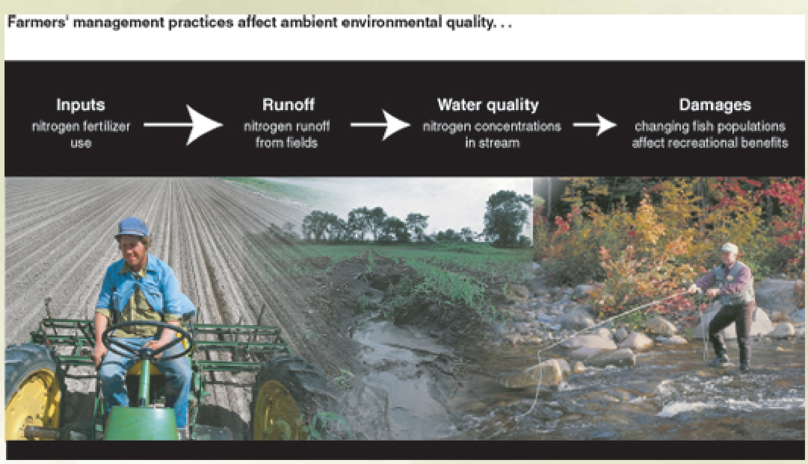
II. A Governmental Perspective

How stated preference techniques can be useful to ERS

- Measuring the success of conservation programs
  - e.g. Conservation Reserve Program (CRP), Environmental Quality Incentives Program (EQIP), Conservation Security Program (CSP)
- Monetizing the environmental impacts of commodity programs

II. A Governmental Perspective

Example of relationships we want to measure:



Source: Smith and Weinberg

II. A Governmental Perspective

Another Example:

Agricultural Trade Liberalization

⇓

Change in world prices and quantity

⇓

Changes in production practices, input use, and outputs

Changes in physical measures of environmental impacts

⇓

Changes in economic measures of environmental impacts

Changes in returns to agricultural production

II. A Governmental Perspective

In stylized fashion,

to evaluate an agr-environmental program, we want to be able to approximate dV/dG

where $dV/dG = dV/dE \cdot dE/dF \cdot dF/dG$

and where V = Nonmarket benefits, G = government payments or expenditures, E = environmental impacts, F = farm management practices (e.g., nitrogen application rates, etc).

II. A Governmental Perspective

- But in general, CVM survey scenarios are designed to produce discrete points in dV/dG or dV/dE , e.g.,
  $V|_{G = \$ \text{ level } 1}$ and $V|_{G = \$ \text{ level } 2}$

or

$V|_{E = \text{pollution level } 1}$ and $V|_{E = \text{pollution level } 2}$

- There is probably little one can do to design a CVM scenario that approximates dV/dG

II. A Governmental Perspective

- Hence, the best path is likely to choose CVM scenarios to maximize the possibility of achieving a statistically significant relationship
  V = f(E,F,G).
- This means choosing a benefit measure V (and CVM scenario) that maximizes the possibility of obtaining significant relationships between the V and policy relevant variables E, F, and G.
- This suggests considering the available environmental process models and data when choosing V.

II. A Governmental Perspective

Examples of notable agri-environmental process models:

- USDA's Erosion-Productivity Impact Calculator (EPIC)
- USDA's Soil & Water Assessment Tool (SWAT)
- USGS's SPAtially Referenced Regressions On Watershed Attributes (SPARROW)

II. A Governmental Perspective

With physical scientists, we need to stress that

- To make full use of environmental indicators to inform decisions, the development and collection of these indicators need to be coordinated and integrated with the development and collection of behavioral data.

With economists, we need to stress that

- To make full use of behavorial data to inform decisions, the development and collection of these indicators need to be coordinated and integrated with the development and collection of environmental indicators data.

Section VI. Methodological Advances in Stated Preference Valuations
Discussion by T. H. Stevens
University of MA, Amherst

I. Embedding in Stated-Preference Methods (Michael Hanemann and Jeff Lazo)

Although I have been unable to obtain a copy of this paper, I found Hanemann's presentation both stimulating and useful. Of particular importance is the notion that some types of embedding, such as geographical scope effects, can often result from rational, well informed decision-making. For example, many respondents may express the same value for preserving a nearby wetland as they do for preserving all wetlands in a larger region simply because the nearby wetland is the only one that is really important to them. Many other logical reasons for scope effects were outlined in this presentation which suggests that (a) it is important to examine psychological factors that might influence respondent's decision making and (b) debriefing should be an important component of the stated preference methodology. Many important issues remain to be addressed, including definition of the relevant choice set for valuation of public goods.

II. Experimental Tests of Provision Rules in Conjoint Analyses for Environmental Valuation (Taylor, Boyle, Morrison).

This paper focuses on a very important issue. Conjoint (choice) analyses is being used widely, but little is known about potential biases that might be associated with this technique. In particular, since provision rules are generally not incorporated within the conjoint format, this method might produce inaccurate results.

The experiments involving hypothetical payments conducted by the authors suggest that:

1. Respondents were more likely to "purchase" a private good when the conjoint question did not include an incentive compatible provision rule.

2. Subjects were less responsive to the price of a public good when the conjoint question did not include an incentive compatible provision rule.

Taken together, these findings imply that results derived from the traditional conjoint approach (without provision rule) are likely biased upward.

Experiments involving real payments were also conducted, but these results were not available prior to Taylor's presentation. However, the presentation seemed to suggest that explicitly stated provision rules reduced hypothetical bias associated with the conjoint analyses. If so, then it is very important to incorporate appropriate provision rules in conjoint analyses.

It is important to note, however, that comparisons were not made between an incentive compatible CV format and an incentive compatible conjoint format. Such a comparison is important because CV and conjoint techniques differ in several respects other than the provision rule. That is, even if conjoint methods are modified to incorporate appropriate provision rules, conjoint and CV results may still diverge because of other differences between these formats. For example:

(1) Substitutes are made explicit in the conjoint (CJ) format and this may encourage respondents to explore their preferences and tradeoffs in more detail. Indeed, as noted by Gan and Luzar (1993), conjoint analysis 'can be characterized as an extension of the referendum closed-end CV method in which large numbers of attributes and levels can be included in the analysis without overwhelming the respondents' (p. 37). As shown by Boxall, et al. (1996), when compared to CJ, CV results may therefore be biased upward because respondents to the 'typical' CV survey are usually asked to consider fewer substitutes.

(2) From a psychological perspective, the process of making choices in the CJ format may be quite different from that associated with making decisions about WTP (Irwin, et al.,

1993; McKenzie, 1993). That is, respondents may react differently when choosing among commodities that have an assigned price as compared to making dollar valuations of the same commodities. Moreover, Irwin, et al. (1993) found that CV questions lead to relatively greater preference for improved commodities, such as TVs and VCRs, while choice questions yielded relatively greater preference for environmental amenities like air quality. Similar results were reported by Brown (1984). Irwin, et al. (1993) concluded that if monetary prices are an attribute, they carry more weight in determining a response measured in dollars (e.g. CV) than they do in determining a rating or choice response. This arises from the fact that choices seem to be driven from reason and arguments to a greater extent than are pricing responses.

(3) CJ respondents can express ambivalence or indifference directly. As a result, CJ surveys may result in relatively less non-response and protest behavior. Moreover, allowing for respondent uncertainty may have a significant effect on the WTP of those who do respond. For example, Ready, et al. (1995) compared a dichotomous choice CV format to a polychotomous choice format. Their CV question asked respondents to determine whether or not they preferred a given program while the polychotomous choice format gave six options (i.e., definitely prefer, probably prefer, maybe prefer, maybe not prefer, probably not prefer, definitely not prefer). This format was motivated by the belief that respondents might be more comfortable answering valuation questions when given the opportunity to express strength of conviction; since the polychotomous method allows for a range of answers, it might produce a more accurate description of respondents' preferences. In two empirical studies, preservation of wetlands and horse farms, the polychotomous format yielded a higher rate of usable responses and much higher WTP estimates.

More recently, Champ, et al. (1997) found that although contingent values were greater than actual donations for an environmental good, when the contingent values were restricted to respondents who said they were very certain to contribute, mean CV and actual donations were not statistically different. Ekstrand and Loomis (1997), Alberini, et al. (1997) and Wang (1997) also found that contingent value estimates vary widely depending on how respondent uncertainty is incorporated in the analysis.

In summary, conjoint (choice) and CV formats differ in several ways, and correction for provision rule may not resolve many of the differences between traditional CV and conjoint estimates.

III. Stated-Choice Experiments to Estimate In-Kind Values for Ecosystem Mitigation (John Hoehn, Frank Lupi, Michael Kaplowitz).

This paper addresses another very important issue--do respondents suffer from information overload in the stated choice format, and if so, what are the consequences and what can be done about this potential problem?

The authors use a split sample approach to compare text and tabular information formats with the result that the tabular presentation was successful in reducing information complexity and information overload.

Specific comments are as follows:

1. An internet survey that produced an 8 percent response rate was used in this study. Much more information is needed with respect to non-respondents.

2. Another interesting research question would be whether the differences observed in this study are also found in mail surveys.

3. In this study, text respondents tended to exhibit loss aversion while tabular respondents did not. But if loss aversion is part of "human behavior", elimination of loss aversion might produce biased results. So, in this sense is a tabular format really "better" than a text version?

References

Alberini, A., Boyle, K., Welsh, M., 1997. Using multiple-bounded questions to incorporate preference uncertainty in non-market valuation. In: Englin, J. (Compiler), Tenth Interim Report, W-133 Benefits and Costs Transfer in Natural Resource Planning, University of Reno, Reno, NV.

Boxall, P., Adamowicz, W., Swait, J., Williams, M., Laviere, J., 1996. A comparison of stated preference methods for environmental valuation. Ecol. Econom. 18, 243-253.

Brown, T., 1984. The concept of value in resource allocation. Land Econom. 60, 231-246.

Champ, P., Bishop, R., Brown, T., McCollum, D., 1997. Using donation mechanisms to value nonuse benefits from public goods. J. Environ. Econom. Manag. 32 (2), 151-162.

Ekstrand, E., Loomis, J., 1997. Estimated willingness to pay for protecting critical habitat for threatened and endangered fish with respondent uncertainty. In: Englin, J. (Compiler), Tenth Interim Report, W-133 Benefits and Costs Transfer in Natural Resource Planning, University of Reno, Reno, NV.

Gan, C., Luzar, E.J., 1993. A conjoint analysis of waterfowl hunting in Louisiana. J. Agric. Appl. Econom. 25, 36-45.

Irwin, J.R., Slovic, P., Licktenstein, L., McClelland, G., 1993. Preference reversals and the measurement of environmental values. J. Rick Uncertrain. 6, 5-18.

McKenzie, J., 1993. A comparison of contingent preference models. Am. J. Agric. Econom. 75, 593-603.

Ready, R., Whitehead, J., Blomquist, G., 1995. Contingent valuation when respondents are ambivalent. J. Environ. Econom. Manag., 29 (2), 181-197.

Wang, H., 1997. Treatment of don't know? Responses in contingent valuation survey: a random valuation model. J. Environ. Econom. Manag. 32, 219-232.

Summary of the Q&A Discussion Following Session VI

Elizabeth David (Stratus Consulting, Inc.)
Dr. David introduced herself by saying that prior to working for Stratus she worked for a number of years with the State of Wisconsin's Department of Natural Resources, and she stated that she would "feel much better" if she knew that John Hoehn had "familiarity with questionnaire design." She cited the University of Michigan's Survey Research Center within the Institute of Social Research, where there is a "whole section that worries about how to design questions." Acknowledging that the wetlands problem is particularly difficult and extremely complicated with "so many services associated with it," she wished that Dr. Hoehn had "grounded his questions about wetlands in the existing literature about how to deal with a very complicated set of interactions."

John Hoehn (Michigan State University)
Dr. Hoehn responded by stating, "We actually *did* work with a number of people from the University of Michigan as consultants on the project. We *certainly did* try to access that knowledge base."

Joel Huber, (Duke University)
Dr. Huber commented, "I wanted to talk to the issue of whether we're *trying* to get from people the *best* answer or their *first* answer. There's a certain notion that there's true utility up there and we need to ask them without them thinking about it too much and get it out. I actually would have gone the other way. If you think about it, what you really *want* to do is not get what they would do *quickly* but what they would do if they *thought* about it. Because here we're talking about policy, and most of these are rich issues and they're *deep* issues. So, I really applaud, John, what you're doing in terms of trying to simplify and trying to actually test. . . . This can be sort of discouraging, because much of the economics becomes harder to apply—the appearance of the answer depends on how you ask the question, and knowing that puts you in a type of limbo because there are all kinds of skills needed that you don't normally have. Typically in your work, though, you have options of doing different versions, so I would suggest taking advantage of this. You can have version A and version B and you don't necessarily need to mention it—if they work out the same, great. What you're aiming for is what a person would do if they thought about it a lot—it's quite different from what I would call the sort of implicit utility."

Michael Kaplowitz (Michigan State University)
Dr. Kaplowitz said, "I just want to make one comment, because a lot of this discussion the last two days has been on economics and ecology, and the work that John (Hoehn), Frank (Lupi), and I are doing—and the work that I think many people here have done—is really work that spans economics and survey research. For example, I never would have thought that we would be publishing in survey research outlets, but our four-step design process is now something that survey researchers are using or are thinking about using in their work in other fields. So, I think there's a lot of crossover and lessons we can learn."

When asked by John Hoehn what book was forthcoming on this topic, Dr. Kaplowitz replied, "Stanley Presser and a bunch of people have a questionnaire development and evaluation text being published by Wiley Press."

Elena Besedin (Abt Associates,Inc.)
Addressing Michael Hanemann, Ms. Besedin commented that Dr. Hanemann, in reporting on his study, had mentioned an internal scope test in which the survey participants indicated that they held widely disparate views as to how many birds would represent a "significant" effect on bird population. She raised the question of whether this really represents a scope issue "compared to, for example, a background information issue." She noted that "sometimes *scientists* have difficulties measuring bird and other wildlife populations." Ms. Besedin added that you "can't really judge whether an effect is large or small" without having some idea of the total population figure. She concluded by asking Dr. Hanemann whether this information (the total population figure) was available to the focus group who gave the noted response, and if so, how would he explain their conclusions.

Michael Hanemann (University of California-Berkeley)
Dr. Hanemann responded by saying that "the survey gave *famously* ambivalent information, because it said: 2,000 birds or under 1%; 20,000 birds or *about* 1%; and 200,000 birds or under 2%. From one perspective, these are all speaking of 1 or 2%--little to no difference. . . . I interpret this as saying that, in fact, people were looking at the percentages, and there's abundant literature from Slovik and others that indicates that percentages are what people think of. The difference between under 1% and under 2% is unimportant, and I think the attitude question about what this means to the population suggests that they were looking at the percentages, and so they had a real basis. Obviously, if they were looking at the numbers, that's striking, but it seems they were focusing on the percentages, and the differences are unimportant."

John Hoehn
Dr. Hoehn referred to Joel Huber's comment that the decision they were trying to get at is one that a person would make if they had a little more time to assimilate information and to think about it. He said, "I think that is certainly a *target*. This format problem is trying to make the assimilation task easier for respondents, so they don't have to spend as much time on assimilation and can put more time into the decision and focus on *that* problem. . . . It *is* a difficult problem, and some of the work we're doing is contributing to that literature on survey design . . . because these are different sorts of questions than asking, "Who are you going to vote for for president?"—and even there you see a lot of variability these days. You know, we *are* asking people to make difficult choices when we address wetlands issues—they're a distinct kind of problem in terms of survey design and the issues they raise with respect to human cognitions."

Michael Hanemann
Dr. Hanemann added, "There's a different strategy, in sociology at least, in attitude measurement. The strategy in attitude measurement is to ask a large battery of questions and then to reduce them. I see this relating to the Lancaster Model. If, by an attitude, you mean something broad, such as patriotism or law-and-order, then it makes sense that there's a large number of questions that would *touch* on that, and you *could* average them. . . . So, when you're measuring something very broad, then it's possible to have a large number of imprecise measurements."

Joel Huber
Dr. Huber followed with these comments: "If you're trying to get attitudes, what you want is quickness—that is, you want to see how a person reacts to a certain "picture." That is often *mediated* by thought. . . . So, some things are attitude questions, but the tradeoffs are what I'd call "rational." They're very different modalities—one is fast and the other is slow, and you're actually *overcoming* your initial thoughts. So, depending on what you want to do, you'd go one way or the other."

END OF SESSION VI Q&A